845 Brook Street, Rocky Hill, CT 06067
T 860.563.0015
ctgreenbank.com

CONNECTICUT
GREEN BANK

June 16, 2017

Dear Connecticut Green Bank Board of Directors:

We have a regular meeting of the Board of Directors scheduled on Friday, June 23, 2017 from 9:00 to 11:00 a.m. in the Colonel Albert Pope Board Room of the Connecticut Green Bank at 845 Brook Street, Rocky Hill, CT 06067.

On the agenda we have the following items:

- **Consent Agenda** – approval of the meeting minutes for the April 28, 2017 regular board meeting and June 9, 2017 special board meeting, and the approval of several position descriptions. Also included are financial statements through April of 2017. We will also be recognizing Norma Glover for her service to the Connecticut Green Bank as this will be her last official board meeting. [Note – we are holding a special event at Yale on Thursday, June, 29th from 5:00-8:00 p.m. in honor of Norma Glover.]

- **Strategy Discussions** – we have invited our academic partners at Yale University to come and present on two areas of research – Solarize and Renewable Heating and Cooling. As a follow-up to our strategic retreat, and need to reduce GHG emissions from how we heat our buildings, we will delve into community based marketing strategies as a potential approach and catalyst to renewable heating and cooling deployment. There are several reports in your meeting materials for your perusal.

- **Committee Recommendations** – the Budget & Operations Committee will be recommending for the Board of Director approval of the FY 2018 targets and budget.

- **Staff Transaction Recommendations** – we will have several transactions that we are recommending for your review and approval, including:

    a. **Commercial, Industrial, and Institutional Sector** – Two CPACE transactions. The information regarding the first in Stamford is included today and the relevant documents for the second in Farmington will be updated on Monday afternoon.

    b. **Residential Sector** – acceptance of RGGI funds from DEEP to support health and safety measures in the LMI sector. We are presently finalizing the implementation guidelines and will upload the final materials early next week

- **Other Business** – if anyone has any other business, we would be happy to discuss it.

If you have any questions, comments or concerns, please feel free to contact me at any time.

We look forward to seeing you next week.

Sincerely,

Bryan Garcia
President and CEO

AGENDA

Board of Directors of the
Connecticut Green Bank
845 Brook Street
Rocky Hill, CT 06067

Friday, June 23, 2017
9:00-11:00 a.m.

Staff Invited: George Bellas, Craig Connolly, Mackey Dykes, Brian Farnen, Bryan Garcia, Ben Healey, Dale Hedman, Bert Hunter, Kerry O'Neill, and Eric Shrago

1. Call to order

2. Public Comments – 5 minutes

3. Consent Agenda* – 5 minutes

   a. Approval of Meeting Minutes for April 28, 2017 and June 9, 2017*
   b. Position Descriptions*
   c. Financial Statements for April 2017
   d. Interest Rate Swap Contract of SL2
   e. Acknowledgement and Recognition

4. Board of Directors Strategic Discussions – 60 minutes

   a. Solarize Your Community – 30 minutes
   b. Renewable Thermal Technologies in Connecticut – 30 minutes

5. Committee Recommendations and Updates* – 30 minutes

   a. Budget & Operations Committee* – 30 minutes

      i. Approval of FY 2017 Budget and Targets* – 30 minutes

6. Staff Transaction Recommendations and Updates – 20 minutes

   a. Commercial, Industrial, and Institutional Sector Program Updates and Transaction Recommendations* – 15 minutes

      i. C-PACE Subsidiary*
      ii. C-PACE Transaction* – Stamford
      iii. C-PACE Transaction* – Farmington

b. Residential Sector Program Recommendations* – 5 minutes

i. Health and Safety Partnership with DEEP* – 5 minutes

7. Other Business – 5 minutes

8. Adjourn

*Denotes item requiring Board action

Join the meeting online at https://global.gotomeeting.com/join/983070221

Or call in using your telephone:
Dial (408) 650-3123
Access Code: 983-070-221

Next Regular Meeting: Friday, July 21, 2017 from 9:00-11:00 a.m.
Connecticut Green Bank, 845 Brook Street, Rocky Hill, CT

RESOLUTIONS

Board of Directors of the
Connecticut Green Bank
845 Brook Street
Rocky Hill, CT 06067

Friday, June 23, 2017
9:00-11:00 a.m.

Staff Invited: George Bellas, Craig Connolly, Mackey Dykes, Brian Farnen, Bryan Garcia, Ben Healey, Dale Hedman, Bert Hunter, Kerry O'Neill, and Eric Shrago

1. Call to order

2. Public Comments – 5 minutes

3. Consent Agenda* – 5 minutes

   a. Approval of Meeting Minutes for April 28, 2017 and June 9, 2017*

   Resolution #1

   Motion to approve the minutes of the Board of Directors Meeting for April 28, 2017 and June 9, 2017.

   b. Position Descriptions*

   Resolution #2

   Motion to approve the position descriptions for Managing Director of Marketing and Director of Residential Programs, Multifamily

   c. Financial Statements for April 2017
   d. Interest Rate Swap Contract of SL2
   e. Acknowledgement and Recognition

4. Board of Directors Strategic Discussions – 60 minutes

   a. Solarize Your Community – 30 minutes
   b. Renewable Thermal Technologies in Connecticut – 30 minutes

5. Committee Recommendations and Updates* – 30 minutes

   a. Budget & Operations Committee* – 30 minutes

i. Approval of FY 2017 Budget and Targets* – 30 minutes

Resolution #3

WHEREAS, on June 9th, 2017 the Connecticut Green Bank Budget and Operations Committee recommended that the Green Bank Board of Directors approve the Fiscal Year 2017 Budget and Targets; and

WHEREAS, on June 9th, 2017 the Connecticut Green Bank Budget and Operations Committee recommended that the Connecticut Green Bank Board of Directors authorize Connecticut Green Bank staff to extend the professional services agreements (PSAs) currently in place or adopt new PSAs with:

I. Adnet Technologies, LLC
II. Archaeological & Historical Services, Inc.
III. Clean Power Research, LLC
IV. Cortland Capital Market Services LLC
V. EnergySage Inc.
VI. Forsyth Street Advisors, LLC
VII. Locus Energy LLC
VIII. METIS, Financial Network, Inc.
IX. New Ecology, Inc.
X. OpFocus, Inc.
XI. Opinion Dynamics Corporation
XII. Paul Horowitz
XIII. SmartPower Inc.
XIV. Strategic Environmental Associates, Inc.
XV. Sustainable Real Estate Solutions, Inc.
XVI. The Connecticut Housing Coalition, Inc.
XVII. Wegowise, Inc.

For fiscal year 2018 with the amounts of each PSA not to exceed the applicable approved budget line item.

NOW, therefor be it:

RESOLVED, that the Connecticut Green Bank Board of Directors hereby approves: (1) the FY 2018 Budget and Targets and, (2) the seventeen PSAs listed above, as both items were recommended by the Connecticut Green Bank Budget and Operations Committee.

6. Staff Transaction Recommendations and Updates – 20 minutes

a. Commercial, Industrial, and Institutional Sector Program Updates and Transaction Recommendations* – 15 minutes

i. C-PACE Subsidiary*

Resolution #4

WHEREAS, in its various programs and private-public partnerships, Green Bank has successfully utilized special purpose entities (“SPEs”) to facilitate private capital investment in certain program; and

WHEREAS, the Green Bank intends to create a new special purpose entity for use in the Commercial Property Assessed Clean Energy Program (“C-PACE”) to, among other things, originate, aggregate and warehouse transaction before such transactions are sold/assigned into an existing or future C-PACE private capital fund.

NOW, therefore be it:

RESOLVED, that the Green Bank Board of Directors (“Board”) authorizes the President of the Green Bank and any other duly authorized officer of the Green Bank, to create a special purpose entity for the limited purpose outline herein as well as that certain memorandum date June 16, 2017 which has been submitted to the Board; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and negotiate and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

ii. C-PACE Subsidiary* – Stamford

Resolution #5

WHEREAS, pursuant to Section 16a-40g of the Connecticut General Statutes, as amended, (the “Act”), the Connecticut Green Bank (the “Green Bank”) is directed to, amongst other things, establish a commercial sustainable energy program for Connecticut, known as Commercial Property Assessed Clean Energy (“C-PACE”);

WHEREAS, the Green Bank Board of Directors (the “Board”) has approved a $40,000,000 C-PACE construction and term loan program; and

WHEREAS, the Green Bank seeks to provide a $413,981 construction and (potentially) term loan under the C-PACE program to Glenbrook Industrial Park LLC, the building owner of 650 Glenbrook Road, Stamford, Connecticut (the "Loan"), to finance the construction of specified clean energy measures in line with the State’s Comprehensive Energy Strategy and the Green Bank’s Strategic Plan.

NOW, therefore be it:

RESOLVED, that the President of the Green Bank and any duly authorized officer of the Green Bank is authorized to execute and deliver the Loan in an amount not to be greater than one hundred ten percent of the Loan amount with terms and conditions consistent with the memorandum submitted to the Board of Directors dated June 15, 2017, and as he or she shall deem to be in the interests of the Green Bank and the ratepayers no later than 120 days from the date of this authorization;

RESOLVED, that before executing the Loan, the President of the Green Bank and any other duly authorized officer of the Green Bank shall receive confirmation that the C-PACE transaction meets the statutory obligations of the Act, including but not limited to the savings to investment ratio and lender consent requirements; and

RESOLVED, that the proper the Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to effect the above-mentioned legal instruments.

iii. C-PACE Transaction* – Farmington

Resolution #6

WHEREAS, pursuant to Section 157 of Public Act No. 12-2 of the June 12, 2012 Special Session of the Connecticut General Assembly and as amended (the “Act”), the Connecticut Green Bank (Green Bank) is directed to, amongst other things, establish a commercial sustainable energy program for Connecticut, known as Commercial Property Assessed Clean Energy (“C-PACE”);

WHEREAS, the Green Bank Board of Directors (the “Board”) has approved a $40,000,000 C-PACE construction and term loan program;

WHEREAS, the Green Bank seeks to provide a $396,488 construction and (potentially) term loan under the C-PACE program to DiTommaso Associates, LLC, the building owner of 11 Executive Drive, Farmington, Connecticut (the "Loan"), to finance the construction of specified clean energy measures in line with the State’s Comprehensive Energy Strategy and the Green Bank’s Strategic Plan; and

WHEREAS, the Green Bank may also provide a short-term unsecured loan (the “Feasibility Study Loan”) from a portion of the Loan amount, to finance the feasibility study or energy audit required by the C-PACE authorizing statute, and such Feasibility Study Loan would become part of the Loan and be repaid to the Green Bank upon the execution of the Loan documents.

NOW, therefore be it:

RESOLVED, that the President of the Green Bank and any other duly authorized officer of the Green Bank is authorized to execute and deliver the Loan and, if applicable, a Feasibility Study Loan in an amount not to be greater than one hundred ten percent of the Loan amount with terms and conditions consistent with the memorandum submitted to the Board dated June 19, 2017, and as he or she shall deem to be in the interests of the Green Bank and the ratepayers no later than 120 days from the date of authorization by the Board of Directors;

RESOLVED, that before executing the Loan, the President of the Green Bank and any other duly authorized officer of the Green Bank shall receive confirmation that the C-PACE transaction meets the statutory obligations of the Act, including but not limited to the savings to investment ratio and lender consent requirements; and

RESOLVED, that the proper the Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to effect the above-mentioned legal instruments.

b. Residential Sector Program Recommendations* – 5 minutes

   i. Health and Safety Partnership with DEEP* – 5 minutes

Resolution #7

WHEREAS, the Connecticut Green Bank ("Green Bank") actively seeks to deploy private capital investment toward clean energy improvements in the state's multifamily housing which in some cases have preexisting health and safety issues that are preventing opportunities for clean energy improvements to be made;

WHEREAS, the definition of "clean energy" per the Green Bank's enabling statute set forth at C.G.S. 16-45n includes renewable energy technologies as well as "financing of energy efficiency projects," but does not include health and safety;

WHEREAS, the Green Bank's enabling statute provides that the Green Bank may make "expenditures that promote investment in clean energy in accordance with a comprehensive plan developed by it to foster the growth, development, and commercialization of clean energy sources," and that "such expenditures may include, but not be limited to…the implementation of the plan developed pursuant to … this section";

WHEREAS, the Green Bank Comprehensive Plan approved by the Board of Directors on July 22, 2016 acknowledges the need to mitigate health and safety issues that act as barriers to realizing clean energy investments opportunities; the Comprehensive Plan also notes that the goals of the Green Bank are to support the implementation of Connecticut's clean energy policies be they statutory (i.e., PA 15-194), planning (i.e., Comprehensive Energy Strategy, Integrated Resources Plan), or regulatory in nature;

WHEREAS, the Connecticut Department of Energy and Environmental Protection (DEEP's) 2013 Comprehensive Energy Strategy and the 2014 report of the Connecticut Department of Public Health highlights a funding gap for health and safety remediation as a significant barrier to energy upgrades in the state.

WHEREAS, Green Bank staff has developed expertise and programmatic capacity in deploying funds to remove health and safety barriers to realize clean energy improvements at multifamily properties consistent with the Green Bank's enabling statute through its current multifamily programs and program partnerships;

WHEREAS, Green Bank Deployment Committee, on May 30, 2017, approved the receipt and administration of $1.5 million in Regional Greenhouse Gas Initiative funds from DEEP for the purpose of funding remediation of energy related health and safety barriers in residential housing through a program titled EnergizeCT Health and Safety Revolving Loan Fund ("H&S Fund");

WHEREAS, Green Bank staff has developed, submitted to and received approval of Health and Safety Fund guidelines, policies and procedures from DEEP, as required by DEEP prior to distribution of funds, per the executed Agreement dated June 1, 2017 between Green Bank and DEEP;

NOW, therefore be it:

RESOLVED, that the Board authorizes administration of the Catalyst Fund Pilot Program as amended to incorporate Health and Safety Fund conditions consistent with the guidelines and memorandum dated June 23, 2017 and associated exhibits submitted to the Board; and;

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

7. Other Business – 5 minutes

8. Adjourn

*Denotes item requiring Board action

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Next Regular Meeting: Friday, July 21, 2017 from 9:00-11:00 a.m.
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Board of Directors Meeting

June 23, 2017

Board of Directors

Agenda Item #1

Call to Order

Board of Directors
Agenda Item #2
Public Comments

Board of Directors

Agenda Item #3

Consent Agenda

Consent Agenda
Resolutions 1 and 2

a. **<u>Meeting Minutes</u>*** – approval of meeting minutes of April 28, 2017 and June 9, 2017

b. **<u>Position Descriptions</u>*** – approval of Managing Director of Marketing and Director of Residential Programs, Multifamily position descriptions

c. **<u>Financial Statements</u>** – through April of 2017

d. **<u>Interest Rate Swap Contract</u>** – update on SL2

e. **<u>Acknowledgement and Recognition</u>** – Norma Glover

Connecticut Green Bank
Board of Directors (Recognition)

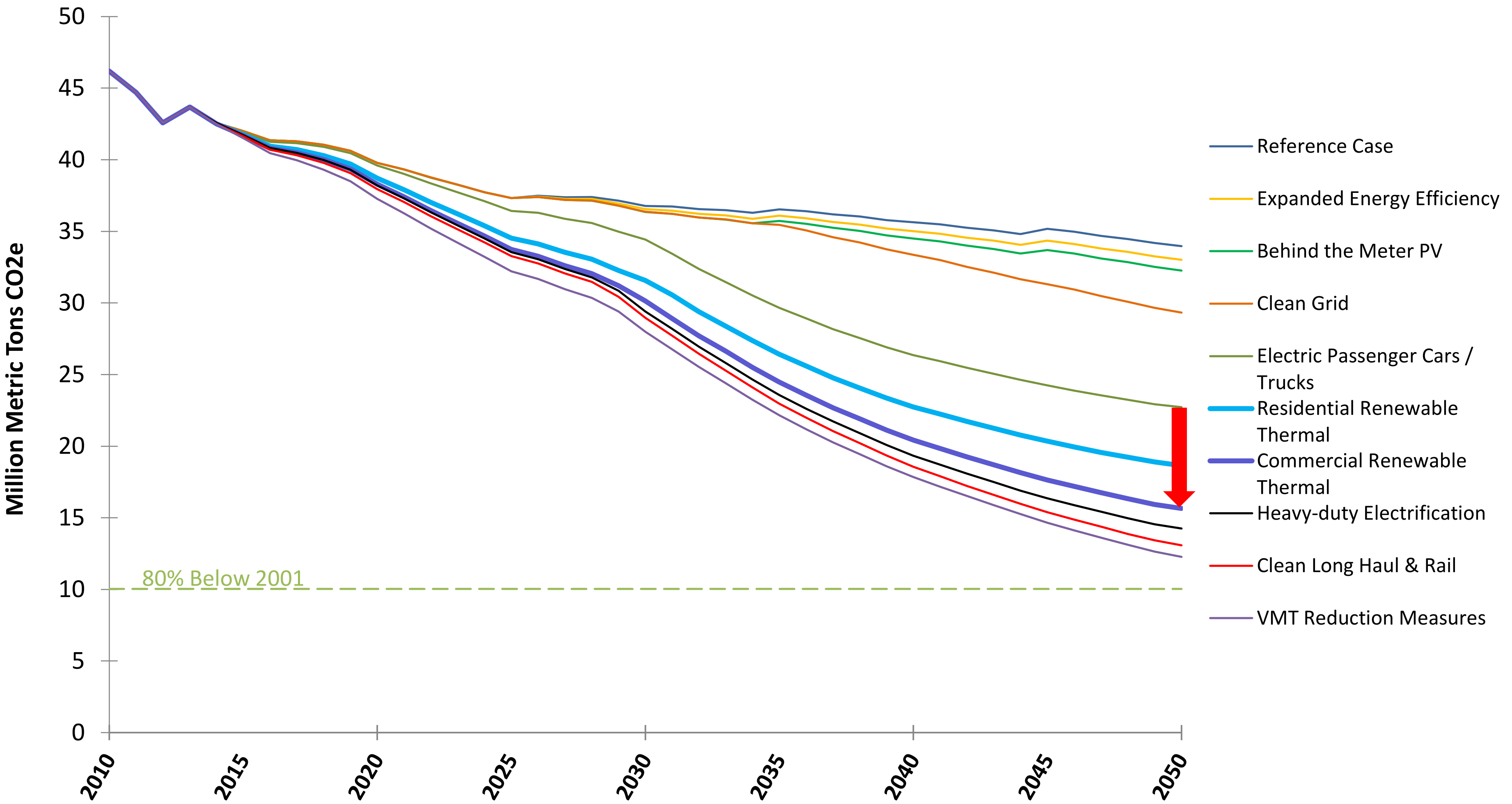
Norma Glover
Founder and Principal
NJG Associates
"The Future of Clean Energy in Connecticut" event at Yale F&ES
on Thursday, June 29th from 5:00-8:00 p.m.

Board of Directors

Agenda Item #4

Strategic Discussions

Strategic Discussion
Hypothetical Emission Reduction Scenario



Strategic Discussion
Residential Renewable Thermal

	2015	2030	2050
35% below 2001 levels by 2030			
Approx. # of Devices	6,000 – 9,000	171,186	847,293
% of Thermal load	0.3%	18%	87%
# of Change Outs /yr.		11,400 (.7%)	33,800 (3%)
45% below 2001 levels by 2030			
Approx. # of Devices	6,000 – 9,000	376,896	847,293
% of Thermal load	0.3%	39%	87%
# of Change Outs /yr.		25,100 (1.7%)	23,500 (1.6%)

- For this scenario renewable thermal refers to air and ground source heat pumps.
- # of Change outs per year is the # of conventional units that would need to be replaced each year in the 2015-2030 and 2030-2050 periods.

Strategic Discussion
Renewable Heating and Cooling

Kenneth Gillingham
Associate Professor of Economics
Yale University

Helle Gronli
Associate Research Scientist
Yale School of Forestry
and Environmental Studies

Board of Directors

Agenda Item #4a

Solarize Your Community

Combining Research & Change: The Influence of Novel Behavioral Strategies in Promoting the Diffusion of Solar Energy

Kenneth Gillingham

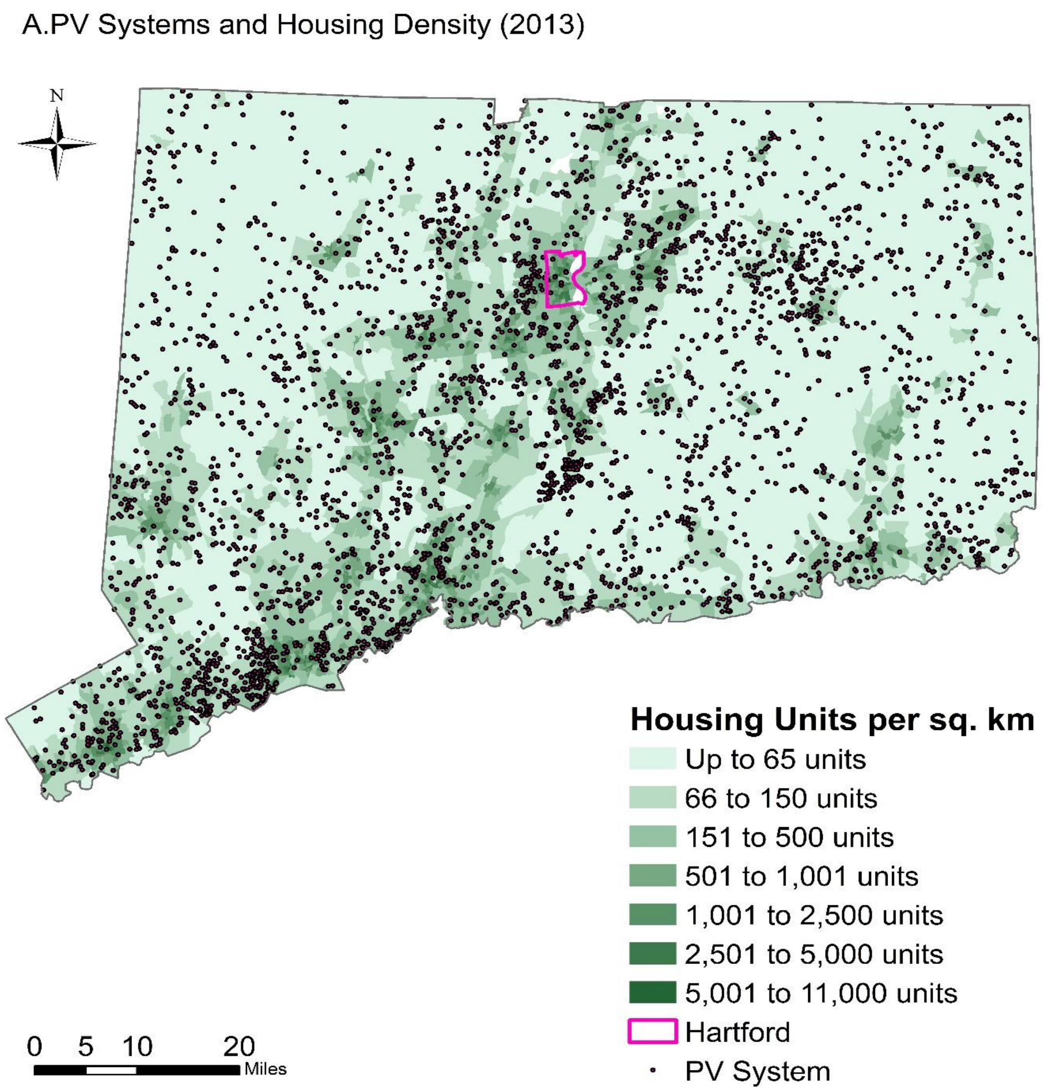
Associate Professor, Yale University

Connecticut Green Bank Board Meeting

June 23, 2017

Collaborative Study on "Solarize" in CT

- What strategies can we use to lead to more solar PV in CT?
- How/why do they work?



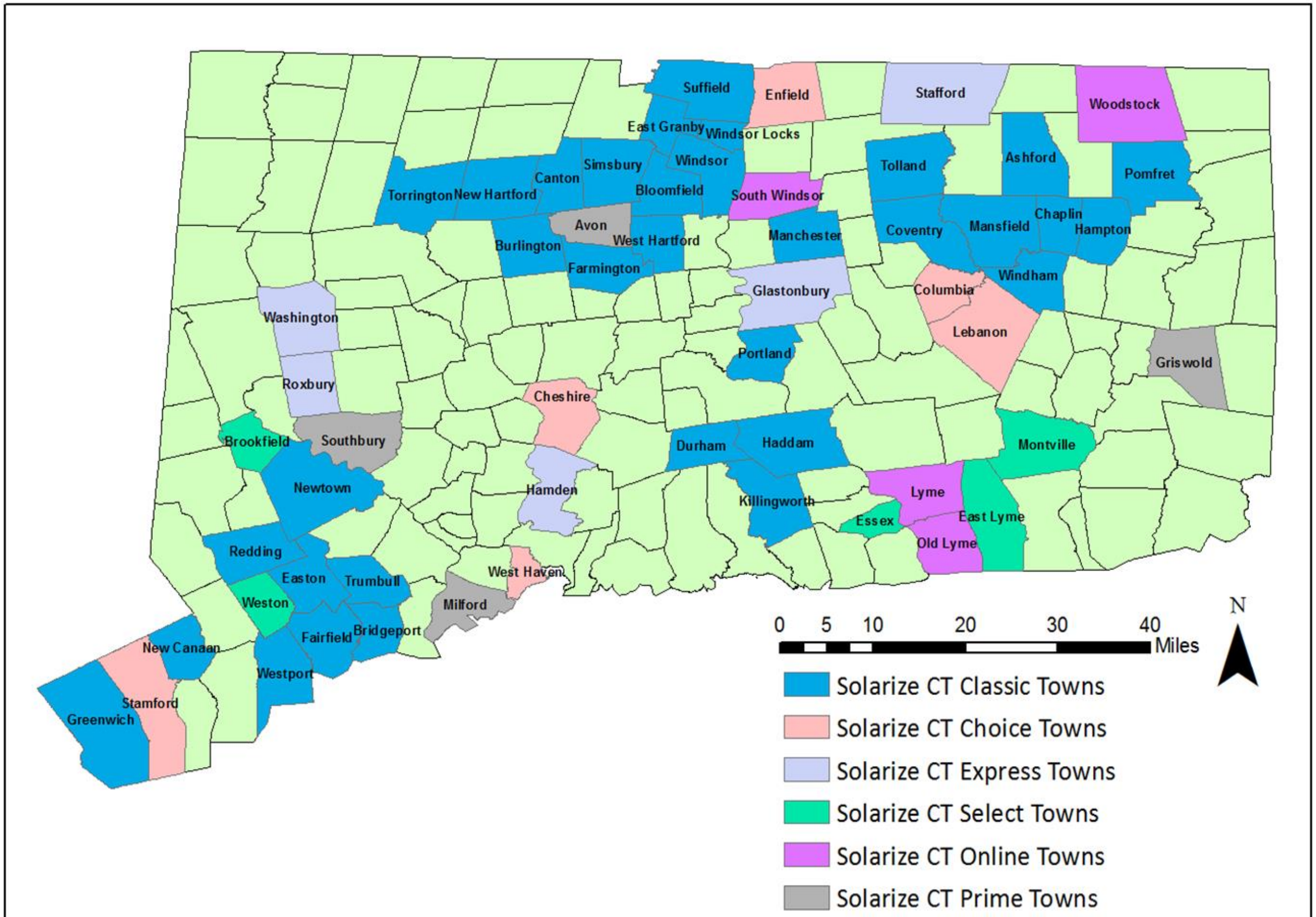
Classic Solarize CT

- Single competitively selected installer

- Tiered group pricing
- Volunteer-driven 20-week outreach campaign

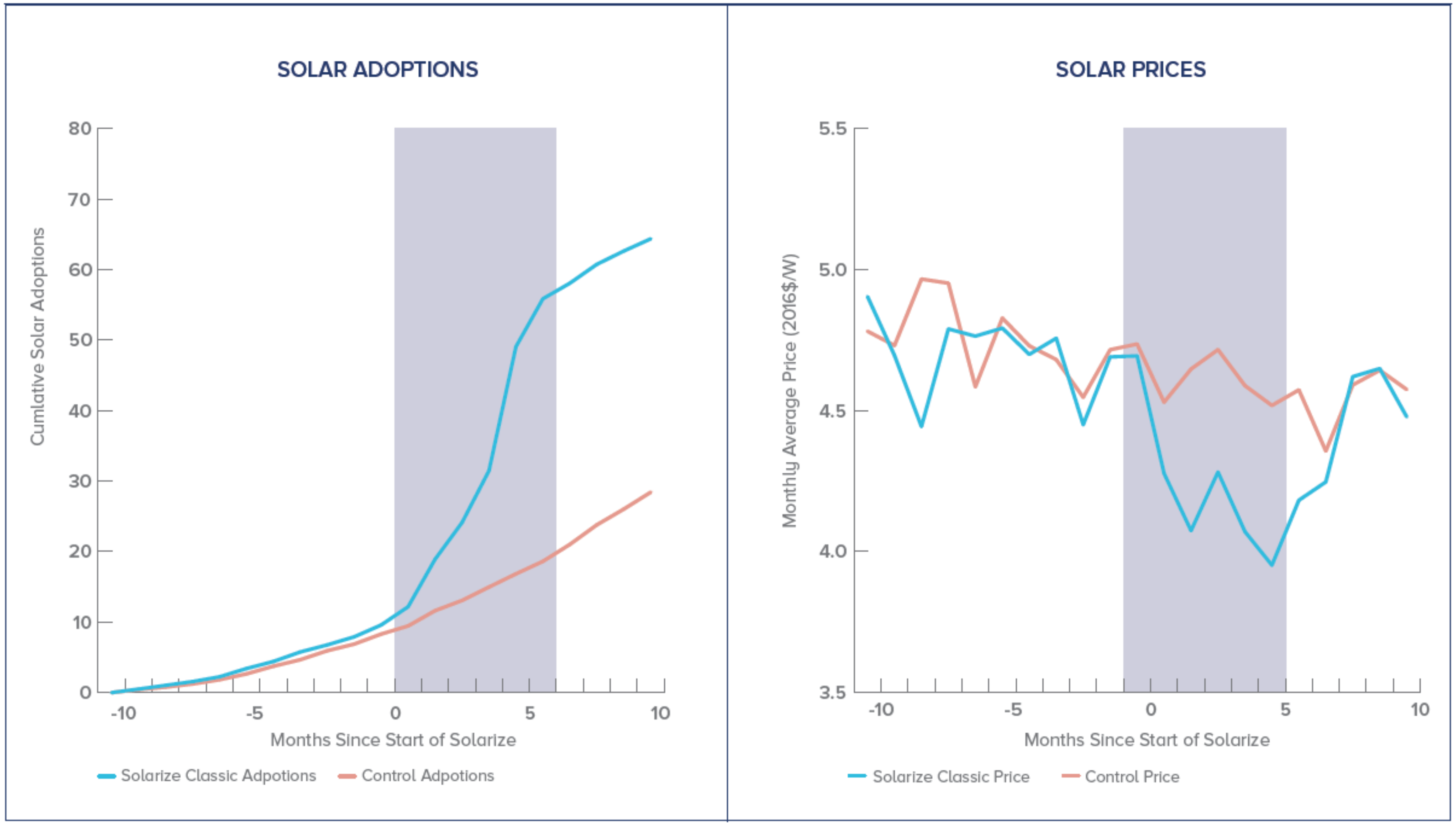
- Media campaign
- Partnership between municipality governments, SmartPower, and the CT Green Bank

Solarize All Over Connecticut!



Experiments to test different hypotheses about what works best

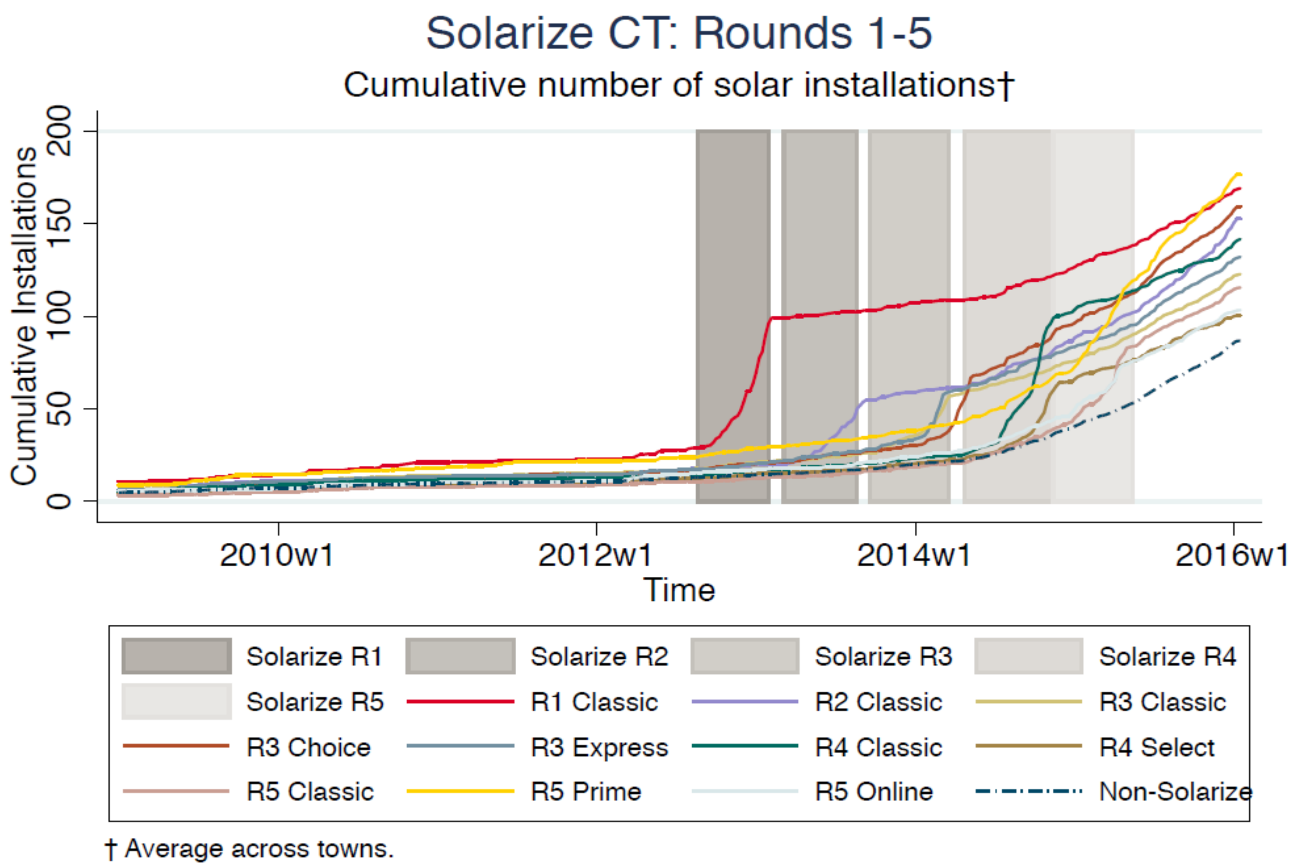
Results: The Hockey Stick



Solarize CT led to a "tipping point" within a few months of launching the campaign. Residential solar adoption significantly increased while prices significantly decreased during the campaign.

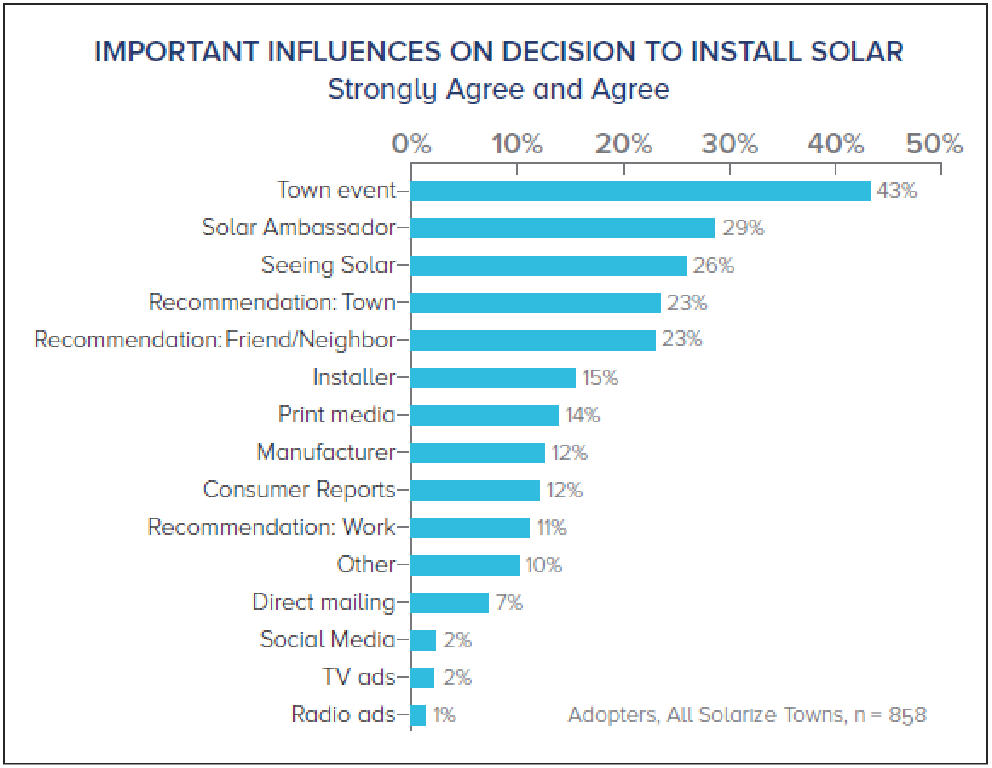
Bollinger, Gillingham, and Lamp (2017) "Tipping Points and Solar Photovoltaic Adoption," Yale University Working Paper

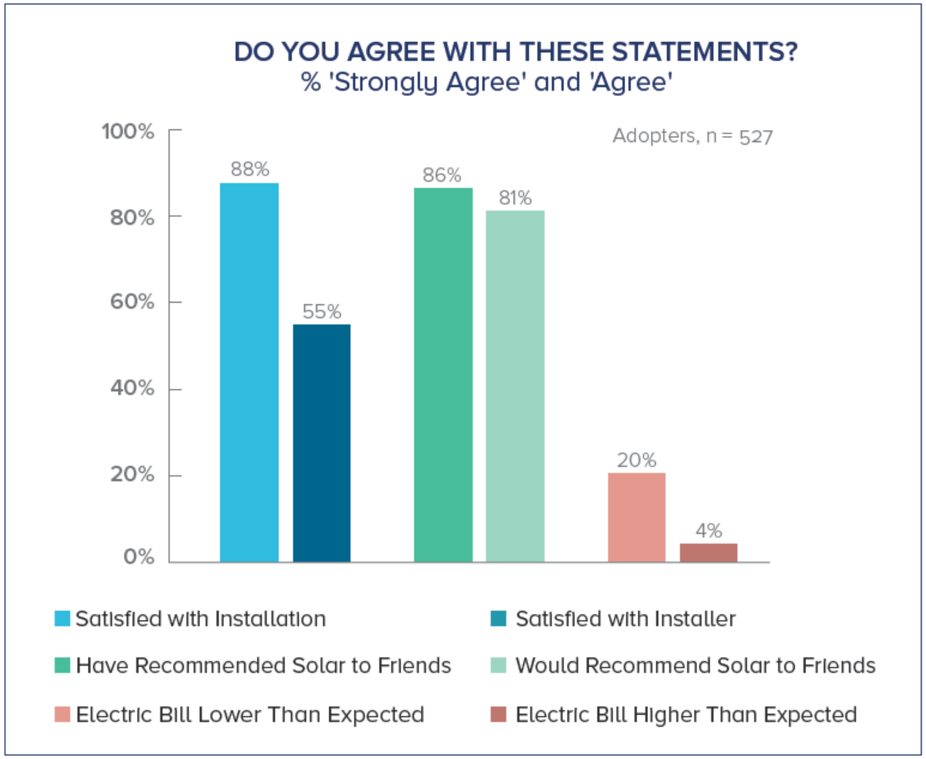
Results by Round



A major increase during all campaigns, with some interesting differences

Survey Results

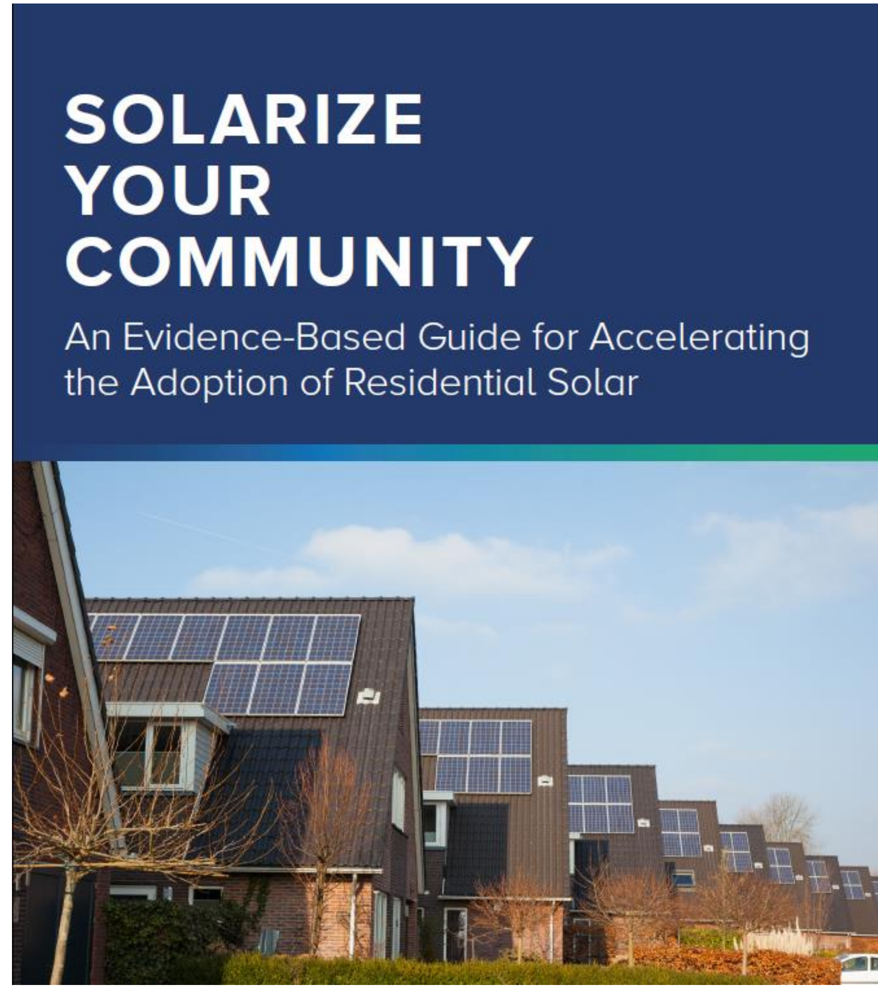




Peer influences are clearly important for the adoption of solar!

Further Key Findings

- Group pricing is not essential for success
- Competition lowers prices further; does not necessarily increase installations
- A shorter campaign can work too, but has less word-of-mouth



http://cbey.yale.edu/programs-research/solar-energy-evolution-and-diffusion-studies-seeds

Key Role of the Student Team

- Ambassador interviews
- Installer interviews
- Guidebook

Hilary Staver
in Bridgeport

"I realized that I was witnessing the Solarize model in action. Fellow members of the community—trusted messengers—were selling the benefits of solar just as much as Astrum. The complex social networks depicted in SEEDS research papers suddenly lit to life for me in the library room." (William Murtha)

The Research Has Won Awards…

- Coverage in the Washington Post
- Mention by DOE Secretary Moniz
- “Project of Distinction” at PV America

And we are continuing the research…

SEEDS II: “Using Behavioral Science to Target LMI and High-Value Solar Installations”

May 01, 2017

Broadening the appeal of solar power to low- and moderate-income households

Sara Harari
MBA , 2019
Master of Environmental Management , 2019

VIEW FULL PROFILE

RELATED TOPICS

RELATED PROGRAMS

Solar Energy Evolution and Diffusion Studies (SEEDS)

RELATED NEWS & INSIGHTS

New project explores increasing solar among low- and moderate-income households

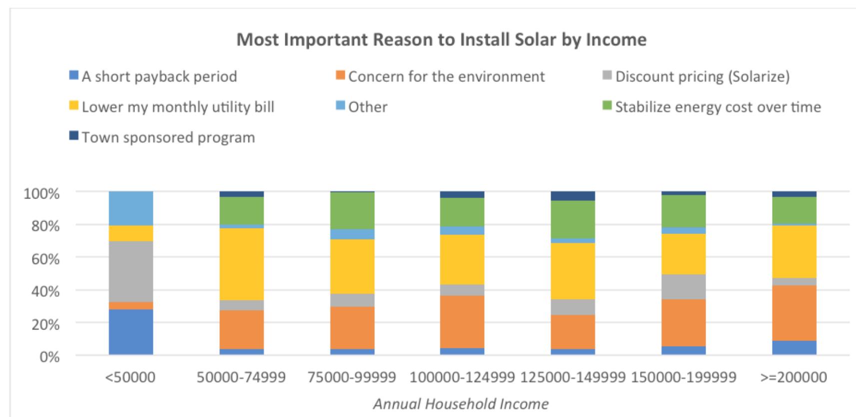
What's the true value of residential solar power?

Yale-Led Project to Widen Access to Household Solar Receives Federal Grant

National guidebook maps the way toward 'tipping points' in solar adoption

As you drive around these days, you may notice a growing number of homes installing solar panels on their roofs. In Connecticut alone there are over 23,000 residential solar installations.[1] In 2011, the Connecticut legislature mandated that the Connecticut Green Bank fund projects to produce at least 30 MW of solar by the end of 2022. By 2015, the Green Bank had supported over 80MW of installed capacity, seven years ahead of schedule.[2]

But why? Why do people decide to install solar? Over the last four years, Yale's Solar Energy Evolution and Diffusion Studies (SEEDS)* team has interviewed thousands of people across



Board of Directors

Agenda Item #5

Committee Recommendations

Budget & Operations Committee

Targets and Budget
Overview

- **Budget** – anticipate similar revenues for FY 2018 with income from REC sales (both RECs and SHRECs)…while keeping expenses flat year-to-year recognizing fiscal situation of the state

- **Deployment and Investment** – deploy no less than 52.5 MW with over $217 million in clean energy investment mobilized, of which about $75 million from the Green Bank and 80% of its investment in loans, with a majority of the remaining in grants that are repaid back over time through the sale of RECs

FY 2018 Targets

Sector	FY 17 Projects	FY 17 Capital Deployed	FY 17 Clean Energy Deployed (MW)	FY 18 Projects	FY 18 Capital Deployed	FY 18 Clean Energy Deployed (MW)
Infrastructure	4,877	$136,918,503	38.5	4,433	$171,300,000	42.3
Residential	952	$40,645,637	5.5	1,185	$35,979,196	5.63
CI&I	50	$$33,279,998	9.1	67-1,667	$34,000,000 - $62,000,000	10.37
Total*	**5,163**	**$194,563,104**	**48.3**	**4,845 - 6,125**	**$217,629,445 - 245,038,400**	**52.5**

To support no less than **4,845 projects**
requiring investment of no less than **$217 million**
to deploy at least **52 MW** of clean energy

REFERENCES

1. FY 2017 YTD – through June 17, 2017

FY 2018 Budget: Investments and Incentives

CONNECTICUT GREEN BANK

	FY 18 Budget	FY 17 Budget	FY 18 %	FY 17 %
Loans – CGB Program Loans	$38,909,950	$17,799,879	52%	41%
Loans – CGB Program Loans: Provisions for Loan Losses	$2,489,760	$1,969,006	3%	5%
Loans – CGB Working Capital Loans to Affiliates, CT SL3	$14,882,644	$6,196,070	20%	14%
Financing - Total	**$56,282,354**	**$25,964,955**	**76%**	**60%**
Credit Enhancements - Loan Loss Reserves - ARRA Funds	$0	$625,000	0%	1%
Credit Enhancements - Loan Loss Reserves - CGB Funds	$1,522,086	$759,276	2%	2%
Credit Enhancements - Loan Loss Reserves - DEEP Funds	$500,000	$0	1%	0%
Credit Enhancements - Interest rate Buydowns - ARRA Funds	$1,570,800	$1,306,340	2%	3%
Credit Enhancements - Interest rate Buydowns - CGB Funds	$100,000	100000	0%	0%
Credit Enhancements - Total	**$3,692,886**	**$2,465,616**	**5%**	**6%**
Incentive - HOPBI/EPBB/PBI/early payoff for PBI Incentives[1]	$14,169,079	$12,549,010	19%	29%
Incentive - Legacy projects	$200,000	$100,000	0%	0%
Incentive - Clean Energy Communities	-	$1,180,000	0%	3%
Incentive - Clean Energy Business Solutions	-	$1,000,000	0%	2%
Incentive - Others	$65,000	$0	0%	2%
Incentive Total	**$14,434,079**	**$14,829,010**	**19%**	**34%**
Investments Total	**$74,409,319**	**$43,259,581**	**100%**	**100%**

To **invest over $70 million in public funds** to **mobilize no less than $217 million in investment** in Connecticut's clean energy economy

FY 2018 Budget: Revenues

Revenue Stream	FY2018 Budget Total	FY2017 Budget Total	YTD FY17 4/30/17	FY17 Projected 12 months
Revenues				
Utility customer assessments	$26,311,000	$26,704,434	$22,443,795	$26,507,774
RGGI auction proceeds - renewables	2,043,200	3,105,350	1,857,874	2,392,647
Interest Income - Cash Intercompany	61,447	-	51,178	61,447
Interest Income - Cash deposits	158,400	40,000	140,412	168,494
Interest Income - Capitalized construction interest	416,570	917,784	284,619	338,619
Interest Income - CPACE Warehouse, benefit assessments	732,592	582,629	567,446	687,446
Interest Income - Loan portfolio, other programs	1,305,205	1,181,284	970,442	1,211,442
Interest Income - Solar lease I promissory notes, net	90,000	90,000	76,038	91,038
CPACE closing fees	100,000	686,400	52,249	52,249
Grant income (federal programs)	49,326	14,632	67,844	67,844
Grant income (private foundations)	-	-	25,000	25,000
REC sales	1,303,734	2,227,500	-	2,300,000
REC sales to utilities under SHREC program	4,476,577	525,333	-	-
Other income - Programs	150,620	122,489	30,119	30,694
Other income - General	100,000	120,000	116,891	119,141
Total Sources of revenue:	$37,298,671	$36,317,834	$26,683,905	$34,053,834

Lost revenues from RGGI as a result of lower auction prices is offset by an **increase in REC** (i.e. spot market) **and SHREC** (i.e., 15-year contracts) sales

FY 2018 Budget: Expenses

Expense	FY18 Budget General Operations	FY18 Budget Programs	FY18 Budget Total Operations & Programs	FY17 Budget Total Operations & Programs	$ Incr / (Decr)	% Incr / (Decr)
Employee compensation	$ 955,220	$ 4,434,200	$ 5,389,420	$ 5,050,091	$ 339,329	7 %
Employee benefits/payroll taxes	732,016	3,406,452	4,138,468	3,918,071	220,397	6 %
Temporary Employees	-	22,150	22,150	96,000	(73,850)	(77)%
Program development and administration	-	3,942,726	3,942,726	4,305,159	(362,433)	(8)%
Marketing	1,217,850	1,888,446	3,106,296	3,533,090	(426,794)	(12)%
EM&V	210,000	461,000	671,000	508,161	162,839	32 %
Consulting & advisory fees	135,500	235,000	370,500	731,750	(361,250)	(49)%
R&D expenditures	810,000	-	810,000	735,000	75,000	10 %
Professional fees: legal and accounting	216,950	316,000	532,950	607,000	(74,050)	(12)%
Bond Issuance Costs	-	-	-	-	-	0 %
Rent and location related expenses	113,538	527,091	640,629	628,818	11,811	2 %
Office, computer & other expenses	313,963	657,932	971,895	798,675	173,220	22 %
Expenses before Financial Incentives:	$ 4,705,037	$ 15,890,996	$ 20,596,034	$ 20,911,815	$ (315,782)	(2)%

.

Doing more with less – Continuing to innovate

FY 2018 Budget: Expenses Key Takeaways

- **<u>Employee Salaries –</u>** Increase due to conversion of temps to perm and new positions (see next slide and staffing plan)
- **<u>Marketing:</u>**
    - Significant reduction in paid media brand spend. More focus on earned media(PR) this year rather than high profile brand advertising
    - Reduction in web development expenses. (e.g. CPACE.com will be completed)
    - Better targeting leads to digital efficiencies and in turn decreased spend
    - FY17 included budget for outreach campaigns that did not materialize, FY18 did not carry their budget over
- **<u>Consulting and Advisory Fees –</u>** reliance on internal team and shift of resources to EMV and to Computer, Office, and other expenses
- **<u>Program Administration and Development –</u>** Decrease in expenses stems from efficiency gains in administration

FY 2018 Budget: Employee Staffing Plan

- **Staff**
  - **Proposing 4 additional FTE’s**
    - Staff Accountant
    - Program Assistant, Residential 1-4 programs (Contingent)
    - Program Associate, Residential 1-4 programs (Durational)
    - Senior Manager, CI&I - Institutional Programs (Contingent)
- **COLA** – 0% as we are a merit-driven organization
- **Merit** – proposing up to 3.0% for FY 2018 (up to 3% in FY2017 and 6.0% in FY 2016)

FY 2018 Budget: Strategic Partners

Partner	Department	RFP	Year of RFP	Work Performed	FY18 Budget
Adnet Technologies, LLC	General Operations	Y	2017	IT Outsourcing	$ 400,000
Archaeological & Historical Services, Inc.	Resi & MultiFamily	N		SHPO Reviews	42,793
Clean Power Research, LLC	S&I	Y	2016	PowerClerk Software	430,000
Cortland Capital Services	CI&I	Y	2013	CPACE - Loan Servicing	84,860
EnergySage Inc.	Resi	Y	2014		36,000
Forsyth Street	R&D	Y	2016	Alternative financing Partners study	125,000
Locus Energy LLC	S&I	Y	2016	Revenue grade meters for PV Systems	570,000
METIS, Financial Network, Inc.	Resi	Y	2014	Resi Data Warehouse	200,000
New Ecology	Multifamily	Y	2015	Sherpa Loan Program administration	248,000
OpFocus	General Operations	Y	2013	IT Consulting	50,000
Opinion Dynamics	General Operations	Y	2013	EMV Consulting	125,000
Paul Horowitz	General Operations	N		EMV Consulting	50,000
SmartPower Inc.	Marketing	N		Outreach	-
Strategic Environmental Associates	General Operations	N		EV Charging Carbon Offsets	95,000
Sustainable Real Estate Solutions, Inc.	CI&I	Y	2012	CPACE Third Party Administrator	619,750
CT Housing Coalition	Multifamily	N		Multifamily Programs - Outreach and Training	135,000
Wegowise	Multifamily	Y	2015	Multifamily Programs - Benchmarking	115,000
					$ 3,326,403

Research and Development

CONNECTICUT GREEN BANK

Research & Development	Purpose	FY 2018 Budget	FY 2017 Budget	FY17 YTD 4/30/17		FY18 to FY17 Budget Incr / (Decr)	% Incr / (Decr)
Consultants:							
Green Bond Certification	Carbon Count	$ 25,000	$ 25,000	$ -		$ -	0%
Green Bond Launch	Consulting related to Issuance of Green Bonds	35,000	35,000	-		-	0%
Benchmarking Outreach	additional benchmarking efforts	25,000					
CDFI or SPE/Tax Letter	Creation of Community Development Financial Institution (CDFI) or Special Purpose Entity (SPE) for Spin Out	150,000	75,000	20,000		75,000	100%
C&I Modules (SRS)	C-PACE CDMP Module Development: 1) Customer Feedback Survey, 2) AVERT algorithm, 3) Program Savings Account	-	75,000	-		(75,000)	-100%
Renewable Thermal Technology	Regional Coordination	25,000	25,000	-		-	0%
Renewable Thermal Technology	Yale Research	50,000	50,000	50,940		-	0%
Renewable Thermal Technology	ASHP EMV	50,000					
Renewable Thermal Technology	GSHP EMV	50,000					
Utility 2.0	Study on Grid Modernization	-	50,000	-		(50,000)	-100%
Alternative Fuel Vehicles	Studies and Pilot Project	150,000	50,000	65,878		100,000	200%
Revenue Development Opportunities	Royalty development	-	250,000	-		(250,000)	-100%
Resi 1-4 and CI	Market studies	100,000	100,000	-		-	0%
Green Bank Academy	Development of GBA	100,000					
All Programs	Energy Burden reduction study	50,000	-	-		50,000	0%
LMI	Solar Pathways (value proposition in LMI space)	15,000	-	-		15,000	0%
		$810,000	$735,000	$136,819		$(150,000)	10%

Board of Directors
Agenda Item #6
Staff Transaction Recommendations and Updates

Board of Directors

Agenda Item #6a

Commercial, Industrial, and Institutional Sector Program Transactions

Board of Directors

Agenda Item #6ai

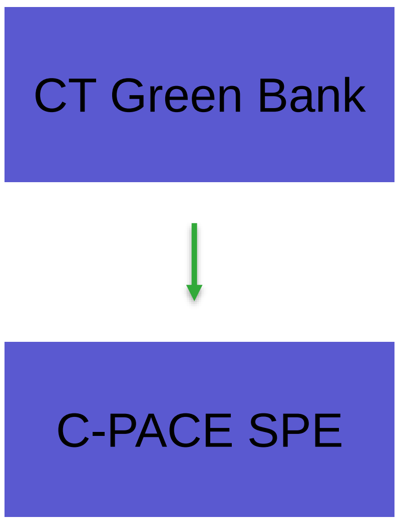
C-PACE Subsidiary

C-PACE Special Purpose Entity

CONNECTICUT GREEN BANK

- CGB continues to originate C-PACE transaction on it’s balance sheet with eventual goal of selling to HA C-PACE or other buyer
- Green Bank has relied on the use of special purpose entities (“SPEs”), which are affiliates or subsidiaries of Green Bank, typically formed as Connecticut limited liability companies or corporations. The use of such SPEs enables Green Bank to structure legal partnerships, mitigate risk, and define the roles and responsibilities of various counterparties to an agreement in order to achieve specific goals without exposing or committing Green Bank’s full balance sheet to that endeavor.

C-PACE Special Purpose Entity



Staff seeks approval for authority for the creation of a C-PACE SPE which would facilitate further scale for the C-PACE Program by creating a dedicated legal vehicle that should more easily enable private capital partners to review the portfolio, verify standardized terms and conditions across a pool of assets, and participate in financings accordingly on an aggregated – rather than asset-level – basis.

Board of Directors

Agenda Item #6aii

C-PACE Transaction – Stamford

650 Glenbrook Road, Stamford Ratepayer Payback

[redacted]

- **$413,981** for a solar PV system
- Projected savings are **10,594 MMBtu** versus **$413,981** of ratepayer funds at risk.

- Ratepayer funds will be paid back in one of the following ways
  - ❑ (a) through a take-out by a private capital provider at the end of construction (project completion);
  - ❑ (b) subsequently, when the loan is sold down to a private capital provider; or
  - ❑ (c) through receipt of funds from the City of Stamford as it collects the C-PACE benefit assessment from the property owner.

650 Glenbrook Road, Stamford Terms and Conditions

- **$413,981** construction loan at 5% and term loan set at a fixed 6% over the 20-year term
- **$413,981** loan against the property
  - ❑ Property valued at [redacted]
  - ❑ Loan-to-value ratio equals [redacted] Lien-to-value ratio equals [redacted]
- DSCR > [redacted]

650 Glenbrook Road, Stamford
The Five W's

- **What?** Receive approval for a **$**413,981 construction and (potentially) term loan under the C-PACE program to Glenbrook Industrial Park LLC to finance the construction of specified energy upgrade
- **When?** Project to commence 2017
- **Why?** Allow Green Bank to finance this C-PACE transaction, continue to build momentum in the market, and potentially provide term financing for this project until Green Bank sells it along with its other loan positions in C-PACE transactions.
- **Who?** Glenbrook Industrial Park LLC, the property owner of 650 Glenbrook Road, Stamford CT
- **Where?** 650 Glenbrook Road, Stamford CT

650 Glenbrook Road, Stamford Project Tear Sheet

[redacted]

650 Glenbrook Road, Stamford
Key Financial Metrics

[redacted]

Board of Directors

Agenda Item #6aiii

C-PACE Transaction – Farmington

11 Executive Drive, Farmington Ratepayer Payback

- **$396,488** for a solar PV system
- Projected savings are **10,594 MMBtu** versus **$396,488** of ratepayer funds at risk.

[redacted]

- Ratepayer funds will be paid back in one of the following ways
  - (a) through a take-out by a private capital provider at the end of construction (project completion);
  - (b) subsequently, when the loan is sold down to a private capital provider; or
  - (c) through receipt of funds from the Town of Farmington as it collects the C-PACE benefit assessment from the property owner.

11 Executive Drive, Farmington Terms and Conditions

CONNECTICUT GREEN BANK

- **$396,488** construction loan at 5% and term loan set at a fixed 5% over the 10-year term
- **$396,488** loan against the property
  - Property valued at [redacted]
  - Loan-to-value ratio equals [redacted]; Lien-to-value ratio equals [redacted]
- DSCR > [redacted]

11 Executive Drive, Farmington
The Five W's

- **What?** Receive approval for a $396,488 construction and (potentially) term loan under the C-PACE program to DiTommaso Associates, LLC to finance the construction of specified energy upgrade
- **When?** Project to commence 2017
- **Why?** Allow Green Bank to finance this C-PACE transaction, continue to build momentum in the market, and potentially provide term financing for this project until Green Bank sells it along with its other loan positions in C-PACE transactions.
- **Who?** DiTommaso Associates, LLC, the property owner of 11 Executive Drive, Farmington CT
- **Where?** 11 Executive Drive, Farmington CT

11 Executive Drive, Farmington Project Tear Sheet

[redacted]

11 Executive Drive, Farmington
Key Financial Metrics

[redacted]

CONNECTICUT GREEN BANK

Board of Directors

Agenda Item #6b

Residential Sector Program Transaction

Health and Safety Partnership with DEEP

Partnership with DEEP
Health & Safety – Overview

- CGB Deployment Committee, on May 30th 2017, approved transfer of $1.5 million of Regional Greenhouse Gas Initiative (RGGI) proceeds from DEEP to the Green Bank to support owners of residential properties that house LMI residents to cover the costs of remediating health and safety issues that that are preventing energy upgrades.
  - Established the EnergizeCT Health and Safety Revolving Loan Fund (“H&S Fund”).
  - CGB to administer H&S Fund and deploy this capital in conjunction with its residential financing products, as well as energy efficiency programs administered by CT’s major energy utilities.
  - Deployment of capital from H&S Fund will initially target multifamily properties, with the ability to provide limited grants on an exception basis.
  - Capital deployment directed at single family properties will be considered in the future but will require additional study, program design, and Board approval.
  - Funds remain with the Green Bank in perpetuity; any capital not deployed at least once by June 30, 2022 by CGB will be returned to DEEP.

Partnership with DEEP – H&S Proposed Catalyst Fund Amendments

- Proposed terms, conditions and guidelines for use of the H&S Fund for multifamily enable easy integration with the Catalyst Fund Pilot Program, previously approved by the Board.
- Amendments to the Catalyst Fund for H&S funded loans, include:
  - On an exception basis, up to 25% of the Health & Safety Fund amount may be granted. Further, additional amounts (above 25%) may be granted on an exception basis for properties owned by non-profits, state and federally funded housing authorities, co-operatives and condominium complexes, based on the needs and financial strength of the property
  - Projects using Health & Safety Funds are subject to the requirements of the state set aside requirements for contractors qualified as small and minority owned businesses: CGS Sec. 4a-60g
  - Clarification of energy audit requirements and qualifications of professionals performing health and safety assessments
- These amendments have been approved by DEEP, per the H&S Fund Agreement between DEEP and CGB. Staff is now requesting review and approval of the amended Catalyst Fund Pilot Program guidelines.

Partnership with DEEP
Health & Safety

NOW, therefore be it:

RESOLVED, that the Board authorizes administration of the Catalyst Fund Pilot Program as amended to incorporate Health and Safety Fund conditions consistent with the guidelines and memorandum dated June 23, 2017 and associated exhibits submitted to the Board; and;

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

Board of Directors

Agenda Item #4b

Renewable Thermal Technologies in Connecticut

Feasibility of Renewable Heating and Cooling in Connecticut

Connecticut Green Bank
Board Meeting June 23rd, 2017

Helle Gronli

Roadmap

- Why a feasibility study?
- What is the potential?
- How do renewable thermal technologies compete?
- What are the challenges?
- What are possible solutions?

Roadmap

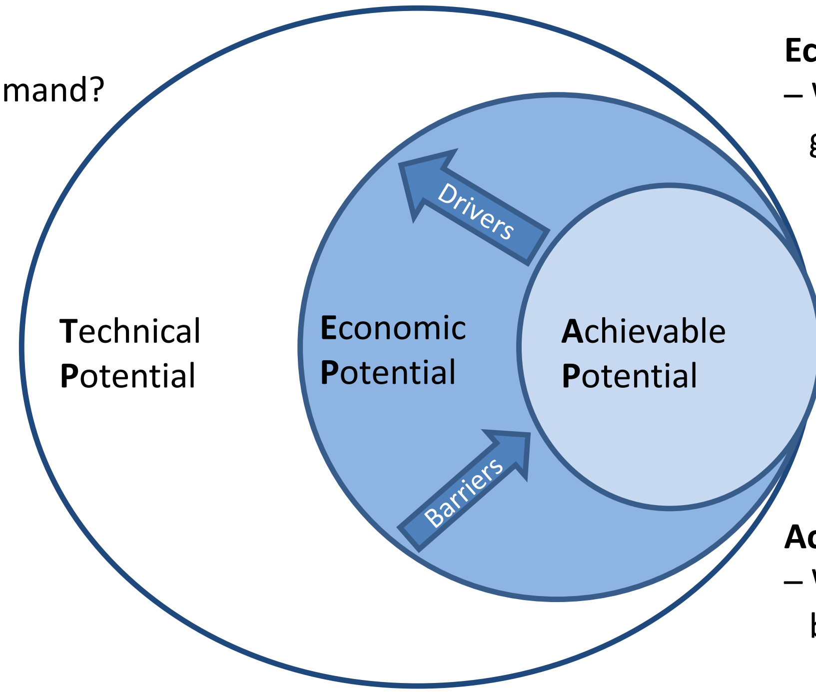
Purpose of the Study

…to assess a realistic contribution from Renewable Thermal Technologies (RTTs) in achieving Connecticut's transition to a less carbon-intensive economy, and to establish the knowledge necessary for effective policies and strategies to advance RTTs

Background

Technical Potential
– How big is the thermal demand?

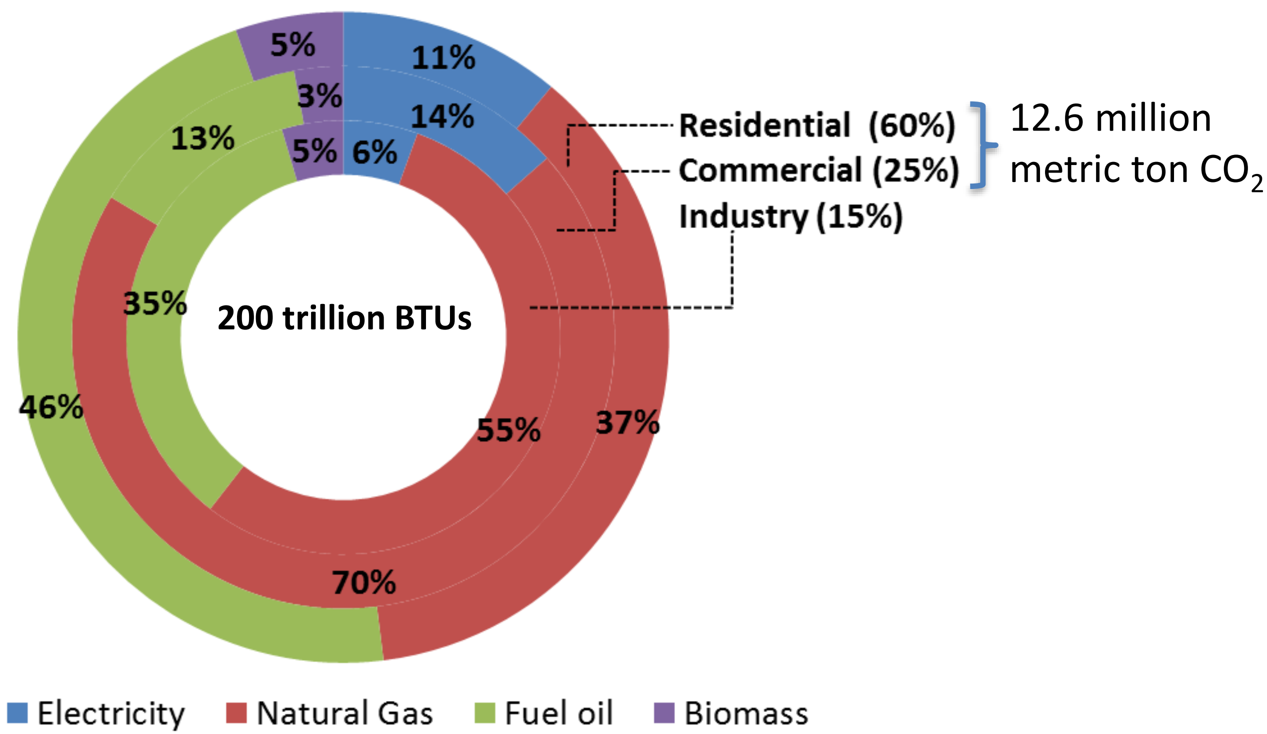
Economic Potential
– What is economically feasible given the competition analysis?



Achievable Potential
– What is realistic given barriers and drivers?

Background

Thermal Demand in Connecticut 2014



The market potential

Sources: EIA SEDS and own analysis

Proposed thermal technology	Instead of	Single-family	Multi-family	Education	Food Service	Health	Hotel	Office
ASHP with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Water Heating	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass pellets	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Green cells: Positive Net Present Value

Competition analysis

Financially Challenging

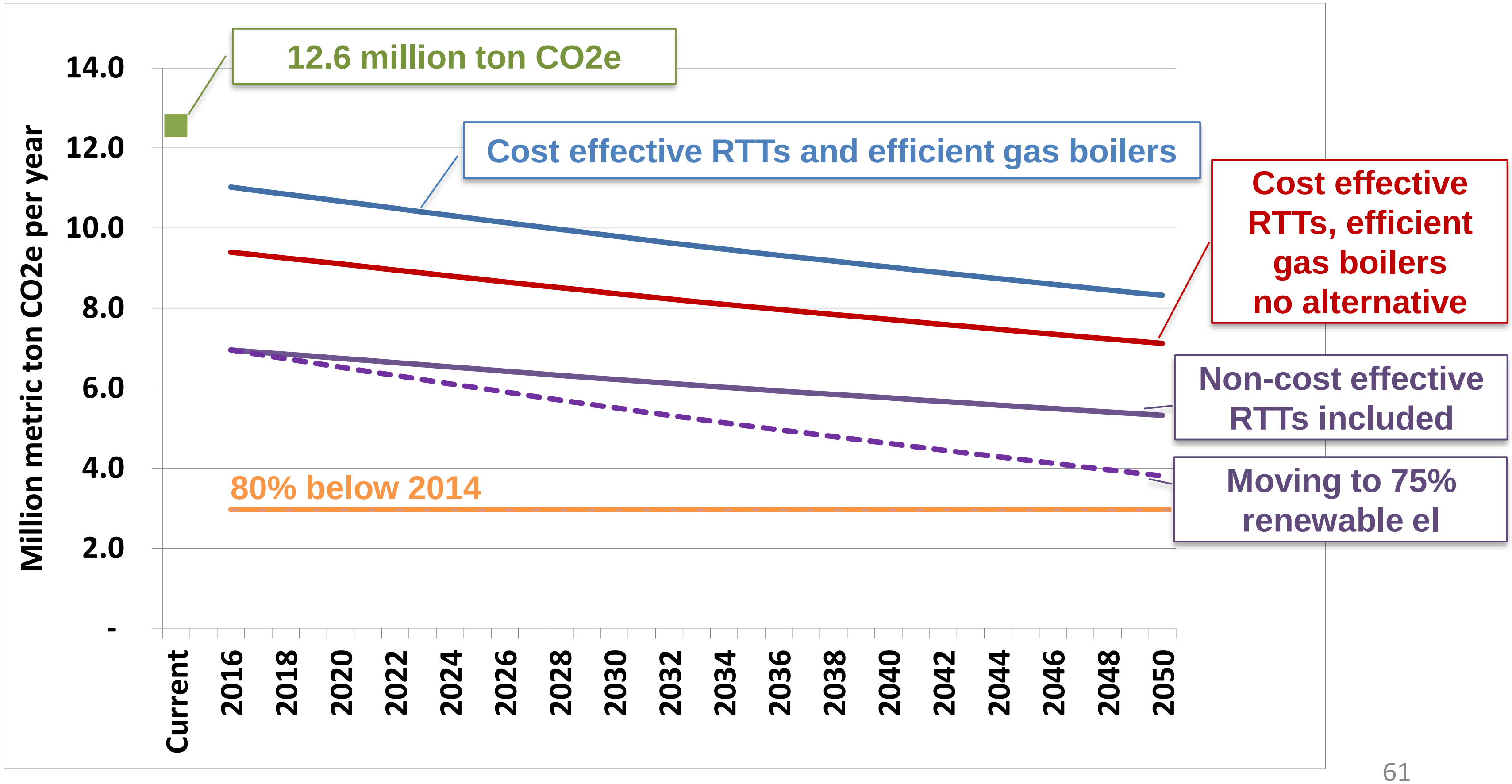
- Heat pumps and solar water heating are competitive to conventional electric technologies

- Pellet boilers replacing fuel oil boilers are financially competitive in several commercial buildings

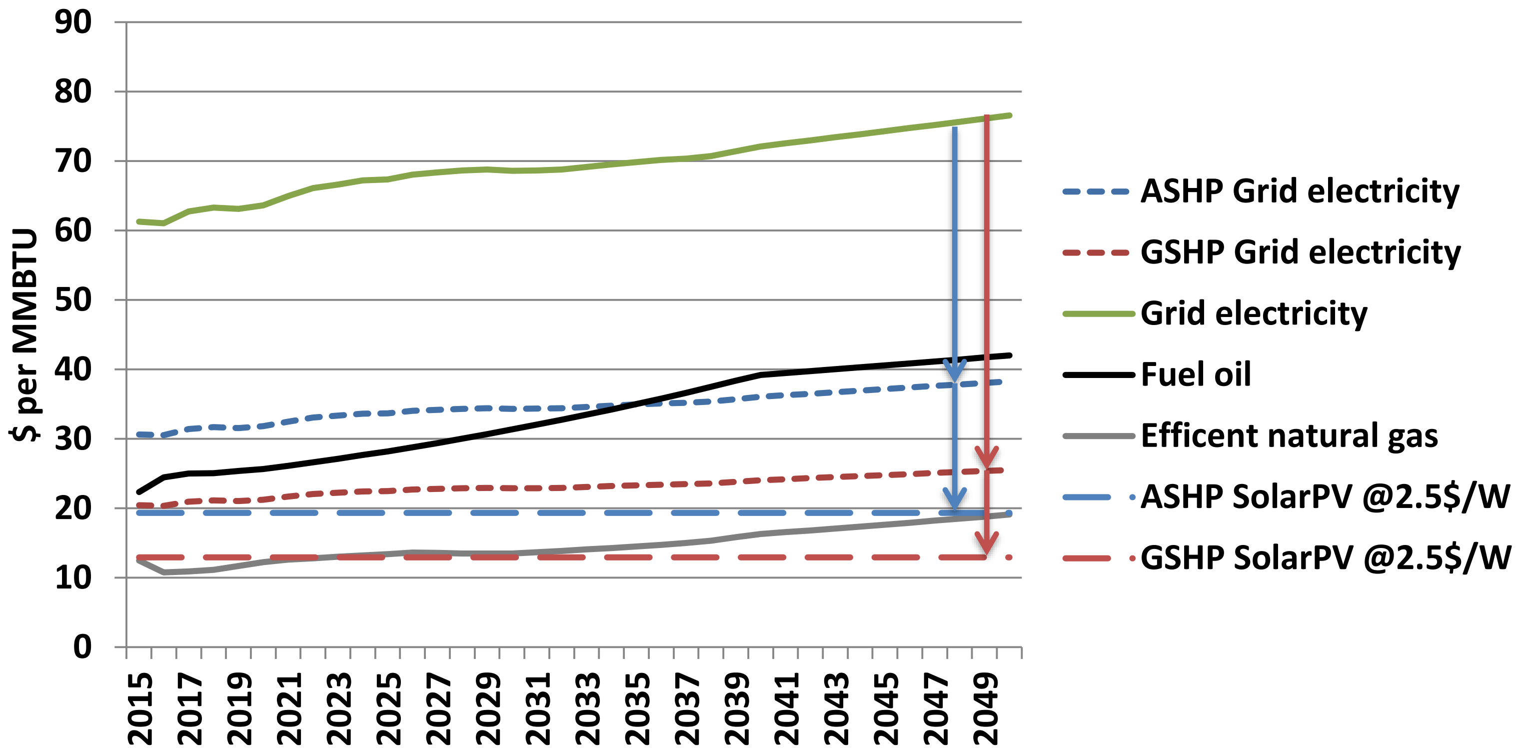
→ Economic potential 19 %

- Highly efficient gas boilers are competitive to conventional electric and fuel oil for space and water heating

Heating and Cooling Buildings – GHG Mitigation



Operational Fuel Costs for Residential Customers



Competition analysis

Sensitivity Analysis

Proposed thermal technology	Instead of	Single-family	Multi-family	Education	Food Service	Health	Hotel	Office
ASHP with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHPs with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Water Heating	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass pellets space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Green cells: Positive Net Present Value in base case
Orange cells: Net Present Value turns positive

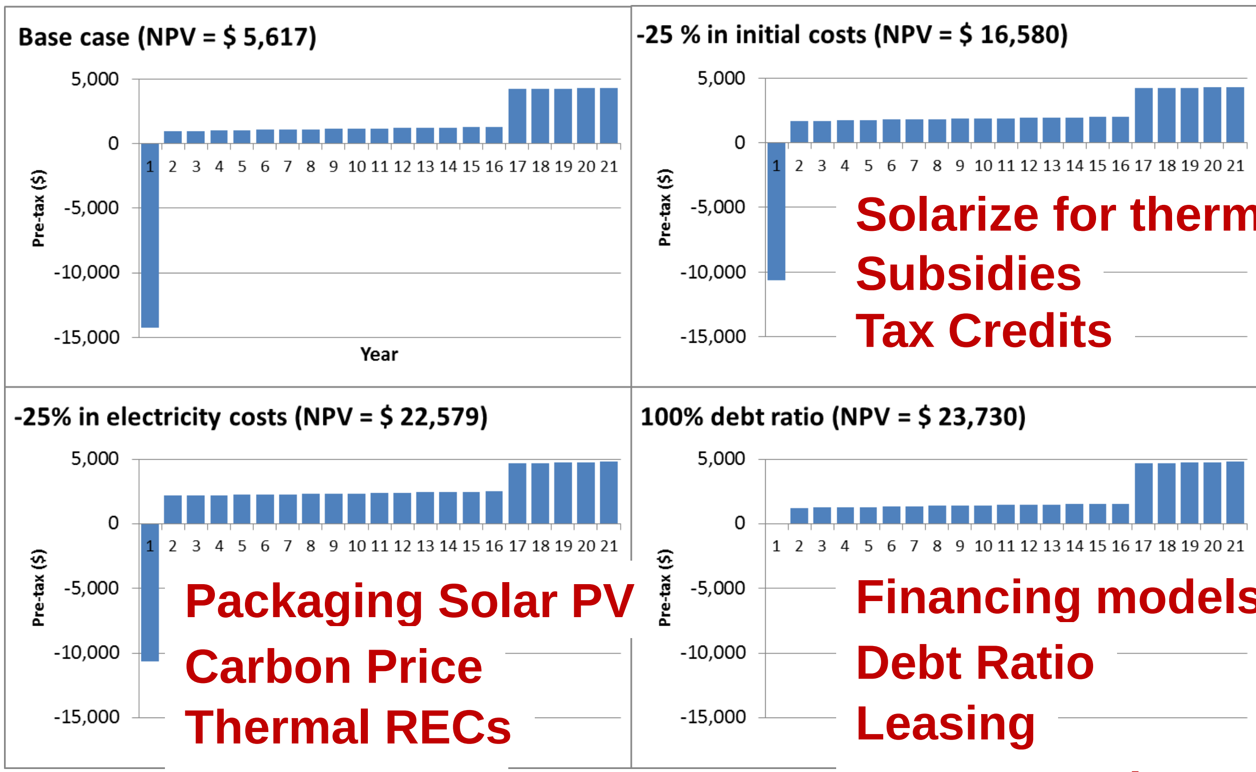
Competition analysis

- Initial costs are 25 % down
- Solar PV reduces electricity costs of heat pumps by 25 %
- Fossil fuel costs are 50 % up

An increasing number of RTTs become competitive against fuel oil

Cash Flow Analysis

Single-family Home Replacing Conventional Electric by GSHP*



Solarize for thermal
Subsidies
Tax Credits

Packaging Solar PV
Carbon Price
Thermal RECs
Interest rates

Financing models
Debt Ratio
Leasing
Energy service agreements

Possible solutions

* Changes are cumulative

Challenges and Opportunities

	UPSTREAM	Heating & cooling market	DOWNSTREAM
BARRIERS	• Fuel availability	• Competence • Performance data • Business models	• High upfront costs • Access to capital • Unfavorable economics • Awareness • Physical constraints
DRIVERS	• Local resources • Price volatility	• Diligent stakeholders • Local governments • Trusted messengers	• Plans and strategies • Grants and rebates • Value proposition • Decision mode • Financing products

Community Purchasing Campaigns

HEATSMART TOMPKINS

- Campaign runs for the second time – 175 enrollments
- Multiple technologies
- 3 pre-selected installers, detailed price guide
- 10 communities

- Campaign ran in 2014
- Single technology – ccASHPs
- 60 of the 500 homes on the island adapted
- One installer
- Tiered pricing

MASSACHUSETTS CLEAN ENERGY CENTER

HeatSmart Mass

- Builds on HeatSmart Tompkins
- Multiple technologies
- Focus communities without gas grid connection
- Starting Fall 2017

- Single technology – ccASHPs
- Currently 4 mainland communities
- 5 pre-selected installers
- Campaigns during Fall 2017

Casco Bay Heat Pump Challenge

Possible solutions

Bringing RTTs to Scale

- Reduce upfront costs
  - Cost reduction campaigns such as “Solarize”
  - Partial load strategies
  - New business and financing models

- Implement market interventions to improve the operational cash flow
  - Multiple measures
  - Performance based incentives
  - Rate structures reflecting the value of renewable thermal

- Enhance awareness and trust
  - Performance verification
  - Trusted messengers
  - Declining block grants and favorable financing

Recommendations

Renewable Heating and Cooling
Update

- **Research** – ongoing partnership with Yale, DEEP, Avangrid and Eversource to understand market for RH&C
- **Collaboration** – regional collaboration with NYSERDA through Renewable Thermal Alliance that is seeking to engage other New England states in RH&C market support and development
- **RSIP Incentive** – new battery storage incentive as part of the balance of plant and indirect support for RH&C and EV additional load on home
- **Smart-E Loan** – special interest rates at 0.99% for RH&C
- **Metering** – developing data collection effort to understand and then communicate RH&C performance
- **Marketing** – preparing for community-based marketing to build the foundation of customer knowledge and contractor competition on RH&C

Board of Directors

Agenda Item #7

Other Business

Other Business

Updates

CONNECTICUT GREEN BANK

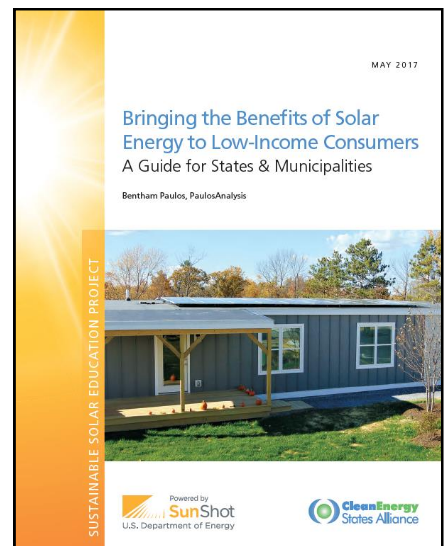
- **Federal Legislation** – Green Bank Act of 2017 released by Congresswoman Esty and Senator Murphy

Hartford Courant

THURSDAY, JUNE 22, 2017

Murphy and Esty Want $10 Billion for 'National Green Bank'

- **Report** – Bringing the Benefits of Solar Energy to Low-Income Consumers by CESA with details from CGB



Board of Directors

Agenda Item #8 – Adjourn

Subject to changes and deletions

CONNECTICUT GREEN BANK
Board of Directors

Draft Minutes – Regular Meeting
Friday, April 28, 2017

A regular meeting of the Board of Directors of the **Connecticut Green Bank (the "Green Bank")** was held on April 28, 2017 at the office of the Connecticut Green Bank, 845 Brook Street, Rocky Hill, CT, in the Colonel Albert Pope board room.

1. Call to Order:

Catherine Smith, Chairperson of the Green Bank and Commissioner of the Department of Economic and Community Development ("DECD"), called the meeting to order at 9:01 a.m.

Board members participating: Bettina Bronisz, State Treasurer's Office; Betsy Crum; Norma Glover (by phone); John Harrity; Reed Hundt (by phone); Rob Klee, Vice Chairperson of the Green Bank and Commissioner of the Department of Energy and Environmental Protection ("DEEP"); Gina McCarthy; Matthew Ranelli; Kevin Walsh (by phone); Tom Flynn (by phone).

Staff Attending: George Bellas, Joe Buonannata, Anthony Clark, Craig Connolly, Mackey Dykes, Brian Farnen, Bryan Garcia, Ben Healey (by phone), Dale Hedman, Bert Hunter, Andrea Janecko, Matt Macunas, Chris Magalhaes, Jane Murphy, Kerry O'Neill, Cheryl Samuels, Eric Shrago, Kim Stevenson, Fiona Stewart, Rudy Sturk, Mariana Trief (by phone) and Mike Yu.

Others Attending: Henry Link, Guy West and Pat Wrice.

2. Welcome New Members to the Board of Directors

Ms. Smith welcomed Betsy Crum and Gina McCarthy to their first meeting as members of the Connecticut Green Bank's Board of Directors. Ms. Smith then presented Ms. Wrice with an Official Proclamation from Governor Malloy recognizing her service to the Board. Members of the Board and Staff shared their thoughts and well wishes with Ms. Wrice.

3. Public Comments

There were no public comments.

4. Consent Agenda

Ms. Smith provided an overview of the consent agenda, which included the minutes from the March 10, 2017 special meeting, an update on the development of environmental impact metrics, and an update on the IT vendor management policy. She called for discussion and a vote on the items in the Consent Agenda.

Upon a motion made by Mr. Walsh, seconded by Mr. Harrity, the Board members voted in favor of adopting the Consent Agenda and Resolutions 1-3 as written. Ms. McCarthy and Ms. Crum abstained from voting due to not having been present for the previous Board of Directors meeting.

Resolution #1

Approval of the minutes from the Board of Directors Meeting for March 10, 2017

Resolution #2

WHEREAS, the Connecticut Green Bank and the Connecticut Department of Energy and Environmental Protection (DEEP) working with the U.S. Environmental Protection Agency (EPA) to assess the Avoided Emissions and Generation Tool (AVERT) to estimate emission benefits resulting from clean energy deployment;

WHEREAS, DEEP and the EPA have demonstrated support for the environmental emissions methodology; and

WHEREAS, the Audit, Compliance, and Governance Committee at a meeting on April 20, 2017, reviewed and now recommend that the Board of Directors approve through the Consent Agenda the proposed Connecticut Green Bank and DEEP Evaluation Framework – Societal Perspective – Environmental Benefit Methodology documentation;

NOW, therefore be it:

RESOLVED, that the Board of Directors approves the proposed Connecticut Green Bank and DEEP Evaluation Framework – Societal Perspective – Environmental Benefit Methodology documentation to be used for reporting, communication, and other purposes as deemed necessary.

Resolution #3

RESOLVED, that the Board of Directors of the Connecticut Green Bank hereby approves the proposed Vendor Management Policy.

5. Committee Recommendations and Updates

Audit, Compliance and Governance ("ACG") Committee

Mr. Ranelli and Mr. Bellas informed the Board that an audit of the financial statements of CT Solar Lease 2 LLC – the lease affiliate of the CT Green Bank – was recently completed for the year ended December 312016 and resulted in a clean audit report. The ACG Committee proposed that the Board approve the draft audited financial statements contingent upon no further adjustments or disclosures materially changing the financial position of CT Solar Lease 2 LLC as presented.

Upon a motion made by Ms. Crum, seconded by Ms. Bronisz, the Board members voted unanimously in favor of adopting Resolution #4, regarding the audited financial statements of CT Solar Lease 2 LLC, as written.

Resolution #4

WHEREAS, Article V, Section 5.3.1(ii) of the Connecticut Green Bank ("Green Bank") Operating Procedures requires the Audit, Compliance, and the Governance Committee (the "Committee") to meet with the auditors to review the annual audit and formulation of an appropriate report and recommendations to the Board of Directors of the Green Bank (the "Board") with respect to the approval of the audit report;

NOW, therefore be it:

RESOLVED, that the Board approves the proposed draft CT Solar Lease 2 LLC audited financial statements the year ended December 31, 2016 contingent upon no further adjustments to the financial statements or additional required disclosures which would materially change the financial position of CT Solar Lease 2 LLC as presented.

Mr. Ranelli and Mr. Bellas also informed the Board that the State audit for fiscal years 2014-2015 resulted in a favorable report with three minor areas to address, and that Staff has since implemented procedures to address the areas of concern and mitigate future issues.

Attorney Farnen updated the Board that Staff continues to monitor the current legislative session for potential impact on Green Bank-related programs. Ms. McCarthy requested additional background information from Attorney Farnen on the Green Bank's legislative priorities so that she can be brought up to speed.

6. Staff Transaction Recommendations and Updates

Infrastructure Sector Program Updates and Transaction Recommendations

Update on Progress to Targets

Mr. Shrago informed the Board that the Infrastructure Sector is behind on its anaerobic digestion ("AD") program goals, despite having four projects in approval status. Mr. Hedman noted that concerns with financing have slowed the progress of some projects, though Mr. Hunter noted that an AD facility in Southington is now online, which should help pave the way for future projects. Mr. Klee concurred with Mr. Hunter, adding that a product of farm AD projects in particular is something that can eventually be land applied. Mr. Harrity highlighted that AD projects have a greater social benefit than just creating electricity.

Regarding the Residential Solar Investment Program ("RSIP"), Mr. Shrago and Mr. Hedman noted that RSIP is also behind targets because some installers have slowed installations due to cash management issues, while others are building projects outside of RSIP – keeping the renewable energy credits ("RECs") and monetizing them in Massachusetts where they are worth more. Mr. Garcia explained that Renewable Portfolio Standards are regional, so it is not uncommon for a state to pay for projects that occur outside its borders, and that Connecticut has paid for projects from other states in the past as well, including biomass projects in Maine and New Hampshire. Ms. Smith requested that Staff provide more information on Connecticut projects that are being sold into out of state markets. Mr. Hedman replied Staff can view online which Connecticut facilities are approved and classified as Class 1 in Massachusetts, adding that there are currently about 450 such projects for residential solar PV.

Residential Solar Investment Program – PBI Commitment Payout

Mr. Yu presented the performance based incentive ("PBI") commitment payout initiative to the Board. He explained that PBIs are paid out quarterly over a six-year period to third-party owners of residential solar photovoltaic systems. For systems energized from 2015 through the beginning of 2017, the total PBI obligation totals about $20 million. Mr. Yu explained that following up on strategic discussions with the Board in January, Staff is proposing paying out up to $5 million for the early termination of these PBIs, to be deployed through June 30, 2017. He added that Staff has notified and received initial interest from the top-5 (by volume) third-party owners, and that the proposed $5 million allocation was assessed to not impact any other Green Bank program. Staff is proposing a “blind auction” through which the third-party owners can provide discounted rates off the incentive to have the PBI commitment paid out in advance of across the six-year period.

Mr. Hundt noted that the initiative appears to have changed since it was presented to the Deployment Committee and suggested that Staff determine a clearer objective. Mr. Hunter replied that because the Green Bank has had success over the beginning of 2017 investing funds in other projects and programs – this proposal being but one of several discussed with the Board in January to invest available cash resources – as a result, the unrestricted cash balance fell considerably. George Bellas, VP Finance and Administration for the Green Bank confirmed Mr. Hunter’s assessment. Mr. Hunter requested guidance from the Board as to how Staff should proceed. Ms. McCarthy stated that Staff should provide the Board with additional background to address the open questions.

Following further discussion, Ms. Smith recommended that Staff return this initiative to the Deployment Committee for further consideration then report back to the Board at a future – or special – meeting. A vote was not held.

Residential Solar Investment Program – Steps 11 through 13

Mr. Garcia explained to the Board that RSIP is now at about 160 megawatts (“MW”) of the 300 MW target of residential solar deployment by 2020, with over 100 MW coming after the launch of the Solar Home Renewable Energy Credit (“SHREC”) in January 2015. He and Ms. O’Neill also highlighted the progress of RSIP for low-to-moderate income (“LMI”) census tracts. Ms. O’Neill noted that about 3,800 LMI customers have gone solar and that while PosiGen Solar is the only installer taking advantage of the LMI incentive, they are not the only installer serving the market. She added that all installers have gotten the Green Bank’s message that income does not correlate with credit.

