Feasibility of Renewable Thermal Technologies in Connecticut

A FIELD STUDY ON BARRIERS AND DRIVERS

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

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Executive Summary 3

Introduction 7

The Literature Framework 10

Methodology 14

Findings and Analysis 16

PROJECT ECONOMICS . . . 16
AWARENESS AND PERCEIVED RISK OF RTTS IN THE MARKETPLACE . . . 18
INSTALLER BUSINESS MODELS AND ACCESS TO EXPERTISE . . . 20
SPLIT INCENTIVES TO OWNERSHIP . . . 23
CLIMATE STRATEGIES AND PLANS . . . 24
RTT'S ADDED INCREMENTAL SERVICE AND VALUE . . . 26
FINANCING . . . 27
FUNCTIONAL LIMITATIONS AND LOCAL OPPORTUNITIES . . . 29

Current Financing Models for RTTs 31

Conclusions and Recommendations 34

SHOW DIRECTION . . . 36
REDUCE UPFRONT COSTS . . . 37
CULTIVATE A COMPETENT AND COMPETITIVE REGIONAL INDUSTRY . . . 40
CREATE VALUE STREAMS . . . 42

References 44

Appendices 47

APPENDIX 1 – CONNECTICUT INCENTIVES . . . 47
APPENDIX 2 – INTERVIEW GUIDES . . . 49
APPENDIX 3 – STAKEHOLDERS PARTICIPATING IN THE STUDY . . . 67
APPENDIX 4 – SUMMARY OF THE WORKSHOP . . . 69

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.

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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.

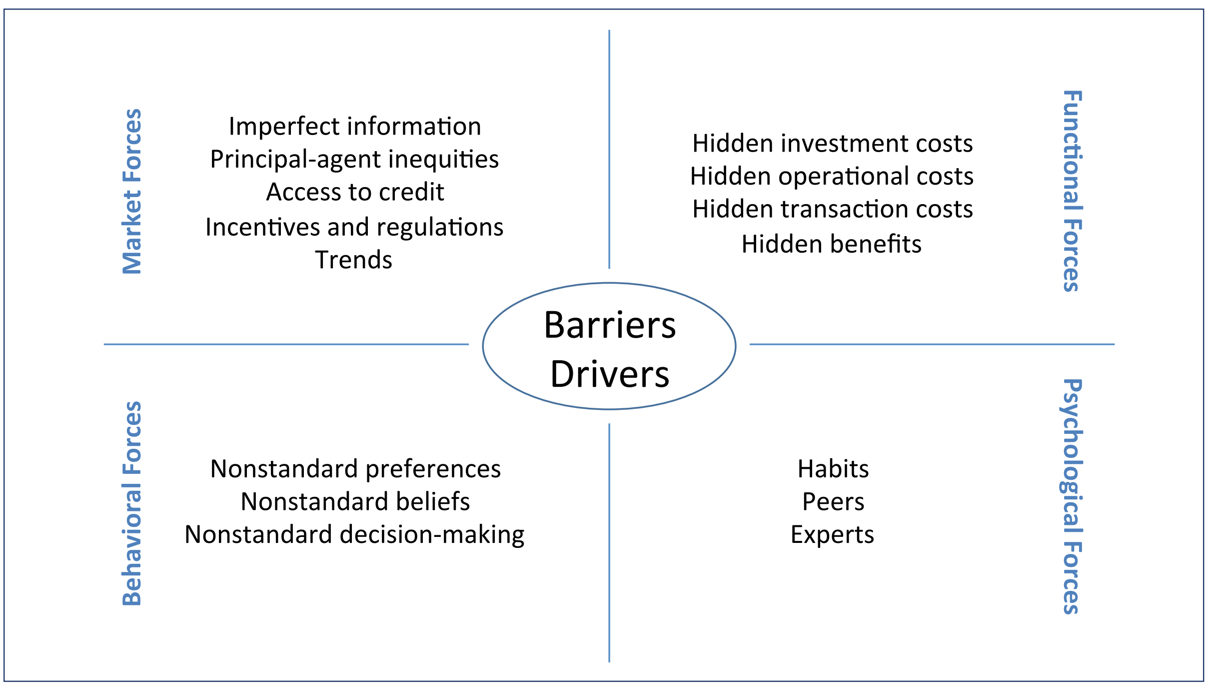

Figure 1 | Explanations for the energy efficiency gap and investments in thermal technologies. Adapted from Gillingham and Palmer (2013) and Michelsen and Madlener (2015).

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.