Mr. Garcia noted for the Board that Connecticut’s solar incentive is lower than those of Massachusetts, New Jersey, and New York, but that we are comparable to our neighbors in terms of installed watts per capita. He said that despite businesses wanting to move to operate in states where incentives are higher, Connecticut is working to encourage installer partnerships and promote deeper energy savings – adding that Connecticut is the only state that requires a home energy audit as part of its residential solar PV incentive program.

Ms. Smith remarked on the importance of Connecticut maintaining an appropriate balance of lowering incentives but also progressing with regards to volume and scale. Mr. Harrity noted that the general perception since the 2016 election appears to be that solar still has both economic and social value.

Mr. Garcia provided a brief update on recent PURA dockets, including the aggregation for SHRECs.

Mr. Garcia proposed Steps 11, 12 and 13 of the RSIP and LMI incentives to the Board. Regarding the LMI, Mr. Garcia highlighted that as it moves out of pilot and into a market segment, Staff continues to work with their utility counterparts to align on financing programs with their offerings. Mr. Garcia, Ms. O'Neill and Mr. Hedman also discussed the Grid Mod / Climate Change pilot under RSIP, describing the importance of making home energy improvements – like going solar alongside renewable heating and cooling and electric vehicles - and socializing the benefits with battery backup systems.

Following further discussion, Ms. Smith called for a motion to vote.

Upon a motion made by Mr. Klee, seconded by Ms. Bronisz, the Board members voted unanimously in favor of adopting Resolution #6 regarding the Schedule of Incentives, as written.

Resolution #6

WHEREAS, Public Act 15-194 "An Act Concerning the Encouragement of Local Economic Development and Access to Residential Renewable Energy" (the "Act") requires the Connecticut Green Bank ("Green Bank") to design and implement a Residential Solar Photovoltaic ("PV") Investment Program ("Program") that results in no more than three-hundred (300) megawatts of new residential PV installation in Connecticut before December 31, 2022 and creates a Solar Home Renewable Energy Credit ("SHREC") requiring the electric distribution companies to purchase through 15-year contracts the Renewable Energy Credits ("RECs");

WHEREAS, as of March 21, 2017, the Program has thus far resulted in nearly one-hundred and sixty megawatts of new residential PV installation application approvals and completions in Connecticut;

WHEREAS, pursuant to Conn. Gen Stat. 16-245a, a renewable portfolio standard was established that requires that Connecticut Electric Suppliers and Electric

Distribution Company Wholesale Suppliers obtain a minimum percentage of their retail load by using renewable energy;

WHEREAS, real-time revenue quality meters are included as part of solar PV systems being installed through the Program that determine the amount of clean energy production from such systems as well as the associated RECs which, in accordance with Public Act 15-194 will be sold to the Electric Distribution Companies through a master purchase agreement entered into between the Green Bank, Eversource Energy, and United Illuminating, and approved by the Public Utility Regulatory Authority;

WHEREAS, pursuant to the Act, the Green Bank has prepared a declining incentive block schedule ("Schedule") that offers direct financial incentives, in the form of the expected performance based buy down ("EPBB") and performance-based incentives ("PBI"), for the purchase or lease of qualifying residential solar photovoltaic systems, respectively, fosters the sustained orderly development of a state-based solar industry, and sets program requirements for participants, including standards for deployment of energy efficient equipment as a condition for receiving incentive funding;

WHEREAS, pursuant to the Act, to address willingness to pay discrepancies between communities, the Green Bank will continue to provide additional incentive dollars to improve the deployment of residential solar PV in low to moderate income communities.

WHEREAS, pursuant to the Act, to address sustained orderly development of a state-based solar industry, the proposed grid modernization and climate change pilot will provide incentives for solar PV to offset the additional energy load from clean energy sources and storage needs.

WHEREAS, pursuant to Section 16-245(d)(2) of the Connecticut General Statutes, a Joint Committee of the Energy Conservation Management Board and the Connecticut Green Bank was established to "examine opportunities to coordinate the programs and activities" contained in their respective plans (i.e., Conservation and Load Management Plan and Comprehensive Plan);

WHEREAS, the Global Warming Solutions Act of 2008 requires Connecticut to reduce its greenhouse gas emissions by 80 percent from 2001 levels by 2050, all the while transportation and the thermal heating and cooling of buildings representing the largest emitting sectors;

WHEREAS, residential solar PV can provide cleaner, cheaper, and more reliable sources of energy for electric vehicles and renewable thermal technologies while creating jobs and supporting local economic development;

WHEREAS, the Deployment Committee has reviewed and recommends that the Board approves of the Schedule of Incentives as set forth in Tables 5, 6, and 7 of the memo dated April 28, 2017 20.0 MW from Step 11, 20.0 MW from Step 12, and 20.0 MW from Step 13.

NOW, therefore be it:

RESOLVED, that the Board, including the Commissioner of the Department of Energy and Environmental Protection, approves of the Schedule of Incentives as set forth in Tables 5, 6 and 7 of the memo dated April 28, 2017 20.0 MW from Step 11, 20.0 MW from Step 12, and 20.0 MW from Step 13.

Commercial, Industrial and Institutional Sector Program Updates and Transaction Recommendations

Update on Progress to Targets

Mr. Shrago noted that the sector is currently slightly behind target due to longer than expected timelines for some projects. Mr. Dykes explained to the Board that the Energy on the Line program currently has 20 projects in its pipeline; however, Staff is having to become involved in projects much earlier on than in traditional C-PACE transactions.

Meriden Hydropower Project

Ms. Trief updated the Board on the Hanover Pond hydropower project in Meriden. She noted that the project has reached substantial completion and is currently operational; and, that in February 2017 the Green Bank issued its first Green Bond - $2.9 million in Clean Renewable Energy Bonds (“CREBs”) for the project. Staff is requesting an increase to the initial Board-approved budget amount of $1.4 million to $1.9 million from the Green Bank’s balance sheet, due to the potential for an increase in project costs.

Ms. Bronisz asked if the additional funds could be bonded rather than come from the Green Bank’s balance sheet. Mr. Hunter replied that the Green Bank had already reached the limit on CREBs, but has balance sheet funds available.

Note: Ms. Smith departed the meeting; Mr. Klee assumed the chairmanship.

With no further discussion, Mr. Klee called for a motion to vote.

Upon a motion made by Mr. Harrity, seconded by Ms. Bronisz, the Board members voted in favor of adopting Resolution #7, the increase in approved Green Bank balance sheet funds for the Hanover Pond Hydro Project, as written. Mr. Ranelli abstained.

Resolution #7

WHEREAS, the Green Bank Board of Directors (the “Board”), at its February 26, April 22, June 22, July 6, July 22, October 21, and December 16, 2016 meetings (the

"Prior Meetings") authorized the following elements of the development of a small hydroelectric facility at the Hanover Pond Dam on the Quinnipiac River in Meriden ("Project"):

i) A guaranty to a third-party lender for construction financing in an amount not to exceed $3.9 million,

ii) Funding from the Green Bank's balance sheet in an amount not to exceed $1,400,000,

iii) A working capital guaranty in an amount not to exceed $600,000 for the benefit of New England Hydropower Company ("NEHC"), the project developer, with a 24-month maturity under the Green Bank's existing working capital facility partnership with Webster Bank;

iv) Term financing based on:

i. Proceeding with the conditions precedent to the issuance of New Clean Renewable Energy Bonds ("CREBs") in an amount not to exceed $3,100,000 within 405 days of the original date of authorization by the Board of Directors (that is, February 26, 2016); and,

ii. Securing the issuance utilizing the Special Capital Reserve Fund ("SCRF") subject to further Board, Office of the Treasurer, and Office of Policy and Management approval;

v) A minimum debt service reserve fund required for the SCRF in an amount not to exceed $300,000;

vi) The creation of a Special Purpose Entity to be wholly owned by the Green Bank, to own, operate, and manage the Project, as required by CREBs regulations;

vii) The official intent that payment of Project construction and financing costs may be paid from temporary advances of other available funds and that such advances shall be reimbursed from the proceeds of the CREBs financing; and

viii) A loan to CGB Meriden Hydro LLC (the "Borrower"), a wholly-owned subsidiary of the Green Bank, for its purchase of the Project, as referred to and pursuant to a Loan Agreement, by and between the Green Bank and the Borrower (the "Loan Agreement");

WHEREAS, staff has determined that the Project has and may incur additional costs and that the economics of the Project are still viable, notwithstanding these additional costs, as more fully explained in a memorandum to the Board dated April 21, 2017;

NOW, therefore be it:

RESOLVED, that the Green Bank is authorized to provide funding from the Green Bank's balance sheet to the Project in an amount not to exceed $1,900,000 (previously approved at the not to exceed amount of $1,400,000); and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

DEEP Microgrid Program – CT Green Bank Financing

Mr. Clark provided the Board with an overview of the DEEP Microgrid Program and presented Staff's recommendation to support the program over fiscal years 2018 and 2019 in the form of term loans not to exceed $5 million in aggregate and supported by DEEP loan loss reserve funds.

With no further discussion, Mr. Klee called for a motion to vote.

Upon a motion made by Ms. Crum, seconded by Mr. Ranelli, the Board members voted unanimously in favor of adopting Resolution #8, the allocation of $5 million in Green Bank funds to support the financing of DEEP Microgrid Program projects, as written.

Resolution #8

WHEREAS, in accordance with (1) the statutory mandate of the Connecticut Green Bank ("Green Bank") to foster the growth, development, and deployment of clean energy sources that serve end-use customers in the State of Connecticut, (2) the State's Comprehensive Energy Strategy ("CES") and Integrated Resources Plan ("IRP"), and (3) Green Bank's Comprehensive Plan for Fiscal Years 2017 and 2018 (the "Comprehensive Plan") in reference to the CES and IRP, Green Bank continuously aims to develop financing tools to further drive private capital investment into clean energy projects;

WHEREAS, pursuant to Green Bank's and Department of Energy and Environmental Policy (DEEP's) shared desire to support microgrids in a programmatic, efficient, and scalable effort, Green Bank Microgrid Program Funds, supported by loan loss reserve funding from DEEP, have the potential to maximize the amount of private capital leveraged into microgrid projects per limited public dollars at risk, resulting in a greater ability to develop and finance eligible projects.

WHEREAS, staff recommends support for the Green Bank Microgrid Program in the form of term loans not to exceed $5,000,000 in aggregate and supported by DEEP Loan Loss Reserve funds;

WHEREAS, Green Bank staff recommends that the Green Bank Board of Directors ("Board") approve an allocation of $5,000,000 (over FY2018 and FY2019 to finance microgrid projects as an expansion of the Green Bank's previous efforts to support microgrid development in the state.

NOW, therefore be it:

RESOLVED, that the Green Bank Board of Directors hereby approves the allocation not to exceed $5,000,000 for the Microgrid Program as described in the memorandum to the Board dated April 21, 2017; and

RESOLVED, that the President of the Green Bank and any other duly authorized officer is authorized to take appropriate actions to make the term loan funding available to Microgrid Program applicants; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned Term Loans.

Residential Sector Program Updates and Transaction Recommendations

Mr. Shrago explained that the Residential sector is on target to exceed its targets due to an expansion of the HVAC channel and the onboarding of Capital for Change as a lender for the Smart-E Loan product. Ms. O'Neill echoed Mr. Shrago's comment and added that both PosiGen and the Multifamily programs are on track to exceed targets as well. She noted that the Multifamily pre-development loan gives great technical assistance to underserved markets and that the benefits of these programs are now becoming more noticeable.

7. Other Business

Mr. Garcia reported to the Board that Staff, through the leadership of Matt Macunas, has built a partnership with Nissan through an unsuccessful DOE grant last fall. Through this partnership, Nissan will now offer a $10,000 point of sale discount to 12 dealerships in the Hartford area for their Leaf product. The Green Bank is supporting this effort as a marketing partner, focused on residential solar PV customers, fleets and staff of the City of Hartford, towns of East Hartford and West Hartford, and potentially the State of Connecticut.

Mr. Garcia also highlighted that the Green Bank is a finalist for Harvard University's "Innovations in American Government Awards." The Green Bank is one of 11 finalists out of a pool of over 550 applicants, and the only finalist representing the energy, environment and transportation sector.

Lastly, Mr. Garcia noted for the Board that a report on Solarize and several reports on renewable thermal technologies are included in their information packets – examples of the great results of the Green Bank's research partnerships with Yale University. These reports will be presented at the next meeting of the Board.

Mr. Harrity informed the Board that an event recognizing Worker Memorial Day would be held later that day in Hartford to recognize fallen workers and noted that Mr. Klee is the keynote speaker.

Mr. Klee concluded the meeting by noting that there are many exciting things happening industry, and once again welcomed Ms. McCarthy and Ms. Crum to the Connecticut Green Bank's Board of Directors.

8. <u>Adjourn</u>: Upon a motion made by Ms. Bronisz, seconded by Mr. Harrity, the Board voted unanimously in favor of adjourning the April 28, 2017 meeting at 11:10 a.m.

Respectfully Submitted,

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Rob Klee, Vice Chairperson

CONNECTICUT GREEN BANK

Board of Directors
Draft Minutes
Friday, June 9, 2017

A special meeting of the Board of Directors of the **Connecticut Green Bank (the "Green Bank")** was held on June 9, 2017 at the office of the Green Bank, 845 Brook Street, Rocky Hill, CT, in the Colonel Albert Pope board room.

1. **Call to Order**

Catherine Smith, Chairperson of the Green Bank, called the meeting to order at 2:01 p.m. Board members participating: Rob Klee, John Harrity, Matt Ranelli (by phone), Norma Glover (by phone), Reed Hundt (by phone), Gina McCarthy (by phone), Betsy Crum (by phone), and Bettina Bronisz (by phone)

Members Absent: Tom Flynn and Kevin Walsh

Others Attending:

Staff Attending: Bryan Garcia, Bert Hunter, Brian Farnen, George Bellas, Eric Shrago, Mackey Dykes, Cheryl Samuels, Jane Murphy, Mike Yu (by phone), Ben Healey (by phone), and Kerry O'Neill (by phone)

2. **Public Comments**

There were no public comments.

3. **Staff Transaction Recommendations**

Bryan Garcia provided an update on the staff transaction recommendations.

a. Commercial, Industrial, and Institutional Sector Program Transaction Recommendation

i. CT Solar Lease 3

Ben Healey discussed CT Solar Lease 3. He explained that the Green Bank had created a Solar Lease Facility for third party financing back in 2012. He stated that they continue to do work on the commercial side, but have ceased work on the residential side. He stated that the CT Solar Lease 2 Fund has been exhausted. He stated that the Onyx Facility has been set up for larger projects. He stated that the Green Bank receives an origination fee for projects associated with Onyx.

Ben Healey stated that CT Solar Lease 3 is a tax equity fund. He stated that the plan is for $9 million in tax equity to come from US Bank. He stated that the remainder will come from the Green Bank. He explained that they will then raise money against the portfolio (that is, to attract a capital provider that would fund a portion of the capital being invested by the Green Bank). Bettina Bronisz questioned if that was what was meant by, back leveraging. Ben Healey confirmed. He stated that the funds from a third-party capital provider will come afterwards, as opposed to up front. He stated that it allows for a quicker closing. Bettina Bronisz questioned if this will be a new special purpose LLC. Ben Healey stated yes, it has already been created pursuant to the previous related Board authorization. He stated that the Operating Agreement will be finalized once the Green Bank closes with US Bank.

Reed Hundt questioned that since the capacity of the CT Solar Lease 2 Fund had been exhausted for both residential and commercial, is the Green Bank backing out of the residential market. Bert Hunter stated that staff had reserved a certain amount of the original SL2 fund for commercial projects. He stated that they had decided to move forward with commercial only. He stated that there were numerous private market solutions for the deployment of residential solar leases and PPAs for local installers and the Green Bank did not want to stand in the way and complete where a market solution now exists. In addition, the ITC was scheduled to sunset at the end of 2016 and staff was not confident that it could use the tax equity in the residential program prior to the expiration of the ITC. Also, the provider of warranty services, Assurant, had given notice that they would not extend the warranty management product – a key element of the residential lease offering. Moreover, as Brian Farnen noted, managing the program was – at the time – consuming considerable staff resources. Bert Hunter stated that the Residential and Finance teams concluded the best thing to do, would be to RFP for Residential PPA Services, a decision and process which was previously discussed with the Board prior to moving forward with the RFP.

Reed Hundt questioned if this was working and if penetration was increasing with the alternative tactic. Bryan Garcia stated that it took some transition in that local contractors have now partnered with TPOs to fill the gap. He stated that they've been able to operationalize it. He stated that they've seen some backing down in terms of solar installs, but he feels that it's due to the fact that Solar City had pulled back. Kerry O'Neill stated that they also opened an RFP for solar financing in the Low to Moderate Income space. She stated that Posigen had responded to that RFP. Reed Hundt expressed his desire to follow the policy to continue to drive solar. He requested regular updates on that progression. Bryan Garcia stated that they would make it a point to include that in the Market Watch Reports.

Commissioner Smith stated that it didn't seem that the previous structure was serving them well. Bert Hunter stated that it did serve Connecticut well, but that since the Green Bank does not have a national platform, staff had to make a decision in the CT marketplace.

Reed Hundt discussed the penetration in CT and surrounding states, stating that CT is at 6%. Bert Hunter stated that they have shifted to emphasizing Low to Moderate Income markets. He stated that that is where they feel the real challenges are. He stated that those are underserved markets.

Brian Farnen stated that by incentivizing the private market, by not directly owning and managing a residential Solar Lease product and all that comes with it, it seemed like a better use of staff, resources, and risk mitigation. Kerry O'Neill stated that the Green Bank was falling behind on what the national providers were able to offer in the market.

Commissioner Smith stated that they need to come up with a way to ramp up on the residential side.

Ben Healey stated that they should be closing in the next few weeks with US Bank. He stated that they are asking for authorization to close the fund and move ahead. He stated that they are asking for an additional 120-day extension.

Upon a motion made by John Harrity, and seconded by, Reed Hundt, Resolution #1 passed unanimously.

Resolution #1

WHEREAS, the Connecticut Green Bank ("Green Bank") executed a term sheet (the "Term Sheet") on February 23, 2017 with U.S. Bank to extend the success of our previous CT Solar Lease 2 program ("SL2") by having U.S. Bank invest approximately $9 million in tax equity financing into a new solar PV fund focused exclusively on commercial-scale systems ("SL3"), in a manner materially consistent, absent debt financing at the project level, with the structure previously approved by the Green Bank Board of Directors (the "Board") with respect to SL2; and

WHEREAS, the Green Bank intends to create a new special purpose vehicle and fund structure for SL3, as broadly set forth in the Term Sheet.

NOW, therefore be it:

RESOLVED, that the Green Bank Board authorizes the President of the Green Bank and any other duly authorized officer of the Green Bank, to negotiate and deliver definitive documentation to enable U.S. Bank tax equity capital and Green Bank sponsor equity to create together a SL3 fund consistent with the Term Sheet, and as he or she shall deem to be in the interests of the Green Bank and the ratepayers no later than 120 days from the date of authorization by the Board;

RESOLVED, that the Green Bank may commit up to $15 million to SL3 for term financing, in anticipation that SL3 will be back-levered once its capacity has been fully utilized and the portfolio appropriately seasoned; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and negotiate and deliver all other documents and instruments as they shall deem necessary and desirable to effect the above-mentioned legal instruments.

b. Residential Sector Program Transaction Recommendation

i. PosiGen Solar for All

Ben Healey discussed PosiGen and Solar for All. He stated that there had already been authorization of the Green Bank Debt Facility. He stated that since the set-up of the facility, 955 systems had been installed, creating 62 full-time jobs, with well over 70% serving LMI households. He stated that $25 million had been leveraged so far. He stated that this has been a successful partnership, stating that the expectation is to achieve a run rate of 100 installations per month, starting in the next month or so.

Ben Healey stated that they are requesting two amendments. He stated that PosiGen had signed a term sheet with a reputable tax equity provider, and that staff would like to take some of the $5 million that has already been authorized and reallocate that towards a bridge loan against future tax equity proceeds. He stated that they are asking for permission to offer $3.5 million. Commissioner Klee questioned where the other $1.5 million would go. Ben Healey stated that this would be a bridge loan that will get repaid when PosiGen closes. He stated that they will continue the term financing at that point, up to the previously authorized $5 million, and that all advances will be as a secured loan. He stated that they would limit the advances in the amount of the collateral that is out there.

Betsy Crum commented on PosiGen and the partnership. She stated that it was a great use of the bridge loan.

Upon a motion made by Commissioner Klee, and seconded by, Bettina Bronisz, Resolution #2 passed unanimously.

Resolution #2

WHEREAS, the Connecticut Green Bank ("Green Bank") has a mandate to deploy its resources to benefit all ratepayers, including low and moderate income ("LMI") residential households;

WHEREAS, the Green Bank has an existing and successful partnership with PosiGen, Inc. (together with its affiliates and subsidiaries, "PosiGen"), whereby the Green Bank has provided a debt capital commitment (the "Loan"), divided into initial and contingent portions of $5,000,000 each, to support PosiGen in delivering a solar lease and energy efficiency finance offering to LMI households in Connecticut;

WHEREAS, PosiGen has closed on $8,500,000 in senior debt capital for its Connecticut activities;

WHEREAS, PosiGen has signed a term sheet for $13,000,000 in tax equity financing, a portion of which will support projects in Connecticut; and

WHEREAS, Green Bank staff now recommends amending the Loan to allow the Green Bank to advance up to $3,500,000 out of the contingent portion of the Loan, including as a bridge loan towards PosiGen closing on its pending tax equity facility (the "Amendment");

NOW, therefore be it:

RESOLVED, that the President of the Green Bank and any other duly authorized officer of the Green Bank, is authorized to execute and deliver the Amendment with terms and conditions consistent with the memorandum submitted to the Board dated June 5, 2017, and as he or she shall deem to be in the interests of the Green Bank and the ratepayers no later than 120 days from the date of authorization by the Board; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to effect the above-mentioned legal instruments.

c. Infrastructure Sector Program Transaction Recommendation

i. **Residential Solar Investment Program – PBI Commitment Payout**

Mike Yu discussed the PBI payout and the fundamental framework. He thanked Reed Hundt for his help in putting them in touch with some of his contacts at Stanford University. He stated that they did incorporate some of the tools that they were offered from them. He stated that their goals remain the same. They believe that it will be a sufficient use of cash. He stated that they will return some of the much-needed cash to the TPO's.

Mike Yu discussed the framework and that it focused on $5 million deployed by June 30. He explained that it will be a sealed auction. He explained that bidders can submit multiple bids for different configurations of discount rate and PBI amount, but that there will be rules around the eligible configurations. He explained that a bidder would not offer up a higher discount rate and more capital. He stated that it would not make economic sense and by default would mean trying to game the auction, so that type of behavior will be prohibited. He stated that there will be a reserve price and a minimum bid size. He stated that this will reduce the risk of auction gaming and mitigates the risk of concentrated bidding power. He stated that the final rate offered will be the same rate to all. He stated that they are working with Dale Hedman to come up with a bid template.

Commissioner Smith questioned if they are required to take up to $5 million or can they stop wherever they choose. Mike Yu stated that if it's $5 million or more above the reserve price, there would be no reason they wouldn't proceed without the full $5 million. Bert Hunter stated that Commissioner Smith was referring to one proposal from the legislature to sweep Green Bank funds, stating that it's just a proposal, but that it's certainly a possibility. Brian Farnen stated that it could be $13 million and potentially $15 million to be swept, but stated that they have been doing all the proactive things to make sure that the Green Bank is in the best possible position. He stated that we don't expect a sweep of that size and it would be detrimental to the clean energy economy, job creation and tax receipts, but that we do need to be prepared.

Commissioner Smith stated that it's very hard to predict what will happen. Betsy Crum stated that committed funds don't appear to be money that will be swept. Commissioner Smith questioned if they get some reduction in funds moving forward, would they still be able to do it. Bryan Garcia stated, yes. John Harrity stated that he feels the Governor is with them and feels that they should proceed. Brian Farnen stated that they have a strong ally in the Governor's Office.

Commissioner Smith thanked the team for all of their hard work.

Upon a motion made by John Harrity, and seconded by Commissioner Klee, Resolution #3 passed unanimously.

Resolution #3

WHEREAS, the Green Bank designed and implemented a Residential Solar Photovoltaic Investment Program ("RSIP") to achieve a minimum of three hundred (300) megawatts of new residential PV installation in Connecticut before December 31, 2022;

WHEREAS, pursuant to Section 106 of the Act, the Green Bank offers direct financial incentives, in the form of performance-based incentives ("PBI") or expected performance-based buydowns ("EPBB"), for the purchase or lease of qualifying residential solar photovoltaic systems;

WHEREAS, the Green Bank seeks to opportunistically reduce some of its obligations under the PBI program by purchasing the obligations at a discount; and

WHEREAS, on May 30, 2017, the Deployment Committee recommended authorizing the allocation and use of up to $5,000,000 of unrestricted Green Bank funds to buy-out PBI obligations.

NOW, therefore be it:

RESOLVED, that the Green Bank Board of Directors ("Board") authorizes the allocation and use of up to $5,000,000 of unrestricted Green Bank funds to buy-out PBI obligations consistent with this memorandum dated June 2, 2017; and

RESOLVED, that the Board further authorizes Green Bank staff to (1) conduct an auction whereby the Green Bank solicits bids from third-party owners to set a market discount rate at which PBI obligations may be bought-out and (2) enter into agreements for the buy-out of such PBI obligations upon conclusion of the auction; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to effect the above-mentioned auction.

4. **Adjourn**

Upon a motion made by John Harrity, and seconded by, Commissioner Klee, the Board Meeting was adjourned at 2:57 p.m.

Respectfully Submitted,

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Catherine Smith, Chairperson

CONNECTICUT GREEN BANK

MANAGING DIRECTOR OF MARKETING

Class Title: Managing Director of Marketing
Direct Reports: Managers, Associates, Assistants
Salary Range: $137,290 – 164,748
Career Series: Managing Director

Reports to: President and CEO
Wage Hour Class: Exempt
Hours Worked: 40

SUMMARY:

The Connecticut Green Bank's (hereafter "CGB") Managing Director of Marketing is responsible for designing and overseeing CGB's marketing and public relations strategies and initiatives. The managing director of marketing will support CGB's aggressive customer acquisition goals while working under a larger statewide brand. Responsible for planning, developing and implementing all of CGB's marketing, communications and public relations strategies and activities, the director also provides marketing consultation and assistance to agency leaders. The Managing Director will communicate key messages internally and to the business community and other key stakeholders to raise awareness and visibility of the organization and its products and programs.

The Managing Director is distinguished from lower level directors by either its oversight of multiple areas in large operational departments, or the management of program services with agency wide internal and/or significant external impact. The Managing Director is the most highly experienced and specialized within the Director career series. While the core duties may overlap significantly with lower level Directors, the Managing Director is an expert in their field and has full managerial and decision making responsibility on issues of significance and consequence (issues of significance and consequence are: 1. Issues involving the use of personnel (hire, fire, progressive discipline, etc.); 2. Issues pertaining to the formulation, interpretation, or administration of policy and/or legislation affecting their program area; 3. Issues involving exceptions or deviations from policy or past practice; 4. significant input into issues involving the allocation of financial resources. In addition, a managing director has complete programmatic responsibility and is responsible for coordinating department wide resources (staff, consultants, budget, etc.) as part of overall responsibility for an entire program with significant internal and external impact.

The Green Bank, a quasi-public authority, is the nation's first state "Green Bank," leveraging public and private funds to drive investment and scale up clean energy deployment in Connecticut. Working at the Green Bank means being part of a dynamic team of talented people who are passionate about implementing the new green bank model, stimulating the growth of clean energy in Connecticut, strengthening our economy, and protecting our environment.

EXAMPLES OF DUTIES:

- Direct marketing, outreach, and communications staff and operations.
- Manage CGB's brand to attract private investment in clean energy in Connecticut.
- Collaborate with program management teams to develop a complex product marketing mix to maximize the marketing budget through the implementation of channel marketing and other strategies.
- Collaborates with sector directors and senior management to develop new products and programs that address and anticipate market needs and preferences.
- Formulate marketing and communications strategies that are in line with CGB's customer acquisition goals. (Key audiences and stakeholders include, but are not limited to, the general public, lending partners, contractors, building owners, government, university and business partners, Connecticut agencies, communities and other entities involved with the growth, development and commercialization of clean energy in Connecticut.)
- Function as primary media contact. Provide expertise to CGB staff in handling media responses. Speak/present to key audiences and stakeholders to promote CGB and its programs.
- Oversee content development and content maintenance for various web properties including the CGB website, other product websites and other electronic communications vehicles.
- Manage and organize external events including exhibits, seminars, networking events and other programs.
- Develop CGB's annual report (or other periodic financial performance publication important to stakeholders), program fact sheets, and other marketing collateral materials needed by the organization and its directors and ensure the timeliness of the information.
- Develop robust testing strategies and analytics to support marketing plans and deploy appropriate measurement tools to measure ROI and customer acquisition effectiveness.
- Develop short and long-term plans and budgets for marketing of programs, monitor progress, assure adherence, and evaluate performance.
- Perform related duties as required.

MINIMUM QUALIFICATIONS REQUIRED
KNOWLEDGE, SKILL AND ABILITY:

- Strategic thinker with strong planning and execution abilities.
- Strong project management skills and vendor and stakeholder management skills.
- Results-oriented with a track record of driving growth in a highly-competitive environment.
- Proven ability to influence key decision-makers and operate effectively in a matrix organization.
- Some experience in product development.

- Strong relationship management, presentation and communications skills that establish trust, credibility and respect.
- Ability to lead and manage a team.
- Must possess a good balance between strategic skills, relationship management and tactical accountability.
- Must have a demonstrated ability to plan and implement broad-based marketing and communications programs.
- Excellent oral and written communication skills are required. Must have the ability to plan marketing events on time and within budget.
- Requires knowledge of tactical business development and marketing principles.
- Ability to communicate effectively, tactfully, and courteously.

EXPERIENCE AND TRAINING:

General Experience:
A bachelor's degree in marketing or communications or a related field and ten (10) years of experience in marketing and/or business development-related positions, preferably in the financial services sector.

Special Experience
Two (2) years of general experience must have been at the director level (or comparable position) with full responsibility for a marketing division.

Substitutions Allowed:

1. A master's degree in marketing, business administration or a related field may be substituted for one (1) additional year of the General Experience.

CAREER SERIES

The career series for this classification is:

- Assistant
- Senior Assistant
- Associate
- Senior Associate
- Manager
- Senior Manager
- Associate Director
- Director
- Managing Director

CONNECTICUT GREEN BANK

DIRECTOR OF RESIDENTIAL PROGRAMS, MULTIFAMILY

Class Title: Director of Residential Programs, Multifamily
Reports to: Vice President, Residential Programs
Direct Reports: As assigned
Salary Range: $99,962 – 149,431
Career Series: Director 1
Wage Hour Class: Exempt
Hours Worked: 40

SUMMARY:

The Director of Residential Programs, Multifamily oversees the development and implementation of all Connecticut Green Bank (CGB) programs focused on the multifamily sector. The director will lead CGB's programs in the area of multifamily housing for both market rate properties and those serving low-to-moderate income residents.

This is a cross-sector position, supporting the goals of the leads of the residential, commercial, and institutional sectors, since multifamily housing exists in each of those sectors. The director will lead the Connecticut Green Bank's multifamily financing efforts in coordination with the leads for the other sectors. The director will assist in the coordination of state and other stakeholders to implement clean energy policy recommendations in the area of multifamily financing.

The Green Bank, a quasi-public authority, is the nation's first state "Green Bank," leveraging public and private funds to drive investment and scale up clean energy deployment in Connecticut. Working at the Green Bank means being part of a dynamic team of talented people who are passionate about implementing the new green bank model, stimulating the growth of clean energy in Connecticut, strengthening our economy, and protecting our environment.

EXAMPLES OF DUTIES:

- Initiates and manages the design of CGB's multifamily housing programs in coordination with the VP of Residential Programs;
- Works closely with financiers, property owners, municipalities and other key stakeholders to create programs that attract their interest and secures their participation;
- In coordination with the Vice President, Residential Programs, works with state agencies, utilities, the Connecticut Energy Efficiency Fund, as well as other key stakeholders, to align multifamily programs where possible and assure Connecticut's energy finance program takes advantage of shared resources and programmatic synergies;
- Ensures all residential multifamily operational (i.e. staff and policies) and organizational (i.e. contracting and reporting) requirements are being implemented and carried out;
- Manages the selection of consultants, where necessary, to support the program in areas where CGB does not have specific in-house expertise;

- Represent CGB on appropriate task forces, committees, and boards relevant to clean energy finance;
- Represents CGB to the public in speaking engagements; and
- Supervises CGB multifamily staff including managers, associates, and assistants. Together with the Vice President, Residential Programs:
- Works with the Chief Investment Officer and finance team to design residential multifamily clean energy financial products to attract private capital;
- Works with the Director of Marketing and marketing team to develop strategies to increase participation in CGB residential multifamily programs and uptake in financial products;
- Works with the President, Director of Operations, Chief Legal Officer and Chief Investment Officer to develop policies and procedures for residential multifamily clean energy financing
- Works in collaboration with the President, Director of Marketing, and & Chief Investment Officer to integrate comprehensive strategies to advance clean energy and contributes to the development and implementation of CGB's comprehensive plan
- Works with the Board of Directors and the President to lead the development of clean energy programs and initiatives;
- Regularly updates the Board of Directors, with support from the President and Executive Vice President and Chief Investment Officer on the development and progress of residential programs;
- Plans, manages and coordinates the multifamily budget in accordance with established and approved performance metrics and targets.

MINIMUM QUALIFICATIONS REQUIRED
KNOWLEDGE, SKILL AND ABILITY:

- Strong knowledge and experience in clean energy finance and/or policy, preferably in the multifamily sector;
- Familiarity with the finance and energy industries, with a particular focus on housing finance;
- Considerable experience in program/project management;
- Ability to work in a team environment as a lead contributor, manager, and facilitator;
- Strong knowledge of business operations and general management including supervisory experience;
- Demonstrated ability to integrate public policy actions into innovative outreach programs and initiatives for the development and deployment of clean energy, particularly in the multifamily sector;
- Considerable ability to develop programs, manage stakeholder processes toward results, and interpret energy policy;
- Understanding of the interaction in clean energy markets between finance and demand;
- Demonstrated ability to understand various scientific and energy-related technological principles and applications, and integrate those concepts into the overall project, program, or CGB;
- Expertise in scalable models for financing building upgrades through a variety of financial products (i.e. loans, ESAs, ESCOs, PPAs);
- Ability to work with external stakeholders including strong facilitation, negotiation, and coordination skills;
- Considerable interpersonal skills, as well as oral and written communications skills;

- Ability to market the benefits of residential clean energy financing products to potential customers;
- Knowledge of State and Federal energy policies and regulations that support clean energy finance; and
- Familiarity with energy efficiency issues and energy efficiency service contracts.

<u>EXPERIENCE AND TRAINING:</u>

General Experience:
A Bachelor's Degree (but a Master's degree is preferred) in finance, environmental science, engineering, economics, political science, business administration, or related field is preferred. Seven (7) years of experience in energy policy and clean energy finance. Experience supervising staff and working across departments is preferred. Experience working with and facilitating collaborative outcomes with various stakeholder groups in energy policy design and project development.

Special Experience:
Two (2) years of the general experience must have been supervising staff involved in project development.

Substitutions Allowed:
1. A Master's Degree in finance, environmental science, engineering, economics, business administration or other related field may be substituted for one additional year of the general experience
2. A professional certification in a relevant field may substitute for one additional year of experience

<u>CAREER SERIES</u>
The career series for this classification is:
- Assistant
- Sr. Assistant
- Associate
- Sr. Associate
- Manager
- Senior Manager
- Associate Director
- Director

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CONNECTICUT GREEN BANK

Memo

To: Board of Directors

From: Bryan Garcia, President and CEO, Bert Hunter, EVP and CIO, Michael Yu, Assistant Director, Finance

CC: Eric Shrago, Chief of Staff, Brian Farnen, General Counsel and CLO, Kerry O'Neill, Director Residential Programs, Mackey Dykes, Director, Commercial and Industrial Programs, Ben Healey, Director, Finance

Date: June 16, 2017

Re: Report to the Board of Directors – Solar Lease 2, Interest Rate Swap Contracts

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INTRODUCTION

At the Board of Directors (the "Board") meeting held on June 26, 2013, the Board passed resolutions authorizing the Solar Lease 2 Program (the "Program") in the manner described in the Program Proposals. As part of the funding structure for the Program, First Niagara (now Keybank) arranged for $26,700,000 in debt financing under a credit agreement (the "Credit Agreement") for the Program's SPV, CT Solar Lease 2 LLC ("CTSL2"). In order to contain exposure to interest rate risk on this funding, the Credit Agreement requires CTSL2 to enter into contracts (each one, an interest rate swap, or simply a "swap") whereby at least 75% of the floating rate interest rate obligation under the Credit Agreement (based on 1 month LIBOR) is exchanged for a fixed rate obligation. As CTSL2 is nearly fully utilized, staff is working with Webster Bank to arrange the final swap that will contain exposure to interest rate risk and fulfill CTSL2's obligations under the Credit Agreement.

The purpose of this memorandum and presentation is to update the Board on the interest rate swaps.

CHARACTERISTICS OF A SWAP AND IMPLICATIONS FOR CTSL2

As stated, CTSL2 is required to enter into swap contracts with respect to a minimum amount of 75% of borrowings under the Credit Agreement. Interest rate swaps generally have the following characteristics

- A swap permits the underlying long term financing to be done on a floating rate basis, with the swap serving to manage interest expense over the life of the loan.

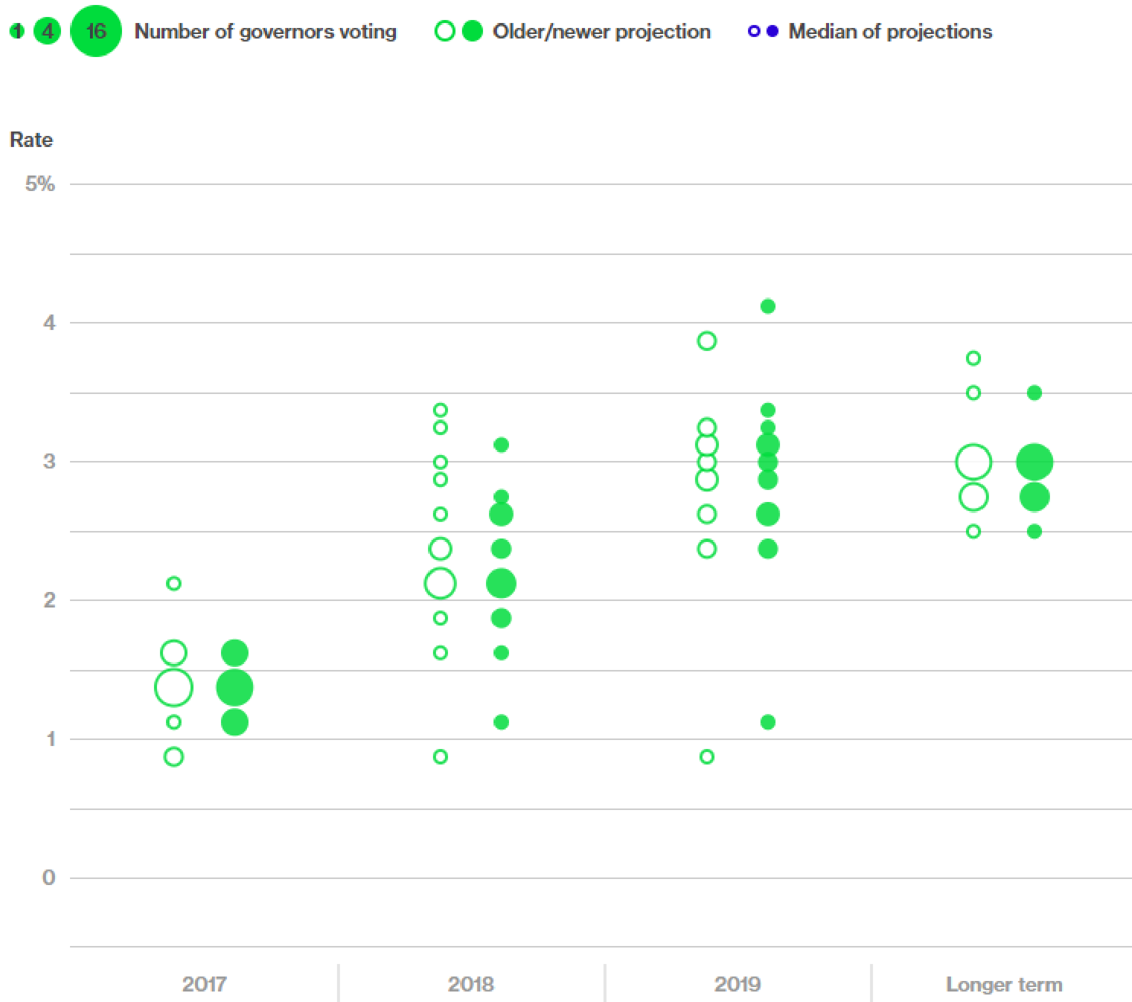
- By separating the funding from the process of managing the organization's debt servicing costs, it provides for more flexibility and advantageous terms for the Green Bank.
- The Green Bank can employ a "Portfolio Approach" to reduce exposure to increased rates, while benefiting from the current low rate environment.
- Allows the Green Bank to fix the rate for the entire term of the loan, or for a shorter period of time.
- The Green Bank can terminate all or a portion of the swap without impacting the underlying financing.
- If a portion of the financing is left on a floating rate, the opportunity exists to pre-pay part of the loan without adjusting the underlying swap overlay.
- In the event of an early termination, allows for a "bilateral" make-whole provision.
- There are no upfront fees associated with a swap transaction.

After discussing how to proceed with the swap program, staff elected to proceed by entering into swap contracts prior to borrowing under the Credit Agreement in order to protect the Program from rising interest rates. The bulk of the swaps were executed in 2016 during historically low interest rates.

10-Year Treasury Rate

In addition, current consensus with regard to future interest rates is that the Federal Reserve will likely increase rates once more in 2017 and a further 75 bps increase in 2018.

Federal Reserve Governors' Votes on Interest Rates (June 14th, 2017)



Given the current and expected interest rate environment and amortization profile of the underlying principal, staff believes it prudent to swap slightly more than the 75% required by the Credit Agreement. Accordingly, staff has requested Webster Bank provide a final swap of $2,000,000 that will bring the swapped percentage of outstanding debt to 80%. Since there is a chance that some of the underlying solar lease transactions could prepay, which could lead to a prepayment of the debt funding associated with the transactions, staff does not recommend any higher percentage of swap coverage as this could lead to breaking swaps prematurely resulting in a potential swap loss (or gain).

SL2 Swap Analysis (6.16.17)

Debt Draws and Swaps						
	Debt	Swaps				Pro Forma
Debt Advances	Initial	Notional	Reference	Current (6.16.17)	Principal Repaid	Outstanding
x1822	3,000,000	3,000,000	CFFNFG2015092802	2,674,875	787,048	2,212,952
x5493	6,000,000	3,000,000	CFFNFG2015111602	2,674,875	696,269	5,303,731
x7814	6,000,000	14,284,725	CFFNFG2014091202	12,659,100	696,269	5,303,731
x4004	3,000,000				348,134	2,651,866
xxxx (3/15/17)	8,300,000				26,748	8,273,252
zzzz (6/29/17)	1,200,633	2,000,000	TBD	2,000,000	0	1,200,633
Total	**$27,500,633**	**$22,284,725**		**$ 20,008,850**	**$ 2,554,468**	**$ 24,946,165**
Swapped Percentage				**80%**		

SUMMARY INTEREST RATE SWAP TERMS (ALL TRANCHES)

Date	Amount	Rate	Reference
Sep-14	14,284,725	2.78%	CFFNFG2014091202
Sep-15	3,000,000	1.96%	CFFNFG2015092802
Nov-15	3,000,000	1.99%	CFFNFG2015111602
Jun-17	2,000,000	2.16%	(estimated pricing)
Total	22,284,725	2.51%	

While as of the date of this memorandum the last swap has yet to be executed, at present the total projected weighted average interest rate of the swaps above (assuming the final swap prices at an estimated 2.16%) is 2.51% which is then added to the credit spread under the Credit Agreement (2.50%) to get CTSL2's total interest cost for the entire swapped portion of 5.01%. This compares favorably to the interest rate used to model the CTSL2 program of 5.25%.

SOLARIZE YOUR COMMUNITY

An Evidence-Based Guide for Accelerating the Adoption of Residential Solar

Project Partners

U.S. Department of Energy Sunshot Initiative SEEDS grant Principal Investigators:
Kenneth Gillingham, Assistant Professor, Yale University, School of Forestry & Environmental Studies
Bryan Bollinger, Assistant Professor, Duke University, Fuqua School of Business

The U.S. Department of Energy SunShot Initiative is a national effort to drive down the cost of solar electricity and support solar adoption. SunShot aims to make solar energy a low cost electricity source for all Americans through research and development efforts in collaboration with public and private partners. Learn more at energy.gov/sunshot.

The Connecticut Green Bank was established by the Governor and Connecticut's General Assembly on July 1, 2011 through Public Act 11-80 as a quasi-public agency that supersedes the former Connecticut Clean Energy Fund. As the nation's first state "Green Bank", the Connecticut Green Bank leverages public and private funds to accelerate the growth of green energy in Connecticut.

SmartPower is the nation's leading non-profit marketing firm dedicated to promoting energy efficiency and renewable energy and has extensive experience with hundreds of community-based energy campaigns and Solarize projects across the country. SmartPower provides participating communities with technical assistance, campaign strategizing and outreach, and media planning.

The Yale Center for Business and the Environment joins two world-renowned graduate schools—the Yale School of Management and the Yale School of Forestry & Environmental Studies—with a network of internal and external leaders working at the interface of business and the environment. We catalyze research and cultivate partnerships that advance business solutions to global environmental problems.

+ 20 Solarize installation companies and 58 towns

About the Partnership

What motivates people to install rooftop solar panels? Which incentives can rapidly boost the adoption of this technology? Which programs are persistently effective, and which are most easily scaled?

Supported by a grant from the U.S. Department of Energy a multidisciplinary set of partners came together to test these questions by examining the uptake of solar through the Solarize CT program. Out of this collaboration, we have produced a guidebook for community and business leaders, active citizens and policymakers detailing the most effective strategies for accelerating the adoption of residential solar.

The Yale School of Forestry and Environmental Studies and **Duke University**, in collaboration with the **CT Green Bank** and **SmartPower**, conducted a series of rigorous controlled field trials to better understand the adoption of residential solar.

The Yale Center for Business and the Environment coordinated the partnership and worked with a team of students to facilitate the research, assist with the data analysis and create this guidebook.

The Connecticut Green Bank, a state-level institution devoted to expanding the region's clean energy sources, accelerated consumer financing options by developing risk-reduction mechanisms in partnership with local lending and capital partners.

SmartPower, a social marketing firm, provided insight and support for Solarize CT, creating high impact on-the-ground community campaigns.

About Solarize

Solarize is a community based program that leverages social interaction to promote the adoption of solar through a group pricing scheme. Solarize campaigns are designed to leverage peers and social networks to spur solar adoption.

Yale Center for Business and the Environment

Yale SCHOOL OF FORESTRY & ENVIRONMENTAL STUDIES

Powered by SunShot U.S. Department of Energy

SmartPower Let's Get Energy Smart.

CONNECTICUT GREEN BANK

DUKE THE FUQUA SCHOOL OF BUSINESS

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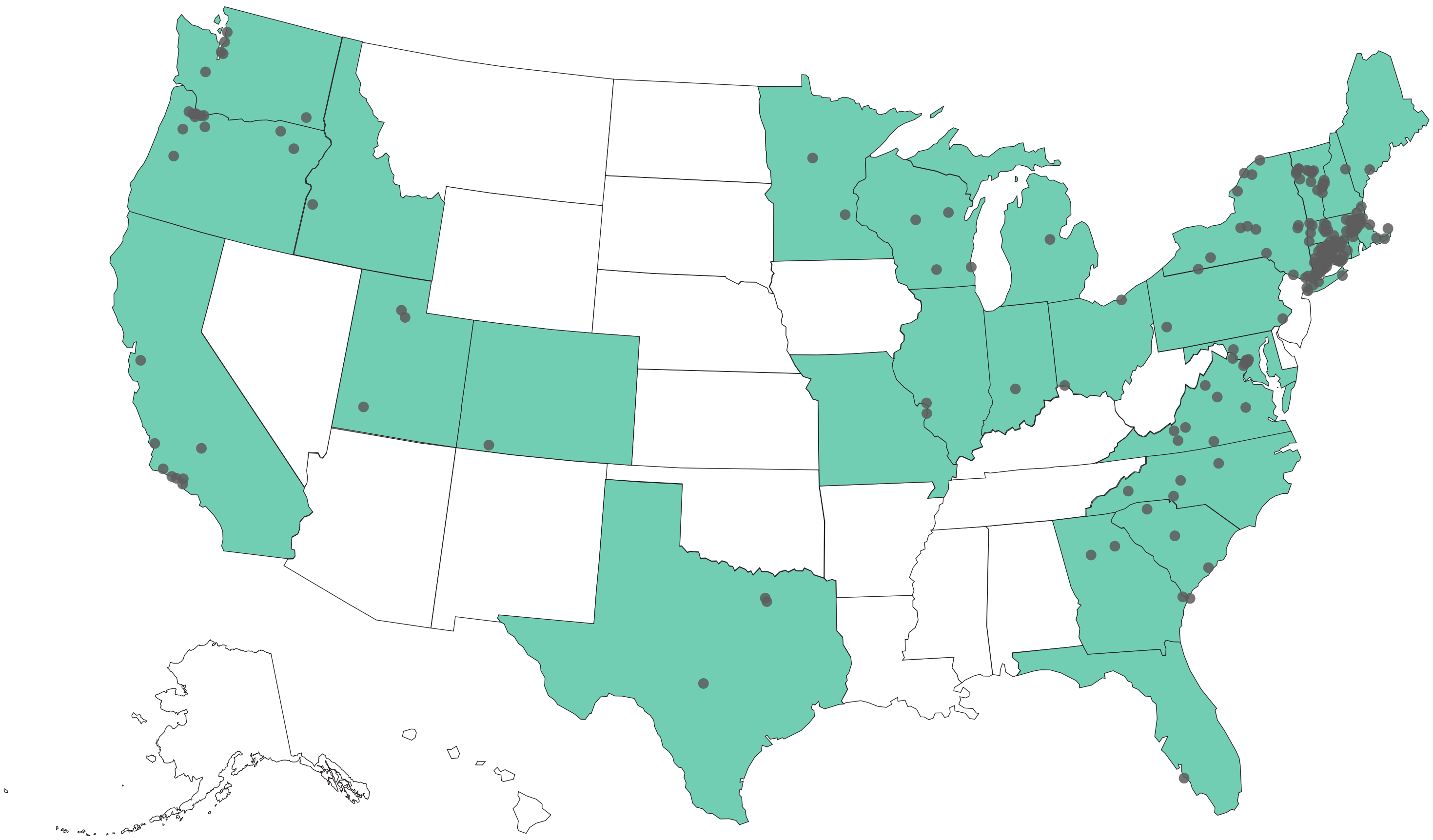
Solarize: A National Movement, Rigorously Tested in Connecticut



This map illustrates the communities that organized Solarize campaigns across the U.S from 2009–2016.[1]

1 Ryan Cook, Meister Consultants Group

Foreword

The national energy economy is undergoing a massive transition. Solar recently became the cheapest source of new electricity generation while other renewable technologies are quickly becoming cost-competitive with traditional fossil-fuel sources; energy infrastructure from the twentieth century is in need of replacement; and states are considering capital-intensive infrastructure projects with an eye to the future—both of regulation and competitiveness.

Distributed, residential solar installations will no doubt be integral to this future.

The following guidebook is based on the promising outcome of a research project focusing on a set of campaigns called Solarize CT, launched across the state of Connecticut from Fall 2013 to Spring 2016. The Solarize campaign, which was designed to increase the adoption of solar energy, ran in 58 towns statewide. The results were striking: **in just three years, the number of homes with solar grew from about 800 to over 12,500**. Solarize played a central role in this expansion.

Solarize CT was rolled out in five distinct phases, allowing for research on different variants of the campaign, with small tweaks to the campaign in each phase. These variants allowed researchers from Yale and Duke Universities to determine the factors that most directly influenced household solar adoption—from the best messaging to ideal campaign lengths to optimized use of social networks. The researchers also examined the behavioral underpinnings of consumer decision-making: why do people decide to install solar panels? What hinders this decision, and what can make the decision more likely? Though Solarize is a national effort with a demonstrated record of success in the town's where it is implemented—the idea was first launched in Portland, OR in 2009—**Solarize CT represents the first large-scale experiment of its kind to rigorously examine specific catalysts of solar adoption.**

For those looking to foster a local solar market, the pages that follow offer explicit guidance that is firmly rooted in research findings. The lessons learned in Connecticut can be applied to streamline policy, design compelling business strategies, and galvanize community-led programs for organic solar growth. This guide offers insight into ***what* to do when fostering a local solar market and *why* to do it**. It is organized into four main sections:

1. Capitalizing on social networks to drive adoption
2. The business case for a solar campaign
3. How a campaign like this benefits communities and local governments
4. The essential components of a successful campaign

Also included is a two-page "how-to" for designing and implementing a campaign with links to templates and resources. For any person or institution interested in how to increase rates of solar adoption, this guidebook will help set and achieve those goals.

Executive Summary

SolarizeCT, which began in 2009, is designed to increase the installation of residential solar systems through local campaigns. The results have been stunning. In a three-year Connecticut campaign (2012–2015), the number of homes with solar grew from about 800 to over 12,500. Research findings based on the campaign—the first of their kind—indicate that the success of Solarize rests on a few key components.

The diffusion of awareness, or spreading of knowledge, about solar through social networks is a surprisingly powerful lever for boosting adoption. For instance, over a six-month period, the presence of one solar rooftop project increased the average number of installations within a half-mile radius by nearly 50 percent.[2] This peer influence effect is even stronger if the panels are visible from the street.[3] Thus, increasing the visibility of solar is clearly an important facet of any solar marketing campaign.

Recognizing that—social networks have a strong influence on decisions to install solar—Solarize campaigns are specifically designed to focus and amplify this peer effect: Solarize makes installations visible; it convenes events where people talk about solar (and watch it being installed); and it supports an energetic, local, and organic marketing campaign.

The findings on the research from Solarize CT also made evident the importance of recruiting the right volunteers ("solar ambassadors") and involving a range of stakeholders. Effective solar ambassadors—people who are respected in the community and passionate about not just the environment, but Solarize specifically—are critical to a successful campaign; towns with strong volunteer leadership demonstrate consistently higher adoption rates.[4]

Beyond these ambassadors, a coalition of support that includes local and state officials, and vetted installers, legitimizes a Solarize campaign in the eyes of customers. Especially because Solarize is a grassroots approach to increasing solar adoption, having trusted sources in positions of leadership who not only support the program, but actually take part in it, makes a difference.[5]

But why should leadership—why should anyone—take part in a Solarize campaign? Besides the environmental benefit, these campaigns generate tremendous benefits for businesses and local economies. On the business side, Solarize CT resulted in a statewide "20–20 rule." Most campaigns ran for roughly 20 weeks and reduced the average cost of solar by 20 percent. This resulted in **more than three times**[6] the number of rooftop installations in participating communities.

2 Graziano and Gillingham (2015), https://academic.oup.com/joeg/article/15/4/815/2412599/Spatial-patterns-of-solar-photovoltaic-system

3 Bollinger and Gillingham (2012), http://pubsonline.informs.org/doi/pdf/10.1287/mksc.1120.0727

4 Kraft-Todd, Gordon, David Rand, Bryan Bollinger, Kenneth Gillingham – "Environmental Actions Speak Louder than Words" Yale University Working Paper

5 Bollinger and Gillingham (2017) Social Learning and Solar Photovoltaic Adoption: Evidence from a Field Experiment. Yale University Working Paper

6 Ibid.

Solarize CT led to a "tipping point" within a few months of launching the campaign. Residential solar adoption significantly increased while prices significantly decreased during the campaign.

Bollinger, Gillingham, and Lamp (2017) "Tipping Points and Solar Photovoltaic Adoption," Yale University Working Paper

For local economies, Solarize creates jobs, bolsters the local solar industry, and streamlines permitting processes by establishing a pipeline of installations with similar characteristics. More broadly, Solarize campaigns overseen by a cross-sectoral coalition create a strong foundation for a robust clean energy market that no single actor could achieve in isolation. **In other words, Solarize has the potential to be a launching point for a much larger investment in the transition to a renewable energy infrastructure.**

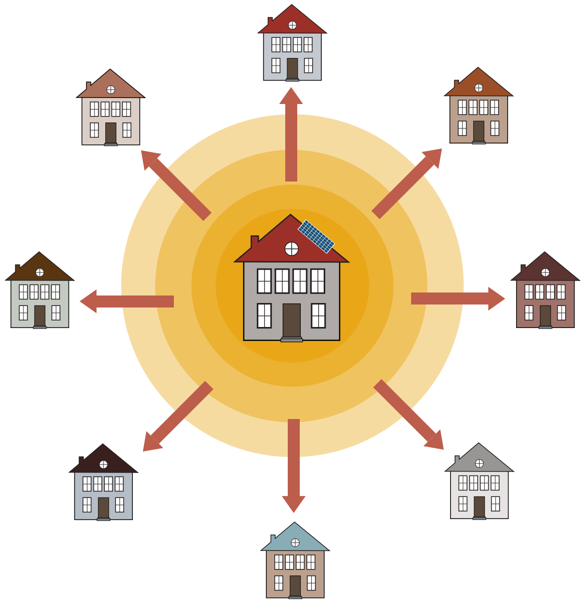
Given these benefits, it's fortunate that designing and implementing a campaign is straightforward and built around three fundamentals:

1. Educate the consumer
2. Find points of motivation
3. Convert interest into a decision to install solar.

This guidebook clearly maps the process for any town, or individual, interested in solarizing their community.

Solar is Contagious. Capitalize on This.

Community social networks are a powerful force for driving solar adoption. Recognizing and using these 'peer effects' accelerates individual decisions to go solar.



SHINE A SPOTLIGHT ON SOLAR: THE DIFFUSION EFFECT

One of the central factors determining whether a given house installed solar was the actions and influence of peers. **Over a six-month period, the presence of one solar rooftop project increased the average number of installations within a half-mile radius by nearly 50 percent.**[7] This peer influence effect is stronger if the panels are visible from the street. This is why installers often attempt to raise the visibility of installations with signs that call out the panels.[8]

Recognizing that social networks have a strong influence on decisions to install solar, Solarize campaigns are specifically designed to amplify social interactions about solar. Under normal circumstances, social interaction on issues of solar energy would occur passively and randomly. Solarize campaigns work in part because they create a forum that concentrates conversation and interaction.

RECRUIT SOLAR ENTHUSIASTS TO SPREAD THE WORD

Community-led marketing leverages a small group of passionate volunteers—Solarize CT dubbed them "solar ambassadors"—to spearhead outreach activities and to organize other volunteers who can canvass and host events. Recruiting the right solar ambassadors is critical to the success of a campaign; towns in Connecticut with strong volunteer leadership demonstrated consistently higher adoption rates.

One of the most powerful predictors of an effective ambassador is that he or she takes part in the Solarize campaign by signing up for an installation. This action proved far more telling of successful ambassadorship than other environmental behaviors like composting, owning a hybrid vehicle, or having double-paned windows. (This is consistent with the well-known notion that "actions speak louder than words.") Surveys and interviews also found that ambassadors who conceptualized

7 Graziano and Gillingham (2015), https://academic.oup.com/joeg/article/15/4/815/2412599/Spatial-patterns-of-solar-photovoltaic-system

8 Bollinger, B, Gillingham, K, Kirkpatrick J, and Sexton, S.—"Visibility and Social Influence" Duke University Working Paper

WHAT DO SOLAR AMBASSADORS DO?

As locally trusted sources, solar ambassadors advance word-of-mouth recommendations for solar PV on three fronts:

- **EDUCATE:** They raise awareness and answer questions about the benefits of solar PV.
- **MARKET:** They organize community events, canvass neighbors and friends to sign up for solar, and publicize the Solarize program through various media.
- **CONNECT:** They act as a liaison between the homeowner and installer.

their role as part of a job rather than as ancillary volunteer work were more persuasive.[9]

Solar tours and live installations serve two ends at once: they facilitate exposure to solar installations among peers, and they offer basic information about the process and benefits of going solar.

Solar tours allow people to meet current owners, see the panels and inverters, and hear first-hand about the owner's experience. In Solarize CT, current owners often showed visitors years of extremely low electric bills along with monitoring systems demonstrating historic and live production numbers. These events feed the curiosity of potential customers, help build trust in solar technology, and make the prospect of renewable electricity visible. They also allow prospective customers to absorb the experiences of others before taking the leap personally.

Live installation events are exactly what they sound like: a chance to watch the installation of solar panels. These require a homeowner who has signed up for panels, lives in a visible location, and is willing to host an event such as a barbeque on his or her lawn. The event gives interested residents an opportunity to watch the raising and attachment of solar panels to the roof. Installation events also provide a great opportunity for press, especially in areas where there is not a lot of solar. Installers on roofs with a party down on the ground makes a great photo op for newspapers and TV. Both the homeowners *and* installer are then on-hand to answer questions about solar and the installation process.

GET CREATIVE WHEN CONNECTING WITH THE COMMUNITY

The more visible a campaign is, the more successful it will likely be. As one town leader in Connecticut put it, "be everywhere in the community." Every town event and town meeting is an opportunity to promote solar—at the Lions Club, farmers' markets, and the library, to name just a few.

In West Hartford, Connecticut, besides posting flyers and tabling at various events, solar ambassadors brought solar to life with distinctive outreach efforts. The first event was a float in a neighborhood parade escorted by

WHAT DOES A LIVE INSTALLATION EVENT LOOK LIKE?

In short, whatever you want it to look like.

For a live installation in the shoreline community of East Lyme, Encon Solar had a full-scale clambake. People were able to watch the panels go up and enjoy fresh clams and corn.

In West Hartford, C-TEC Solar had a barbeque with balloons drawing people to the event. Homeowner Mickey Toro (who is the president of C-TEC) even gave people rides in his Tesla. The corner location of his house attracted a lot of people simply out for a stroll; a number of folks signed up for site visits on the spot.

9 Kraft-Todd, Gordon, David Rand, Bryan Bollinger, Kenneth Gillingham—"Environmental Actions Speak Louder than Words" Yale University Working Paper

marching ambassadors wearing sun hats and carrying signs. Runners also participated in a winter "mitten run" wearing Solarize t-shirts. PTA members got the schools involved with a video of students singing "Here Comes the Sun" interspersed with a rooftop tour of the school's solar installation. West Hartford has many neighborhood associations; members of these associations conducted outreach through blogs and email groups. Toward the end of the campaign, ambassadors got together to make phone calls reminding people about the approaching deadline and asking them if they had any questions concerning solar.

COMBINING THESE APPROACHES FOR SUCCESS: DEFINING A SOLARIZE CAMPAIGN

Solarize campaigns are locally organized community outreach efforts aimed at getting a critical mass of homes to "go solar" together in a limited amount of time, typically a few months.

The campaigns leverage group-purchasing power: customers can purchase solar systems in bulk for significantly less money than the typical market rate through the creation of a steady stream of purchases and installations.

A classic Solarize model combines four key strategies—town-supported outreach and education, pre-selected solar installers from competitive bidding, discount pricing, and a limited time period—and typically unfolds in four basic stages:

STAGE 1

Well in advance of the campaign launch, Campaign organizers reach out to several local solar installation companies and invite them to participate in an RFP process to be the solar installer(s) for the campaign. The Campaign organizers and three selected volunteers from the community conduct a thorough review and interview process based on selection criteria. These criteria can include quality, experience, and locally specific requirements, such as 'Made in America' hardware. The Campaign organizers and the three-person community volunteers choose the designated installer for the Solarize CT campaign.

STAGE 2

Interested community members are recruited to volunteer their time telling friends and neighbors about the program. Prior to the campaign launch they plan the outreach and media strategy to get the word out about the Solarize campaign. Over the course of the campaign, these solar ambassadors spearhead outreach activities and organize other volunteers to canvass and host events.

STAGE 3

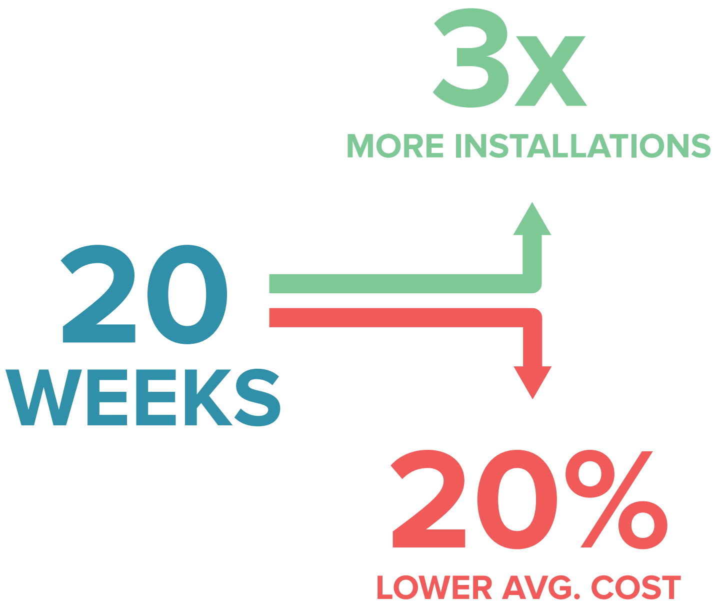
Town champions, distinct from solar ambassadors and typically from the First Selectman's/Mayor's office and/or a Clean Energy Task Force, come together with local or state-level partners, as well as with the chosen installer and solar ambassadors, to launch an intensive community outreach campaign.

STAGE 4

With the support of solar ambassadors, the designated installer follows up with members of the community who express an interest in solar, offering a tiered discount pricing structure whereby the more customers that sign up to install solar during the 20 weeks of the campaign, the cheaper the price per watt for everyone.

A Striking Business Case

Using a tight timeline and bulk discounts can result in dramatic outcomes.



THE 20–20 RULE

Most Solarize CT campaigns ran for roughly 20 weeks. Over this period, they reduced the average cost of residential solar by 20–30 percent. The campaigns **more than tripled** the number of installations in each community and significantly expanded the size of the market (one out of five households that signed a contract through Solarize had never before considered installing panels[10]).

Thus, the 20–20 rule—a 20 week campaign, a 20 percent cost reduction for customers resulting in more than three times the number of installations. This is a compelling benchmark for the solar installation business.

WIDE-RANGING BENEFITS FOR SOLAR INSTALLERS

Beyond the increase in sales and market-size—20–100 new contracts over the course of the campaign— installers saw a number of benefits from Solarize. For instance, Solarize programs introduced benefits of scale and reputation to smaller firms that are typically reserved for larger, name-brand companies.

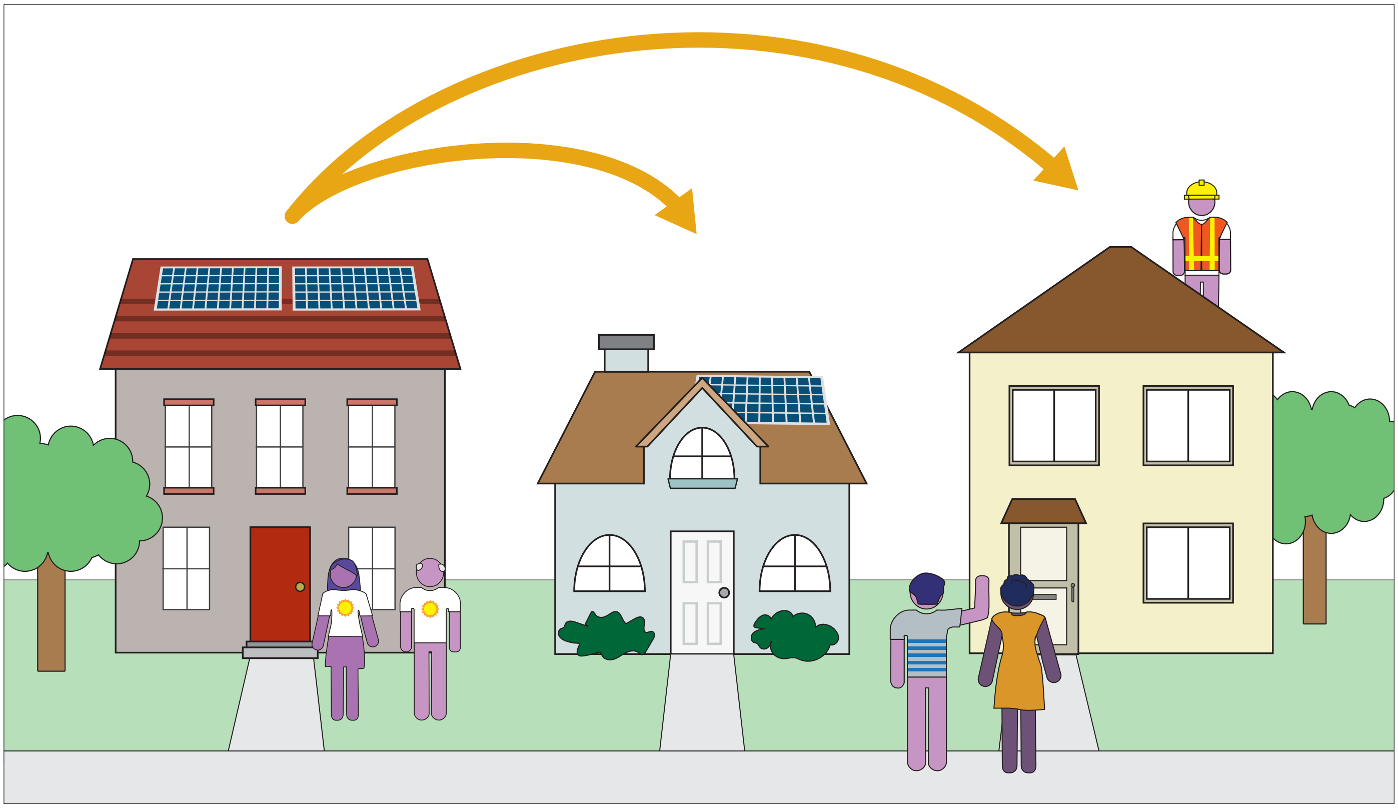
Participating solar installers also reported that Solarize CT significantly lowered customer acquisition costs through:

- Greater awareness of solar among customers
- Increased brand recognition of Solarize
- Reduced marketing spend
- Geographic concentration of customers (reducing travel time)
- Higher lead volumes
- Higher close rates
- Shorter time to sale

These are valuable benefits, considering that costs unrelated to solar hardware made up 55 percent of a system's price tag in the U.S. in 2015.

As a result of the volume of signed contracts, all installers reported growth in their business. To meet demand, many hired additional employees. After the Solarize CT campaigns ended, several installers continued offering discounted pricing to customers who signed-up after

10 Bollinger and Gillingham (2017) Social Learning and Solar Photovoltaic Adoption: Evidence from a Field Experiment. Yale University Working Paper



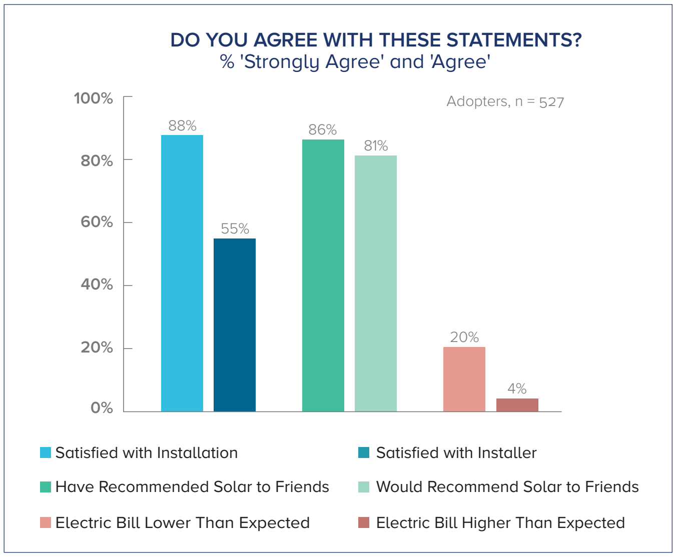
the deadline. The majority of installers reported that there were persistent benefits of participating in Solarize as customers contacted them even after the campaign was over.

In some instances, such rapid growth also created challenges. Where solar adopters reported reasons for being unsatisfied, they felt that problems stemmed from the installation company having insufficient bandwidth to handle the spike in demand. But as the section below describes, customer satisfaction generally remained high.

CUSTOMERS ARE OVERWHELMINGLY HAPPY WITH THE RESULTS

Customers in the research survey data from the Solarize CT program provided mostly positive feedback. Almost 90 percent were very satisfied with their installations, and more than 80 percent would recommend (or have already recommended) solar to others. Overall, the program provided accurate information about costs: only 2 percent of households said that their electricity bill was higher than expected after the installation. Reasons that solar adopters reported being unsatisfied included lack of responsiveness, missed deadlines, and inadequate training for technicians.

Of course, it goes almost without saying that the selection of a reliable installer, who is prepared for a large increase in business, is of fundamental importance to campaign success and future adoptions.



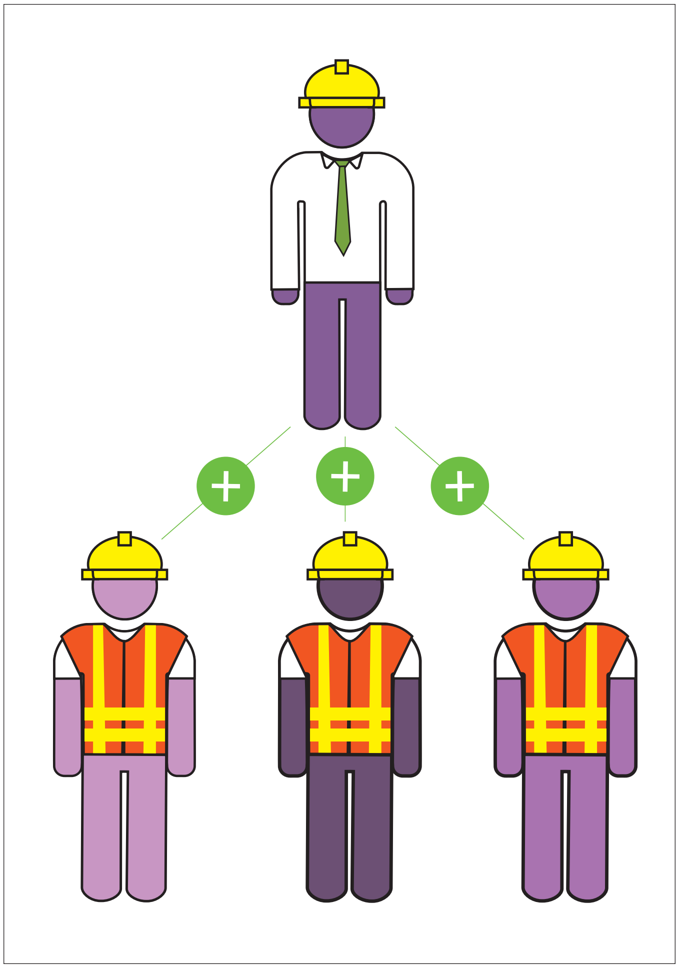
The Tremendous Benefit to Local Communities

From a stronger local economy to streamlined policy, running a Solarize campaign offers communities an array of social benefits beyond simply more solar panels.

SUPPORTING JOB GROWTH AND WORKFORCE INVESTMENT

Solarize campaigns strengthen consumer demand and spur job growth within the solar industry. Nearly every installer that took part in Solarize CT hired new employees for a variety of positions, like electricians and sales representatives. One solar installer even created a standing Community Solar division in its company, dedicating resources to develop and participate in community solar programs.

Given the difficulty of filling so many new positions so quickly—a relative dearth of qualified employees existed in Connecticut—the state created jobs training programs and recruitment fairs.



A PATH TO EFFICIENT MARKETS AND STREAMLINED POLICY

Solarize CT convened groups from across sectors to support the campaign. This broad coalition of organizations and community leaders—from a quasi-public financing agency to a nonprofit clean energy marketing firm—created a foundation for a sustainable clean energy market that no single actor could have achieved in isolation.

A SHARED SENSE OF COMMUNITY PURPOSE

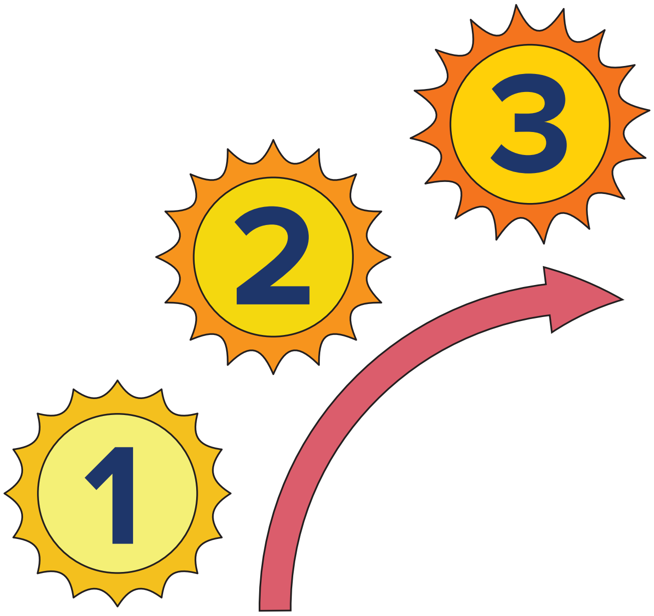
Having the support of town leadership on community-based campaigns is paramount in building legitimacy for the campaigns, and serves to bring leadership and citizens together toward a shared sense of purpose. The Town of Portland was lucky to have First Selectwoman Susan Bransfield as one of its solar ambassadors. Bransfield was very involved in the installer review and selection process and very supportive of the Clean Energy Task Force's efforts. She even opened up her own home for a solar open house, where she talked about her personal experience going solar. Having her to lead by example increased social proof, one of the strongest motivations for human behavior. Especially since Solarize is a grassroots approach to increasing solar adoption, having trusted sources in positions of leadership who not only support the program, but actually take the recommended action, makes a difference.

Solarize campaigns, through the quick deployment of a large amount of solar, also help to establish uniform processes and build trust among communities. Creating a pipeline of installations with similar characteristics streamlines permitting, economic development, and job growth for governments.

In short, this combined policy and market mechanism to promote solar deployment not only benefits suppliers and customers, but it also can accelerate the growth and maturity of a statewide renewables market.

Three Critical Elements of a Successful Campaign

A well-designed campaign comprises three basic steps: first, raise awareness. Second, understand and tap into customer motivation. Third, convert motivation to action.



EDUCATION: GETTING THE CUSTOMER GOOD INFORMATION

The first step is getting the word out—educating town residents about both the campaign underway and the value of solar. In Solarize CT, local print newspapers were the single most important source for learning about the campaign. Other effective avenues were workshops, town events, and town websites; interestingly, social media was the least effective method for spreading the word.

Prominent visual displays like banners and yard signs also kept the campaign front-of-mind among residents. In towns where local regulations restricted public signage the lack of a constant visual reminder damaged the success of the campaign.

Outside of specific channels for marketing, four basic principles appear to drive household awareness of solar:

1. **Community networks** are the backbone of success, not just because they help to spread the word but also because they increase trust in the technology. Parent-teacher organizations (PTOs), clubs, civic groups, libraries, and churches are all great convening points to build community connections. Hosting events like those described above—solar tours and live installations—serves the same end.

2. Campaigns are most effective if **tailored** to the specific characteristics of the community. For instance, analysis of the Solarize CT campaign found that younger groups were most sensitive to price, which meant that the discount offered through Solarize attracted them to installations. Pricing mattered less and less moving up age brackets; older segments of the population were, instead, more persuaded by the trustworthiness provided by town sponsorship and vetted installers. (While solar ambassadors from the Connecticut campaign stressed that a “perfect pitch” should be tailored to the specific audience, they said that every communication should highlight the urgency of the campaign and the credibility earned through official support.)

3. Helping homeowners get their **technical questions** answered is as important as initially gaining their attention. Solarize workshops, usually held

at the launch of a campaign, and then periodically throughout the campaign, are simple ways to answer residents' technical questions.

4. Coalition towns i.e towns that partner on Solarize campaigns to increase capacity and potential adopters perform well, suggesting that a **friendly competition between towns can motivate** customers and/or campaign organizers.

MOTIVATION: MOVING NEW CUSTOMERS TOWARD SOLAR ADOPTION

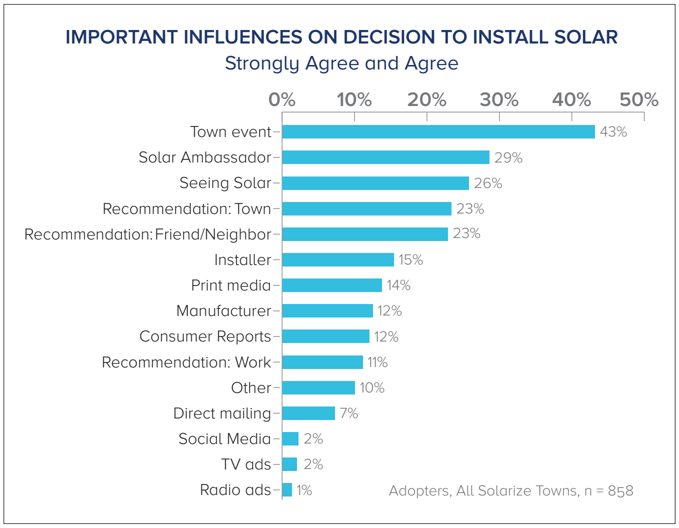
Customer education is a necessary first step, but some information is more motivating than other information in a campaign.

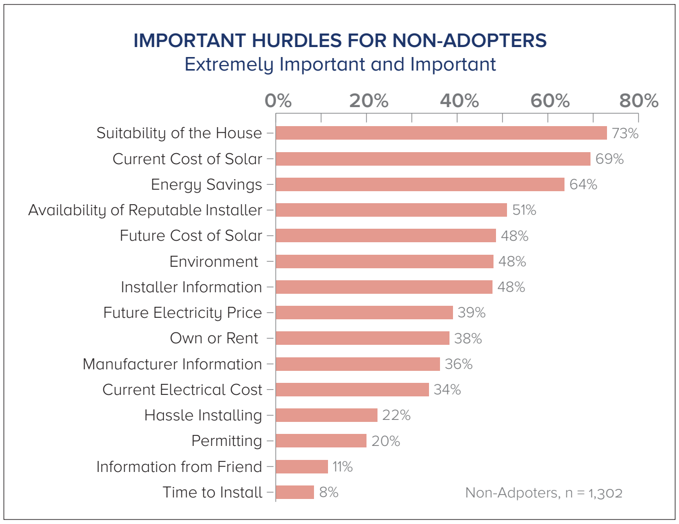
Start with the economics of going solar. Communicating the discount provided through Solarize—a tiered pricing model in which more money is saved when more people sign up—plus the prospect of saving money on energy bills. From there, once you have a better feel for the customer, introduce complementary reasons for going solar. Solar ambassadors—the locals spearheading a campaign—should think creatively about this facet of communication; it's better to avoid leaning exclusively on arguments like "it saves you money" or "it's good for the environment."

For example, in Simsbury, Connecticut, ambassadors found customers who were not simply motivated by the return on investment of solar. Some saw solar as a way to give back to the rising generation of their grandchildren. Others, frustrated with the local electric utility in the wake of power outages cause by Hurricane Sandy, were persuaded by ambassadors who framed solar as a way of gaining independence from the utility. A diversity of messages around the value of solar serves a campaign well.

Support from trusted actors, like local government and high-profile citizens or elected officials, also helps motivate people to install solar. Municipal leaders who dedicate themselves to the success of local campaigns (through sponsorship of promotional materials, town-led events, personal outreach, etc.) legitimize the campaign as a program that residents can have faith in. Solar installers were especially appreciative of this third-party credibility.

In thinking about what motivates people to adopt solar, it's important to also consider specific hurdles to adoption. In the Solarize CT campaign, 75 percent of non-adopters mentioned unsuitability of their house as a reason for not going solar, and nearly 70 percent highlighted the current cost of solar as a barrier. While siting issues are difficult to overcome, innovative financing options, such as power purchase agreements, play a





critical role in unlocking solar for households. Leaders of a Solarize campaign should map these hurdles in planning and preempt them in execution.

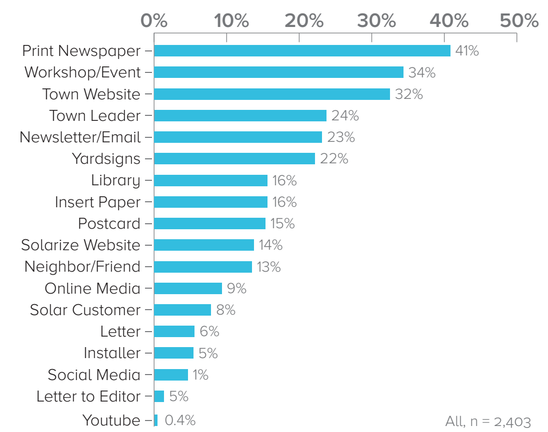
ACTION: CONVERTING INTEREST INTO INSTALLATIONS

Finally, two components of a campaign are especially useful for turning prospective buyers into paying customers.

First, the urgency of the campaign, with its strict (generally 20 week) deadline, is a particularly powerful force for motivating action. The majority of sign-ups in Connecticut occurred in the last several weeks of the campaign. In fact, knowing that the campaign end-date motivated customers to take action, installers were able to time their investment of resources at this stage of the campaign. (Notably, campaigns with end-dates close to the winter holidays and poor weather faced challenges with converting community outreach activities into customer sign-ups.)

Second, social diffusion—the combined influence of peers talking about and installing solar—has a marked effect on citizens' final decision to install solar. Create as many opportunities as possible for people to meet and talk about solar; highlight installations as they go up.

HOW DID YOU HEAR ABOUT SOLARIZE



STARTING THE SOLARIZE CAMPAIGN RIGHT

How a town or city introduces its community to Solarize helps set the campaign tone. Solarize CT was careful to schedule launch events that matched the sponsor community, asking towns to find a venue that would attract people and seat at least 100.

Every launch had elements in common: introductions by the Energy Committee Chair, a welcome by the Chief Elected Official, a presentation by SmartPower and CT Green Bank, and a presentation by the solar installer, who detailed a number of practicalities, from "how solar works" to "how to pay for a system." But each event also had its own charm and culture; they took place in historic buildings, school cafeterias, grange halls, town halls, and libraries. Easton/Redding/Trumbull held their launch on Sunday afternoon—full brunch included—because commuters came home from work too late to attend evening meetings. Westport launched its campaign at a local environmental center with wine and cheese.

MARKETING AND COMMUNICATION

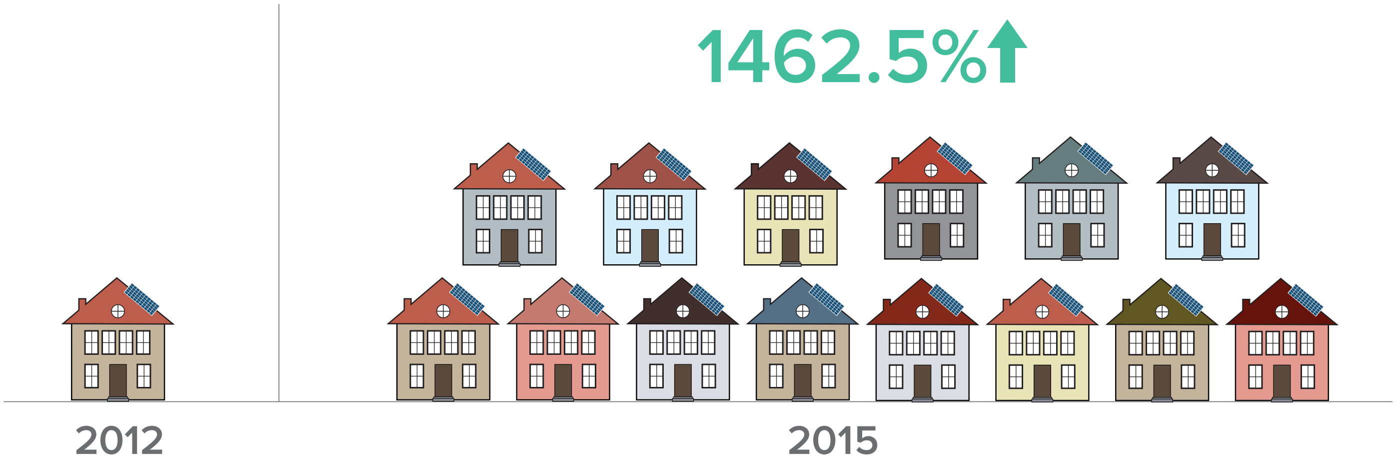
Constant communication is key, and marketing strategies should integrate both local media and live events. A few examples of outlets for advertising the campaign: town newsletters, the town website, local newspapers, workshops, town events, and local meeting groups. Prominent visual displays, such as banners and yard signs, are especially helpful to keep the campaign front-of-mind. In the Solarize Connecticut campaign, the six most effective methods for reaching community members, in order, were: print newspapers, workshops/events, the town website, the town leader, a newsletter/email, and yard signs.

BUILD A COALITION OF STAKEHOLDERS

For the Solarize CT campaign, organizations from the public, private, and nonprofit sectors were all involved. These broad partnering efforts created a rich ecosystem around a renewable energy market. Presented below are the core stakeholders for the campaigns in Connecticut, with a short summary of their roles.

- State agency: lends support and legitimacy to a campaign; accelerates consumer-financing options alongside local lending partners.
- Town leadership: provides legitimacy and raises awareness
- Solar ambassadors: locally trusted sources who advanced word-of-mouth recommendations, recruit volunteers, and organize/host informational events
- Installer: connects with consumers, follow-up on leads, installs solar systems
- Marketing firm: if budgeting permits, a marketing firm can help spread the word

The Path Forward



In Connecticut, solar installations increased dramatically from 2012–2015

Solarize campaigns have the potential to dramatically increase the adoption rate of rooftop solar photovoltaic systems. Connecticut's experience demonstrates a radical effect: in just three years, the number of homes with solar grew from about 800 to over 12,500, with Solarize responsible for about 20 percent of this growth. Campaigns leverage existing social networks and provide a wide range of benefits:

- Reduced energy bills for consumers
- Streamlined permitting, economic development, and job growth for governments
- Cohesion around a single campaign for communities
- New customers, increased sales, and business expansion for solar installers
- A reduction in greenhouse gas emissions through the replacement of fossil fuel energy sources with renewables

More broadly, the coalition of organizations supporting a Solarize campaign create a strong foundation for a robust clean energy market that no single actor could achieve in isolation.

As such, these campaigns are more than a simple behavioral or marketing innovation for capitalizing on the power of social networks. Rather, Solarize serves as an innovation with the potential to induce widespread progress around renewable energy. As the price of renewables continues to drop, and the profile of renewables continues to rise, consumers will be more predisposed to consider solar as a valuable energy option.

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U.S. Department of Energy

This work was supported by the U.S. Department of Energy Solar Energy Evolution and Diffusion Studies (SEEDS) program.

Appendix A – Experimental Design of Solarize CT

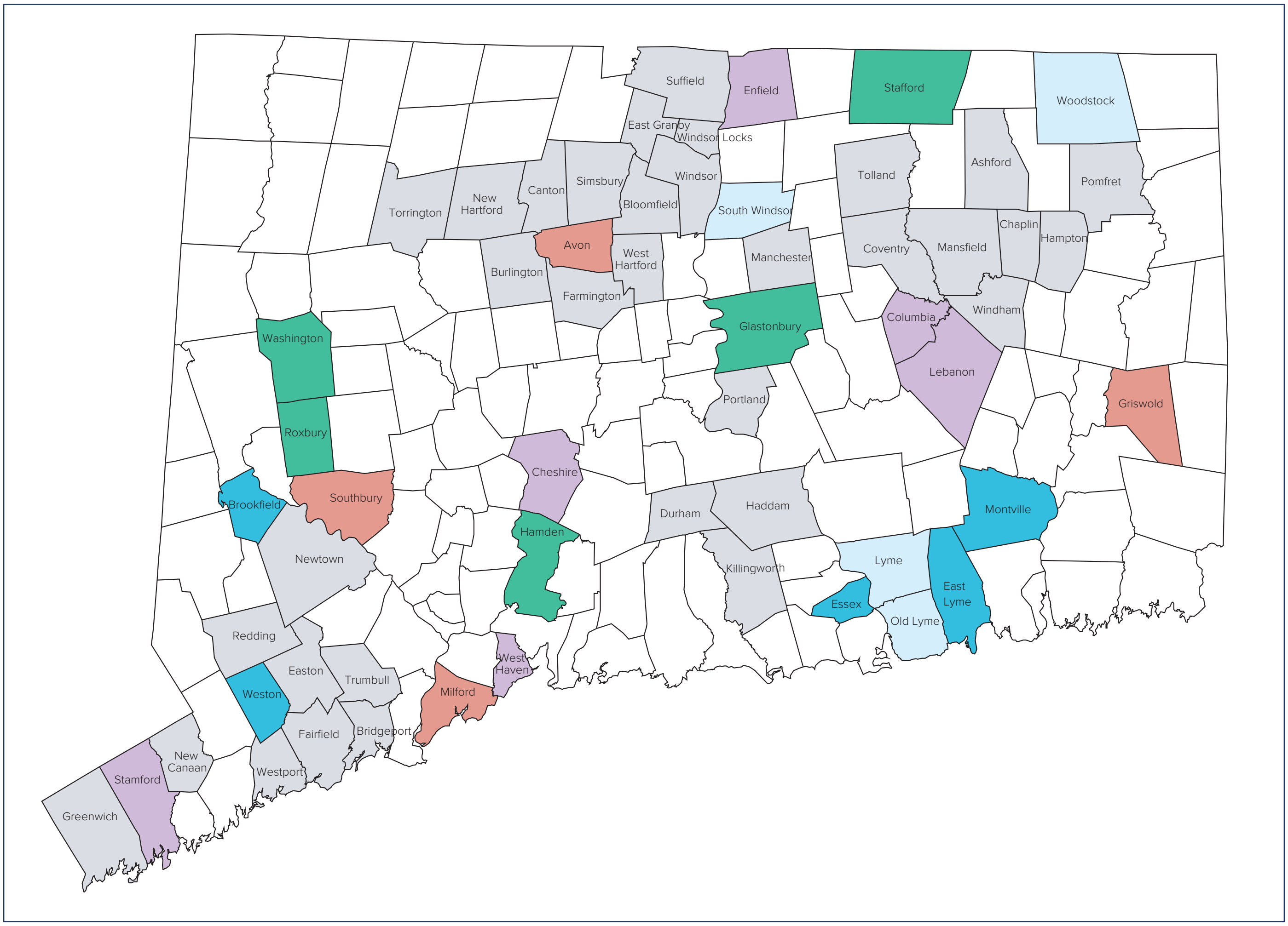
Solarize campaigns share central tenets of community-based outreach, a clear end-date, discount pricing, and some number of pre-determined installer(s) or price options. Our research tested five variations on the "Classic" model, which is described below. By adjusting a single campaign variable at a time, researchers from Yale and Duke Universities were able to capture the direct value of single aspects of the campaign. How important, for instance, is the 20-week campaign length? Might that be shortened without sacrificing effectiveness?

The table and figure across offer, respectively, a snapshot of each model and where it was implemented across the state.

The table on page 22, for each variation, offers a thorough summary, its benefits and potential considerations if implementing.

VARIATIONS OF SOLARIZE CT

MODEL	TOWN MOTIVATION	LENGTH OF CAMPAIGN	PRICING OFFER	# INSTALLERS	QUOTE COMPARISON
Classic	Competitive Application	20 Weeks	Tiered	1	N/A
Select	Selected At Random	20 Weeks	Tiered	1	N/A
Express	Competitive Application	10-12 Weeks	Tiered	1	N/A
Prime	Competitive Application	20 Weeks	One Low Price	1	N/A
Choice	Competitive Application	20 Weeks	Tiered	2-3	In-Person
Online	Competitive Application	20 Weeks	N/A	5+	Online Platform



MODEL	HOW IT WORKS	BENEFITS	CONSIDERATIONS
Classic[11]	• 20 Weeks • Tiered Pricing • One Installer	• 20 weeks allowed communities time to plan and execute their campaigns • Single installer simplified choice for customers and simplified coordination for campaign organizers • Tiered pricing encouraged a peer-to-peer effect with customers striving to reach the highest tier • Proven model nationwide	• With a single selected Solarize installer, residents did not have a choice of installation company if they wanted to take advantage of the Solarize discount • Smaller installers needed to expand capacity quickly to meet higher demand
Express[12]	• 12 Weeks • Tiered Pricing • One Installer	• Suggestive evidence that Express was more effective per week, but less effective in aggregate (neither difference is statistically significant). Theoretically, Express campaigns could save implementation costs. (This was not the result of Solarize CT) • Word of mouth played a much smaller role in leading people to adopt	• Express did not deliver the expected cost savings: SmartPower and CT Green Bank had to increase their administrative support and increase their investment in coordination efforts to meet the earlier deadline • Towns needed to invest in up-front planning to make marketing effective during the short campaign • All installers who participated in an Express program reported that the timeframe was too short
Choice[13]	• Multiple Installers • One Low Price	• Compared to Classic, Choice towns were more successful in terms of the percentage increase in total number of installations. Several installers competing for business appeared to play a key role in this uptake dynamic • Solarize Choice towns had the lowest prices – the average system price in Choice towns was 2.65$/W compared to 2.72$/W in Round 3 Classic towns • Choice experienced sustained price discounts post-campaign • Customers felt confident that they were getting a good price with participation of multiple installers • Strong growth rates were observed post-campaign, suggesting that the campaign brought installers in touch with more residents	• Installers and Solar Ambassadors reported that choice created confusion for some customers • More coordination effort was required • Installers highlighted the need for strong guidelines to execute effectively. A number of installers reported poor customer experience, lost leads due to overwhelming or conflicting information, and increased cost of customer acquisition

MODEL	HOW IT WORKS	BENEFITS	CONSIDERATIONS
Select[14]	• Towns Selected At Random To Join	• Allowed residents to experience the benefits of a Solarize campaign even if their towns did not have the time or resources to commit to the application process • For some towns, the “you’ve been chosen” message was motivating as a special opportunity • Results show that Solarize can still be effective in randomly selected municipalities	• Whilst still effective, results show a lower effect when municipalities do not opt-in on their own; level of interest/ resources may be lower
Prime[15]	• One Low Price • Single Installer	• Simplified the decision-making process for residents: one installer and one price • Word-of-mouth from community members declined in effectiveness but was offset by other word-of-mouth channels (friends, coworkers, etc.)	• Limited homeowners’ choice to a single installer • Without the pressure of tiered pricing, with discounts contingent on numbers signed up, residents may have been less inclined to encourage others in their towns to install with them
Online[16]	• Compare Quotes Online, • Multiple Installers	• Gave residents more choice and provided them with easily accessible information to make decisions • Customers were able to easily compare quotes with apples-to-apples assumptions • Residents were able to utilize the assistance of an online solar coach to help guide them in their decision • Competition among installers reduced prices—a reduction that persisted even after the campaign ended	• In CT, the Solarize Online campaigns generally did not perform as strongly • Limited installer visibility and engagement • With many participating installers, it was reported that some customers felt an overload of information; onus on customer to compare installer quotes • Potential technical barriers associated with user access of online platform

11 Gillingham and Bollinger (2017) “Social Learning and Solar Photovoltaic Adoption: Evidence from a Field Experiment,” Yale University Working Paper
12 Bollinger, Gillingham, and Tsvetanov (2016) http://environment.yale.edu/gillingham/BollingerGillinghamTsvetanov_SalesDurationGroupBuys.pdf
13 Bollinger, Gillingham, and Lamp (2017) “Long Run Effects of Competition on Solar Photovoltaic Demand and Pricing,” Yale University Working Paper
14 Gillingham and Bollinger (2017) “Social Learning and Solar Photovoltaic Adoption: Evidence from a Field Experiment,” Yale University Working Paper
15 Bollinger, Gillingham, and Tsvetanov (2016) - http://environment.yale.edu/gillingham/BollingerGillinghamTsvetanov_SalesDurationGroupBuys.pdf
16 Bollinger, Gillingham, and Lamp (2017) “Long Run Effects of Competition on Solar Photovoltaic Demand and Pricing,” Yale University Working Paper

Appendix B – Financing Residential Solar Installations

Though the mix of reasons for participating in Solarize varied across demographics, the discount pricing consistently proved to be the predominant motivation. In fact, nearly 70 percent of respondents highlighted the current cost of solar as a barrier to adoption.

Innovative financing options, such as power purchase agreements, therefore have a critical role to play in unlocking solar for households.

In Connecticut, the CT Green Bank, a state-level institution devoted to expanding the region's clean energy sources, lent its support to the Solarize program in three basic ways:

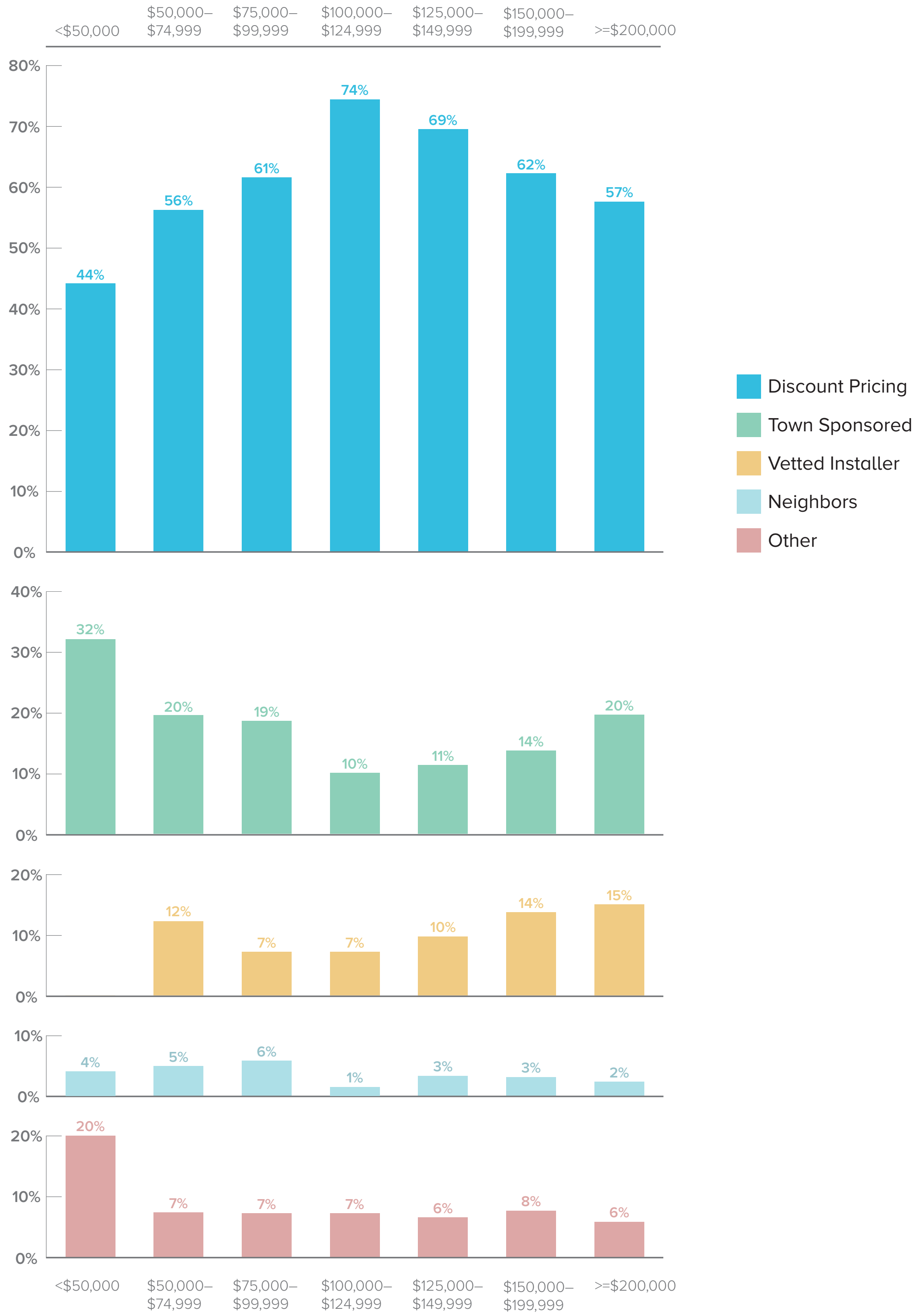
1. The Bank oversaw the Request for Proposal process among solar installers, vetting all of the applicants and establishing quality controls. This formal "stamp of approval" gave homeowners confidence in local suppliers.

2. The Bank contracted with the clean energy marketing organization SmartPower to raise the profile of solar across the state.

3. Most importantly, the Bank accelerated consumer financing options by developing risk-reduction mechanisms in partnership with local lending and capital partners.

The existence of the CT Green Bank has prompted private-sector investment in clean energy infrastructure at a scale that may otherwise have been impossible. States pursuing Solarize should consider in what capacity they can help homeowners overcome the barrier of cost.

MOST IMPORTANT REASON FOR PARTICIPATING BY INCOME



Feasibility of Renewable Thermal Technologies in Connecticut

MARKET POTENTIAL

Helle Grønli, Fairuz Loutfi, Iliana Lazarova, Paul Molta, Prabudh Goel, Philip Picotte and Tanveer Chawla

March 2017

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ACKNOWLEDGEMENTS

This project has been supported financially by the Connecticut Green Bank, Yale University as well as United Illuminating and Eversource through the CT Energize initiative. The Connecticut Department of Energy and Environmental Protection (DEEP) served as an advisor.

In preparing this report, the Yale team benefitted particularly from the extensive collaboration, insights, and experience of key players pursuing the deployment of renewable and efficient energy solutions in the Connecticut market. Without the thorough debate around assumptions, and the reality check of results along the way, the conclusions would not be as well founded. We would like to thank the following individuals for substantive contributions to the study:

- Bryan Garcia, Connecticut Green Bank
- Lynne Lewis, Connecticut Green Bank
- Neil McCarthy, Connecticut Green Bank
- Jeff Howard, DEEP
- Joe Swift, Eversource
- Peter Klint, Eversource
- Patrick McDonnell, United Illuminating
- Philippe Huber, United Illuminating (at the time of the analysis)

In addition, we would like to thank Natural Resources Canada for making RETScreen Expert available for the team and patiently responding to our questions. We are furthermore indebted to numerous regional program administrators for providing portfolios of technical and economic data for renewable thermal projects supported through their programs. Namely, the Massachusetts Clean Energy Center, Northern Forest Center, New Hampshire Public Utilities Commission, Vermont Clean Energy Development Fund, and Connecticut Green Bank.

The Yale team remains solely responsible for any errors or omissions in this report.

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LIST OF ACRONYMS

AEO Annual Energy Outlook

ACS American Community Survey

ASHP Air Source Heat Pump

CBECS Commercial Buildings Energy Consumption Study

CDD Cooling Degree Days

CES Comprehensive Energy Strategy

CO_2e Carbon Dioxide Equivalent

CT Connecticut

DEEP Department of Energy and Environmental Protection

EIA Energy Information Agency

EPC Energy Performance Contract

ESCO Energy Service Company

EUI Energy Use Intensity (BTU/Square feet)

GC3 CT Governor's Council on Climate Change

GHG Greenhouse Gas

GSHP Ground Source Heat Pump

HDD Heating Degree Days

NPV Net Present Value

PACE Property Assessed Clean Energy

PSD Program Savings Document

PV Photo Voltaic

RECS Residential Energy Consumption Study

RTT Renewable Thermal Technologies

SCC Social Costs of Carbon

SEDS State Energy Data System

SHW Solar Hot Water

TPO Third Party Ownership

TRECs Thermal Renewable Thermal Credits

Executive Summary

Renewable thermal technologies (RTTs) harness renewable energy sources to provide heating and cooling services for space heating and cooling, domestic hot water, process heating, and cooking.[1,2]

In 2014, a total of 344 trillion British thermal units (BTUs) were delivered for stationary energy purposes in residential, commercial, and industrial sectors in Connecticut (CT).[3] Over 60 percent of the energy used in residential and commercial buildings was for space heating and cooling in 2012.[4] Changing from fossil fuels to RTTs in heating and cooling buildings, as well as in heating industrial processes, has the potential to provide a valuable contribution to meeting Connecticut's statutory target of reducing greenhouse gas emissions 80 percent below 2001 levels by 2050.

The purpose of the "Feasibility of renewable thermal technologies in Connecticut" research project is twofold: to assess a realistic contribution from RTTs in achieving Connecticut's transition to a less carbon-intensive economy, and to establish the knowledge necessary for effective policies and strategies to advance RTTs in Connecticut. In addition to this market potential study, the project included a field study on RTT market barriers and drivers.[5]

Although application of RTTs in the industrial sector is promising, both because of the sector's large thermal demand and because it produces waste energy that can be utilized, it has not been included in this study due to its heterogeneity and complexity.

Our analysis estimates a thermal demand in Connecticut buildings of 126 trillion BTUs in 2050, with a sensitivity range of 103–142 trillion BTUs. The lower end of the sensitivity range assumes higher annual rates of deep retrofits and stricter building codes; the upper end of the range assumes that outdoor temperatures will remain at current levels for the next several decades. In fact, however, significantly

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1 Cooking is not part of this study.

2 This definition has been adapted by the Renewable Thermal Alliance, a private-public partnership established to develop the infrastructure for large-scale deployment of renewable thermal technologies in Northeast America: http://cbey.yale.edu/programs-research/renewable-thermal-alliance

3 EIA State Energy Data System: http://www.eia.gov/state/seds/. Delivered energy is net of electricity losses.

4 2013 Connecticut comprehensive energy strategy: http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf

5 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

higher temperatures during both heating and cooling seasons are expected as the region's climate changes,[6] and our analysis indicates that this results in a net reduction in the overall thermal demand of buildings.

Today, approximately 83 percent of the thermal demand of residential and commercial buildings is supplied directly by fossil fuels. Heating and cooling buildings and domestic hot water represent around 12.6 million metric tons CO_2e emissions per year, which corresponds to 30 percent of Connecticut's GHG emissions in 2013.[7] RTTs can play an important role in realizing a low carbon future. However, current market prices, existing installations and infrastructures represent considerable economic challenges to RTTs.

The competition analysis—examining how RTTs compete with traditional thermal technologies—includes seven archetypal categories of existing buildings. The RTTs include three alternative cases for air source heat pumps (ASHPs) representing different end-uses and physical limitations of the existing heating system. The RTT analysis also includes ground source heat pumps (GSHPs), solar hot water (SHW), and biomass. (Biomass pellets are used as a proxy for solid biomass in this study.) To supplement the RTT analysis, the study also examined highly efficient natural gas boilers as an alternative to traditional thermal technologies. Incumbent technologies include fuel oil, natural gas (standard efficiency), and conventional electric technologies (e.g., electric resistance heating). Financial viability has been evaluated on the basis of net present value and simple payback.

The base case assumes that RTTs deliver the end-user's entire annual thermal demand. Generally, heat pumps are assumed to deliver the user's space cooling and heating, and biomass and highly efficient natural gas are assumed to deliver the user's space and water heating. Solar hot water and ASHP water heaters are assumed to deliver the water heating. No financial incentives are included in the base case. No infrastructure costs have been included, with the exception of some heat pump alternatives in which the level of incremental installation costs has been varied to take into account existing building's physical limitations have to some extent been handled by varying the level of incremental installation costs.

Our competition analysis shows that 19 percent of today's thermal demand in Connecticut buildings can be met competitively by RTTs, representing an unrealized potential for reduced annual GHG emissions of 1.4 million metric tons CO_2e.[8] Of particular interest are air source heat pumps to replace conventional electric technologies for space heating and cooling and biomass pellets to replace fuel oil in some commercial settings.

6 U.S. Global Change Research Program, "National Climate Assessment," http://nca2014.globalchange.gov/.

7 See http://www.ct.gov/deep/lib/deep/climatechange/2012_ghg_inventory_2015/ct_2013_ghg_inventory.pdf

8 The GHG emission calculations are based on the RETScreen Expert inventory and rely on its modeling concept.

Fuel prices have a large impact on how competitive RTTs are compared to conventional thermal technologies. Currently at $16.63 per MMBTU,[9] natural gas prices are low, and natural gas boilers out-compete conventional and renewable thermal technologies in most settings.

To reduce GHG emissions by 80 percent in the thermal demand of buildings by 2050 (relative to 2001 levels), the GHG emissions related to thermal end-uses would have to be reduced from 12.6 million metric tons CO_{2e} to approximately 3 million tons CO_{2e}. This would require a considerable reduction in thermal demand in combination with deployment of RTTs and de-carbonized electricity generation. In today's market conditions, an array of interventions is necessary to realize Connecticut mandatory emission reduction targets using renewable thermal alternatives that currently present both favorable and unfavorable economics.

Although replacement of standard gas and fuel oil boilers with highly efficient gas boilers represents one of the cheapest means to reduce GHG emissions today, doing so extensively is not sufficient to reach the target and would lock in fossil fuel technologies that could prevent Connecticut from achieving an 80 percent reduction in GHG emissions by 2050. The high share of natural gas boilers in the commercial sector already represent a barrier to RTTs and thus inhibits Connecticut's ability to achieve needed reductions in GHG emissions. Nevertheless, replacing standard natural gas boilers with highly efficient gas boilers and decarbonizing the gas grid by, for example, injecting biogas from anaerobic digestion could supplement market strategies to promote RTTs.

Projections in this report are illustrations of what may happen given certain assumptions and methodologies. The team has performed several sensitivity analyses to evaluate the impact of potential market changes and policy instruments. Unless otherwise indicated, the practice has been to change only a single parameter at a time.

9 EIA SEDS as of October 2016.

PARAMETER FOR SENSITIVITY ANALYSIS	DESCRIPTION	MAIN IMPACT ON NET PRESENT VALUE COMPARED TO BASE CASE
Base case	See Appendix A for key assumptions	Heat pumps are competitive with conventional electric technologies in most customer categories. Additional costs related to physical limitations such as ductwork are a challenge, particularly in commercial sector settings. Solar water heating as an alternative to conventional electric technologies is competitive in the residential sector and for commercial customers with a considerable demand for hot water. Biomass is competitive as an alternative to fuel oil in many commercial settings. Highly efficient natural gas boilers are generally competitive with conventional electric technologies and fuel oil boilers.
Fuel costs	50 percent increase for incumbent case	All heat pump alternatives and solar water heating are competitive with conventional electric technologies across all customer categories. Biomass is competitive with fuel oil, and highly efficient natural gas boilers are competitive with standard efficient gas boilers.
	100 percent increase for incumbent case	Heat pumps and solar water heating are competitive with fuel oil in several customer categories, particularly in commercial settings. Biomass pellets are competitive with natural gas. Highly efficient natural gas boilers are competitive with standard gas boilers.
	25 percent reduction for proposed case	Only ASHPs for space heating and cooling, and ASHP water heaters remain competitive with conventional electric heating. Solar water heating remains competitive with conventional electric heating in residential sector. Biomass is competitive with fuel oil in all customer groups.
	Solar PV delivers drive energy of proposed case	Solar PV at an installation cost of $2.5 per Watt improves the competitiveness of heat pumps and solar water heating. Although GSHPs still have a negative, net present value due to high incremental installation costs, their operational costs are competitive with those of natural gas boilers.

PARAMETER FOR SENSITIVITY ANALYSIS	DESCRIPTION	MAIN IMPACT ON NET PRESENT VALUE COMPARED TO BASE CASE
Incremental initial costs	25 percent reduction	RTTs are generally competitive with conventional electric technologies. Biomass is competitive with fuel oil in residential sector, and highly efficient natural gas boilers are competitive with standard natural gas boilers in most customer categories.
	RTT for partial load (60 percent of capacity and ~80 percent of load)	In general, renewable technologies become more competitive with traditional thermal technologies.
Carbon price	Carbon price of $41 per tCO2	A few additional heat pump alternatives are competitive with conventional electric technologies. Biomass is generally competitive with fuel oil.
Thermal Renewable Energy Certificates (TRECs)	TRECs corresponding to a market price of $25 per MWh	Impact similar to the carbon price alternative.
Financial terms	25 percent reduction of debt interest rate	Minor impact on NPV.
	25 percent increase of debt term, with economic life of asset as maximum debt term	Minor impact on NPV.
Sets of simultaneous changes	25 percent reduction of • incremental initial costs • electricity prices for the proposed case due to use of solar PV • pellet prices A carbon price of $120 per tCO2	Heat pumps and solar water heating are competitive with conventional electric technologies for all customer categories. ASHPs, biomass, and highly efficient natural gas boilers are competitive with fuel oil. Biomass and highly efficient natural gas are competitive with standard natural gas boilers.
	25 percent reduction of • incremental initial costs • electricity prices for the proposed case via use of solar PV 50 percent increase of incumbent case fuel costs	As in previous case but additional heat pump alternatives become competitive. Fuel prices are less predictable than a carbon price.

Table 1 | Overview of sensitivity analysis

With the current market situation, combinations of marketing strategies, financing products, and policy instruments—such as a stricter building code combined with TRECs, soft cost strategies and financing products—are required to make RTTs competitive.

This report concludes with the following recommended market strategies to improve the competitiveness of RTTs, which are supplementing the recommendations of the field study on barriers and drivers: [10]

1. Reduce upfront costs. Initial installation costs have large impacts on how competitive the RTT is and how much capital the customer has to raise upfront. Available strategies:
   - Cost reduction campaigns à la Solarize.[11]
   - Partial-load strategies: using RTTs to displace most of the thermal demand for space heating but not requiring them to cover 100 percent of the capacity needed for peak demand.
   - New business and financing models to eliminate upfront costs and secure 100 percent financing via loans, leases, and property assessed clean energy financing.

2. Implement market interventions to improve the operational cash flow. Available strategies:
   - Packaging RTTs with solar PV and deep renovation.
   - Favorable interest rates and debt terms to reduce risk for private lenders, lend credibility to the technology, and qualify it as environmentally friendly.
   - Carbon pricing.
   - Thermal Renewable Energy Certificates.
   - Explore rate mechanisms that recognize the value of RTTs in reducing demand for natural gas and electricity.

3. Enhance awareness and trust in RTTs through marketing efforts, trusted messengers, and proven installations. Available strategies:
   - Performance verification to show that the technologies deliver as promised and to facilitate new financial models and attract investors.
   - Green Bank involvement in projects and technologies to enhance credibility.
   - Declining block grants.

4. Use the building code and standards to reduce thermal demand and establish a predictable minimum market for RTTs.

This market potential study has not evaluated the feasibility of district energy. District energy and thermal grids may represent opportunities for cheap and clean thermal energy, exploiting waste energy from electricity generation and industrial processes.

10 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

11 Solarize CT is a community-based program that leverages social interaction to promote the adoption of solar through a group-pricing scheme intended to reduce soft costs. See http://solarizect.com/

CHAPTER 1
Introduction

Background

In 2014 a total of 344 trillion BTUs were delivered for stationary energy purposes in residential, commercial, and industrial sectors in Connecticut.[12] Over 60 percent of the energy used in residential and commercial buildings is for space heating and cooling.[13] Changing from fossil fuels to renewable thermal technologies (RTTs) in heating and cooling buildings, as well as in heating industrial processes, has the potential to provide a valuable contribution to meeting Connecticut's statutory target of reducing greenhouse gas emissions to 80 percent below 2001 levels by 2050.

The purpose of the "Feasibility of renewable thermal technologies in Connecticut" research project is twofold: to assess a realistic contribution from RTTs in achieving Connecticut's transition to a less carbon-intensive economy, and to establish the knowledge necessary for effective policies and strategies to advance RTTs in Connecticut.

The goal of reducing Connecticut's greenhouse gas (GHG) emissions by 80 percent below 2001 levels by 2050 was adopted in the 2008 Global Warming Solutions Act.[14] The Governor's Council on Climate Change (GC3), established in April 2015, is charged with examining the opportunities and challenges as the state pursues to achieve this target.

Analysis by the GC3 to date, has demonstrated that meeting the 2050 target will require a combination of measures across the entire state economy.[15]

The business context for RTTs will be different in 2050 and will be influenced by actions taken today. This can be illustrated by Figure 1, which spans four futures along two axes: thermal electrification versus gas expansion, and individual versus community solutions.

12 EIA State Energy Data System: http://www.eia.gov/state/seds/. Delivered energy is net of electricity losses.

13 2013 Connecticut Comprehensive Energy Strategy: http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf

14 See https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm

15 Analysis presented to the GC3 on July 26th: http://www.ct.gov/deep/cwp/view.asp?a=4423&Q=568878&deepNav_GID=2121

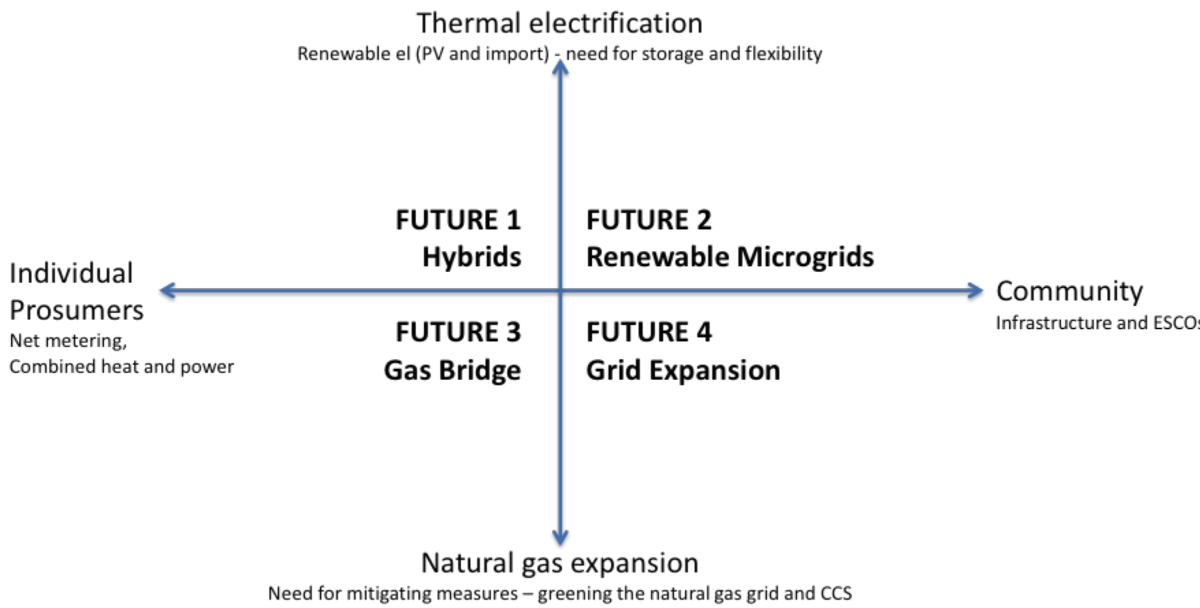


Figure 1 | Possible future competition fields for RTTs. Intended for illustration only.

The market for RTTs in future 1 would be different from that of future 4, with regard to both physical infrastructure and relative prices.

This study has not evaluated the feasibility of district energy. District energy and thermal grids represent opportunities for cheap and clean thermal energy, for instance by exploiting waste energy from electricity generation and industrial processes. These processes have not been included due their heterogeneity and complexity. District energy, community thermal grids and industrial thermal processes can offer important opportunities for RTT.

Framework for the Study

The framework for the project incorporates Connecticut's desire to move toward a cheaper, cleaner, and more reliable energy future while creating economic growth. The study has been guided by the definitions in Table 2.

CHEAPER A fuel source is considered cheaper for the customer when the net lifetime costs represented by the net present value of the technology are lower than that of the alternative that would otherwise have been preferred.	**CLEANER** A technology is considered cleaner when it has lower operating emissions of greenhouse gases (GHG) than the alternative technology that would otherwise have been preferred by the customer.
MORE RELIABLE A reliable energy system: • has enough energy to cover basic end-uses at a reasonable cost at all times • is robust in the face of short- and long-term changes in any individual energy source • is based on several energy sources that interact and complement each other	**ECONOMIC GROWTH**[16] Investment in and deployment of RTTs creates direct, indirect, and induced jobs. Direct economic benefits come from effects created by an investment in clean energy resources.[17] Indirect economic benefits result from changing demands that help produce clean energy technologies.[18]

Table 2 | Key terms for this study. Note: The above definitions present non-binding evaluation criteria and have been formulated to guide the research process.

16 See http://www.ctgreenbank.com/wp-content/uploads/2017/02/CTGReenBank-Memo-CT-Dept-Economic-Community-Development-October142016.pdf

17 e.g., income of local contractor, sales of equipment.

18 e.g., income of supplier companies, sales of materials for the equipment.

Definitions of Technologies

Renewable thermal technologies harness renewable energy sources to provide heating and cooling services for space heating and cooling, domestic hot water, process heating, and cooking.

RTTs utilize a broad range of renewable energy sources that otherwise could be lost. RTTs include:

- Heat pumps, such as air source heat pumps, ground source heat pumps, and heat pump water heaters
- Solid biomass, such as wood chips, pellets, and wood
- Liquid and gaseous biofuels
- Solar thermal technologies
- Waste heat technologies, including district heating and cooling

Different RTTs deliver heating and cooling at different temperature levels. Temperature levels are important to define the suitability of different technologies for meeting specific heat requirements in various end-use sectors. RTTs can range from small domestic applications to large-scale applications used in industrial processes and district heating and cooling networks. As RTTs often utilize locally available energy resources to meet on-site heating and cooling demand, customized solutions are often required.

We have applied the following definition of renewable energy resources:

"**Renewable energy resources** represent the annual energy flows available through sustainable harvesting on an indefinite basis. While their annual flows far exceed global energy needs, the challenge lies in developing adequate technologies to manage the often low or varying energy densities and supply intermittencies, and to convert them into usable fuels. Except for biomass, technologies harvesting renewable energy flows convert resource flows directly into electricity or heat. Their technical potentials are limited by factors such as geographical orientation, terrain, or proximity of water, while the economic potentials are a direct function of the performance characteristics of their conversion technologies within a specific local market setting."[19]

19 Grubler A, Nakicenovic N, Pachauri S, Rogner H-H, Smith KR, et. al. (2014): Energy Primer. International Institute for Applied Systems Analysis, Laxenburg, Austria, p. 40.

Market Definitions

This study analyzes the market potentials of various thermal technologies according to the framework shown in Figure 2.[20]

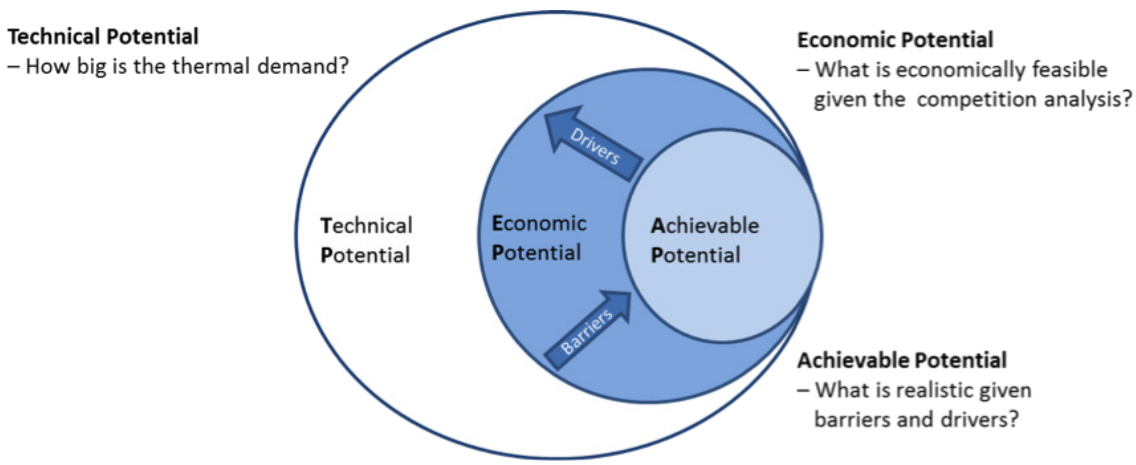


Figure 2 | Framework for market potentials.

TECHNICAL POTENTIAL

Technical Potential, also known as Total Addressable Market, is the theoretical maximum amount of thermal energy use that could be served by renewable thermal technologies, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end-users to adopt the technologies. It is often estimated as a "snapshot" in time assuming immediate implementation of renewable thermal technologies.

The technical potential for RTTs in Connecticut has been estimated and analyzed in Chapter 4: Technical Potential—Demand Analysis.

20 The market definitions are based on the framework offered by the National Action Plan for Energy Efficiency (2007). Guide for conducting energy efficiency potential studies. Prepared by Philip Mosenthal and Jeffrey Loiter, Optimal Energy, Inc. www.epa.gov/eeactionplan

ECONOMIC POTENTIAL

Economic Potential, also known as Serviceable Available Market, refers to the subset of the technical potential that can be cost-effectively served by renewable thermal technologies as compared to conventional thermal technologies. Both technical and economic potential are theoretical numbers that assume immediate implementation of renewable thermal technologies, with no regard for the gradual "ramping up" process typically in deployment of new technologies. In addition, they ignore market barriers to ensuring actual implementation of renewable thermal technologies. Finally, they consider only the costs of renewable thermal technologies themselves, ignoring any programmatic costs (e.g., marketing, analysis, administration) that would be necessary to deploy them widely.

The economic potential for RTTs in Connecticut has been estimated and analyzed in Chapter 5: Economic Potential—Competition Analysis.

ACHIEVABLE POTENTIAL

Achievable Potential, also known as Serviceable Obtainable Market or maximum achievable potential, is the amount of thermal energy use that RTTs can realistically be expected to serve assuming the most aggressive program scenario possible (e.g., providing end-users with payments for the entire incremental cost of the RTT).

The achievable potential takes into account real-world barriers to convincing end-users to adopt renewable thermal technologies, the non-measure costs of delivering programs (for administration, marketing, tracking systems, monitoring, and evaluation, etc.), and the capability of programs and administrators to ramp up program activity over time.

This report analyzes current technical and economic potential associated with RTT deployment in Connecticut. Barriers and drivers have been mapped through a field study documented in a separate report.[21]

21 EIA State Energy Data System: http://www.eia.gov/state/seds/. Delivered energy is net of electricity losses.

CHAPTER 2
State of the Market

The residential sector is the largest user of energy, with a net consumption of 171 trillion BTUs in 2014; this is followed by the commercial sector, (112 trillion BTUs) and then the industrial sector (62 trillion BTUs).[22]

The mix of energy sources for thermal purposes, estimated at 200 trillion BTUs, varies across the sectors as shown by Figure 3.[23]

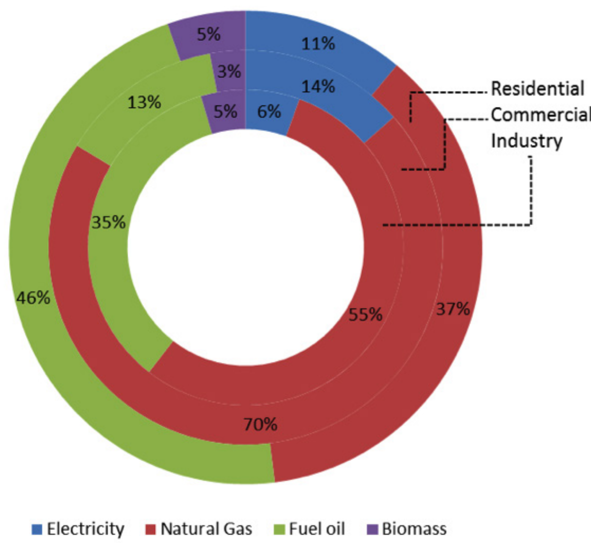


Figure 3 | Estimated current mix of energy sources for thermal purposes. Sources: EIA SEDS, AEO 2015 and own analysis in chapter 4.

As can be seen from Figure 3, the residential and industrial sectors have a high share of fuel oil, while natural gas dominates the commercial sector. The share of thermal demand supplied by electricity may comprise electrically driven heat pumps. However, the share of heat pumps in Connecticut appears to be low.

The number of RTT installations can be estimated based on feedback from the industry and sample surveys: the Connecticut Geothermal Association[24] indicates that the number of residential and commercial GSHPs installed in Connecticut per year is approaching 700. New construction seems to

22 EIA State Energy Data System: http://www.eia.gov/state/seds/. Delivered energy is net of electricity losses.

23 The current mix of energy sources for thermal purposes has been estimated based on the technical potential from Chapter 4, the consumption by energy sources from EIA SEDS 2014 and the energy by end-use from AEO 2015.

24 Email correspondence August 28th, 2016

dominate the installations. Residential wood use was 339 thousand cords-equivalent of wood in 2014 and 3.9 trillion BTUs for commercial and industrial wood and biomass waste use that same year.[25] The Biomass Thermal Energy Council indicates that cumulative installations of biomass in Connecticut are fairly low and slow-building, explained by a higher rate of natural gas connections in CT than in other New England states.[26] Solar assisted thermal systems were supported through The Connecticut Clean Energy Fund (CCEF), the predecessor to the Connecticut Green Bank, from 2009 through 2013. Two different programs together funded 278 residential and 86 commercial solar thermal installations, and industry representatives indicate that the market has slowed down since then.[27]

In 2014, NMR Group concluded a sample survey among 180 single-family homes that also registered thermal systems.[28] The number of respondents to the study secured a confidence interval of 90 percent. Based on this study and the number of single-family homes in Connecticut in 2013, the total number of RTT installations for space heating in Connecticut has been estimated according to Table 3.

RTT	SINGLE-FAMILY HOMES	SHARE OF HOMES IN EACH PRIMARY FUEL CATEGORY	ESTIMATED TOTAL INSTALLATIONS (AS OF 2013)
ASHP	Primary source	1.7 percent	14,740
	Secondary source	2.8 percent	24,560
GSHP		0.6 percent	4,910
Solar assisted system		1.1 percent	9,820
Biomass[29]	Pellets	1 percent	8,841
	Wood	1 percent	8,841

Table 3 | Estimated total number of renewable thermal installations for space heating in Connecticut in 2013. Sources NMR Group and DCED.[30,31]

25 See http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_fuel/html/fuel_use_ww.html

26 Email correspondence September 21st, 2016

27 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

28 NMR Group Inc (2014): Single-Family Weatherization Baseline Assessment.

29 Due to rounding of percentages in Table 6-1 of the NMR study, the number of homes with wood and pellet installations is reported here as identical.

30 See http://www.ct.gov/ecd/cwp/view.asp?a=1106&q=250640

31 See 2000 Census of Population and Housing: http://www.ct.gov/ecd/LIB/ecd/20/14/2000censushousingandhousing.pdf

The number of detached and attached single-family homes was 884,120 in 2013. Based on this, the NMR study indicates that approximately 565,840 households used fuel oil as the primary energy source for space heating. 9 percent of the homes of the NMR study had installed ASHP for space cooling, and GSHP provided cooling to 1 percent of the homes.

A separate field study conducted by Yale University[32] shows that the RTT market is thin, with only a few installers providing RTTs and most of these focusing on specific technologies. With the exception of ductless ASHPs, the supply side of RTTs is characterized by low demand, low rates of cooperation across technologies, and a general discontent with the level of financial support, particularly compared to solar PV. An inadequate supply chain for pellets is perceived as another challenge. There have been issues related to the quality of installations of some RTTs, and there is a general difficulty finding qualified employees for this sector.

The demand side, on the other hand, experiences difficulties finding installers. This creates concerns related to future maintenance and replacement of RTTs. However, even more prevalent seems to be the customer awareness of RTTs, including their basic use and their distinction from solar PV. Financing options are generally unknown to the customers, who often are highly cost conscious and price sensitive at the time of the investment decision.

32 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

CHAPTER 3
Methodology

Overall Framework

The role of RTTs in achieving Connecticut's GHG reductions was studied with a bottom-up approach that analyzes the cost effectiveness of competing thermal technologies. The analysis was first done on a project level; then results were aggregated on the state level.

The technical potential represents the estimated maximum size of the state's market for thermal energy at different points in time, including the end-uses of space heating, space cooling, and water heating. The competitiveness of RTTs compared to conventional thermal technologies was analyzed for different customer categories using a commercially available tool, RETScreen Expert developed by CanmetENERGY Research Center at Natural Resources Canada.[33] (Appendix D).

The most competitive technology was chosen as the preferred technology for each customer segment and its particular thermal end-use. The economic evaluations on project levels were aggregated and calibrated to correspond to the technical potential.

Figure 4 presents the steps of this approach graphically.

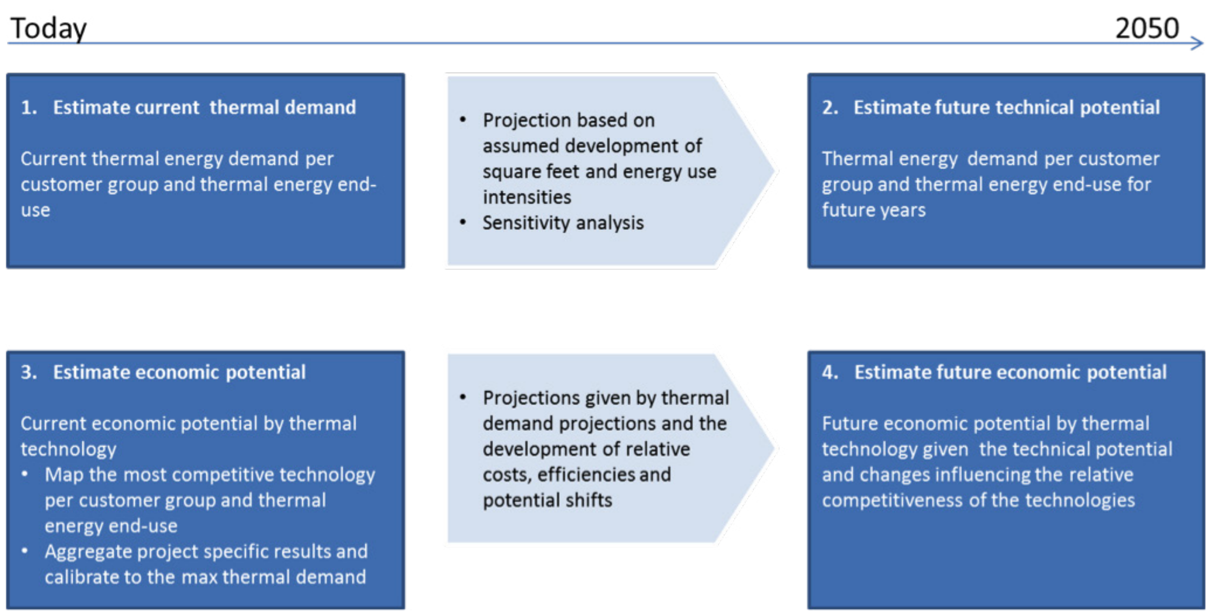


Figure 4 | The overall methodological framework for estimating technical and economic potential for RTTs.

33 http://www.nrcan.gc.ca/energy/software-tools/7465

The study has attempted to use data at a state or regional level where available. The EIA Annual Energy Outlook (2015) has also been an important reference for several assumptions in the analysis.

STEP 1—ESTIMATE THE CURRENT THERMAL DEMAND

First, the current demand for thermal energy end-uses per customer group was estimated. The aggregate demand for space heating, space cooling, and water heating was calculated by multiplying the total square footage of the existing building stock, differentiated by customer category, with the respective Energy Use Intensity (EUIs).

STEP 2—ESTIMATE FUTURE THERMAL DEMAND

The technical potential was estimated till 2050. For space heating, space cooling, and water heating, the technical potential was estimated by multiplying the square footage of existing building stock, projected new buildings, and projected demolitions by the respective EUIs, known and projected. The projected EUIs for the future periods were established using the current EUIs adjusted for an annual energy efficiency rate in the year in question.

Sensitivity analyses were established to highlight the uncertainty related to future projections. The sensitivity analyses highlight the impacts of applying different references for current average EUIs, energy efficiency rate, outdoor temperature levels, and required building standards of new buildings.

The technical potential was used to calibrate the estimated economic potential per customer group and end-use for the different years being studied.

STEP 3—ESTIMATE THE CURRENT ECONOMIC POTENTIAL

The modeling on a project level seeks to evaluate the cost-competitiveness and cleanness of RTTs against incumbent technologies. The simulations let decision-makers understand how different technologies perform, and how different assumptions and incentive structures affect competitiveness.

Running scenarios, we can provide a quantitative understanding of how much each RTT affects the use of fossil fuels, and thus reduces GHG emissions in Connecticut.

The simulation results for each archetypal customer were scaled to the state level using respective thermal load data and growth rates for representative customer groups. Lifecycle costs and benefits are considered using simple cash-flow and NPV models. In addition, the performance of the RTTs in terms of delivered thermal related end-use services is used to calculate the impact on GHG reductions relative to the state-level goals.

The conceptual steps for estimating the economic potential based on project evaluation are illustrated in Figure 5.

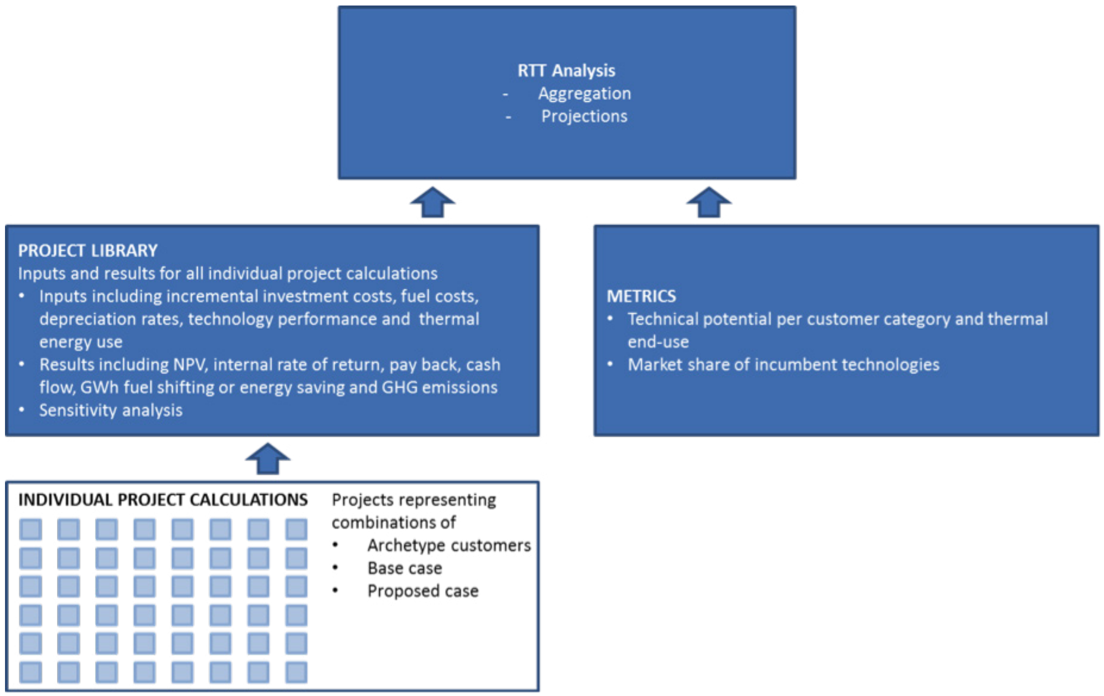


Figure 5 | Concept for estimating the economic potential for RTTs.

In order to analyze the cost effectiveness of RTTs, the research team applied RETScreen Expert due to its flexibility, inclusion of a broad range of technologies, ability to generate energy and emission changes, as well as its complex financial analysis capabilities. The model allows for comparing base cases representing incumbent or conventional technologies to the proposed cases of different RTTs. In addition to RTTs, highly efficient natural gas boilers were included to the analysis.

The model calculations of this study include:

- 7 archetypal customers
- 3 incumbent thermal technologies
- 7 proposed renewable or highly efficient thermal technology alternatives

The combinations of incumbent thermal technologies and proposed RTTs for all archetypal customers represent individual projects that constitute a "project library" of input and output data.

The "RTT analysis" aggregates individual results to a state level using input and results from the project library as well as metrics from the technical potential analysis.

STEP 4—ESTIMATE FUTURE ECONOMIC POTENTIAL

The economic potential was projected to 2050 by linear extrapolation of the individual project calculations within the scope of the technical potential.

The economic potential is influenced by the relative competitiveness of the technologies, given by investment costs, fuel prices, financial incentives and policies, performance of thermal technologies, and type of thermal end-uses served by each technology. The projected technical potential defines the maximum market that the different technologies compete within.

Sensitivity analyses were established to highlight the uncertainty of the competition analysis. The sensitivity analyses highlight the impacts of applying different relative costs and prices of the technologies as well as financial incentives and instruments.

Future Projections and Shifts

The projections assume linearity between today and 2050. There may be several shifts that can cause a break in this linearity, such as new superior technological solutions, new policies, economic shifts, or changes in other parts of the energy system.

Shifts, to some extent, will be interrelated, e.g. a new technology solution can be facilitated through policy choices and experiences of climate change. We have studied implications of a set of policy alternatives through the sensitivity analysis, but have only to a limited extent accounted for shifts due to innovations or future policies.

The market diffusion of novel and energy-efficient technologies is often prevented by high initial costs. Economies of scale and improvements of technologies can drive down costs and improve the competitiveness of the technologies. The cost-benefit performance of technologies can be improved through technological learning, which can be mapped through so-called learning rates. The technological learning rate quantifies the rate at which the costs decline with each doubling of cumulative production.

The learning rates of RTTs have been studied to a lesser extent than those of technologies for electricity generation, such as solar PV. Weiss et al (2010)[34] have reviewed some RTTs as part of their study of energy demand technologies. They find learning rates of energy demand technologies of 18 percent +/- 9 percentage points. Residential heat pumps are found to be in the upper end of this range, and conventional residential heating technologies in the lower end. Learning rates for heat pumps will, however, depend on the degree of site specificity.

34 Weiss, Martin; Martin Junginger; Martin K. Patel and Kornelius Blok (2010): A review of experience curve analyses for energy demand technologies. Journal of Technology Forecasting and Social Change 77 (2010), 411–428

Learning rates for different technologies, from heat pumps to conventional boilers, show time dependency and variability depending on the system boundaries chosen for analysis. Quality of data, choice of period, costs included in the analysis etc. influence the results, which limits the applicability of the learning curve approach for modeling technology change in energy and emission scenarios.

Most RTTs included in this analysis are globally mature technologies experiencing incremental improvements over time. The market for RTTs in Connecticut, however, appears to be immature. An immature market influences cost levels through lack of volume both in acquisition and installation.

Learning rates will impact the analysis only to the extent that they differ across technologies. We assume that the relative competitiveness of technologies remains the same. However, reduced incremental costs of RTTs compared to conventional alternatives is highlighted through the sensitivity analysis.

Addressing GHG Emissions

The analysis has shown which technology would be a customer's "first choice" from a purely economic point of view. These "first choices" are then used to estimate the change in GHG emissions that would result from replacing one thermal technology with another. The GHG emission calculations are based on the RETScreen Expert inventory and rely on its modeling concept. The GHGs included are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The GHG emission factors are fixed for the entire lifetime of the project. The following emission factors have been applied in this study:

- Electricity: 0.281 $kgCO_{2e}$ per kWh (0.302 $kgCO_{2e}$ per kWh including transmission losses), which corresponds to the average mix of energy sources delivered to the New England ISO grid
- Biomass pellets (refuse-derived pellets): 0.036 $kgCO_{2e}$ per kWh
- Fuel oil: 0.252 $kgCO_{2e}$ per kWh
- Natural gas: 0.179 $kgCO_{2e}$ per kWh

GHG emission factors depend on the carbon accounting method and data that is applied. The RETScreen Expert GHG emission factors are based on the IPCC Guidelines for National GHG Inventories.[35] This inventory represents average values for direct GHG emitted relative to a defined amount of activity such as energy demand.

The RETScreen inventory was chosen to make sure that the GHG emission factors are calculated according to a uniform methodology across energy sources. This implies applying average GHG

35 The RETScreen GHG emission factors take into account emerging rules for carbon finance. The emission analysis section of RETScreen Expert was developed in collaboration with the United Nations Environment Programme and the Prototype Carbon Fund at the World Bank. More information on GHG emissions factors in RETScreen Expert can be found in the model's user manual.

emission factors for the energy sources, which may not capture the variability of emissions by the origination of the energy sources. The IPCC framework furthermore focuses on direct emissions rather than emissions over the entire lifecycle of the energy source. GHG emissions in extraction, transportation, transformation into usable fuels and combustion may vary both across and within categories of energy sources.

It was outside of the scope of this study to map local GHG emission factors based on the origin of the energy sources.

As shown by the Oil-Climate Index of the Carnegie Endowment for International Peace,[36] total GHG emissions from the highest-emitting oil are about 60 percent higher than for the lowest-emitting oil. The Oil-Climate Index addresses both the issue of averages not capturing the full range of observed variability in emissions and the issue of including emissions throughout the lifetime of the fuel. Due to the wide range of emissions from global oils, it matters which oil is burned. Natural gas faces similar issues, where extraction and transformation potentially can cause large variability in emissions depending on the origin of the natural gas.

Unlike CO_2 emissions factors for fossil fuels, factors for biomass[37] combustion are not directly included in energy sector accounting. This accounting convention is based on the rationale that CO_2 of biogenic origin is part of the natural carbon cycle: carbon stored in biomass fuel has been sequestered from the atmosphere relatively recently, and it is assumed that when the fuel is burned the carbon released will be offset by carbon taken up when new biomass is grown. The assumption is made without regard for the specific forest husbandry policies and practices prevailing in the region where the biomass was harvested, even though these policies and practices strongly influence the rate of carbon uptake. A lifecycle carbon accounting framework based on New England biophysical characteristics and forest management practices has been applied in some studies comparing biomass to fossil fuels.[38]

36 See http://carnegieendowment.org/2015/03/11/know-your-oil-creating-global-oil-climate-index-pub-59285

37 Biomass is defined as any organic matter derived from plants or animals available on a renewable basis. Biomass used for energy includes wood and agricultural crops, herbaceous and woody energy crops, municipal organic wastes as well as animal manure. Biomass feedstock can be provided as a solid, gaseous or liquid fuel, and can be used for generating electricity and transport fuels, as well as heat at different temperature levels for use in the building sector, in industry and in transport. Source: International Energy Agency (IEA)(2014): Heating without global warming. Market developments and policy considerations for renewable heat.

38 Manomet Center for Conservation Sciences (2010): Massachusetts biomass sustainability and carbon policy study: Report to the Commonwealth of Massachusetts Department of Energy Resources. Buchholz, Thomas, and John Gunn (2016): Northern Forest wood pellet heat greenhouse gas emissions analysis methods summary.

The biogenic emissions framework of the IPCC Guidelines for National Greenhouse Gas Inventories represents the most widely accepted framework for national reporting of biogenic GHG emissions, although application of this framework in the European Union and elsewhere is subject to criticism.[39]

Emissions inventories, such as those compiled by the US EPA, also address emissions from land use, land-use change, and forestry. To the degree that bioenergy production affects the amount of carbon stored on land, it will impact the emissions or absorption of carbon reflected in the national greenhouse gas inventory. However, by convention, these emissions are not attributed to the energy sector, even when they stem from use of combustion technologies.[40]

Scientists have explored various ways to estimate the potential climate impact of biogenic CO_2 emissions. Such estimates invariably focus on hypothetical scenarios involving the terrestrial carbon cycle. They range from analyses based on individual stands of trees or crop plantations[41] to integrated land use models also incorporating agricultural and forestry economics.[42] In general, such assessments find that policies that enhance terrestrial carbon storage are beneficial and can be reconciled with bioenergy use. Notably, however, aggressive use of bioenergy in the absence of policies designed to enhance terrestrial carbon storage can be counterproductive, at least in the short and medium term.

In short, both the type of biomass used and local land-use management influence land use-related GHG emissions from biomass. The adequacy of biomass stock in New England and the adequacy of the region's forest husbandry policies and practices were not taken into account in this study.[43] Neither was the origin of fuel oil or natural gas applied in the region.

39 See, e.g.: Warren Cornwall (2017): Biomass under fire: Is wood a green source of energy? Scientists are divided. Science Magazine. http://www.sciencemag.org/news/2017/01/wood-green-source-energy-scientists-are-divided. John Upton (2015): Pulp fiction: The European accounting error that's warming the planet. Climate Central. http://reports.climatecentral.org/pulp-fiction/1/.

40 US EPA (2016): Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014. EPA 430-R-16-002. See in particular footnote (a) to the summary table and Section 3.10.

41 Cherubini, F., G. P. Peters, T. Berntsen, A. H. Strømman, and E. Hertwich (2011): CO_2 emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming. GCB Bioenergy 3(5): 413–426.

42 Klein, D., F. Humpenöder, N. Bauer, J. P. Dietrich, A. Popp, B. Leon Bodirsky, M. Bonsch, and H. Lotze-Campen (2014): The global economic long-term potential of modern biomass in a climate-constrained world. Environmental Research Letters 9(7).

43 For several reasons, CT DEEP does not agree with the methodology this study adopted for biomass: (a) the emissions factor adopted for biomass combustion does not account for the region's existing forestry practices, even though forestry practices strongly influence the lifecycle GHG emissions associated with using the region's woody biomass as fuel; (b) the analysis of biomass's potential contribution to meeting the state's thermal demand does not account for the extent of the commercial biomass pellet market that can be maintained with biomass feedstock's sustainably harvested in New England; (c) extensive development of biomass as a thermal fuel in Connecticut likely would conflict with the state's statutory goals for complying with National Ambient Air Quality Standards for criteria pollutants; and (d) claims about the market potential of biomass combustion in Connecticut and the GHG benefits associated with this potential should be considered in the context of other air pollutants.

A further caveat is that in this study the GHG calculations use “biomass pellets” as a proxy for solid woody biomass. The RETScreen Expert inventory provides factors for two solid biomass fuels: “biomass” (meaning woody biomass) and “refuse-derived pellets.” The latter—selected for this study—has a substantially higher GHG value and therefore represents a conservative alternative within the IPCC framework. Gaseous or liquid fuels produced with biomass feedstock were not analyzed.

This study focuses on GHG emissions only. Air-pollutants such as particulate matters are not considered.

Limitations and Boundaries

Though this bottom-up approach facilitates detailed analysis of specific technologies, thermal demand categories, and financial models, it has its limitations.

Analyses have been done for a set of archetypal customers for the residential and commercial sectors using a variety of RTTs. The RTT choice for each setting is nuanced, as capital for investments, surface area, orientation of exterior surfaces, incumbent fuel type, and end-uses can vary greatly. Given the complexity and potential permutations, we have addressed some of the most common customer categories, technologies, and end-uses. We recognize this assumption as a limitation, albeit a necessary one, to this project. The building categories that have been analyzed cover buildings of different sizes and with varying thermal energy needs, as can be seen from Table 4.

RESIDENTIAL	COMMERCIAL		
• Single-Family home • Apartment building	• Hotel • Medium office	• Education • Food Services	• Hospital inpatient

Table 4 | Archetype customers established for economic evaluation.

The economic and environmental evaluations are defined by the boundaries of the analysis. The boundaries have implications as to which costs and benefits are included, and the level and differentiation of prices and GHG emission factors. This is illustrated by Figure 6.

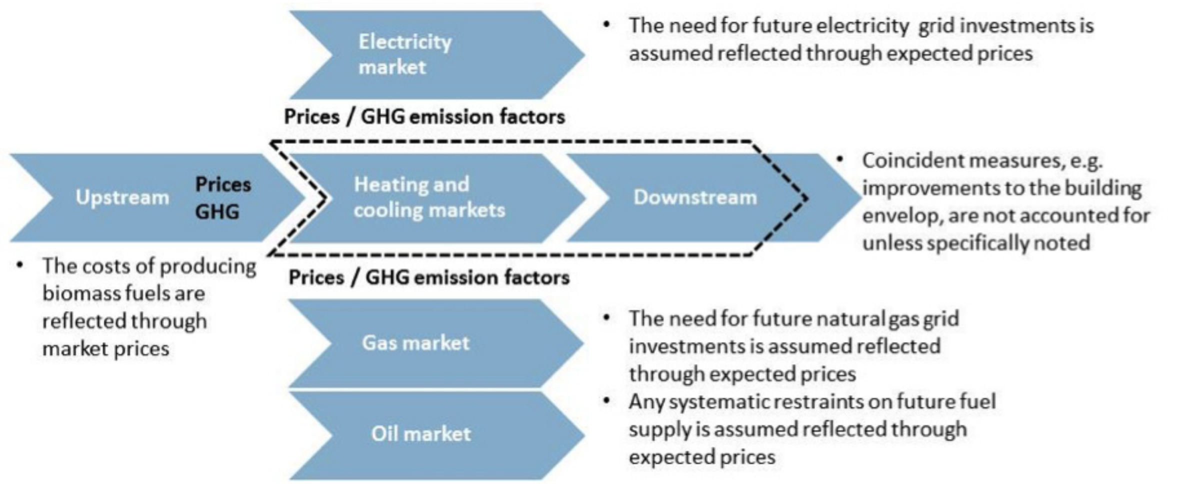


Figure 6 | Boundaries to the analysis.

The dotted arrow represents the boundaries of the economic analysis, and the interaction with the energy system at large. The upstream parts of the value chain, such as the production of processed biofuels, are represented through market prices delivered to the facility. Any future changes in the overall energy system are expected to be accounted for through price projections, where applicable.

The price projections of this study are based on the growth rates applied in the AEO 2015. The average electricity rates and natural gas rates of Connecticut are the base of the projections. Recent decisions[44] to cancel plans for added natural gas pipeline capacity were not known at the time of publishing AEO 2015.

Although RTTs can effectively help alleviate peaks in the energy demand of Connecticut by diversifying the pool of energy supply and delivering services balanced throughout the day and night, it is necessary to be aware of the features of the different RTTs compared to conventional alternatives. RTTs have different impacts on the electricity and gas loads depending on their drive energy, efficiency over the year, and which energy source they replace. This has not been subject to analysis in this study.

RTTs often utilize locally available energy resources to meet the specific on-site heating and cooling demand of one or several buildings, thus customized solutions are often required. Though the bottom-up approach allows for some representation of specific conditions, the need for simplicity and conciseness limits modeling of the full range of combinations of existing technologies and resources. The following assumptions have been made regarding the investment choices of the customers:

44 October 25th, 2015: DEEP press release on canceling the natural gas RFP.

INCUMBENT ENERGY SOURCES	RENEWABLE THERMAL TECHNOLOGIES AND THERMAL END-USES
• Space cooling is based on electricity • Space heating and hot water is based on the same energy source: electricity, fuel oil, or natural gas • Space heating based on electricity is provided by electric baseboard	• ASHP delivers space heating and cooling • GSHP delivers space heating and cooling • SHW delivers hot water • Bio delivers space heating and hot water • Efficient natural gas boilers deliver space heating and hot water • ASHP water heaters deliver hot water

Table 5 | Assumptions for technology choices.

To avoid additional complexity in the analysis, the RTTs have been modeled to deliver the whole thermal demand of a building over the year, that being for space cooling, heating or hot water. Even if the incremental installation costs are given per installed capacity, this may exclude some financially favorable solutions. Oversizing RTTs should be avoided both to restrict installation costs and secure efficient operations; and keeping the incumbent energy source for peak load operations may be desirable. See chapter 6.2.2 for an analysis of some partial load alternatives.

ASHPs and SHW are considered a supplementary technology to the incumbent. Even if these technologies are applied as primary energy source, the incumbent technology often has to be kept as a backup. The implication of this classification for the analysis is related to assumptions on avoided costs. See Appendix A.

CHAPTER 4
Technical Potential—Demand Analysis

The demand for hot water, space heating, and cooling in the state of Connecticut represents the total technical potential for thermal technologies.[45]

The time frame of the analysis extends to 2050, with 2014 as the basis for the projections and EUIs established for residential and commercial customers.

The technical potential for buildings is driven by the expected development of square footage of different building categories and the EUIs for thermal purposes. Expected energy efficiency rates for different customer categories have been applied. The projections have been informed by the AOE and CT residential housing and population data.

Assumptions for Demand Projections

The assumptions cover the methodology of estimating floor space, EUIs, as well as the base case for the relevant customer segment.

The total number of housing units is assumed to grow at a net rate corresponding to the expected population growth as estimated by Connecticut State Data Center.[46]

The projections for commercial thermal demand through 2050 have considered AEO New England growth factors for different categories of commercial customers and AEO projections of square feet by distribution of the New England workforce by category.

Temperature change impacts on space heating and cooling have been considered to affect heating and cooling days as follows, based on AEO for New England:

- Annual rate for heating degree days -0.5 percent
- Annual rate for cooling degree days 0.9 percent

Cooled space relative to heated space has been considered to remain unchanged in the base case.

45 Thermal energy demand for cooking, clothes drying, and other thermal uses is not included in this study.

46 2015–2025 Population projections for Connecticut. November 1, 2012 edition

CUSTOMER SEGMENT	BASE CASE ASSUMPTIONS
Residential	• Renovation affects 1 percent of the floor space per year. These renovations reduce the need for space heating by 25 percent, on average • Technical systems for space and water heating representing 3 percent of the floor space are replaced with more efficient equipment each year. Efficiency gain for space and water heating is 15 percent, on average
Commercial	• Renovation affects 0.4 percent of the floor space per year. These renovations reduce the need for space heating by 20 percent and space cooling by 20 percent, on average • Technical systems for space heating representing 2 percent of the floor space are replaced with more efficient equipment each year. Efficiency gain is 15 percent, on average • Technical systems for water heating representing 2 percent of the floor space are replaced with more efficient equipment each year. Efficiency gain is 20 percent, on average. • Technical systems for space cooling representing 3 percent of the floor space are replaced with more efficient equipment each year. Efficiency gain is 30 percent, on average.

Table 6 | Base case assumptions on technical demand potential.

Residential Sector

The population of Connecticut is 3.597 million[47] and lives predominantly in single-family homes.[48] According to the 2000 Census, 64 percent of residential units were single-family homes. The rest of the residential building base consists predominantly of multi-family buildings.

The aggregated residential technical potential is estimated to be 88.6 trillion BTUs by 2050 in the base case, with a sensitivity range between 73.1 and 100.4 trillion BTUs.

- Building age, performance, and size are all important drivers of thermal demand in the residential sector.
- Older houses predominate, and they also have higher EUIs, thus presenting a viable retrofit opportunity in the future.
- Cooled space is negligible in comparison to space and water heating, but climate impacts and increased CDD could drive demand for cooling in the future.
- Through 2050, residential thermal demand declines, at different rates depending on factors such as regulations on energy efficiency (building codes), and retrofit rates and depths.
- The reference case of an 80 percent reduction in residential thermal energy demand implies a technical potential of 24 trillion BTUs in 2050.[49] To achieve this, a more-than 5.5 percent annual rate of deep retrofit would be required until 2050, *ceteris paribus*.

47 See http://www.census.gov/quickfacts/table/PST045215/09

48 EIA defines a Single Family Home as follows: "A housing unit, detached or attached, that provides living space for one household or family. Attached houses are considered single-family houses as long as they are not divided into more than one housing unit and they have independent outside entrance." http://www.eia.gov/consumption/residential/terminology.cfm#m

49 The Global Warming Solutions Act (2008) requires an economy-wide reduction in GHG emissions by 2050 (relative to 2001) but does not specify a degree of reduction to be achieved in any particular sector or context. The 80 percent reduction in emissions from residential thermal energy demand envisioned here is hypothetical.

ENERGY USE INTENSITIES

The EUIs applied in the analysis are differentiated by thermal purpose and type of residential building, as can be seen in Figure 7.

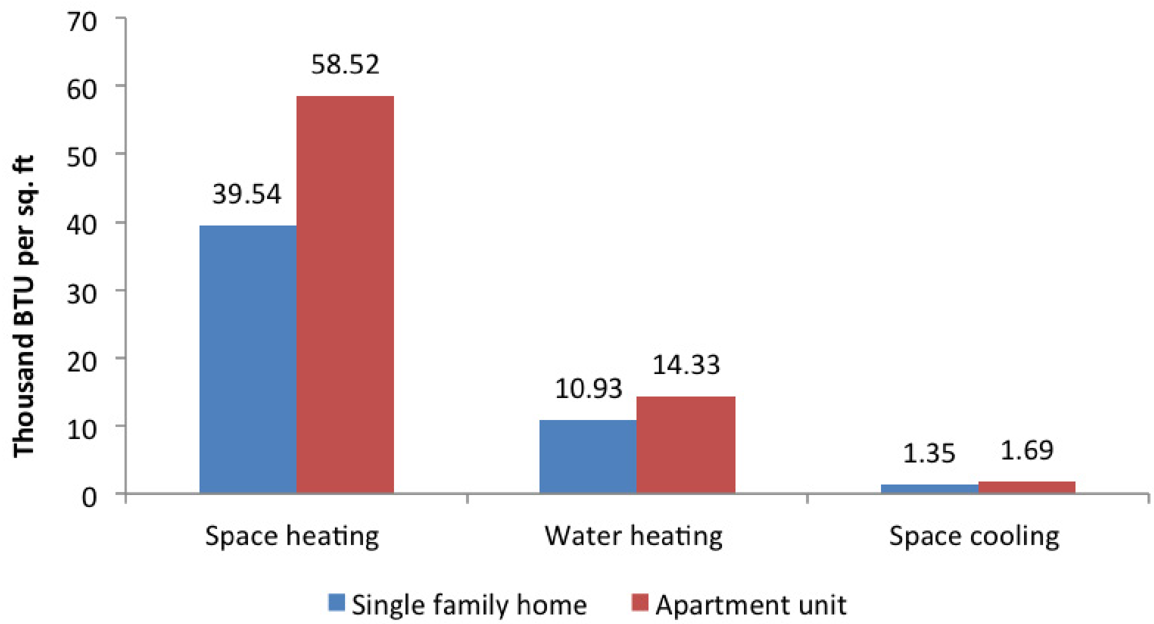


Figure 7 | Residential energy use intensity per square feet (2014 mean values), Source: RECS 2009 and PSD 2016.

Space heating per square foot is significantly higher in apartment units than in single-family homes. This can be explained by a higher share of conditioned space of the total square feet of the housing unit.

The EUIs for cooling are low, mainly due to a low share of central cooling in residential buildings in Connecticut.

The EUIs for space heating of buildings undergoing demolition has been estimated based on the weighted average age of the buildings built before 1960 and their EUIs for space heating (see Figure 9). The EUIs for newly constructed single-family homes are based on the 2016 PSD.

Assumptions for the cooling EUIs in new buildings are the same as for existing; thus cooling values in new buildings may be underestimated. Buildings undergoing demolition are assumed to not have space cooling.

ESTIMATED THERMAL ENERGY DEMAND

The size of the building is an important driver for thermal energy demand of residential buildings. The square footage has been established for CT through the number of homes in different categories, the average square feet, and growth rates of population and demolitions.

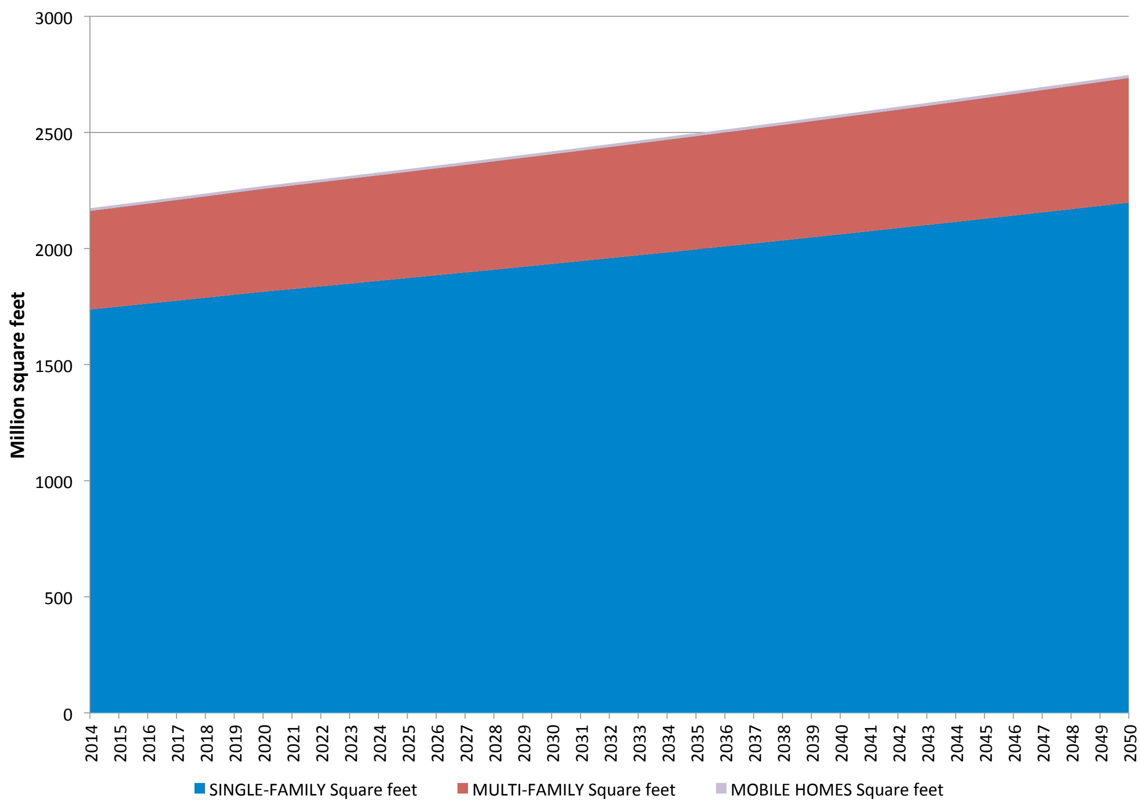


Figure 8 | Estimated heated floor space for occupied housing units, 2014–2050. Sources: CT DECD, American Community Survey, RECS 2009 and AEO 2015.[50]

The estimation shows a relatively steady building base over the time period.

The share of new residential buildings is relatively negligible compared to the existing building base. According to the analysis, approximately 89 percent of the estimated heated residential base in 2050 will have already been built. This represents a viable opportunity for RTTs and underlines the importance of replacing thermal installations at housing renovations.

50 Mobile homes are excluded from the rest of the analysis.

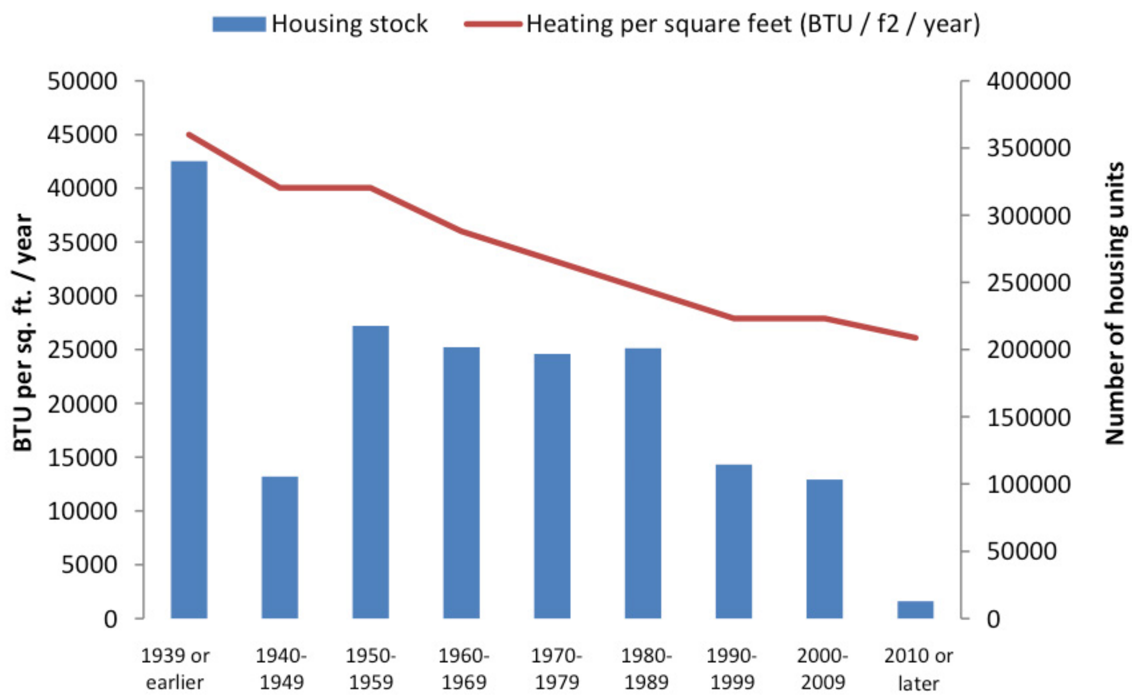


Figure 9 | Age Distribution of CT Housing. Sources: ACS 2014 and PSD 2016.

It is important to note the relation between building performance and age. As seen in Figure 9, the heating intensity declines for more recently constructed buildings. Older construction tends to have more air and heat leaks, which contribute to a higher demand for heating and cooling. In relation to age, it is also worth mentioning that relatively old buildings (built in 1939 or earlier) have a high representation in the distribution. The rate of new buildings has gradually declined since 1989.

The prevalence of older constructions has a direct relationship to the opportunity to install RTTs versus conventional technologies when retrofitting the building or heating system.

The size of buildings impacts its energy demand. This study assumes that the distribution between single-family and multi-family homes remains unchanged over time.

Energy demand is also related to occupancy levels and number of people per house. The occupancy rate distinguishes whether a building has occupants or is generally vacant. Data from the CT Department of Economic and Community Development[51] shows a great variation of vacancy rates across the state,

51 See http://www.ct.gov/ecd/cwp/view.asp?a=1106&q=250640

ranging from 3 to 38 percent (Tolland and Cornwall, respectively). While the average is 8 percent, it is challenging to forecast future social dynamics; occupancy nonetheless has implications on the energy demand of buildings.

The annual energy efficiency improvement rate applied to new construction is 0.73 percent for space heating, reflecting the historic development of Figure 9.

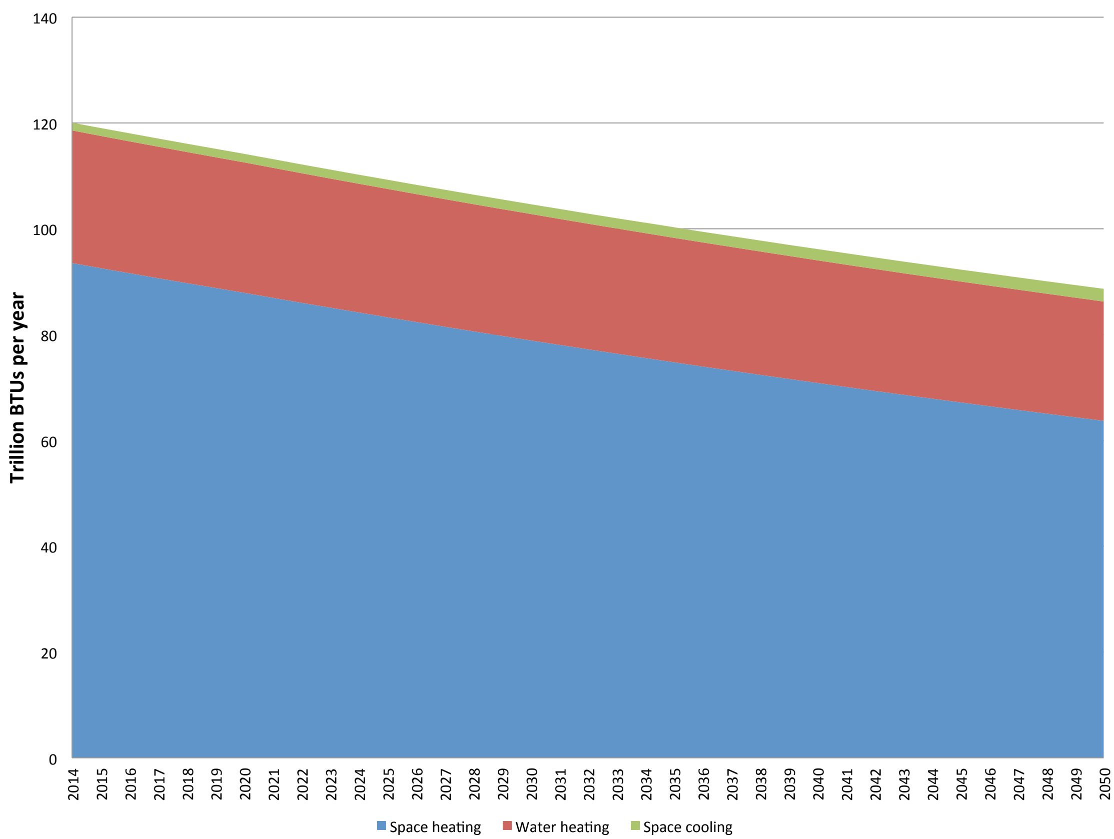


Figure 10 | Estimated residential thermal energy demand, 2014–2050.

The overall thermal energy demand follows a downward trend through 2050, despite the slight increase in the housing square footage. This decrease constitutes a lower burden on the electric and natural gas grid, and is a result, among other things, of the assumed rate of retrofit and energy efficiency.

The average EUI for space heating becomes 1.63 percent more efficient each year and remains the dominant thermal end-use.

Water heating is, expectedly, the second largest demand. The average EUI for water heating becomes 0.92 percent more efficient each year.

Looking to 2050, it is relevant to note the negligible contribution of cooling to the aggregate demand. With the potential increase in CDD and various other climate impacts, cooling may become a more sought after service and thus considerably drive the demand curve, particularly if trends shift from local units to centralized cooling systems. This explains the positive annual growth rate of average EUI for space cooling of 0.71 percent.

SENSITIVITY ANALYSES

Sensitivity analyses have been run against the base case above to account for the uncertainty of thermal demand. Table 7 describes one analysis as it reflects an increased share of cooled space and unchanged outdoor climate.

SENSITIVITY ALTERNATIVES	DESCRIPTION	TECHNICAL POTENTIAL
75 percent cooled space	Cooled space as a share of heated space increases: • From 50 percent to 75 percent for single-family homes • From 41 percent to 75 percent for multi-family homes This can be caused by increasing the number of homes with installed air conditioning or by cooling a larger space in homes with cooling already installed.[52]	The technical potential is estimated at 89.8 Trillion BTUs in 2050 as compared to 88.6 Trillion BTUs in the base case.
No climate change	The number of HDD and CDD is assumed to be the same in the future as today. Base case assumes change rates of -0.5 and 0.9 for respectively HDD and CDD.	The technical potential is estimated at 100.4 Trillion BTUs in 2050 as compared to 88.6 Trillion BTUs in the base case.

Table 7 | Sensitivity analyses residential sector. Share of cooled space and lower outdoor temperature.

Figure 11 shows the sensitivity alternatives related to a higher share of cooled space and other outdoor temperatures:

52 According to RECS2009, 75 percent of homes had air condition installed and 23 percent had central air conditioning.

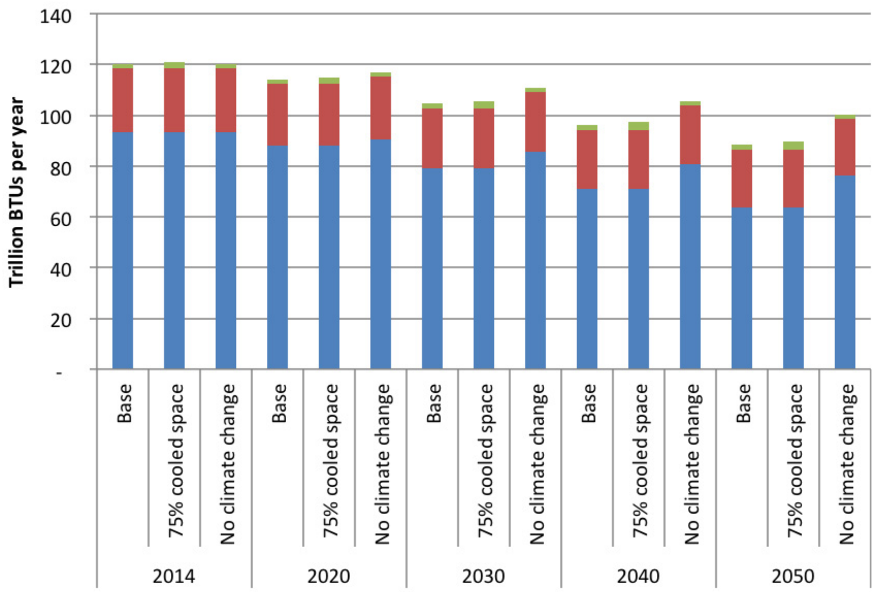


Figure 11 | Sensitivity analyses residential sector. Share of cooled space and lower outdoor temperatures.

Table 8 describes another set of sensitivity analyses allowing for an overall increase in energy efficiency of buildings through retrofits and stringent "passive house" standards.

SENSITIVITY ALTERNATIVES	DESCRIPTION	TECHNICAL POTENTIAL
New Passive	Assumes passive house standard for all new residential homes. The passive house standard assumes an EUI of 4,755 BTUs per square foot of space heating and cooling.	The technical potential is estimated at 81.3 Trillion BTUs in 2050 as compared to 88.6 Trillion BTUs in the base case.
DR @ retrofit	Assumes all renovation is a deep retrofit corresponding to a 75 percent reduction in energy to space and water heating. The annual renovation rate remains at 1 percent per year.	The technical potential is estimated at 73.1 Trillion BTUs in 2050 as compared to 88.6 Trillion BTUs in the base case.
Minus 80 percent[53]	Assumes 80 percent reduction of total thermal energy demand by 2050.	The technical potential is estimated at 24.0 Trillion BTUs in 2050 as compared to 88.6 Trillion BTUs in the base case.

Table 8 | Sensitivity analyses residential sector. Assumptions on energy efficiency.

53 The Global Warming Solutions Act (2008) requires an economy-wide reduction in GHG emissions by 2050 (relative to 2001) but does not specify a degree of reduction to be achieved in any particular sector or context. The 80 percent reduction in emissions from thermal energy demand envisioned here is hypothetical.

Table 11 shows the sensitivity related to a more ambitious standard for new buildings and a higher rate of deep retrofit.

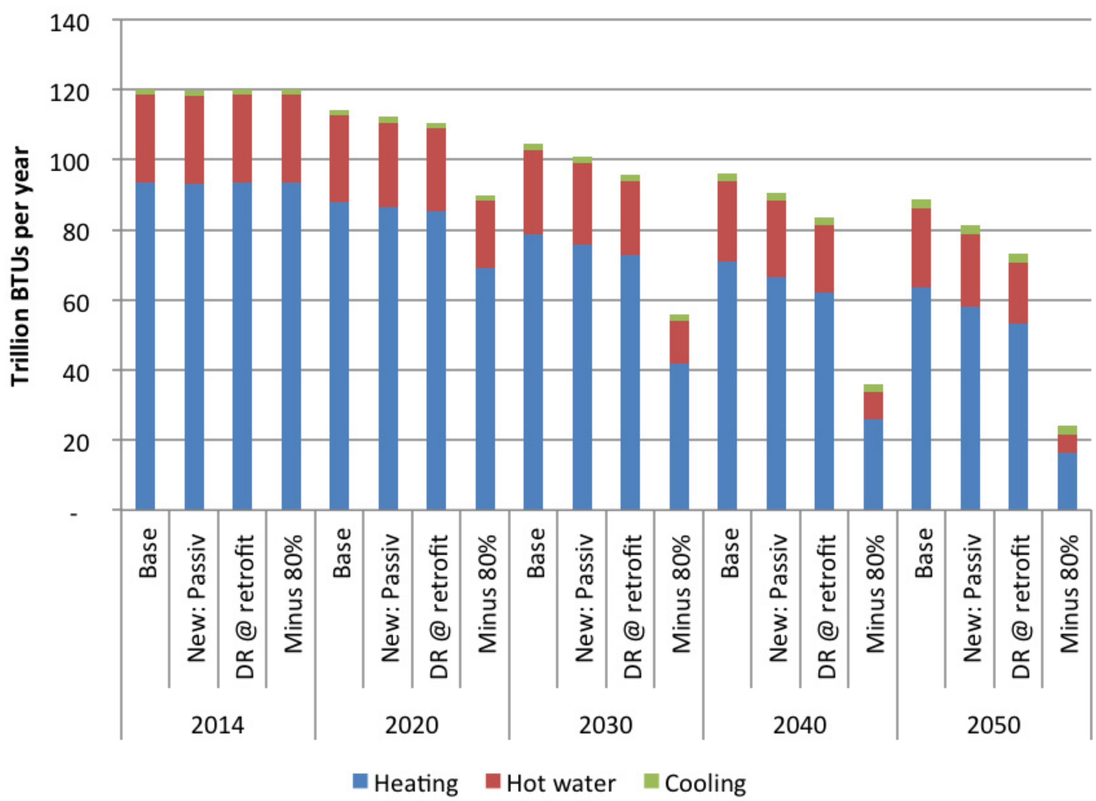


Figure 12 | Sensitivity analyses residential sector. Assumptions on energy efficiency.

In all sensitivity analyses, cooling remains a small portion of the total demand. In a 75 percent increase of the total cooled space there is a small increase by the end of the period.

The sustained levels of thermal demand over time translate to the need for reliable, affordable, and environmentally friendly sources of energy.

The sensitivity analysis on energy efficiency rates precludes a more rapid overall decrease in thermal demand due to efficiency measures. The assumptions for the sensitivity analysis of “Passive house” and “DR @ retrofit” speak to the importance of building codes in a transition to an efficient and low-carbon building base.

Commercial Sector

Although the energy demand of this sector is lower than in residential, extensive and steady growth of commercial office space is expected.

The technical potential of the commercial sector is estimated to 37.2 trillion BTUs in 2050 in the base case, with a sensitivity range between 30.3 and 41.3 trillion BTUs

- As the rate of new building is assumed to be high in the commercial sector, ambitious building codes can provide a considerable contribution to lowering thermal energy demand.
- While reducing the need for space heating through stricter codes, the need for space cooling may increase.
- Warmer winters and summers will provide a net reduction in thermal energy demand.
- The reference case of an 80 percent reduction in commercial thermal energy demand implies a technical potential of 9.8 trillion BTUs in 2050.[54] To achieve this, an annual rate of deep retrofit of around 4.7 percent would be required until 2050, *ceteris paribus*.

54 The Global Warming Solutions Act (2008) requires an economy-wide reduction in GHG emissions by 2050 (relative to 2001) but does not specify a degree of reduction to be achieved in any particular sector. The 80 percent reduction in emissions from commercial thermal energy demand envisioned here is hypothetical.

ENERGY USE INTENSITIES

The EUIs of different subsectors from the commercial sector relay important information about where the greatest opportunities and challenges lie.

Figure 13 shows the aggregated EUIs applied to existing commercial buildings in this study.