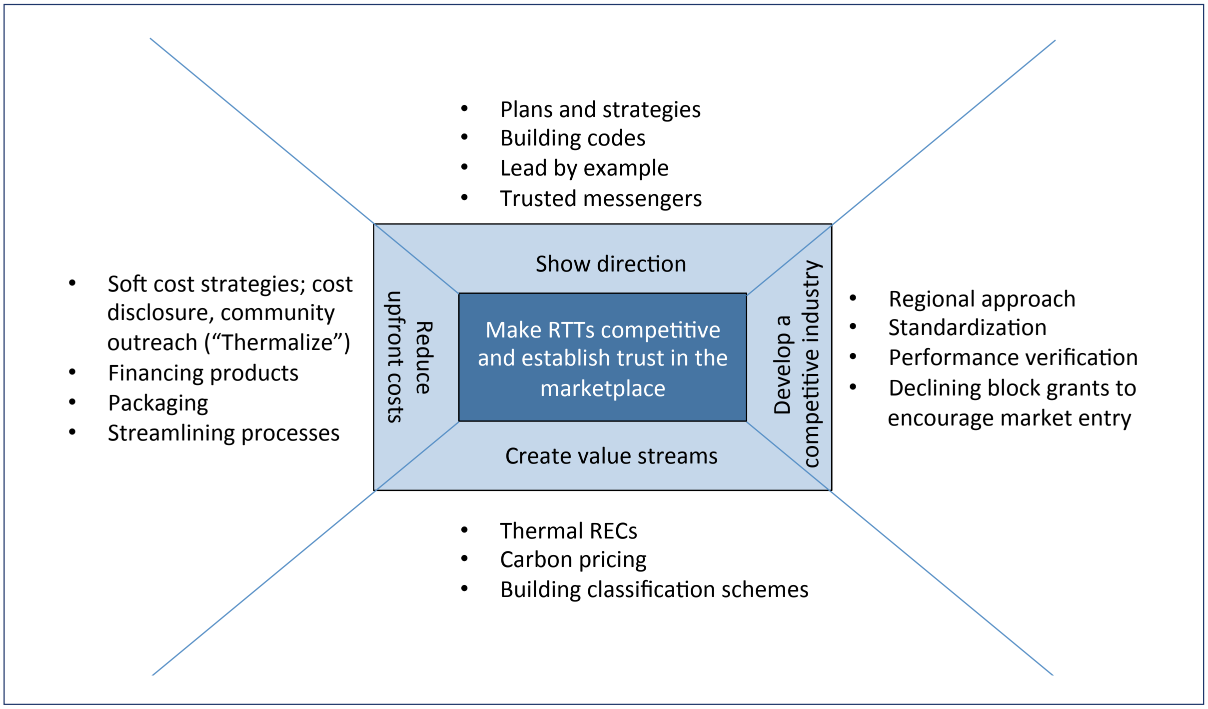

Figure 3 | Recommendations to address barriers and drivers for RTTs.

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.

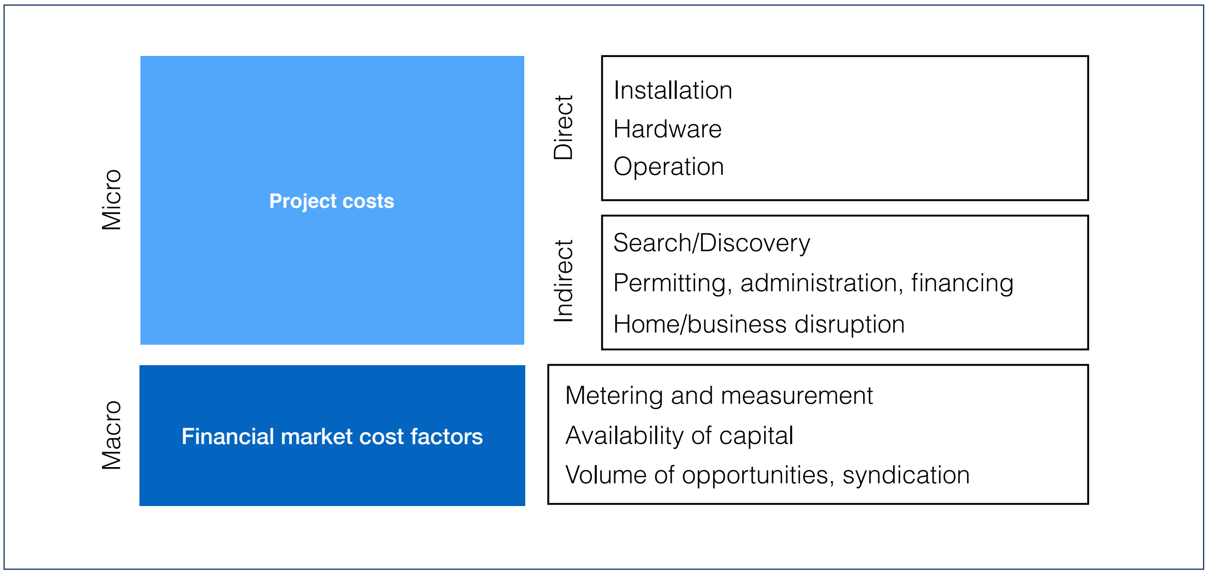

Figure 4 | Investment cost taxonomy

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
		Subsidies		Eversource and UI energy efficiency programs	Eversource and UI energy efficiency programs Home energy solutions rebate program Ground source heat pump subsidy
		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
	Performance based	Tax incentives			Production tax credit for commercial geothermal and closed-loop biomass
		Subsidies			
		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
		Subsidies			USDA - Rural Energy for America Program (REAP) Grants Weatherization Assistance Program (WAP) USDA - High energy cost grant program
		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
	Performance based	Tax incentives			
		Subsidies			
		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

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- 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.

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 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 without 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 geothermal 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 customers 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??