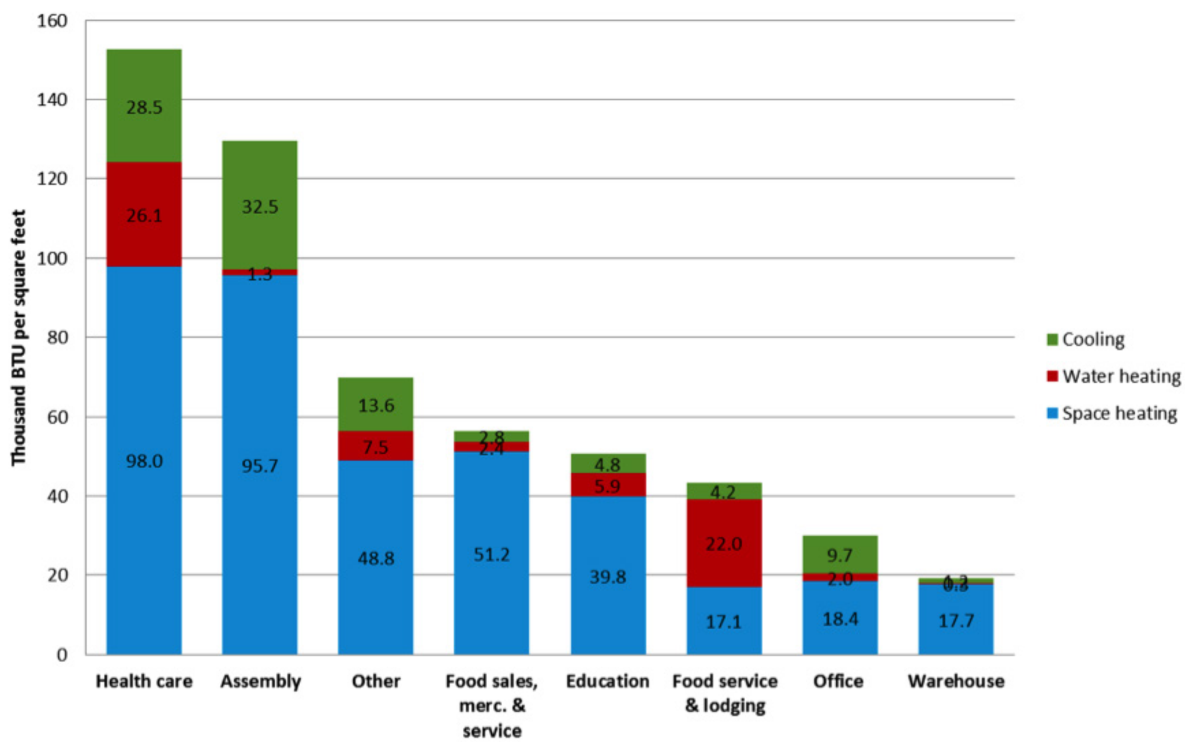


Figure 13 | Commercial Energy Use Intensity per square feet (2014 mean values). Source: CBECS 2012.

Health Care and *Assembly*[55] are the most energy intense categories in terms of space heating. Providing a reliable energy source that sustains life-supporting and supply chain operations is particularly crucial for *Health Care*.

Health Care also dominates water heating, followed by the *Food Service* and *Lodging sectors*. *Assembly* is the most space-cooling-intense sector, followed by *Health Care*.

The annual energy efficiency improvement rates applied to the EUIs of new construction and demolitions are 0.55 percent for space heating and 0.32 percent for cooling, informed by the AOE 2016.

55 Assembly: Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls

ESTIMATED THERMAL ENERGY DEMAND

The size of buildings along with the type of business they house is an important driver for thermal energy demand of commercial buildings. The square footage for the Connecticut commercial building stock has been established using AEO 2015 projections for New England. The projected distribution of employees relies on NAICS sectors and states, and has been applied to elaborate on the Connecticut commercial square feet.

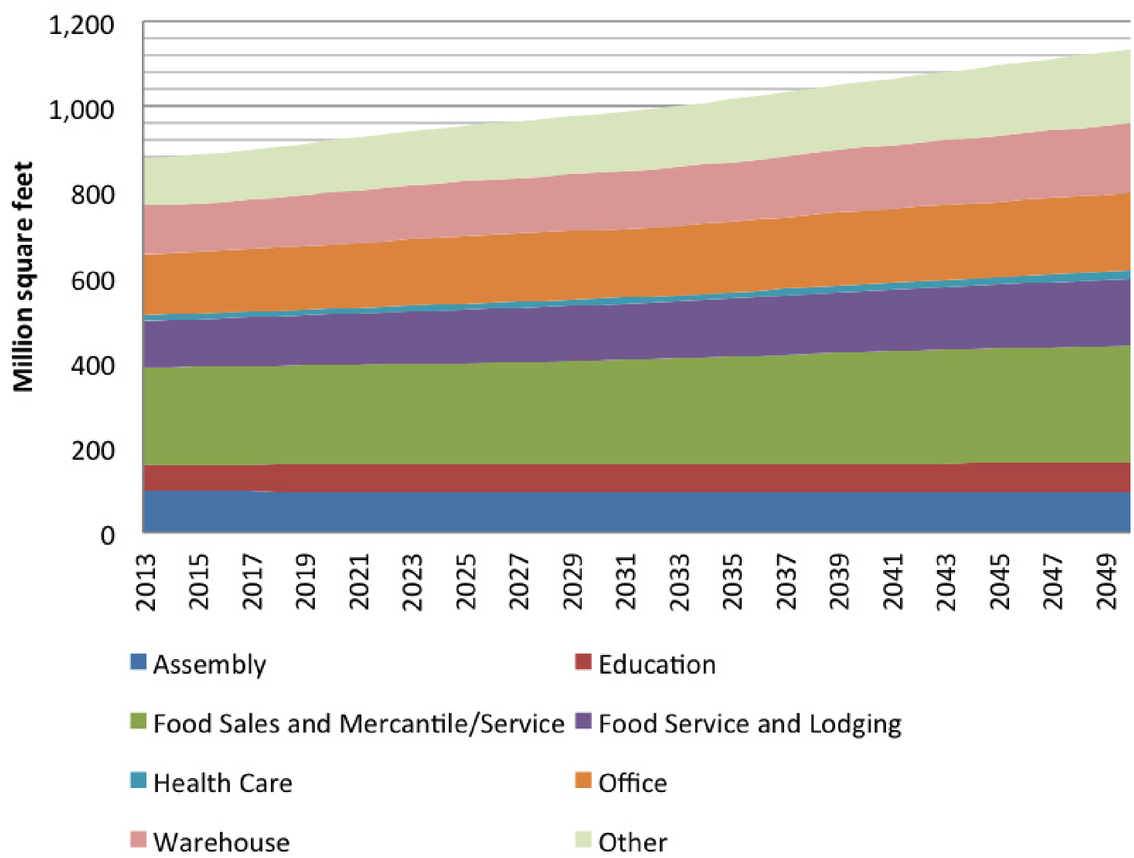


Figure 14 | Estimated floor space, commercial customers in CT. Sources: Elaborated from the AEO 2015 and the US Census Bureau.

The commercial space in Connecticut is dominated by *Food Sales* and *Mercantile/Service* buildings in particular, followed by *Office*.

The highest net positive annual growth of floor space is found in the category *Other*, followed by *Health Care, Warehouse*, and *Food Services and Lodging*. With the exception of *Assembly*, all commercial building categories have an expected net positive annual growth of floor space over the period.

Health Care occupies a moderately small portion of commercial floor space, but is the most energy intense in terms of BTUs per square feet and per year. Second to it in terms of BTUs per square feet and per year are the *Assembly* buildings.

Unlike the residential sector, the expected growth in new commercial construction is significant. According to the analysis, approximately 37 percent of the estimated commercial space in 2050 will have already been built, corresponding to an annual rate of new constructions of 2 percent.

New construction is more likely to have higher energy efficiencies through a better building envelope, as well as overall improved performance through more efficient technologies and enhanced energy management. New commercial buildings represent an important opportunity for RTTs.

There is an overall reduction in aggregate commercial thermal demand through 2050. Space heating declines most drastically, while space cooling demand increases slightly. Overall, the high rate of new construction in the commercial sector precludes a gradual transition to efficiency and reduced demand.

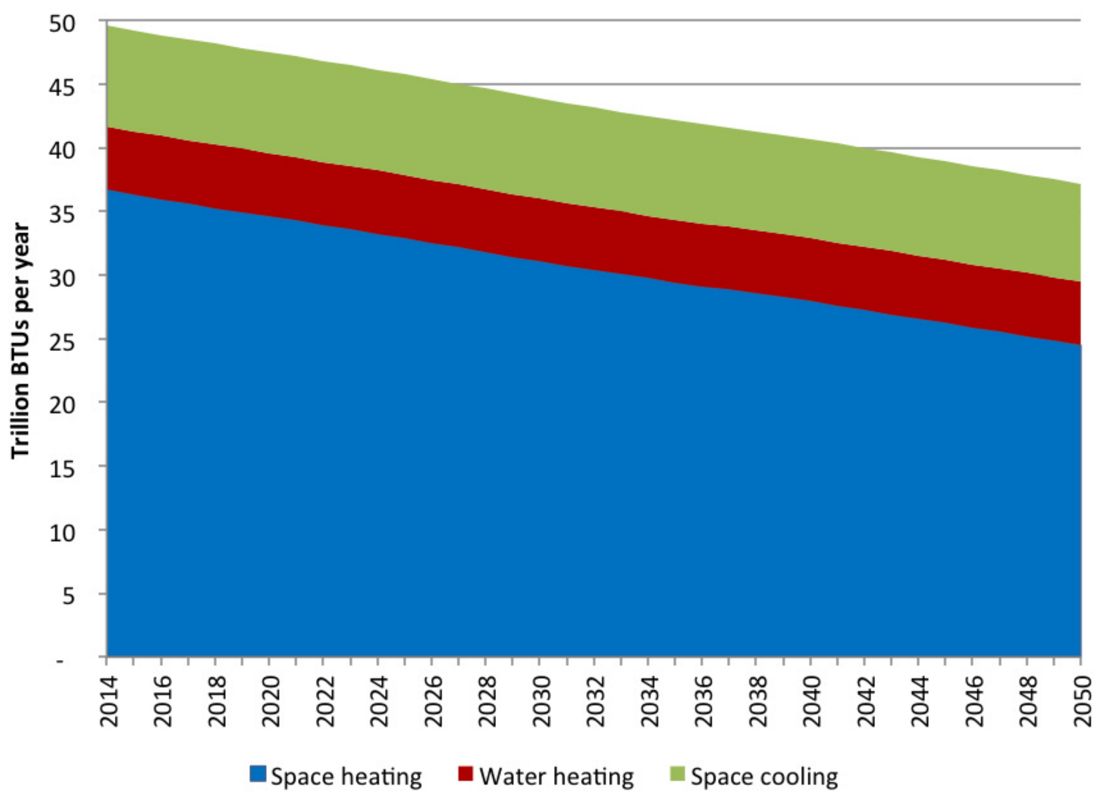


Figure 15 | Estimated commercial thermal demand by end-use. 2014–2050.

The average EUI for space heating becomes 1.76 percent more efficient, water heating becomes 0.68 percent more efficient and space cooling 0.76 percent more efficient each year.

The development can be explained by:

- New, more efficient commercial buildings replacing old inefficient ones at a high rate.
- Increased outdoor temperatures causing a reduction in the number of heating degree-days and an increase in the number of cooling degree days.
- Structural changes, where commercial buildings with high EUIs increase their share of the total floor space. Examples are *Health Care, Food Service and Lodging*, and *Other.*
- Energy efficiency achieved through renovations and replacement of less efficient technologies.

The largest commercial consumers of thermal end-uses are estimated to be the *Food Sales* and *Assembly* sub-sectors. Given their expansive floors spaces, they present a viable opportunity for RTTs.

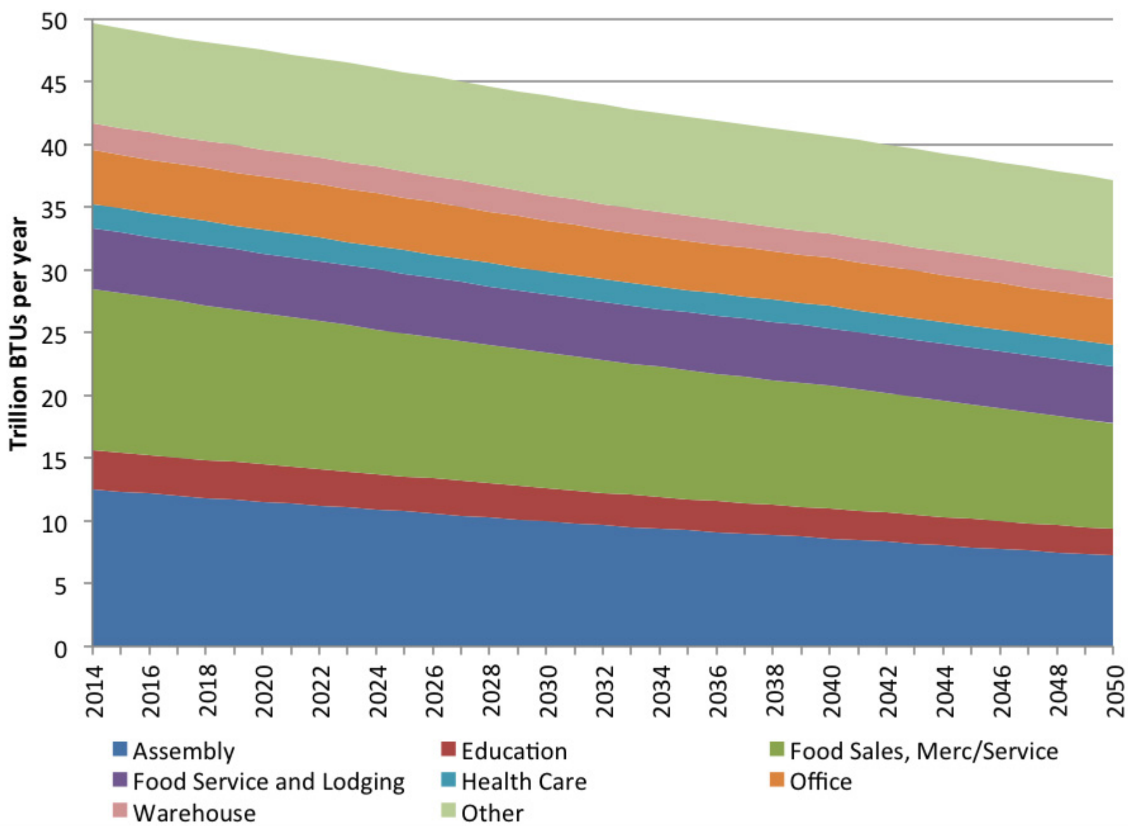


Figure 16 | Estimated commercial thermal energy demand by sector. 2014–2050.

SENSITIVITY ANALYSES

The following sensitivity analyses have been performed to analyze variations in the commercial thermal demand as a result of different references for EUIs.

SENSITIVITY ALTERNATIVES	DESCRIPTION	TECHNICAL POTENTIAL
Buildings Energy Data Book (BEDB) EUIs[56]	The EUIs from the BEDB were applied for existing buildings. The EUIs have been adjusted for CT relative to the national HDD and CDD, as well as national energy efficiency growth rates from the AEO.	The technical potential is estimated at 37.4 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.
International Energy Conservation Code (IECC) for New Construction[57]	The EUIs for new commercial buildings built today are based on the IECC 2012. The categorization of commercial sectors deviates from CBECS, and assumptions have been made to adapt the estimated IECC values to categorization used in this study.	The technical potential is estimated at 30.3 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.
CBECS 2003	Based on the EUIs from CBECS 2003, adjusted to 2014 values for the growth of the regional HDD and CDD for the period 2003–2014 (AEO 2016).	The technical potential is estimated at 41.3 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.

Table 9 | Sensitivity analyses commercial sector. Alternative references for EUIs.

56 Department of Energy, Buildings Energy Data Book, table 3.1.13: http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.13

57 As calculated by Pacific Northwest National Laboratory in the study "Energy and energy cost savings analysis of the IECC for commercial buildings", 2013 (PNNL-22760).

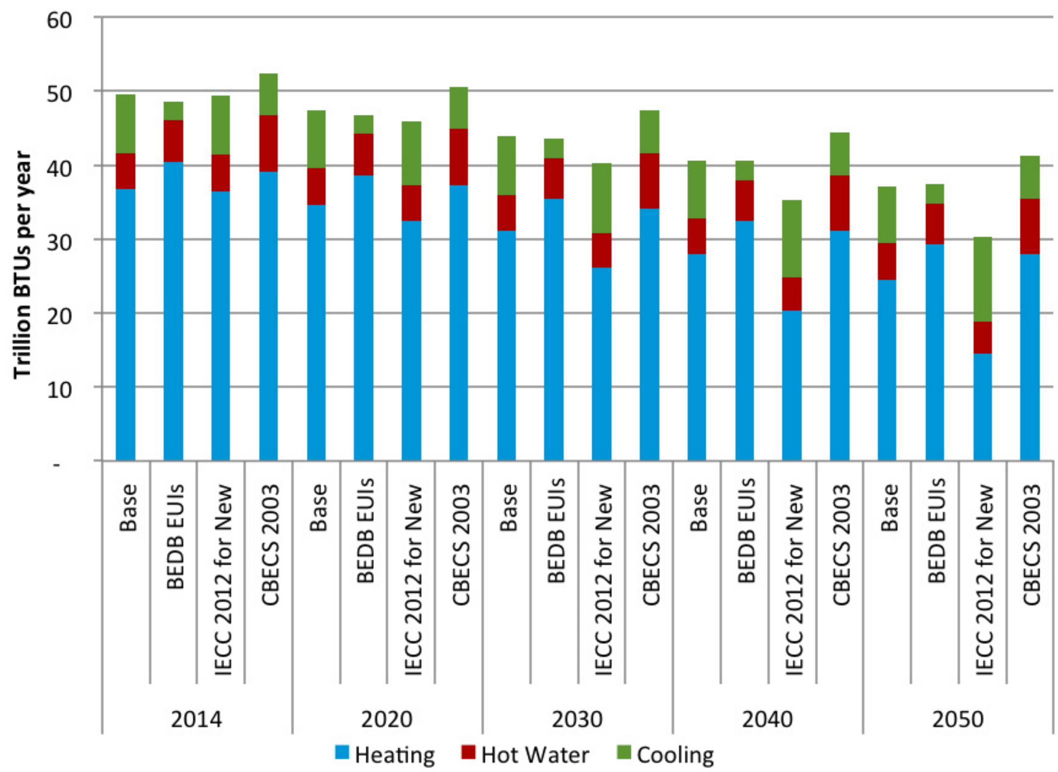


Figure 17 | Sensitivity analyses commercial sector. Alternative references for EUIs.

The BEDB EUIs preclude deviations from the base case on the distribution of thermal energy between both end-uses and customer groups. This results in a higher estimated technical potential with a higher share of space and water heating and a considerably lower share of space cooling.

The IECC 2012 EUI values for new commercial construction drive down technical potential in 2050 considerably. An ambitious building code in a customer segment with a high share of new construction makes a difference. The 2016 Connecticut State Building Code (CSBC) based on the International Code Council's 2012 International Codes is effective for projects in which permit applications were made on or after October 1, 2016.[58]

The CBECS 2003 sensitivity analysis concludes with higher space and water heating demand (but lower cooling demand) compared to the base case. The base case assumes EUIs from CBECS 2012, and the difference can be explained both by energy efficiency between 2003 and 2012, as well as the selection of participants.

58 See http://das.ct.gov/images/1090/NR_Connecticut_Codes_Final.pdf

Another set of sensitivity analyses assumes a higher share of energy efficiency and a choice of outdoor temperatures. Assumptions are presented in Table 10.

SENSITIVITY ALTERNATIVES	DESCRIPTION	TECHNICAL POTENTIAL
No climate change	The number of HDD and CDD is assumed to be the same in the future as today.	The technical potential is estimated at 40.4 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.
DR @ retrofit	Assumes that all renovations are deep retrofits corresponding to a reduction of all thermal end-uses of 75 percent. The annual renovation rate remains at 0.4 percent per year.	The technical potential is estimated at 34.6 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.
Minus 80 percent[59]	Based on base case assumptions except for annual renovation rate and extent of retrofit. For 80 percent reduction in today's energy consumption, approximately 5.5 percent of the commercial floor space has to be renovated each year at an achieved reduction of thermal energy use of 75 percent.[60]	The technical potential is estimated at 9.8 Trillion BTUs in 2050 as compared to 37.2 Trillion BTUs in the base case.

Table 10 | Sensitivity analyses commercial sector. Assumptions on energy efficiency and outdoor temperature.

59 The Global Warming Solutions Act (2008) requires an economy-wide reduction in GHG emissions by 2050 (relative to 2001) but does not specify a degree of reduction to be achieved in any particular sector or context. The 80 percent reduction in emissions from thermal energy demand envisioned here is hypothetical.

60 As a comparison, the new built rate in the AEO is assumed to be 2 percent per year.

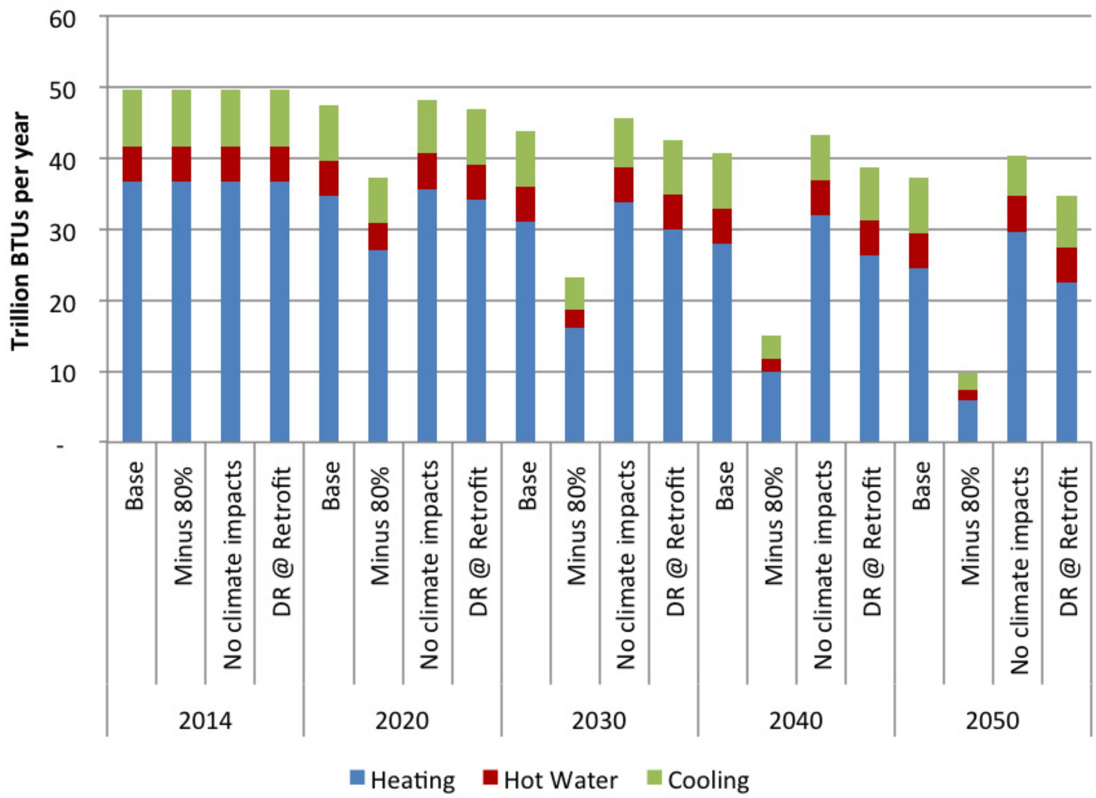


Figure 18 | Shows the results of the 3 sensitivity analyses.

In a No climate change sensitivity analysis, the technical potential remains steady over time with a slight decline.

Space cooling retains its relative ratio across the sensitivity alternatives. Overall, it plays a more significant role than in the residential sector, due to the implicit cooling needs of some of the services in the commercial sector.

Under the Minus 80 percent sensitivity analysis, the thermal energy use in the commercial sector in 2050 is estimated to be approximately 80 percent lower than 2014. An aggressive rate of deep renovations would drive the technical potential to as low as 9.8 trillion BTUs.

CHAPTER 5
Economic Potential—Competition Analysis

The financial competitiveness of technologies providing thermal services has been analyzed and the economic potential has been estimated. Main findings include:

- The economic potential for RTTs in residential and commercial building is currently around 31 trillion BTUs, representing 19 percent of the estimated thermal demand.
- RTTs are more competitive in the commercial sector than the residential sector.
- Heat pumps are financially favorable as a robust thermal solution replacing conventional electric technologies across all customer groups and end-uses.
- There is large, untapped, and financially favorable potential to replace old fuel oil in residential and commercial buildings with highly efficient natural gas boilers and biomass pellets. The adaptation of highly efficient natural gas boilers at a large scale will not offer sufficient reduction of GHG emissions to reach Connecticut's climate targets.
- Any existing fuel oil boiler replaced by a new fuel oil or standard natural gas boiler represents a lost opportunity for a cheaper and cleaner future.

Case Study Results

Different combinations of incumbent and proposed alternative thermal technologies have been analyzed for different archetypal customers, with financial viability and impact on GHG emissions quantified.

The competition analysis—examining how RTTs compete with conventional thermal technologies—is based on the assumptions in Appendix A, and detailed results by customer category can be found in Appendix B.

Physical limitations related to existing buildings have to some extent been handled through the level of incremental installation initial costs. See Appendix A for more information.

Financial incentives are not included in the competition analysis and will be discussed separately in the sensitivity analysis of Chapter 6. Appendix E offers an overview of current financial incentives in Connecticut.

The competition analysis assumes the relative installation costs of the technologies to remain unchanged over the period. The impacts of changes in relative installation costs between RTTs and conventional technologies are considered in the sensitivity analysis.

Due to the need for simplification, the analysis contains some limitations that may influence the financial feasibility of RTTs. Specifically:

- To avoid additional complexity in the analysis, the RTTs have been modeled to deliver the whole thermal demand of a building over the year, that being for space cooling, heating or hot water. Even if the incremental installation costs are given per installed BTU/h, this may exclude some financially favorable solutions. Oversizing RTTs should be avoided both to restrict installation costs and secure efficient operations; keeping the incumbent energy source for peak load operations may be desirable.
- Some RTTs can supply thermal end-uses in addition to those we have incorporated in our case studies. These could influence the financial evaluation.
- Technologies that provide low-temperature heat may have difficulty delivering enough heat to existing buildings on the coldest days. Improvements of the building envelope to accommodate heat pumps have not been accounted for.
- Economies of scale, particularly for the commercial sector, may be underestimated in the study.
- Some customer categories may face regulatory and technical requirements related to their thermal load that pose limitations on RTTs. For example, strict requirements stipulate hot water temperatures for certain processes in food and healthcare.
- Potential costs of gas grid connection or electricity grid upgrades have not been accounted for.

Table 11 summarizes the competition analysis, with the range of simple payback and cases with positive NPV marked in green.

RTT USED	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity	5–15	5–15	5–15	5–15	5–15	5–15	5–15
	Fuel Oil	>15	>15	>15	>15	>15	>15	>15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15
ASHP space heating and cooling with ductwork needed	Electricity	5–15	5–15	5–15	>15	5–15	5–15	>15
	Fuel Oil	>15	>15	>15	>15	>15	>15	>15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15
ASHP Hot Water	Electricity	<5	<5					
	Fuel Oil	>15	>15					
	Natural Gas	>15	>15					
GSHP space heating and cooling	Electricity	5–15	5–15	5–15	>15	>15	>15	>15
	Fuel Oil	>15	>15	>15	>15	>15	>15	>15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15
Solar Hot Water	Electricity	5–15	5–15	>15	5–15	5–15	>15	>15
	Fuel Oil	>15	>15	>15	>15	>15	>15	>15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15
Biomass space heating and hot water	Fuel Oil	5–15	>15	5–15	5–15	5–15	5–15	>15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15
Highly efficient natural gas	Electricity	<5	<5	<5	5–15	<5	<5	5–15
	Fuel Oil	<5	<5	<5	<5	<5	<5	5–15
	Natural Gas	>15	>15	>15	>15	>15	>15	>15

Table 11 | Case study results for different combinations of incumbent and proposed technologies for different archetype customers.

- Replacing conventional electric technologies with ASHPs for space heating and cooling is a financially favorable alternative across all customer categories.
- ASHP water heaters are financially feasible alternatives to electric water heaters for residential customers. ASHP water heaters for commercial hot water demand have not been included in the analysis.
- SHW is a financially feasible alternative to electric water heaters for residential customers and commercial customers with high demand for hot water per square foot.
- GSHPs are financially feasible alternatives to conventional electric technologies for space heating and cooling for customer groups with a large total number of hours of use and high demand for space heating per square foot.
- Biomass-pellet boilers are a financially feasible alternative to fuel oil for commercial customers with a large demand for space heating and hot water per square foot.
- Highly efficient natural gas boilers are a financially feasible alternative to both conventional electric boilers and fuel oil for space and water heating across customer categories.

Overall Economic Potential in Connecticut

The competition analysis found the most cost efficient combination of incumbent and proposed technologies for archetypal customer. The total market for thermal energy, as estimated by the base case of the demand analysis of Chapter 4, was split across winning technologies, accordingly.

If several combinations of incumbent and proposed technology are favorable for an archetypal customer, the most favorable has been applied. The results are discussed from two scenarios:

1. Competitive RTTs have priority: efficient natural gas is excluded as an alternative to the incumbent.
2. Efficient natural gas included: efficient natural gas is included as an alternative to the incumbent.

RESIDENTIAL SECTOR

Residential demand for hot water and space heating and cooling was estimated to be 120 trillion BTUs in 2014. Fuel oil was the dominant energy source (46 percent), followed by natural gas (37 percent), electricity (11 percent), and biomass (5 percent). The total GHG emissions related to this residential thermal demand is estimated to be 9.1 million tons of CO_2 equivalent.[61]

61 Estimations are based on the thermal demand estimated in Chapter 4, the consumption by energy sources from EIA SEDS 2014, the energy by end-use from AEO 2015, the GHG emission factors from Chapter 3, and the efficiency assumptions from Appendix A.

SCENARIO 1—COMPETITIVE RTTS HAVE PRIORITY

The economic potential of RTTs in the residential sector is estimated to be 16.2 trillion BTUs when highly efficient natural gas boilers are excluded from the analysis and competitive RTTs have priority. This is 14 percent of the estimated technical potential (see Figure 19).

- ASHPs replace thermal demand for space heating and cooling currently based on conventional electric technologies. Although GSHPs have a positive NPV for multi-family homes, they are less favorable than ASHPs.
- SHW has a positive NPV, but is less favorable than ASHP water heaters, which serve the domestic hot water demand with electricity as an incumbent.
- Biomass is not considered financially favorable through the competition analysis, but we assume that biomass maintains its current share of the demand for space heating and hot water.
- Under current market conditions, none of the RTTs are considered financially favorable to fuel oil or natural gas as the primary energy source, and we assume that the customer keeps or reinvests in the incumbent technology.

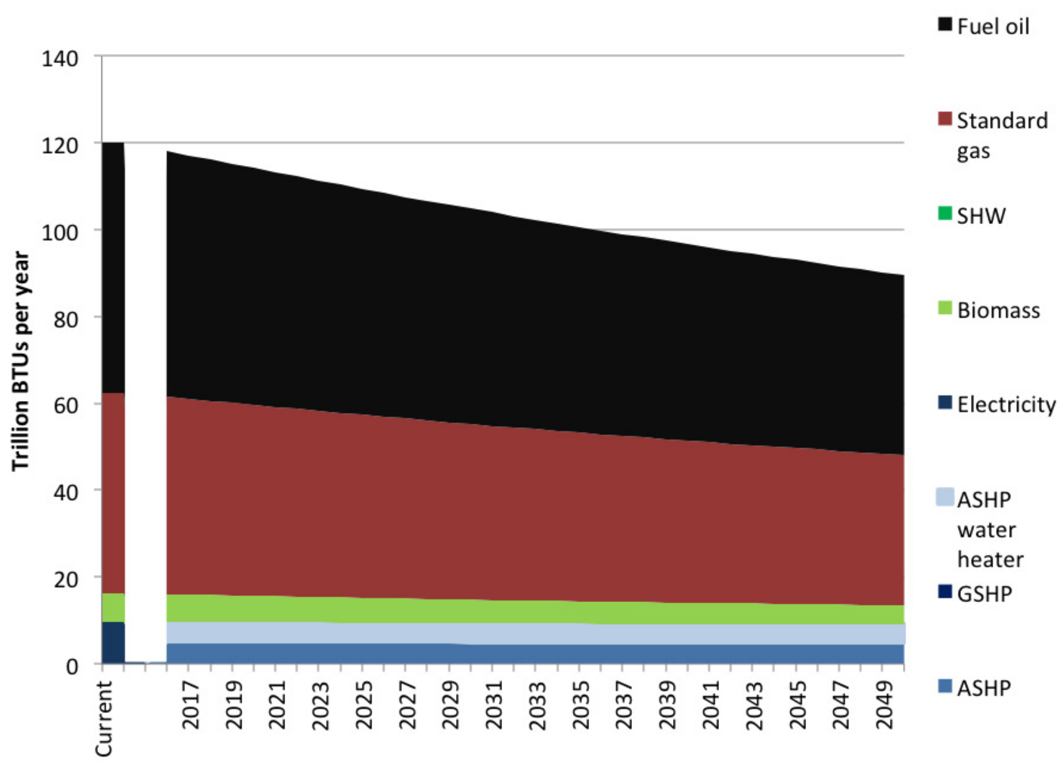


Figure 19 | Preferred thermal technology, excluding highly efficient natural gas boilers. Residential sector.

While energy efficiency is driving total thermal demand down over the period, fossil fuels will continue to dominate as energy sources if relative prices remain the same and customers are allowed to reinvest in incumbent technologies. Cooling is provided by ASHPs, water and space heating by a combination of thermal technologies. As a consequence of increased demand for cooling, the share of RTTs increases to 15 percent by 2050.

SCENARIO 2—EFFICIENT NATURAL GAS INCLUDED

The economic potential of RTTs in the residential sector has been estimated at 11.9 trillion BTUs when highly efficient natural gas is included in the competition analysis. This is 10 percent of the estimated technical potential (see Figure 20).

- In the current market, highly efficient natural gas seems to be the most financially favorable technology for replacing fuel oil and conventional electric technologies for space and water heating.
- Cooling is an additional service that may lead to ASHPs being chosen over efficient natural gas boilers. Cooled space has been used as a key for splitting the relevant part of the market between ASHPs and efficient natural gas boilers.[62]
- The demand for space cooling is served by ASHPs.
- Highly efficient natural gas replaces the demand that currently is served by fuel oil.

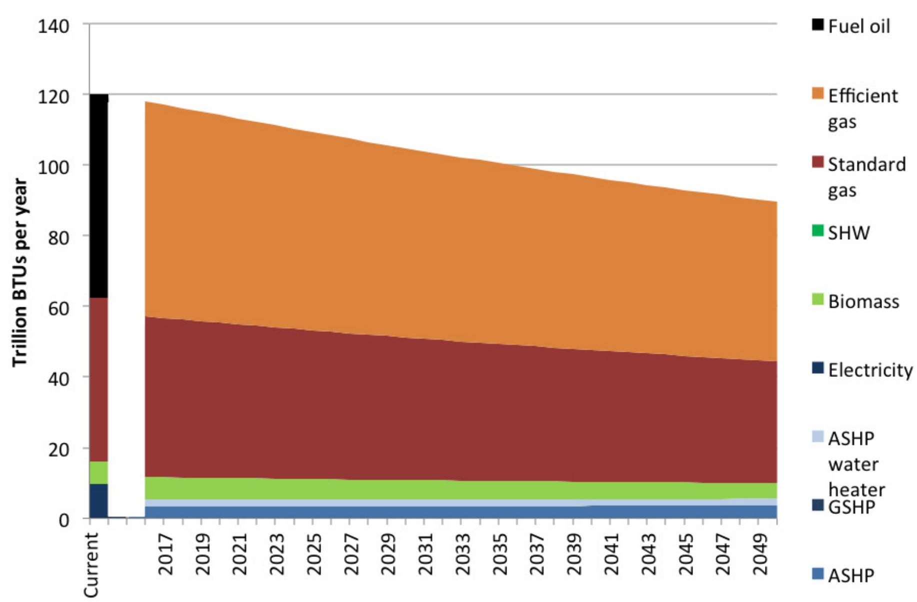


Figure 20 | Preferred thermal technology, including highly efficient natural gas boilers. Residential sector.

62 The cooled area of single-family and multi-family homes is 50% and 41%, respectively (RECS 2009).

Natural gas will be the main energy source when highly efficient natural gas boilers are included in the competition analysis. There are a few elements that have to be taken into consideration in this analysis:

- No connection fees have been included for natural gas grid expansions.
- No costs related to storage and transportation of natural gas have been included.

The economic potential for highly efficient natural gas boilers for customers located far from the existing gas grid may therefore be overestimated.

As a consequence of increased demand for cooling, the share of RTTs increases slightly over the period.

COMMERCIAL SECTOR

The commercial demand for hot water and space heating and cooling is estimated at 49.6 trillion BTUs for 2014. Natural gas was the dominant energy source (70 percent), followed by electricity (14 percent), fuel oil (13 percent), and biomass (3 percent). The total GHG emissions related to the commercial thermal demand have been estimated at 3.5 million tons CO2 equivalents.[63]

SCENARIO 1—COMPETITIVE RTTS HAVE PRIORITY

The economic potential of RTTs in the commercial sector has been estimated to be 15.4 trillion BTUs when highly efficient natural gas boilers are left out of the competition and competitive RTTs have priority. This is 32 percent of the estimated technical potential (see Figure 21).

- ASHPs replace thermal demand for space heating and cooling currently based on conventional electric technologies. Although GSHPs have a positive NPV for *Education* and *Health Care*, they are less favorable than ASHPs.
- SHW has a positive NPV for *Food Service* and *Health Care* and fulfills hot water demand, with electricity as the incumbent.
- With the exception of *Office* buildings, biomass appears to be a financially feasible alternative to fuel oil for space and water heating.
- The current demand served by biomass is assumed to continue being served by biomass.
- We assume that the customer keeps or reinvests in the incumbent technology when none of the RTTs are competitive.

63 Estimations are based on the estimated thermal demand from Chapter 4, the consumption by energy sources from EIA SEDS 2014, the energy by end-use from AEO 2015, the GHG emission factors from Chapter 2, and the efficiency assumptions from Appendix A.

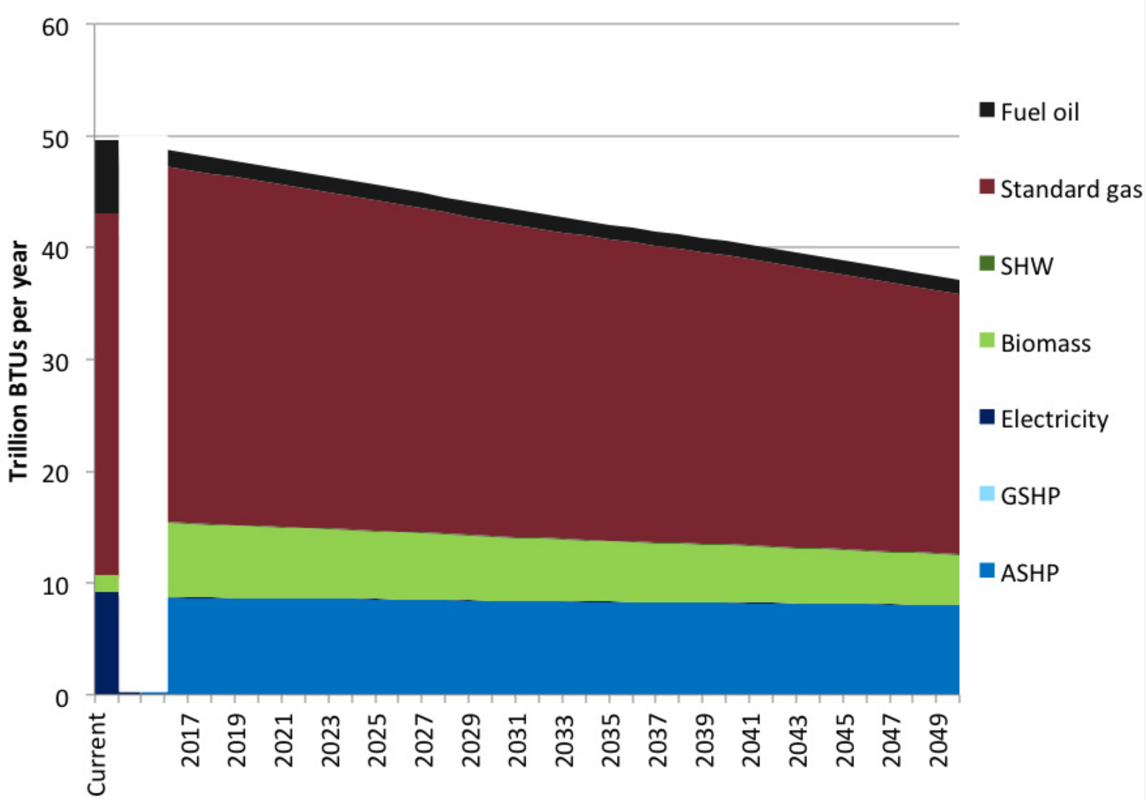


Figure 21 | Preferred thermal technology, excluding highly efficient natural gas boilers. Commercial sector.

While the total thermal demand is expected to be reduced over the period as a consequence of energy efficiency and structural changes, the demand for space cooling is expected to rise due to a warmer climate. As a consequence, the share of RTTs will increase to 34 percent over the period. Natural gas will maintain its dominant position in the commercial sector if the current market conditions prevail. With biomass pellets coming up as a financially favorable alternative to fuel oil, the issue of fuel availability should be investigated. Thin supply chains for biomass pellets may add transportation costs in some areas of the state.

SCENARIO 2—EFFICIENT NATURAL GAS INCLUDED

The economic potential of RTTs in the commercial sector has been estimated to be 10.2 trillion BTUs when highly efficient natural gas boilers are included in the analysis. This is 21 percent of the estimated technical potential (see Figure 22).

- Highly efficient natural gas seems to be the most financially favorable technology for replacing fuel oil and conventional electric technologies for space and water heating.
- Cooling is an additional service that may lead to ASHPs being chosen over efficient natural gas boilers. ASHPs serve the demand for space cooling and space heating currently served by conventional electric technologies.
- Highly efficient natural gas boilers replace the demand that currently is served by fuel oil.
- Biomass is less financially favorable than efficient natural gas boilers, and we assume that biomass maintains it current share of the demand for space heating and hot water.

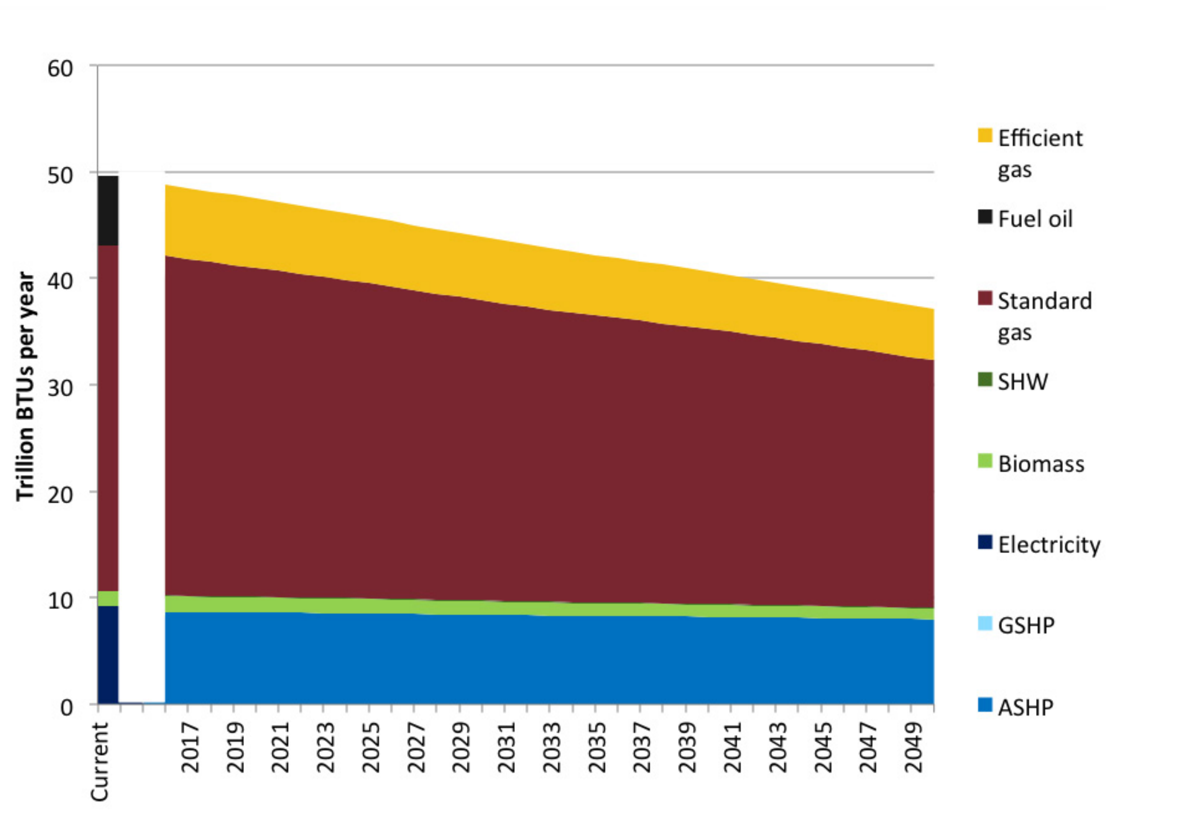


Figure 22 | Preferred thermal technology, including highly efficient natural gas boilers. Commercial sector.

Natural gas will be the dominant energy source when highly efficient natural gas boilers are considered in the financial analysis. Similar to the residential sector, distance to the current natural gas grid would impact the feasibility of highly efficient natural gas boilers replacing fuel oil.

Given the current and assumed market conditions, a considerable share of thermal demand will continue being served by standard natural gas boilers. Due to low natural gas prices and incremental investment costs, existing thermal demand served by standard natural gas boilers may be the most challenging share of thermal demand to turn cleaner absent market interventions.

As a consequence of increased demand for cooling, the share of RTTs increases slightly over the period.

Estimated GHG emissions

The GHG emissions of different combinations of thermal technologies have been estimated for the scenarios described in Table 12.[64]

	THERMAL TECHNOLOGIES		
	Competitive RTTs have priority	**Efficient natural gas boilers included**	**Competitive RTTs have priority, GSHPs replace fuel oil, efficient gas boilers replace standard boilers**
Current electric grid mix (GHG emission factor 0.301 kgCO_2e/kWh)	Scenario 1a	Scenario 2a	Scenario 3a
75 % renewable electricity by 2050 (GHG emission factor 0.075 kgCO_2e/kWh	Scenario 1b	Scenario 2b	Scenario 3b

Table 12 | Scenarios for combinations of thermal technologies and electricity generation.

- The b-scenarios are based on a gradual change of energy sources in the electricity generation. Achieving 75 percent renewables by 2050 corresponds to the scenarios presented to the Governor's Council on Climate Change on September 8th, 2016.
- Scenario 3 represents a situation in which more RTTs and efficient gas boilers are installed than the competition analysis suggests. The thermal demand is supplied by RTTs where RTTs were found to be competitive in scenario 1. Fuel oil as an energy source is fully replaced by GSHPs, and standard natural gas boilers are replaced by highly efficient natural gas boilers. This scenario would imply replacing incumbent technologies with several technologies that are not competitive at today's prices.

64 For reasons spelled out in footnote 43 in chapter 3.3, DEEP's view is that the GHG emissions reductions that this section associates with biomass combustion are not reliable.

RESIDENTIAL SECTOR

The GHG emissions of the energy sources delivering thermal service to meet current residential demand are estimated to be 9.1 million tons CO_{2e} per year.

Figure 23 shows the estimated GHG emissions related to residential thermal demand through 2050 given different combinations of thermal technologies at the customer end, and different energy sources used for electricity generation.

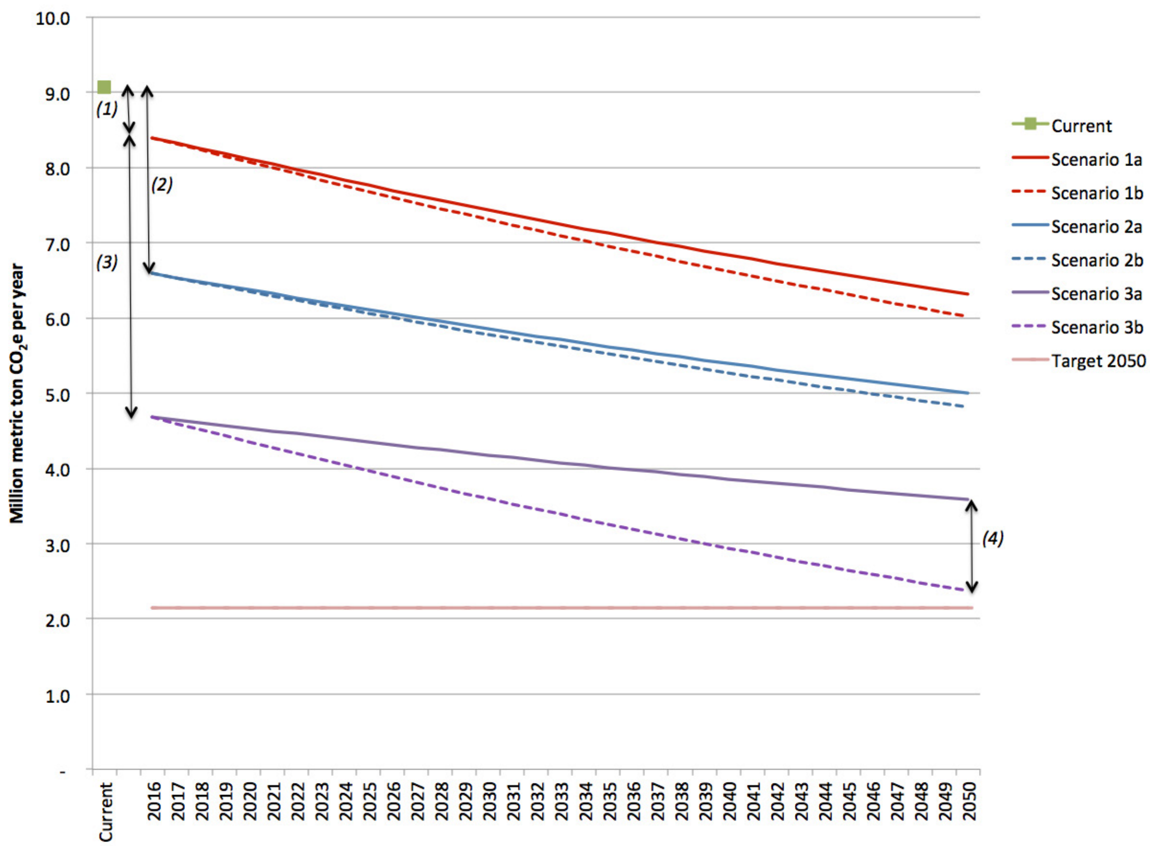


Figure 23 | Estimated GHG emissions for different combinations of thermal technologies. Residential sector.

- Installing all competitive RTTs from scenario 1 would bring an immediate reduction of 0.6 million tons CO_{2e} per year (1). This represents a financially viable but unrealized potential for reduced GHG emissions.
- Installing competitive efficient gas boilers and RTTs, represented by scenario 2, would bring an immediate reduction of 2.4 million tons CO_{2e} per year (2). This represents a financially viable but unrealized potential for reduced GHG emissions.

- Competitive RTTs and an expedited replacement of existing fuel oil and gas boilers with GSHPs and efficient natural gas boilers would reduce the GHG emissions by close to 50 percent of the current levels (3).
- With greater shares of heat pumps, a 75 percent renewable electricity mix would add a reduction of 1.2 million tons CO_2e by 2050 in scenario 3 (4).
- With scenario 3, the GHG emissions in 2050 are estimated at 2.4 million tons CO_2e. An 80 percent reduction of GHG emissions relative to 2001 would represent a target of around 2.1 million tons CO_2e.[65]

Achieving significant emissions reductions requires meeting thermal demand with a combination of a high share of RTTs and cleaner electricity. Replacing standard natural gas and fuel oil boilers with highly efficient natural gas boilers will give immediate GHG reductions, but not enough to achieve long term targets. Market interventions are necessary to realize RTT alternatives with both favorable and unfavorable economics.

65 The Global Warming Solutions Act (2008) requires an economy-wide reduction in GHG emissions by 2050 (relative to 2001) but does not specify a degree of reduction to be achieved in any particular sector or context. The 80 percent reduction in emissions from thermal energy demand envisioned here is hypothetical.

COMMERCIAL SECTOR

The GHG emissions of energy sources delivering thermal service to meet current commercial demand are estimated to be 3.5 million tons CO_{2e} per year.

Figure 24 shows the estimated GHG emissions related to commercial thermal demand through 2050 given different combinations of thermal technologies at the customer end, and different energy sources used for electricity generation.

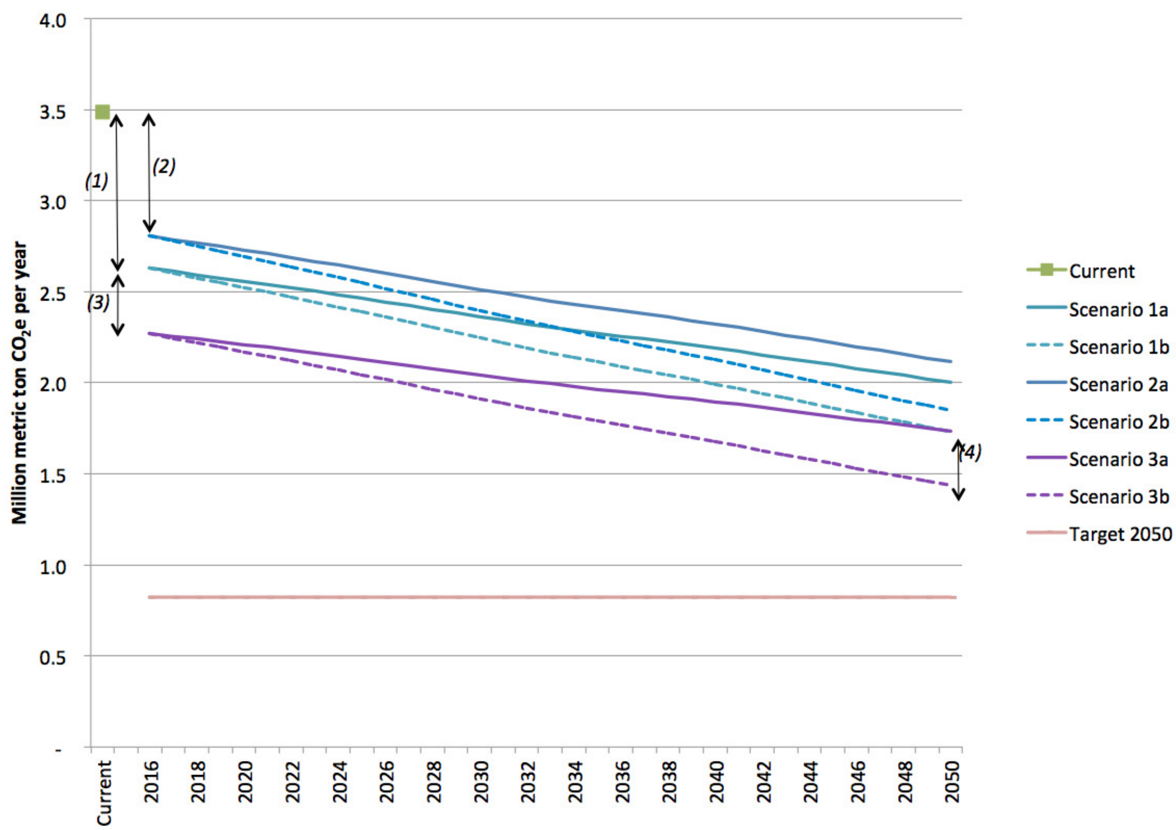


Figure 24 | Estimated GHG emissions for different combinations of thermal technologies. Commercial sector.

- Installing all competitive RTTs from scenario 1 would bring an immediate reduction of 0.8 million tons CO_{2e} per year (1). This represents a financially viable but unrealized potential for reduced GHG emissions.
- Installing competitive RTTs and efficient gas boilers (scenario 2) would bring an immediate reduction of 0.7 million tons CO_{2e} per year (2). This represents a financially viable but unrealized potential for reduced GHG emissions.

- Competitive RTTs and an expedited replacement of existing fuel oil and gas boilers with GSHPs and efficient natural gas boilers would reduce the GHG emissions to close to 65 percent of the current levels (3).
- With greater shares of heat pumps, a 75 percent renewable electricity mix would add a reduction of 0.4 million tons CO_2e by 2050 in scenario 3 (4).
- With scenario 3b, the GHG emissions in 2050 are estimated to be 1.6 million tons CO_2e. An 80 percent reduction of GHG emissions relative to 2001 would represent a target of around 0.8 million tons CO_2e.

While including financially favorable highly efficient natural gas boiler results in the lowest GHG emissions for the residential sector (scenario 2), excluding highly efficient natural gas boilers and allowing financially favorable RTTs to gain ground provides the lowest GHG emissions in the commercial sector (scenario 1). This is due to biomass pellets being financially favorable for commercial customers.[66] The GHG emission factor applied for biomass in this study was 0.036 $kgCO_2e$/kWh.

Realizing significant emissions reductions requires thermal demand to be served by a combination of a high share of RTTs and cleaner electricity. Replacing standard natural gas and fuel oil boilers in the commercial sector with highly efficient natural gas boilers will give GHG reductions, but not enough to achieve long term targets. Market interventions are necessary to realize alternatives both with favorable and unfavorable economics.

Although replacement of standard gas and fuel oil boilers with highly efficient gas boilers represents one of the cheapest means to reduce GHG emissions today, doing so extensively is not sufficient to reach the target and would lock in fossil fuel technologies that could prevent Connecticut from achieving an 80 percent reduction in GHG emissions by 2050. The high share of natural gas boilers in the commercial sector already represents a barrier to RTTs and thus inhibits the state's ability to achieve needed reductions in GHG emissions. Replacing standard natural gas boilers with highly efficient gas boilers and decarbonizing the gas grid by, for example, injecting biogas from anaerobic digestion could supplement market strategies to promote RTTs.

Removing the competitive biomass alternatives from the RTT mix, or applying a higher GHG emission factor, would increase the gap between the target and what the scenarios can achieve.

66 See chapter 3.3 for more information on the GHG emission factors used.

CHAPTER 6
Sensitivity Analysis

We have included sensitivity analyses both to test the solidity of the findings and to analyze the implications of market interventions.

Figure 25 summarizes a set of market interventions to increase the diffusion of RTTs in Connecticut.[67]

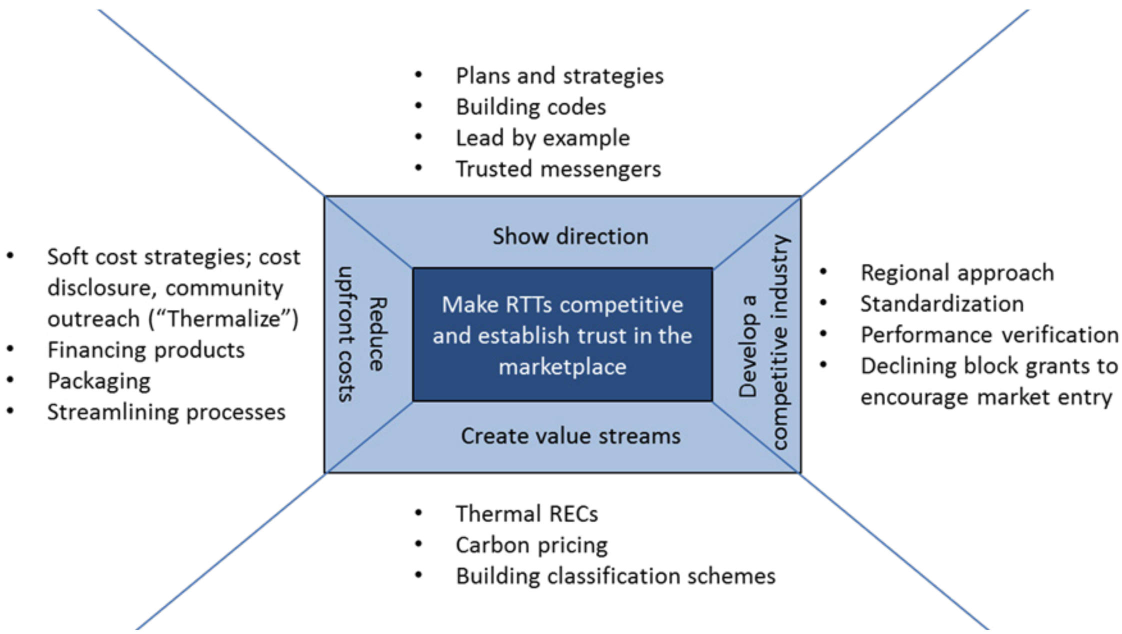


Figure 25 | Market interventions to increase the diffusion of RTTs.

The market interventions in Figure 25 consist of a range of regulatory measures, financial products, and marketing strategies. The analysis of this report focuses on the interventions that can be quantified through costs or revenue streams. However, a combination of regulations, financial incentives, and marketing efforts pulling the same direction will have a larger impact on RTT deployment than stand-alone measures.

The most influential parameters in the sensitivity analysis are incremental initial costs, fuel costs of incumbent case, and fuel costs of proposed case. Which is most influential varies from case to case, but the order of magnitude is typically that shown by Figure 26.

67 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

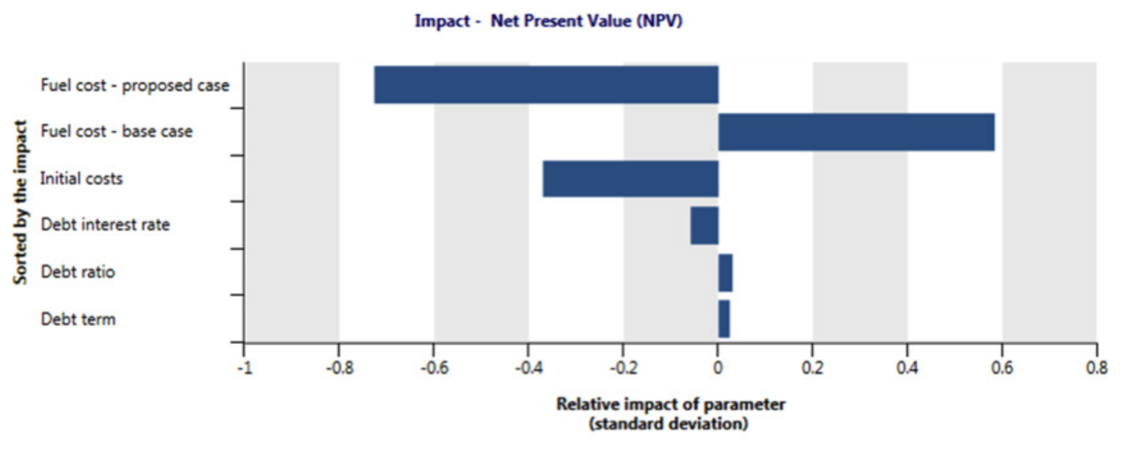


Figure 26 | Relative impacts of parameter from the financial evaluation. Example: ASHP replacing fuel oil in single-family homes.

The general trend presents the overwhelming importance of fuel costs to the competitiveness of the proposed (RTT) versus the base alternative (incumbent technology). Incremental initial costs have the greatest impact in cases including GSHPs, although fuel costs strongly influence even this technology. Overall, debt ratio, debt term, and debt interest rate are of relatively little significance to project economics. However, financial conditions are important for other reasons, such as reducing the upfront costs, shifting customer cash flow, and establish trust in the solution.

The importance of fuel costs in the financial analysis is evident from Figure 27 as well. Taking fuel content and efficiency of heating equipment into consideration, this shows the operating fuel costs of different heating alternatives for residential customers (assumptions in Appendix A).

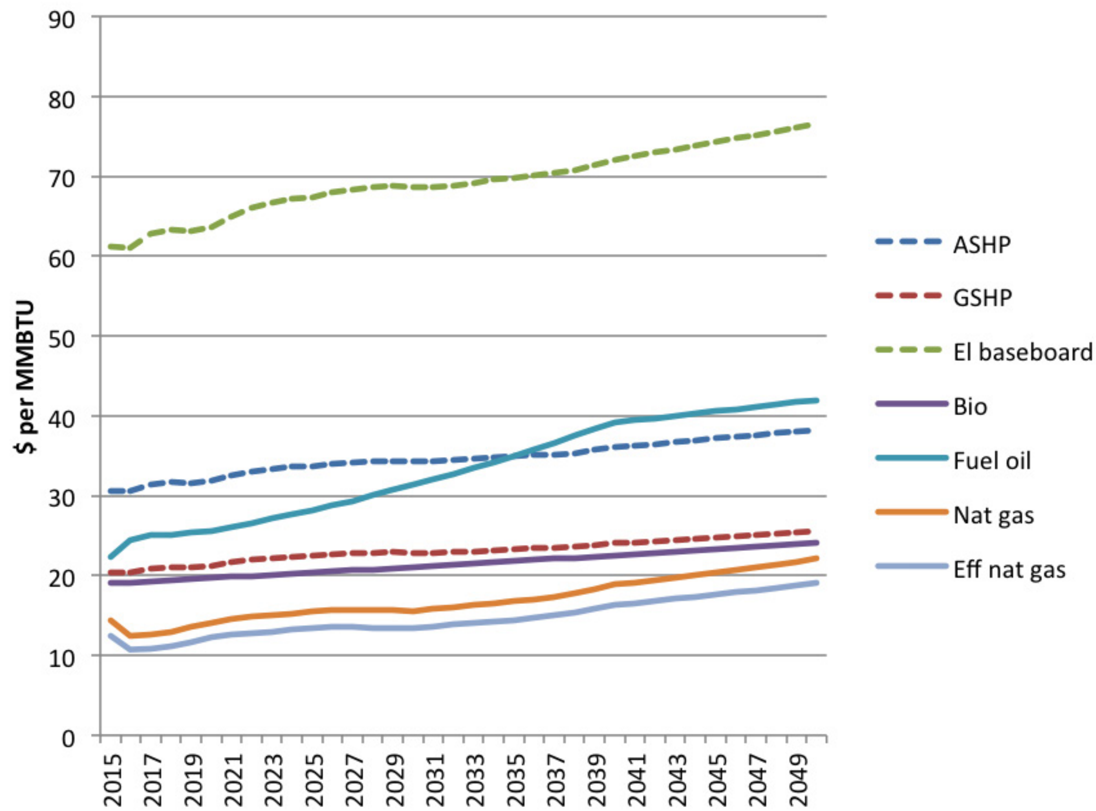


Figure 27 | Projected operational fuel costs for different energy sources for heating technologies (2013 prices). Residential sector.

Electricity for heating is currently considerably more expensive than fuel oil and natural gas, and projections through 2050 continue the trend. In order to pay for the higher installation costs of RTTs, the operational costs have to be proportionately lower for RTTs than for the conventional alternatives. With current price assumptions, operational fuel costs are lower than fuel oil for GSHPs and biomass, but higher than natural gas.

To analyze the most influential parameters and possible market interventions, we have included the sensitivity analysis shown by Table 13.

PARAMETER	DESCRIPTION OF ANALYSIS
6.1 Fuel costs	6.1.1. 50 percent increase of incumbent case
	6.1.2. 100 percent increase of incumbent case
	6.1.3. 25 percent reduction of proposed case
	6.1.4. Solar PV delivers drive energy of proposed case
6.2. Incremental initial costs	6.2.1. 25 percent reduction (whole load installation)
	6.2.2. RTT for partial load (60 percent of capacity and ~80 percent of load)
6.3 Carbon price	Carbon price corresponding to the social cost of carbon
6.4. Thermal Renewable Energy Certificates (TRECs)	TRECs corresponding to market prices
6.5. Financial terms	6.5.1. 25 percent reduction of debt interest rate
	6.5.2. 25 percent increase of debt term, with economic life of asset as maximum debt term
6.6. Sets of simultaneous changes	6.6.1. 25 percent reduction of initial costs, 25 percent reduction of electricity prices for the proposed case due to use of solar PV, 25 percent reduction of pellet prices and a carbon price of $120 per tCO_2
	6.6.2. 25 percent reduction of initial costs, 25 percent reduction of electricity prices for the proposed case due to use of solar PV, and a 50 percent increase of incumbent case fuel costs

Table 13 | Sensitivity analysis applied to the financial evaluation of RTTs. Numbering referring to chapter.

For sensitivity analyses 6.1 through 6.6 only one parameter has been analyzed at a time. Sensitivity analysis 6 shows the sensitivity of changing several parameters at a time.

6.1—Fuel Costs

Fuel costs, both for the incumbent and the proposed case, have a large impact on the competitiveness of the RTTs. Change of relative prices are particularly relevant.

Prices of different energy sources have varied extensively over the last 25 years, as shown by Figure 28.

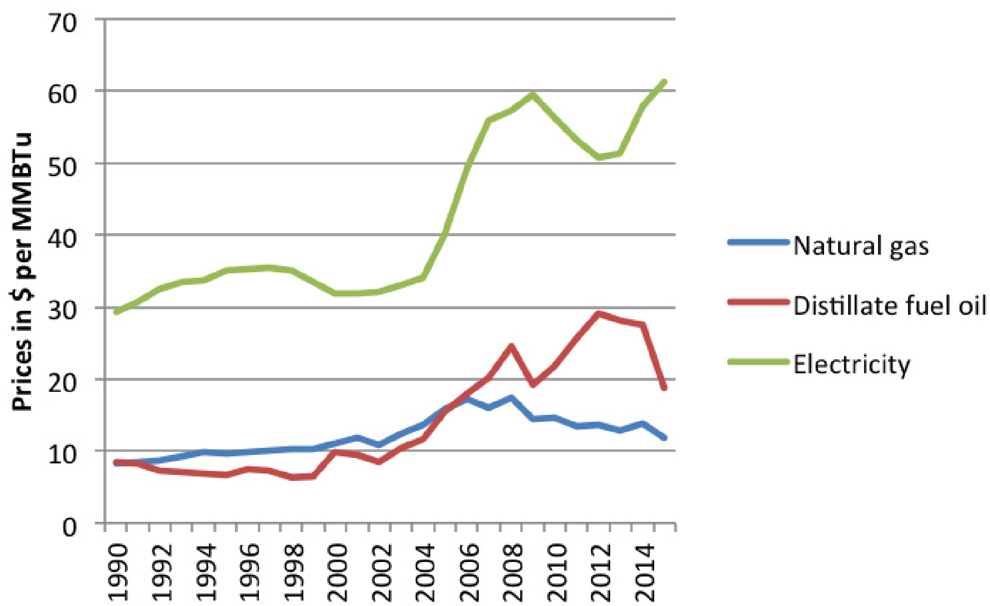


Figure 28 | Annual residential energy prices in Connecticut for the period 2000–2015 (nominal values). Source: EIA SEDS

Figure 28 shows larger price shifts for fuel oil and electricity than for natural gas over the period. Natural gas prices have been lower than fuel oil prices in the residential sector since 2005. The volatility within one year can be considerable as well. In 2015 the monthly residential natural gas prices varied between $11 and $21.5 per MMBTU and the weekly residential fuel oil prices varied between $16.4 and $25.1 per MMBTU.

As energy prices are volatile and may change considerably over time, we have analyzed the sensitivity of changes in fuel costs.

With the exception of sensitivity analysis 6.1.4—solar PV delivering the drive electricity for the proposed cases—both incumbent and proposed cases have been adjusted for alternatives where the energy source is the same for both cases.

50 PERCENT FUEL COST INCREASE FOR INCUMBENT CASE

Table 14 shows the implication for RTT competitiveness based on a 50 percent increase in fuel costs for the incumbent case.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 14 | Sensitivity analysis for a 50 percent increase of incumbent fuel costs. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

The main implications of increasing the fuel costs of the incumbent case by 50 percent are

- Heat pumps to replace conventional electric heating and traditional air-conditioning become competitive for all customer categories.
- ASHP water heaters to displace fuel oil for residential hot water become competitive for single-family homes.
- SHW is a competitive alternative to electricity for water heating across all customer segments.
- Biomass for space heating and hot water is competitive with fuel oil in all customer categories.
- Highly efficient natural gas boilers become economically feasible alternatives to standard natural gas boilers. Generally, higher fuel costs makes more energy efficient alternatives using the same fuel attractive.

100 PERCENT FUEL COST INCREASE FOR INCUMBENT CASE

Table 15 shows the implication for RTT competitiveness based on a 100 percent increase in fuel costs for the incumbent case.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 15 | Sensitivity analysis for a 100 percent increase of incumbent fuel costs. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

The main implications of increasing fuel costs of the incumbent case by 100 percent are:

- Heat pumps become a competitive alternative to fuel oil in many customer segments, including the more expensive heat pump systems.
- Heat pumps to replace conventional electric heating and traditional air-conditioning become competitive for all customer categories.
- ASHP water heaters to displace fuel oil for residential hot water become competitive.
- SHW is a competitive alternative to electricity for water heating and for fuel oil in several customer categories.
- Biomass for space heating and hot water is competitive with fuel oil and standard natural gas boilers in all customer categories.
- Highly efficient natural gas boilers are competitive alternatives to standard natural gas boilers. Generally, higher fuel costs makes more energy efficient alternatives using the same fuel attractive.

25 PERCENT FUEL COST REDUCTION FOR PROPOSED CASE

Table 16 shows the implication for RTT competitiveness given a 25 percent reduction of fuel costs for the proposed case.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 16 | Sensitivity analysis for a 25 percent reduction of fuel costs of the proposed case. Green cells indicate cases with positive NPV in the incumbent case, orange cells indicate cases that turn positive and blue cells indicate cases that turn from positive NPV in base case to negative NPV in the sensitivity analysis.

The main implications of reducing the fuel costs of the proposed case by 25 percent are:

- Replacing conventional electric technologies with heat pumps becomes less attractive when electricity purchased from the grid becomes cheaper. The operational expenses of both the proposed and incumbent case are reduced and the savings are lower.
- Replacing a standard gas boiler with a highly efficient gas boiler becomes less attractive. Lower gas prices will lower the operational expenses of both the proposed and incumbent cases. The benefit of a more efficient boiler is reduced.
- Biomass pellets for space heating and hot water is competitive for fuel oil in all customer categories.

SOLAR PV DELIVERS THE DRIVE ELECTRICITY OF THE PROPOSED CASE

Combining solar PV with electricity-driven RTTs offers an opportunity to reduce both the operational costs of RTTs and the GHG emissions related to the technology. The impact on GHG emissions for residential sector was illustrated in scenario 3b of Figure 23; the impacts on operational fuel costs are illustrated in Figure 29.

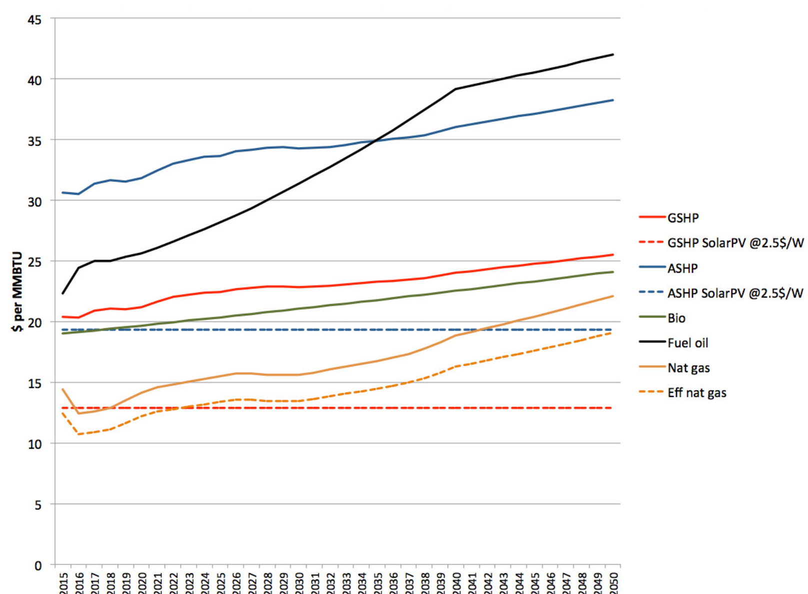


Figure 29 | Projected operational fuel costs for different energy sources for heating technologies. Residential sector.

The Solarize CT campaign,[68] initiated under the SunShot program and championed by the CT Green Bank, is a viable example of a community-based model that aggregates installations and streamlines the supply chain. In 2013, the program reported that since its beginning all participating towns had doubled their solar installations while homeowners saved at least 24 percent on the per-watt cost of

68 http://solarizect.com/

solar PV.[69] The solar PV market currently sees installation costs of $3 per Watt, tax credits taken into consideration.[70] Expectations are that the installation costs of solar PV will continue to drop.

Figure 29 compares the costs of electricity for operating a GSHP on grid electricity versus a solar PV. At installation costs of $2.5 per Watt,[71] GSHPs combined with solar PV have operational fuel costs at levels similar to natural gas. An installation cost of $2.5 per Watt corresponds to a 36 percent reduction of electricity prices.

Table 17 shows the implication for RTT competitiveness of a 36 percent reduction of the electricity costs of heat pumps and SHW as a consequence of bundling with solar PVs installed at $2.5 per Watt.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity	green	green	green	green	green	green	green
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity	green	green	orange		orange	orange	orange
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity	green	green					
	Fuel Oil	orange						
	Natural Gas							
GSHP space heating and cooling	Electricity	green	green	green		green	orange	orange
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity	green	green	orange	green	green	orange	
	Fuel Oil							
	Natural Gas							

Table 17 | Sensitivity analysis for a combining heat pumps with solar PV at $2.5 per Watt. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

69 http://beccconference.org/wp-content/uploads/2013/12/BECC_gillingham.pdf

70 State incentives of $0.4 per Watt are not included.

71 Solar PV assumes 30 percent tax rebate

Combining solar PV with heat pumps and SHW offers a competitive financial case for the customer, given an expected future cost reduction of the installation of solar PV. The generation profile of the solar PV can influence this result, though, and should be looked into.

6.2—Incremental Initial Costs

High upfront cost appears to be one of the most important barriers to RTTs, both because it reduces the economic feasibility and because it increases the hurdle of mobilizing capital. Market interventions that reduce high upfront costs would have a positive impact on the competitiveness of RTTs, and successful programs and financial incentives influencing on initial costs have been implemented both for RTTs and other technologies:

- The Solarize CT campaign resulted in installation cost reductions of 13 percent as installation costs went from $3.45 to $3 per Watt.
- The HeatSmart Thompson pilot in New York State resulted in an average cost reduction of 20 percent.
- The current CT residential subsidies cover 3–5 percent of the incremental installation costs.
- Solar thermal installations placed in service by end of 2019 are given a tax rebate of 30 percent, after which the size of the credit is ramped down.

25 PERCENT REDUCTION OF INCREMENTAL INITIAL COSTS

The implications of reducing initial costs by 25 percent are shown by Table 18.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 18 | Sensitivity analysis for a 25 percent reduction of initial costs. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

The main implications of reducing initial costs by 25 percent are:

- Heat pumps are competitive in almost all customer categories, replacing conventional electric technologies for heating and cooling.
- SHW is competitive in all customer categories except Office, replacing electric water heating.
- Biomass for space heating and hot water becomes competitive, replacing fuel oil in residential buildings.
- Highly efficient gas boilers become competitive against standard gas boilers in most customer categories.

RTTS FOR PARTIAL LOAD

To avoid additional complexity in the analysis, RTTs have been modeled to deliver the whole thermal demand of a building. Oversizing RTTs should be avoided both due to installation costs and efficient operations, and keeping the incumbent energy source for peak load operations may offer higher profitability. Partial-load strategies, such as the RTT providing thermal services to parts of the building or during parts of the year have not been included in the general competition and sensitivity analyses.

To gain insight into the economic implications of dimensioning the RTT for partial load, the RTT still being the primary thermal energy source, calculations have been done for residential GSHPs and ASHPs dimensioned for 60 percent of peak heating load. An installed capacity of 60 percent of peak heating load can typically deliver 80 percent of the demand for space heating due to the shape of the thermal demand curve over the year. The incumbent fuel oil boiler is used on the coldest days. The results are indicated by Figure 30 and 31.

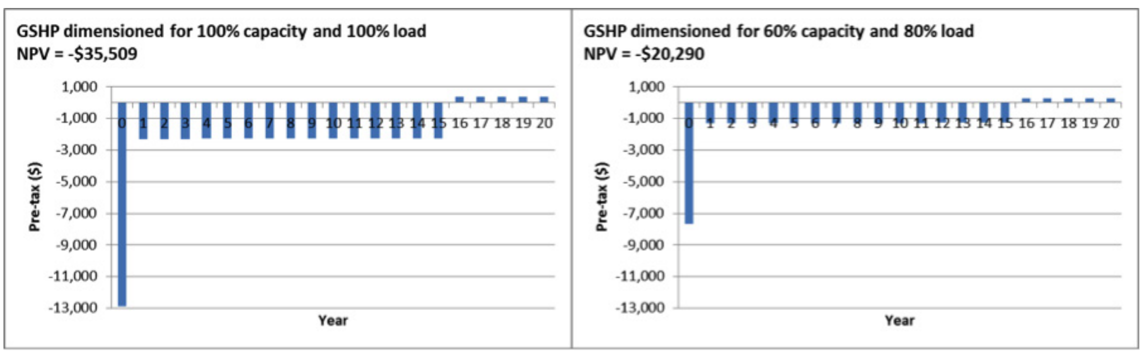


Figure 30 | Net present value and cash flow for a residential GSHP replacing fuel oil for respectively full and partial load.

When dimensioning the residential GSHP for 60 percent of the estimated peak heating load instead of 100 percent, the customer can save on installation costs. This can be seen from Figure 30, as the initial costs of year 0 change from just below $13,000 to $7,600. This case study shows an improvement in NPV of some 40 percent.

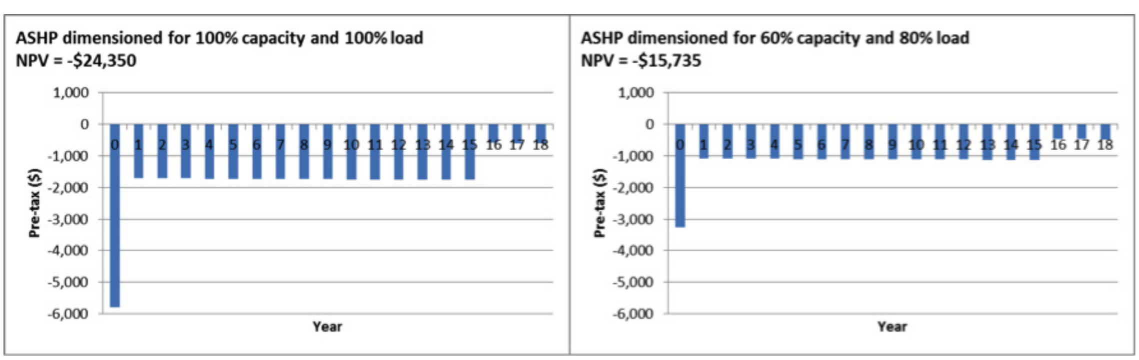


Figure 31 | Net present value and cash flow for a residential ASHP replacing fuel oil for respectively full and partial load.

When dimensioning the residential ASHP for 60 percent of estimated peak heating load instead of 100 percent, the customer can save on installation costs. This can be seen from Figure 31, as the initial costs of year 0 change from just below $6,000 to just above $3,200. The case studied shows an improvement in NPV of some 35 percent.

Allowing for strategies where the RTT is supplemented by the incumbent thermal technology at peak thermal demand will often improve the financial case.

6.3—Carbon Pricing

"The "social cost of carbon" (SCC) is a concept that reflects the marginal external costs of emissions; it represents the monetized damage caused by each additional unit of carbon dioxide, or the carbon equivalent of another greenhouse gas, emitted into the atmosphere." [72]

Many countries have begun accounting for the SCC in regulatory decisions and implementing market mechanisms to incentivize individuals and organizations to consider the full costs of their action on society. Examples include carbon taxes, or cap-and-trade systems, like the Regional Greenhouse Gas Initiative (RGGI) of the Northeast and Mid-Atlantic States of U.S. and the European Emissions Trading System (EU ETS).

The EPA and other federal agencies use the SCC to estimate regulatory climate benefits.[73] In our study we have included a carbon price corresponding to the EPA SCC with a 3 percent discount rate:

- A carbon price of $41 per metric ton $CO_{2}e$[74]
- The carbon price is applied over the whole lifetime of the asset
- An annual escalation rate of 1.9 percent

Table 19 shows the implication for RTT competitiveness of a carbon price as described above.[75]

72 Kotchen, Matthew J. (2016): Which social cost of carbon? A theoretical perspective. National Bureau of Economic Research, Working Paper 22246

73 https://www.epa.gov/climatechange/social-cost-carbon

74 United States central estimate for 2015 (Interagency Working Group 2013)

75 For reasons spelled out in footnote 43 in Chapter 3.3, DEEP maintains that the cost-competitiveness benefits described here as accruing to biomass from SCC are not reliable.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 19 | Sensitivity analysis for a carbon pricing alternative. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

The main implications of a carbon price corresponding to the SCC are:

- Biomass pellets to replace fuel oil for space heating and hot water will be competitive across all customer categories.
- Heat pumps to replace conventional electric technologies for space heating and cooling will be competitive in a few additional customer categories.

The influence on the economics of RTTs depends on the set value of the carbon price, but it is undoubtedly a positive point of leverage for changing the relative operational fuel costs in favor of low-emitting technologies. However, the carbon price has to be around $90 per metric ton CO_{2e} to have the same impact on the competitiveness of RTTs in the analyzed customer segments as a 25 percent increase in fossil fuel prices.

6.4—Thermal Renewable Energy Certificates

The electric supply and distribution companies in Connecticut are mandated to meet a Renewable Portfolio Standard (RPS) requirement of 27 percent renewable electricity generation by 2020. The RPS generally does not create Renewable Energy Credits (RECs) for renewable thermal energy.

While a carbon price assigns a cost on the use of polluting technology, a REC awards the use of clean technologies and establishes an avoided cost of carbon. As of April 2016, 12 states have included renewable thermal technologies in their RPS, with variations over which technologies have been included, how performance is measured and monitored, how the thermal energy is valued, and how it is classified in the RPS.[76]

Regionally, New Hampshire has created a separate sub-category for RTTs in its RPS: TRECs. Electricity producers are now required to generate or acquire equivalent thermal RECs as part of their renewable energy portfolio. Massachusetts has created an Alternative Energy Portfolio Standard (APS) generating Alternative Energy Credits (AEC) for a range of RTTs. Massachusetts' APS is distinct from the RPS, but essentially acts as a separate tier.

76 http://www.cesa.org/assets/Uploads/Renewable-Thermal-in-State-RPS-April-2015.pdf

In our study we have included a TREC based on the experience of New Hampshire:

- One TREC is valued as the equivalent of 1 MWh. The drive energy of heat pumps is deducted in determining the TREC
- A TREC is priced at $25 per MWh[77]
- TRECs are given for a period of 15 years
- The TREC price escalates at an annual rate of 1 percent

Providing a monetary incentive under a state RPS requirement could influence the economics of RTTs and offer incentives to utilize resources across businesses.

Table 20 shows the implication for RTT competitiveness of a TREC, as described above.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							

77 The rate of TRECs in New Hampshire, as of 2016 is $25/MWh. http://www.puc.state.nh.us/sustainable%20energy/renewable_portfolio_standard_program.htm

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 20 | Sensitivity analysis for a TRECs alternative. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

The influence on the competitiveness of RTTs depends on the value of the TREC, but it is undoubtedly a positive point of leverage to change the relative operational fuel costs in favor of low-emitting technologies. The impact on the competitiveness of RTTs of a TREC of \$25 per MWh seems to be similar to a carbon price of \$41 per metric ton CO_2e in our analysis.

Representing technologies that can be measured with some degree of certainty, TRECs not only can be an instrument to fund larger installations, such as thermal loops and industrial fuel switching, but smaller projects through aggregation. Including TRECs would equate renewable energy from thermal technologies with renewable energy from electricity generation, which would make private investors optimize between thermal and electrical energy.

6.5—Financial Terms

Financial terms can reduce barriers to RTTs such as high upfront costs, financing costs, awareness, and risk through trust in the technology. This can involve low interest rates, longer debt terms, and conditions to make the investment cash flow positive for the customer.

Table 21 shows the impact of a reduction of the debt interest rate by 25 percent, from 3.5 to 2.6 percent, in the residential sector, and from 4 to 3 percent for commercial customers (with a 15-year debt term). As a comparison, the current interest rate of a residential Smart-e loan is 2.99 percent over 10 years, and 5 percent over 10 years for commercial PACE.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 21 | Sensitivity analysis for a 25 percent reduction of debt interest rates. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

Table 22 shows the impact of an increase of debt term by 25 percent, limited by the economic life of the asset.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 22 | Sensitivity analysis for an increase of debt term. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

From a purely economic point of view, the implication of reducing the debt interest rate and increasing the debt term seems to be small. Reducing the debt interest rate makes biomass competitive in the residential sector and ASHPs with ductwork competitive in additional commercial segments.

Although not the most impactful parameters on NPV, financial terms matter to the customers for other reasons. Favorable financing terms through a recognized organization:

- reduce the risk for private lenders, and the project can achieve lower rates on other loans.
- give attention and credibility to the technology.
- qualify the technology as an environmentally friendly technology.

6.6—Sets of Simultaneous Changes

Larger market impact and probability for success can be achieved through intervention on several parameters at a time. The impact of sets of simultaneous changes has been analyzed for the following packages of measures and technologies.

PACKAGE 1:
INCREMENTAL INITIAL COSTS, FUEL COSTS, AND CARBON PRICE

- Incremental initial costs 25 percent lower
- Solar PV reduces electricity costs of heat pumps and SHW by 25 percent
- Pellets prices 25 percent lower
- Carbon price of $120 per tCO_2

PACKAGE 2:
INCREMENTAL INITIAL COSTS, SOLAR PV, AND INCREASED FOSSIL FUEL COSTS

- Incremental initial costs 25 percent lower
- Solar PV reduces electricity costs of heat pumps and SHW by 25 percent
- Fossil fuel costs 50 percent higher

Table 23 shows the impact of changing several variables at the same time: initial costs, solar PV, lower pellet prices, and a carbon price. Table 24 shows the impact of changing several variables at the same time: initial costs, solar PV, and increased fuel costs for the fossil fuels.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 23 | Sensitivity analysis for sets of simultaneous changes in initial costs, solar PV for heat pumps, and carbon price. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

PROPOSED THERMAL TECHNOLOGY	INSTEAD OF	SINGLE-FAMILY	MULTI-FAMILY	EDUCATION	FOOD SERVICE	HEALTH	HOTEL	OFFICE
ASHP space heating and cooling with no ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP space heating and cooling with ductwork needed	Electricity							
	Fuel Oil							
	Natural Gas							
ASHP water heating	Electricity							
	Fuel Oil							
	Natural Gas							
GSHP space heating and cooling	Electricity							
	Fuel Oil							
	Natural Gas							
Solar Hot Water	Electricity							
	Fuel Oil							
	Natural Gas							
Biomass space heating and hot water	Fuel Oil							
	Natural Gas							
Highly efficient natural gas	Electricity							
	Fuel Oil							
	Natural Gas							

Table 24 | Sensitivity analysis for sets of simultaneous changes in initial costs, solar PV for heat pumps, and increased fuel costs incumbent case. Green cells indicate cases with positive NPV in the base case and orange cells indicate cases that turn positive in the sensitivity analysis.

- Combinations of market interventions are necessary to make heat pumps competitive against fuel oil.
- Natural gas is persistently the most economically favorable alternative for space and water heating.

6.7—Implications for Cash Flow

Net present value, payback, and internal return will indicate to what extent a project is economically favorable. As the future is uncertain, the implications on cash flow may be more interesting for the customer than NPV: How much money will I have to pay "net out of pocket" annually with this alternative compared to that? This can be illustrated with the single-family home category replacing conventional electric technologies with GSHPs for space heating and cooling, as shown by Figure 32. The cash flow over the lifetime of the project (20 years) is shown for 4 cumulative steps:

1. The base case analysis for the single-family home installing a GSHP for space heating and cooling instead of conventional electric heating and traditional air conditioning shows a positive NPV of $5,600. However, due to a 70 percent loan ratio, the customer has an initial cash payment of around $14,000 that has to come from his or her savings.

2. If, however, the initial incremental installation costs had been 25 percent lower, e.g. as a consequence of a grant, a "Thermalize" campaign, combinations of both, etc., the project would be economically more favorable and the initial cash payment would be $3,500 lower than for the base case. The customer would need 25 percent less savings to quality for a loan requiring 30 percent equity.

3. If, in addition to the 25 percent lower initial incremental installation costs, the customer had leased a solar PV installation at a rate 25 percent lower than the electricity prices from the electric grid, the GSHP would be considerably more economically favorable. The customer would be able to benefit from lower operational costs without increasing the need for raising capital upfront.

4. All prior steps imply that the customer has to raise capital upfront as the project is funded at a 70 percent debt ratio. Not all customers are able or willing to invest large amounts upfront, e.g. because they do not have the capital, they prefer constant and predictable payments, or they do not know how long they will stay in the house. The design of financial products, such as leasing, EPC, PACE, and on-bill financing, can overcome these barriers. As can be seen from the 100 percent debt ratio case, the cash-flow has shifted to positive for all years. The annual net benefit is somewhat lower for case 4 than case 3, but still favorable with a positive NPV.

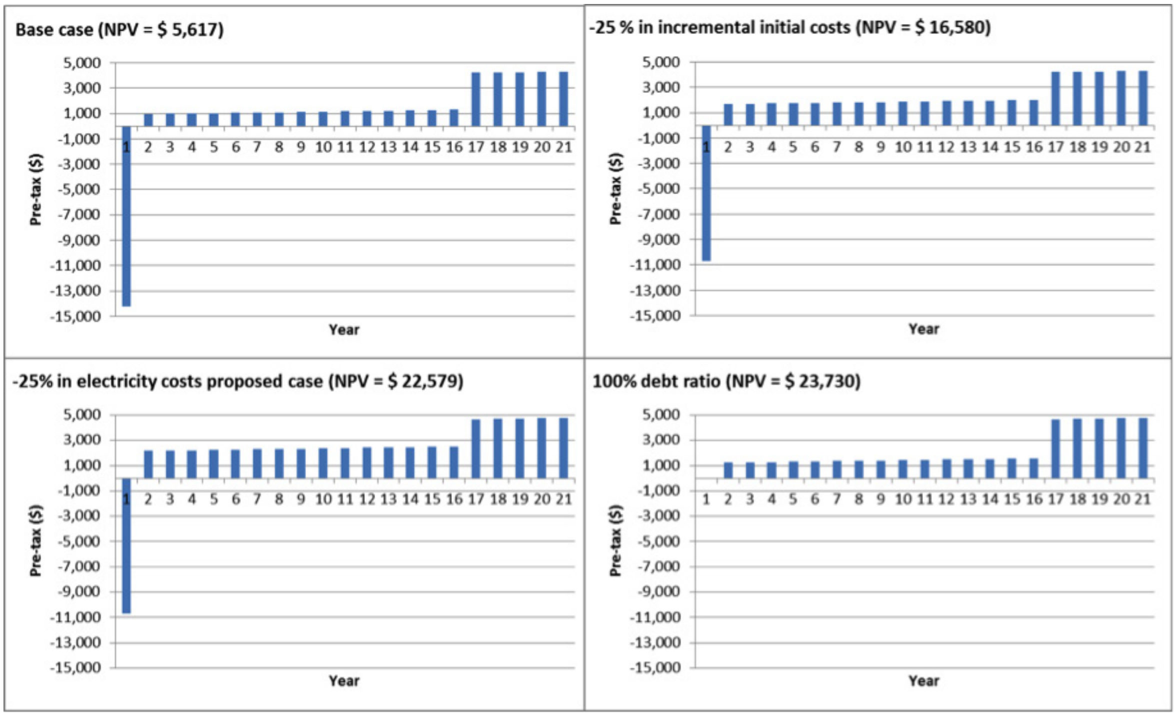


Figure 32 | Cash flow analysis. Single-family home replacing electricity with GSHP for space heating and cooling.

This example shows how combinations of marketing campaigns, financial products, and energy technologies can contribute to the attractiveness of RTTs.

CHAPTER 7
Recommendations

The market potential for RTTs remains considerable through 2050, and a high RTT deployment rate is needed to achieve the 2050 GHG emission targets. Several RTTs are currently challenged by unfavorable economics and non-economic barriers. To bring the market for RTTs to a scale capable of providing major contributions to reducing GHG emissions, a bundle of measures is needed.

While the companion field study[78] recommends a wide range of strategies and measures to break down barriers and build up drivers, the following recommendations focus specifically on market interventions directly targeting the technical potential and financial competitiveness of RTTs.

1. **Reduce upfront costs.** Initial installation costs have large impacts on RTT economics and how much capital the customer has to raise upfront. Initial installation costs are higher for RTTs than for the alternatives, and lower initial installation costs would considerably enhance favorability. The following market strategies would contribute to reducing the barrier of high upfront costs:
   - Cost reduction campaigns à la Solarize[79] that make RTTs more competitive with conventional thermal technologies, as shown in 6.2.1.
   - Partial-load strategies: using RTTs to displace most of the thermal demand for space heating but not requiring them to cover 100 percent of the capacity needed for the peak demand generally improves the financial evaluation, as shown in 6.2.2.
   - New business and financing models removing upfront costs and securing 100 percent financing: loans, leases, and property assessed clean energy (PACE) financing. This is illustrated by the cash-flow analysis in 6.7, where the need to raise money up front is leveled out.

2. **Implement market interventions to improve the operational cash flow.** The analysis shows that fuel costs have a large impact on the financial feasibility of RTTs. Strategies to reduce the operational costs of RTTs relative to the alternatives using fossil fuels would favor the cleaner technologies; so would strategies to establish revenue streams:
   - Packaging RTTs with solar PV and deep renovation may improve the economics, as shown solar PV in 6.1.4.
   - Favorable financing—interest rates and debt term—that reduces risk for private lenders, gives credibility to the technology, and qualifies it as environmentally friendly. This has been discussed in 6.5.

78 Grønli, Helle; Joseph Schiavo, Philip Picotte and Amir Mehr (2017): Feasibility of Renewable Thermal Technologies in Connecticut. A field study on barriers and drivers.

79 Solarize CT is a community-based program that leverages social interaction to promote the adoption of solar through a group-pricing scheme to reduce soft costs.

- Carbon pricing, as discussed in 6.3, would provide leverage for changing the relative operational fuel costs in favor of RTTs.
- Thermal Renewable Energy Certificates (TRECs), discussed in 6.4, reward the use of clean technologies much as a carbon price would.
- Explore rate mechanisms that recognize the value of RTTs in reducing demand for natural gas and electricity.

3. **Enhance awareness of—and trust in—RTTs through marketing efforts, trusted messengers, and proven installations.** Strategies include:
    - Performance verification through metering and monitoring to show that the technologies deliver as promised. Over- or underperformance would have implications similar to those illustrated by the fuel cost sensitivities discussed in 6.1. Performance verification would facilitate new revenue streams and business models, such as Thermal Renewable Energy Certificates, third-party ownership, green bonds, and Energy Performance Contracts. The level of required accuracy would influence the additional cost. We recommend evaluating the cost-benefits of various methods for performance verification with respect to the purpose it will serve, differentiated by customer segments.
    - Green Bank involvement, which enhances credibility, as discussed in 6.5.
    - Declining block grants[80] enhance the competitiveness of RTTs through a reduction of the incremental initial costs, as shown by Chapter 6.2.1.

4. **Use the building code and building standards to establish a predictable minimum market for RTTs.** In addition to stricter requirements for the building envelope (see Chapter 4), which eventually will favor low-temperature solutions such as heat pumps, the code can signal clearly which energy systems to install and which to avoid in new buildings. This will help attain the GHG emission targets as discussed in 5.3, and we recommend evaluating the possibilities of using the building code to:
    - Avoid oil boilers in new construction.
    - Establish a minimum efficiency level for fossil fuel boilers.
    - Require a share of renewable heating and cooling in new construction.

This market potential study has not evaluated the feasibility of district energy. District energy and thermal grids may represent opportunities for cheap and clean thermal energy, exploiting waste energy from electricity generation and industrial processes. The field study on barriers and drivers does provide some recommendations to promote thermal grids.

80 Declining block grants are grants and rebates that decrease over a certain time period according to a pre-determined profile.

This study has revealed some areas where further research could be valuable:

- An evaluation of where limited bioenergy resources would bring the highest value: transportation, electricity generation, or heating buildings and processes.
- A quantification of GHG emission factors across all energy sources specific for Connecticut or New England.
- Demand and generation profiles of different energy technologies and their interaction with the electricity and natural gas grids.

Appendices

APPENDIX A
Assumptions for the Competition Analysis

Building Size and Efficiency

		RESIDENTIAL		COMMERCIAL				
		SINGLE FAMILY	APARTMENT	HOTEL	OFFICE	HOSPITAL	EDUCATION	FOOD SERVICES
Building size (sq ft)[1]		2000	29063	119479	48438	201554	38750	5651
Energy Use Intensities (MBTU/ year/ sq ft)[2]	**Space heating**	46.4	58.5	25.8	33.4	112.7	61.5	58.9
	Space cooling	1.4	1.7	1.7	7.1	10.4	3.1	3.5
	Hot water	5.6	7.3	31.7	3.3	39.6	7.2	31.1
Peak load (kW)[3]	**Space heating**	15	328	637	363	4383	427	83
	Space cooling	1	20	82	126	468	59	7
	Hot water	4	86	841	30	1489	80	48
Annual demand (MMBTUs)[4]	**Space heating**	79	1701	3081	1618	22722	2385	333
	Space cooling	3	49	199	344	2086	120	20
	Hot water	11	213	3787	162	7978	280	176

Table 25 | Building Size and Efficiency

1. The average building size of different categories have been informed by the Connecticut Program Savings Document for 2016, RECS 2009, and CBECS 2003.
2. The Energy Use Intensities have been informed by the Connecticut Program Savings Document for 2016, RECS 2009, and CBECS 2003 (adjusted for the energy efficiency rate from the reference case of the Annual Energy Outlook 2015).
3. The peak load has been elaborated based on the estimated annual thermal demand and hours of utilization time from the Connecticut Program Savings Document for 2016.
4. The annual demand has been estimated based on the building size and the EUIs.

The following dimensioning rules have been applied to the case studies:

- For technologies delivering both space heating and hot water, the peak load for space heating has generally defined the installed capacity. The installation costs for the largest users of hot water—Food Service, Health Care, and Hotel—have been increased by 50 % of the needed capacity to capture hot water.
- For technologies delivering both space heating and cooling, the peak load for space heating has defined the installed capacity.

Cost and Efficiency Assumptions

TECHNOLOGY	SECTOR	INSTALLED COST PER KW ($/KW)[1]	EFFICIENCY[2]	FUEL BTU CONTENT[3]	FUEL COSTS[4]	FUEL COST ESCALATOR[5]	PROJECT LIFE[6]	COMMENT
Natural gas (standard)	Residential	255	82%	1028 Btu/ft3	11.82 $/ thousand ft3	1.6%	20	
	Commercial	255	82%		8.18 $/ thousand ft3	1.6%	30	
Natural gas (highly efficient)	Residential	470	95%		11.82 $/ thousand ft3	1.6%	As proposed case	
	Commercial	470	95%		8.18 $/ thousand ft3	1.6%		
Ductwork[7]	Residential	560						
	Commercial	660						
Electric water heater	Residential	500 $/unit	0.71 energy factor	3412 Btu/kWh	0.209 $/kWh	0.6%	10	
	Commercial							
Electric cooling	Residential	320	SEER 13	3412 Btu/kWh	0.209 $/kWh	0.6%	As proposed case	
	Commercial	320	EER 11		0.1595 $/kWh	0.6%		
Fuel oil	Residential	255	84%	0.1371 mmBtu/gal	1.96 $/gal	0.7%		
	Commercial	255	84%		1.96 $/gal	0.7%		
ASHP	Residential	1100	200% for heating. 18 SEER	3412 Btu/kWh	0.209 $/kWh	0.6%	18	
	Commercial	1100	200% for heating. 18 SEER		0.1595 $/kWh	0.6%	18	
ASHP water heater	Residential	1100 $/unit	2.0 energy factor		0.209 $/kWh	0.6%	10	
	Commercial					N/A	N/A	
GSHP	Residential	2110	300% for heating / cooling 15.1 EER (22.61 SEER)	3412 Btu/kWh	0.209 $/kWh	0.6%	20	
	Commercial	2010	300 % for heating / cooling 15.1 EER (22.61 SEER)		0.1595 $/kWh	0.6%	25	
Biomass pellets	Residential	920	80%	7750 Btu/lb	$260 / ton	260	20	Storage included
	Commercial	790	85%		$230 / ton	230	25	
SHW	Residential	960 $/ m2 aperture	2.5 SEF	0.35 kWh/ ft2/day	0.209 $/kWh	0.6%	20	
	Commercial	1440 $/m2 aperture	2.5 SEF		0.1595 $/kWh	0.6%	20	

Table 26 | Installation costs, efficiency, fuel BTU content, fuel prices, and project life per technology

1. The installation costs have been informed by regional project data provided by the CT Green Bank, Massachusetts Clean Energy Center, New Hampshire Public Utilities Commission, Vermont Public Services Department, and the Northern Forest Center. In addition, we have consulted the RETScreen cost database, the report “Massachusetts renewable heating and cooling opportunities and impacts study” (Meister Consulting Group 2012), and the report “Research on the costs and performance of heating and cooling technologies” (Sweett, 2013). See Appendix C.
2. The efficiencies of different technologies have been informed by the CT Program Savings Document, the RETScreen database, Massachusetts Clean Energy Center central biomass program, and Energize CT.
3. The fuel BTU content is from the Annual Energy Outlook 2015.
4. The fuel costs have been informed by the Energy Information Agency SEDS and the regional project portfolio.
5. The fuel costs escalators have been derived from the reference case of the Annual Energy Outlook 2015.
6. The project life of different technologies has been informed by the CT Program Savings Document 2016 and the Annual Energy Outlook 2015. The project life for the incumbent technology follows the project life of the proposed technology in our financial calculations.
7. The term “Ductwork” is used for all necessary retrofit of thermal infrastructure.

TECHNOLOGY	SECTOR	INCREMENTAL COST OVER INCUMBENT ALTERNATIVE ($/KW) OR ($/M2 APERTURE)			
		NATURAL GAS	ELECTRIC	FUEL OIL	AC
Natural gas (highly efficient)	Residential	215	1030	215	
	Commercial	215	1030	215	
ASHP no ductwork	Residential	1100	1100	1100	-320
	Commercial	1100	1100	1100	-320
ASHP ductwork	Residential	1660	1660	1660	-320
	Commercial	1760	1760	1760	-320
ASHP water heater	Residential	600 /unit	600 /unit	600 /unit	
	Commercial				
GSHP	Residential	2415	2670	2415	-320
	Commercial	2415	2670	2415	-320
Biomass pellets	Residential	665	1480	665	
	Commercial	535	1450	535	
SHW	Residential	960	960	960	
	Commercial	1440	1440	1440	

Table 27 | Incremental installation costs per installed kW, unit or aperture

PROPOSED TECHNOLOGY	BASE TECHNOLOGY	RESIDENTIAL ($PER UNIT)		COMMERCIAL ($PER UNIT)				
		SINGLE FAMILY	APARTMENT	HOTEL	OFFICE	HOSPITAL	EDUCATION	FOOD SERVICES
Natural gas (highly efficient)	Electricity	18,437	337,903	719,484	410,082	4,952,593	482,277	94,108
	Natural gas	3,849	70,533	136,893	78,024	942,308	91,761	17,905
	Fuel oil	3,849	70,533	136,893	78,024	942,308	91,761	17,905
ASHP no ductwork	Electricity	19,333	359,660	674,065	358,777	4,671,453	450,465	89,391
	Natural gas	19,333	359,660	674,065	358,777	4,671,453	450,465	89,391
	Fuel oil	19,333	359,660	674,065	358,777	4,671,453	450,465	89,391
ASHP ductwork	Electricity	29,357	543,375	1,094,294	598,294	7,564,119	732,149	144,356
	Natural gas	29,357	543,375	1,094,294	598,294	7,564,119	732,149	144,356
	Fuel oil	29,357	543,375	1,094,294	598,294	7,564,119	732,149	144,356
ASHP water heater	Electricity	600						
	Natural gas							
	Fuel oil							
GSHP	Electricity	47,794	875,923	1,700,019	968,955	11,702,146	1,139,538	222,361
	Natural gas	42,871	791,061	1,511,340	835,996	10,434,870	1,011,698	198,906
	Fuel oil	42,871	791,061	1,511,340	835,996	10,434,870	1,011,698	198,906
Biomass pellets	Electricity	26,492	485,530	923,231	526,211	6,355,098	618,850	120,758
	Natural gas	11,904	218,161	340,641	194,154	2,344,812	228,334	44,555
	Fuel oil	11,904	218,161	340,641	194,154	2,344,812	228,334	44,555
SHW	Electricity	5,135	117,642	1,732,342	65,578	3,065,587	169,409	99,101
	Natural gas	5,135	117,642	1,732,342	65,578	3,065,587	169,409	99,101
	Fuel oil	5,135	117,642	1,732,342	65,578	3,065,587	169,409	99,101

Table 28 | Incremental installation costs per installed system

	END USES	DUCTWORK NECESSARY	STATUS OF TECHNOLOGY	DISPLACES EXISTING TECHNOLOGY
Natural gas (highly efficient)	Space heating; Hot water	No	Primary	Yes
ASHP no ductwork	Space heating; Space cooling	No	Supplementary	Incumbent as back up
ASHP ductwork	Space heating; Space cooling	Yes	Supplementary	Incumbent as back up
ASHP water heater	Hot water	No	Primary	Yes
GSHP	Space heating; Space cooling	Yes	Primary	Yes
Biomass pellets	Space heating; Hot water	No	Primary	Yes
SHW	Hot water	No	Supplementary	Incumbent as back up

Table 29 | Summary of assumptions determining incremental installation costs

	RESIDENTIAL		COMMERCIAL					IND
	SINGLE FAMILY	APARTMENT	HOTEL	OFFICE	HOSPITAL	EDUCATION	FOOD SERVICES	BAKERIES
Depreciation rate[1]	5.2%	5.2%	4.9%	5.8%	4.6%	5.4%	4.5%	4.7%
Debt interest rate[1]	3.5%	3.5%	3.5%	3.5%	3.5%	4.0%	3.5%	3.5%
Debt ratio	70%	70%	70%	70%	70%	70%	70%	70%
Inflation	2%	2%	2%	2%	2%	2%	2%	2%
Debt term	15 years	15 years	15 years	15 years	15 years	15 years	15 years	15 years

Table 30 | Summary of assumptions determining incremental installation costs

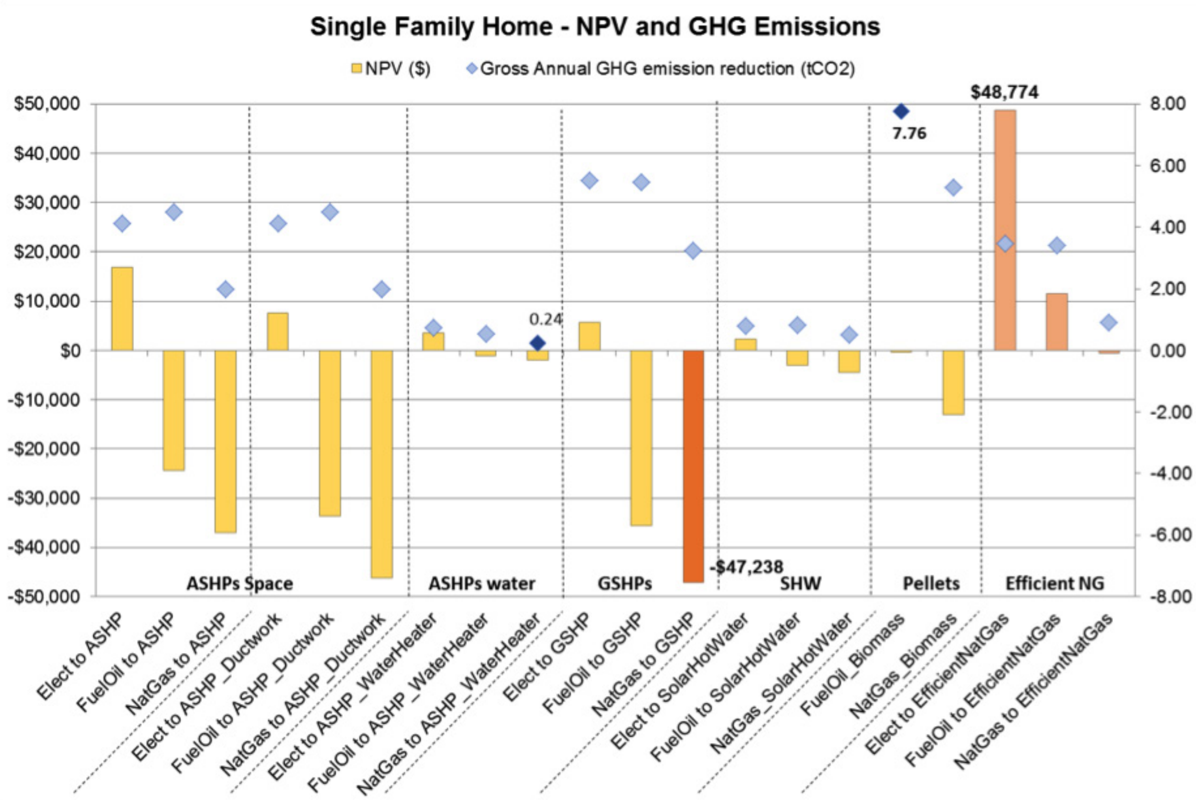
1. Informed by http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm.
The depreciation rate is the weighted average of the debt interest rate and the equity interest rate.

APPENDIX B
RETScreen Calculation Archetypes

Single Family Home (SFH)

MAIN FINDINGS

- All cases replacing electricity with ASHPs, SHW, or efficient natural gas boilers have a positive NPV
- The case with the highest NPV for SFH is replacing electricity with Efficient Natural Gas
- The case with the lowest NPV for SFH is replacing natural gas with GSHP
- The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
- The lowest GHG emission reductions result from replacing a standard natural gas boiler with an ASHP water heater



HOW TO READ THE FIGURE

- The cases are grouped by Proposed Case (RTT) and then organized based on the fuel used in the Base Cases (incumbent)
- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO2 equivalents (scatter marks)

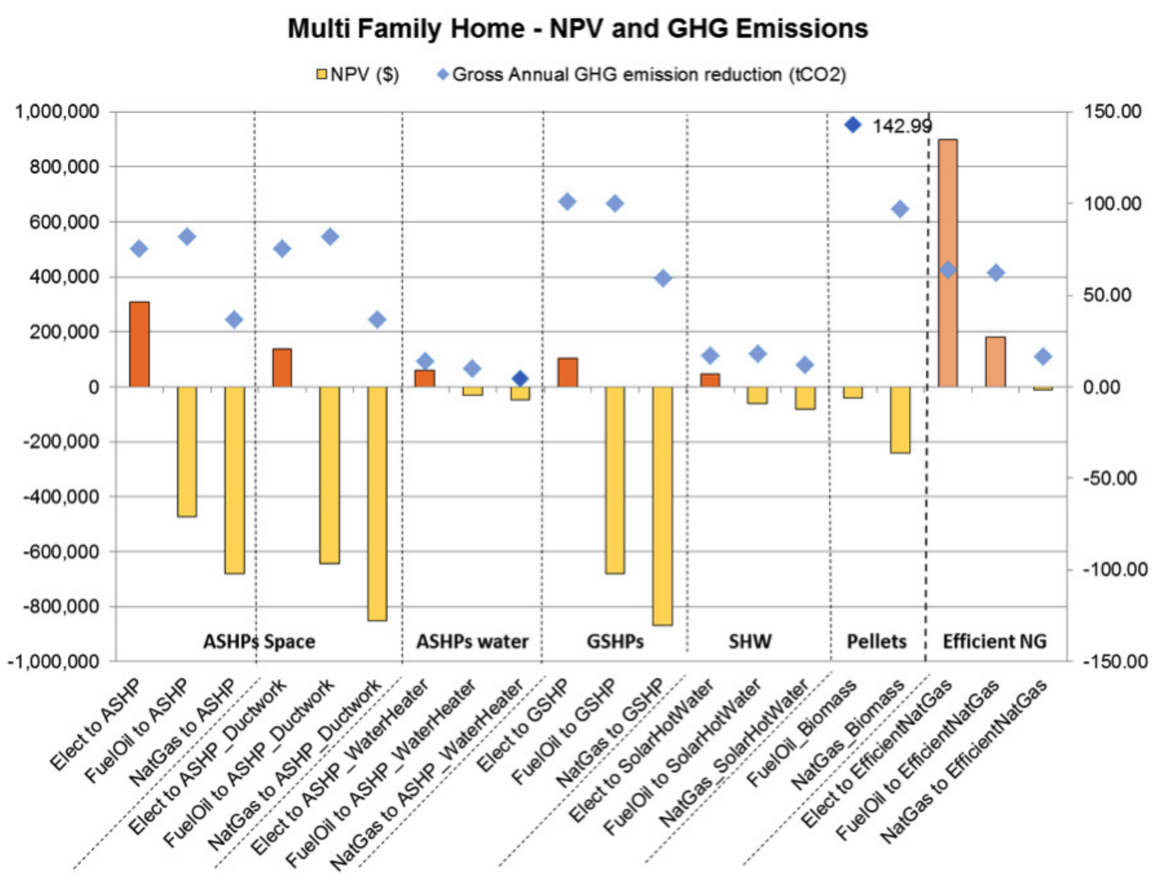
MAIN ASSUMPTIONS

1. Building size: 2,000 sq. ft.
2. Capacity needed for installation (kW):
   - 17.9 for proposed cases including space heating
   - 3.77 for proposed cases including water heating
   - 1.12 for proposed cases including cooling
3. Operating hours:
   - 1,519 hours per year for heating
   - 708 hours per year for cooling
4. Hot water:
   - 54.4 gallons per day used
   - 126 °F
   - 10% heat recovery efficiency
5. Annual demand (MMBTUs):
   - Space Heating: 92.8
   - Space Cooling: 2.7
   - Domestic Hot Water: 11.1
6. Incremental initial costs:
   - Electricity, Fuel oil or Natural Gas to ASHP: $19,332
   - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $29,356
   - Electricity, Fuel oil or Natural Gas to ASHP Water Heater: $600
   - Electricity to GSHP: $47,435
   - Fuel oil or Natural Gas to GSHP: $42,870
   - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $5,135
   - Fuel oil or Natural Gas to Biomass: $11,904
   - Electricity to Efficient Natural Gas: $18,437
   - Fuel oil or Natural Gas to Efficient Natural Gas: $3,849

Apartment—Multi Family Home (MFH)

MAIN FINDINGS

- Replacing electricity with heat pumps, SHW, or efficient natural gas boilers has a positive NPV
- The case with the highest NPV for SFH is replacing electricity with Efficient Natural Gas
- The case with the lowest NPV for MFH is replacing natural gas with GSHP
- The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
- The lowest GHG emission reductions result from replacing a standard natural gas boiler with an ASHP water heater



HOW TO READ THE FIGURE

- The cases are grouped by Proposed Case (RTT) and then organized based on the fuel used in the Base Cases (incumbent)
- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO2 equivalents (scatter marks)

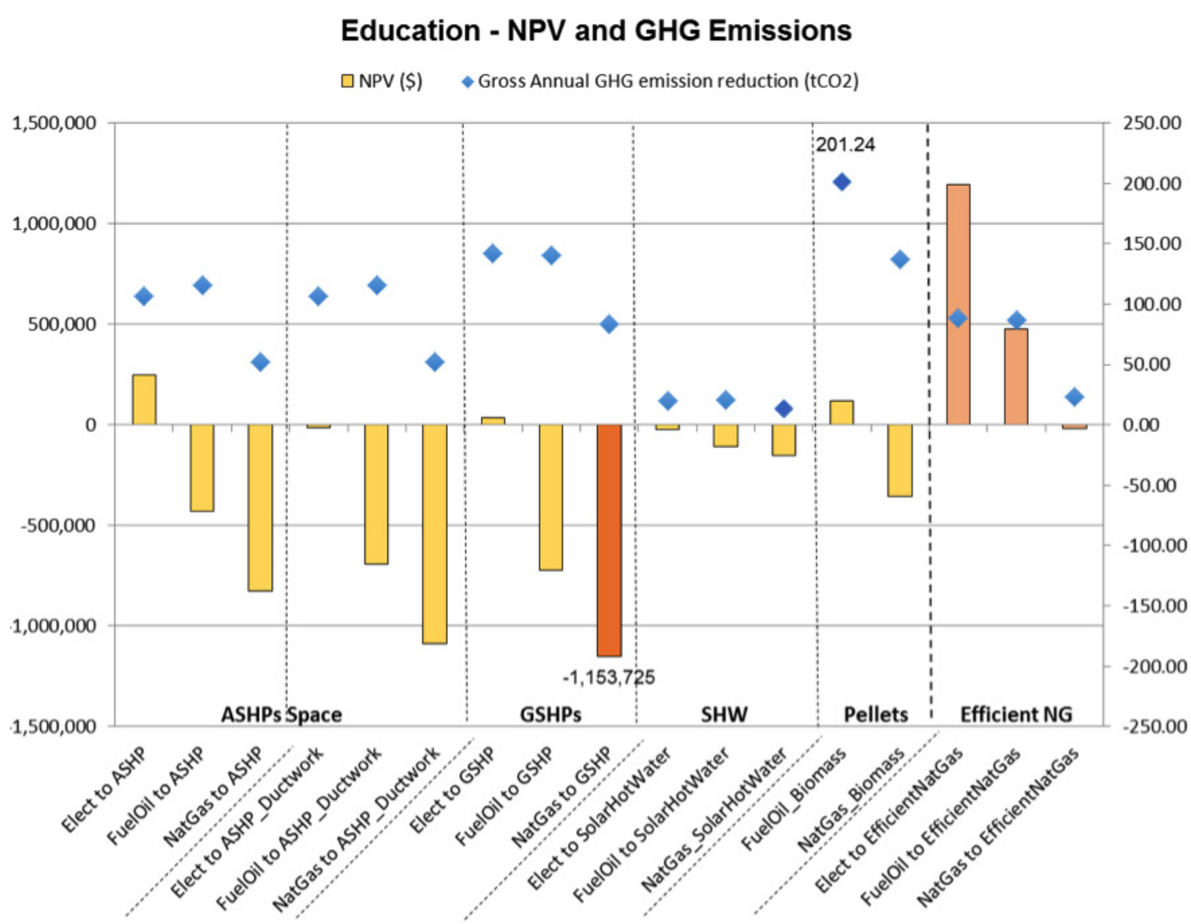
MAIN ASSUMPTIONS

1. Building size: 29,063 sq. ft.
2. Units: 33
3. Capacity needed for installation (kW):
    - 328 for proposed cases including space heating
    - 86 for proposed cases including water heating
    - 20 for proposed cases including cooling
4. Operating hours:
    - 1,519 hours per year for heating
    - 708 hours per year for cooling
5. Hot water:
    - 1,046 gallons per day used
    - 126 °F
    - 10% heat recovery efficiency
6. Annual demand (MMBTUs):
    - Space Heating: 1,700
    - Space Cooling: 48.3
    - Domestic Hot Water: 213
7. Incremental initial costs:
    - Electricity, Fuel oil or natural gas to ASHP: $354,294
    - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $538,080
    - Electricity, Fuel oil or Natural Gas to ASHP Water Heater: $19,800
    - Electricity to GSHP: $869,254
    - Fuel oil or Natural Gas to GSHP: $785,759
    - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $117,642
    - Fuel oil or Natural Gas to Biomass: $218,160
    - Electricity to Efficient Natural Gas: $337,840
    - Fuel oil or Natural Gas to Efficient Natural Gas: $70,520

Education

MAIN FINDINGS

1. The cases with a positive NPV include:
   - Electricity to GSHP
   - Fuel Oil to Biomass
   - Electricity to ASHP
   - Electricity or fuel oil to efficient natural gas (highest NPV)
2. The case with the lowest NPV for education is replacing natural gas with GSHP
3. The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
4. The lowest GHG emission reductions result from replacing a standard natural gas boiler with solar hot water



HOW TO READ THE FIGURE

- The cases are grouped by Proposed Case (RTT) and then organized based on the fuel used in the Base Cases (incumbent)
- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO2 equivalents (scatter marks)

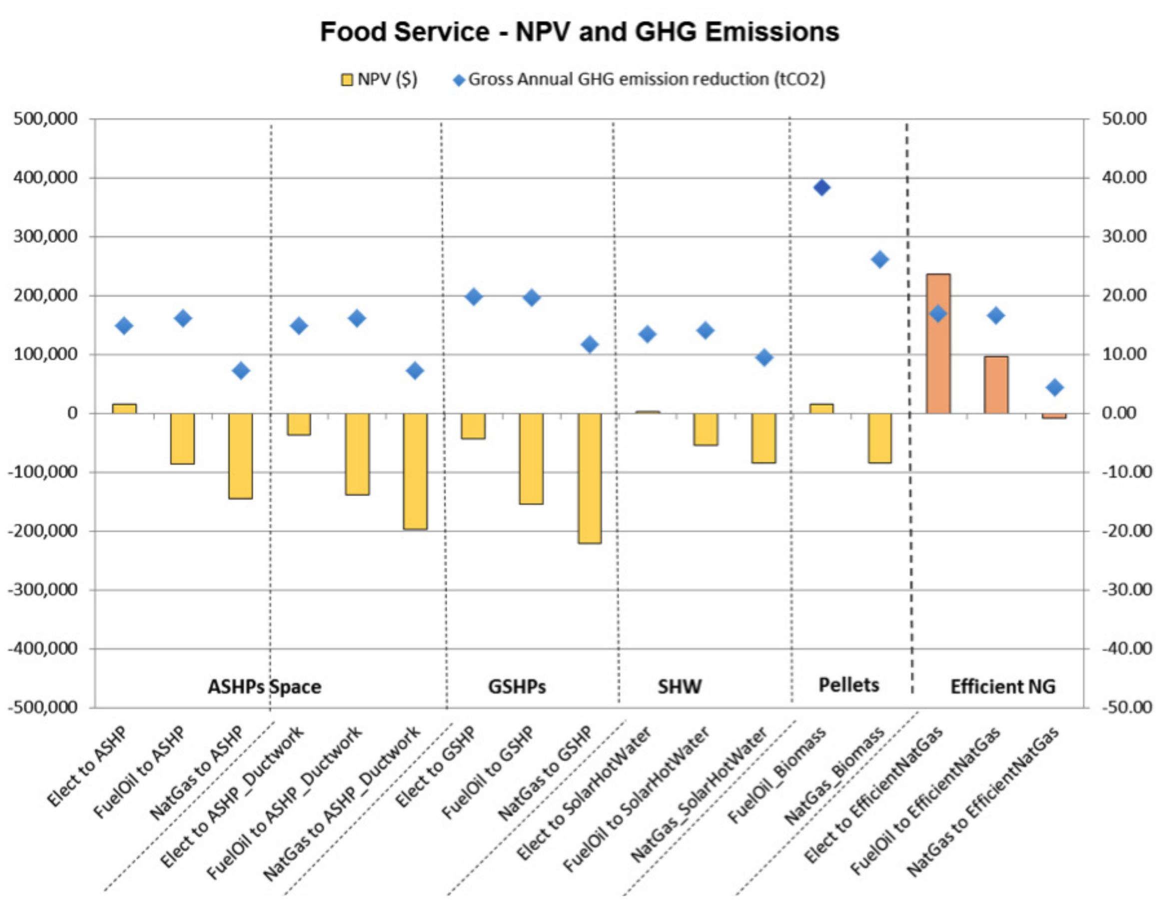
MAIN ASSUMPTIONS

1. Building size: 38,750 sq. ft.
2. Capacity needed for installation (kW):
   - 427 for proposed cases including space heating
   - 80 for proposed cases including water heating
   - 59 for proposed cases including cooling
3. Operating hours per year:
   - 1,637 hours per year for heating
   - 594 hours per year for cooling
4. Hot water:
   - 1,373 gallons per day used
   - 126 °F
   - 10% heat recovery efficiency
5. Annual demand (MMBTUs):
   - Space Heating: 2,384.5
   - Space Cooling: 120.42
   - Domestic Hot Water: 279.98
6. Incremental initial costs:
   - Electricity, Fuel oil or Natural Gas to ASHP: $450,820
   - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $732,640
   - Electricity to GSHP: $1,121,210
   - Fuel oil or Natural Gas to GSHP: $1,012,325
   - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $169,409
   - Fuel oil or Natural Gas to Biomass: $228,445
   - Electricity to Efficient Natural Gas: $439,810
   - Fuel oil or Natural Gas to Efficient Natural Gas: $91,805

Food Service

MAIN FINDINGS

1. The cases with a positive NPV include:
   - Electricity to Solar Hot Water
   - Electricity to ASHP
   - Fuel Oil to Biomass
   - Electricity or fuel oil to efficient natural gas (highest NPV)
2. The case with the lowest NPV for food service is replacing natural gas with GSHP
3. The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
4. The lowest GHG emission reductions result from replacing a standard natural gas boiler with an efficient natural gas boiler



HOW TO READ THE FIGURE

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- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO_2 equivalents (scatter marks)

MAIN ASSUMPTIONS

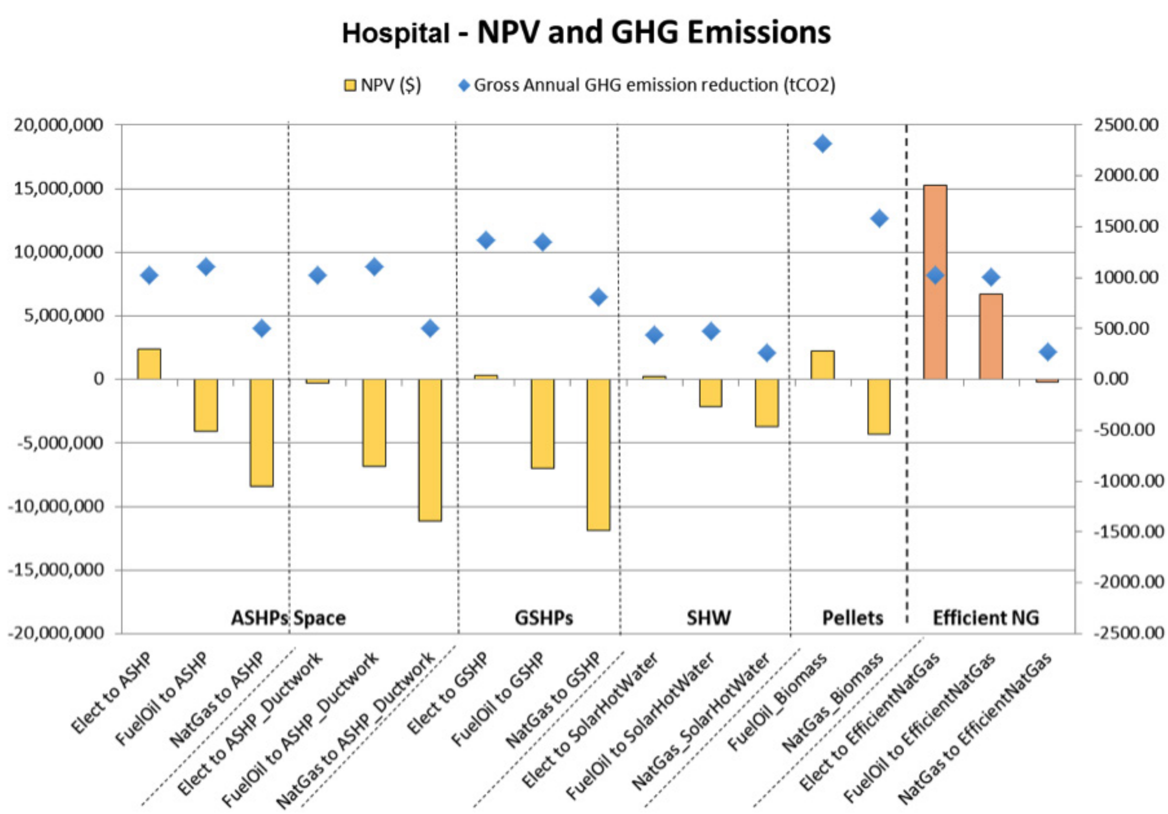
1. Building size: 5,651 sq. ft.
2. Capacity needed for installation (kW):
   - 83.28 for proposed cases including space heating
   - 48 for proposed cases including water heating
   - 7 for proposed cases including cooling
3. Operating hours per year:
   - 1,172 hours per year for heating
   - 837 hours per year for cooling
4. Hot water:
   - 862 gallons per day used
   - 126 °F
   - 10% heat recovery efficiency
5. Annual demand (MMBTUs):
   - Space Heating: 333.12
   - Space Cooling: 19.8
   - Domestic Hot Water: 175.75
6. Incremental initial costs:
   - Electricity, Fuel oil or Natural Gas to ASHP: $89,368
   - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $144,333
   - Electricity to GSHP: $220,118
   - Fuel oil or Natural Gas to GSHP: $198,881
   - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $99,101
   - Fuel oil or Natural Gas to Biomass: $44,555
   - Electricity to Efficient Natural Gas: $85,778
   - Fuel oil or Natural Gas to Efficient Natural Gas: $17,905

Hospital

MAIN FINDINGS

1. The cases with a positive NPV include:
   - Electricity to Solar Hot Water
   - Electricity to GSHP
   - Electricity to ASHP
   - Fuel Oil to Biomass
   - Fuel oil or electricity to efficient natural gas (highest NPV)

2. The case with the lowest NPV for hospital is replacing natural gas with GSHP
3. The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
4. The lowest GHG emission reductions result from replacing a standard natural gas boiler with solar hot water



HOW TO READ THE FIGURE

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- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO2 equivalents (scatter marks)

MAIN ASSUMPTIONS

1. Building size: 201,554 sq. ft.

2. Capacity needed for installation (kW):
    - 4,383 for proposed cases including space heating
    - 1,489 for proposed cases including water heating
    - 468 for proposed cases including cooling

3. Operating hours per year:
    - 1,519 hours per year for heating
    - 1,307 hours per year for cooling

4. Hot water:
    - 38,476 gallons per day used (for the cases from electricity, fuel oil or natural gas to solar hot water, natural gas to biomass, and natural gas to efficient natural gas)
    - 39,112 gallons per day used (for the cases from fuel oil to biomass and from electricity or fuel oil to efficient natural gas)
    - 126 °F
    - 10% heat recovery efficiency

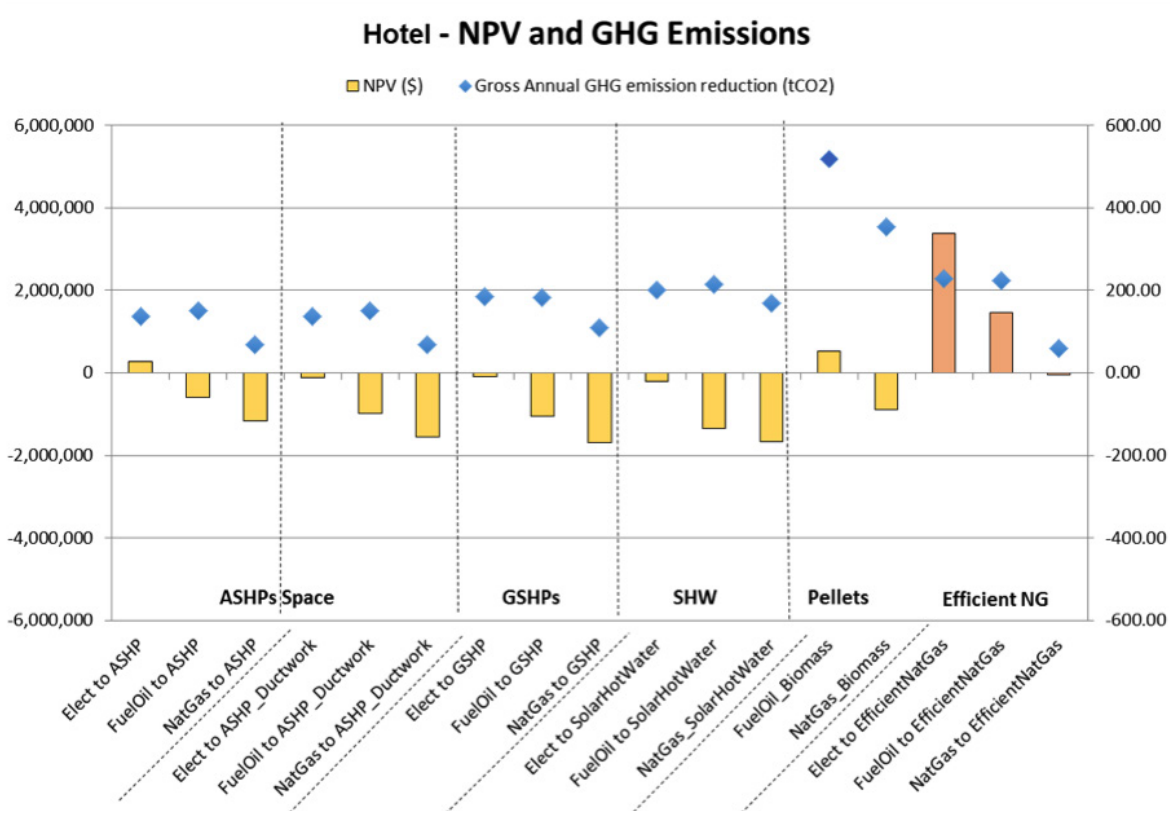
5. Annual demand (MMBTUs):
    - Space Heating: 22,721.88
    - Space Cooling: 2,086.17
    - Domestic Hot Water: 7,977.92

6. Incremental initial costs:
    - Electricity, Fuel oil or Natural Gas to ASHP: $4,671,540
    - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $7,564,320
    - Electricity to GSHP: $11,552,850
    - Fuel oil or Natural Gas to GSHP: $10,435,185
    - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $3,065,587
    - Fuel oil or Natural Gas to Biomass: $2,344,905
    - Electricity to Efficient Natural Gas: $4,514,490
    - Fuel oil or Natural Gas to Efficient Natural Gas: $942,345

Hotel

MAIN FINDINGS

1. The cases with a positive NPV include:
   - Electricity to ASHP
   - Fuel Oil to Biomass
   - Electricity, fuel oil or natural gas to efficient natural gas
2. The case with the highest NPV for hotel is replacing electricity with efficient natural gas
3. The case with the lowest NPV is replacing natural gas with GSHP
4. The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
5. The lowest GHG emission reductions result from replacing a standard natural gas boiler with an efficient natural gas boiler



HOW TO READ THE FIGURE

- The cases are grouped by Proposed Case (RTT) and then organized based on the fuel used in the Base Cases (incumbent)
- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO_2 equivalents (scatter marks)

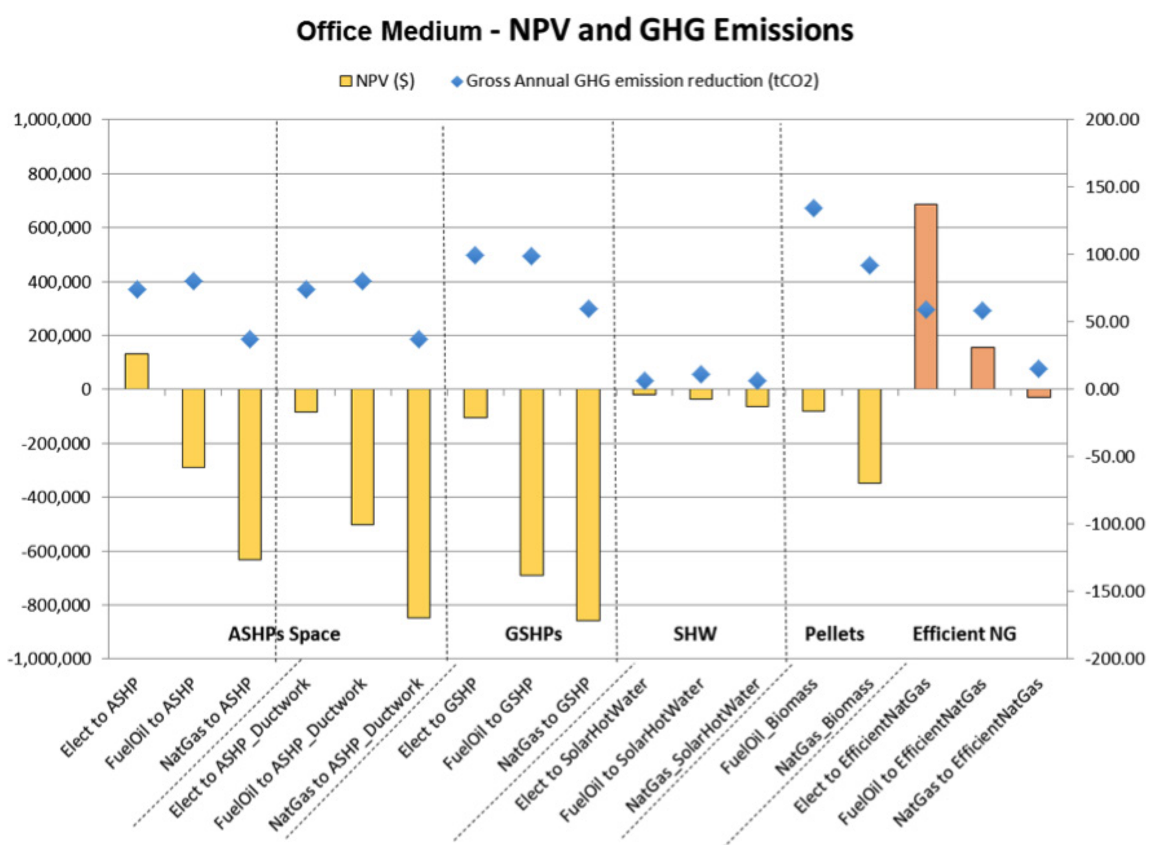
MAIN ASSUMPTIONS

1. Building size: 119,479 sq. ft.
2. Capacity needed for installation (kW):
   - 637 for proposed cases including space heating
   - 841 for proposed cases including water heating
   - 82 for proposed cases including cooling
3. Operating hours per year:
   - 1,418 hours per year for heating
   - 708 hours per year for cooling
4. Hot water:
   - 18,264 gallons per day used (for the cases from electricity, fuel oil, or natural gas to solar hot water)
   - 18,566 gallons per day used (for the cases from fuel oil or natural gas to biomass and from electricity, fuel oil, or natural gas to efficient natural gas)
   - 126 °F
   - 10% heat recovery efficiency
5. Annual demand (MMBTUs):
   - Space Heating: 3,081.42
   - Space Cooling: 198.73
   - Domestic Hot Water: 3,787
6. Incremental initial costs:
   - Electricity, Fuel oil or Natural Gas to ASHP: $674,460
   - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $1,094,880
   - Electricity to GSHP: $1,674,550
   - Fuel oil or Natural Gas to GSHP: $1,512,115
   - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $1,732,342
   - Fuel oil or Natural Gas to Biomass: $340,795
   - Electricity to Efficient Natural Gas: $656,110
   - Fuel oil or Natural Gas to Efficient Natural Gas: $136,955

Office Medium

MAIN FINDINGS

1. The cases with a positive NPV include:
   - Electricity to ASHP
   - Electricity or fuel oil to efficient natural gas
2. The case with the highest NPV for office medium is replacing electricity with efficient natural gas
3. The case with the lowest NPV is replacing natural gas with GSHP
4. The largest GHG emission reductions result from replacing fuel oil boilers with biomass boilers
5. The lowest GHG emission reductions result from replacing electricity with solar hot water



HOW TO READ THE FIGURE

- The cases are grouped by Proposed Case (RTT) and then organized based on the fuel used in the Base Cases (incumbent)
- The left y-axis shows the NPV amount in USD (bar chart)
- The right y-axis shows the gross annual GHG emission reduction as tons of reduced CO2 equivalents (scatter marks)

MAIN ASSUMPTIONS

1. Building size: 48,438 sq. ft.

2. Capacity needed for installation (kW):
    - 363 for proposed cases including space heating
    - 30 for proposed cases including water heating
    - 126 for proposed cases including cooling

3. Operating hours per year:
    - 1,306 hours per year for heating
    - 797 hours per year for cooling

4. Hot water:
    - 793 gallons per day used
    - 126 °F
    - 10% heat recovery efficiency

5. Annual demand (MMBTUs):
    - Space Heating: 1,617.6
    - Space Cooling: 343.6
    - Domestic Hot Water: 161.7

6. Incremental initial costs:
    - Electricity, Fuel oil or Natural Gas to ASHP: $358,980
    - Electricity, Fuel oil or Natural Gas to ASHP with ductwork: $598,560
    - Electricity to GSHP: $928,890
    - Fuel oil or Natural Gas to GSHP: $836,325
    - Electricity, Fuel oil or Natural Gas to Solar Hot Water: $65,578
    - Fuel oil or Natural Gas to Biomass: $194,205
    - Electricity to Efficient Natural Gas: $373,890
    - Fuel oil or Natural Gas to Efficient Natural Gas: $78,045

APPENDIX C
Cost Analysis

Project-specific installation costs for different RTTs have been provided by different program administrators across New England, as shown by Table 31.

TECHNOLOGY	YEARS OF DATA POINTS	MASSACHUSETTS	VERMONT	CONNECTICUT	NEW HAMPSHIRE
GSHP	**2010–2015**	Hard costs / Soft costs / Abnormal costs		Total costs / Abnormal costs	
ASHP	**2015**	Total costs			
Biomass	**2010–2015**	Hard costs / Soft costs / Abnormal costs	Total costs		Hard costs / Soft costs / Abnormal costs
Solar Thermal	**2009–2015**	Total costs	Total costs	Total costs	
Efficient Oil Boilers	**N/A**			Total costs	

Table 31 | Project-specific data available for the project

The resolution of the installation costs varies across states and technologies. Table 31 shows the available resolution of the costs. To the extent possible we differentiate between

- Hard costs—the costs of the equipment. Hard costs include equipment such as the central heater or cooler, collectors, drilling, bulk, and thermal storage.
- Soft costs—the costs of the installation work.
- Abnormal costs—the costs of necessary adaptations of the existing building and HVAC system. Examples of costs included in this category are upgrading distribution and ductwork.
- Total costs indicate that no differentiation has been made by type of costs.

The costs have been adjusted for inflation and are nominated by 2015 values. The cumulative rate of inflation was found through the US Inflation Calculator:[81]

- 2009–2015 10.5 %
- 2010–2015 8.7 %
- 2011–2015 5.4 %
- 2012–2015 3.2 %
- 2013–2015 1.7 %
- 2014–2015 0.1 %

The average installation costs per kW are shown by Table 32.

TECHNOLOGY	RESIDENTIAL			COMMERCIAL		
	Hard Costs ($/kW)	Soft Costs ($/kW)	Total Costs w/o ductwork ($/kW)	Hard Costs ($/kW)	Soft Costs ($/kW)	Total Costs w/o ductwork ($/kW)
GSHP	1,358	753	2,111	N/A	N/A	2,003
ASHP	N/A	N/A	1,089	N/A	N/A	N/A
Biomass	759	165	924	626	161	786
Solar Thermal	1,703	1,118	2,821	1,971	1,264	3,235
Efficient boilers	N/A	N/A	470	N/A	N/A	N/A
Ductwork	N/A	N/A	558	N/A	N/A	664

Table 32 | Average installation costs ($/kW) Renewable Thermal Technology projects in New England

- The installation costs for GSHPs in residential buildings are for retrofit projects. Due to a small selection, the installation costs for GSHPs in commercial buildings are for retrofit projects and new buildings.
- The installation costs for GSHPs include equipment and installation work related to drilling loops. Costs related to upgrading distribution systems and ducts are not included.
- The installation costs for Biomass include storage. The cost category “Miscellaneous” has been excluded.
- The installation costs for SHW exclude the cost category “Miscellaneous.”
- The installation costs for each RTT do not include costs related to upgrading the distribution system/ductwork. Costs related to upgrading the distribution system / ductwork have been calculated separately.
- The installation costs for Ductwork in residential buildings are for GSHP retrofit projects.
- The installation costs for Ductwork in commercial buildings are for GSHP retrofit and new construction projects.

81 http://www.usinflationcalculator.com/

The number of projects included in the statistics of New England projects is shown by Table 33.

	RESIDENTIAL	COMMERCIAL
GSHP	321	25
ASHP	1,913	
Biomass	385	47
Solar Thermal	1,832	189
Efficient boiler	96	
Ductwork	285	18

Table 33 | Number of samples in the New England average installation costs.

For some technologies, particularly for the commercial sector, the extent of the data is limited. We have therefore compared the New England cost data to other sources, as shown by Table 34.[82, 83, 84]

TECHNOLOGY ($/KW)		RETSCREEN AVERAGE		NEW ENGLAND PROJECTS AVERAGE		MEISTER CONSULTING GROUP		SWEETT	
		RES	COM	RES	COM	RES	COM	RES	COM
ASHP		1300		1089	N/A	N/A		820–1590	1981
GSHP	Equipment & Installation	1236		2111	2003	2131	2841	2770–3360	1640–2410
	Horizontal Loop Total	1996							
	Vertical Loop Total	3156							
Biomass Pellets		306		924	786	800 to 1700	400 to 600	1323	290 to 800
Biomass chips		N/A		N/A		N/A	491 to 600	N/A	
Solar Thermal		Glazed: 480–960 $/aperture Evacuated: 840–1440 $/aperture		2821	3235	2000 to 2500	1412 to 2763	1440 to 2880	N/A
Gas Boiler	Standard	182	182	N/A		8450 to 9100 $/unit	24000 to 28000 $/unit	N/A	
	Highly efficient	N/A		470	N/A	N/A		N/A	
Fuel oil boiler		182	182	N/A		8450 to 9100 $/unit	24000 to 28000 $/unit	N/A	
ASHP water heater		N/A		1000 to 1200 $/unit (50 gallon)		N/A		N/A	
Electric water heater		N/A		450 to 500 $/unit (50 gallon)		N/A		N/A	
Ductwork		N/A		558	664	N/A		N/A	
Air-conditioning		320		N/A		N/A		N/A	

Table 34 | Comparison of different sources of RTT cost data.

The average New England installation costs have been used in the RETScreen calculations where these data seem reasonable compared to the references: ASHPs, GSHPs, biomass pellets, and highly efficient gas boilers. For other proposed and base case technologies, RETScreen values have been used. With the exception of solar hot water, the average RETScreen installation costs have been applied. The New England cost analysis suggests that the costs for solar hot water installations per aperture are on the higher end.

82 http://www.nrcan.gc.ca/energy/software-tools/7465

83 Meisters Consultants Group (2012): Massachusetts renewable heating and cooling opportunities and impacts study. March 2012

84 Sweett (2013): Department of Energy and Climate Change. Research on the costs and performance of heating and cooling technologies. February 2013

APPENDIX D
RETScreen Expert

The RETScreen International Clean Energy Project Analysis Software (www.retscreen.net) is a clean energy decision-making tool specifically aimed at facilitating pre-feasibility and feasibility analysis of clean energy technologies as well as ongoing energy performance analysis. RETScreen empowers professionals and decision-makers to identify, assess, and optimize the technical and financial viability of potential clean energy projects. This decision intelligence software platform also allows managers to measure and verify the actual performance of their facilities and helps find additional energy savings and production opportunities.

RETScreen Expert has been developed by Natural Resources Canada (NRCan), a department of the Government of Canada.

The software can be used worldwide to evaluate the energy production, lifecycle costs, greenhouse gas emission reductions, financial viability, and risk for various types of proposed energy efficient and renewable energy technologies, as well as cogeneration projects.[85]

RETScreen Expert (available in 36 languages from September 2016) leverages a global database of project inputs including:

- A climate database of 6,700 ground-station locations around the globe and incorporation of the improved NASA Surface Meteorology and Solar Energy Dataset for populated areas. (These are input directly into the RETScreen software).
- A product database consisting of technical features of energy technologies and cost ranges.
- An emission factor database representing, among other things, the national or state specific electricity generation mix.

All clean energy technology models in the RETScreen Software have a common look and follow a standard approach to facilitate decision-making with reliable results. Each model also includes integrated product, cost, and weather databases and a detailed online user manual, all of which help to dramatically reduce the time and cost associated with preparing pre-feasibility studies.

85 Clean Energy Project Analysis, RETScreen® Engineering & Cases Textbook https://web.archive.org/web/20150711130124/http://www.retscreen.net/ang/d_t_info.php

The standard analysis in the RETScreen Software consists of several steps:

1. Choose location for the climate data
2. Define the facility, including benchmark analysis and the performance of the building envelope and industrial processes
3. Define the energy demand and equipment, both for base case and proposed case
4. Pursue cost analysis, including incremental installation costs, fuel costs, and escalation rates
5. Emission reduction analysis at different levels of detail
6. Financial analysis including net present value, internal rate of return, and cash flows
7. Sensitivity and risk analysis on financial variables such as fuel costs, installation costs, debt ratio, interest rates, and carbon price

The RETScreen Software facilitates project implementation by providing a common evaluation and development platform for the various stakeholders involved in a project. The tool can be used for zzmarket studies; policy analysis; information dissemination; training; sales of products and/or services; project development & management; and product development/R&D.[86]

Thus the analysis of RET Screen provides output for a constructive dialogue between funders and lenders; regulators and policy makers; consultants and product suppliers; developers and owners.

The vast capabilities of RETScreen enrich the depth of the analysis although this translates into high levels of complexity and require some specialized training and familiarization with the tool.

Overall, the RETScreen Software is increasing and improving access to clean energy technologies, building awareness and capacity, and helping to identify opportunities that facilitate the implementation of energy projects that save money, while reducing greenhouse gas emissions.

More information: www.retscreen.net

86 Clean Energy Project Analysis, RETScreen® Engineering & Cases Textbook

APPENDIX E
Tax Credits, Rebates and Other Incentives

TECHNOLOGY	SECTOR	INCENTIVE			
		ITC	OTHER TAXES	REBATES	LOANS
Natural gas boilers (highly efficient)	Residential		6.35%[4]	$300	2.99% / 10 years[3]
	Commercial		6.35%[4]	$8/unit MBH	5% / 10 years[5]
ASHP	Residential		6.35%[4]	$500	2.99% / 10 years[3]
	Commercial		6.35%[4]	$5000 and up[2]	5% / 10 years[5]
ASHP water heater	Residential			$400[7]	2.99% / 10 years[3]
	Commercial				
GSHP	Residential		6.35%[4]	$500—$1500	2.99% / 10 years[3]
	Commercial		6.35%[4]	$5000 and up[2]	5% / 10 years[5]
Biomass pellets boilers	Residential				2.99% / 10 years[3]
	Commercial				5% / 10 years[5]
SHW	Residential	30%[1]	6.35%[4]		2.99% / 10 years[3]
	Commercial	30%[1]	6.35%[4]		5% / 10 years[5]

Table 35 | Tax credits, rebates and other incentives

1. 30% for facilities put under construction prior to December 31, 2019. Thereafter phase out by end of 2022. For commercial facilities there will be continued tax credits of 10% after 2022.
2. Eligibility in the service areas of Eversource and United Illuminating, Cool Choice program.
3. The interest rate and loan term is for Smart-e bundles implying that the customer has to bundle several measures.
4. Sales tax incentive through Connecticut Department of Revenue Services.
5. The interest rate is the lowest C-PACE rate, which starts at 5% for 10-year and goes up by 10 basis points for each year. Loan term is for C-PACE.
6. Eligibility in the service areas of Eversource and United Illuminating. Energy Star Heat Pump Water Heater program.

Feasibility of Renewable Thermal Technologies in Connecticut

A FIELD STUDY ON BARRIERS AND DRIVERS



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March 2017

Yale Center for Business and the Environment
energize CONNECTICUT CT
CONNECTICUT GREEN BANK
EVERSOURCE ENERGY
UI

Acknowledgements

This project has been supported financially by the Connecticut Green Bank, Yale University as well as United Illuminating and Eversource through the CT Energize initiative. The Connecticut Department of Energy and Environmental Protection (DEEP) served as an advisor.

In preparing this report, the Yale team benefitted particularly from the extensive collaboration, insights, and experience of key players pursuing the deployment of renewable and efficient energy solutions in the Connecticut market

- **Bryan Garcia**, Connecticut Green Bank
- **Lynne Lewis**, Connecticut Green Bank
- **Neil McCarthy**, Connecticut Green Bank
- **Jeff Howard**, DEEP
- **Joe Swift**, Eversource
- **Peter Klint**, Eversource
- **Matt Gibbs**, Eversource (at the time of the study)
- **Patrick McDonnell**, United Illuminating
- **Philippe Huber**, United Illuminating (at the time of the study)

We are further indebted to a long list of stakeholders in Connecticut for insightful input into the potential to deploy renewable thermal technologies in Connecticut. We particularly want to thank these individuals for dedicating valuable time to share their experiences and opinions on what makes renewable thermal technologies attractive investments.

The Yale team is solely responsible for any errors or omissions in this report.

Executive Summary

Renewable thermal technologies (RTTs) constitute a broad class of renewable energy technologies that provide thermal energy services. Examples include solar hot water, heat pumps, biomass, and district energy systems, among other technologies and means of implementation. Increased deployment of RTTs can shift carbon-intensive thermal end-uses to cleaner energy sources. Diffusion of RTTs in Connecticut is relatively low, motivating an interest in how proliferation of these renewable technologies might be improved in the state.

The purpose of the research project, "Feasibility of renewable thermal technologies in Connecticut," is to assess a realistic contribution from RTTs in achieving Connecticut's transition to a less carbon-intensive economy, and to establish the knowledge necessary for effective policies and strategies to advance RTTs in Connecticut. In addition to this field study on barriers and drivers, the project includes an assessment of market potential, published separately.[1]

This report documents the results of a field study conducted in 2015 and 2016 to identify key barriers to and drivers of deployment. The field study consisted of a series of in-person and telephone interviews with stakeholders from across the value chain of RTTs, ranging from residential and commercial customers to installers and regulatory agencies. Factors influencing a customer's decision to invest in RTTs at different stages of the value chain are shown below.

Scaling up deployment of RTTs in Connecticut will require a mix of actions involving energy policy, financing products, financial incentives, and relevant industries. Connecticut's efforts to advance RTT deployment should aim to create a marketplace for thermal energy technologies in which RTTs are both competitive relative to non-renewable technologies and trusted as practical and reliable solutions.

Recommendations stemming from the field study are grouped into four focus areas for overcoming barriers to adoption: 1) show direction, 2) reduce upfront costs, 3) develop a competent and competitive regional industry and 4) create value streams.

1 Grønli, Helle; Fairuz Loutfi, Iliana Lazarova, Paul Molta, Prabudh Goel, Philip Picotte and Tanveer Chawla (2017): Feasibility of Renewable Thermal Technologies in Connecticut. Market potential.

	UPSTREAM	Heating and cooling market	DOWNSTREAM
BARRIERS	• Fuel availability • Price volatility	• Competence and experience of experts • Unclear potentials due to lack of performance data (prior to and after RTT) • Nascent industry with unproven business models	• High upfront costs • Access to capital • Unfavorable economics compared to alternatives • Awareness of RTTs and its applicability • Physical constraints
DRIVERS	• Local resources that offer opportunities (e.g. waste heat from processes and buildings, wood chips from local industry, favorable ground conditions)	• Diligent stakeholders • Local governments as facilitators • Green Bank funding and investment support opens doors to other funding	• Long term plans and strategies • Grants and rebates • Value proposition; classification schemes, revenue streams • Being in a decision mode • Financing products

Barriers and drivers across the value chain for RTTs.

SHOW DIRECTION

Increasing awareness and creating demand through institutional means

RTTs are an integral part of the built environment. **Building codes** and performance standards represent powerful regulatory tools for influencing the selection of RTTs where they are most frequently deployed (building stock) and contributing to a market for RTTs.

Public institutions can **lead by example** as large property owners and energy users and as land-use planners. When state government, municipalities, and educational institutions take the lead in early technology adoption, the learning from these projects can be widely diffused. Government support and involvement in RTT projects can also show direction in the marketplace. For example, in Bridgeport, municipal support (both financial and in-kind) facilitated the development of a thermal grid[2] that would otherwise carry significantly more risk than private developers might be willing to accept. Governments' early adoption and institutional support is important to the deployment of thermal grids, which are particularly capital- and infrastructure-intensive.

2 A "thermal grid" distributes steam, hot or chilled water produced at a central or decentralized plant or facility for thermal purposes.

The Green Bank and utilities can serve an important role as "**trusted messengers**", and can help establish trust by providing loans and support programs targeted towards RTTs.

REDUCE UPFRONT COSTS

Addressing unfavorable project economics and high capital outlays

The most significant barrier encountered in the field study was cost: in many cases, RTTs are not yet cost-competitive with other technologies and high upfront costs are challenging with regard to cash flow.

Technologies tend to be expensive at the point of market introduction, and high upfront costs can be reduced by expanding market volume. This leads to increased competition and streamlined installations through repetition. Thermal energy installations typically are characterized by a need for case-by-case design and customization in the installation process, adding to project costs. Connecticut's "Solarize" campaign around solar photovoltaic panels has proven successful for reducing costs. A similar campaign ("Thermalize") for renewable thermal technologies is recommended as a **strategy to reduce soft costs**. Standardization in terms of system designs, installation procedures, contracts, and sizing would go far toward reducing customization needs.

Financing products can be designed to address several aspects of high upfront costs, including access to capital and cash flow over the life of the asset. Various financing products have different strengths in addressing barriers, and include on-bill financing, loans, leasing, property assessed clean energy (PACE), and savings-backed products such as Thermal Service Contracts or Energy Performance Contracts.

The field study found that financing played a pivotal role in project economics, and more broadly the decision to select RTTs over competing technologies. Financing products should account for the fact that **packaging** RTTs with other renewable energy technologies and energy efficiency measures is a reliable way to boost return on investment and increase the value that a customer can get from an investment. The process from when the customer decides to install thermal technology to the point when the installation is finalized can be time-consuming and full of hurdles if it is not **streamlined** as much as possible. This includes access to financing.

DEVELOP A COMPETITIVE INDUSTRY

Creating a well-supported and trustworthy base of installers and experts

A pool of qualified RTT installers, designers, and developers is a prerequisite for a well-functioning RTT market. To be attractive, the market should promise a certain volume, have low entry barriers, and be predictable over time. A **regional market approach** could address barriers and drivers affecting both installers and customers.

The field study found that the industry would benefit from **standardization**, which would help to establish viable business models and lower soft costs associated with these technologies. This standardization applies not only to technological best practices and installations, but also to the contracting, permitting and financing processes, where administrative simplification would benefit installers and customers.

Finally, the field study found that verification of RTTs' **performance** is an important prerequisite for widespread adoption, either through metering or validated monitoring methods. Technologies that can be metered and monitored facilitate benchmarking that increase customer trust in the products. Performance verification also facilitates new revenue streams and business models such as Thermal Renewable Energy Certificates, third-party ownership, green bonds, and Energy Performance Contracts.

Declining block grants with an announced profile will encourage market entry and help create momentum for a "Thermalize" (or other) marketing campaigns.

CREATE VALUE STREAMS

Reducing unfavorable operational economics and an unclear business case

To improve the economics, the marketplace should look to new business and financing models as well as energy policies for additional sources of revenue. This study proposes the creation of **Thermal Renewable Energy Credits** (TRECs), which can serve as a production incentive for RTT installations, and **carbon pricing**, which would improve the project economics of RTTs by internalizing the cost of carbon into the operation of conventional alternatives. These incentives scale with project size and provide a consistent cash flow to improve project economics; they also encourage project developers to optimize the use of clean energy sources.

Building certification schemes make it possible for customers to separate high-quality buildings from low-quality buildings in terms of energy efficiency and energy costs. This quality difference would be reflected in the property value and market rents, creating revenue related to the RTT investment.

Introduction

Thermal end-uses accounted for 70 percent and 44 percent of energy delivered to US residential and commercial customers in 2013, respectively (EIA, 2015). Renewable Thermal Technologies[3] (RTTs) can replace existing thermal end-uses based on fossil fuels and electricity, and thus provide an essential contribution to achieving states' climate ambitions. As such, RTTs are gaining increased interest across the Northeastern United States.

Connecticut's ambition is to achieve an 80 percent emissions reduction by 2050 compared to year 2001, as spelled out in the state's 2008 Global Warming Solutions Act. The 2013 Connecticut Comprehensive Energy Strategy highlights strategic measures based on the idea of moving away from subsidies; these measures are intended to use public funds to leverage a larger share of private capital, and thus increase funds into energy efficiency, renewable power, natural gas availability, and transportation infrastructure. The strategy proposes economic incentives designed to drive down the costs of new technologies, making them competitive with fossil fuel alternatives. Furthermore, natural gas is recognized as a bridge to a sustainable energy future, with manufacturing industries anchoring this expansion. RTTs are currently included in the state's energy strategy to the extent that they can be considered energy efficiency measures.

In 2014, a total of 344 trillion BTU was delivered for stationary energy purposes in residential, commercial, and industrial sectors in Connecticut.[4] Of that, roughly 39 percent was based on natural gas and 28 percent on fuel oil. Connecticut's electricity mix is dominated by natural gas and nuclear power. Connecticut is part of the regional wholesale market operated by the Independent System Operator for New England (ISO New England). New England increasingly relies on natural-gas fired generation, which can expose the region to significant energy supply, reliability, and price issues. Natural gas as a proportion of the electric system capacity mix is expected to increase to 49.2 percent by 2018 and 56.7 percent by 2024 (ISO New England, 2015).The region experiences issues related to lack of fuel certainty particularly in winter, due to limited gas pipeline capacity in New England. Increased use of dual-fuel units is discussed as one of the solutions to this issue, which would be an economical choice but have concerns regarding burning oil.

Connecticut has among the highest retail electricity rates in the US. The introduction of shale gas has made natural gas an economically attractive choice, and oil prices are currently at a record low.

3 Renewable thermal technologies (RTTs) harness renewable energy sources to provide heating and cooling services for space heating and cooling, domestic hot water, process heating, and cooking. For the purpose of this report, both onsite supply and distribution through district heating and cooling are included.

4 EIA State Energy Data System: http://www.eia.gov/state/seds/. Delivered energy is net of electricity losses.

Building characteristics may pose functional limitations on the range of RTT alternatives that customers can realistically choose. Heat pumps deliver low-temperature heat, and their ability to deliver sufficient heat is influenced by how well a given building is insulated and the distribution system in place. Pellets and wood chips require space for fuel storage and chimneys. These functional limitations can be overcome by investment in energy efficiency and retrofits to the distribution systems—often a barrier to adoption. However, if customers are already retrofitting their house and heating system, the additional costs of better insulation or a novel distribution system (based on a different medium and temperature) may not be particularly high. RTTs can be scaled to serve the whole thermal load or partial loads.

Around 60 percent of residential units in Connecticut were built before 1970 (ACS, 2014), and new residential buildings were constructed at an estimated annual rate of 0.7 percent over the period 2000-2014.[5] An estimated 45 percent of the commercial square feet in the New England census were built before 1970 (EIA, 2015b). This indicates that a large share of the building stock is older than 50 years, with heating systems of a similar age.

There are several financial incentives available for RTTs in Connecticut, including: rebates provided by the Connecticut Energy Efficiency Fund through the electric utilities, favorable loans and green bonds from the Connecticut Green Bank, tax exemptions on both state and federal levels,[6] and property assessed clean energy (PACE) (Appendix 1). Following the financial turmoil of 2008, an economic stimulus package was made available through the American Recovery and Reinvestment Act (ARRA) of 2009. The Connecticut Clean Energy Fund (CCEF)[7] offered grants for ground source heat pumps and solar thermal installations with ARRA and CCEF funding over the period 2009–2012; at the time of writing, several of these incentives are no longer available.

A total of 523 residential and 27 commercial ground source heat pumps were installed with the support of the ARRA program over the period 2009 through 2012. Solar assisted thermal systems were supported through the ARRA program in late 2009 through 2011 and a utility-funded follow-on program from 2011 through 2013. The two programs together funded 278 residential and 86 commercial solar thermal installations. The ARRA funded solar thermal systems are monitored by remote metering. The metering data is to a limited extent available due to non-functioning data transmission to a central hub. The ground source heat pumps supported through the ARRA program are not metered, and insight into actual performance of these installations is not easily available.

The electric suppliers and distribution companies in Connecticut are mandated to meet a Renewable Portfolio Standard (RPS) of 27 percent renewable electricity generation by 2020. The RPS generally does

5 Based on statistics on demolitions and housing inventory estimates by State of Connecticut, Department of Economic and Community Development

6 From 2017, the only RTT covered by the federal Investment Tax Credit (ITC) is solar thermal.

7 CCEF was the predecessor of the CT Green Bank

not create Renewable Energy Credits (RECs) for renewable thermal energy. Waste heat recovery systems capturing waste heat or pressure from industrial or commercial processes, or electricity savings from conservation and load management programs, may count as Class III resources[8] under certain conditions. Connecticut has existing programs that incentivize or otherwise support RTTs, but more generally, a comprehensive support scheme for RTTs is lacking.

To be able to develop a market for RTTs in Connecticut based on scalable and replicable incentives, an in-depth understanding of what influences this market is necessary. We address the following research questions:

- What makes different categories of customers decide to invest in RTTs?
- What stops different categories of customers from investing in RTTs?

The study builds on empirical literature covering the energy efficiency gap, diffusion of technologies, and customers' decision making related to energy investments. Most of this empirical literature focuses on residential customers. The research was built on qualitative interviews of stakeholders with different roles in the market. This included a sample of customers, financial institutions, government institutions, installers, and industry associations. Stakeholders were selected from each group such that representation was obtained for residential, commercial, and industrial markets. Detailed interview guides can be found in Appendix 2.

8 Department of Energy and Environmental Protection. Public Utilities Regulatory Authority: http://www.ct.gov/pura/cwp/view.asp?a=3354&q=415186

The Literature Framework

Literature on consumer and behavioral economics defines a broad theoretical foundation for consumer behavior and rationality. In the context of deploying new energy technologies, consumers may face complex sets of decisions and preferences that encourage or inhibit the adoption of technology, even if adoption is rational from a purely economic standpoint. The purpose of this research is to map and categorize drivers that promote and barriers that inhibit investments in economically competitive RTTs. This research will seek to identify market, regulatory, and behavioral forces across the value chain that influence the adoption potential of RTTs, using Connecticut as a case.

Although a considerable number of studies exist on the adoption of energy efficiency measures in the residential sector, there is less literature on the adoption of RTTs. There is even less empirical work on identifying barriers and drivers to energy related investments in the commercial and industrial sectors. This chapter gives a brief overview of the research framework for barriers and drivers to energy efficiency in general, and RTTs in particular, across all sectors. Due to the focus of the literature, the main findings center downstream on the residential segment. Characteristics of RTTs may cause some additional barriers and drivers as compared to those of energy efficiency.

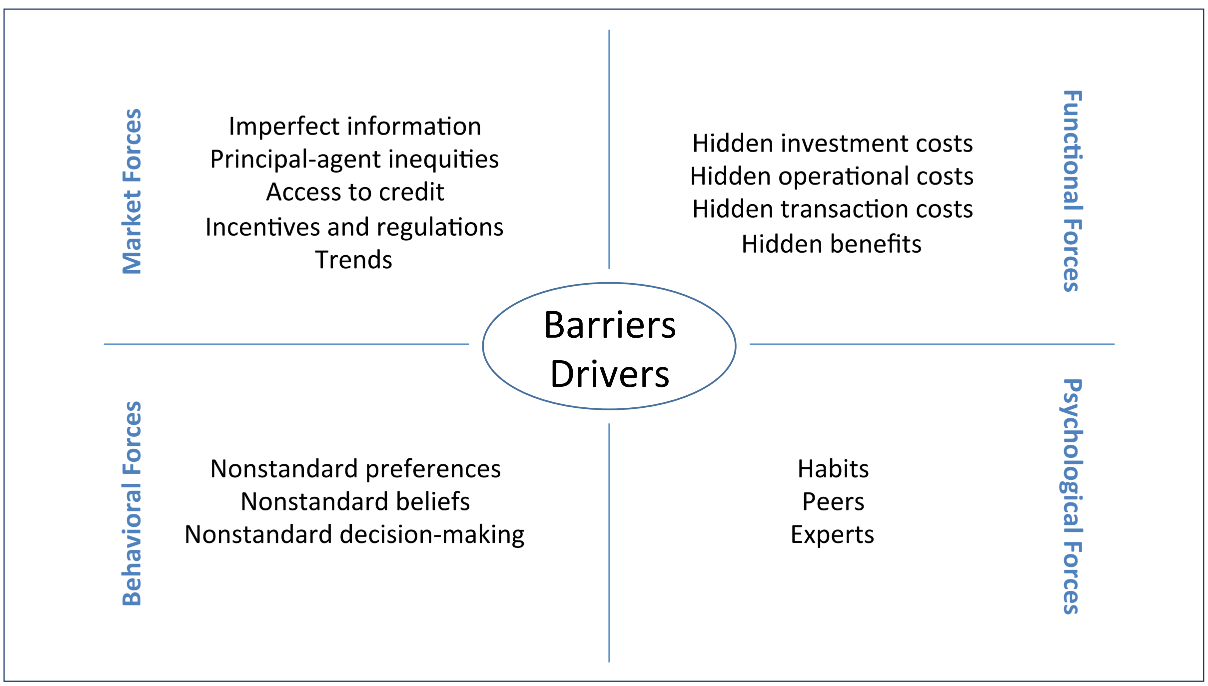

Figure 1 | Explanations for the energy efficiency gap and investments in thermal technologies. Adapted from Gillingham and Palmer (2013) and Michelsen and Madlener (2015).

The phenomenon of consumers failing to make energy saving investments with a positive net present value is known as the “energy efficiency gap”. While first discussed from a neoclassical economics perspective (Hausman, 1979), the literature now incorporates other economic perspectives (e.g., Gillingham and Palmer, 2013). Figure 1 shows a framework for discussing barriers and drivers from different perspectives. In this framework, each force can act as a barrier or driver, depending on the particular circumstance.

Gillingham and Palmer (2013) discuss a range of explanations for the energy efficiency gap as described by neoclassical and behavioral economics. They conclude that more than 30 years of literature suggests that consumers behave as if they have high discount rates; at the same time, recent engineering studies indicate a vast untapped potential for negative-cost energy efficiency investment. Measurement errors may contribute to the observed gap, due to explanations such as hidden costs, exaggerated engineering estimates of energy savings, consumer heterogeneity, and uncertainty.

Klöckner and Nayum (2016) tested 24 barriers to and drivers of energy efficiency upgrades in private homes based on a stage-based model of decision-making. The four stages of decision-making assumed in their study were 1) “not being in a decision mode,” 2) “deciding what to do,” 3) “deciding how to do it,” and 4) “planning implementation.” The perception that it was not the right point of time was found to be a barrier to energy efficiency upgrades across most stages in the decision-making process. Owning the dwelling was necessary to even be in a decision mode. Expecting higher comfort levels and lower energy costs appeared to be drivers to start deciding what to do, while indecision was an important barrier to deciding how to go through with upgrades. The time required to supervise contractors was an important obstacle to planning implementation. While some barriers and drivers appeared relevant to all stages of the decision-making process, others were distinct to specific stages.

“An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003). Rogers’ studies of diffusion of innovation concluded that an early adopter is generally younger, has more financial resources, higher education, higher social status, searches more for information, interacts with innovators, is more social, and shows higher degree of opinion leadership than a late adopter.

Stieß and Dunkelberg (2013) tested several hypotheses related to the adoption of low- and zero-carbon (LZC) technologies like loft insulation, high-efficiency condensing boilers, and renewable heating systems in households. Their findings showed that the adoption of LZC technologies followed both economic and non-economic motives, where benefits such as increased thermal comfort and the adoption of a prestigious technology or a low-carbon lifestyle were valued. The majority of homeowners in the study associated the economic benefits of LZC technologies with a medium- or long-term perspective and a desire to become less exposed to fluctuating energy markets. The study also showed that the adopters of LZC technologies consult a broader range of experts and sources than the non-adopters.

Graziano and Gillingham (2015) found a strong relationship between adoption of solar photovoltaic installations and the number of nearby previously installed systems—a peer effect. The built environment and policies were also found to be of importance. Their findings suggest that the peer effect is conveyed through social interaction and visibility.

Ruokamo (2016) studied household preferences of hybrid home heating systems in new detached buildings—hybrid home heating systems being combinations of complementary heating technologies, such as district energy, solid wood, wood pellet, electric storage heating, ground source heat pumps, and air source heat pumps. The results showed that district heating and ground source heat pumps were the favored main heating alternative, with combined solar and water heater systems and air source heat pumps both favorable supplemental sources.

Michelsen and Madlener (2015) classified resistance to innovation with a framework of functional barriers, psychological barriers, and socio-demographic factors. They found that homeowners who replaced a fossil-fuel based heating system with a renewable heating system were driven by external threats such as expected price increase of oil, knowledge of renewable heating system, and the wish to contribute to environmental protection. Homeowners in rural German areas and homeowners with bigger homes were more likely to switch. Homeowners who did not replaced their fossil-fuel based system perceived that renewable heating systems require relatively more attention during their operation; maintaining existing habits was important to them. The likelihood of switching was lower for older homes, where the compatibility with existing infrastructure was a challenge.

Sopha et. al. (2011) found that adopters of wood pellet heating showed characteristics of early adopters according to diffusion and innovation theory (Rogers, 2003), while non-adopters displayed characteristics of late adopters. A few deviations existed between the empirical findings of the study and the theory; the adopter group had lower incomes and education levels compared to the non-adopter group. This was explained by functional limitations related to retrofitting the house and localization. Early adopters were found to have more peers recommending the solution than non-adopters.

Sopha and Klöckner (2011) demonstrated that habit is significant in explaining decision making for heating systems, where lack of perceived behavioral control and behavioral lock-in pose relevant barriers to the adoption process.

Sopha et. al. (2013) simulated the heating system decision-making by Norwegian households based on empirical research. Their results suggested that increased adoption of wood-pellet heating is dependent on improved functional reliability and fuel stability. Spatial results of simulations indicated that wood-pellet adopters resided near wood-pellet suppliers, whereas heat-pump adopters and electric heating adopters were distributed all over Norway.

Organizations often adopt innovation through one of two types of decision: 1) collective decision by consensus, or 2) authority decision by a few high-level individuals within an organization (Rogers, 2003). Within an organization, certain individuals are termed “champions”. These individuals stand behind an innovation and break through opposition. The innovation process of organizations contains five stages: agenda setting, matching, redefining, clarifying, and routinizing.

Enova (2012b) commissioned a comprehensive study on potentials and barriers to energy efficiency in the building sector in 2012. Barriers were placed in five categories: 1) practical, 2) technical, 3) economic, 4) attitude, and 5) knowledge. Barriers in the commercial sector (both public and private buildings) were analyzed by applying qualitative methods that differentiated between existing and new buildings. The study pointed out that barriers were often interdependent. For instance, the costs at any given time were not only influenced by the price of competing technologies but also by competence and experience in the market. Economic barriers, such as high upfront costs, rigid rules, and difficulty getting access to capital for public building owners were found to be the most important. Skepticism and lack of internal support, conflicting governmental requirements, low awareness of current energy use, and potential improvements to a building were also important barriers.

Enova (2009) mapped the potential of and barriers to energy efficiency in Norwegian land-based process industries. The most important barrier to reaching full potential was found to be economic infeasibility due to a low rate of return and internal and external risks. Other barriers to energy efficiency in the process industry were limited access to capital, lack of external infrastructure to utilize waste energy, low awareness, and lack of competency and capacity within organizations.

District energy systems were among the lowest cost and most efficient solutions for a low-carbon pathway in cities, according to the United Nations Environment Programme (UNEP, 2013). Through studying 45 modern district energy systems in cities around the world, a research project led by UNEP compiled different drivers for realizing district heating projects. The study concluded that local governments were the most important actors in catalyzing investments in district energy systems, juggling several roles at once: planner, regulator, role model, advocate, provider of infrastructure, and facilitator of finance. The study also mapped some typical barriers to district energy: awareness of technology applications and their benefits, integrated infrastructure and land-use planning, knowledge and capacity in structuring projects to attract financing, data to evaluate energy density, accounting methods for efficiency ratings, high upfront capital costs, high costs of feasibility studies, and disadvantageous energy pricing regimes or market structures.

Methodology

This research, based on a series of in-depth qualitative interviews, aims to gain deeper insight into what makes different categories of customers decide to invest in RTTs in Connecticut. The advantage of in-depth interviews is that they provide a flexible and iterative method, and therefore offer detailed information on the interviewee's personal experience, perspectives, and histories.

As the perception of what drives or inhibits investments in RTTs may differ depending on what role you have in the market, we wanted to study the research question from different stakeholders' perspectives. The study involved market participants from the whole RTT value chain, including residential customers, commercial customers, industrial customers, installers, financing institutions, and governmental agencies.

Based on a framework from surveying the empirical literature, we developed a set of interview guides for each stakeholder group (Appendix 2). These guides were designed with open-ended questions. Most interviews involved two investigators from the research team. The interviews were partly organized as in-person meetings, and partly as phone interviews. The interviews were documented through field notes. As the constellation of investigators varied from interview to interview, the interviews were audio recorded when possible. The interviews lasted from 30–90 minutes.[9]

In general, customers in Connecticut are unfamiliar with RTTs. To gain insight into what makes customers invest in RTTs we needed participants with some familiarity with the various thermal technologies. Therefore, we chose to recruit the participants from the list of private persons and organizations involved in incentives from the Connecticut Green Bank, or its predecessor, CCEF. An introductory email was sent from the Connecticut Green Bank to around 30 customers and installers, after which the research team reached out directly by mail or phone. In addition, the research team contacted directly some stakeholders that were known to be familiar with RTTs. Altogether the team completed 25 interviews; a descriptive overview of the interviewees can be found in Appendix 3.

Generally, customers participating in the study are more knowledgeable than most people about energy solutions. The commercial customers cover private and public companies with a long-term perspective on their existence; this provides longer-term considerations on investments in energy technologies. The installer group is dominated by companies that install different types of RTTs, although some of them also install traditional oil and gas boilers.

9 This qualitative field study was conducted between January and May 2016, by a team consisting of the principal investigator and three graduate student research assistants. Interviews were recorded where feasible and permission was obtained for quotation usage. The protocols for this field study were filed with and approved by Yale University's Institutional Review Board.

After finalizing the interviews, we explored possible solutions to barriers to and drivers of customer investment in RTTs. This followed an iterative process according to the “Design thinking” approach developed by the Hasso Plattner Institute of Design at Stanford University. The results are summed up in Appendix 4.

Findings and Analysis

At a high level, RTTs have characteristics that are unique relative to other energy technologies, such as solar photovoltaic panels and energy improvements of the building envelope. These characteristics informed our analysis of what RTTs need to achieve widespread diffusion in the Connecticut marketplace.

This section, organized by thematic categories of barriers and drivers, elaborates on the factors that influence RTT deployment, in residential, commercial, and industrial customer classes.

Project Economics

Over the course of the field study, the research team consistently heard that favorable project economics relative to alternative technologies were a prerequisite for RTT investments. High upfront costs to RTT project implementation—capital requirements of RTT vary from technology to technology—presented a barrier for all stakeholders interviewed. Beyond initial capital costs, the long-run operating costs (maintenance and performance) were a further concern among customers, though these represented a smaller barrier relative to upfront costs.

Residential customers described long-run energy cost savings as a principal goal of RTT installation; high upfront costs made these investments prohibitive, gave these projects an intolerably long payback time, or made non-RTT alternatives more attractive. Customers were able to overcome these barriers through combinations of personal savings, tax benefits, grants, and loan financing. Cash flow presented itself as a concern for several customers, given the structure of incentives and the need for financing at particular milestones in the project. This problem was particularly acute for customers receiving the Federal Government's Investment Tax Credit for project costs; these tax credits could not be realized until tax filing in the first quarter of each year, while construction costs were often incurred at other times throughout the year. A residential customer emphasized the need for a large cash outlay, in spite of available incentives:

> *We were looking for rebates and just called up the companies. Installers really know the rebate rules well. The problem is: when you put everything up on your roof, there's an outlay of money—and you're cash poor until the tax rebate is returned.*[10]

Residential customers were acutely aware of the "run rate" that they could expect to realize with RTTs relative to other technologies. Several customers interviewed switched to RTTs from an oil boiler, which they consistently remarked was expensive and unpredictable to maintain. Several residential customers

10 Radmanovic, Daniel. Interviewed by Joseph Schiavo. Telephone. New Haven, CT, 7 April 2016.

added that volatility of fuel costs was an additional motivator for switching away from fossil fuel systems. Establishing a positive comparison in terms of operating costs was important for these customers—expected savings would prompt a switch to RTTs, while negligible improvements tended to dissuade larger RTT investments. Surprisingly, customers seemed willing to expand the size of upfront investments when incremental benefits could be obtained. Specifically, we encountered several customers who combined energy efficiency improvements (insulation, window upgrades, etc.) with large geothermal investments to maximize the benefits of a new energy system, in spite of appearing to worsen the initial barrier of high upfront costs. A residential customer explained that combining energy investments made sense from both efficiency and financing perspective:

> *Investments were synergistic. As geothermal becomes more efficient, so does use of Solar PV, which made spray foam insulation in the attic a good investment.*[11]

We asked all residential customers interviewed about the payback period on their RTT investment that they would consider acceptable; but no customers in the sample expressed a hard-and-fast time period. One customer implied that long-term savings, or the strategic nature of an RTT investment, was more important than a tangible financial payoff.

Commercial and industrial customers generally face stricter economic constraints than residential customers. One school district remarked that a project payback period of greater than 5 to 6 years was intolerable from an investment perspective and a non-profit organization stipulated a 2- to 3-year payback period. Several interviewees mentioned the difficulty of justifying large capital outlays for benefits perceived as small and occurring over a long time horizon, even if this runs counter to the long-term existence of the business or institution. Many organizations also require formalized business cases or solicitation processes to quantify expected costs and benefits of projects. This is not always easy to estimate for RTTs due to poor insights into existing energy consumption alongside uncertainty around technology performance. Larger businesses face further constraints, such as investors who operate on very short time horizons. Maintenance costs and feasibility assessments were also on the minds of commercial customers. The management company for a multi-family housing complex pointed out that, for geothermal systems in particular, they were fearful that a small marketplace of competent contractors would make service costly and difficult to obtain at times. This is contrasted with traditional fossil energy technologies, where local expertise is more widely available and commoditized. Businesses and institutions that consider thermal energy systems critical to operations expressed concerns that a small network of contractors and suppliers represents a risk to the continuity of business.

In terms of operating costs, a consistent theme of sensitivity to fuel prices was evident. Installers of ground source heat pumps remarked that demand for these RTTs is directly related to fuel prices,

11 Radmanovic, Daniel. Op. cit.

following the costs of oil and natural gas. The recent sustained period of low oil and gas prices has depressed demand for these technologies as a hedge for fossil fuel prices. Indeed, customers can be expected to seek less-costly substitutes when fossil fuel prices are high, as high fossil fuel prices support the financial justification for an RTT system.

Mitigating these barriers requires both reductions in installed costs for RTTs, and increased access to and flexibility in financing deployments of these technologies.

Awareness and Perceived Risk of RTTs in the Marketplace

Thermal technologies are normally not visible, placed in basements or mechanical rooms. As such, there is a tendency to take them for granted, to remain unaware of their presence unless they stop working. This contrasts with renewable electricity technologies, such as solar photovoltaic panels or wind turbines, which are generally easy to see in the landscape or on rooftops. This attribute of RTTs prevents them from benefiting from salience as a driver of deployment. Customers are not as easily made aware of the availability of RTTs and the value these technologies can provide. With this in mind, it should be expected that the marketplace is less aware of RTTs, compared to the solar PV market, where installations are easily visible. An installer remarked:

> *PV is killing solar thermal. The payback [for solar thermal technologies] with the tax credit is good, but it's not as sexy as PV," calling attention to the salience benefits solar PV technologies enjoy relative to solar thermal.*[12]

Indeed, the relative invisibility of RTTs may prevent these technologies from benefiting from an important 'peer effect' discussed by Bollinger and Gillingham (2012). One installer remarked that the solar thermal panel market is essentially competing for roof space with PV, which compounds the relative lack of awareness RTTs face among likely customers. However, the small footprint of RTTs may act as a driver: some customers perceive a small or invisible footprint as a benefit. Seamless integration of RTTs into the home or landscape can have the appeal of hiding unsightly energy infrastructure.

Relative to traditional thermal technologies, RTTs tend to suffer from a deficit of awareness in the mainstream marketplace. Interviews with residential customers revealed wide variance in conceptions of which technologies are considered "renewable thermal" and the types of energy services these technologies are meant to provide. Solar thermal technologies were frequently confused with photovoltaics, and some customers were unaware of applications where solar thermal technologies work to provide heating or cooling. Some customers were unaware that geothermal systems are able to provide

12 Wierzbicki, Stephen. Interviewed by Philip Picotte. Telephone. New Haven, CT, 12 May 2016.

cooling services in addition to heating. Similar differences in product conceptions were encountered in air source heat pumps, with some customers surprised to learn of the heating and cooling potential these technologies can provide. Some customers were unaware of recent advances in air source heat pump technologies, and had a conception that these technologies would be ineffective if installed in cold climates.

The geothermal market, however, tended to include classes of customers that were highly informed and aware of these technologies and their applications. One installer observed:

> *Geothermal customers are normally well-researched and ready to make the investment.*[13]

RTTs can, to various degrees, be complex to operate and understand. RTT systems are interconnected and interdependent with the rest of the building and infrastructure. Furthermore, customers may be unaware of the impact a ground source heat pump may have on electricity consumption. A customer remarked that he felt installers had a tendency to oversell the expected performance of systems, which has the effect of creating dissatisfied customers and discredited technologies. As another example, a customer may find the process of securing a biomass supply contract to be complex or time consuming. Whereas renewable electricity technologies produce a fungible commodity in electricity, RTTs provide benefits that are less obvious to realize. One residential customer remarked that it's possible to "see" the value of net-metered electricity, while the thermal comfort RTTs provide is more ethereal.

A lack of awareness of RTT capabilities extends to district energy applications. Commercial and industrial customers who were interviewed expressed skepticism toward locally centralized generation sources, and perceived dependence on an external heat source as a vulnerability, instead preferring traditional technologies (such as oil or gas boilers) that allow for autonomous generation. The long-term cost and procurement of fuel for a district energy heat source was a further uncertainty, which can have major implications for the economics of the system. This can be mitigated through a long-term contract that specifies a quantity of energy to be provided at an agreed-upon service level, with provisions for procuring alternative sources of energy during an interruption.

Across all market segments, we discovered a similar unawareness of the incentives and support programs available to RTTs. Customers in all classes expressed that information about incentives and educational resources were disparate and difficult to discover. Existing state resources, principally Energize CT, make it easy for customers to discover the tactical details of financial products and incentives for energy technologies, but these resources do not include neutral information about different technologies, permitting, or how to discover which technology might be best suited to the need at hand. Furthermore, the incentives that do exist are somewhat uncoordinated, in that

13 Elkin, Steve. Interviewed by Philip Picotte. Telephone. New Haven, CT, 27 April 2016.

customers, in many cases, needed to combine local and federal incentives to make their installations economic. This presented many logistical and financial challenges of cash flow, paperwork, and administration. Similarly, opportunities to introduce customers to RTTs through complementary incentive programs (i.e. energy efficiency) are lacking in the marketplace.

Installer Business Models and Access to Expertise

RTTs are at a comparative disadvantage in terms of the business models available for deployment and access to a large market of installers. Well-developed industry structures that exist for fossil fuel technologies are not established for RTTs.

A particular feature of the market is the lifecycle by which thermal energy technologies tend to be replaced or upgraded. For all customer classes, many replacement situations arise from an unplanned maintenance event in which a system fails when it is needed. Residential customers described situations in which oil boilers needed replacement during the winter months. In these situations, sufficient lead time does not exist to undertake the involved planning process of correctly designing and installing of RTTs—customers require heat *immediately,* and so they seek the fastest and most cost-effective path, typically replacing the component of the fossil fuel system that needed repair. In these emergency situations, we noted that customers typically call an oil company they have a maintenance or fuel contract with, explaining why replacement of these technologies with newer models is the most common path. This "stickiness" is a barrier to RTT deployment. Installers competent in both fossil technologies and RTTs would be better positioned to facilitate consideration of other options. One customer went as far as to emphasize that his family considered reliable heating to be an issue of security.

Another class of customers exists that undertakes thermal energy investments proactively. Several residential customers completed substantial RTT installations upon purchase of an unoccupied home, which they noted allowed them to avoid substantial construction while they were living in their homes and to obviate the need for heating or cooling systems to function. This class of customer was able to explore energy system options, get estimates from multiple installers, and make decisions free of time pressure. Customers described the challenges of coordinating project financing and administration. One customer explained that he was able to invest significant time and effort into coordinating a ground source heat pump installation because of a part-time work schedule that allowed him flexibility with his time.

Successful installers seemed to recognize that in the sale of thermal energy technologies to residential customers, emphasizing a technology's ability to provide thermal comfort is key. One installer remarked that thermal comfort is the primary driver of sales, with savings acting as a secondary benefit. Interviews with residential customers revealed that conversations about RTTs with installers showed considerable focus on the question of thermal comfort, particularly around system sizing and decisions to make incremental investments (for example, supplementing a smaller geothermal system with an air source heat pump). Placing an inordinate emphasis on the financial or environmental benefits of RTTs is then a barrier: customers care about thermal comfort and installer sales forces should speak to this customer need. The manager of local utility's energy efficiency program observed:

> *When we talk to customers after the fact, they never talk about energy savings. They are always thrilled about how comfortable/quiet the home now feels. It's an interesting transformation—'forget the savings, we love how comfortable our home is'.*[14]

More broadly, the resources available to allow customers to discover and learn about RTTs are limited in scope and availability, hindering deployment. From all sectors, we consistently heard that the resources available to facilitate the discovery of RTT technologies, demonstrate their capabilities, and show customers how to get started are disparate, uncoordinated, and not robust. One installer spoke of the long-term problem of finding skilled employees to install and service RTTs. This labor shortage, to the extent that it has not already constituted a barrier to RTT diffusion, will continue to worsen without a larger volume of RTT projects. One installer remarked that his firm established an in-house training and certification program to provide knowledge where they felt it was lacking. One RTT industry representative remarked that possibilities exist for installers to collaborate amongst each other to offer bundled or lower cost solutions, but installers are not incentivized to develop these partnerships.

Installers also pointed out that many wholesale supply channels and infrastructures, such as those for the delivery of biomass, are relatively underdeveloped in comparison to fossil fuels. Unstable supply chains for bio resources were also noted by a commercial customer; pellets have to be bought out of state and might not be available in sufficient quantity when most needed. Current distributor or wholesale business models are simply not configured to provide a robust set of systems and parts for ready deployment.

Commercial and industrial customers further described the nascent development of the RTT market as a barrier to undertaking large-scale, sophisticated projects. Energy Service Companies (ESCOs) have a business model wherein commercial and industrial customers agree to share the savings of an energy technology upgrade with the financing and installing entity. Commercial and industrial customers are willing to pay a premium for these services as a means of contractually guaranteeing savings, reducing risk, and outsourcing the expertise required to undertake energy projects. Several commercial and industrial customers interviewed remarked that ESCOs limit most of their business to lighting and straightforward building envelope measures, leaving out more complicated and costly investments. A manager for a university's energy projects pointed out that:

14 Gibbs, Matt. Interviewed by Philip Picotte. In-person. New Haven, CT, 19 February 2016.

> *ESCOs are typically incentivized to choose projects that are most easily executed and can guarantee savings with relatively short payback periods. This approach may not allow for deep investigation and retrofits of whole building systems.*[15]

This is likely a function of the added expense of deeper infrastructure upgrades and the need for a long payback time horizon (lighting, for example, is essentially immediate). For ESCOs, these “low hanging fruit” investments are the least-cost and least-risk ways to deliver energy savings. These factors are barriers to easy integration of RTTs to installer and ESCO business models. Commercial and industrial customers are willing to pay a premium for these services as a means of contractually guaranteeing savings, reducing risk, and outsourcing the expertise required to undertake energy projects.

A skills gap and small talent pool may also be barriers to the Connecticut RTT market. Reflecting on the marketplace, a university’s energy project manager observed:

> *Projects such as the deep retrofit of the Empire State Building are highly successful when they are executed by teams with sophisticated technical and project management skills as well as strong systems perspectives. Such teams are not easy to find or create. The work force needs to be developed.*[16]

Along similar lines, standardization also presented a potential driver to RTT markets through cost reduction and streamlining processes.End-use needs, existing structures, and available resources are not homogenous across customers and customer groups. Although some RTT applications can be standardized across customers, each particular thermal energy demand may dictate wide variance in installation parameters and viability. Furthermore, locally varying resources often offer opportunities for applying RTTs —such as waste heat for a district energy system or wood chips from forestry for a biomass system. Therefore, RTTs are characterized by a need for tailor-made solutions and expert advice, both with regards to choice of technology and systems design. The degree of customization required tends to scale directly with the size of projects; by implication, commercial and industrial customers tend to require more customization than residential customers. Standardization of technology, installation, systems design, and agreements can drive market development through lower costs, less hassle, and greater trust in the solution.

A more general theme was the observation that large players have yet to emerge in the RTT market, in the way that SolarCity, Sunrun, Posigen, and others have in the solar PV market. These players, who are present in many markets, have established credibility that commercial customers, in particular, find

15 Paquette, Julie. Interviewed by Philip Picotte. New Haven, CT, 15 April 2016.

16 Paquette, Julie, op. cit.

important. An educational institution explained that working with a well-established and well-known installer makes management and governmental approval of projects easier to obtain. Also of note is the heterogeneity that exists between technologies: some RTTs enjoy wider market penetration than do others. One installer of solar hot water systems characterized the challenges his business model faces as a product of a small overall market for this technology in Connecticut. In contrast, installers characterize air source heat pumps as having a much wider scope of demand that has attracted a larger network of installers. Another installer, calling attention to the challenge of running a profitable and effective RTT installation business, said:

> *It's tough to do business in this State. Customers apply pressure for lower prices. It's challenging to run a good business that pays employees well and provides healthcare. I need to maintain a talented staff to design and install systems.*[17]

Split Incentives to Ownership[18]

The literature of energy efficiency has extensively treated the topic of split incentives, wherein the business case for investing in energy technologies falls apart when the owner of a building does not stand to benefit from improvements (costs are passed through to tenants) or where building occupants are not empowered to make decisions on energy investments. For residential customers, this problem typically manifests in multi-family situations where utility expenses are the responsibility of the tenant and thermal energy use based on fuel oil is the responsibility of the landlord. This removes any incentive on the landlord's part to improve the energy technologies installed on the property that are fueled by the utilities. For commercial and industrial customers, the split incentive problem is much the same; rental properties do not incent investment on the tenant's part. Commercial and industrial customers may be subject to additional contractual stipulations, making energy projects more complex and difficult to undertake. A business development organization explained that many commercial rental properties occupied by corporate clients have no organization or funding for undertaking energy projects beyond the decision of a building to occupy.

One manager of multifamily residential properties explained that providing incentives (subsidies) to landlords to undertake energy investments is, to him, an important way to remedy the split incentive problem. Some property managers installed electric baseboard heating or air source heat pumps as a means of passing through energy expenses to tenants (shifting from master-metered oil or gas to tenant-metered electricity for thermal energy). Particularly in instances where a tenant's rent is subsidized, opportunities exist for subsidies to extend to energy capital improvements in multi-family properties or public housing projects.

17 Stephen Wierzbicki

18 Only building owners were included in the interview sample. It would be helpful to interview tenants in future research.

The energy efficiency project manager for a public school district described another manifestation of the split incentive problem that arises in institutional settings. Large institutions often have separate budgets for capital expenses and operating expenses, which can make energy investments complicated to plan. (RTTs require capital expenses to install but generate savings in operational budgets.) Furthermore, competition for limited funds amongst departments in the same organization can create barriers to getting energy investments approved.

Climate Strategies and Plans

Climate strategies and plans on state, governmental, and company levels can present a driver to RTT deployment, to the extent that RTTs represent a substantial reduction in carbon emissions relative to fossil fuel technologies. In general, climate strategies and plans that mandate reductions in carbon emissions will create demand for abatement, which RTTs can provide. An overview of current Connecticut regulations and incentives related to RTTs can be found in Appendix 1.

As discussed above, RTTs are not explicitly included in Connecticut's current state-level energy policy, although some resources may be considered for Class II RECs. As it stands, the prospect of satisfying RPS needs using other technologies is likely crowding out RTTs. Similarly, the lack of a carbon tax or other means to internalize the social cost of carbon has the effect of inhibiting demand for RTTs. No directly applicable policy at the US Federal level, beyond the investment tax credits,[19] exists to incentivize these technologies.

Customers in all classes—residential, commercial, and industrial—expressed concern over the future availability of subsidies, net metering, and REC programs that incentivize energy technology investments. Installers described "stop and start" effects in the markets for solar hot water and ground source heat pumps in Connecticut, as a result of grant programs that were phased out and reinstated. This creates uncertainty in the investment process and exposes customers to potentially large changes to the long-run business case they establish for investment. Furthermore, regulatory stability is a prerequisite for installers wanting to pursue business models on RTTs; certainty about long-term availability and solvency of incentive programs makes it easier for installers and customers to justify long-term investments.

Connecticut's Comprehensive Energy Strategy is an important document giving direction to the market. The Green Bank, as a quasi-public institution responsible for facilitating the realization of parts of this strategy, was described as making possible favorable financing terms that allowed customers to overcome high upfront investment costs. All classes of customers described the role of the Connecticut Green Bank in providing financing for RTT investments as an important driver of investment decisions.

19 Of the RTTs, only solar thermal will be applicable for ITCs from 2017

Several projects of the customers interviewed were funded by a mix of state and utility grants in combination with Green Bank loans.

City and local governments can act as drivers of RTT installations, particularly in district energy applications. The research team interviewed several stakeholders involved in a district energy project in Bridgeport, Connecticut. In this case, the city government acted as a facilitator of the project, providing approvals for district energy infrastructure installations and financing through tax-exempt municipal bonds. The project developer described the city government's partnership as crucial to moving the project forward. A local university is negotiating a long-term contract as an anchor customer for this district energy system, providing assurance the private developer needed of a credit-worthy off taker. The same is the case for the city as an owner of property. Hence planning for district energy systems needs the involvement of local governments, which have regulatory authority to move district energy projects forward.

Policies and standards created at more specific and localized levels exert strong influence on the selection of energy technologies. Broadly, LEED, Energy Star, and other building certification programs are drivers of RTT deployment; these programs create demand for RTTs, as they mandate certain energy consumption profiles or require the installation of particular technologies to meet established criteria. Variations of such standards are also implemented at the firm-level. A public school district interviewed informed us that they created an in-house certification system and set of criteria for building energy efficiency, which constitutes the principal criteria against which potential energy investments are evaluated. Establishing and disseminating building certification criteria, or even building codes relevant to RTTs, will drive demand for these technologies. Firms also establish long-term sustainability plans that influence the selection of energy technologies. Such policies can mandate goals for carbon emissions, set benchmarks for renewable energy consumption, and set building efficiency standards, among other possible goals. Two universities interviewed described these institutional strategies as key drivers of technology selection, including one university that is piloting a program to place a price on carbon emissions.

With climate and long-term energy plans in mind, it is nonetheless important to note limitations to the role these plans play as drivers of investment. A local university explained: Environmental values or academic value [of energy investments] are the "icing on the cake", and energy investments have to provide savings from day one. We cannot afford to pay extra for environmental value, and the project has to be 'Zero out of pocket'," calling attention to the financial concerns that drive these decisions.[20]

20 Anastasi, Chris. Interviewed by Amir Mehr. In-person. Bridgeport, CT, 11 March 2016.

RTT's Added Incremental Service and Value

A consistent theme of using RTTs to deliver new, incremental services was encountered in customer interviews. The opportunity of using RTTs to do more than simply replace a fossil fuel system emerged as a driver of deployment. Customers want to feel as if they are "getting something more" in return for their investment in RTTs. Importantly, the benefits of incremental services work to alleviate the salience deficit that RTTs tend to face: new services give customers a tangible gain that they can see and feel. This drives investment.

Residential customers who undertook investments in geothermal systems often did so in order to add air conditioning services in addition to replacing existing (oil fired) heating services. This additional value served to improve the case for investment, in terms of both thermal comfort and financial savings. One customer expressed that the cost of upgrading an oil boiler in need of replacement *and* installing a central air conditioning system was roughly equivalent to the cost of a geothermal system, which made it easier to justify this RTT option:

> *Our house didn't have an air conditioning unit, which improved the case for geothermal. [When considering the cost of an] Air conditioning unit and oil, geothermal makes financial sense.*[21]

A similar story was told for air source heat pumps. In many cases, customers were able to add heating or cooling to a portion of their homes. The incremental value added of air source heat pumps, however, extends further: these technologies allow for the expansion of heated and/or cooled area within a home. Since these technologies are relatively inexpensive to install and require minimal ductwork or outdoor footprint, we encountered customers who considered them a viable way to heat or cool an additional room.

Commercial customers expressed a similar desire to gain additional value from RTT systems, but also introduced resiliency as a value that RTTs are capable of delivering. A public university explained that ongoing negotiation to connect to a local district heating grid is motivated, in part, by a desire to gain access to a more reliable energy source than its local (oil-fired) heat plant. The co-benefits that RTTs can deliver to customers may be an important driver in investment decisions.

Co-benefits of installing RTTs exist in further contexts. A university described its decision to connect to a district energy grid as partly motivated by a desire to be a "living lab" for energy technologies. Such a project provided academic value to the institution. Similarly, the municipality involved in the same project described the installation of a thermal grid as a tool for differentiating the city as a low-cost location for building operations.

21 Daniel Radmanovic

Financing

As with any investment in energy technology, RTTs constitute a large upfront capital investment. This is often project-financed to restrict upfront equity contribution to a tolerable amount and to provide a reasonable rate of return on the investment in the long run. Notions of making RTT investments both *possible* (i.e. upfront capital cost is financeable) and *cash-flow positive* (i.e. the savings of the investment offsets debt service) were necessities for all classes of customers.

Our interview with the Connecticut Green Bank surfaced several critical success factors for making RTTs viable, from a financing perspective. The bank found success in making the value (or savings) of energy investments available to customers immediately, meaning that the all-in financed monthly cost of the system (thermal or electric) would provide immediate savings in comparison to the customer's existing cost of fossil fuel. This aspect of providing net-positive cash flow to customers—in all classes—was, in many cases, a prerequisite for investment. Lease products are particularly well-suited to provide these savings. In the case of these products, the all-in monthly lease cost of the system is intended to provide a margin of savings to the customer. In the opinion of the bank, it is more convincing to present customers with the prospect of additional free cash flows rather than additional energy savings. Designing financial products that provide such free cash flows, along with a tolerable upfront equity contribution (if there is any at all) are prerequisites for widespread deployment of RTTs in Connecticut. As with all financial products, their viability is predicated on interest rates low enough to allow for an attractive payback period and rate of return.

The subtle ways that customers are engaged in the financing process, as it relates to the availability of incentives, the net upfront cost of installation, and the long-run cash flow of operation, surfaced as important in several interviews. A geothermal installer noted:

> *Upfront cost hides actual cost-effectiveness.*[22]

This may be particularly true for geothermal technologies, which require a substantial upfront investment for completion. More generally, the manager of an energy efficiency program for a local utility remarked that in his experience:

> *People love a deal. This is common in car sales - something like 0 percent financing is attractive to customers, even if the premium is in the car.*[23]

The way that investments, incentives, and financing packages are presented matters and has a strong influencing effect on the customer's final decision.

22 Duffy, Chris. Interviewed by Philip Picotte. Telephone. New Haven, CT, 5 May 2016.

23 McDonnell, Patrick. Interviewed by Philip Picotte. In-person. Orange, CT, 8 March 2016.

Generally, loan and lease products are the primary means of financing RTTs today. Loans have the advantage of providing customers with full equity ownership of all accrued benefits and savings; leases free customers of up-front capital contributions but do not impart permanent ownership of the system. RTTs are disadvantaged relative to renewable electrical technologies in that incentives have not been established to the same extent for thermal energy. RTTs can provide savings, but do not, in the absence of Renewable Energy Certificates or net metering, provide direct revenue. The revenue that electrical technologies can provide fueled the growth of the solar power purchase agreement (PPA), which facilitates installation of energy systems with no equity contribution from the customer, in exchange for a long-term contract for power provision. A "thermal PPA" may be possible, but such an arrangement would be predicated on creating demand for RTTs in the market, or otherwise placing a standardized value on a unit of thermal energy. Arrangements of third-party ownership can be other means of financing RTTs.

The timing of RTT installations presented itself as a significant barrier or driver, depending on the particulars of the situation. Several residential customers explained that they saw an opportunity to undertake a disruptive upgrade of their energy systems in the interim period between buying a home and the start of occupancy. These circumstances allowed the customers to go without heating or cooling for an extended period of time, but were predicated on access to sufficient capital to facilitate the prolonged period of living outside the home. Furthermore, seizing this opportunity required access to the cash flows necessary to finance all upfront installation costs coincident with the purchase of a new home. This is a high bar for customers to meet.

Commercial and industrial customers described financing as an essential driver of RTT investments. These customers emphasized that energy is not their primary business competency, and as such they were hesitant to evaluate, make, and manage large and complicated energy investments. Hence, they viewed access to inexpensive capital as an important means of both obtaining low-cost capital and removing risk from the investment process. These firms had no desire to make energy investments a significant part of their balance sheets. Installers, however, encountered administrative difficulties in coordinating financing—some installers described an inordinate amount of time required to facilitate loan application approval and funding. A large private university explained the emergence of the ESCO business model to remediate challenges of internal capacity and decision processes. Before ESCOs existed, the university needed to coordinate and organize engineering feasibility studies and construction project management in-house, using their own capital. This increased costs for the institution, and subjected energy investments to many levels of internal scrutiny. ESCOs were able to integrate these services and provide capital for financing, which streamlines projects for the university, allowed the institution to benefit from the ESCO's industry expertise, and reduced overall risks and project implementation complexity.

The measurability of RTT investments presented itself as a persistent challenge among many stakeholders interviewed.Thermal energy, like electrical energy, is measurable. However, the measurability of thermal energy is often less obvious than electrical energy, in part because thermal energy is often itself treated as a final energy service, whereas electricity is a secondary energy source. It is straightforward to measure the number of kilowatt-hours of energy consumed; quantifying thermal comfort is less obvious. Nonetheless, the secondary energy generation of RTTs can be quantified and measured, typically in terms of British Thermal Units (BTUs) or Joules (J). Further complexity comes from the decision of where the point of metering should occur in RTT implementations, and how the size of the system relates to its performance. Measurability, when effective, can act as a driver to deployment. Thermal meters however, are generally characterized as being less accurate and costlier than electric meters, which presents barriers for RTTs. This may be particularly important for enabling alternative, service-oriented business models (e.g. pay by the BTU). Difficulty in metering early RTT projects was cited as a barrier to creating accurate valuations of the benefits these investments provided, making future financing efforts more difficult.

Functional Limitations and Local Opportunities

Existing building performance is a determinant of RTT economic and physical feasibility. The ability for RTTs to provide thermal comfort, for instance, can be dependent on the quality of a building's envelope. Similarly, the availability of infrastructure and, where applicable, fuel, are another determinant of RTT feasibility. For example, proximity to a heat source determines the feasibility of connecting to a district energy system, and the quality of insolation influences the ability of a solar hot water system to perform. The choice, combination, and scale of RTTs will to some extent be defined by existing infrastructure, both within and around the building under consideration. Stakeholders in a district energy project described the confluence of both a source of waste heat for the thermal grid and the presence of off-takers as essential prerequisites for project viability. Similarly, a large university ruled out biomass as a source of thermal energy based on a short supply of local feedstocks and a lack of sufficient storage space at the point of consumption. Individual building characteristics also function as barriers or drivers of energy investments. A commercial customer explained that asbestos remediation was a barrier to undertaking investments in energy efficiency or thermal energy supply systems. However, such investments can also be serendipitous in their timing. To take the example of asbestos remediation, once the fixed cost of removing drywall is realized for remediation purposes, it is easier to justify upgrades to insulation or ductwork.

To be viable, district energy projects require a confluence of enabling factors. A developer of a local district energy project listed several attributes that must be in place as prerequisites for investment:

> *Population density, source of waste heat, high credit customers, strong legislative support, green bank line of credit to complete feasibility studies, and buy-in and support from the [heat source] owner and others who got involved.*[24]

Alignment is required both in terms of the physical attributes of the installation and in terms of financing and customer availability.

24 Donovan, Daniel. Interviewed by Joseph Schiavo. In-person. Bridgeport, CT, 25 March 2016.

Current Financing Models for RTTs

Given high capital costs, decisions to undertake energy projects are typically facilitated using some form of financing. In general, the goals of these financial products include overcoming high upfront cash requirements, delivering monthly cost savings to customers, and otherwise making capital-intensive projects affordable. Importantly, the characteristics of financial products used to finance energy investments influence the value proposition of the investment itself. Beyond providing access to otherwise unaffordable technologies, energy financing is frequently sold as a business model in which measurable savings are passed on to the customer. Consideration of appropriate financing mechanisms for RTTs requires a twofold assessment of both the ability of these products to provide positive net present value and the business value that these products can provide.

With some exceptions, RTTs can be financed using similar products available for other renewable energy technologies and energy efficiency. Leventis et. al. (LBNL, 2016) offer a typology of financing products for efficiency financing and an evaluation of these financing products' impact on market barriers. The overview of different financing models is based on this typology.

GRANTS AND TAX REBATES – Direct cash awards or rebates used to subsidize the cost of project

ADVANTAGES	DISADVANTAGES
• Provide immediate cash benefits that reduce upfront costs of installation • Shorten payback periods • Lower cash flow barriers to entry • Enable lower monthly payments (where applicable) • Generate attention • Generate trust when provided by a trusted source	• Costly; requires taxpayer or utility funding • Not considered scalable • Create disincentive for installers to reduce costs and find efficiencies

LOANS; SECURED OR UNSECURED – Loan financing for all or parts of the project cost. Either backed (secured) or not (unsecured) by collateral

ADVANTAGES	DISADVANTAGES
• Facilitate outright ownership by customers • Alleviate problem of high upfront cash requirements • In some cases, subsidized or below-market interest rates • Facilitate syndication and securitization, for market expansion	• Require verification of creditworthiness • Payments are fixed and do not vary with project performance • Where applicable, subsidies and interest rate buy-downs require public funding • Interest rate risk

LEASES; CAPITAL OR OPERATIONAL[25] – Project equipment leases; capital lease involving a purchase of the leased equipment, or operating lease involving no purchase at the outset

ADVANTAGES	DISADVANTAGES
• Typically require little to no upfront cash payments • Payments can be right-sized to provide a margin of savings to the customer on the energy bills • Facilitate the replacement of equipment at the end of term	• Equity does not accrue to property owner • Financing institution must accurately project depreciation • Lifetime project cost savings decreased relative to loan financing. Higher monthly payments

PROPERTY-ASSESSED CLEAN ENERGY (PACE) – Financing secured by an assessment on property taxes. Generally available only to commercial and industrial customers, with limited residential use

ADVANTAGES	DISADVANTAGES
• Strong security for lenders • Lowers cost of capital • Simplicity in payments and collection • Makes the investment cash-flow positive • Transfers to a new occupant, which reduces barriers related to occupancy time horizon	• Requires explicit policy in place at local levels • Unless the value of the asset financed by PACE is reflected in the property sales price, the PACE liability may impact negatively on the property value

ON-BILL FINANCING AND REPAYMENT – Financing provided directly by, or through, servicing utilities. Financing charges appear as line items on monthly energy bills

ADVANTAGES	DISADVANTAGES
• Associates financing charges with borrower's credit history, via utility bill • Historically high payment and collection rates • Lowers cost of capital • Can make the investment cash-flow positive • Access to financing for more people • Transfers to a new occupant, which reduces barriers related to occupancy time horizon	• Requires alignment and coordination with servicing utilities • Success of transfer balance to new occupant in case of bankruptcy or foreclosure is untested • Unless the value of the asset financed on-bill is reflected in the property sales price, the liability may impact negatively on the property value

25 Project equipment leases; capital lease involving a purchase of the leased equipment, or operating lease involving no purchase at the outset

SAVINGS-BACKED OR PERFORMANCE BASED ARRANGEMENTS – Financing provided directly by, or through, servicing utilities. Financing charges appear as line items on monthly energy bills

ADVANTAGES	DISADVANTAGES
• Generally, overcomes the high upfront costs barrier to entry • Delivers tangible energy services to customers • All installation, maintenance, and logistics handled by ESCO • Creates a market for energy services • Frees customers from the need to own and manage energy assets	• Requires an ESCO with access to capital, expertise, and scale

Leventis et. al. (LBNL 2016) have evaluated the barriers to energy efficiency that are addressed by the specific financing products that they discussed. This is shown by Table 1.

BARRIER	UNSECURED LOAN	SECURED LOAN	LEASING	ON-BILL	PACE	SAVINGS-BACKED ARRANGEMENTS
Access to capital	○	○	○	●	○	○
Cash flow	○	●	○	○	●	●
Application process	●		●	●		
Split incentives				○	○	
Occupancy duration				●	●	
Customer debt limits				○	○	○

Table 1 | Barriers addressed by financing products. Source: Leventis et. al. (LBNL 2016). Note: Filled-in circles suggest that a particular barrier may be largely addressed by a financing product, while empty circles suggest that the product has medium potential to address the barrier.

As can be seen from Table 1 , financing products can address several barriers, but not all. Stimulating the market requires a mix of market interventions, including regulatory mechanisms and financing products. Appendix 1 provides an overview of current regulations and financial incentives in the RTT field in Connecticut.

Conclusions and Recommendations

Connecticut's 2050 greenhouse gas reduction target is ambitious. A new fossil fuel boiler will normally be in operation for at least 20 years, locking the customer into fossil fuel for a long time, regardless of energy efficiency measures taken. Instituting measures that guide customers away from these path-dependent decisions for heating and cooling purposes will be an important driver of the success of Connecticut's GHG reduction policy. RTTs represent low-emitting solutions for heating and cooling.

This study reveals a set of factors that influence customers' RTT investment decisions at different stages of the value chain, as shown by Figure 2.

	UPSTREAM	Heating and cooling market	DOWNSTREAM
BARRIERS	• Fuel availability • Price volatility	• Competence and experience of experts • Unclear potentials due to lack of performance data (prior to and after RTT) • Nascent industry with unproven business models	• High upfront costs • Access to capital • Unfavorable economics compared to alternatives • Awareness of RTTs and its applicability • Physical constraints
DRIVERS	• Local resources that offer opportunities (e.g. waste heat from processes and buildings, wood chips from local industry, favorable ground conditions)	• Diligent stakeholders • Local governments as facilitators • Green Bank funding and investment support opens doors to other funding	• Long term plans and strategies • Grants and rebates • Value proposition; classification schemes, revenue streams • Being in a decision mode • Financing products

Figure 2 | Barriers and drivers across the value chain for RTTs.

For RTTs to be deployed at scale, they must become the preferred choice for customers. To be preferred, the technologies have to be recognized, trusted, and competitive, in terms of price, delivered comfort, and performance. We suggest a set of initiatives that will address the barriers and benefit from market drivers at different stages of the value chain. Broadly, these recommendations are grouped into four categories.

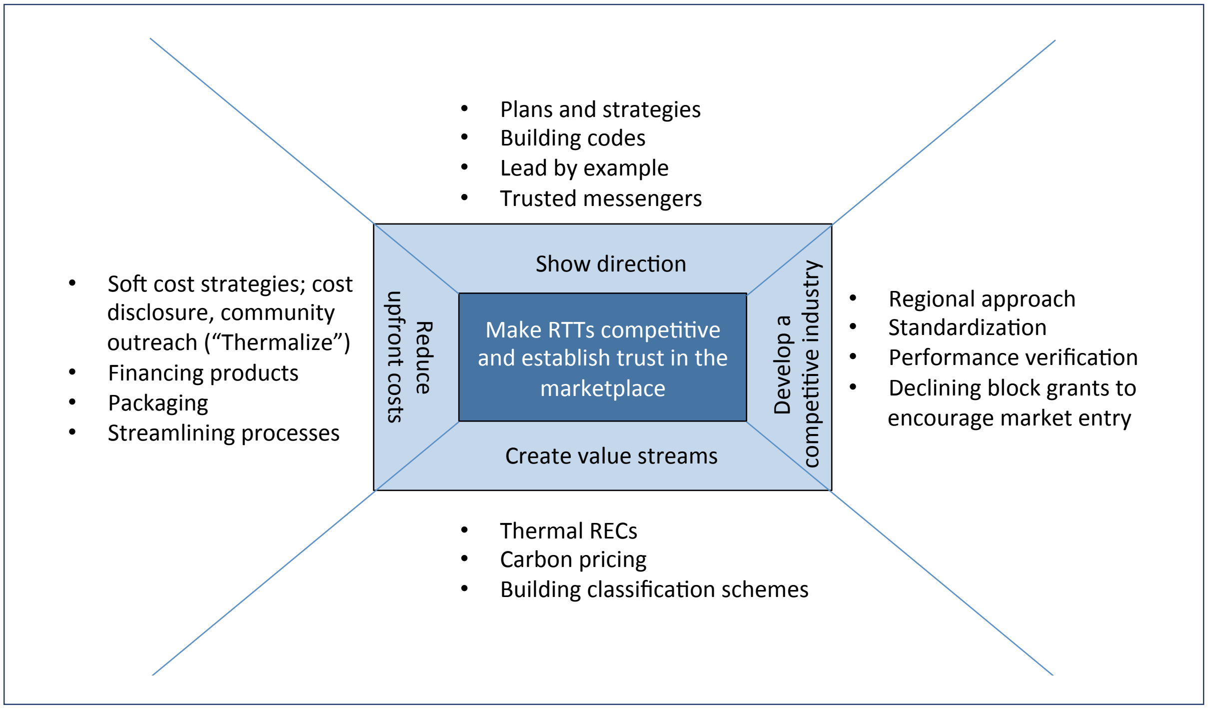

Figure 3 | Recommendations to address barriers and drivers for RTTs.

The first, "**Show direction,**" addresses low awareness and aims to create demand for RTTs through institutional means—that is, measures that governments can take to encourage the uptake of RTTs. The second, "**Reduce upfront costs**," addresses unfavorable project economics and high capital outlays (caused by high installation costs) compared to conventional thermal technologies. We propose creating financial products and strategies to both improve the value proposition of RTT investments and create conditions where the financing of RTTs can achieve scale. "**Develop a competent and competitive regional industry**," describes the need for a well-supported and trustworthy base of installers and experts focused on the RTT industry. Installers and experts are critical to RTT adoption because they are at the front line of customer decisions; their expertise directly influences a project's performance. The final category, "**Create value streams**," addresses unfavorable operational project economics and an unclear business case in short and long term. These recommendations support finding and promoting the additional value streams that RTTs can provide, both in terms of incremental energy services and an active market for renewable thermal energy.

The companion report on market potential (Grønli et. al. 2017), supplements the recommendations below by suggesting specific market interventions influencing on the competitiveness of RTTs.

Show Direction

A low-emission future requires long-term perspectives on the development and interaction of buildings and energy infrastructures like the electricity grid, the natural gas grid, and the thermal grid. The largest challenge may be related to the extent to which a low-emission future requires changes in this infrastructure. Influencing adoption of RTTs provides a leverage point for lowering emissions. Governments, in particular, can provide important signals about the long-term direction of the energy markets and its infrastructure, both through plans and action.

GOVERNMENTAL STRATEGIES AND PLANS

Governmental strategies and plans communicate the direction of policies and action, both on a national and local level. The Comprehensive Energy Strategy for Connecticut that is soon to be published will send important signals to the RTT market.

Local governments have a role with regards to land use planning and regulation. These can be used to include the perspective of thermal grids and possible industrial parks, utilizing synergies of exchange of surplus thermal energy between buildings and processes. Energy and climate roadmaps for cities may increase awareness of the local governments' roles as owners of buildings, planners, regulators, and providers of infrastructure.

Thermal grids provide flexibility to utilize several low-cost energy sources such as waste heat from waste incineration, surplus heat from data centers, surplus electricity from variable generation, and surplus heat from solar thermal installations. Additionally, easy access to a thermal grid facilitates a higher rate of fuel shifting. Thermal grids may be instrumental to achieving Net Zero Energy Districts (NZED).

The field study found that interest exists from both developers and potential customers in thermal grids; however, there is risk in a lack of institutional support for these complicated investments. If governments act to create a favorable environment for collaboration—through facilitating heat density maps, feasibility studies (including own buildings), and data initiatives—complexity and risk can be reduced for private actors.

THE BUILDING CODE

The building code can be used to show direction for building standards and energy systems under construction today and slated for future construction. In addition to stricter requirements for the building envelope, which eventually will favor low-temperature solutions such as heat pumps, the code can signal which energy systems to install and which to avoid in new and existing buildings. Examples include required minimum levels of renewable energy, disallowing fossil fuel boilers, and minimum levels of flexibility and efficiency. Although the number of new buildings per year is limited, requirements offer a nascent RTT industry a market segment in which it can start developing salient business models; these, in turn, can spread and adapt to the existing building stock. We recommend evaluating the current building code in this respect.

LEAD BY EXAMPLE

Public institutions, such as governments, municipalities, and educational organizations, can lead by example. Choosing RTTs for heating and cooling does not only create credibility for other customer groups, but it also helps to establish a nascent industry given the public sector is often a large property holder and energy user.

Public institutions also work on long time horizons, allowing them to establish leadership in investments and long-term energy service contracts. As large users of energy for heating and cooling, with a considerable purchasing power, public institutions may be more likely to see a favorable benefit cost analysis for RTTs as well. (Grønli et. al. 2017).

There can be several ownership models for RTTs, whether for stand-alone units or whole infrastructure projects, like thermal grids. As a large customer, public institutions can be instrumental in the development of standardized models and contracts, allowing the most logical ownership model for each given situation to emerge. Templates for tendering processes and standardized contracts that ensure consistency with public procurement requirements will not only facilitate public entities' participation, but can serve as models for third party ownership across a broader spectrum of customers.

TRUSTED MESSENGER

Lenders who are unfamiliar with RTTs may require a higher risk premium or be reluctant to provide financing, and a trusted messenger may facilitate the financing process. Green Bank funding generally—and first-loss arrangements specifically—provides credibility and risk reduction to the technology and project; it may also secure better financing terms than customers would otherwise receive. Investment support through other program administrators such as utilities similarly advices the customer in choosing technology. For residential customers, this credibility is linked to the technologies included in a program. For larger customers and projects, credibility is created on a project-by-project basis.

Reduce Upfront Costs

In the field study, we consistently received the feedback that costs and long-term economic considerations were a primary consideration for prospective RTT installations. Although both installation and operational costs are important when a customer chooses which technology to use for heating and cooling, high upfront costs seem to represent a particularly important barrier. This barrier has two aspects to it: 1) high installation costs influence competitiveness when compared with conventional technologies, and 2) high upfront costs require considerable capital.

The installation costs related to installing RTTs vary depending on the type of technology, the state of the existing internal system and building envelope, thermal service to be delivered, and the overall size of the installations. Roughly, the costs can be categorized into heating-cooling unit, storage, drilling and digging, pipes, planning and permitting, retrofit of internal distribution or building envelope, financing, and installation. Figure 4 provides a taxonomy of project investment costs.

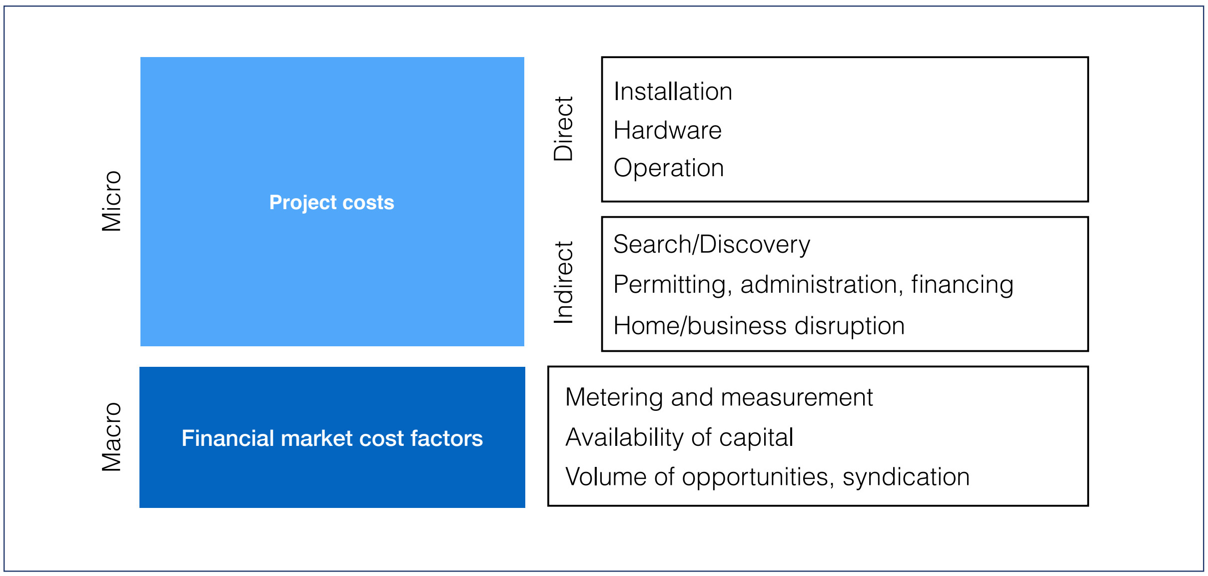

Figure 4 | Investment cost taxonomy

Although some customers are able to finance RTT investments without raising capital, many will have to find external sources of financing to make these investments possible. Financing has costs, and the higher the risk the financing institutions perceive, the more expensive capital tends to be.

In addition to direct costs related to the installation and operation of the thermal technology, there are indirect costs related to searching for information, evaluating options, applying for permits and grants, disturbing core business, and raising capital. These costs are less visible, but will influence the customer's decision making.

STRATEGIES TO REDUCE SOFT COSTS

Several studies support that technologies are expensive at the point of market introduction, but eventually become cheaper due to technological learning. This technological learning applies to both producing the equipment (hard costs) and the installation work (soft costs). To achieve technological learning, the market has to attain certain volumes and scale. As several RTTs can be categorized as technologically mature in a nascent East coast market, the effect of technological learning is expected to be highest with regard to soft costs. **Strategies to reduce soft costs** will contribute to lower installation costs.

The Connecticut Green Bank's "Solarize"[26] campaign was highly effective in both raising awareness of solar PV technologies and reducing customer acquisition and soft costs. Pilots such as HeatSmart[27] Thomson of New York indicate that a similar campaign ("Thermalize") for renewable thermal technologies could have similar outcomes.

FINANCING PRODUCTS

Financing products can be designed to address several aspects of high upfront costs, access to capital, and the cash flow over the life of the asset. According to Leventis et. al. (LNBL, 2016), on-bill financing is the most advantageous to address the challenge of access to capital. While any financing product may offer cash-flow-positive terms to customers depending on the scope of the project, Leventis et. al. suggest that secured loans, PACE, and savings-backed products are preferable. Their argument is that the security associated with secured loans and PACE tends to allow for longer terms and lower rates without credit enhancement, which can facilitate more positive cash flow arrangements. Savings-backed arrangements, such as Thermal Service Contracts or Energy Performance Contracts, tend to be structured so as to be cash-flow positive.

RTTs represent a range of technologies with different features; they can scale in size from serving residential customers to district energy and industrial purposes. Financing products should take this into consideration as the importance of the barriers and drivers may vary between RTTs. Mass-market strategies can be applied to some RTTs, while tailored products may be necessary for others.

Furthermore, some RTTs would benefit from applying different financing products to different parts of the installation. Thermal grids and ground source loops are installations with considerable technical lifetimes, but the costs are sunk should the asset be left idle. Boilers and heat pumps have shorter technical lifetimes, but are to a larger extent movable. These characteristics may allow for designing different financing products and business models.

26 Solarize CT is a community-based program that leverages social interaction to promote the adoption of solar through a group-pricing scheme intended to reduce soft costs. See http://solarizect.com/

27 See http://www.solartompkins.org/

PACKAGES OF MEASURES AND FINANCING PRODUCT

Preparing packages of measures and financing products may make it easier for the customers to realize cost benefits and inspire the customers to do more renovation at one time. The reasons why customers opt for thermal technologies may vary, and the packages can target each decision-making situation; an oil boiler breaking down in the middle of the winter may demand a different financing package than the retrofit of an internal heat distribution system.

Bundling RTTs with solar PV and energy efficiency measures was identified as a driver of deployment in the field study, not to mention the co-benefits these installations can provide.

STREAMLINING

If not streamlined as much as possible, the process from when a customer decides to install RTT to the point of final installation can be time-consuming and full of hurdles. Examples of steps that may benefit from streamlining and standardization are:

- Harmonization of permitting processes across cities and states
- Coordination between governmental offices
- Coordination of work, e.g. digging of trenches for infrastructure
- One-stop-shop for financial products and incentives
- Standard contracts for "thermal service agreements", templates for tendering and public procurement processes
- Ownership and business models
- Installation processes and systems designs
- Certifications

Cultivate a Competent and Competitive Regional Industry

A pool of qualified RTT experts and suppliers is a prerequisite for a well-functioning RTT market. To be attractive, the market should promise a certain volume, have low barriers to entry, and be predictable over time. Both the mainstream market and the market for customized solutions would benefit from a professionalized RTT industry with long-term business models including services related to maintenance and correction. Conditions supportive of RTTs contribute to the attractiveness of the market.

Being mature technologies in a nascent market, RTTs may seem riskier to customers and lenders than they actually are. Measures to reduce the risk will increase confidence in the technologies.

REGIONAL APPROACH

A regional approach to address barriers and drivers of RTT deployment is recommended, as both installers and customers benefit from a regional market. Unless rules for certification, taxes, incentives, and permissions vary extensively across states, the installers of RTTs are not limited to operation in one state. However, if there are large differences in interstate business environments, this will serve as a barrier to entry. Standardization of contracts and procedures, along with harmonization of rebate programs and qualifying criteria, installer certification, data definitions, permission processes, and financing models are examples of possible areas for coordination and shared experience.

STANDARDIZATION

Standardization of contracts, tendering and public procurement processes, financing models, verification methods, certification, and ownership models may make it easier to raise private capital for RTTs. Standardization helps the industry develop salient business models based on common and trusted reference for doing business.

PERFORMANCE VERIFICATION

Performance verification, either through metering or other accepted monitoring methods, will not only reduce the risk for the customer, but it will increase lender confidence in the project performance, which is an important driver according to IMT (2016). Performance verification provides customers information on the quality of the installation and potential malfunctions during its lifetime. Proving performance will create customer trust in the solutions. Performance verification will also facilitate new revenue streams and business models, such as Thermal Renewable Energy Certificates, third-party ownership, green bonds, and Energy Performance Contracts. The level of required accuracy will influence the additional cost. We recommend evaluating various methods for performance verification with respect to the purpose it will serve for various customer segments and the related costs and benefits.

DECLINING BLOCK GRANTS

Incentives supporting RTTs provide valuable information to the customer and function as a marketing campaign. Incentives may range from grants to cheap loans and leasing products. To avoid “start and stop” market effects, it is important to be clear about the duration and potential ramping down of grants and rebates. Declining block grants with an announced profile will encourage entry to the market and help to create momentum with efforts like the proposed “Thermalize” campaign.

Create Value Streams

RTTs can utilize resources that would otherwise be wasted. These include waste heat from industrial processes (thermal electricity generation, data centers, and waste heat incineration) and waste products that can be transformed into fuel for heating (biogas and wood chips from old building materials). The promotion of additional value streams not only makes RTTs more favorable economically, but it allows for new financing products and business models supporting RTTs.

THERMAL RENEWABLE ENERGY CREDITS

Include Thermal Renewable Energy Credits (TRECs) in the Renewable Portfolio Standard (RPS) to establish revenue streams on renewable thermal energy.. Given the limited availability of RECs for thermal energy, renewable resources such as biogas may not be used where they add the most value when they are awarded credits for only one of several possible applications (electricity generation.) Including thermal energy in the RPS incentivizes project developers to optimize the use of energy sources to a larger extent than they otherwise would. As a market for RECs has already been established for renewable electricity, adding thermal energy could be done with relatively low effort.

Thermal RECs, which depend on technologies that afford performance verification with some degree of certainty, can be instrumental in funding both large installations and small projects in aggregate. However, high costs related to heat meters and performance verification may imply that participating in TREC trading is worth the effort mostly for larger installations.

CARBON PRICING

Carbon pricing would internalize the social costs of carbon in customers' investment decisions. This would increase the operational costs of conventional alternatives and improve the project economics of RTTs. Visualizing the costs of carbon on the profit and loss statement may appear as an important driver to low-carbon solutions of companies, increasing the awareness of RTTs.

BUILDING CERTIFICATION SCHEMES

To promote investments in RTTs regardless of a customer's time horizon requires the perception that the investment will generate value regardless of occupancy period. Building certification schemes make it possible for the customer to separate high-quality buildings from low-quality buildings; this quality difference would be reflected in the property value and rents, creating additional value to the RTT investment. Building certification may, further, diminish the split incentive issue inherent in rental properties. LEED, Living Building Challenge, and Energy Star are examples of existing voluntary classification schemes.

Open access to all aspects of building performance data makes energy projects more attractive from an investor's point of view (Energy Efficiency Financial Institutions Group, 2015). High-performance buildings are well suited to low temperature heating and high temperature cooling sources that several RTTs provide. Developers of high-performance buildings in cities are focusing increasingly on classification schemes such as LEED (Kolstad, 2016). Several studies support that "green buildings" achieve higher rents. [28]

RATE MECHANISMS

Explore rate mechanisms that recognize the value of RTTs in reducing demand for natural gas and electricity. RTTs can effectively help alleviate peaks in Connecticut's energy demand by diversifying the pool of energy supply and delivering services balanced throughout the day and night. However, it is necessary to be aware of the features of the different RTTs compared to conventional alternatives. RTTs have different impacts on electricity and gas loads depending on their drive energy, efficiency over the year, and which energy source they replace. We recommend evaluating the rate structure in this respect.

28 The publication "Green Building and Property Value. A Primer for Building Owners and Developers" by IMT and the Appraisal Institute refers to several studies trying to quantify the higher rents achieved by "green buildings".

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Appendices

Appendix 1 – Connecticut Incentives

REGULATIONS			Upstream	Mid Stream	Downstream
			Above-market-level incentives. Applies to the distribution and wholesale businesses	*Infrastructure-level incentives. Applies to district energy and other infrastrutures*	*Project-level implementation incentives (all customer classes)*
State	Upfront	CO2			
State	Upfront	Quota	CT renewable portfolio standard Contractor licensing	CT renewable portfolio standard Contractor licensing	CT renewable portfolio standard CT Building Code Contractor licensing Zoning Permitting
State	Performance based	CO2			
State	Performance based	Quota	Energy efficiency requirements for state government		
Federal	Upfront	CO2			
Federal	Upfront	Quota	Energy goals and standards for Federal Government Green power purchasing goal for Federal Government		
Federal	Performance based	CO2			
Federal	Performance based	Quota			

INCENTIVES			Upstream	Mid Stream	Downstream
			Above-market-level incentives. Applies to the distribution and wholesale businesses	*Infrastructure-level incentives. Applies to district energy and other infrastrutures*	*Project-level implementation incentives (all customer classes)*
State	Upfront	Tax incentives		Sales and use taxes for items used in renewable energy industries	Sales and use tax exemption for solar and geothermal systems Property tax exemption for renewable energy systems
State	Upfront	Subsidies		Eversource and UI energy efficiency programs	Eversource and UI energy efficiency programs Home energy solutions rebate program Ground source heat pump subsidy
State	Upfront	Finance		Municipal (infrastructure) bonds for district energy Qualified Energy Conservation Bonds (QECBs)	Smart- E Loans Energize CT heating loan program Energy conservation loan program Geothermal Heat Pump rebates C-PACE Clean energy on-bill financing Small business energy advantage loan program Local option - Residential sustainable energy program
State	Performance based	Tax incentives			Production tax credit for commercial geothermal and closed-loop biomass
State	Performance based	Subsidies			
State	Performance based	Finance	RECs (class III)		Lead by Example – Energy savings performance contracting program (state and municipal)
Federal	Upfront	Tax incentives		Credit for home builders Investment Tax Credit for solar thermal (ITC)	Modified Accelerated Cost-Recovery System (MACRS) Residential energy efficiency tax credit Energy-efficient new homes tax
Federal	Upfront	Subsidies			USDA - Rural Energy for America Program (REAP) Grants Weatherization Assistance Program (WAP) USDA - High energy cost grant program
Federal	Upfront	Finance	Clean renewable energy bonds U.S. Department of Energy - Loan guarantee program	Clean renewable energy bonds U.S. Department of Energy - loan guarantee program	Energy-efficient mortgages USDA - Rural Energy for America Program (REAP) loan guarantees
Federal	Performance based	Tax incentives			
Federal	Performance based	Subsidies			
Federal	Performance based	Finance			Energy Efficiency Fund (Electric and Gas) - Residential energy efficiency financing

Appendix 2 – Interview Guides

INTERVIEW GUIDE – GOVERNMENT AGENCIES

INTRODUCTION

This interview is part of the project "Feasibility of renewable thermal technologies in Connecticut", which is a cooperation between Yale University, the Yale Center for Business and the Environment, the Connecticut Department of Energy and Environmental Protection, the Connecticut Green Bank, Eversource, and United Illuminating. The purpose of the project is to determine a realistic contribution from renewable thermal technologies to achieve Connecticut's overall target of reducing greenhouse gases, and what factors make the customers invest or not invest.

Renewable thermal technologies (RTTs) are technologies that use renewable energy resources to provide heating and cooling. RTTs can deliver domestic hot water, process heating, space heating and space cooling. These needs are normally served by petroleum, natural gas or electricity today. For the purpose of this project, the following RTTs are included:

- Air Source Heat Pumps and Ground Source Heat Pumps
- Devices burning biomass such as wood chips and wood pellets
- Biofuels such as biogas and biodiesel
- Solar thermal such as solar water heaters
- Waste heat recovery technologies

The purpose of this interview is to gain deeper insight into what makes customers decide whether to invest in these technologies. The project covers residential, commercial and industrial customers. **[Focus for Government Agencies: How do Governmental Agencies view RTTs role in the future, and what regulatory mechanisms do they consider important to develop these markets?]**

The interview is estimated to last 45 to 60 minutes. Is it OK if we record the interview? The audiotape will be destroyed after the study is finalized.

The answers will be treated as confidential, and we will seek your approval for any quotations we wish to publish. You are free to end the interview at any time.

MUNICIPALITIES

[Role as regulator]

1. Describe the number and profile of buildings owned and operated by the municipality.
   [Clues if needed: Square feet, type of buildings, owner vs renter, age of building]
   [This question should be sent out in advance]

2. How does your town heat and cool its buildings today?
   [This question should be sent out in advance]

3. How would you describe the technologies for heating and cooling that you are aware of?
   [If necessary, mention the alternatives]

4. Has the municipality prepared a master energy plan that guides the choice of thermal technologies in the municipality? If yes, describe the main elements of this plan.
   [Refer to project name if known: BGreen 2020, Stamford 2030 District.... If examples of choices are needed: Choice of energy source at municipal new building, choice of energy source at retrofit of existing buildings, land use regulations, permits...]
   [Consult List no 1 - thermal technologies]

5. Please describe the energy projects that have recently been undertaken in your municipality. We are interested in both projects for municipality-owned buildings, and those by residents or businesses in the municipality.
   [Request experience - good or bad]

6. Describe the regulatory measures that would apply to renewable thermal energy projects in the municipality.

7. Describe the municipal permitting / approval process for thermal technologies for (1) residential customers and (2) commercial/industrial customers.
   [Differentiate by type of RTT: Heat pump, bioenergy, solar water heaters, district energy]

8. What do you regard as critical success factors in order for district energy systems to be realized in your municipality
   [If clues are needed: Consult List no 2 – Barriers and Drivers]
   [If the answer is positive – follow up by asking how the municipality would facilitate district energy]

9. From your perspective, what are the most important factors restricting investments in Renewable Thermal Technologies in your municipality?
   [For the municipality to switch to RTTs, and for the city's residential and commercial buildings to switch]

10. From your perspective, what factors have to be in place in order for Renewable Thermal Technologies to be a preferred choice of the municipality in the future?
    [Generally, and for different RTTs in particular: Air Source Heat Pumps, Ground Source Heat Pumps, Solar Hot Water, Bioenergy, District Energy]

11. Other issues that the interviewee finds relevant

CT STATE GOVERNMENT

1. How would you describe the technologies for heating and cooling that you are aware of?
   [If necessary, mention the alternatives]

2. CT has established a thriving Solar PV market. In your opinion, what are the most important factors that influenced that success, and which might be applied to Renewable Thermal Technologies?

3. In your opinion, what were the most important challenges the State had to overcome in developing the Solar PV market? To what extent can this help inform a strategy for Renewable Thermal Technologies?

4. From your perspective, what are the most important incentives and regulations for promoting Renewable Thermal Technologies

   1. Existing today?
   2. To be put in place for the future?
      [Request the rational for future incentives and regulations – which problems would they solve?]

5. Mention the five most important policy changes that you see coming to achieve Connecticut's energy and climate ambitions

6. What does this imply for Renewable Thermal Technologies?

7. What conflicts might exist between the expansion of Renewable Thermal Technologies and other technologies?
[Examples if needed: More efficient natural gas boilers vs RTTs, energy efficiency vs RTTs. If examples have to be given – ask the interviewee to elaborate and evaluate]

8. Other issues that the interviewee finds relevant

INTERVIEW GUIDE – FINANCIAL INSTITUTIONS

INTRODUCTION

This interview is part of the project “Feasibility of renewable thermal technologies in Connecticut”, which is a cooperation between Yale University, Yale Center for Business and the Environment, the Connecticut Department of Energy and Environmental Protection, the Connecticut Green Bank, Eversource and United Illuminating. The purpose of the project is to determine a realistic contribution from renewable thermal technologies to achieve Connecticut’s overall target of reducing greenhouse gases, and what factors make the customers invest or not invest.

Renewable thermal technologies (RTTs) are technologies that use renewable energy resources to provide heating and cooling. RTTs can deliver domestic hot water, process heating, space heating and space cooling. These needs are normally served by petroleum, natural gas or electricity today. For the purpose of this project, the following RTTs are included:

- Air Source Heat Pumps and Ground Source Heat Pumps
- Devices burning biomass such as wood chips and wood pellets
- Biofuels such as biogas and biodiesel
- Solar thermal such as solar water heaters
- Waste heat recovery technologies

The purpose of this interview is to get a deeper insight into what makes customers decide to invest in these technologies or not. The project covers residential, commercial and industrial customers. **[Focus for Financial Institutions: How do Financial Institutions view RTTs role in the future, and what barriers exist to enhance the role of RTTs?]**

The interview is estimated to last 45 to 60 minutes. Is it OK for you if we record the interview? The audiotape will be destroyed after the study is finalized.

The answers will be treated as confidential, and we will seek your approval for any quotations we wish to publish. You may choose to end the interview at any time.

GREEN BANKS

1. How many projects involving Renewable Thermal Technologies have your organization helped financing the last five years?
   [Differentiated by residential, commercial, industrial as well as per RTT]

2. Give examples of best practices that you have observed in successful financing projects for Renewable Thermal Technologies?
[Request examples for both residential, commercial and industrial customers. Ask the interviewee to mention why he/she considers the project(s) to be successful]

3. Comment on projects that have been problematic to finance or execute.
[Request examples for both residential, commercial and industrial customers. Ask the interviewee to mention why the project(s) were difficult to finance or execute]

4. What do you regard as critical success factors in order for district energy systems to be realized (as contrasted with distributed energy technologies)?

5. From your perspective, what are the most important factors restricting investments in Renewable Thermal Technologies?
[Generally, and for different RTTs in particular: Air Source Heat Pumps, Ground Source Heat Pumps, Solar Hot Water, Bioenergy, District Energy]

6. From your perspective, what factors have to be in place in order for Renewable Thermal Technologies to be the preferred choice for customers in the future?
[Generally, and for different RTTs in particular: Air Source Heat Pumps, Ground Source Heat Pumps, Solar Hot Water, Bioenergy, District Energy]

7. What market barriers are your support programs for Renewable Thermal Technologies designed to overcome?
[Consult List 2 if examples are needed]

8. Describe the successes and failures of programs like SmartE and C-PACE. What are considerations for making these programs successful in the CT market?

9. What role can your organization play in deploying Renewable Thermal Technologies?

10. Mention the five most important policy changes that you see coming to achieve Connecticut's energy and climate ambitions

11. What does this imply for Renewable Thermal Technologies?

12. Other issues that the interviewee finds relevant

UTILITIES

1. What are the lessons learned about the Connecticut market through the energy efficiency programs your organization promotes?

2. How many projects involving Renewable Thermal Technologies have your organization helped financing the last five years?
   [Repeat the list of renewable thermal technologies before asking this question. Answer should be differentiated by residential, commercial, industrial as well as per RTT]

3. What methods of financing could be made available to Renewable Thermal Technologies through your organization?
   [Mention examples if necessary: On-bill finance, system charge, grant]

4. Give examples of best practices that you have observed in successful financing projects for Renewable Thermal Technologies?
   [Request examples for both residential, commercial and industrial customers. Ask the interviewee to mention why he/she considers the project(s) to be successful]

5. Comment on projects that have been problematic to finance or execute.
   [Request examples for both residential, commercial and industrial customers. Ask the interviewee to mention why the project(s) were difficult to finance or execute]

6. Describe the successes and failures of programs like SmartE and C-PACE. What are considerations for making these programs successful in the CT market?

7. From your perspective, what factors have to be in place in order for Renewable Thermal Technologies to be the preferred choice for customers in the future?
   [Generally, and for different RTTs in particular: Air Source Heat Pumps, Ground Source Heat Pumps, Solar Hot Water, Bioenergy, District Energy]

8. From your perspective, what are the most important factors restricting investments in Renewable Thermal Technologies?
   [Consult List 2 if necessary. Request the interviewees' view on general basis as well as for different RTTs in particular: Air Source Heat Pumps, Ground Source Heat Pumps, Solar Hot Water, Bioenergy, District Energy]

9. What do you regard as critical success factors in order for district energy systems to be realized (as contrasted with distributed energy technologies)?

10. Other issues that the interviewee finds relevant

INTERVIEW GUIDE – CUSTOMERS

INTRODUCTION

This interview is part of the project "Feasibility of renewable thermal technologies in Connecticut", which is a cooperation between Yale University, Yale Center for Business and the Environment, the Connecticut Department of Energy and Environmental Protection, the Connecticut Green Bank, Eversource and United Illuminating. The purpose of the project is to determine a realistic contribution from renewable thermal technologies to achieve Connecticut's overall target of reducing greenhouse gases, and what factors make the customers invest or not invest.

Renewable thermal technologies (RTTs) are technologies that use renewable energy resources to provide heating and cooling. RTTs can deliver domestic hot water, process heating, space heating and space cooling. These needs are normally served by petroleum, natural gas or electricity today. For the purpose of this project, the following RTTs are included:

- Air Source Heat Pumps and Ground Source Heat Pumps
- Devices burning biomass such as wood chips and wood pellets
- Biofuels such as biogas and biodiesel
- Solar thermal such as solar water heaters
- Waste heat recovery technologies

The purpose of this interview is to get a deeper insight into what makes customers decide to invest in these technologies or not. The project covers residential, commercial and industrial customers.**[Focus for customers: To what extent do the customers know RTTs and what are the factors influencing on investment decisions in heating and cooling technologies?]**

The interview is estimated to last 45 to 60 minutes. Is it OK for you if we record the interview? The audiotape will be destroyed after the study is finalized.

The answers will be treated as confidential, and we will seek your approval for any quotations we wish to publish. You are free to end the interview at any time.

RESIDENTIAL

1. Are you the owner of your current residence? How long have you lived in your current residence?

2. Would you be responsible for any decisions on investments in energy technologies at your residence? If not, who would have to agree?
   [Clues: Landlord, homeowners' association]

3. Tell us about your household's current energy consumption for space heating and cooling, hot water?
[List examples of heating and cooling – consult List 1]
[Clues to guide direction: Describe how you use heat and air conditioning in a typical year? What temperatures are comfortable to you? Age of heating device? Distribution system? Number of residents? Annual energy costs / consumption?]

4. How would you describe the technologies for heating and cooling that you are aware of?
[If necessary, mention the alternatives in List 1]

5. In [insert the relevant year] you received a rebate / Smart E loan from the Connecticut Green Bank for financing a [insert the relevant RTT]. Tell us about your reasons for investing in this device
[Clues: Economic reasons and which, environmental reasons, retrofitting the house, advice from peers, grant. Consult List 2 and ask the interviewee to elaborate if necessary]

6. Describe the process leading up to the point of contacting the CT Green Bank
[Clues: What initiated the process? Where did you search information? Referrals? What caught interest? What made you decide?]

7. What was your experience from installing and financing this device?
[Clues: Easy to find information, ease to orient her/himself in the market, available installers, competent installers, financing, costs as expected, need for adaptations of building or heating system. Consult List 2 and ask the interviewee to elaborate if necessary]

8. What is your experience from operating this device?
[Clues: Ease of use, energy costs, response from others, availability of fuel. Consult List 2 and ask the interviewee to elaborate if necessary]

9. Suppose that your [use reference to question on current energy devices] is old and has to be replaced. What are the considerations that you would make when you explore replacing it?
[Clues: Investment costs, operational costs, limitations of existing building, ease of use, financing, competent installers .. Consult List 2 if necessary]

How would you go about to replace it with a new one?
[Clues: Who would you contact? Where would you seek information? Who's opinion would be important for your decision? How would you finance it?...]

10. What would be the three most important factors making you decide in favor of a renewable thermal technology?
    - **A.** Guaranteed cost savings
    - **B.** Good for the environment
    - **C.** 100 percent upfront financing
    - **D.** Expert advice
    - **E.** Fast recovery of investment through lower annual energy bills
    - **F.** Comfort
    - **G.** Increased property value
    - **H.** Easy to use and low maintenance

    [Have the interviewee elaborate his / her choices]

11. What would be your considerations if you were to choose between changing your heating and cooling source as compared to changing windows and insulating your house?

12. Other issues that the interviewee finds relevant

COMMERCIAL

[For customers having received Green Bank support: 8 – 11 are important. For customers not having received Green Bank support: Ask if they have changed their heating or cooling device the last years, and then continue with questions 9 – 11.]

1. Does your company / organization own the building you occupy, or do you rent?

1. Describe your business and its need for heating and cooling.

2. What do you use to meet those heating and cooling needs today?
   [Consult List 1 if necessary]

3. Describe the internal decision making process of energy related projects at your company / organization.
   [Who would be involved? Who would make the decision? Budget or operational expenses? Priority compared to other investment projects?]

4. How would you describe the technologies for heating and cooling that you are aware of?
   [If necessary, mention the alternatives]

5. Suppose that the energy infrastructure of your company's building(s) is old and has to be replaced. What would be the most important considerations to make for your company?
   [Clue from question 3]
   [Clues: Investment costs, operational costs, limitations of existing building, ease of use, financing .. Consult List 2]

6. Which of these technologies would you consider when you have to replace your existing thermal energy solution and why?
   - **A.** Air Source Heat Pumps
   - **B.** Ground Source Heat Pumps
   - **C.** Solar Hot Water
   - **D.** Bioenergy such as wood pellets
   - **E.** District Energy
   - **F.** Natural Gas
   - **G.** Fuel oil/heating oil/propane

7. In [insert the relevant year] your organization received a rebate / loan from the Connecticut Green Bank for financing a [insert the relevant RTT]. Tell us about your reasons for investing in this device
   [Clues: Economic reasons and which, environmental reasons, retrofitting the house, advice from peers, grant. Consult List 2 and ask the interviewee to elaborate if necessary]

8. Describe the process leading up to the point of contacting the CT Green Bank
   [Clues: What initiated the process? Where did you search information? Referrals? What caught interest? What made you decide?]

9. What was your experience from investing and installing this device?
   [Clues: Easy to find information, ease to orient her/himself in the market, available installers, competent installers, financing, costs as expected, need for adaptations of building or heating system. Consult List 2 and ask the interviewee to elaborate if necessary]

10. What is your experience from operating this device?
    [Clues: Ease of use, energy costs, response from others, availability of fuel. Consult List 2 and ask the interviewee to elaborate if necessary]

11. What would be the three most important factors making you decide in favor of a renewable thermal technology?
    - **A.** Guaranteed cost savings
    - **B.** Good for the environment
    - **C.** 100 percent upfront financing
    - **D.** Expert advice
    - **E.** Fast recovery of investment through lower annual energy bills
    - **F.** Comfort
    - **G.** Increased property value
    - **H.** Easy to use and low maintenance

    [Have the interviewee elaborate his / her choices]

12. What would be your considerations if you were to choose between changing the heating and cooling source as compared to changing windows and insulating your building?

13. Describe your organization's ability to access capital for these types of projects.

14. Other issues that the interviewee finds relevant

INDUSTRIAL

1. Describe the particular needs for thermal energy of your business. Specify if process heating and cooling is required.

2. What are the current energy sources for thermal purposes?

3. Describe your company's internal decision making process for energy-related projects.
   [Who would be involved? Who would make the decision? Budget or operational expenses? Priority compared to other investment projects?]

4. Suppose that the energy infrastructure of you company is old and has to be replaced. What would be the most important considerations to make for your company?
   [Clues: Investment costs, operational costs, limitations of existing building, ease of use, financing .. Consult List 2]

5. Which of these technologies would you consider when you have to replace your existing thermal energy solution and why?
   A. Air Source Heat Pumps
   B. Ground Source Heat Pumps
   C. Solar Hot Water
   D. Bioenergy such as wood pellets
   E. Biogas
   F. District Energy
   G. Natural Gas
   H. Fuel oil/heating oil/propane

6. Have you been involved in a Renewable Thermal Technology project before? Tell us about it.
   [Clues: Type of project, e.g., replacing furnace, renovate heating system, facilitating for the utilization of waste heat, energy efficiency measures for thermal purposes]

7. Describe the process leading up to the point of investing in the technology?
   [Clues: What initiated the process? Where did you search information? Referrals? What caught interest? What made you decide?]

8. What was your experience from investing and installing this device?
   [Clues: Easy to find information, ease to orient her/himself in the market, available installers, competent installers, financing, costs as expected, need for adaptations of building or heating system. Consult List 2 and ask the interviewee to elaborate if necessary]

9. What is your experience from operating this device?
   [Clues: Ease of use, energy costs, response from others, availability of fuel. Consult List 2 and ask the interviewee to elaborate if necessary]

10. What is most important to your organization when considering an energy technology investment?
    [Clues: Guaranteed cost savings, 100 % upfront financing, expert advice, high internal rate of return, low operational costs, fast recovery of investment through lower annual energy bills]

11. Describe your organization's ability to access capital for these types of projects.

12. Other issues that the interviewee finds relevant

INTERVIEW GUIDE – INSTALLERS

INTRODUCTION

This interview is part of the project "Feasibility of renewable thermal technologies in Connecticut", which is a cooperation between Yale University, Yale Center for Business and the Environment, the Connecticut Department of Energy and Environmental Protection, the Connecticut Green Bank, Eversource and United Illuminating. The purpose of the project is to determine a realistic contribution from renewable thermal technologies to achieve Connecticut's overall target of reducing greenhouse gases, and what factors make customers invest or not invest.

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- Devices burning biomass such as wood chips and wood pellets
- Biofuels such as biogas and biodiesel
- Solar thermal such as solar water heaters
- Waste heat recovery technologies

The purpose of this interview is to get a deeper insight into what makes customers decide to invest in these technologies or not. The project covers residential, commercial and industrial customers. **[Focus for installers: What do installers experience as the most important factors influencing on customer decisions investing in thermal technologies or not?]**

The interview is estimated to last 45 to 60 minutes. Is it OK for you if we record the interview? The audiotape will be destroyed after the study is finalized.

The answers will be treated as confidential, and we will seek your approval for any quotations we wish to publish. You are free to end the interview at any time.

QUESTIONS

1. What types of thermal technologies does your company install?

2. How many projects did your company have the 1) last year, 2) last 5 years?
   A. Air Source Heat Pumps
   B. Ground Source Heat Pumps
   C. Solar Hot Water
   D. Bioenergy such as wood pellets
   E. District energy
   F. Natural Gas
   G. Fuel oil/heating oil/propane

3. What kind of customers do you serve?
   [Clues: Residential, Commercial, Industrial. Type of buildings. Public vs private]

4. Are there particular challenges you see in delivering Renewable Thermal Technology to each of these groups?
   [Clues: Lack of awareness, prejudices, physical limitations of buildings, capital restraints, alternative source is cheaper. Consult List 2 for more]

5. Describe the trends you see in the industry.
   [Clues: Which technologies are currently thriving/struggling? What do you experience as being important to your customers? Competition in the industry? Quality of work?)

6. What do you think about the reputation and position of Renewable Thermal Technologies in the renewable energy sector?
   [Considered environmentally friendly? Easy to use? Comfortable? Low energy costs? Energy savings? Innovative and modern?]

7. How would you describe these technologies when you advise your customers who need to replace their existing boiler?
   A. Air Source Heat Pumps
   B. Ground Source Heat Pumps
   C. Solar Hot Water
   D. Bioenergy such as wood pellets
   E. District energy
   F. Natural Gas
   G. Fuel oil/heating oil/propane

8. What is your process on advising customers on heating and cooling solutions?
   [Clues: What types of questions do you ask and what are the main considerations for advising one technology over another?]

9. What are the most important factors that make your customers wishing to install Renewable Thermal Technologies?
   [Consult List 2 for examples if necessary]

10. What are the most important factors that make your customers hesitant to install Renewable Thermal Technologies?
    [Consult List 2 for examples if necessary]

11. Are there credit or incentive programs that your firm is offering to customers? Is financing an option? Which of these programs work well? Which don't work well?

12. Describe how you train your staff to install new Renewable Thermal Technologies

13. Other issues that the interviewee finds relevant

INTERVIEW GUIDE – INDUSTRY ASSOCIATIONS

INTRODUCTION

This interview is part of the project "Feasibility of renewable thermal technologies in Connecticut", which is a cooperation between Yale University, Yale Center for Business and the Environment, the Connecticut Department of Energy and Environmental Protection, the Connecticut Green Bank, Eversource and United Illuminating. The purpose of the project is to determine a realistic contribution from renewable thermal technologies to achieve Connecticut's overall target of reducing greenhouse gases, and what factors make the customers invest or not invest.

Renewable thermal technologies (RTTs) are technologies that use renewable energy resources to provide heating and cooling. RTTs can deliver domestic hot water, process heating, space heating and space cooling. These needs are normally served by petroleum, natural gas or electricity today. For the purpose of this project, the following RTTs are included:

- Air Source Heat Pumps and Ground Source Heat Pumps
- Devices burning biomass such as wood chips and wood pellets
- Biofuels such as biogas and biodiesel
- Solar thermal such as solar water heaters
- Waste heat recovery technologies

The purpose of this interview is to get a deeper insight into what makes customers decide to invest in these technologies or not. The project covers residential, commercial and industrial customers. **[Focus for Industry Associations: What does the industry generally experience as barriers and drivers to RTTs?]**

The interview is estimated to last 45 to 60 minutes. Is it OK for you if we record the interview? The audiotape will be destroyed after the study is finalized.

The answers will be treated as confidential, and we will seek your approval for any quotations we wish to publish. You are free to end the interview at any time.

1. How would you describe the technologies for heating and cooling that you are aware of?
   [If necessary, mention the alternatives]

2. From your perspective, what are the most important factors restricting investments in Renewable Thermal Technologies?
   [Ask the interviewee to answer both for RTTs generally, and for the technology he/she represents specifically. Consult List 2 if necessary to give examples]

3. From your perspective, what factors have to be in place in order for Renewable Thermal Technologies to be the preferred choice of customers in the future?
   [Follow up: Are these factors different for the technology you represent compared to other renewable energy technologies? Consult List 2 if necessary to give examples]

4. What do you regard as the advantages and disadvantages of district energy systems vs distributed energy technologies?

5. What do you regard as critical success factors in order for district energy systems to be realized (as contrasted with distributed energy technologies)?

6. How do you forecast the overall market size for the technology you represents?

7. How well do customers (residential, commercial, industrial) understand Renewable Thermal Technologies and recognize these technologies as viable options when making decisions?

8. In your opinion, what are the most important challenges facing the industry you represent?
   [Clues: Competence of installers, regulations, costs, awareness of customers. Consult List 2 for more examples if necessary]

9. Which companies, in terms of manufacturers, distributors, and installers, are the main players in [the technology represented by the interviewee] ? How were they able to differentiate themselves?

10. What makes [the technology represented by the interviewee] attractive relative to other technologies, such as natural gas?

11. How easy is it for customers to access information on Renewable Thermal Technologies? Where do you send customers who are looking for information?

12. Other issues that the interviewee finds relevant

Appendix 3 – Stakeholders Participating in the Study

TYPE OF STAKEHOLDER	# INTERVIEWED	DESCRIPTION OF EACH INTERVIEWEE
Residential customer	5	• Environmentally conscious single family renovating their recently bought home. Unfamiliar with oil. Simultaneous measures: energy efficiency, ground source heat pumps (GSHP), solar thermal, and PV. Received incentives • Single family renovating their recently bought home. Unfamiliar with oil. Simultaneous measures: energy efficiency, GSHP, solar PV, ductwork. Received incentives • Single family considering different renewable energy options, particularly solar PV, and air source heat pump (ASHP). Considering selling their house in the near future, and expecting increased salability with cooling. No incentives • Single family having done measures over 18 years. Received incentives for solar PV and solar hot water. Replaced the oil boiler with a gas boiler connected to the grid • Multi-family with GSHP installed when the apartment building was being built. Received incentives
Commercial customer	6	• University close to a waste heat source • University with own energy provision, both electricity and thermal. Sources from natural gas, thermal grid, GSHP, and solar thermal • Municipality with several unexploited waste heat sources available and long-term sustainability plan • Museum having installed GSHP with incentives. Several sources covering different parts of the building. • Public School. Department investing in new schools and refurbishments, leaning toward LEED. • City with coordinated energy efficiency effort across commercial customers
Industrial customer	2	• Industrial customer utilizing jacket water rand exhaust and turning it into space heating, space and process cooling • Industrial customer owned by private equity

Installers	5	• Installer of geothermal systems based on an ESCO model. Focus on district energy • Regional installer of bioenergy installations primarily in residential buildings. Does also install oil and gas boilers • Installer of solar thermal, mostly hot water, but also cooling and dehumidification. Both residential and commercial customers • Installer of solar thermal, mainly in residential buildings. Has also done installations for low-income buildings and an industrial customer • Installer of solar thermal water heating, geothermal, ASHP, and ductless ASHP
Financing institutions	3	• Public and private companies providing financial incentives for selected RTTs in Connecticut
Other stakeholders	4	• Regulator • Project developer of district energy based on waste heat • Industry association • Manufacturer of pellets and wood chip boilers

Appendix 4 – Summary of the Workshop

RTT BARRIERS AND DRIVERS SOLUTIONS WORKSHOP: SYNTHESIZED FINDINGS

Problem Statement 1: RTT financing should be a profitable investment for both customers and lenders, and should be scalable and repeatable.

Problem Statement 2: The RTT market should allow customers and installers to discover RTTs as an energy option, and make the value RTTs can provide obvious to all stakeholders.

MARKET-LEVEL SOLUTIONS

- Metering technology and reporting processes should be standardized to facilitate transparency in system performance and comparability across installations (all RTTs)
- To alleviate the policy risk of incentives disappearing after a large capital investment, customers should have assurance that earlier adopters will be grandfathered in the event incentives are phased out
- Bundling energy efficiency and other investments with RTT investments maximizes co-benefits and improves the financial viabiltiy of projects
- A Thermal Renewable Energy Credit (T-REC) should be instituted to provide positive cashflow for financing, and to make RTT benefits salient

CUSTOMER CLASS-SPECIFIC SOLUTIONS

Residential

- Simple, readily-available financing packages, standard offers
- RTT financing should consist of lease and loan products
- Dealer and installer education and support programs
- Awareness campaign: RTT education and technology discovery
- Streamlined, integrated marketing materials on Energize CT website
- Partner with suppliers: Home Depot/Lowes, contractor networks to increase availablity of RTT technologies and expertise
- Integrate RTT system sizing/suitability analysis into HES audits

Commercial

- Promote performance-based contracts with installers/manufacturers
- Compile and publish best practices and case studies
- Bundle off-the-shelf equipment, financing, and incentives
- Developed standardized installation and financing contracts

Industrial

- State-level tax credits linked to CAPEX
- Compile and publish best practices and case studies
- C-PACE financing
- Develop industrially-focused marketing campaign
- Tailor financing and technology bundles to subsets of industry, to account for heterogeneity across energy demands
- Make RTT available through ESCOs to increase visibility and profliferation
- Pilot projects for new classes of industrial customers

RTT BARRIERS AND DRIVERS SOLUTIONS WORKSHOP: MAPPING TO BARRIERS AND DRIVERS

MAIN BARRIERS

BARRIER	RECOMMENDATIONS
High upfront costs RTTs require significant upfront capital investments to install, while the benefits they provide accrue over the long-term life of the technology	• Simple, readily-available financing packages, standard offers • RTT financing should consist of lease and loan products • State-level tax credits linked to CAPEX • To alleviate the policy risk of incentives disappearing after a large capital investment, customers should have assurance that earlier adopters will be grandfathered in the event incentives are phased out • A Thermal Renewable Energy Credit (T-REC) should be instituted to provide positive cashflow for financing, and to make RTT benefits salient • C-PACE financing • Tailor financing and technology bundles to subsets of industry, to account for heterogeneity across energy demands • Create financial mechanism to smooth cash flows of large capital investments (e.g. allow for realization of ITC before tax filing)
Lack of knowledge The economic and technical advantages RTTs can provide are not salient and obvious to customers. The performance of a RTT system is not immediately tangible to customers. RTTs are disadvantaged from a general market-awareness perspective.	• Metering technology and reporting processes should be standardized to facilitate transparency in system performance and comparabiity across installations (all RTTs) • Integrate RTT system sizing/suitability analysis into HES audits • Streamlined, integrated marketing materials on Energize CT website • Develop cross-channel marketing campaigns tailored to customer segments • Bundling energy efficiency and other investments with RTT investments maximizes co-benefits and improves the financial viability of projects • Awareness campaign: RTT education and technology discovery for uninformed customers new to the energy space

BARRIER	RECOMMENDATIONS
Installer business models not supported for RTT growth Installers in the RTT space are disadvantaged relative to competing energy technologies. Current business models favor fossil energy technologies and create limited opportunities for customers to discover RTTs and installers skilled in their installation.	• Dealer and installer education and support programs • Promote performance-based contracts with installers/manufacturers • Compile and publish best practices and case studies • Develop standardized installation and financing contracts • Make RTT available through ESCOs to increase visibility and proliferation • Pilot projects for new classes of industrial customers • Bundle off-the-shelf equipment, financing, and incentives • Partner with suppliers: Home Depot/Lowes, contractor networks to increase availablity of RTT technologies and expertise • Continue utility programs of subsidizing energy efficient or RTT equipment upstream
Split incentives hinder logical investments in RTT Split incentives render irrelevant business cases for RTTs that make financial sense. Residential, commercial, and industrial rental properties provide limited opportunities for investment benefits to accrue to energy users who stand to benefit.	• Create advertising platform/marketing materials for landlords to market energy-efficient apartments • Require disclosure of expected energy costs in lease signings/listings

MAIN DRIVERS

DRIVER	RECOMMENDATIONS
Climate policy Climate and environmental policies can create demand for renewable thermal technology implementations.	• Restructure CT Renewable Portfolio Standards to include RTTs
New services RTT installations are particularly successful when they provide new incremental services to the customer (e.g. geothermal provides cooling to a residential customer previously with-out air conditioning)	• Target customers that stand to make incremental gains from the installation of RTTs (e.g. target customers without air conditioning for geothermal installations) • Bundle RTTs or sell as part of packaged solutions to maximize value provided • Market the ability RTTs have to provide improved thermal comfort (residential customers) or low-cost incremental heating and cooling (air source heat pumps)
Financial Structures Tax code-based subsidies encourage investment in RTTs by reducing high upfront capital costs.	• The Federal Investment Tax Credit should be extended to cover geother-mal heat pumps at the same level of support given to Solar PV and Solar Hot Water • State-level tax credits can make up for gaps in RTT subsidies absent in current ITC • Informational resources should be created to help business and custom-ers discover available incentives and simplify the process of getting them • Production-based subsidies: T-RECs or similar to Production Tax Credit • Promote performance-based contracts with installers/manufacturers • Financial products: loans, leases, C-PACE financing • Subsidies for geothermal??

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CONNECTICUT GREEN BANK

Memo

To: Board of Directors of the Connecticut Green Bank

From: George Bellas (VP of Finance and Administration) and Eric Shrago (Director of Operations)

CC: Bryan Garcia (President and CEO)

Date: June 16, 2017

Re: Fiscal Year 2018 Targets, Proposed Annual Budget, and Strategic Partners

---

Attached is the draft FY 2018 Operating Budget for the Connecticut Green Bank. This memo outlines key recommendations from the Budget & Operations Committee with regards to the Targets and Budget for the Board of Directors review and approval.

I. Targets

The senior management team proposed, and the Budget and Operations Committee reviewed and recommends to the Board of Directors the approval of the following targets for FY 2018 in the Comprehensive Plan

Infrastructure Sector

Program	FY 18 Projects	FY 18 Capital Deployed	FY 18 Clean Energy Deployed (MW)
RSIP	4,431	$ 136,300,000	37.0
Anaerobic Digester	1	$ 20,000,000	1.6
Strategic Investments	1	$ 15,000,000	3.7
Total:	**4,433**	**$ 171,300,000**	**42.3**

Residential Sector				
Program	FY 18 Projects	FY 18 Capital Deployed		FY 18 Clean Energy Deployed (MW)
Smart-E	440	$	8,153,050	1.3
Posigen (LMI Targeted Solar)	720	$	20,087,746	4.5
Multifamily Term Loans	16	$	7,550,000	0.6
Multifamily Pre-Development Loans	9	$	188,400	-
Total:	**1,185**	**$**	**35,979,196**	**6.4**

Commercial, Industrial, and Institutional Sector				
Program	FY 18 Projects	FY 18 Capital Deployed		FY 18 Clean Energy Deployed (MW)
C-PACE	51	$	24,400,000	6.4
CT Solar Lease	25	$	15,000,000	6.3
SBEA	1,600	$	28,000,000	
Total:	**67-1667**		**$34,000,000-$62,000,000**	**10.4**

Connecticut Green Bank				
Sector	FY 18 Projects	FY 18 Capital Deployed		FY 18 Clean Energy Deployed (MW)
Infrastructure Sector	4,433	$	171,300,000	42.3
Residential Sector	1,185	$	35,979,196	5.6
Commercial, Industrial, and Institutional Sector	67-1667		$34,000,000-$62,000,000	10.4
Total:	**4,845 - 6,451**		**$ 217,629,445 - $ 246,996,946**	**52.5** [1]

II. Budget

In accordance with Section V of the Connecticut Green Bank operating procedures, enclosed is the Fiscal Year 2018 Annual Operating Budget. The Budget and Operations Committee met on May 26, 2017 and June 09, 2017 to review the proposal and has recommended approval by the Board of Directors.

[1] Residential solar projects that receive financing from CGB also receive an incentive in RSIP so are counted in each sector's goal. Similarly, there is overlap between Posigen supported LMI targeted solar projects and RSIP as well as between CPACE and the Commercial Lease. They have been removed from the total to avoid double counting

P-1	Projected Revenues and Expenses FYE June 30, 2018
P-2	Employee Staffing Plan
S-1	Program Loans and Working Capital Advances
S-2	Credit Enhancements
S-3	Program Incentives and Grants

III. Review of Strategic Partners

Enclosed with the budget materials is a list of Strategic Partners for review, discussion, and reauthorization. These external partners have been reviewed and approved by the Budget and Operations Committee and are being recommended by the Budget and Operations Committee for approval by the Board of Directors.

S-4	Strategic Partners

<u>Resolutions:</u>

WHEREAS, on June 9th, 2017 the Connecticut Green Bank Budget and Operations Committee recommended that the Green Bank Board of Directors approve the Fiscal Year 2017 Budget and Targets; and

WHEREAS, on June 9th, 2017 the Connecticut Green Bank Budget and Operations Committee recommended that the Connecticut Green Bank Board of Directors authorize Connecticut Green Bank staff to extend the professional services agreements (PSAs) currently in place or adopt new PSAs with:

I. Adnet Technologies, LLC
II. Archaeological & Historical Services, Inc.
III. Clean Power Research, LLC
IV. Cortland Capital Market Services LLC
V. EnergySage Inc.
VI. Forsyth Street Advisors, LLC
VII. Locus Energy LLC
VIII. METIS, Financial Network, Inc.
IX. New Ecology, Inc.
X. OpFocus, Inc.
XI. Opinion Dynamics Corporation
XII. Paul Horowitz
XIII. SmartPower Inc.
XIV. Strategic Environmental Associates, Inc.

XV. Sustainable Real Estate Solutions, Inc.
XVI. The Connecticut Housing Coalition, Inc.
XVII. Wegowise, Inc.

For fiscal year 2018 with the amounts of each PSA not to exceed the applicable approved budget line item.

NOW, therefor be it:

RESOLVED, that the Connecticut Green Bank Board of Directors hereby approves: (1) the FY 2018 Budget and Targets and, (2) the seventeen PSAs listed above, as both items were recommended by the Connecticut Green Bank Budget and Operations Committee.

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CONNECTICUT GREEN BANK

Memo

To: Connecticut Green Bank Board of Directors

From: Mackey Dykes, VP, Commercial, Industrial and Institutional Programs

CC: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Brian Farnen, General Counsel and CLO; George Bellas, VP, Finance and Administration; Mike Yu, Senior Manager, Clean Energy Finance; Ben Healey, Director, Clean Energy Finance; Alex Kovtunenko, Counsel, Commercial, Industrial and Institutional Programs

Date: June 16, 2017

Re: Establishing a SPE for C-PACE transactions

BACKGROUND

The Connecticut Green Bank ("Green Bank") continues to administer a very successful Commercial Property Assessed Clean Energy Program ("C-PACE Program"), with $98.7MM[1] in closed C-PACE project financing. In its role as a lender in the C-PACE Program, Green Bank has excelled at originating transactions and crafting public-private partnerships for financing such transactions, including a first of its kind commercial PACE securitization with Clean Fund, and, more recently, a partnership with Hannon Armstrong for a facility with an accordion feature up to $100MM to co-invest in eligible C-PACE transactions.

In structuring such funds, facilities, and public-private partnerships in other programs (such as CT Solar Lease II and III), Green Bank has often relied on the use of special purpose entities ("SPEs"), which are affiliates or subsidiaries of Green Bank, typically formed as Connecticut limited liability companies or corporations. The use of such SPEs enables Green Bank to structure legal partnerships, mitigate risk, and define the roles and responsibilities of various counterparties to an agreement in order to achieve specific goals without exposing or committing Green Bank's full balance sheet to that endeavor.

Green Bank currently manages six such SPEs, as follows: CGB Meriden LLC, CT Solar Loan I LLC, CT Solar Lease 2 LLC, CT Solar Lease 3 LLC, CEFIA Holdings LLC, and CEFIA Solar Services Inc. (each being a "CGB SPE"). Since all CGB SPEs are used to serve specific functions in existing funds or programs, it would be infeasible to use any existing CGB SPE for the C-PACE Program.

PROPOSAL

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[1] Current through the end of the first calendar quarter of 2017. Includes Green Bank financed projects as well as third party capital provider projects.

Consistent with previous authorizations from the Green Bank Board of Directors (the "Board") to create Green Bank SPEs, Green Bank staff is now seeking approval from the Board for the establishment of an SPE for the C-PACE Program. Such an SPE would be used to, among other things, enter into financing agreements directly with eligible C-PACE borrowers who meet Green Bank underwriting criteria. Such transactions would be aggregated and warehoused in such SPE (currently they are held directly on Green Bank's balance sheet) until they are ready to be sold/assigned pursuant to an existing C-PACE Program fund/investment agreement (i.e. Hannon Armstrong) or one to be established in the future. The creation of such SPE would facilitate further scale for the C-PACE Program by creating a dedicated legal vehicle that should more easily enable private capital partners to review the portfolio, verify standardized terms and conditions across a pool of assets, and participate in financings accordingly on an aggregated – rather than asset-level – basis.

Resolutions

WHEREAS, in its various programs and private-public partnerships, Green Bank has successfully utilized special purpose entities ("SPEs") to facilitate private capital investment in certain program; and

WHEREAS, the Green Bank intends to create a new special purpose entity for use in the Commercial Property Assessed Clean Energy Program ("C-PACE") to, among other things, originate, aggregate and warehouse transaction before such transactions are sold/assigned into an existing or future C-PACE private capital fund.

NOW, therefore be it:

RESOLVED, that the Green Bank Board of Directors ("Board") authorizes the President of the Green Bank and any other duly authorized officer of the Green Bank, to create a special purpose entity for the limited purpose outline herein as well as that certain memorandum date June 16, 2017 which has been submitted to the Board; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and negotiate and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

Submitted by: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Mackey Dykes, VP, Commercial, Industrial and Institutional Programs; Brian Farnen, General Counsel and CLO; George Bellas, VP, Finance and Administration

650 Glenbrook Road: A C-PACE Project in Stamford, CT

Address	650 Glenbrook Road, Stamford CT 06906			
Owner	Glenbrook Industrial Park LLC			
Proposed Assessment	$413,981.00			
Term (*years*)	20			
Term Remaining (*months*)	Pending construction completion			
Annual Interest Rate	6.0%			
Annual C-PACE Assessment	$36,061.00			
Savings-to-Investment Ratio	1.43x			
Average DSCR	[redacted]			
Lien-to-Value	[redacted]			
Loan-to-Value	[redacted]			
Projected Energy Savings (mmBTU)		EE	RE	Total
	Per year	--	554	554
	Over term	--	10,594	10,594
Estimated Cost Savings (incl. ZRECs and tax benefits)	Per year	--	$51,190	$51,190
	Over term	--	$1,023,833	$1,023,833
Objective Function	25.59 kBTU / ratepayer dollar at risk			
Location	Stamford			
Type of Building	Manufacturing/Industrial Plant			
Year of Build	1943			
Building Size (*sf*)	181,216			
Year Acquired by Owner	1975			
As-Complete Appraised Value	[redacted]			
Mortgage Lender Consent	[redacted]			
Proposed Project Description	Renewable Energy – 135 kW Solar			
Est. Date of Construction Completion	Pending closing			
Current Status	Awaiting Approval			
Energy Contractor	[redacted]			
Notes				

11 Executive Drive: A C-PACE Project in Farmington, CT

Address	11 Executive Drive, Farmington, CT 06032			
Owner	DiTommaso Associates, LLC			
Proposed Assessment	$396,488			
Term (*years*)	10			
Effective Annual Interest Rate	5.07%			
Annual C-PACE Assessment	$51,034			
Savings-to-Investment Ratio	2.44			
Average DSCR	[redacted]			
Lien-to-Value	[redacted]			
Loan-to-Value	[redacted]			
Projected Energy Savings (mmBTU)		EE	RE	Total
	Per year	-	677	677
	Over term	-	6,774	6,774
Estimated Cost Savings (incl. ZRECs and tax benefits)	Per year	-	$75,339	$75,339
	Over term	-	$753,389	$753,389
Objective Function	17.09 kBTU / ratepayer dollar at risk			
Location	Farmington			
Type of Building	Sports Complex			
Building Size (*sf*)	128,958			
Year Acquired by Owner	Initial 40% of property acquired in 2003, then another 50% acquired in 2008, and then final 10% acquired in 2012			
Assessed Value	[redacted]			
Mortgage Lender Consent	[redacted]			
Proposed Project Description	Installation of 131 kW and 40 kW Solar PV Systems			
Est. Date of Construction Completion	Pending closing			
Current Status	Awaiting Board of Directors Approval			
Energy Contractor	[redacted]			
Notes	-			

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Memo

To: Connecticut Green Bank Board of Directors

From: Kim Stevenson, Associate Director, Multifamily Programs

Cc: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Brian Farnen, General Counsel and CLO; Eric Shrago, Director of Operations; George Bellas, VP Finance and Administration; Kerry O'Neill, Vice President of Residential Programs, John D'Agostino, Associate Director, Multifamily Programs

Date: June 23, 2017

Re: $1,500,000 EnergizeCT Health and Safety Revolving Loan Fund Implementation Guidelines and V.2 of the Multifamily Catalyst Fund Pilot Program Guidelines, amended to incorporate use of funds from the EnergizeCT Health and Safety Revolving Loan Fund

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Background

On May 30, 2017 Green Bank staff submitted and received approval, by the Green Bank Board of Directors' Deployment Committee, for Green Bank and DEEP staff to jointly develop an EnergizeCT Health and Safety Revolving Loan Agreement ("Agreement") whereby the Green Bank shall establish a revolving loan fund ("the EnergizeCT Health and Safety Revolving Loan Fund") using $1.5 million of Regional Greenhouse Gas Initiative (RGGI) dollars from the Department of Energy & Environmental Protection (DEEP) to support owners of residential properties that house low and moderate income residents, including multifamily and single-family properties, to cover the costs of remediating health and safety issues that must be addressed in conjunction with implementation of energy efficiency upgrades.

Per the Agreement, and before distribution of EnergizeCT Health and Safety Revolving Loan Fund funds, the Green Bank has received DEEP approval of EnergizeCT Health and Safety Revolving Loan Fund ("Health & Safety Fund") Implementation Guidelines dated June 2017, attached as Appendix 1 (page 5). These Health & Safety Fund Implementation Guidelines are general guidelines that apply to the multifamily and single-family residential sectors.

The Health & Safety Fund Implementation Guidelines also include multifamily guidelines that amend the guidelines approved by the Board for the Catalyst Fund Pilot Program on January 20, 2017. These amended Catalyst Fund Pilot Program Guidelines (Version 2) integrate the Health and Safety Fund as a source of capital for the Catalyst Fund Pilot Program. The amended guidelines have been designed so that the Health and Safety Fund funds augment and can be easily woven into current Green Bank multifamily loan programs as well as utility incentive programs, including those under the joint EnergizeCT Multifamily Initiative. These amended Catalyst Fund Pilot Program Guidelines (Version 2) are attached as Appendix A of Appendix 1 (page 10).

Per Green Bank governance protocols, the amended guidelines for the Catalyst Fund Pilot Program (Version 2) must be brought to the Green Bank Board of Directors for review and approval, which is the purpose of this memo.

The May 30th 2017 memorandum to the Deployment Committee, including approved resolutions for the Health and Safety Fund, are attached in Appendix 2.

Proposal

Green Bank staff request review and approval from the Board of Directors for amended Catalyst Fund Program Guidelines in Appendix A of Appendix 1 which incorporate the addition of funds from the $1.5 Million *EnergizeCT Health and Safety Revolving Loan Fund* to be used for remediation of health and safety work related to energy upgrades. The substantive changes to the guidelines are:

- A provision for grants for health and safety remediation, on an exception basis, if certain tenant income thresholds are met; and
- The requirement that funded projects comply with state set-aside contracting rules if EnergizeCT Health and Safety Revolving Loan funds are used in that project.

Resolutions

WHEREAS, the Connecticut Green Bank ("Green Bank") actively seeks to deploy private capital investment toward clean energy improvements in the state's multifamily housing which in some cases have preexisting health and safety issues that are preventing opportunities for clean energy improvements to be made;

WHEREAS, the definition of "clean energy" per the Green Bank's enabling statute set forth at C.G.S. 16-45n includes renewable energy technologies as well as "financing of energy efficiency projects," but does not include health and safety;

WHEREAS, the Green Bank's enabling statute provides that the Green Bank may make "expenditures that promote investment in clean energy in accordance with a comprehensive plan developed by it to foster the growth, development, and commercialization of clean energy sources," and that "such expenditures may include, but not be limited to…the implementation of the plan developed pursuant to … this section";

WHEREAS, the Green Bank Comprehensive Plan approved by the Board of Directors on July 22, 2016 acknowledges the need to mitigate health and safety issues that act as barriers to realizing clean energy investments opportunities; the Comprehensive Plan also notes that the goals of the Green Bank are to support the implementation of Connecticut's clean energy policies be they statutory (i.e., PA 15-194), planning (i.e., Comprehensive Energy Strategy, Integrated Resources Plan), or regulatory in nature;

WHEREAS, the Connecticut Department of Energy and Environmental Protection (DEEP's) 2013 Comprehensive Energy Strategy and the 2014 report of the Connecticut Department of Public Health highlights a funding gap for health and safety remediation as a significant barrier to energy upgrades in the state.

WHEREAS, Green Bank staff has developed expertise and programmatic capacity in deploying funds to remove health and safety barriers to realize clean energy improvements at multifamily properties consistent with the Green Bank's enabling statute through its current multifamily programs and program partnerships;

WHEREAS, Green Bank Deployment Committee, on May 30, 2017, approved the receipt and administration of $1.5 million in Regional Greenhouse Gas Initiative funds from DEEP for the purpose of funding remediation of energy related health and safety barriers in residential housing through a program titled EnergizeCT Health and Safety Revolving Loan Fund ("H&S Fund");

WHEREAS, Green Bank staff has developed, submitted to and received approval of Health and Safety Fund guidelines, policies and procedures from DEEP, as required by DEEP prior to distribution of funds, per the executed Agreement dated June 1, 2017 between Green Bank and DEEP;

NOW, therefore be it:

RESOLVED, that the Board authorizes administration of the Catalyst Fund Pilot Program as amended to incorporate Health and Safety Fund conditions consistent with the guidelines and memorandum dated June 23, 2017 and associated exhibits submitted to the Board; and;

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

Submitted by: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Kerry O’Neill, Vice President, Residential Programs; Kim Stevenson, Associate Director, Multifamily Programs; and John D’Agostino, Associate Director, Multifamily Programs.

<u>Appendix 1</u>

CT Green Bank Residential Multifamily and Single-Family Programs

EnergizeCT Health and Safety Revolving Loan Fund

(“Health & Safety Fund”)

Implementation Guidelines

(June 2017)

Health & Safety Fund Goals and Purpose:

The EnergizeCT Health and Safety Revolving Loan Fund (“Health and Safety Fund”) now housed at the Green Bank to provide gap funding, in the form of loans, and, on an exception basis, grants for health and safety measures that enable implementation of energy improvements for owners unable to secure adequate funding from other sources.

Health and Safety Fund-funded programs will be required to meet implementation guidelines as described below.

Background

Residential financing products have often lacked sufficient funding to implement substantive energy improvements for low- and moderate-income properties that present a spectrum of complex financial, health and safety challenges. Participating properties will be those with high energy burdens and operating costs. They may present a multitude of challenges, including energy-related health and safety (H&S) issues, that must be addressed before implementing clean energy measures.

The Green Bank staff has deep expertise in affordable housing development, energy systems analysis, building science and finance, and has become the go-to resource for energy underwriting for state agencies and institutions such as the Department of Housing (DOH) and Connecticut Housing Financing Authority (CHFA). Green Bank staff expects that participating properties will present complex financing and technical/energy issues for which the Green Bank, given its expertise, is uniquely qualified to evaluate and underwrite. The reality is traditional funders are typically ill equipped to effectively evaluate and address clean energy projects in the affordable housing space.

Such challenges include, but are not limited to:

- *Properties serving low income tenants are up to 5 times more energy-use intensive than average benchmarks for similar property types. Further, the US Department of Housing and Urban Development (HUD) spends nearly 23 percent of this budget—over $1.5 billion (nationally) — on utilities to heat, cool, power and provide water for public housing units.[1] Public and affordable/low-income properties present significant opportunities for energy savings[2].*
- *Based on Home Energy Solutions contractor reports, utility program administrators estimate that 20-40% of units cannot complete energy efficiency/weatherization services due to H&S issues[3].*
- *Representative H&S improvements necessary to implement clean energy measures include:*
    - *Pre-installation of high-efficiency heating systems – asbestos and asbestos-like materials containment/remediation/removal;*
    - *Pre-weatherization/air and duct sealing – mold, moisture remedies, lead remediation or encapsulation;*
    - *Pre-insulation – knob and tube wiring, leak repair, asbestos or asbestos-like materials containment/remediation/removal; and*
    - *Pre-installation of high efficiency windows – lead encapsulation/remediation/removal.*

At present, other than limited resources available to households receiving federal weatherization assistance and limited allocations in existing clean energy financing products, and limited amounts available through utility-administered energy efficiency programs, there is *no* Connecticut public agency or non-profit organization providing substantive resources to specifically address these energy-related challenges faced by residential properties serving low- and moderate-income residents. This is especially an issue for those that DO NOT receive support from the competitive programs at HUD, DOH and CHFA. The Connecticut Department of Energy and Environmental Protection (DEEP's) Comprehensive Energy Strategy and the 2014 report of the Department of Public Health highlights this funding gap as a significant barrier to energy upgrades in the state.

The Health & Safety Fund has been established at the Green Bank through a transfer of $1.5 million of Regional Greenhous Gas Initiative proceeds from DEEP. The Health & Safety Fund will complement and integrate with Green Bank financing products and utility-administered energy efficiency programs, recognizing the fact that numerous properties have serious and

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[1] US Department of Housing and Urban Development: Benchmarking Utility Usage in Public Housing, 2007 Report

[2] http://www.energyefficiencyforall.org/potential-energy-savings

[3] Ongoing conversations from 2014-2016 with DEEP, utility, EEB and contractor personnel. DEEP has requested utility program administrators to begin collecting data on H&S issues in 2016.

costly health and safety issues and will benefit significantly from targeted funding with flexible lending criteria that includes loans and, on an exception basis, grants.

The Health and Safety Fund will help inform the design of scalable programs that can effectively address energy-related challenges faced by residential properties in the state serving low- and moderate-income residents.

Development & Administration:

The Health & Safety Fund will focus on multifamily housing first. This is the logical place to begin because the Green Bank Multifamily Programs are already established and under operation and can be easily modified to integrate the Health & Safety Fund. Version 2 of the Program Guidelines for the Multifamily Catalyst Pilot Fund, amended to integrate the Health & Safety Fund, are attached as Appendix A.

Single-family programs that incorporate health and safety lending require further analysis for design and development, which the Green Bank has initiated, but which is expected to take some time. The single-family energy lending environment is far more complex than the multifamily sector. There are five energy financing programs currently for homeowners that might need to be integrated into the Health and Safety Fund, involving at last count 14 separate lenders (programs include EnergizeCT Heating Loan, Smart-E Loan, 0% Payment Plan Loan, Energy Conservation Loan and PosiGen Solar Lease and Energy Savings Agreement). Single-family programs are expected to be developed once the multifamily program is underway, and in consultation with DEEP staff.

Requirements and Terms:

REQUIREMENTS & TERMS	
Loan and Grant Type	Loans that provide financing enabling the implementation of qualifying energy improvements and remediation of safety measures that prohibit implementation of qualifying energy improvements. Subordinate, secured debt or unsecured debt may also be considered based on requirements of existing debt and property/project financials. On an exception basis, if a single-family property houses a household at 60% of state median income or below, or a multi-family property serves at least 60% of its households at 80% of area median income or below, then up to 25% of the Health & Safety Fund amount may be granted. Further, additional amounts (above 25%) may be granted on an exception basis for properties owned by non-profits, state and federally funded housing authorities, co-operatives and condominium complexes, based on the needs and financial strength of the property. The Health & Safety Fund shall be established as a revolving loan fund.

Income Requirements	The Health & Safety Fund shall serve low and moderate income residential property owners using relevant definitions applied by utility company, DOE, HUD, DOH, CHFA or DEEP program requirements, as appropriate to the relevant single- or multifamily program being delivered.
Eligible Energy Improvements	Health and Safety Fund financing is intended to support investments in and implementation of comprehensive, deeper energy improvements. Examples of eligible energy improvements include: 1) Measures incented by the electric/gas utilities' criteria for rebates as specified in a Letter of Agreement (LOA) or Letter of Participation (LOP). 2) Eligible measures under Green Bank financing products or other work associated with implementation of the State's Comprehensive Energy Strategy and the current Connecticut Electric and Natural Gas Conservation and Load Management Plan 3) Fuel conversions and associated improvements, provided selected equipment meets efficiency specifications required to qualify for utility incentives and/or US EPA Energy Star energy efficiency criteria 4) Energy storage 5) Electric vehicle charging stations 6) Other energy upgrades with a commercial track record of realized savings, as approved by the Green Bank 7) Project commissioning 8) Energy performance monitoring and verification 9) Assessment/ audit costs Relevant energy assessments and audits performed by qualified service providers that meet Green Bank and utility company requirements, may be required on a program by program basis, as relevant.
Eligible Health & Safety Improvements	For multifamily housing, property owners must complete a whole building energy audit satisfactory to the Green Bank and performed by qualified energy and health and safety service provider(s), as relevant and appropriate. The audit must identify substantive energy improvements, cost of improvements and expected energy savings and health and safety (H&S) issues impeding energy improvements. Such audit must be conducted by an energy professional with BPI Energy Auditor or BPI Healthy Home Assessor or equivalent qualifications. . Examples include, but are not limited to, measures to contain, address, remove, or remediate mold, sources of mold, asbestos, asbestos-like materials, lead paint, or other hazards; and/or amelioration or replacement of leaking pipes, roofs, leaking combustion equipment, carbon monoxide, radon gas, knob and tube wiring, etc. Costs of the relevant audits and assessments are also eligible for loan funds. For single family housing, energy and health and safety audit requirements will be considered and established at a later date, when health and safety loan programs are developed for this sector.

Loan/ Grant Amounts	Up to $300,000 (higher amounts subject to Deployment Committee or Board of Director approval based on funding availability and project feasibility.
Loan Term	Up to 20 years.
Loan Rate	Subject to program design and underwriting – anticipated in 0% to 6% range.
Prepayment	Allowed with no penalty.
Loan Fees	To be determined as appropriate for the relevant single- or multifamily program.
Eligible Properties	Residential single and multifamily properties serving low- and moderate-income residents including, but not limited to: private, non-profit or housing authority-owned apartment buildings, coops, condominiums, or assisted living communities.
Energy Monitoring	Required for multifamily housing using a Green Bank-approved energy performance monitoring system. All energy usage and monitoring data must be made available electronically to Green Bank on a monthly basis. Summary reports shall be provided to DEEP on an annual basis. Single-family requirements TBD on a program basis and may not be required if data gathering and reporting create requirements and complexity that prohibit customer interest and participation in a program. Summary reports shall be provided to DEEP on an annual basis.
Contractor Requirements	Projects using Health & Safety Funds are subject to the requirements of CGS Sec. 4a-60g "Set Aside Program for small contractors and minority business enterprises, individuals with disabilities and nonprofit corporations" unless exempt from these requirements by the Department of Administrative Services (DAS) Diversity Program. For contracts using non-exempted funding sources and subcontracting any portion of work, contractors are required to subcontract 25% of the total contract value to small businesses certified by the DAS and are further required to subcontract 25% of that 25% to minority and women small contractors certified as minority business enterprises by the DAS.
Underwriting	Determined on a program by program basis.
Advances	Determined on a program by program basis.

Appendix A

CT Green Bank Multifamily Programs

Catalyst Fund Pilot Program

Program and Underwriting Guidelines

Version 2.0 (Released June 2017)

Program Goals and Purpose:

The Multifamily Program has identified lack of sufficient funding available to implement substantive energy improvements for low- and moderate-income properties that present a spectrum of complex financial, health and safety challenges. The Connecticut Green Bank's *Catalyst Fund Pilot Program* ("Pilot Program") draws on its own funding and funding from Department of Energy and Environmental Protection's EnergizeCT Health and Safety Revolving Loan Fund ("Health and Safety Fund") now housed at the Green Bank to provide gap funding, in the form of loans, and, on an exception basis, grants for health and safety measures that enable implementation of energy improvements for residential property owners unable to secure adequate funding from other sources. Pilot Program-funded projects will be required to meet Program and Underwriting Guidelines as described below.

Participating Pilot Program properties will be those with high energy burdens and operating costs. They may present a multitude of challenges, including energy-related health and safety (H&S) issues, that must be addressed before implementing energy measures.

The Green Bank Multifamily team has deep expertise in affordable multifamily housing development, energy systems analysis, building science and finance, and has become the go-to resource for multifamily energy underwriting for state agencies and institutions such as the Department of Housing (DOH) and Connecticut Housing Financing Authority (CHFA). The Multifamily Program expects that participating properties will present complex financing and technical/energy issues for which the Green Bank, given its expertise, is uniquely qualified to evaluate and underwrite, but traditional funders are ill equipped to effectively evaluate and address.

Such challenges include, but are not limited to:

- *Properties serving low income tenants are up to 5 times more energy-use intensive than average benchmarks for similar property types. Further, the US Department of Housing and Urban Development (HUD) spends nearly 23 percent of this budget—over $1.5 billion (nationally) — on utilities to heat, cool, power and provide water for public housing* *units.*[4] *Public and affordable/low-income properties present significant opportunities for energy savings*[5]*.*

- *Based on Home Energy Solutions contractor reports, utility program administrators estimate that 20-40% of units cannot complete energy efficiency/weatherization services due to H&S issues*[6]*.*
- *Representative H&S improvements necessary to implement clean energy measures include:*
    - *Pre-installation of high-efficiency heating systems – asbestos and asbestos-like materials containment/remediation/removal;*
    - *Pre-weatherization/air and duct sealing – mold, moisture remedies, lead remediation or encapsulation;*
    - *Pre-insulation – knob and tube wiring, leak repair, asbestos or asbestos-like materials containment/remediation/removal; and*
    - *Pre-installation of high efficiency windows – lead encapsulation/remediation/removal.*

At present, other than limited resources available to households receiving federal weatherization assistance and limited allocations in existing clean energy financing products, and limited pilot amounts available through utility-administered energy efficiency programs, there is *no* Connecticut public agency or non-profit organization providing substantive resources to specifically address these energy-related challenges faced by multifamily properties serving low and moderate income residents, especially those that DO NOT receive support from the competitive programs at HUD, DOH and CHFA. The Connecticut Department of Energy and Environmental Protection (DEEP's) Comprehensive Energy Strategy and the 2014 report of the Department of Public Health highlights this funding gap as a significant barrier to energy upgrades in the state.

The EnergizeCT Health and Safety Revolving Loan Fund ("Health & Safety Fund") has been established by DEEP at the Green Bank through a transfer of $1.5 million of Regional Greenhous Gas Initiative proceeds to complement and integrate with the Green Bank's residential programs, including multifamily and single family programs and utility-administered energy efficiency programs, recognizing the fact that numerous properties have serious and costly health and safety issues and will benefit significantly from targeted funding with flexible lending criteria that includes loans and, on an exception basis, grants.

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[4] US Department of Housing and Urban Development: Benchmarking Utility Usage in Public Housing, 2007 Report

[5] http://www.energyefficiencyforall.org/potential-energy-savings

[6] Ongoing conversations from 2014-2016 with DEEP, utility, EEB and contractor personnel. DEEP has requested utility program administrators to begin collecting data on H&S issues in 2016.

The Pilot Program will help inform the design of scalable programs that can effectively address energy-related challenges faced by affordable multifamily properties in the state.

Pilot Program and Underwriting Guidelines:

These guidelines apply to term financing for the implementation of energy improvements. The Multifamily team expects that a number of these properties may have H&S issues that must be addressed before implementing energy measures. Program guidelines for Pilot Program funding applies based on the severity of necessary H&S improvements, as defined below:

1. Properties with H&S implementation costs funded through the Pilot Program that represent **<u>less than 50% of the total project cost</u>** ("Category 1 Properties").
2. Properties with H&S implementation costs funded through the Pilot Program that represent **<u>50% or more of the total project cost</u>** **<u>but no greater than 75%</u>** ("Category 2 Properties").

"Total project cost" is defined as all costs necessary to implement an energy project and generally includes pre-development costs, financing costs, energy measures, remediation of H&S obstacles, commissioning, and post-implementation monitoring and verification. See Attachment C for an example of how total project costs are calculated.

Category 1 Properties can be funded through the Pilot Program subject to the terms and guidelines in Attachment A, which builds from the HDF/MacArthur financing term sheet.

Category 2 Properties can be funded through the Pilot Program, subject to the guidelines outlined in Attachment A and the additional guidelines set forth in Attachment B. These guidelines are designed to ensure H&S remediation will lead to significant energy improvements and there is either ratepayer[7] or non-ratepayer[8] funding committed for the implementation of energy improvements.

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[7] Pursuant to CT Gen Stat § 16-245n(c), the Connecticut Green Bank administers the Clean Energy Fund on behalf of Connecticut ratepayers. Ratepayer funded programs also include utility-administered efficiency and demand management programs.

[8] Including, but not limited to, charitable gifts, grants, contributions as well as loans from individuals, corporations, university endowments and philanthropic foundations.

Appendix A: Attachment A

Catalyst Fund Pilot Loan Program ("Pilot Program")

REQUIREMENTS & TERMS

<table>
<tr><th colspan="2">Loan Product Details</th></tr>
<tr><td>Loan and
Grant Type</td><td>Term loan that provides gap financing enabling the implementation of qualifying energy improvements and remediation of safety measures that prohibit implementation of qualifying energy improvements.

Subordinate, secured debt or unsecured debt may also be considered based on requirements of existing debt and property/project financials.

For remediation of health and safety measures funded by the Health & Safety Fund, on an exception basis, if a multi-family property serves at least 60% of its households at 80% of area median income or below, then up to 25% of the Health & Safety Fund amount may be granted. Further, additional amounts (above 25%) may be granted on an exception basis for properties owned by non-profits, state and federally funded housing authorities, co-operatives and condominium complexes, based on the needs and financial strength of the property.</td></tr>
<tr><td>Eligible Energy
Improvements</td><td>Property owners must complete a whole building energy audit satisfactory to the Green Bank and performed by qualified energy and health and safety service provider(s), as relevant and appropriate. The audit must identify substantive energy improvements, cost of improvements and expected energy savings and health and safety (H&S) issues impeding energy improvements. Such audit must be conducted by an energy professional with BPI Energy Auditor or BPI Healthy Home Assessor or equivalent qualifications.

The audit must identify substantive energy improvements, cost of improvements and expected energy savings and health and safety (H&S) issues impeding energy improvements.

Pilot Program funds are intended to support investments in and implementation of comprehensive, deeper energy improvements. Examples of eligible energy improvements include:
1) Measures incented by the electric/gas utilities' criteria for rebates as specified in a Letter of Agreement (LOA) or Letter of Participation (LOP).
2) Eligible measures under Green Bank financing products or other work associated with implementation of the State's Comprehensive Energy Strategy and the current Connecticut Electric and Natural Gas Conservation and Load Management Plan
3) Fuel conversions and associated improvements, provided selected equipment meets efficiency specifications required to qualify for utility incentives and/or US EPA Energy Star energy efficiency criteria
4) Energy storage
5) Electric vehicle charging stations
6) Other energy upgrades with a commercial track record of realized savings, as approved by the Green Bank
7) Project commissioning
8) Energy performance monitoring and verification</td></tr>
</table>

Eligible Health & Safety Improvements	Health and safety improvements directly impeding energy improvements and identified through a qualified whole building audit may be funded. Examples include, but are not limited to, measures to contain, address, remove, or remediate mold, sources of mold, asbestos, asbestos-like materials, lead paint, or other hazards; and/or amelioration or replacement of leaking pipes, roofs, leaking combustion equipment, carbon monoxide, radon gas, knob and tube wiring, etc.
Loan/ Grant Amounts	Up to $300,000 (higher amounts subject to Deployment Committee or Board of Director approval based on funding availability and project feasibility – see required "Coverage Ratio").
Loan Term	Up to 20 years.
Loan Rate	Subject to underwriting – anticipated in 0% to 6% range.
Prepayment	Allowed with no penalty.
Loan Fee	0.50% upfront; may be rolled into loan. Fee may be waived at the discretion of Green Bank staff.
Eligible Properties	Residential properties with 5 or more units serving low- and moderate-income tenants including, but not limited to: private, non-profit or housing authority-owned apartment buildings, coops, condominiums, or assisted living communities.
Energy Monitoring	Required using a Green Bank-approved energy performance monitoring system. All energy usage and monitoring data must be made available electronically to Green Bank on a monthly basis.
Contractor Requirements	Projects using Health & Safety Funds are subject to the requirements of CGS Sec. 4a-60g "Set Aside Program for small contractors and minority business enterprises, individuals with disabilities and nonprofit corporations" unless exempt from these requirements by the Department of Administrative Services (DAS) Diversity Program. For contracts using non-exempted funding sources and subcontracting any portion of work, contractors are required to subcontract 25% of the total contract value to small businesses certified by the DAS and are further required to subcontract 25% of that 25% to minority and women small contractors certified as minority business enterprises by the DAS.
Underwriting	
Coverage Ratio	Net Operating Income (NOI)/debt service (including the proposed gap financing after considering savings that are expected to result from the financing) of at least 1.10x. Ratio may be reduced with a mortgage or significant personal / corporate guaranty for properties with strong overall financials, smaller dollar volume loans, or otherwise at discretion of Green Bank staff.

Borrower/Sponsor Financials	• Existing DSCR > 1.0 OR projected > 1.0 DSCR subsequent to energy improvement(s) implementation • Current assets / current liabilities >1.0 • Total Liabilities / Tangible Net Worth not in excess of 3.00:1.00 • Mortgage payments and taxes are current or subject to a reasonable plan to make current
Miscellaneous	
Advances	Loan funds will be advanced in accordance with a disbursement schedule approved by Green Bank staff. This includes written confirmation and approval, as applicable, of all required: - Municipal inspections by appropriate municipal officials - Utility inspections by appropriate local electric or gas utility company - For projects that include energy conservation measures beyond those approved for incentives under a utility letter of agreement, final inspection and written approval by a qualified third party approved by the Green Bank

Appendix A: Attachment B

Category 2 Property Additional Guidelines

1. *Substantive energy improvements* must be implemented. ***"Substantive Energy Improvements" is*** defined as follows:
    a. Projected energy use intensity (EUI[9]) reduced by > 10% from baseline – for projects with multiple buildings, average EUI across all buildings > 10% from average baseline.

    b. For projects involving only the replacement of heating and/or domestic hot water systems, the new system must meet efficiency specifications required to qualify for utility incentives and be at least 10% more efficient than the system being replaced.

2. Property owners must complete a whole building energy audit satisfactory to the Green Bank and performed by qualified energy and health and safety service provider(s), as relevant and appropriate. The audit must identify substantive energy improvements, cost of improvements and expected energy savings and health and safety (H&S) issues impeding energy improvements. Such audit must be conducted by an energy professional with BPI Energy Auditor or BPI Healthy Home Assessor or equivalent qualifications. The audit must identify energy improvements, cost of improvements and expected energy savings, and health and safety issues impeding energy improvements.

3. H&S work financed through the Pilot Program must be tied to implementation of *Substantive Energy Improvements*. To ensure the implementation of *Substantive Energy Improvements*, sources of funds, satisfactory to the Green Bank, to cover the costs of *Substantive Energy Improvements* need to be presented. Satisfactory documentation will be in the form of a commitment letter and/or term sheet.

[9] Calculated as **energy** per square foot per year: the total **energy** consumed by the building in one year (measured in kBtu or GJ), divided by the total gross floor area of the building.)

Appendix A: Attachment C

Example Demonstrating Definition/ Calculation of Total Project Costs

EXAMPLE: COZY TOWN ESTATES				
	Energy Items	**H&S Items**	**Total Costs**	**Utility Incentive**
Pre-Development	$50		$50	
Insulation	$200		$200	($150)
High efficiency heating system	$150		$150	($50)
LED lighting	$50		$50	($40)
Asbestos & mold remediation		$700	$700	
Monitoring & Verification	$10		$10	
Totals	**$460**	**$700**	**$1,160**	**($240)**
% of Total Cost	**40%**	**60%**		

The total project cost in this example is $1,160

Appendix A: Attachment D

Case Study Examples of Properties that May Benefit from the Pilot Program

Case Study 1 – Seabury Cooperative, New Haven

Overview

Seabury is a 2-building, 88-unit resident-owned low and moderate-income housing cooperative, located adjacent to the Yale campus and ideally situated in an employment hub with easy access to public transportation. Due to its location, developers frequently approach Seabury's Board with acquisition offers.

Potential Energy Improvements, Health & Safety

The well-designed property is a community asset constructed in 1972 and is now in need of numerous capital improvements, the most pressing of these include replacement of electric boilers that provide domestic hot water with high efficiency solutions, a failing roof and elevators, and the need for many small repairs.

United Illuminating funded a ASHRAE Level II Energy Audit for the property in 2014. The potential savings of the most cost-effective measures identified by the audit have an estimated savings to investment ratio (SIR) of 5.6. The replacement of the property's electric resistance heating could decrease heating costs by an additional 41%. For a property that has expended its reserves to cover the cost of its ever-increasing utilities, these prospective savings have the potential to return a project to financial viability.

Green Bank Technical Assistance to-date

To-date, the Green Bank multifamily team has provided the Coop Board and its property management with extensive technical assistance to develop a comprehensive strategy to improve the property's energy efficiency and performance, health and safety, and financial viability. Revitalization of the property will preserve an important housing resource and serve community needs. Challenges include reducing the cost of maintaining aging systems, enhancing the capacity of Seabury's Board to successfully manage the property into the future, eliminating health and safety hazards and re-establishing healthy reserve levels.

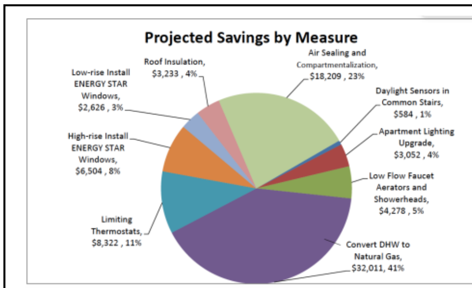

Figure 2: Projected Savings by Measure

Case Study 2 – Success Village Cooperative, Bridgeport and Stratford

Overview

Success Village is a resident-owned cooperative with 924 units in 97 buildings. It is a strong and vibrant community serving low- and moderate-income residents. This historical property was built in the period from 1941 and 1951 as housing for defense workers and veterans.

Potential Energy Improvements, Health & Safety

The property's benchmarking indicates that this is the worst performing property in our current BenchmarkCT portfolio.

Success Village is heated from a central plant of five boilers (four of which are currently operational) that feed steam throughout the campus through a network of degraded, and asbestos-laden steam pipes. One boiler has been decommissioned due to unsafe conditions. Others are close to failing. Units lack sufficient insulation, weather sealing, efficient lighting and other cost effective measures. Thus, in the winter months, residents living in units closest to the central heating plant frequently prop their windows open to dissipate the excessive heat, while residents of units farthest from the plant receive little heat and employ electric heaters as a stop-gap heating solution.

Pipes leak, portions of the steam heating system are 75 years old, and all systems are failing and need to be replaced. The coop association pays for heating – and is suffering from crushing energy bills. Inefficiencies include one original boiler that requires a level of service not currently available, heating the ground surrounding the steam tunnels and the lack of any consistent weatherization. The cost of operating this inefficient system has led to increases in carrying charges many residents find onerous. The possibility of heating system failure and high operational costs jeopardize this important housing resource.

Green Bank Technical Assistance to-date

To-date, Green Bank staff have provided extensive technical assistance to support the Board's knowledge of the property's energy issues, development of financial documentation necessary for lending, securing professional services and developing an integrated approach to making the development more sustainable. Without this assistance, the Board is unable to secure funding for the energy improvements.

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Appendix 2

Memo

To: Connecticut Green Bank Board of Directors

From: Kim Stevenson, Associate Director, Multifamily Programs

Cc: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Brian Farnen, General Counsel and CLO; Eric Shrago, Director of Operations; George Bellas, VP Finance and Administration; Kerry O'Neill, Vice President of Residential Programs, John D'Agostino, Associate Director, Multifamily Programs

Date: May 30, 2017

Re: $1,500,000 Green Bank Multifamily EnergizeCT Health and Safety Revolving Loan Fund

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Background

On January 23, 2015, the Connecticut Green Bank (the "Green Bank") Board of Directors (the "Board") approved a Program Related Investment ("PRI")[1] in the amount of $5,000,000 from the John D. and Catherine T. MacArthur Foundation ("MacArthur") to support the Green Bank's efforts to accelerate energy efficiency and clean energy upgrades in affordable multifamily properties across the state of Connecticut as outlined in the proposal presented by the Green Bank to MacArthur ("MacArthur Proposal"). The proposal is presented as Exhibit A.

Due to state contracting compliance challenges with MacArthur, on December 18th, 2015, the Board approved the Housing Development Fund ("HDF") as a third-party receiver and administrator of the MacArthur funds due to HDF's shared programmatic goals and experience in the state's affordable multifamily housing sector (see Exhibit B).

On January 23, 2017, the Board further approved a *Catalyst Fund Pilot Program* ("Pilot Program"), to provide $1.5M in gap funding in the form of loans to enable implementation of energy improvement projects for affordable property owners unable to secure adequate funding through traditional financing programs. The Pilot Program provides financing for properties that present complex financing and technical/energy issues that the Green Bank, given its expertise, is uniquely qualified to evaluate and underwrite, but traditional funders are less well equipped to consider and address (see Exhibit C).

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[1] Program Related Investments (PRIs) are investments made by foundations to support social welfare activities that involve the return of capital within an established timeframe. PRIs include financing methods commonly associated with banks or other private investors, such as loans, loan guarantees, linked deposits, and even equity investments in charitable organizations or in commercial ventures, with concessionary rates and terms.

At present, other than limited resources available to households receiving federal weatherization assistance and limited allocations in existing clean energy financing products, and limited pilot amounts available through utility-administered energy efficiency programs, there is *no* Connecticut public agency or non-profit organization providing substantive resources to specifically address these energy-related challenges faced by multifamily properties serving low and moderate income residents, especially those that DO NOT receive support from the competitive programs at HUD, DOH and CHFA. The Connecticut Department of Energy and Environmental Protection (DEEP's) 2013 Comprehensive Energy Strategy and the 2014 report of the Department of Public Health highlights this funding gap as a significant barrier to energy upgrades in the state. DEEP requires that weatherization professionals implementing the federal weatherization assistance program and weatherization professionals implementing the current utility-administered Electricity and Natural Gas Conservation and Load Management Plan collect data on homes identified as needing to be deferred from weatherization until health and safety concerns are addressed.

The Green Bank is working to help fill some of these gaps in our multifamily programs through the MacArthur PRI funds and the Catalyst Fund Pilot Program, but additional resources are needed to have substantive impact on the residential market.

Given the Green Bank's growing expertise and capacity in financing energy and energy-related health and safety improvements as well as the significant need in the residential market for resources to remediate energy related health and safety barriers, and given available Regional Green House Gas Initiative ("RGGI") funds at DEEP, DEEP believes it is most prudent to have the Green Bank receive and manage these RGGI funds for the purpose of funding remediation of energy related health and safety barriers in residential housing through a program titled EnergizeCT Health and Safety Revolving Loan Fund ("H&S Fund").

Proposal

The Green Bank staff and DEEP staff are jointly developing an EnergizeCT Health and Safety Revolving Loan Agreement ("Agreement") whereby the Green Bank shall establish a revolving loan fund ("the EnergizeCT Health and Safety Revolving Loan Fund") using $1.5 million of Regional Greenhouse Gas Initiative (RGGI) dollars from the Department of Energy & Environmental Protection (DEEP) to support owners of residential properties that house low and moderate income residents to cover the costs of remediating health and safety issues that must be addressed in conjunction with implementation of energy efficiency upgrades (The final Agreement, to be executed by DEEP and Green Bank, shall be materially similar to the document in Exhibit D).

The Green Bank will establish and administer this fund to be used in conjunction with its other residential financing products administered by Green Bank staff and program service providers, as well as other energy efficiency programs administered by CT's major energy utilities

The EnergizeCT Health and Safety Revolving Loan Fund will be established as a revolving loan fund for residential properties with households at or below 80% of area median income.

On an exception basis, if a single-family property serves a household at 60% of state median income or below, or a multi-family property serves at least 60% of its households at 80% of area median income or below, then up to 25% of the H&S Fund amount may be granted, conditional upon completion of the remedial work. Further, additional amounts (above 25%) may be granted on an exception basis for properties owned by non-profits, state and federally funded housing authorities, co-operatives and condominium complexes, based on the needs and financial strength of the property.

Before distribution of the H&S funds, the Green Bank shall seek and receive DEEP approval of the program underwriting guidelines, terms, and conditions and shall provide documentation that a dedicated accounting process is in place to manage the revolving fund. These underwriting guidelines, terms and conditions will be directionally similar to guidelines developed and approved by the Board for the Catalyst Fund Pilot Program. They will be designed so that the H&S funds augment and can be easily woven into current Green Bank loan programs as well as utility incentive programs, including those under the joint EnergizeCT Multifamily Initiative. (It is the intent of staff to bring these program guidelines to the Board for approval at the June Board Meeting.)

It is Green Bank's intention to use and develop these funds for our multifamily programs. We may consider program development for our single-family programs at a future date and will bring back such program expansion for approval at a later date.

Further, development and deployment of the H&S Fund shall help inform the design of future scalable programs that can effectively address energy-related challenges faced by residential properties across the state.

These funds are restricted for the containment and remediation of health and safety conditions that prevent completion of clean energy improvements at residential properties and the revolved funds remain with the Green Bank in perpetuity.

The full $1.5 million will be drawn down by the Green Bank upon signing the Agreement. Any EnergizeCT Health and Safety Revolving Loan Fund capital not deployed at least once by June 30, 2022 by the Green Bank will be returned to DEEP.

Resolutions

WHEREAS, the Connecticut Green Bank ("Green Bank") actively seeks to deploy private capital investment toward clean energy improvements in the state's multifamily housing which in some cases have preexisting health and safety issues that are preventing opportunities for clean energy improvements to be made;

WHEREAS, the definition of "clean energy" per the Green Bank's enabling statute set forth at C.G.S. 16-45n includes renewable energy technologies as well as "financing of energy efficiency projects," but does not include health and safety;

WHEREAS, the Green Bank's enabling statute provides that the Green Bank may make "expenditures that promote investment in clean energy in accordance with a comprehensive plan developed by it to foster the growth, development, and commercialization of clean energy sources," and that "such expenditures may include, but not be limited to…the implementation of the plan developed pursuant to … this section";

WHEREAS, the Green Bank Comprehensive Plan approved by the Board of Directors on July 22, 2016 acknowledges the need to mitigate health and safety issues that act as barriers to realizing clean energy investments opportunities; the Comprehensive Plan also notes that the goals of the Green Bank are to support the implementation of Connecticut's clean energy policies be they statutory (i.e., PA 15-194), planning (i.e., Comprehensive Energy Strategy, Integrated Resources Plan), or regulatory in nature;

WHEREAS, the Connecticut Department of Energy and Environmental Protection (DEEP's) 2013 Comprehensive Energy Strategy and the 2014 report of the Connecticut Department of Public Health highlights a funding gap for health and safety remediation as a significant barrier to energy upgrades in the state.

WHEREAS, Green Bank staff has developed expertise and programmatic capacity in deploying funds to remove health and safety barriers to realize clean energy improvements at multifamily properties consistent with the Green Bank's enabling statute through its current multifamily programs and program partnerships;

WHEREAS, Green Bank staff is now requesting approval to receive and administer $1.5 million in Regional Greenhouse Gas Initiative funds from DEEP for the purpose of funding remediation of energy related health and safety barriers in residential housing through a program titled EnergizeCT Health and Safety Revolving Loan Fund ("H&S Fund").

NOW, therefore be it:

RESOLVED, that the Board authorizes approval to receive and administer $1.5 million in Regional Greenhouse Gas Initiative funds DEEP for the purpose of funding remediation of energy related health and safety barriers in residential housing through the H&S Fund;

RESOLVED, that programmatic terms and conditions for distribution of these funds will be brought to the Board for approval at a future date and will be directionally consistent with the guidelines and memorandum dated January 13, 2017 regarding the H&S Fund and associated exhibits submitted to the Board; and

RESOLVED, that the proper Green Bank officers are authorized and empowered to do all other acts and execute and deliver all other documents and instruments as they shall deem necessary and desirable to affect the above-mentioned legal instruments.

Submitted by: Bryan Garcia, President and CEO; Bert Hunter, EVP and CIO; Kerry O'Neill, Vice President, Residential Programs; Kim Stevenson, Associate Director, Multifamily Programs; and John D'Agostino, Associate Director, Multifamily Programs.

MAY 2017

Bringing the Benefits of Solar Energy to Low-Income Consumers

A Guide for States & Municipalities

Bentham Paulos, PaulosAnalysis

SUSTAINABLE SOLAR EDUCATION PROJECT

Powered by SunShot
U.S. Department of Energy

Clean Energy States Alliance

ABOUT THIS GUIDE AND THE SUSTAINABLE SOLAR EDUCATION PROJECT

Bringing the Benefits of Solar Energy to Low-Income Consumers: A Guide for States & Municipalities is one of six program guides produced by the Clean Energy States Alliance (CESA) as part of its Sustainable Solar Education Project. The project aims to provide information and educational resources to help states and municipalities ensure that distributed solar electricity remains consumer friendly and its benefits are accessible to low- and moderate-income households. In addition to publishing program guides, the Sustainable Solar Education Project is producing webinars, an online course, a monthly newsletter, and in-person training on topics related to strengthening solar accessibility and affordability, improving consumer information, and implementing consumer protection measures regarding solar photovoltaic (PV) systems. More information about the project, including a link to sign up to receive notices about the project's activities, can be found at *www.cesa.org/projects/sustainable-solar*.

ABOUT THE U.S. DEPARTMENT OF ENERGY SUNSHOT INITIATIVE

The U.S. Department of Energy SunShot Initiative is a collaborative national effort that aggressively drives innovation to make solar energy fully cost-competitive with traditional energy sources before the end of the decade. Through SunShot, the Energy Department supports efforts by private companies, universities, and national laboratories to drive down the cost of solar electricity to $0.06 per kilowatt-hour. Learn more at *www.energy.gov/sunshot*.

ABOUT THE AUTHOR

Bentham Paulos is an independent consultant and writer based in Berkeley, California. He provides consulting services on energy policy, technology, and trends to nonprofits, government agencies, foundations, and corporations, and is a regular contributor to *Greentech Media*, *POWER Magazine*, and other publications. More information is at PaulosAnalysis.com.

ACKNOWLEDGMENTS

Thank you to the following individuals for their contributions to the guide: Todd Bluechel of CollectiveSun; Anthony Clark, Emily Basham, Brian Farnen, Isabelle Hazlewood, Ben Healey, Edward Kranich, Kerry O'Neill, Selya Price, Kim Stevenson, and Nicholas Zuba at Connecticut Green Bank; Tim Lindl at Keyes & Fox LLP; Karla Loeb at Posigen; Melanie Santiago-Mosier at VoteSolar; and Diana Chace, Maria Blais Costello, Samantha Donalds, Nate Hausman, Warren Leon, and Robert Sanders at the Clean Energy States Alliance.

DISCLAIMER

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SECTION 1
Executive Summary

The declining cost of solar energy is creating opportunities for all Americans to save money on their energy bills. And no one benefits from energy savings more than low-income consumers, who pay a much higher portion of their income for energy than middle- and high-income consumers.

But being poor creates barriers to accessing solar power and its economic benefits. Low-income consumers lack sufficient savings that can be used to buy solar systems, and they may have low credit scores or a lack of credit history that may impede their ability to finance a system. They are often renters, or live in multifamily housing, without ownership of their roof.

Many programs and policies that encourage solar deployment rely on leveraging public dollars with private investment, where a small contribution of public funding can trigger

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a larger contribution from the market. A 30 percent tax credit on a solar investment, for example, is matched by a 70 percent investment by a homeowner. But low-income consumers are less able or likely to respond to this kind of offer, so some policy incentives fail to reach low-income populations. One alternative is to provide a greater portion of public funding directed toward low-income consumers, but that means limited public budgets don't yield as much private investment or as many solar projects.

Policymakers have been trying a range of approaches to bring solar to low-income consumers. This guide surveys the field and recent studies to give a sense of what is being tried, and what could be tried. It examines what has and hasn't been working, and what factors determine whether a given policy or program might work in a given circumstance.

There are many existing government programs and policies aimed at reducing poverty, providing housing, and promoting clean energy. These provide a strong starting point for how to bring the benefits of solar power to low-income households. But there are also many new and emerging ideas, including government policies and programs, new business approaches, and philanthropic and volunteer initiatives.

SUMMARY OF SOLUTIONS, BY CATEGORY

Much of the activity around low-income solar access has been aimed at *financing* to solve the first-cost barrier that low-income households face. Financing ideas either adapt existing techniques or develop new approaches. Property Assessed Clean Energy (PACE), Pay As You Save (PAYS), and third-party ownership arrangements are just a few of the many financing ideas discussed in this paper.

There are also many government policies and programs that are being adapted or created for low-income solar to make it more affordable. Some of these are *compensation mechanisms*, which allow customers to capture the full value of their solar investment. The most common examples are net metering for solar generators located on the customer's side of the meter, and virtual net metering, which enables community solar by tracking output from off-site generation. Compensation mechanisms are distinct from *direct incentives*, whereby government policies provide explicit financial or other inducements.

Energy assistance programs are also starting to see the value of low-cost solar as a way to reduce energy burdens, often in combination with energy efficiency measures. The Low-Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance Program (WAP) are starting to include solar as cost-saving measures. Many states have existing utility rate discount or bill payment programs that could harness solar to generate savings for consumers

While much attention focuses on solar's direct benefits to low-income customers by reducing energy bills, solar can also provide indirect help by cutting costs for *low-income support services*. The U.S. Department of Housing and Urban Development (HUD), especially, is starting to use solar to improve energy security for the millions of low-income Americans it serves, while saving taxpayers some of the $5 billion HUD spends annually on utility bills. By installing solar technologies, shelters, food kitchens, churches, and service organizations of all kinds could redirect energy savings toward their primary mission.

SUMMARY OF RECOMMENDATIONS

This guide is primarily for policymakers interested in bringing the benefits of solar to low-income consumers and communities. While this guide makes some policy and program recommendations, it recognizes that not all policymakers face the same constraints, policy environments, stakeholders, economics, and opportunities.

To be helpful to all readers, regardless of their specific situation, the guide suggests some design principles for developing a successful low-income solar program. It highlights some options that seem especially relevant, universal, or promising; and it describes a simple segmentation of audiences—homeowner, tenant, and support service—and the implications of reaching each of them. Finally, the guide presents several scenarios that may apply to states in certain situations.

Of course, the recommendations presented in this guide may not be best in any given circumstance. The lengthy discussion of other solutions is intended to help guide possible alternative actions.

In short, successful low-income policies and programs share some design principles: they are tailored to low-income consumers; they are cost-effective and financially sustainable; they have measurable results; and they are flexible enough to adapt to changing conditions and new learning.

The guide offers several suggestions for policies and programs that seek to expand solar to low-income consumers:

- Leverage existing state energy policy to support low-income solar deployment, such as by adapting net metering, portfolio standards, and financial incentives for renewables.

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- Incorporate solar into low-income energy efficiency programs to reduce implementation costs and provide deeper savings for households with very high energy burdens.
- Adapt existing housing and anti-poverty programs to include solar, such as LIHEAP and WAP, public housing, and economic development incentives.
- Set up a financial vehicle that can develop, test, and deploy innovative financial strategies and provide leadership and technical expertise to other agencies.
- Promote volunteerism to provide low-cost solar to low-income communities, such as new solar homes built by Habitat for Humanity—and reinforce it through supportive incentives and policies.
- Partner with trusted allies in reaching out to low-income communities to ensure greater buy-in and program enrollment.
- Ensure any low-income solar policies and programs will actually provide tangible benefits to low-income households and communities.

In choosing which policy approaches to take, it may first be useful to consider the specific solar consumer you are trying to assist, and the current policy and market environment.

Not all low-income solar customers are the same. They face different challenges and may need different solutions or different combinations of solutions to overcome them. For example, low-income homeowners can see clear benefits from owning solar systems, but may face first-cost hurdles. Tenants of apartment buildings may not be able to own a rooftop system, but they may be able to benefit from a flexible community solar program. Low-income housing landlords may be able to benefit from tax credits, energy savings, and increase in property value from going solar but may be unwilling to share those savings with tenants. Groups that provide support to low-income communities face their own hurdles and opportunities. As nonprofit or governmental agencies, they may enjoy low-cost financing, but may not be able to access tax credits and other incentives.

The very definition of "low-income" varies widely, from one government agency or jurisdiction or program to another. Some programs, for example, include all households earning less than 60–80 percent of the area median income as low income, while others use income relative to the federal poverty level. Definitions can have a significant impact on program design and implementation. Being consistent with other programs may be important, or it may be helpful to target particular customer segments within the low-income customer class. "Moderate-income" households may best be served by different programs and policies tailored to fit their needs. This guide largely avoids these definitional complications to provide general guidance that can be adapted to specific situations.

Lastly, to help inform programmatic options, the guide presents a few sample scenarios that state and local agencies may face when thinking about low-income solar program development. These scenarios vary by the state policy environment for renewables, the type of audience to be reached, energy costs, and other low-income energy policies.

SECTION 2

Situation

PROBLEMS

Because energy consumption by households does not vary as widely as household income, the "energy burden," or percent of income spent on energy, is greatest for low-income households. Simply put, low-income households spend a larger proportion of their income on energy than other Americans do.

In a recent study of the 48 largest U.S. cities, the American Council for an Energy Efficient Economy (ACEEE) found that households with income below 80 percent of median income in that area, minority households, low-income households residing in multifamily buildings, and renting households all experienced higher energy burdens than the average household in the city. The median energy burden across all of the cities was 3.5 percent, while the median low-income household's energy burden was more than twice as high at 7.2 percent. The poorest of the poor have an even greater energy burden. In 17 of the cities studied, the lowest quarter of low-income households experienced an energy burden greater than 14 percent—led by a staggering 25 percent energy burden in Memphis.[1]

Cities in the Southeast had the highest energy burdens for low-income households, with Memphis, New Orleans, Birmingham, and Atlanta all exceeding 10 percent. High energy demand in these cities is largely driven by electricity used for air conditioning. They were closely followed by northern cities like Philadelphia, Pittsburgh, and Providence, where heating bills are a significant factor.

Low-income neighborhoods are also disproportionately and adversely impacted by traditional forms of energy production. According to the National Association for the Advancement of Colored People (NAACP), people of color and low-income households are more likely to live within three miles of a coal power plant, and thus more likely to suffer from higher incidence of poor health, higher medical bills, and lower property values. The per capita income in these neighborhoods is $18,400, below the poverty threshold, and 15 percent lower than the U.S. average income of $21,587.[2]

OPPORTUNITY

Solar power costs have been declining rapidly and are at parity with retail electricity rates in an increasing number of states and utility service territories.[3] As a result, distributed solar has been growing rapidly in the United States, at over 50 percent per year from 2011 to 2016.[4]

California has the most distributed solar, but other states and regions are seeing substantial growth.

In addition to innovations in technology and manufacturing techniques, solar is benefiting from new business models and financing mechanisms. Solar developers are offering leases and loans, as well as selling electricity directly to customers through power purchase agreements (PPAs). Marketers are offering "no money down" deals to customers, and at prices that are lower than retail electricity rates, at least initially.

Lower costs and new business models have made it easier for solar to expand into households of all income levels. According to an analysis by Kevala Analytics, 65 percent of residential solar installed in California in 2015 was in zip codes with median household incomes (MHI) of $70,000 or less, up from 49 percent in 2008. (The statewide MHI for California was $64,500 in 2015.) Meanwhile, just 6 percent of installations in the state occurred in neighborhoods with an MHI above $100,000, down from 19 percent in 2008. In fact, as shown in **Figure 1**, there were nearly as many installations in low-income neighborhoods—about 20,000 cumulative by 2015—as in high-income neighborhoods.[5]

This was true even as direct rebates under the California Solar Initiative largely phased out by 2014.[6] While California's affordable solar housing programs, Multifamily Affordable Solar Housing (MASH) and Single-Family Affordable Solar Housing (SASH), have continued to provide rebates to low-income households, supporting about 6,500 projects to date, some low-income households are going solar without state subsidies.

"These trends illustrate what makes intuitive sense—the market for solar is strongest among people where a 10–20 percent savings in their electricity costs is meaningful enough to drive investment in alternative electricity supplies," according to the Kevala analysis.

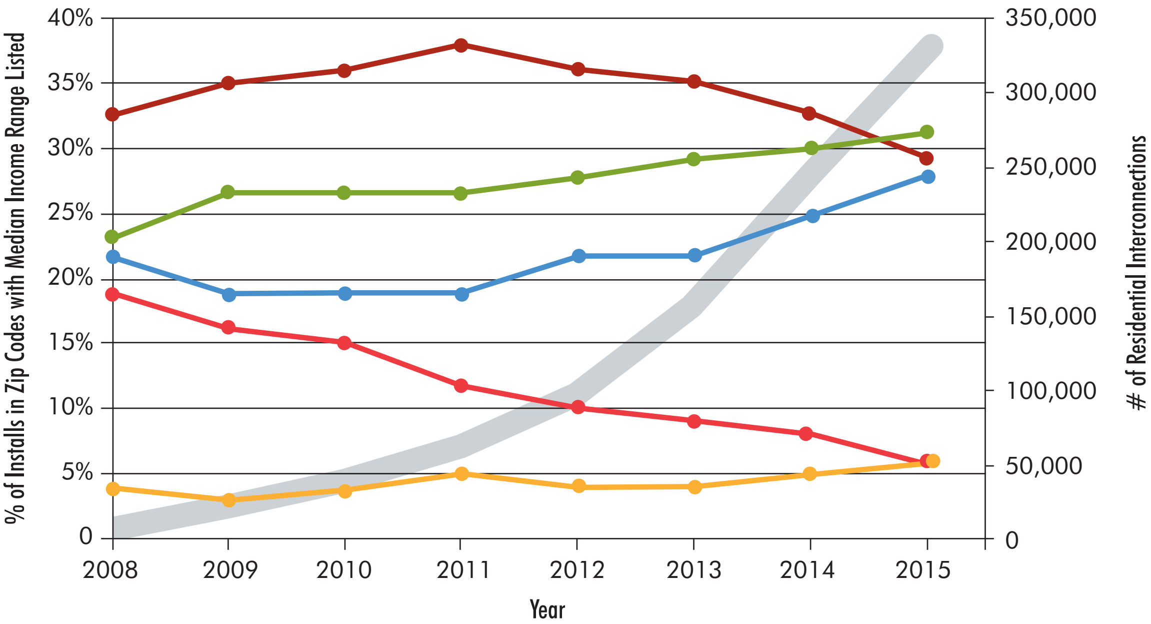
As part of a State Energy Strategies grant funded by the U.S. Department of Energy, Lawrence Berkeley National Laboratory (LBNL) is conducting further research on the demographics of solar adopters.[7]

For customers who can't or don't want to put solar on their own property, developers in some places are offering "community solar," which allows a customer to subscribe to or buy a portion of an offsite solar installation and receive utility bill credit from its output. In Minnesota, for example, over 400 MW of community solar projects will likely be online by 2017.[8] Community solar enables a wider range of customers—renters, apartment dwellers, and people in homes that are ill-suited for rooftop solar panels—to participate in the solar economy.

By some estimates, at least half of all households in the U.S. are not viable candidates to host a solar PV system on their own property. Community solar offers a way for these utility customers to share the benefits from off-site solar installations. The National Renewable Energy Laboratory (NREL) calculates that community solar could represent between a third and a half of the distributed PV market in 2020.[9]

Although there are many government and private-sector programs and policies to help low-income households with their energy bills, few of them have used solar power to reduce energy costs. Solar power has not been as cost-effective as other measures such as weatherization and lighting. Now, with the decline in the cost of solar, that is changing.

FIGURE 1: **Household Income and Solar Adoption in California (2008–2015)**



Source: Kevala Analytics, *Whitepaper: Income Distribution of Rooftop Solar Customers*, November 24, 2015, *https://kevalaanalytics.com/wp-content/uploads/Kevala-CA-Residential-Solar-Income-Analysis.pdf*.

CUSTOMER BARRIERS

A number of barriers impede the adoption of solar by low-income households—intrinsic barriers as well as barriers stemming from policy decisions.

Low-income customers typically don't have enough savings to pay cash or down payments for solar systems. Though U.S. solar prices dropped to an average of $4.10 per watt in 2015, according to LBNL, that still requires an average investment of $16,400 for a 4-kW system.[10]

In addition, many low-income consumers do not pay enough income tax to take full advantage of federal tax credits for solar power. In fact, 45 percent of American households pay no income tax at all.[11] The bottom half of taxpayers represent only 15 percent of total U.S. income.[12] The federal Residential Energy Efficient Property tax credit[13] offers a 30 percent credit against income tax liability on solar system expenditures, with the ability to carry the credit forward one year. A $10,000 system, for example, would generate a tax credit of $3,000, requiring a taxable income of at least $26,000 a year, assuming there are no other credits or deductions taken. Research has shown that taxpayers with gross income of less than $40,000—about 60 percent of filers—almost never use the solar tax credit.[14]

Credit scores are used by lenders and by third-party solar companies to evaluate the risk of financing a solar system. Credit requirements vary among companies and lending programs, but scores of at least 650–680 are often required. There is a market perception that low-income consumers suffer from low credit scores, which often prevents third-party solar providers from marketing to low-income communities. In truth, the correlation between income and credit quality can vary widely by state and may not be as strong as has sometimes been assumed. (See **Box 1**, "The Correlation between Low Income and Low Credit Scores," on p. 12.) Nevertheless, some low-income consumers may have insufficient lending activity to generate a credit score, automatically barring them from solar offerings.

BOX 1

The Correlation between Low Income and Low Credit Scores

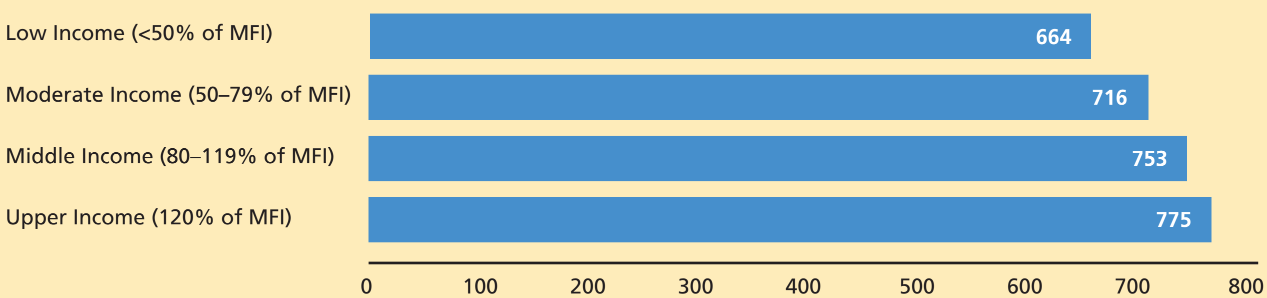
The conventional wisdom concerning low-income customers is that they may have poor credit scores or a lack of credit history. Because most solar marketers rely on credit scores when they approve financing, solar companies may avoid marketing to low-income customers.

The Minneapolis Federal Reserve Bank found a direct correlation between income levels and credit score, with the lowest quartile (less than half of area median family income) having a FICO credit score 100 points lower than the highest quartile.[15] (**See Figure 2**.) The Fed's Board of Governors has reported that "individuals in high-income census tracts have a mean TransRisk Score of 57.9; in low-income census tracts, the mean is 32.5."[16]

Research by the U.S. Consumer Finance Protection Bureau has also found that 26 million low-income Americans are "credit invisible"—that is, one in every ten adults does not have any credit history with one of the three nationwide credit reporting companies. "There is a strong relationship between income and having a scored credit record," the U.S. Consumer Finance Protection Bureau writes. "Almost 30 percent of consumers in low-income neighborhoods are credit invisible and an additional 15 percent have unscored records. These percentages are notably lower in higher-income neighborhoods. For example, in upper-income neighborhoods, only four percent of adults are credit invisible and another five percent have unscored credit records."[17]

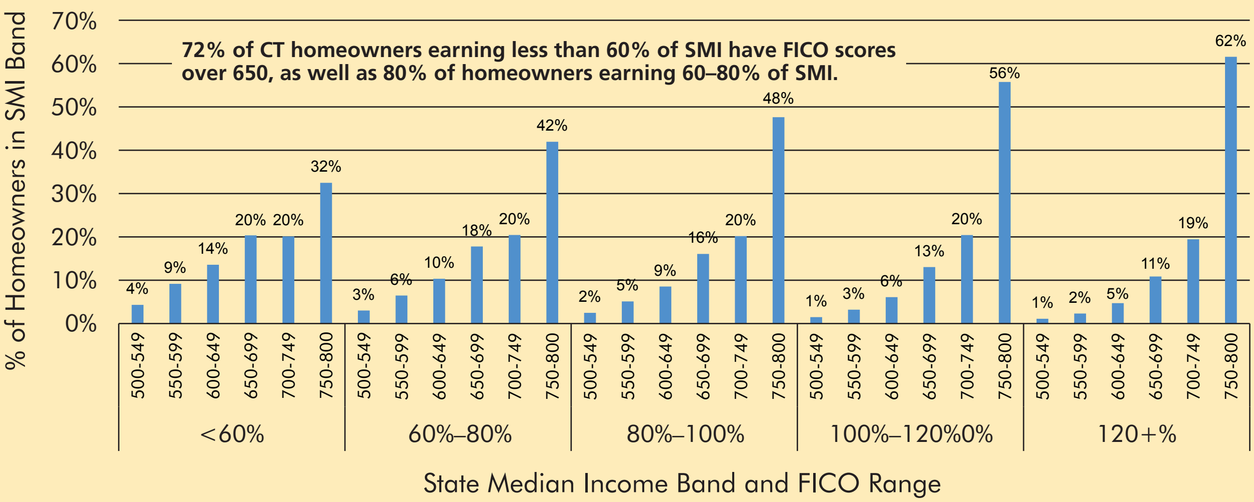
In 2007, the Center for American Progress, using data from the Fed's Survey of Consumer Finance, found that lower-income consumers were more likely to be denied credit or to not apply for fear of being rejected.[18] The housing crash of 2008–2009 has made lenders even less likely to extend credit to low-income consumers.[19] **But . . .** while low-income households may be more likely to be credit-impaired, it does not mean that all of them are. Solar marketers are still doing business in low-income communities. A recent report by GTM Research and Power Scout estimates that there are over 100,000 low-income (<$45,000 per year) households with solar in the four states of their study, representing over 532 MW of solar capacity.[20] Low-income households are less likely to have solar compared to the overall population, but only slightly, and it may be diminishing as solar costs fall.

FIGURE 2: **Minneapolis Federal Reserve Bank: Credit Score by Income Bracket**



Source: Minneapolis Fed, via *Valuepenguin.com*.

FIGURE 3: **CT Homeowners 2012 FICO scores by State Median Income (SMI)**



Source: Connecticut Green Bank.

In New Jersey and Massachusetts, about 33 percent of solar homes had income levels below the state median, while California and New York had lower representation in low-income communities of 29 percent and 24 percent respectively.

And the perceived link between income and credit score may be overstated. Recent research by the Energy Programs Consortium (EPC) and the Connecticut Green Bank has found a lack of correlation between income and credit levels in some cases. The EPC recently evaluated the Warehouse for Energy Efficiency Loans, or "WHEEL" program, an unsecured residential energy efficiency loan and secondary market program. Using personal income and credit data from Equifax's Work Number database, EPC found that "52 percent of consumers with incomes at or below $60,000 have Equifax Risk Scores greater than 640," and that the income and FICO scores of WHEEL borrowers were not related. However, by including only customers with credit scores of 640 or better, EPC left out the 30 percent of the population who have lower scores—as low as 300. While it may be true that customers with higher credit scores can have any income level, it does not necessarily follow that low-income consumers have high credit scores. "While the data are confined to the WHEEL program and are necessarily skewed towards individuals with higher FICO scores," EPC noted, "they do provide anecdotal evidence that an individual's income is not predictive of his creditworthiness."[21]

Further, proprietary research from the Connecticut Green Bank has found little correlation between income levels and credit scores in their state. The Bank used credit score data from Experian, comparing it with income levels at the city level. As shown in **Figure 3**, while low-income homeowners are less likely to have the highest credit rating, they are otherwise similar to homeowners in other income brackets. Connecticut has seen a rapid increase in solar in low-income areas, including by marketers who rely on credit scores to underwrite finance offerings.

Many low-income consumers who live in multifamily rental property usually do not have access to the roof and have no incentive or ability to invest in the long-term benefits of a solar power system for that property. Often, multifamily buildings have a single "master" electric meter for the building's common areas (billed to the building owner), and sub-meters for individual apartments (billed to the tenant). In this situation, the tenants pay their utility bills, while landlords are responsible for investing in the appliances, building infrastructure, and other features that affect energy consumption.

This can result in the classic market failure known as "split incentives," where costs and benefits of a building improvements (such as adding solar) can have differing impacts on who makes the investments and who benefits from them (i.e., the costs of improvements are incurred by the building owner, but the majority of the benefits from the investment go to the renters, or vice versa). A landlord who does not pay the utility bills on a multifamily housing property will not see the full bill savings from an investment in solar power on that building.[22] On the other hand, a landlord who does pay utility bills for tenants may be an especially attractive prospect for solar power, as discussed below. While landlords are ineligible to take the residential tax credit for solar, they may be eligible for a 30 percent commercial tax credit on solar expenditures[23] as well as accelerated depreciation or other state and local incentives.

There are other challenges to be considered. Low-income customers who are recent immigrants may have a language barrier to learning about solar power, or to understanding marketing materials. A lack of internet access can be a barrier to solar marketing, much of which takes place through sophisticated online tools. Low-income households may also lack the time and resources to contemplate their energy use and their ability to go solar—since they are simply too busy making ends meet. And they can be suspicious of marketing offers around solar power, which can come from unfamiliar companies or sound too good to be true.[24]

Finally, solar marketers themselves may not be interested in marketing to low-income households if they are getting enough business from wealthier customers. Many solar companies do not seem to advertise their services in low-income communities or make their marketing materials available in languages other than English.

POLICY BARRIERS

Low-income customers also face policy barriers that prevent them from enjoying the benefits of solar power. Rate design may be the most fundamental policy issue for all solar customers, with distinct implications for low-income customers.

A national debate is underway about how electric utilities should recover their fixed costs, as customers use less energy due to greater efficiency and the cost-effectiveness of self-generation with solar power. A total of 212 state and utility-level distributed solar policy and rate changes were proposed, pending, or enacted in 2016, in 47 states, according to the North Carolina Clean Energy Technology Center.[25] Of these, there were 71 utility requests in 35 states plus D.C. to increase monthly fixed charges—paid regardless of how much energy is consumed—while lowering the rates for electricity. For solar customers, higher fixed charges have the effect of lowering the value of solar power and energy efficiency, making both a less attractive investment for customers.

Research by the National Consumer Law Center (NCLC) has shown that low-income consumers would be disproportionately affected by bills that have a greater emphasis on fixed charges. Analysis of a proposal by Madison Gas & Electric to raise fixed charges from $10 to $19 per month indicated that high electricity users (usually wealthier households) would have seen bills fall by 2.7 percent, while low-use households would have seen a 5.5 percent increase in utility bills. Since low-income, minority, and elderly households use less electricity than their higher-income counterparts, NCLC concluded that a higher fixed charge "raises profound equity and social justice concerns."[26]

Low-income customers also face policy barriers that prevent them from enjoying the benefits of solar power. Rate design may be the most fundamental policy issue for all solar customers, with distinct implications for low-income customers.

Some utilities and regulators have proposed to apply demand charges, commonly used for larger commercial and industrial customers, to the residential sector. The amount of a demand charge is determined by the greatest amount of electricity (kilowatts) demanded by a customer at one time in a month, typically over a 15-minute or one-hour interval.

The Salt River Project (SRP), a utility in Arizona, is one of the few utilities in the country to impose residential demand charges, and they are mandatory only for customers with solar power systems. SRP levies a fixed charge of $32 per month for solar customers, plus a demand charge ranging from $8 to $33 per kilowatt in the summer, combined with an electric rate as low as only 3.9 cents per kWh off-peak.[27] Since SRP changed its rate structure, the average savings from solar has declined and the number of new solar installations has fallen dramatically. SRP estimates that only 14 percent of solar customers are saving money under the new rate design.[28]

NCLC argues that the use of demand charges for residential customers, especially for low-income households, is inappropriate, because demand charges are predicated on the consumer being able to control his or her peak demand and to lower it to avoid higher charges. Residential customers lack the basic information to know when their peak demand occurs, since only about half of households in the U.S. have smart meters capable of measuring real time data, and virtually no customers have a way to track their own household consumption in real time.[29] Without knowing when peaks will or have occurred, a household is at a loss to take action to avoid them, making a residential demand charge an arbitrary cost. Moreover, low-income customers may not have the flexibility to avoid usage peaks even if they know when they occur.

A third type of rate design is time-sensitive pricing, where utility rates change according to market conditions and the time of day, season, and system. The most common is time-of-use (TOU) pricing, where rates change to a known amount over a fixed time period—such as peak pricing on summer afternoons when system demand is high, and off-peak prices on spring evenings when demand is low.

TOU rates can be quite beneficial to solar power if peak rates are offered during times of peak solar production since solar homes often produce more power than the household consumes during sunny peak times. For the solar home, the optimal time-of-use net metering will enable the peak power exported to the grid to be credited at on-peak prices. In the evening, when solar generation ends, the customer buys power from the utility, usually at lower off-peak rates. By "selling high and buying low," customer-owned solar becomes more valuable to the customer than it would be under flat rates.[30] However, advocates for low-income consumers have mixed feelings about time-sensitive rates. Although TOU rates can allow consumers to change behavior to save money by shifting consumption to off-peak periods, they can also result in higher bills for customers who are unable to shift. NCLC encourages regulators to make TOU rates voluntary or to have an opt-out provision for customers unable to benefit from them.[31] If TOU rates offer peak pricing at times when solar generation is not at its peak, the value of solar can also be diminished, resulting in decreased potential for solar bill savings for the solar consumer.

Another form of rate design for low-income customers may be an inadvertent barrier to solar, even though it benefits those households. Many states require utilities to offer discounted rates to low-income customers, to lower their utility bills. These have the effect of making self-generated solar power less competitive and less attractive by reducing the money a customer can save from going solar. The Interstate Renewable Energy Council (IREC) has proposed revisions to California's rate program, California Alternate Rates for Energy (CARE), to facilitate the use of solar power in a "CleanCARE" program. This proposal is discussed below in the section on Adapting Current Low-Income Energy Policies to Solar.

In addition to rate design, there are other policy and program barriers. Public agencies have limited budgets for subsidizing solar installations. Because low-income households have a limited ability to assume the costs of a solar system, they typically offer little capital to leverage public funds. As a result, government programs that cover the cost for most of, or an entire, solar installation can only afford to help a relatively few customers.

Washington, D.C.'s Affordable Solar Program is a case in point. In 2015–2016, the program installed almost 300 solar systems on low-income housing, with the costs fully covered through a combination of a federal tax credits, solar renewable energy credits (SRECs), and a rebate of $2.50 per watt. While the program exceeded goals, it was small compared to the overall demand for low-income energy assistance.

The declining cost of solar will allow limited funds to create greater benefits, but full funding programs like the Affordable Solar Program can only be maintained if they have a sustainable source of funding.

SECTION 3

Recommendations

The falling cost of solar power creates an opportunity to lower the energy burden on low-income households. Low-cost solar power can benefit anyone through potentially lower electricity costs, but low-income households have an especially urgent need to save money.

However, solar for low-income households does not always align with the way policymakers have traditionally thought about energy policy. A standard assumption is that a public-sector incentive will elicit a private-sector reaction. A 30 percent tax credit, for example, will inspire a homeowner to pay the remaining 70 percent for an emerging technology. Policymakers like this leverage because it makes the most of limited public dollars, suggests an exit strategy as the technology matures, and apportions the costs in line with the benefits—some benefits, like clean air, are public while others, like saving money, are private.

In this scenario, however, low-income people would likely be unable to pay a 70 percent share. Nor do they often have the tax appetite to take advantage of tax-based incentives, the ability to afford additional debt, or a credit status that allows them to finance a solar investment from the money saved by going solar.

Low-income customers therefore require different approaches. In this section, we discuss some design principles for developing a successful low-income solar program. We then lay out some options that seem especially relevant to states. Of course, the exact details and policies would need to vary from state to state based on local factors.

DESIGN PRINCIPLES

Successful low-income solar policies and programs will be:

- **Tailored to low-income consumers.** Low-income customers face situations that inhibit many solar-friendly policies from benefiting them directly. They could be renters, live in multifamily housing, and have credit problems, for example. Solar policies must take into account these challenges if the goal is to reach a low-income audience.

- **Cost effective.** Incentives should strive to deliver the maximum return on public investment and maximum impact for the consumer. They should take advantage of the falling cost of solar power and get the most out of limited public funds.

- **Financially sustainable.** Effective programs must be sustained, since it takes time to affect markets and consumer behavior. If a program requires funding, the funding source must be available for a number of years, at a level sufficient to the need.
- **Measurable.** Ongoing support for a policy or program, or changes in direction, will depend on objective evaluation. Performance indicators need to be identified, tracked, and used for future program design.
- **Flexible.** Low-income solar is just starting to get the attention it deserves. It is not necessarily obvious what the right policies and programs are. Moreover, different programs and regions may have different goals. With more experience, agencies will be able to learn from others and from program evaluations. They will need to be flexible enough to change design elements in the face of new information.

STATE OPTIONS

States are in different stages in terms of policy and market development, public support, and funding options for low-income solar. Moreover, federal policies and programs may change, thereby altering what is possible at the state and local level. Although the options that each state has will vary, the following approaches apply to many.

- **Leverage state energy policy to support low-income deployment.** Many states already have policies to encourage renewable energy. State renewable portfolio standards (RPSs), financial incentives, community solar, and net metering policies can all be adapted to support low-income solar. Colorado, for example, experimented with a requirement for community solar programs to include low-income customers, while Washington, D.C. and Massachusetts have used their RPS programs to provide financial incentives for low-income solar.
- **Adapt housing and anti-poverty programs to include low-income solar.** There is currently a vast array of federal and state programs intended to reduce poverty and promote economic development, two things that solar power can help with. Energy assistance programs like LIHEAP and WAP can be or are being adapted to include solar power as cost-effective measures. There are more opportunities in the many public housing programs, economic development incentives for impacted communities, and job training and placement initiatives (See **Box 2**, p. 20.) HUD has been turning to solar to reduce the $5 billion a year it spends on utility bills in public housing.
- **Set up a financial vehicle.** There are many financial strategies that can increase low-income access to solar. They may require enabling legislation or new regulations and involve working with utilities, solar developers, county agencies, and financial institutions. Because of the diversity of options, legal and regulatory complexity, and potential range of stakeholders, it may be beneficial to establish a lead agency with specialized skills in project finance. The Connecticut Green Bank, for example, does not advance a single "policy," but it serves as a multifaceted innovator that develops, tests, and deploys new financial strategies, and provides leadership to other stakeholders and agencies. Given the many financing vehicles

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that already exist, the expertise and leadership of an agency steeped in clean energy financing can be just as important as having a substantial endowment.

- **Promote volunteerism.** Using solar power to help low-income consumers can be appealing to the public, at the same time as it helps solve social and environmental problems. Volunteer labor can drive down the cost of installations while providing job training and community service opportunities. Groups like Habitat for Humanity and Grid Alternatives have found success with this approach. It can be encouraged through public policies, including financial and promotional support, preferential permitting, and public recognition.

- **Partner with trusted low-income allies.** In many cases, government officials and program managers may not be best situated to promote programs in low-income communities. Early stakeholder engagement and coalition building can help ensure greater buy in and program enrollment. Partnering with organizations that are trusted within the particular market segments you are trying to reach, such as low-income outreach and advocacy groups, community action agencies, and other service institutions, can reinforce mutual trust and improve outreach and marketing.

- **Ensure programs provide tangible benefits to low-income consumers.** It may seem obvious to say that low-income customers should benefit from low-income solar programs, but in practice it can be difficult to achieve. For example, installing solar on a low-income, multifamily building won't necessarily provide savings for the low-income building tenants. Poorly designed programs could even have unintended, adverse consequences for low-income customers. Low-income solar programs should complement existing programs and provide real financial benefits for the low-income customer they serve.

BOX 2

Solar Workforce Development Programs

This guide specifically focuses on extending the benefits of solar power to low-income consumers. But solar can also help poor people to get good jobs. The United States solar industry employed just over 260,000 workers and accounted for 2 percent of all jobs created in 2016.[32] When appropriate opportunities are provided for low-income training and participation, solar industry jobs can offer robust benefits, a decent wage, and a path up the career ladder. According to the Solar Foundation's 2016 National Solar Jobs Census, companies with job postings for solar installers advertised a median wage of $26 per hour.[33] There are many examples of government and private sector programs to provide workforce development in the solar industry. Here are just a few:

GRID Alternatives, a nonprofit solar developer, provides no- to very-low-cost solar power for low-income families, hands-on installation experience for job seekers and community volunteers, technical assistance and turnkey installation services to multifamily affordable housing developers, and help to utilities to develop community solar projects dedicated to low-income communities.

GRID Alternatives offers several workforce development programs. RISE (Realizing an Inclusive Solar Economy) is a full-service program, with everything from recruitment events to referrals and retention assistance. It delivers training for 4,000 workers in partnership with over 70 job training organizations and community colleges in California, Colorado, New York, New Jersey, the Mid-Atlantic, and New England.

GRID Alternatives also implements the Single-family Affordable Solar Housing (SASH) program in California, with an integrated job development program. GRID dedicates approximately 20 percent of its internal installations for trainees to gain hands-on experience with real-world solar installations. This becomes a double benefit to the low-income community since many solar job trainees come from the same neighborhoods that the SASH Program aims to serve.[34] *www.gridalternatives.org/what-we-do/workforce-development*

Solar1 is a nonprofit in New York City that installs solar and makes energy efficiency improvements for affordable housing projects, in conjunction with workforce development and other programs. It manages the Green Workforce Training Program, a center that trains and certifies unemployed individuals and incumbent building staff in energy efficiency, renewables, and green building operations and maintenance. It has trained over 1,500 unemployed and underemployed individuals since starting in 2004. *www.solar1.org/green-workforce*

Green City Force is an AmeriCorps program in New York City that engages young adults from low-income communities in national service related to the environment. Since its founding in 2009, it has engaged over 400 18- to 24-year-old residents of the New York City Housing Authority (NYCHA) in its Clean Energy Corps program. Seventy-five percent of the recruits had no income in the year leading up to the program, and of those who did, their average annual income was $2,000. The Clean Energy Corps is a six- or 10-month, full-time program that involves one day of training and four days in the field each week performing work such as energy audits in low-income homes, urban agriculture and horticulture, and coating rooftops as part of the NYC-CoolRoofs campaign. The federal AmeriCorps program, with an annual budget of $1 billion, has supported volunteer and job training activity since 1994, including the GRID Alternatives SolarCorps program since 2006. *www.greencityforce.org*

GoSolarSF is a City of San Francisco program that provides rebates for solar, explicitly linked to workforce development. To be eligible for a rebate, systems must be installed by companies that participate in the City's Office of Economic and Workforce Development program to employ San Francisco workers. Installers must make "good faith" efforts to hire workers from the First Source Hiring Program, which connects dislocated workers and economically disadvantaged individuals with entry level jobs. Larger rebates are offered for projects in the city's "environmental justice zip codes" and for income-eligible households. *http://sfwater.org/index.aspx?page=133*

MARKET SEGMENTATION

The obstacles for solar access for low-income consumers differ, depending on household budget, dwelling situation, and location. While definitions vary, HUD defines low-income households as having incomes of less than 80 percent of area median income, while "very low" income households are less than 50 percent.

Households with slightly higher levels of income seem to have fewer constraints to going solar, as shown by the analysis of solar deployment in California cited earlier.[35] In recent years, households in zip codes with median household income (MHI) of $40,000 to $55,000 have seen rapid growth in solar, making up 28 percent of new residential solar installations in 2015. The statewide MHI for California was $64,500 in 2015.[36] Growth in this segment has persisted even as the California Solar Initiative (CSI) largely phased out residential rebates by 2014.

The Connecticut Green Bank commissioned research on market segmentation in Connecticut to understand solar uptake for different income demographics, and to better target programs for low-income households. The research described the characteristics of past adopters, based on income, education levels, and other factors, as well as of potential solar prospects. Analyzing 66 different consumer profiles, the research identified a class of "Prudent Yankees" in Connecticut who are lower income, older, and less likely to have a college degree, but who are especially interested in saving money with solar.[37]

Within the low-income category there are sub-sectors that may require different policy and program approaches. The most important split is between homeowners and renters, but there are also significant differences between urban apartment dwellers and households in rural trailer parks, and between seniors on fixed incomes and younger age groups. Moreover, programs can focus on either low-income customers themselves or the institutions that help support them.

Tenants—Low-income customers in apartment buildings or rental housing face significant barriers to solar. They don't own the roof, they may not be long-term residents, and they experience the split-incentive problem (where landlords don't invest in energy-saving measures because the tenant pays the utility bill). In some states, the primary solar solution has been to connect renters with off-site community solar through virtual net metering (VNM). But for this to be successful, community solar needs to be combined with policies that solve credit problems and marketing risk for low-income customers.

A different approach is to encourage the landlord to invest in solar, especially for publicly subsidized or publicly-owned housing, where it can deliver long-term savings to taxpayers. Many low-income housing programs and policies can fund solar, including the New Markets Tax Credit, the Low-Income Housing Tax Credit, the Public Welfare Investment authority of banks, "green finance" offerings from FHA and Fannie Mae, and the many offerings of HUD, including the Community Development Block Grant. State energy agencies may want to learn more about these programs, and to collaborate with local implementing agencies. See the section on using solar for low-income support services.

Homeowners—Low-income homeowners don't have the rooftop access issues that hamper renters from adopting solar, but they may still face financial barriers. They may also face structural and legal barriers, such as roofs in poor condition, electrical code violations, or property tax liens. The most important policies for enabling homeowners to adopt solar are fair net metering and interconnection rules, but low-income homeowners may need further assistance in the form of rebates, tax credits that can be easily monetized, innovative financing techniques, such as on-bill repayment and PACE financing, strong consumer protection provisions, measures to handle potential credit issues, and policies to reduce risk for third-party providers, such as loan loss reserves.

Low-income support services—Groups that provide support services to low-income communities can often adopt solar more easily than can individual low-income households. Service institutions such as homeless shelters, food banks, and clinics typically have longer-term occupancy, more financing options, and can host larger, more cost-effective solar systems. The money they save on energy expenditures can be redirected toward their primary mission.

Nonprofit organizations and government agencies may not directly be able to monetize state or federal tax credits, but this can be solved by partnering with a third party that can. Government agencies can also tap into forms of financing not available to other sectors, such as bonds, fees, taxes, and the array of federal housing and economic development programs. Nonprofits may be able to raise capital through grants and charitable contributions. State and local energy agencies can help facilitate solar deployment on government and nonprofit buildings by setting up compatible financing mechanisms.

SAMPLE SCENARIOS

The policies or programs a state or municipality should pursue will depend on local conditions, but here are some possible scenarios:

- If a state has a robust renewable energy policy infrastructure, then those policies and associated programs can be adapted to serve low-income solar needs. RPS, net metering, or community solar programs could have low-income quotas or targeted credits. Rebate or incentive programs could provide higher incentives for the low-income market.

- If a jurisdiction has a large number of low-income households in either single-family or multifamily housing, programs should be tailored to reach those two different market sectors. As mentioned above, reaching tenants of multifamily housing may require techniques such as virtual net metering, or it may require focusing programs on the landlord rather than the tenant.

- If a state has relatively high retail electricity prices, then smaller financial incentives may be needed to encourage uptake by low-income households. In that case, the programs may focus more on stimulating the market and directing solar developers toward low-income households, and less on providing subsidies.

- If a state has discounted electricity rates for low-income customers, then solar can be a way to lock in utility program costs while meeting clean energy goals. Community solar can be a flexible way to reach discount-rate customers regardless of location, while solar installed on multifamily public housing can be a way to reach many customers on discounted rates with an on-site solar system.

SECTION 4

Discussion of Solutions

Despite the many barriers to adopting solar PV for low-income households, the declining costs and significant benefits of solar have created strong interest from government agencies, utilities, energy companies, and non-government organizations to expand the benefits of solar in low-income communities. A growing body of research describes and proposes a wide variety of policies and programs. This guide has drawn extensively on these reports, adding some new ideas and exploring some in greater depth. Still, this is a rapidly evolving field, with new programs and policies emerging all the time.

OTHER RESEARCH

A roundup of recent research on public low-income solar programs can be found in, *A Directory of State Clean Energy Programs and Policies for Low-Income Residents*, a report released by the Clean Energy States Alliance (CESA).[38] The report catalogs dozens of programs that promote clean energy, especially solar power, as a way to reduce the energy burden of low-income customers. As shown in the **Table 1**, many of these programs offer direct incentives to reduce (or eliminate) solar costs to low-income households, or financing programs that reduce borrowing costs. CESA posts the report on its website and strives to keep the report updated with new program developments.

Nevertheless, with programs being implemented, changed, and phased out regularly, Table 1 is not meant to be a comprehensive catalog of all states' low-income clean energy programs, but instead is designed to illustrate the variety of programmatic approaches states are pursuing.

The declining costs and significant benefits of solar have created strong interest from government agencies, utilities, energy companies, and non-government organizations to expand the benefits of solar in low-income communities.

TABLE 1: **Summary of Low-Income Solar Programs**

State	Program Name	Technology	Direct Incentives	Finance Assistance	Shared Solar	Mandate	High-level and Conceptual	Other / Notes
Alaska	Alaska Affordable Energy Strategy	Unspecified					●	
California	Single-Family Affordable Solar Housing (SASH) Program	Solar PV	●					
California	Multifamily Affordable Solar Housing (MASH) Program	Solar PV	●					Hiring requirements.
California	Multifamily Affordable Housing Solar Roofs (MAHSR) Program	Solar PV	●					Hiring requirements.
California	California New Solar Homes Partnership	Solar PV and energy efficiency	●					This isn't exclusively a low-income program.
California	California Solar Initiative Thermal Program	Solar hot water	●					
California	Solar For All California	Solar PV	●					
California	Net Metering Program	Unspecified					●	
Colorado	Colorado Community Solar Gardens	Solar PV			●	●		Under a 2016 settlement, low-income Xcel customers will have access to 18.75 MWs of dedicated community solar capacity between 2017 and 2019.
Colorado	Low-Income Solar Demonstration Project	Solar PV			●			Designed to demonstrate the viability of community solar models that serve low-income customers.
Colorado	Rooftop Low-Income Program	Solar PV	●					DOE has authorized the Colorado Energy Office to integrate rooftop solar into its Weatherization Assistance Program services.
Connecticut	Low-to Moderate Income Performance Based Incentive (LMI PBI)—Residential Solar Investment Program (RSIP)	Solar PV	●					
Connecticut	Solar For All Program	Solar PV and energy efficiency	●	●				State green bank investment in lease fund of private LMI solar and EE provider.
Connecticut	Smart-E Loans	Solar PV, energy efficiency, and other renewables		●				
Connecticut	Connecticut's Multifamily Market Programs	Solar PV and energy efficiency	●	●	●			Solarize-style group purchasing; benchmarking, and loan financing options. Direct incentives from Z-RECs.
Connecticut	Commercial Property Assessed Clean Energy (C-PACE)	Solar PV and energy efficiency		●				
Connecticut	Commercial Solar Financing program	Solar PV		●				PPA Financing for both rated and unrated credits including nonprofits and housing authorities.

TABLE 1: **Summary of Low-Income Solar Programs** (CONTINUED)

State	Program Name	Technology	Direct Incentives	Finance Assistance	Shared Solar	Mandate	High-level and Conceptual	Other / Notes
Connecticut	Kresge Solar+Storage Initiative Program	Solar PV + battery energy storage		●				Third-party owned solar PV + battery energy storage for affordable housing and community assets.
Connecticut	Shared Clean Energy Facilities Pilot	All Class I renewables			●	●		
District of Columbia	Affordable Solar	Solar PV	●					
District of Columbia	Solar for All	Solar PV					●	Broad aim to reduce by at least 50% the electric bills of at least 100,00 low-income DC households by the end of 2032.
District of Columbia	Small-Scale Solar Initiative	Solar PV	●					
District of Columbia	Multifamily Housing Energy Efficiency Rebates	Energy efficiency and solar hot water	●					
Hawaii	Green Energy Market Securitization (GEMS) Program	Solar PV		●				
Illinois	Solar for All	Solar PV	●		●			Includes job training and incentives for low-income participation in community solar and projects that benefit facilities and nonprofits serving low-income households.
Maryland	Community Solar Pilot Program	Solar PV			●	●		
Maryland	Multifamily Energy Efficiency Improvement Programs	Energy efficiency	●	●				
Massachusetts	Mass Solar Loan	Solar PV		●				
Massachusetts	Affordable Access to Clean and Efficient Energy Initiative	Unspecified					●	
Massachusetts	Community Clean Energy Resiliency Initiative	Unspecified	●					Energy resilience grants to municipalities, favoring low-income communities.
Massachusetts	Solar Massachusetts Renewable Target (SMART)	Solar PV	●					The final design of this successor program to the Massachusetts' Solar Carve-Out II (SREC II) program includes an incentive adder for low-income solar.
Minnesota	The Renewable Energy Equipment Grant Program	Renewable Energy Equipment, including Solar PV	●					A pilot solar electric program provides grant funding for renewable energy equipment, including solar, in WAP-eligible, low-income households.

TABLE 1: **Summary of Low-Income Solar Programs** (CONTINUED)

State	Program Name	Technology	Direct Incentives	Finance Assistance	Shared Solar	Mandate	High-level and Conceptual	Other / Notes
Minnesota	Minnesota Housing Finance Agency Fix-up Program	Repairs, remodels and energy improvements, including solar PV		●				Offers low-interest,fixed-rate home improvement loans to income-eligible consumers for owner-occupied projects.
New York	Affordable Solar	Solar PV	●					
New York	Affordable Solar Predevelopment and Technical Assistance	Solar PV	●					Competitively awarded funding for multifamily affordable housing solar project or community solar project for low- and moderate-income households.
New York	Low-Income Forum on Energy (LIFE)	Unspecified					●	
New York	Shared Renewables Program	Solar PV, wind, and other renewable energy			●	●		
New York	New York Clean Energy Fund	Unspecified					●	The fund operates multiple portfolios but some investment is dedicated to initiatives to benefit low- and moderate-income residents.
Oregon	Savings Within Reach	Energy efficiency	●					
Oregon	Community Solar Program	Solar PV			●			Enabling legislation includes a 10% percent target for low-income customer participation. Program rules are under development.
Washington	Evergreen Sustainable Development Standards (ESDS)	Unspecified						Green building performance standard for state-funded affordable housing.
Washington	Ultra-Efficient Affordable Housing Demonstration	Energy efficiency, solar hot water, ground source heat pumps, natural cooling, and solar PV	●	●				

Source: Clean Energy States Alliance, *Directory of State Clean Energy Programs and Policies for Low-Income Residents* (July 2016 edition, with updates).

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In addition to the guides and webinars that CESA has prepared in 2016 on low-income solar under the Sustainable Solar Education Project,[39] the following recent reports explore policy options for extending the benefits of solar power to low-income consumers.

- ***Breaking Ground: New Models That Deliver Energy Solutions to Low-Income Customers***, by Rocky Mountain Institute (RMI).[40] In *Breaking Ground*, RMI explores four business models that can be used to bring the benefits of distributed energy resources (including rooftop solar) to low-income customers. By using cooperative models, tenants of multi-family housing can solve credit barriers, reduce costs, and aggregate their buying power and ability to provide utility services.
- ***Bridging the Solar Income Gap*****,** by the GW Solar Institute, based on a symposium in 2014.[41] The GW Solar Institute, at George Washington University in Washington, DC, held a symposium on low-income solar in 2014, and prepared a report to capture the findings.
- ***Bringing Community Solar to a Broader Community*** (Working Draft), by Fresh Energy.[42] Minnesota is seeing substantial growth in community solar, thanks to favorable policies and strong public demand. Fresh Energy, based in Minnesota, rounds up policies, programs, and financing approaches from a number of states that encourage greater participation by low-income consumers, and makes recommendations.

- ***Low- and Moderate-Income Solar Policy Basics***, by National Renewable Energy Laboratory.[43] This online policy primer notes some of the key barriers low- and moderate-income consumers face in accessing the benefits of solar energy. It raises promising financing strategies and funding sources for transcending these barriers.

In addition to the guides and webinars that CESA has prepared in 2016 on low-income solar under the Sustainable Solar Education Project, several recent reports explore policy options for extending the benefits of solar power to low-income consumers.

- ***Low Income Solar Policy Guide***, by GRID Alternatives, Vote Solar, and the Center for Social Inclusion.[44] This policy guide details the barriers that low-income households and people of color face in going solar. It then presents a "policy toolbox" of various options to overcome those barriers, including examples of program models. The guide, which is regularly updated, is available for download and has also been organized into a website at *www.lowincomesolar.org*.

- ***Shared Renewable Energy for Low- to Moderate-Income Consumers: Policy Guidelines and Model Provisions***, by the Interstate Renewable Energy Council (IREC).[45] IREC's *Policy Guidelines and Model Provisions* give detailed guidance to state, local, and utility programs to help them increase access to community solar by low and moderate-income consumers. The report identifies and explains barriers that low- and moderate-income (LMI) customers face in participating in shared renewable energy programs, and suggests approaches to overcome those barriers. The report also discusses IREC's CleanCARE idea, which proposes a way for low-income energy programs to incorporate renewable energy.

- ***Solar For All: What Utilities Can Do Right Now to Bring Solar Within Reach for Everyday Folks***, by the Southern Environmental Law Center.[46] This report recommends policies that include innovative finance options, community solar, and incorporating solar into existing energy assistance funds and programs. It draws from examples in the Southeast U.S., especially.

- ***State Policies to Increase Low-Income Communities' Access to Solar Power***, by the Center for American Progress.[47] This concise paper explores experience in California, Louisiana, and Colorado, and makes policy and program recommendations.

SECTION 5

Overview of Policy and Program Options

The reports described in Section 4 catalog many options, some of which are being tried already, some that are extensions of existing programs, and others that would be entirely new. Borrowing from these reports and other sources, the following section describes policy and program options in the following categories:

- Compensation mechanisms
- Direct incentives
- Financing and investments
- Adapting current low-income energy policies to solar
- Using solar for low-income support services

More detail is provided on some of these options, with an eye toward implementation issues that local, state, and federal agencies, solar marketers, nonprofit groups, financial institutions, and other stakeholders will face.

COMPENSATION MECHANISMS

Compensation mechanisms include net metering and community (or shared) solar.

Net Metering

Net metering is available in over 40 states, providing a simple way for customers to export solar power to the grid when they have a surplus, and get power back when they need it. Virtual net metering (VNM) enables customers to count the generation of off-site solar generators against their bill, as if it were behind their utility meter. VNM is used to track the value of offsite, shared solar projects that are customer-owned or customer-subscribed, and to credit the value of that solar energy generation against their electricity consumption charges on their utility bills.

Whether or not net metering constitutes a subsidy is a point of much debate currently, as many states are reexamining their net metering policies in the face of rapid solar adoption.[48] It could be considered an enabling mechanism for any customer-owned solar, rather than a specific support for low-income customers. But without it, any other policy or program support for low-income solar will be less effective.

Net metering can be adapted to provide extra help to low-income households. For example, California currently allows VNM, but only between solar systems located on the roof of a multifamily building and the tenants of that building. A proposal by the California Public Utilities Commission (CPUC) staff would expand VNM to allow credits from a customer-sited solar system to be allocated to any residential customer in the same low-income community.[49] This is based on a similar policy in Massachusetts that is not limited to low-income communities.

In comments filed in the CPUC case, the Solar Energy Industries Association (SEIA) and Vote Solar pointed out that VNM would enable a developer to "provide solar power through power purchase agreements (PPAs) with a number of participants in a geographical area, and replace them with other participants throughout the lifetime of the project," thus reducing the risk of contracting with customers with low credit scores.[50] This would create, in effect, competitive electricity suppliers for low-income households, using solar power valued at retail rates.

Mississippi has a variant on net metering that provides benefits to low-income households. Under its policy, any power exported to the grid in real time is not net metered, but is paid at the avoided generation cost plus a 2.5 cent per kWh premium. The two largest investor-owned utilities in the state, Entergy Mississippi and Mississippi Power, are required to offer an additional 2 cents per kWh adder to the first 1,000 qualifying low-income customers who wish to net meter. To be eligible for this added incentive, the customers must have household income at or below 200 percent of the federal poverty level, or similar requirement approved by the Commission. This adder will stay in place for 15 years from the date the customer begins the service.[51]

Community Solar

The design of community or shared solar offerings is still emerging. In some states, community solar is designed to save customers money, relying on virtual net metering to allow consumers to capture the value. In other states, customers pay a premium to participate in community solar owned by a utility, much like a green pricing program.

Policymakers have been seeking ways to increase low-income participation in community solar. In some cases, programs are being adapted to benefit low-income households, while in others, low- and moderate-income customer participation is simply mandated.

In Colorado, the Community Solar Gardens Act of 2010 required developers to allocate a minimum of 5 percent of their output to low-income customers.[52] While well-intentioned, the requirement proved to be difficult to implement. In many cases, solar developers decided to simply give away subscriptions to low-income customers to fulfill the requirement, with the cost being absorbed by other subscribers. Even marketing free subscriptions to low-income customers came with a host of communication and administrative challenges. The resulting higher cost to other subscribers may have reduced enrollment. Consequently, some viewed the requirement as a restraint on project development.[53]

In November 2015, the Colorado PUC approved a legal settlement between the state's largest utility, Xcel Energy, and various stakeholder organizations. Under the terms of the settlement, Xcel agreed to take on the five percent low-income requirement that community solar garden developers had previously been responsible for. Xcel also agreed to a contract for up to 4 MW of community solar gardens dedicated solely to low-income subscribers.[54]

In Minnesota, the Just Community Solar Coalition, a network of NGOs, is encouraging churches and other customers to act as "anchor tenants," buying a variable amount of energy each month to make up for the customer churn expected from low-income households. This reduces marketing risk and makes developers more willing to accept customers with low credit scores.[55]

In Massachusetts, Co-op Power, a customer-owned energy cooperative, includes low-income customers in a community solar project as both subscribers and co-owners. Low-income customers' participation is supported financially through sales of solar renewable energy certifications (SRECs) and virtual net metering credits, and they are eligible for subsidized loans from the Massachusetts Solar Loan Program.[56]

In New York, Brooklyn Power's Building Co-op model allows members of a building co-op to invest jointly in on-site distributed energy resources, including solar. Lenders consider the credit-worthiness of the co-op rather than of the individual members, so low-income residents are able to participate.[57]

Maryland is undertaking a three-year pilot program for 218 MW of community solar to supply low- and moderate-income customers. Power52, a solar developer cofounded by football star Ray Lewis, is hiring and training local workers to build solar projects in low-income neighborhoods. The projects will supply customers of Baltimore Gas & Electric who receive energy assistance through the Office of Home Energy Programs.[58]

In Hawaii, the Public Utilities Commission has received comments from stakeholders regarding its proposal to include a carve-out for LMI customers in its community-based renewable energy (CBRE) program framework. The Commission's proposal found that "utilities are well-positioned to identify and reach LMI customers that may be interested in CBRE program participation." The proposal would require utility-owned CBRE facilities to serve at least 75 percent LMI customers.[59] The Hawaiian Electric Companies have proposed an alternative to this obligation, asking that a 15 percent carve-out for low-and moderate-income customers be required for all CBRE projects regardless of ownership.[60]

Hosting Solar

While not limited to low-income customers, a number of utilities are offering to rent roof space from homeowners to site utility-owned PV systems, with the electricity flowing into the grid, rather than displacing power used by the home. CPS Energy in San Antonio, Texas, pays a bill credit of 3 cents per kWh in their Solar Host SA program, while Arizona utility APS and the Los Angeles Department of Water and Power pay a fixed $30 a month to the homeowner.[61] This arrangement delivers fewer benefit to customers, but solves the first cost and financing barriers that low-income homeowners face and may present less risk for the consumer. These programs typically have not had income-eligibility restrictions for participation, but utilities could be encouraged to focus them, at least in part, on low-income neighborhoods.

DIRECT INCENTIVES

Direct incentives include rebates, tax credits, and compliance certificates.

Tax Credits and Rebates

The most common direct incentive for solar is federal tax credits, such as the Residential Energy Efficient tax credit worth 30 percent of the investment cost of a customer-owned PV system.[62] As mentioned above, because the credit is applied against the federal income tax owed by the filer, it requires a sufficient income and tax burden to be fully captured, which can be a problem for low-income people.[63]

Many states also offer tax credits or rebates for solar, with some providing extra incentives for low-income households. New York's residential Affordable Solar program doubles the rebates offered under the NY Sun program for homeowners with total household income less than 80 percent of the area or state median income. Launched in October 2015, rebate levels decline as installation landmarks are met, and vary by region.[64]

So far, the program has seen little uptake. New York State Energy Research & Development Authority (NYSERDA) reports that the added incentive supported 102 projects in 2016, with an additional 66 projects in the pipeline at year's end. More than 50 solar installers used the added incentive to serve low- and moderate-income homeowners across the state.[65] During the same period, over 20,000 projects were completed under the non-low-income incentive program. Solar installers in New York report that a doubling of the regular incentive is insufficient to overcome financing and other barriers they face in serving low-income customers.[66]

Louisiana has offered a tax credit of up to 50 percent of the installed cost of residential solar, with a maximum of $10,000 per system. This credit began in 2008 and was fully subscribed in 2016, a year and a half ahead of schedule.[67] While not geared specifically to low-income customers, they have been the primary beneficiary of the credits. Solar installer PosiGen counts more than 8,000 customers in the state, including more than 3,000 in New Orleans, totaling more than 75 MW of capacity. PosiGen notes that 75 percent of all its customers are at or below area median income (AMI). Most of these customers combine solar with energy efficiency offerings.[68]

California has two programs for single-family and multifamily affordable solar housing (known as SASH and MASH). The SASH and MASH rebate programs began in 2008, and were reauthorized in 2013 with $54 million in new funding for each program.

MASH gives upfront rebates for multifamily solar projects of $1.10 per watt for projects that serve common areas of a building, and $1.80 per watt for projects that benefit tenants. To date, the MASH program has funded 25.7 MW of solar capacity across 370 projects, serving over 6,880 tenant units through virtual net metering. An additional 165 MASH projects are reserved, with a capacity of more than 29 MW. More than $83 million in incentives have been paid to completed projects with an additional $46 million reserved for pending projects. The program is authorized through 2021 but is currently closed pending new funding sources.[69]

The SASH program provides rebates of $3 per watt for families with household income of less than 80 percent of the AMI. Just over 6,000 PV systems on low-income single-family housing, with almost 300 more pending, have been installed and interconnected through the program. These installations are supported by approximately $100 million in incentives and represent 18.8 MW of solar capacity. The SASH program has also helped enroll 5,826 low-income homeowners to the utilities' Energy Savings Assistance programs and has trained over 28,800 volunteers. California's SASH program shares similarities with the Affordable Solar Program in Washington, D.C., described on page 16.

Renewable Energy Certificates (RECs)

Another financial incentive for solar is the use of renewable energy certificates (RECs). About 30 states have renewable portfolio standards (RPSs) that require utilities or electricity retailers to get a portion of their energy from renewable sources. Twenty-two of these (plus the District of Columbia) have set-asides for solar specifically.[70] Certificates are used to track compliance with RPS programs: RECs for renewables in general, and in those states with a solar carve-out, SRECs. In states with RPSs, utilities must acquire and retire a sufficient number of RECs (and, if applicable, SRECs) to meet their obligations, thus creating a revenue stream for renewable energy generators.

The value of RECs and SRECs is determined by supply and demand, by the cost of renewables relative to wholesale market prices, and through competition among suppliers. As a result, their value can vary dramatically by location and over time. Policymakers have begun using SRECs as a way to provide financial support for low-income solar programs.

Washington, D.C.'s Affordable Solar Program relies on the value of SRECs sold by developers plus the 30 percent federal solar tax credit, and fills the remaining gap with a rebate financed by alternative compliance payments. The rebate plus the tax credit cover about 70 percent of the cost of residential solar installations on low-income properties, while SREC sales create a rapid payback and ongoing savings (see **Table 2**).

The program, originally called Solar Advantage Plus, installed almost 300 systems on low-income homes in 2015 and 2016, with a rebate worth $2.50 per watt and a maximum of $10,000 per system.[71] The total program cost was about $2.5 million over the two years, with funds coming from RPS alternative compliance payments (ACPs) and the Sustainable Energy Trust Fund, a public goods charge collected from all gas and electric customers in Washington, D.C.

As shown in Table 2, the high value of SRECs are an important part of the financial model for solar in Washington, D.C. Utilities buy SRECs to comply with the solar portion of the D.C. Renewables Portfolio

TABLE 2: **Example of Solar Pro Forma—Washington, DC** (ACTUAL VALUES MAY VARY)

4	kw system size
$6.000	Cost per kW
$24,000	System cost
$7,200	Value of 30% federal tax credit
$16,800	Cost after tax credit
$2,500	Value of Affordable Solar rebate per kW
$10,000	Total rebate value
$6,800	Cost after rebate and tax credit
5256	Annual output (kWh) at 15% capacity factor
$0.47	SREC price
$2,470	Annual SREC value
$0.15	Electricity price
$788	Annual electricity value
$3,259	Annual value to homeowner of SREC and electricity savings
5.155	Simple payback period after federal tax credit (years)
2.087	Simple payback period after federal tax credit and rebate (years)

Standard, recently expanded to five percent from solar power by 2032. If SRECs are in short supply or prices are too high, utilities can make an alternative compliance payment of $500 per MWh (or 50 cents per kWh).[72] Utilities paid about $700,000 in ACPs in 2015, a number that is expected to rise due to the recently raised RPS target.

According to the U.S. Department of Energy, D.C. SREC prices have exceeded $470 per MWh (47 cents per kWh) for the past three years, more than twice as much as any other state with solar RPS requirements.[73]

At these prices, SRECs could be worth almost $2,500 per year for a 4 kilowatt PV system. They are monetized by being sold to utilities by the installer or owner of the solar system. Of course, SREC prices fluctuate according to supply and demand, and may deliver smaller benefits to low-income households in future years.

The federal tax credit is also a significant contributor, worth 30 percent of the installed cost of a system. As noted above, if a low-income homeowner is unable to take the full value of the tax credit, the installer can use a third-party ownership model, leasing the system or selling the power to the customer.

Finally, the rebate for low-income households shortens the payback period considerably and delivers bigger ongoing savings.

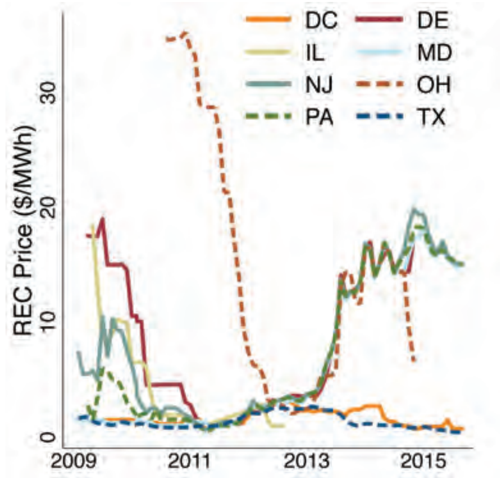
In Massachusetts, the SREC value itself is adjusted to support low-income solar projects. Under the SREC II program, the Massachusetts RPS awarded different levels of SRECs for different kinds of solar projects, based on a variety of factors. Low-income solar projects earned a full SREC, while those sited on brownfields earned 0.8 credits, for example.[74] SREC prices in Massachusetts have been worth about 20 cents per kWh in recent years.

Massachusetts has developed a new solar incentive program called the Solar Massachusetts Renewable Target (SMART) to replace its SREC II program. Like the SREC II program, the proposed SMART program will include

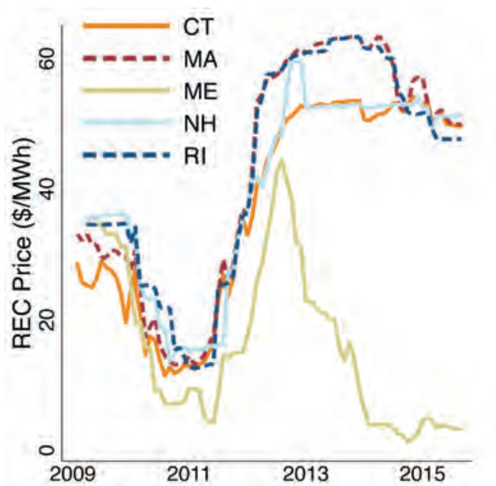
REC prices show wide variation across states and regions, and are highest in the Northeast (Figures 3A and 3B). Solar RECs (Figure 3C) also show a wide range, but are highest in DC and Massachusetts. Voluntary market RECs are selling at less than $1 per MWh.

Source: NREL, *Status and Trends in the U.S. Voluntary Green Power Market* (2014 Data), *http://www.nrel.gov/docs/fy16osti/65252.pdf*.

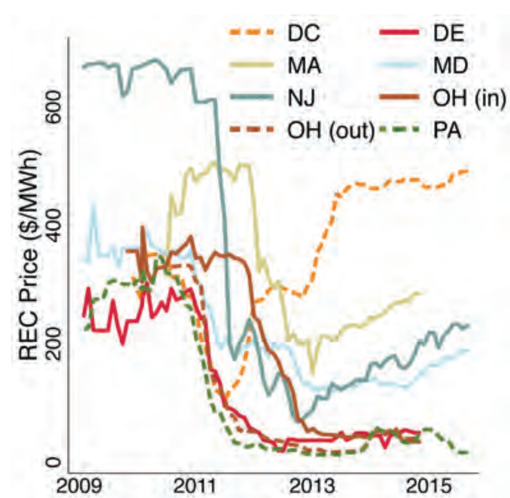
FIGURE 4: **REC and SREC Pricing**



A. Compliance REC pricing in the Midwest, Mid-Atlantic, and Texas



B. Compliance REC pricing in New England



C. SREC Pricing

FIGURE 5: **Connecticut's Solar Home Renewable Energy Credit Program**

When panels produce electricity for a home, they also produce Solar Home Renewable Energy Credits (SHRECs). The Green Bank collects all the SHRECs produced.

Utilities enter into 15-year contracts with the Green Bank to purchase the stream of SHRECs produced from residential solar systems for RPS policy compliance.

The Green Bank then uses the revenues from the 15-year fixed price contracts to continue attracting private investments into the residential solar market through the RSIP program.

A SHREC policy for over 300 MW attracts over $1 billion of private investment in residential solar in CT, contributes $532 million to the state economy, create 6,000 job-years, and saves ratepayers estimated $68 million in energy cost from the Class I RPS policy.

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Sources: Connecticut Center for Economic Analysis at the University of Connecticut (February 10, 2015).
Sustainable Energy Advantage (February 10, 2015)—energy cost savings based on IRP assumptions of RPS compliance costs.

additional incentives for low-income customers (defined as those who qualify for reduced utility rates). Systems under 25 kW that serve low-income customers would receive 15 percent higher compensation than other similar-sized systems; and community solar systems serving primarily low-income customers would receive an adder of 6¢ per kWh, compared to other community solar systems, which would receive a 5¢ per kWh adder.[75]

As shown in **Figure 5**, the Connecticut Green Bank takes ownership of the RECs produced by residential solar systems (called Solar Home RECs, or SHRECs) in exchange for the incentives paid to the customer under the Residential Solar Investment Program. The Green Bank then sells the SHRECs to utilities for RPS compliance, and uses the revenues to support further incentives, including solar programs for low-income customers.[76]

EPA's Clean Energy Incentive Program

The Clean Power Plan (CPP), introduced by the U.S. EPA under the Obama administration, includes the Clean Energy Incentive Program (CEIP) for early-action solar projects "implemented to serve low-income communities that provide direct electricity bill benefits to low-income community ratepayers."

Under the CEIP, states would issue early action emission rate credits (ERCs) for eligible renewable energy and low-income community projects. For projects in low-income communities, EPA would give a two-for-one match from a pool of credits that EPA would hold in reserve, allocated to states based on their emission reduction targets.[77]

The CPP is undergoing litigation, and the Trump administration opposes the plan, making it highly unlikely that it will be implemented. The concepts, however, may be relevant for regional emission trading systems, like the Regional Greenhouse Gas Initiative and California's AB32 program.

Prizes and Other Incentives

Some state and local governments and other entities are offering prizes, training, and other incentives for promoting low-income solar housing.

- Through its Green Permits program, the City of Chicago offers expedited permitting and potentially reduced fees for building projects that incorporate green elements like solar power. This could be applied to low-income solar on public housing, for example.[78]

- Nonprofit and quasi-public agencies can support technical assistance and training for low-income solar projects. GRID Alternatives is the most prominent nonprofit provider in this space for low-income solar. With foundation and corporate funding, it offers free assistance for multifamily housing projects across the country. GRID Alternatives also works with NeighborWorks America, a congressionally chartered corporation that receives a direct annual appropriation of about $200 million to work on affordable housing. Neighbor-Works is supporting GRID Alternatives to provide technical assistance for low-income housing projects in nine communities.[79]

- Prizes and commendations can be a low-cost way for governments to encourage and publicize low-income solar projects. New York offers the 76West Clean Energy Business Competition to encourage innovative clean-energy businesses in the state. The most recent round solicited 175 applicants and awarded a total of $2.5 million to the six finalists.[80] A Habitat for Humanity solar homes project in Michigan discussed below was awarded the U.S. Department of Energy 2016 Housing Innovation Award, the Zero Energy Hero Award from the GreenHome Institute, and the Midwest Project of Distinction Award for 2016 from the Solar Energy Trade Shows LLC.[81]

In late 2016, the U.S. Department of Energy's SunShot Initiative launched the Solar in Your Community Challenge, a nationwide prize challenge to develop new models for low-income solar and for solar to serve nonprofit institutions.

- In late 2016, the U.S. Department of Energy's SunShot Initiative launched the Solar in Your Community Challenge, a nationwide prize challenge to develop new models for low-income solar and for solar to serve nonprofit institutions.[82] Teams were invited to submit proposals to compete for up to $60,000 in seed money and up to $10,000 in technical assistance. After the projects are completed, prizes will be awarded to the most successful and scalable projects and programs, including a $500,000 grand prize. The U.S. Department of Energy hopes to elicit creative ideas and new models, and to give a boost to local innovations in low-income solar.

- NYSERDA offers grants of up to $200,000 under its Affordable Solar Predevelopment and Technical Assistance fund.[83] This program is intended "to address resource gaps and solve market barriers preventing the development of solar installations serving LMI income households." Grants can be used to solve legal and financial barriers, for example, but not to pay for engineering or construction.

FINANCING POLICIES

Most ideas being tried or proposed for low-income solar expansion involve finance. Governments and other entities are trying a variety of finance tools to lower purchase prices for solar, to make financing less costly and more streamlined for consumers, and to overcome the problem of low or no credit scores for low-income consumers.

One set of options is to set up a method of repayment that lowers risk for the lender, and thereby lowers the cost of financing. This can include repayments on utility bills, on property tax bills, or embedded in utility tariffs.

On-Bill Repayment

On-bill repayment (also called on-bill recovery or on-bill financing) lets customers pay for energy improvements in installments on their utility bill. The savings from the improvement, such as from energy efficiency or solar, offset the cost of the measure, so utility bills that include the repayment may be similar to or lower than what they were before the improvements were made.

On-bill repayment has been offered since the 1970s, facilitating over $1.83 billion in loans, according to LBNL.[84] There are about 45 programs currently active in 32 states. Cumulative default rates are low, ranging from zero to three percent. In 2014, over 20,000 on-bill loans were made, including $76 million in residential loans, $89 million in commercial and industrial loans, and $14 million in institutional loans.

BOX 3

Advantages and Disadvantages of On-Bill Finance

Advantages

- Savings are paired directly with repayment on the same bill.
- Can be structured to meet the needs of different markets.
- Provides a relatively secure revenue stream because failure to pay can be tied to disconnection.
- Can use past bill replacement as a proxy for credit.

Disadvantages

- Utilities are often reluctant to take on the role of financing entity; potential exposure to consumer lending laws and alterations to billing systems are required.
- Can be costly and complicated to set up.
- If transferability is not allowed, homeowners or businesses must pay off entire loan upon sale of property, which could result in not all of the energy savings being realized.

Source: U.S. Department of Energy. *http://energy.gov/eere/slsc/bill-financing-and-repayment-programs*

Still, as noted in **Box 3** on the advantages and disadvantages of on-bill finance, utilities may be reluctant to play such an active role in financing, since lending laws can vary by state. Rules must be established around whether and how utilities can disconnect service in the case of customer default and the transferability of loan obligations between customers.

Currently, over 90 percent of the total volume comes from just five programs. As experience grows with on-bill repayment, and if default rates stay low, lenders and utilities may become more comfortable with it.

On-bill repayment has been used by the Green Jobs–Green New York program since 2009. Administered by NYSERDA, the on-bill repayment program has approved 7,144 loans to residential customers, worth almost $38 million. Almost 2,200 of these included solar installations.[85]

While on-bill repayment makes it more convenient for any customer to finance energy improvements, there are some adjustments that can be made for low-income customers. For example, New York is using bill payment history as a proxy for credit scores, for customers who lack sufficient credit history. The New York program is currently offering loans of up to $25,000 at a rate of 3.49 percent. It takes credit scores as low as 540, as long as customers have low debt compared to their income (known as a debt-to-income ratio, or DTI).[86]

Loans can also be obligated to utility meters, rather than to the customers themselves. This can make it easier for landlords to take a loan to make property improvements, knowing that tenants will be repaying the loan on their utility bills. There are little data on how common or popular this feature is, but Midwest Energy's How$mart Kansas program has had 120 renters (out of 989 residential projects) use it as of 2013.[87]

EEtility, an energy services company, worked with the Ouachita Electric Cooperative in Arkansas to develop the Home Energy Lending Program (HELP) to finance energy efficiency improvements through loans that are paid back on utility bills. Of the 300 retrofits performed in 2015, 80 percent were for low-income households. The coop recently switched over to a similar product, called HELP PAYS (Pay As You Save), as described below.[88]

Property-Assessed Clean Energy (PACE)

PACE enables property owners to finance energy improvements through a special assessment on their property taxes, with funding provided by local and state governments, or by private sector lenders. It can be used for commercial properties (such as multifamily housing) as well as for single-family homes. PACE offers some advantages over traditional financing tools, but some disadvantages as well (see **Box 4**, p. 40).[89]

PACE financing for residential projects was delayed for many years due to the concern of federal mortgage finance agencies about its impact on mortgages. Different types of debt have a ranking of priority for payment, in event of a default. PACE finance is typically senior to mortgages, making lenders more confident that the money will be paid back, and potentially making them willing to offer better terms.[90] But HUD and the Federal Housing Finance Administration (FHFA) refused to insure mortgages that were subordinate to PACE debt. (Lenders can voluntarily make PACE debt subordinate to mortgages, and a few states require it.)

In 2013, California established a $10 million loan loss reserve fund to compensate mortgage holders for PACE finance losses, in the event of a foreclosure. However, FHFA responded that it "was not prepared to change its position on California's first-lien PACE program" since it "fails to offer full loss protection." So far, no claims have been made against the fund, according to Berkeley Lab.[91]

On July 19, 2016, the White House and HUD issued guidance outlining the conditions under which the FHFA would insure a PACE-encumbered property, especially in event of foreclosure. The guidelines say that PACE should be treated like any other property tax assessment and not as a traditional loan product. They prohibit lenders from demanding the remaining balance of a PACE assessment be paid off at foreclosure; instead, they require it to stay with the property as it transfers to a new owner.[92]

According to David Gabrielson, Executive Director of PACE Nation, a PACE advocacy organization,

> *HUD/FHA accept that because PACE assessments remain with a property upon sale, including foreclosure sales, PACE isn't really senior to their mortgage interests.… Because they*

BOX 4

Advantages and Disadvantages of PACE Financing

ADVANTAGES

- Allows for secure financing of comprehensive projects over a longer term, making more projects cash flow positive.
- Spreads repayment over many years and removes the requirement that the debt be paid at sale or refinance.
- Can lead to low interest rates because of the high security of loan repayments attached to the property tax bill.
- Helps some property owners deduct payments from their income tax liability.
- Allows municipalities to encourage energy efficiency and renewable energy without putting general funds at risk.
- Taps into large sources of private capital, such as the municipal bond markets.

DISADVANTAGES

- Available only to property owners.
- Cannot finance portable items (screw-in light bulbs, standard refrigerators, etc.).
- Can require dedicated local government staff time.
- High legal and administrative setup.
- Not appropriate for investments below $2,500.
- Potential resistance by lenders/mortgage-holders whose claims to the property may be subordinated to the unpaid assessment amount should the property go into foreclosure.
- Default on PACE assessment can lead to loss of property.*

Source: U.S. Department of Energy. *http://energy.gov/eere/slsc/property-assessed-clean-energy-programs*, except for *.

recognize the valid public purpose associated with PACE, they're willing to treat PACE assessments in arrears the same way they treat other property taxes and assessments.[93]

Residential PACE interest rates typically range from six to nine percent. The Consumer Action Coalition points out that these interest rates are low compared to credit card or contractor financing, but high compared to a home equity line of credit (HELOC) or second mortgage.[94]

Depending on the particular PACE program, PACE assessments can be made on the same day as application, since they rely on the value of the home rather than on the creditworthiness of the borrower. The average assessment is over $20,000, and even though credit checks are not used in underwriting them, the typical FICO score of individuals receiving PACE assessments is between 700 and 720.

PACE financing can be used for low-income solar projects in two ways: 1) commercial PACE can finance solar deployment on multifamily housing or by nonprofits that serve low-income communities, and 2) residential PACE can cover homes owned by low-income residents.

As of 2016, over $3.3 billon had been put toward PACE financing for 132,000 residential energy projects. While 26 states have passed legislation enabling residential PACE, active programs only exist currently in California and Florida and communities in Missouri and New York. Almost 84 percent of the residential activity in the U.S. was generated by the Home Energy Renovation Opportunity (HERO) Program in California, operated by Renovate America. About 37 percent of residential projects included renewable energy.[95]

Commercial PACE has been more widespread, with 46 active programs in 19 states, since it hasn't encountered the same regulatory objection. Enabling legislation has been adopted in 33 states and the District of Columbia, as of Q3 2016. Still, California and Connecticut account for about $230 million of the $332 million cumulative total financing since 2009. About 40 percent of the 998 commercial PACE projects included solar power, according to PACE Nation.[96]

PACE financing can be used for low-income solar projects in two ways: 1) commercial PACE can finance solar deployment on multifamily housing or by nonprofits that serve low-income communities, and 2) residential PACE can cover homes owned by low-income residents.

Funding solar for nonprofits can be especially complicated, because they're unable to take advantage of tax credits and other tax benefits. In these cases, it may be useful to combine PACE financing with other financing tools, like the use of tax equity investors. In one example, commercial PACE financing was used to fund energy efficiency improvements and solar power at a HUD-assisted YWCA shelter for homeless women in Washington, D.C.[97] The project spent $700,000 on energy improvements, including a 30 kW solar system for about $120,000. PACE financing was used for $635,000 while a tax equity investor and other sources supplied the balance.

TABLE 3: **YWCA Benefits**

Property Owner: Annual Benefit	
Utility Savings	$73,000
PACE Payments	$(66,000)
Net Cash Flow	**$7,000**
Equity Investor Benefits	
SREC Revenue	$72,000
ITC	$36,000
Depreciation	$35,500
Total Benefit	**$143,500**
Tax Equity	-$65,000
Net Benefit	**$78,500**

Source: PACE Nation

The property owner (the YWCA) was able to see utility bill savings that exceeded the PACE payments by $7,000 per year.

The investor was able to monetize the federal tax credits (ITC) and depreciation over five years that the nonprofit YWCA would not have been able to use. A significant part of the revenue stream was the sale of the solar renewable energy certificates (SRECs), which amounted to $72,000 over the term of the contract (see **Table 3**).

Ownership of the solar system will be transferred to the YWCA after 15 years.

A significant benefit of using PACE financing was that the property owner did not have to make a capital investment in the project, as shown in **Table 4**. PACE financing allowed a positive cash flow throughout the 15-year term. If the project were self-funded it would have had a payback period of just over 10 years.

A project called CivicPACE is working to bring PACE financing to tax-exempt organizations, such as nonprofits, affordable housing, faith-based institutions, and schools, with a focus on Cincinnati, Austin, and Washington, D.C. The project is funded by the U.S. Department of Energy SunShot Initiative.[98]

California Governor Brown announced the Multifamily PACE Pilot in 2015, in partnership with the MacArthur Foundation. This pilot will enable PACE financing for certain California multifamily properties, including specific properties within the portfolios of HUD, the California Department of Housing and Community Development, and the California Housing Finance Agency. The $3 million program of technical assistance and

TABLE 4: **YWCA Finances: Self-Funded v. PACE-Funded**

	Self-Funded	PACE
Investment by Property Owner	$700,000	$0.00
Annual Utility Savings	$77,000*	$73,000
Annual PACE Payment	$0.00	$(66,000)
Net Benefit Year 1	$(623,000)	$7,000
Annual Net Benefit Year 2–15	$77,000	$7,000
5-year NPV of Cash Flows (@6% discount rate)	$(305,000)	$27,000
10–year NPV of Cash Flows (@6% discount rate)	$(56,000)	$58,000
5–year IRR	-15%	Infinite
10–year IRR	3%	Infinite

Source: PACE Nation *Includes SREC Income credit support may include a loan loss reserve and/or a debt-service reserve fund. The pilot is intended "to inform project performance and repayment experience while managing finance risk perception."[99]

As discussed above, PACE could also be used to finance solar on homes owned by low-income residents. Rather than depend on credit scores or income levels, PACE lenders simply require homeowners to have enough value and equity in their homes to qualify for PACE financing. Underwriting tests typically require that borrowers have at least 10 percent equity in the home, that PACE financing not exceed 15 percent of home value, and that total property-related debt (mortgages plus the PACE assessment) not exceed the home's value.

Because PACE participants aren't ordinarily asked what their incomes are, there is little data on low-income customer participation. However, a survey focused on California's HERO program, the largest residential PACE program in the country, found that PACE customers have similar income and education levels to the general population.[100] Customers that get energy-related rebates, on the other hand, tended to have much higher incomes and slightly more education than average.

For example, 58 percent of rebate participants had an income of $100,000 or more, compared to 38 percent of HERO respondents and 36 percent of the general population. About 12 percent of PACE customers in the study earned less than $40,000 per year, which is proportionally less than the general population, where 18 percent are in that income bracket.

The National Consumer Law Center and other low-income advocates argue that PACE financing is not appropriate for low-income homeowners, due to the risk of foreclosure and loss of the home if homeowners default on their payment.[101] "Based on our experience with low-income consumers," they write, "we oppose marketing of PACE loans to low-income households. Rather than encouraging struggling, low-income homeowners to take on additional debt, [agencies] should prioritize these homeowners for access to existing federal and state programs that provide free or low-cost energy efficiency upgrades."

They point out that PACE interest rates are higher than some other financing options, especially in states with special finance programs for low-income homes, like the no-interest-loan offered by the Mass Save HEAT program in Massachusetts. They argue that PACE assessments should be subject to the federal Truth in Lending Act (TILA) and other federal consumer protection laws. These laws require clear disclosure of costs several days before consummation of the transaction, the right to cancel the transaction within three business days, a ban on kickbacks, the right to dispute billing errors during servicing of the loan, and clear rules for enforcement. Legislation to regulate PACE under the TILA was recently introduced in Congress.[102]

The biggest risk of PACE is that it is based on the value of the home, not on the ability of the customer to repay the assessment. NCLC cites this as perhaps the most dangerous aspect of PACE finance for low-income home-owners, and calls it out for special regulatory attention. Consumer protection rules could help make PACE programs more appropriate for low-income homeowners. Specifically, if each project involved an assessment by a trusted third party that the project was likely to be cash-flow positive, saving more money in electric bills than it cost, the risk to homeowners could be significantly reduced. A project that is cash-flow positive should make it easier for homeowners to meet all of their financial obligations.

Pay As You Save

With Pay As You Save (PAYS), the utility rather than the homeowner invests in the energy upgrade. The utility gets paid back through the customer's tariff. There is no loan or lien, and the repayment obligation stays with the property rather than with the customer. The monthly repayment charge is always lower than the money saved from reduced energy, and it remains on the bill for that location until all costs are recovered.

PAYS has been adopted by four rural electric coops to finance energy efficiency improvements, including some regions with severe economic distress. As mentioned earlier, the Ouachita Coop in Arkansas started using an on-bill repayment approach in 2015, but recently switched over to a PAYS approach, to better reach renters and low-income households, with limited capacity to take on debt.

With Pay As You Save, the utility rather than the homeowner invests in the energy upgrade. The utility gets paid back through the customer's tariff. There is no loan or lien, and the repayment obligation stays with the property rather than with the customer.

In the first quarter of operation, renters accounted for one-third of the participants. (Renters had been ineligible to participate in the previous loan program.) More than 60 multifamily housing units were assessed in the first quarter and all of those residents accepted the energy efficiency offer by opting into the tariff.[103]

Compensating for Low or No Credit Scores

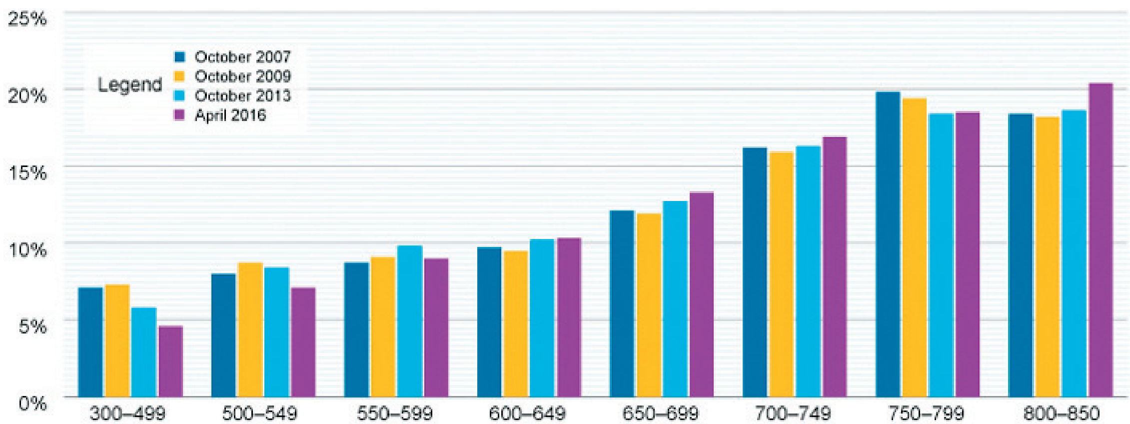
Every kind of financing is affected by the perceived ability of the customer to repay it. The most common way to measure a person's ability to pay is through a credit score, which is derived from payment history, debt burden, the length and type of credit used, and other factors. Credit cards, home and car loans, and student loans are the most common forms of credit history. Low-income customers who don't take loans or use a credit card may have a low credit score, or none. See Box 1 on page 12 on the correlation between low income and low credit scores.

According to the Fair Isaac Corporation (FICO), credit scores have been improving since the housing crash and recession of 2008. The national average FICO score is at an all-time high of 699, while 20.7 percent of consumers have scores less than 600.[104]

The Green Jobs–Green New York program has developed two tiers of qualifications for making loans for energy efficiency and solar power. Tier 1 loans use standard underwriting criteria relying primarily on credit scores and debt-to-income ratios. Tier 2 uses mortgage payment history instead of FICO scores, and a sliding debt-to-income ratio requirement to account for reduced household energy costs. These changes address what are "currently the most common cause of loan denials." Tier 2 loans made up 12 percent of loans made under the program as of June 2015.[105]

Additional approaches are being tested by the Solstice Initiative, a nonprofit community solar marketer in Massachusetts. With funding from the U.S. Department of Energy SunShot Initiative, Solstice will use customer data on income, FICO score, and utility, rent, and cell phone repayment history to develop new qualifying metrics for low-income households. They

FIGURE 6: **Annual U.S. Consumer Credit FICO Score Ranges Since 2005**



	PERCENT OF POPULATION											
FICO® Score 8	October 2005	October 2006	October 2007	October 2008	October 2009	October 2010	October 2011	October 2012	October 2013	October 2014	October 2015	April 2016
300–499	6.6	6.5	7.1	7.2	7.3	6.9	6.3	6.0	5.8	5.2	5.0	4.6
500–549	8.0	8.0	8.0	8.2	8.7	9.0	8.7	8.5	8.4	7.9	7.4	7.1
550–599	9.0	8.8	8.7	8.7	9.1	9.6	9.9	9.9	9.8	9.5	9.2	9.0
600–649	10.2	10.2	9.7	9.6	9.5	9.5	9.8	10.1	10.2	10.3	10.3	10.3
650–699	12.8	12.5	12.1	12.0	11.9	11.9	12.1	12.2	12.7	12.8	13.0	13.3
700–749	16.4	16.3	16.2	16.0	15.9	15.7	15.5	16.2	16.3	16.6	16.8	16.9
750–799	20.1	19.8	19.8	19.6	19.4	19.5	19.6	18.8	18.4	18.1	18.3	18.5
800–850	16.9	17.9	18.4	18.7	18.2	17.9	18.1	18.4	18.6	19.6	20.0	20.4
TOTAL*	100	100	100	100	100	100	100	100	100	100	100	100

All columns may not add up to 100% due to rounding. © 2016 Fair Isaac Corporation

will then enroll customers in community solar programs and compare actual payment.[106]

Another way to address the credit problem is through credit enhancement tools, such as loan guarantees or loan-loss reserves, offered by a public agency. These tools reduce the risk of lending to customers with lower credit scores or debt-to-income ratios by either guaranteeing the loan itself or providing a fund that lenders can apply to for repayment of defaulted loans.[107] The $30 million Mass Solar Loan program, launched in December 2015, is one example of a loan-loss reserve and has additional incentives for low- and moderate-income customers (with thresholds based on household size).[108]

For more information on solar loan program design, see CESA's Sustainable Solar Education Project guide titled *Publicly Supported Solar Loan Programs: A Guide for States and Municipalities*.[109]

Third-Party Ownership Models

Many states allow third parties to own rooftop solar systems and provide solar power to a customer through a lease, a power purchase agreement (PPA), an energy service agreement, or a managed energy service agreement. These third-party ownership models are used to develop, fund, and deploy energy improvements.

Nine states specifically prohibit third-party arrangements for solar, while the legality is unclear in another 15 states. These states could stimulate solar deployment for low-income customers by enabling third-party ownership.[110]

TABLE 5: **Green Jobs–Green New York Two-Tiered Loan Underwriting Standards** (AS OF JUNE 20, 2015)

Standard	Tier 1 Loans	Tier 2 Loans
Minimum FICO	640 (680 if self-employed for 2 years+) (720 if self-employed <2 years)	540
Mortgage payment history	None	Current on all mortgage payments, if any (as reported on the credit report), for the past 12 months. No mortgage payments more than 60 days late during the past 24 months.
		Up to 70% for FICO 540–599
		Up to 75% for FICO 600–679
		Up to 80% for FICO 680+
		Up to 100% for applicants who are qualified as owner-occupants for Aassisted Home Performance with ENERGY STAR Subsidy for the subject property of the loan ($5,000/50%).
Max Debt-to-Income Ratio	Up to 50%	Up to 70% for FICO 540–599
Bankruptcy	No bankruptcy, fore-closure, or repossession within last 7 years	No bankcruptcy, foreclosure, or repossession within last 2 years
Judgments	No combined outstanding collections, judgements, charge-offs, or tax liens >$2,500	

Source: Green Jobs-Green New York, 2015 Annual Report.
https://www.nyserda.ny.gov/-/media/Files/EDPPP/GJGNY/Annual-Report-GJGNY/2015-GJGNY-Annual-Report.pdf.

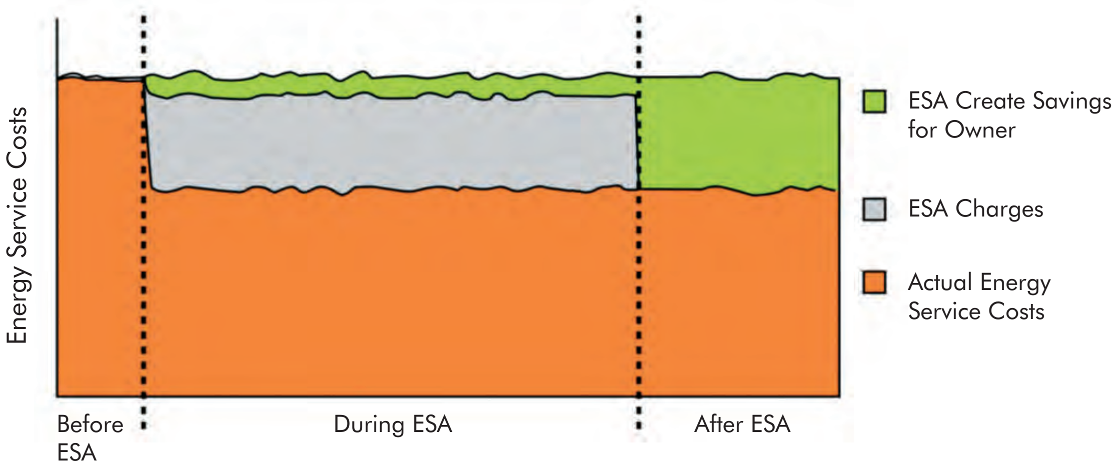
The most common third-party ownership models for solar—PPAs and leases—are used when a developer installs solar on the customer's property and either leases it to or sells the power to the customer. Third-party models dominated the solar industry for several years, since they allowed customers to go solar with "no money down." More recently, as the price of solar installations has dropped, customers are increasingly likely to own the system outright.[111]

Under an energy service agreement (ESA), the third-party provider is paid by the energy savings from the project, at a net savings to the customer.[112] With a managed energy services agreement (MESA), the third-party takes over paying the customer's utility bill. The MESA provider then invests in energy efficiency and onsite generation to reduce their expenses.

ESAs and MESAs have been most common for energy efficiency projects with commercial and industrial customers, including low-income multifamily housing. They are less commonly offered to single-family residential customers. One example is Sealed, a company that offers a shared savings deal to homeowners in New York.[113]

Third-party solar providers have only rarely served low-income customers. Because credit score is an important factor in determining the financial risk of taking on a customer, low-income customers with perceived poor credit scores have not been attractive to marketers.

FIGURE 7: **Profile of an Owner's Energy Service Costs**



Source: Associated Renewable

Yet third-party ownership may be advantageous to a low-income consumer, since the company maintains the system, is responsible for regulatory and equipment risk, and the service can be transferred to the new owner in event of a home sale. For low-income seniors, especially, having someone else monitor, operate, and maintain the system would be a boon.

At least one solar company, PosiGen, is marketing to low-income communities. Based in New Orleans and currently operating in three states, PosiGen offers the "Solar for All" product, a standardized PV installation in three sizes sold under a 20-year lease for between \$55 and \$99 a month, with no deposit, no credit check and no background check.[114] They have sold nearly 1,000 solar leases to Connecticut homeowners, two-thirds of whom were low- or moderate-income.

PosiGen combines solar with energy efficiency, by integrating with state efficiency programs in Connecticut and offers a 20-year energy service agreement for efficiency measures in Louisiana. Because the combined efficiency and solar faithfully delivers savings, they claim to have "very low" default and delinquency rates. PosiGen retains control of the solar systems and can turn them off remotely. This shows the homeowner that they are better off paying for the solar system than reverting to the utility bill.

In Connecticut, PosiGen works closely with the Connecticut Green Bank, which provides subordinated debt into the lease fund, a performance-based solar incentive with elevated rates for qualifying low-to-moderate income customers, and collaborates on community-based outreach campaigns, recruiting low-income customers in four cities. PosiGen has tax equity partners who can take advantage of federal tax credits. They have explored getting discounted financing from banks under their Community Reinvestment Act obligations (as discussed later) but have had limited success due to the relatively complicated structure of transactions.[115]

States can accommodate third-party ownership models in low-income solar program design. The SASH program in California was recently revised to allow a third-party ownership model. By partnering with the financial services firm Spruce (formerly Clean Power Finance and Kilowatt Financial LLC) the SASH program can better capture federal Investment Tax

Credit (ITC) benefits, plus participating families receive the benefits of a performance guarantee, system monitoring, and a 20-year warranty coverage. SASH continues to offer a rebate of $3 per watt, which covers a significant portion of system costs. Third-party owned projects have quickly become the method of choice for the program, accounting for over 70 percent of systems installed during the first half of 2016.[116]

Group Purchase Programs (Solarize)

The cost of solar can be driven down through bulk purchases. "Solarize" programs have implemented intensive short-term marketing and outreach campaigns in specific communities as a way to reduce costs and increase sales.

Solarize initiatives have been run by states, municipalities, and nonprofit organizations across the country, including in large cities such as New York, Portland, and Washington D.C. In some cases, campaigns have also organized around particular affinity groups (businesses, churches, and colleges, for example) rather than by municipality.

Solarize campaigns have been run specifically to attract interest from low-income consumers. PosiGen has worked with the Connecticut Green Bank to do campaigns in low-income communities designated as "distressed" by the state. Their "Solar for All" campaign in Bridgeport has installed over 250 PV systems since 2015.

While not aimed specifically at low-income households, the Solarize Connecticut effort has sold 2,400 systems in 73 municipalities, including in nine of the 25 designated distressed communities. The program has been successful overall, cutting costs as much as 25 percent lower than systems installed outside the campaigns.[117] The participation of low-income customers is currently being studied by Yale researchers, with funding from a U.S. Department of Energy SunShot Initiative grant.[118]

For more information on Solarize program design, see CESA's guide titled *Planning and Implementing a Solarize Initiative: A Guide for State Program Managers*.[119]

Crowdfunding

Crowd-sourced funding, where donations or investments are solicited from the public, was initially seen as a major opportunity for low-cost solar financing, especially for "socially worthy" recipients like nonprofit organizations and low-income households.

A hallmark of crowd-sourcing is that it involves investors that are not "accredited;" accredited investors have an income of over $200,000 per year and a net worth of over $1 million. Crowd-sourced investors can either be seeking a market rate of return, a less than market rate (so called "mission" investing), or making a charitable donation.

Solar Mosaic, based in Oakland, was a leading early proponent of crowdfunding, organizing about $5 million in financing for a few dozen projects. In 2014, Mosaic switched to financing residential solar projects through large institutional investors, due to the higher efficiency of raising a large amount of capital from one source rather than from many sources.

The market maturity and declining cost of solar have attracted more conventional funding sources, like investment banks, reducing the need to try alternative pathways. Nevertheless, crowdfunding can still be a good match for certain types of projects that seek to benefit low-income communities. Moreover, the federal Jumpstart Our Business Startups Act or JOBS Act, may encourage more crowdfunding by easing various securities regulations. Passed in 2012, the implementing rules went into effect in May 2016.[120] The rules were heavily criticized, however, and legislation to reform them, the Fix Crowdfunding Act (H.R. 4855), passed the House in July 2016 and is pending in the Senate.[121]

Over 30 states allow crowdfunding between investors and projects within their state (intrastate), while another eight states have pending legislation.[122] These states tend to have more flexible rules and higher investment limits, which may encourage more investment.

At least three companies continue to offer crowd-sourcing for nonprofit solar projects: CollectiveSun, RE-volv, and Everybody Solar.

RE-volv has completed only four projects to date, but it aims to raise $3 million to finance solar energy systems for over 100 nonprofits over the next three years. One of its recent projects was completed in August 2016, putting solar on Serenity House, an outreach ministry of the Arch Street Methodist Church in North Philadelphia. Working with Swarthmore College students, the project raised $15,000 in donations to cover the cost of the installation. Arch Street will pay RE-volv for the installation over a 20-year lease, with payments 15 percent less than Serenity House's current electricity bill. RE-volv plans to reinvest these lease payments into future solar projects.[123]

© RE-volv

Another model is Everybody Solar, based in Santa Cruz, California, which accepts donations for specific solar projects that benefit nonprofit groups, such as homeless shelters and job training workshops. The donations pay the full cost of the system, which is given free of charge to the nonprofit. Everybody Solar currently has fully funded four projects and is fundraising for a fifth.[124]

CollectiveSun offers a different model, "crowd lending," exclusively to nonprofit organizations, such as churches and group homes. While the main benefit that CollectiveSun provides nonprofits is its ability to apply tax credits to reduce any nonprofit solar installers bid by 15 percent, the company also offers assistance to its nonprofit partners in financing the remaining cost of the system.

CollectiveSun works with the nonprofit to recruit individual lenders to finance a solar project. The lending is provided by supporters of the nonprofit, with interest and loan duration set by the nonprofit, but typically around four to five percent for 10–12 years. The loan terms are set so the energy savings are greater than the annual debt service obligations. Crowd lending can be combined with other sources of finance, such as bank loans, PACE, and program-related investments from foundations.

Todd Bluechel, the Vice President of Sales for CollectiveSun, thinks crowd lending works better than a donation model for nonprofits, since it doesn't compete with other donations.[125]

The nonprofit uses the crowd-lent money to buy a prepaid PPA from CollectiveSun. With a prepaid PPA, the customer pays for the electricity upfront, rather than monthly. The nonprofit then repays the crowd-lenders at a rate less than what it had been paying for electricity.

CollectiveSun owns the project for the first six years to capture the tax benefits and accelerated depreciation. At that point, ownership of the system transfers to the nonprofit. Since the prepaid PPA rate includes the cost of the transfer, there is no additional charge to buy the system. The nonprofit may continue to pay its lenders after the transfer, depending on the duration of the loan.

CollectiveSun has completed about a dozen projects and claims to have about 150 in the pipeline.

Federal Economic Development Programs

There are a host of existing federal policies and programs for low-income people and communities that do or could provide funding for low-income solar energy. As solar becomes more cost effective, it becomes increasingly attractive as a way to reduce living expenses, lower the cost of providing services, promote local economic development, and improve the environmental quality of a community.

State and local governments and quasi-public bodies are often the implementing agencies for these federal programs, through block grants or other means. In other cases, the federal government can be a partner, supporting programs created at the state or local level. Understanding the scope and rules of these programs can help to identify additional pathways for financing low-income solar initiatives.

Given the vast scale of the federal government and the potential for change in the new administration, the discussion of options here is not comprehensive.

Community Development Financial Institutions (CDFI) and **Community Development Entities (CDE)** are institutions designed to encourage economic development in low-income communities. They are typically banks or credit unions with a primary mission of community development, serving a specific target market, providing development services, and with oversight by a community. There are about 1,000 certified CDFIs in the United States, which originated $3.4 billion in loans and investments in 2015. CDEs primarily serve to implement New Market Tax Credits.[126]

These institutions draw on a variety of federal financial programs, including the Community Development Financial Institutions Fund, Financial Assistance and Technical Assistance Awards, and New Market Tax Credits.

As solar becomes more cost effective, it becomes increasingly attractive as a way to reduce living expenses, lower the cost of providing services, promote local economic development, and improve the environmental quality of a community.

The Community Reinvestment Act (CRA) of 1977 requires banks to do business in low-income communities. It was enacted in response to "redlining" practices, where banks would refuse to finance activity in low-income communities and communities of color. The Act does not require banks to undertake specific or risky or unprofitable measures. Instead, regulators periodically evaluate a bank's record on meeting CRA obligations, such as making loans to people of different income levels and businesses and farms of different sizes, and the geographic distribution of loans. That evaluation can influence regulatory decisions about expanded operations, mergers, and acquisitions. As a result, banks have created special CRA-related lending programs, adopted more flexible underwriting practices, educated potential borrowers, facilitated government programs for low-income communities, and coordinated with public and private institutions.[127]

CRA activity has already included clean energy. The Solar and Energy Loan Fund (SELF), a CDFI based in Florida, has financed more than $2 million of energy upgrades since 2011, typically in small loans to households. For example, the fund received a CRA loan of $300,000 from PNC Bank in 2014 to finance home energy upgrades for low- and moderate-income households.[128]

Federal agencies recently updated their official guidance on the interpretation and application of CRA regulations. In their guidance, they specifically note that clean energy qualifies for community development loans "when the renewable energy or energy-efficiency improvements help reduce operational costs and maintain the affordability of single-family or multifamily housing or community facilities that serve low- and moderate-income individuals."[129]

Public Welfare Investments are bank investments (as opposed to loans) in community and economic development entities and projects that are designed primarily "to promote the public welfare." Such investments help the bank meet CRA requirements, and can include affordable housing, homeless shelters, projects to serve disabled and elderly low-income people, and projects qualifying for the Low-Income Housing Tax Credit (LIHTC). Banks can also invest in economic development and job creation for low-income communities, including renewable energy projects in low-income communities.[130] US Bank and Bank of America used their Public Welfare Investment authority to support solar projects in California that benefited low-income communities, including 11 rental housing communities in the MASH program.[131]

The New Markets Tax Credits (NMTC) program allocates tax credits to CDEs to bring private investment to low-income communities. Between 2003 and 2014, $38 billion in direct NMTC investments were made in businesses, leveraging nearly $75 billion in total capital investment to businesses and revitalization projects in communities with high rates of poverty and unemployment. The program was reauthorized in 2015 for five years, at $3.5 billion annually.[132]

A number of renewable energy projects have used the NMTC, which can be worth as much as 39 percent of project costs over five years, including solar projects at the Cincinnati Zoo and the Salt Lake County Convention Center.[133] Thirteen states have their own state NMTC programs.[134]

The Low-Income Housing Tax Credit (LIHTC) gives investors a federal tax credit for development of low-income units in rental housing projects, over a 10-year period. The credit is permanent under the law, but the amount of the credit fluctuates; new legislation in 2015 creates a minimum value of nine percent of the project investment. States are allocated credits based on population, and give them out following a Qualified Allocation Plan (QAP).[135] The credits can be used in combination with federal renewable energy tax credits and may qualify as a CRA activity for banks.

State Qualified Allocation Plans often include green building criteria, including energy efficiency and renewable energy, which are used in scoring bids from potential developers. As of 2010, all states had at least one green building criteria in their QAP, while some incorporated third-party certification programs, like Enterprise Green Communities.[136] (See **Figure 8**.) QAPs can be updated periodically to incorporate new applications, like solar power.

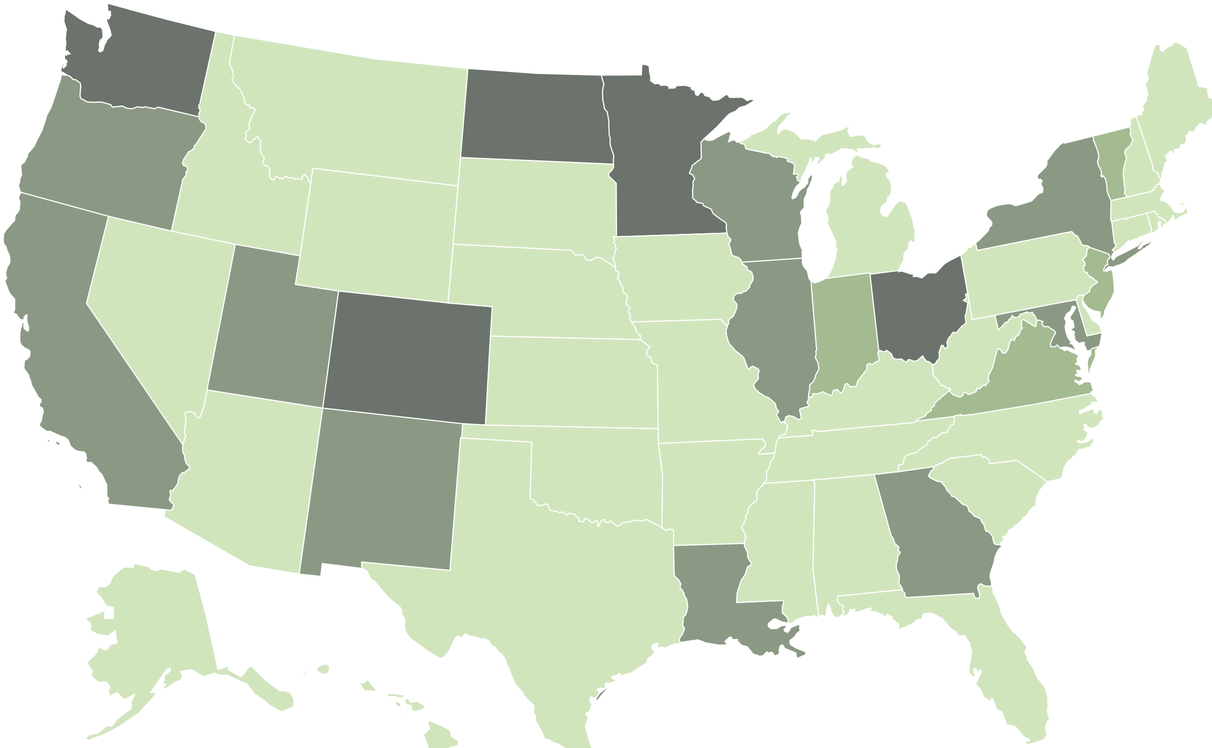
Green building criteria in QAPs can be supplemented with requirements for publicly-owned housing, and with developer incentives, like fast-track permitting or greater density allowances for new construction.

Green financing from federal entities, such as Fannie Mae and Freddie Mac, the government-sponsored enterprises that support mortgage lending, plus the Federal Housing Administration (FHA, part of HUD), all offer "green financing" products and policies to encourage greater energy efficiency in housing. While these offerings are not specifically geared toward low-income homeowners, they can help reduce housing costs through lower energy bills.

Fannie Mae financed $1.2 billion in Green Rewards loans in the first half of 2016. Freddie Mac rolled out its program in July of 2016. Both offer a similar suite of discounted loans for qualified buildings. They claim to have reserved $550 million in loans in the first month of operations.[137]

Many programs are aimed at multifamily housing. In 2009, the FHA began offering mortgage insurance premium reductions on green multifamily loans, a program it enhanced earlier this year. Fannie Mae's Multifamily Green Financing program started in 2012, offering

FIGURE 8: **Green Building Measures in Low-Income Housing Tax Credits**



Green Building Programs Selected as Threshold or Incentive Criteria

- Enterprise Green Communities Criteria
- Enterprise Green Communities & Other Third-Party Green Building Programs
- Other Third-Party Green Building Programs
- QAP incorporated at least one green building measure such as Smart Growth, Health Protection, Energy Efficiency, or Resource Coservation

Source: Enterprise Community Partners, *Green Affordable Housing Policy Toolkit*, 2010

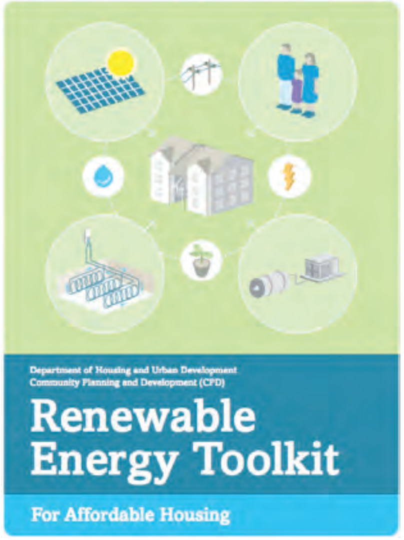
a suite of financing products that encourage energy and water upgrades at existing multi-family housing. Their products, including Green Rewards and Green Preservation Plus, offer lower interest rates and additional loan proceeds, plus free energy and water audits.

Others address single-family homes. Under its PowerSaver program, FHA offers loans for energy improvements, including a second mortgage of up to $25,000 for energy efficiency, solar PV, solar hot water, geothermal, or other renewable energy projects.[138] The loans are intended for owner-occupied homes, and require a minimum credit score of 660.

FHA also offers an Energy Efficient Mortgage, under its Solar and Wind Technologies policy, that allows borrowers to get a larger mortgage to pay for a new solar or wind energy system at the time of home purchase or refinance.[139]

Housing and Urban Development offers a suite of programs that provide funding and support for low-income communities and can be used for renewable energy. Altogether, these programs have spent almost $100 billion since 2003.[140]

- **Renew 300: Advancing Renewable Energy in Affordable Housing** is a new program with a goal of deploying 300 MW of solar for federally-supported affordable housing by 2020, and includes rooftop, community, and shared solar installations. HUD provides technical assistance but not funding through this program.[141]
- **The Community Development Block Grant (CDBG)** program has given block grants to local government for forty years. CDBG funds have supported solar on low-income housing, on water treatment plants in low-income communities, and on institutions that provide services to low-income clients. It also includes a loan guarantee element under Section 108.
- **The Neighborhood Stabilization Program** gave out $7 billion in federal grants under the CDBG program between 2008 and 2010, for rehabilitating blighted properties.
- **The HOME Investment Partnerships Program (HOME)** provides formula grants to states and localities—often in partnership with local nonprofit groups—to fund a wide range of activities including building, buying, and rehabilitating affordable housing or providing direct rental assistance to low-income people. It is the largest federal block grant to state and local governments designed exclusively to create affordable housing for low-income households.
- **Self-help Homeownership Opportunity Program (SHOP)** awards grant funds to non-profit organizations that use "sweat equity" and volunteers to build homes for low-income families. This could include the Habitat for Humanity solar projects discussed later.



HUD released the *Renewable Energy Toolkit* report in July 2016 for recipients of HUD Community Planning and Development grants "to make renewable energy and on-site generation systems part of their affordable housing development programs" under the HOME, CDBG, Housing Opportunities for Persons with AIDS (HOPWA) or Emergency Solutions Grant programs.[142]

The toolkit gives specific guidance about renewable energy technologies, assessment, financing, and deployment on affordable housing. One notable financing tool it cites is the Section 108 loan guarantee component of the CDBG Program. It can be used to finance economic development, housing rehabilitation, public facilities and large-scale physical development projects. Its flexibility "makes Section 108 one of the most potent and important public investment tools HUD offers to local governments," according to the toolkit, including the ability to invest in renewable energy projects.

U.S. Department of Agriculture programs, such as the USDA's Office of Rural Development (RD) programs that provide rural economic development and support to impoverished rural communities, can provide assistance. Since 2009, USDA has provided financing for more than 14,000 energy projects nationwide through $2.1 billion in loans, loan guarantees, and grants.

- **The Rural Development Multi-Family Housing Energy Efficiency Initiative** incorporates energy improvements into various pre-existing rural housing programs. The funding guidelines note that on-site generation "will earn additional…points and increase a project's viability regarding USDA-RD program funding."[143]
- **The Energy Efficiency and Conservation Loan Program** provides low-interest loans to Rural Electric Coops for energy improvements. It has given out almost $60 million in loans since inception in 2013.[144]
- **The Rural Energy for America Program (REAP)** provides grants and loans for energy efficiency and distributed renewable energy projects in rural areas. It is not earmarked for low-income customers, but can be used for that purpose. REAP was created in 2002, and between 2008 and 2016 helped to finance 10,753 renewable energy and energy efficiency projects with almost $360 million in grants and $430 million in loan guarantees.[145]

Green Banks

A green bank is a government-supported financial institution—typically a state but also at the local level—that promotes clean energy through financial offerings.[146] A green bank is not a policy, but rather a platform that can implement or facilitate a variety of financial programs. State green banks exist in Connecticut, New York, and Hawaii. The first local green bank was in Montgomery County, Maryland. Mayor Bowser recently proposed starting one in Washington, D.C.,[147] and the Nevada legislature is considering instituting one in its state as well.[148]

Green banks can provide affordable financing for low-income solar projects by providing credit enhancement mechanisms, such as loan guarantees or loan-loss reserves, or by providing low-interest loans to project developers.

Green banks can provide affordable financing for low-income solar projects by providing credit enhancement mechanisms, such as loan guarantees or loan-loss reserves, or by providing low-interest loans to project developers.

For example, the Connecticut Green Bank helps multifamily housing owners with third-party PPAs for solar, owning, maintaining, and insuring the system and selling power to the building owner under a 20-year term.[149] It also works with Capital for Change, Inc (C4C) (formerly the Connecticut Housing Investment Fund) to market a Low Income Multifamily Energy (LIME) Loan, an unsecured loan for units with many low-income tenants, and offer gap financing and credit enhancement options.[150]

Place-Based Investments

A community can be targeted for special assistance through place-based investments, such as through an Energy Special Improvement District (E-SID). Local governments can authorize a district to be eligible for financing for energy improvements. The project can be funded through sales of revenue or general obligation bonds, with property owners in the E-SID paying back the improvements through a property assessment. As of 2012, E-SIDs were authorized in 27 states and Washington, D.C.[151]

The Center for Social Inclusion has proposed a variation on the E-SID concept called Energy Investment Districts, specifically for attracting energy investments to low-income communities. The EID would be managed by a trust and a community board, which could be hosted by a CDFI or other institution. The trust would be responsible for attracting funds from public and private sources that would be invested in clean energy. Unlike an E-SID, the goal is to have greater community input, a focus on low-income communities, and the flexibility to facilitate multiple sources of income.[152]

One example of an Energy Investment District is in Fayetteville, Arkansas. Legislation in 2013, which enabled PACE financing in Arkansas, also allowed cities, counties or the state to create E-SIDs. Fayetteville's Energy Improvement District Number 1 was created in October 2013 to implement and manage PACE for the City of Fayetteville.[153] The District has the authority to issue municipal bonds to finance the PACE programs, provide loans to interested residents, and create and manage a revolving loan fund that helps make the program sustainable. The only customer so far to use PACE for energy efficiency improvements is Communities Unlimited, a nonprofit whose mission is "to move rural and under-resourced communities in areas of persistent poverty to sustainable prosperity." Four other businesses have applied.[154]

Reduced-Cost Solar Development

While falling costs have helped make solar more affordable for all customers, making it even cheaper can increase deployment for low-income customers. Some nonprofit organizations have been tapping volunteer labor and donated equipment to drive down the installation cost for low-income solar projects.

The federal AmeriCorps program, with an annual budget of $1 billion, has supported volunteer and job training activity since 1994, including the GRID Alternatives SolarCorps program since 2006.[155]

PG&E, one of California's major investor-owned electric utilities, has worked with the nonprofit Habitat for Humanity since 2005 to incorporate solar into homes built by Habitat in the PG&E service territory. The company has donated $10.6 million worth of equipment while PG&E staff have volunteered 12,000 hours to help build over 600 solar homes. Each house is estimated to save the occupant $500 per year in energy costs.[156]

The local Habitat chapter in Traverse City, Michigan, is building a neighborhood of affordable homes that are "net zero," homes that produces as much energy as they consume over a year. The super-efficient, all-electric homes have 7.4 kW solar systems. Habitat plans for 20 housing units when fully built. Volunteers help build the houses, including the homeowner, who puts in "sweat equity" as a condition of ownership.[157]

The McKnight Lane Affordable Housing Development in rural Vermont demonstrates how solar, paired with energy efficiency and battery storage systems, can bring economic and energy security benefits to tenants. The project consists of 14 high-efficiency modular homes with solar and battery systems, owned by the Addison County Community Trust and rented to qualifying low-income tenants. The result is net-zero energy costs for the owners plus backup power for emergencies for the tenants. The batteries also allow the local utility, Green Mountain Power, to manage peak energy demand and reduce costs for all customers.[158]

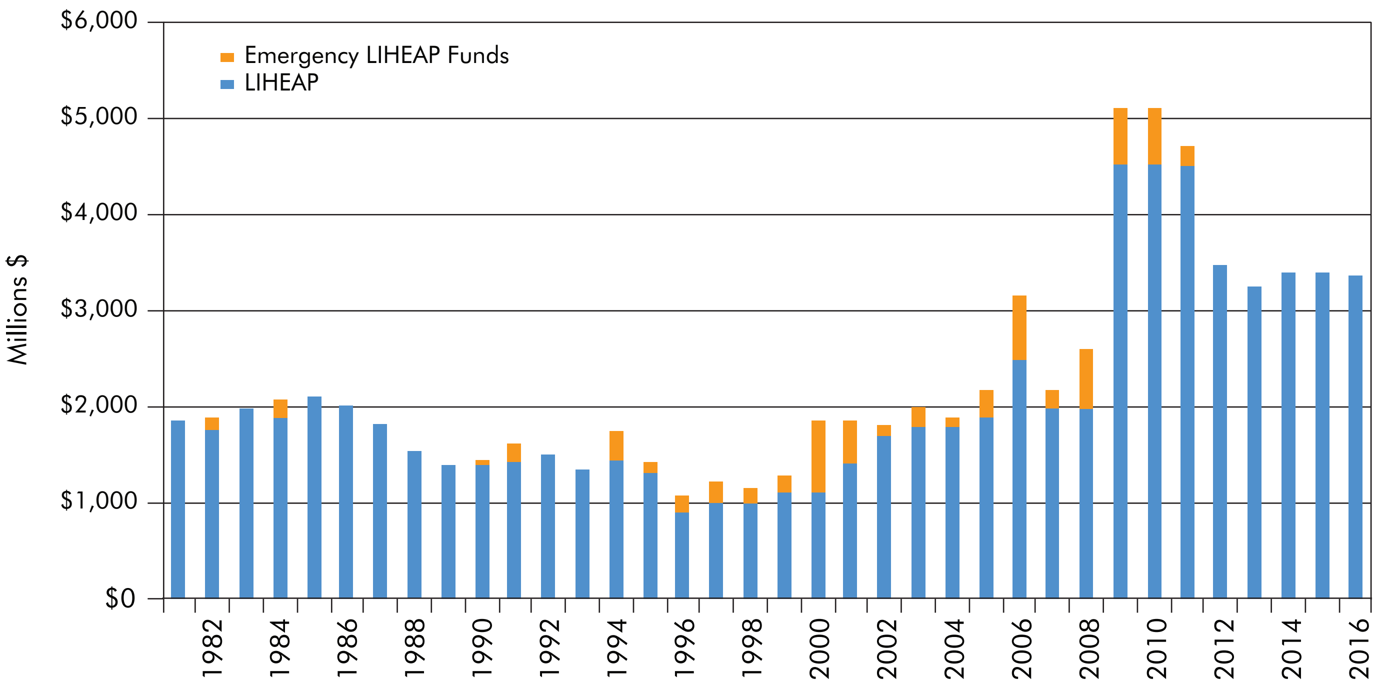
ADAPTING CURRENT LOW-INCOME ENERGY POLICIES TO SOLAR

Federal and state governments have a long history of providing energy support for low-income customers through discounted rates and such programs as the Weatherization Assistance Program (WAP) and the Low-income Home Energy Assistance Program (LIHEAP). These policies and programs are beginning to use solar as another tool to reduce energy burdens for low-income customers.

LIHEAP, administered by the Department of Health and Human Services (HHS), helps pay heating and electricity bills for low-income customers. As shown in **Figure 9**, LIHEAP has been funded at around $3.4 billion per year in recent years.[159] The much smaller WAP pays to make homes more energy efficient, thus reducing energy burdens in the future. WAP is administered by the U.S. Department of Energy. As shown in **Figure 10** (p. 58), WAP has been funded at over $200 million per year over the past three years. Both programs are implemented by states.

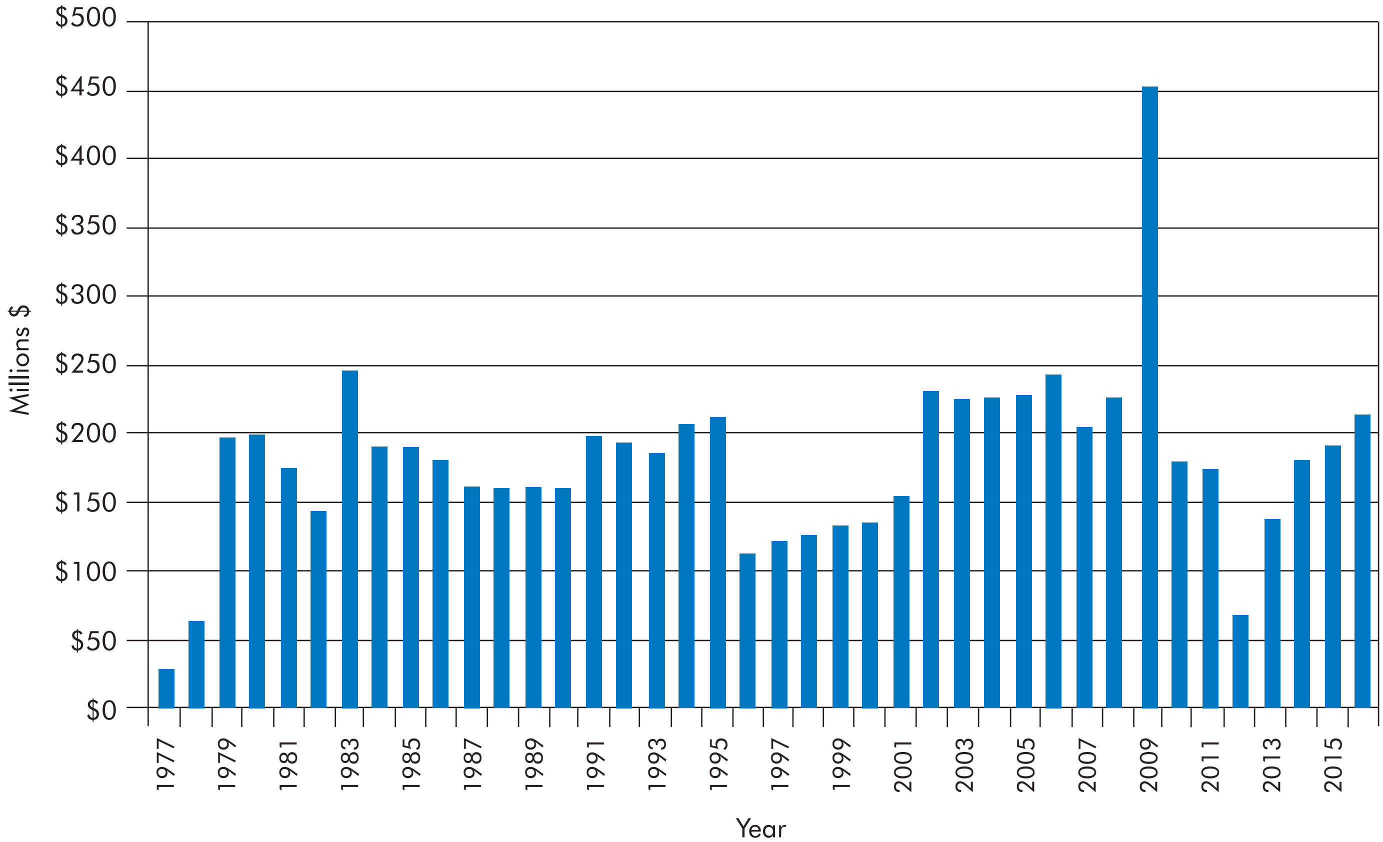
The energy saving measures supported by WAP funds have to pass a cost-effectiveness screen to be eligible, as determined by the U.S. Department of Energy. Solar PV was not an eligible technology until October 2015, when it was added in response to a request by the Colorado Energy Office.[160]

FIGURE 9: **LIHEAP Federal Funding Levels (1982–2016)**



Source: LIHEAP Clearinghouse, https://liheapch.acf.hhs.gov/Funding/energyprogs_gph.htm.

FIGURE 10: **WAP Federal Funding Levels (1977–2016)**



Source: LIHEAP Clearinghouse, https://liheapch.acf.hhs.gov.

Colorado did its first weatherization project with rooftop solar in August 2016, along with efficiency measures like insulation, storm windows, low-flow showerheads, and LED bulbs.[161] The PV system is expected to net roughly $6,200 in energy cost savings over 20 years.

"WAP requires that all its home performance services be cost-tested through an approved energy audit to determine that the savings-to-investment ratio is one or greater," according to the DOE. "The continued decline in the price of solar PV has made it possible for rooftop PV solar to meet this requirement. [The Colorado] project offers a glimpse of what's next in the field of weatherization and demonstrates what other states can do to expand services."[162]

While LIHEAP is principally intended to help low-income customers pay energy bills, states are allowed to use some of the funds for energy conservation measures. The California Department of Community Services and Development set aside $14.7 million from its annual LIHEAP allocation to fund a pilot program that put solar on low-income homes to reduce bills. From 2010 to 2012, the project funded solar systems on 545 single-family homes, plus 14 multifamily apartment building projects with 937 individual units.[163]

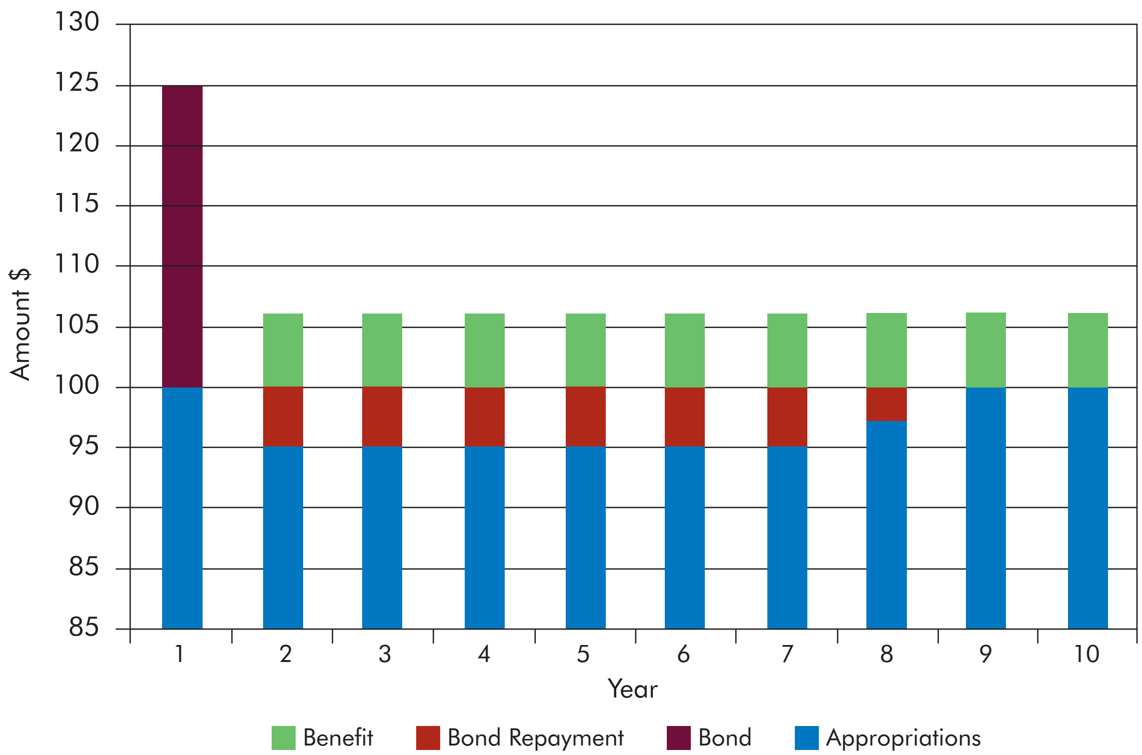
The LIHEAP pilot led to California's Single-family and Multifamily Affordable Solar Housing Programs (SASH and MASH). In 2014 and 2015, the state legislature allocated $75 million and $79 million in California Climate Investments (generated by the AB32 cap-and-trade program) for low-income weatherization projects administered by the Department of Community Services and Development. About one-third of the funds were earmarked for single-family solar projects. As of early 2016, $6.3 million had been used to fund 582 solar projects.[164]

One persistent objection to using LIHEAP funds for long-term investments like solar is that it could create a short-term cash flow problem, given that there is not enough LIHEAP funding to meet all current needs, let alone invest in future cost reductions.

One solution could be to finance solar LIHEAP investments with other investment vehicles, like a green bond, which can be paid back from future payments from LIHEAP that are equal to or less than the benefits they would have acquired. Several state and local governments have developed "green bonds" to finance environmental improvements.[165] For instance, in November 2016, New York announced a $100 million green bond allowing the New York State Homes and Community Renewal's Housing Finance Agency to finance over 640 "green and affordable" units for residents in four counties.[166]

In the conceptual graph shown in **Figure 11**, LIHEAP appropriations of $100 per year are supplemented by a $25 bond in year one that delivers $6 of annual benefits. The bond is repaid over seven years, at an interest rate of 5 percent, creating a net benefit of $1 in those years. After the bond is repaid, the total LIHEAP investment will be delivering $106 of annual benefits.

FIGURE 11: **Conceptual Graph of $100 per Year LIHEAP Appropriation with $25 Initial Bond**



$100 per year supplemented by a $25 bond repaid over seven years at a 5 percent interest rate creates a net benefit of $1 in those years.

Source: PaulosAnalysis

One risk factor that may deter investors is that LIHEAP funds are appropriated annually by Congress, and appropriations are uncertain.

Many states and utilities offer rate or bill discounts to low-income customers. As part of California's net metering proceeding before the California Public Utilities Commission (CPUC), IREC has proposed using solar as a way to reduce energy burdens for low-income customers in California, financed by the California Alternate Rates for Energy (CARE) program. CARE provides rate discounts worth $1.3 billion per year to over 4.5 million households.

IREC's CleanCARE pilot program proposal would allow participants in the program "to redirect their share of CARE funds towards the purchase of renewable generation from a third-party owned renewable energy facility located in a disadvantaged community and receive the resulting net energy metering bill credits on their electricity bills." The program would ensure that the bill impact would be the same or greater than under the regular CARE program.[167] CleanCARE is being considered in the context of various CPUC dockets.

USING SOLAR FOR LOW-INCOME SUPPORT SERVICES

While solar programs can directly help low-income customers save money on their utility bills, customers can also benefit indirectly. Solar power can be used to lower the cost of providing support services to low-income communities, helping stretch limited budgets. States can develop solar programs to support providers of services to low-income communities.

Public Housing

Subsidized public housing is provided by state and local governments, as well as by nonprofit and for-profit organizations. As discussed previously, it is supported by a variety of funding mechanisms, many from the federal government.

Public housing agencies are using solar power to lower the long-term cost of providing housing. In Minnesota, the St. Paul Public Housing Agency signed a contract with Geronimo Energy to provide 10 high-rise apartment buildings with 100 percent solar through the state's Community Solar Garden policy. The buildings provide affordable housing to 1,600 low-income seniors and other individuals. The agreement will save the Authority an estimated $130,000 per year in energy costs and over $3 million over the life of the contract. The Authority will re-invest the savings to provide residents with affordable housing opportunities.[168]

The New York City Housing Authority is planning an even larger solar project, with a goal of 25 MW of PV on city-owned buildings, along with a 20 percent cut in energy intensity.[169]

In some cases, pairing solar PV with battery storage can enhance the value proposition for low-income housing developers. For instance, solar+storage can cut bills by reducing demand charges and by generating revenue through the provision of grid services. It also offers resiliency benefits, providing reliable power for essential electric services during outages.

Additionally, pairing battery storage with solar can provide more value to the utility. In the face of changing net metering policies and utility rate tariffs, storage may provide longer-term value than standalone solar systems do.[170] For more information, see the CESA guide for states and municipalities on *Solar+Storage for Low- and Moderate-Income Communities*.[171]

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Section 8 (Housing Choice Vouchers)

A larger number of low-income households live in privately-owned housing supported by the federal rent subsidy program called Housing Choice Vouchers, previously known as Section 8. There are two types of vouchers: tenant-based vouchers are given to support specific low-income families, and move with the tenant; and project-based vouchers are given to support properties that are dedicated to affordable housing.

HUD provides rental assistance to about three million households each year, including assistance with utility costs. As of 2007, HUD was paying in excess of $5 billion per year for energy in public and subsidized housing, with over half of that for Section 8 housing.[172]

Solar power could be used to reduce utility expenditures by tenants, landlords, and HUD, saving money for federal taxpayers. Project-based vouchers are more conducive to enabling solar, since the investments are literally attached to the building, rather than moving with tenants.

Depending on state laws, property owners could act as a utility and sell power to the tenants through a third-party PPA. HUD reimburses affordable housing owners for monthly utility costs, not for long-term solar investments. By using a PPA, the cost of solar becomes a regular utility cost.[173]

Public housing agencies (PHAs) can also use energy service performance contract to get access to solar. In HUD's "Rate Reduction Incentive," a PHA that takes extraordinary steps to save energy can keep some or all savings from the contract, rather than passing the savings on to HUD. In some cases, PHAs can use PACE financing if they meet certain requirements, for example, if their FHA loan is in first position for recovery.

One chronic impediment to such ideas depends on who pays the bills, who benefits from the savings, and who owns the property. If the tenant pays the utility bill, the landlord has no incentive to invest in solar; and the tenants can't invest in solar since they don't own the property.

Another impediment for affordable housing is that rent levels are programmatically set. The rent level for affordable housing varies by program, but in many cases, tenants pay no more than 30 percent of their income for rent and utilities. If a solar improvement triggers a utility allowance adjustment, the tenant's rent may be raised to offset the utility cost savings. As a result, utility savings resulting from a solar improvement in an affordable housing project may not be captured by the tenant at all.[174] One workaround idea is to convert the value of community solar generation into a cash payment, rather than a discount on utility bills, and give the check to eligible tenants. Or HUD could source the power supply for tenant-based vouchers from community solar projects, in states that allow such flexibility.

Under its Renew 300 program, HUD is providing technical assistance to landlords, such as education, identifying sources of capital, and standardized legal forms.[175]

Solar infrastructure In Low-Income Communities

Solar can also provide benefits to the many support organizations that provide services to low-income residents and communities, such as nonprofits and government agencies.

Many of the financing strategies already discussed can be used by nonprofits, including power purchase agreements and crowd-funding. CollectiveSun, mentioned earlier, specializes in crowd-lending for solar projects on nonprofit organizations, including group homes and churches.

Soulardarity is a nonprofit group in Highland Park, Michigan, that is seeking to raise $1.5 million to put solar-powered street lights in a low-income suburb of Detroit. In 2011, DTE Energy repossessed over 1000 streetlights from Highland Park, as part of a debt-forgiveness deal for non-payment of bills.[176] Soulardarity has installed six lights so far, and is raising money through community events, networking and crowd funding efforts. They recently organized a bulk purchase of 50 solar lights for alleys and homes.

The Just Community Solar Coalition in Minneapolis is working with churches and other organizations to help low-income communities benefit from the state Community Solar Garden program. They have recruited Shiloh Temple International Ministries, a Pentecostal church, to host a 200-kilowatt rooftop solar array that will supply community solar to subscribers in the neighborhood.

To reduce the risk of default from low-income customers who may have low credit scores, the Coalition is also recruiting "backup subscribers" who would take over a contract for a short period until a new subscriber is found. For example, a church may buy a 10 percent share of the project, but would agree to buy additional power that would have gone to any customers who default on payment.[177]

SECTION 6

Conclusion

Public policy has long sought to reduce the burden of energy costs for low-income households through financial assistance and energy efficiency measures. The declining cost of solar power offers new opportunities to help the poor, while simultaneously reducing pollution, improving energy security and resiliency, and strengthening the economy.

In many ways, solar power is no different than other energy saving measures that can benefit low-income households. As solar begins to meet the cost effectiveness tests of those policies and programs, it can be a powerful new tool, expanding benefits and injecting a new level of interest and excitement.

Efforts to bring the benefits of solar to low-income consumers can benefit from the experience of utility energy efficiency programs, as well as from decades of experience in government programs to provide housing and alleviate poverty. There are many existing and emerging models that can be applied. What works best will depend on programmatic goals and local factors like utility rates, housing stock, income levels, community support, and the policy milieu of each implementing agency.

In this policy guide, we have sought to build on the work of others, as well as to contribute a few new ideas. As experience in the field increases, more insight will be gained as to what does and doesn't work well. This guide should be considered as just a starting point.

The declining cost of solar power offers new opportunities to help the poor, while simultaneously reducing pollution, improving energy security and resiliency, and strengthening the economy.

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Clean Energy States Alliance (CESA) is a national, nonprofit coalition of public agencies and organizations working together to advance clean energy. CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country.

CESA works with state leaders, federal agencies, industry representatives, and other stakeholders to develop and promote clean energy technologies and markets. It supports effective state and local policies, programs, and innovation in the clean energy sector, with an emphasis on renewable energy, power generation, financing strategies, and economic development. CESA facilitates information sharing, provides technical assistance, coordinates multi-state collaborative projects, and communicates the views and achievements of its members.