Design Charrette on Advanced Energy Efficiency Opportunities in Cambridge

Final Report

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I. Executive Summary

The Cambridge Energy Innovation Charrette was held in Cambridge, Massachusetts, on November 5-7, 2007. Participants from the Cambridge Energy Alliance, the Kendall Foundation, the Barr Foundation, Rocky Mountain Institute, and various experts from local institutions met to develop strategies to achieve energy reduction goals proposed by the Cambridge Energy Alliance. These goals were to:

- Reduce peak electric demand in the City of Cambridge by 50 MW;
- Reduce fossil fuel consumption in the City of Cambridge by 5 percent; and
- Identify targets for the Boston Innovation Challenge.

In order for the City of Cambridge to meet these ambitious goals, it will be necessary to pursue a portfolio of solutions. An idea that has been embedded in the plan to achieve the 50 MW peak energy reductions was to use Energy Service Companies (ESCOs). However, RMI's analysis has indicated that the use of ESCOs alone may not allow the City of Cambridge to meet its goals in the five-year time frame it has established. Therefore, additional solutions will need to be explored.

The report then focuses on what portfolios of energy reduction solutions have the potential to achieve the City's goals. As shown in RMI analysis, the 50 MW goal cannot be met by using common ESCO efficiency measures. Therefore, RMI recommends that the City aggressively pursue additional efficiency measures in the existing residential and commercial sector and new residential construction sectors.

It should be noted that while fuel reduction strategies are not explicitly analyzed in this report, a qualitative discussion of the charrette outcomes is reiterated here for the transportation sector. Also, it is assumed that with the energy reductions in the built environment, fuel consumption from heating and hot water will decrease.

Next steps are given for the Cambridge Energy Alliance and the city to pursue in order to achieve the stated goals. These steps include immediate implementation, seeking out additional funding options, establishing a baseline for the city of Cambridge's energy and fuel uses, and begin to develop new goals for after the initial five-year period.

Options to achieve 50 MW reduction goal

1) ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at very high penetration rates.

2) Aggressive new residential construction efficiency requirements approaching 100% participation + a mix of regular ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at higher participation rates.

3) Institutional efficiencies + aggressive new residential construction efficiency requirements approaching 100% participation + regular ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at lower participation rates.

II. Overview and Objectives

Charrette

On November 5 - 7, the City of Cambridge, in collaboration with Rocky Mountain Institute (RMI), Kendall Foundation, Barr Foundation, Harvard University, and Massachusetts Institute of Technology (MIT), conducted an innovation charrette aimed at identifying opportunities and strategies to reduce Cambridge's energy demand by 50 megawatts (MW) and fossil fuel use by 5 percent.

The charrette identified improvements in technology, system design and operations to reduce energy usage, peak demands and emissions, while saving money and enhancing facility performance (occupant comfort, worker productivity, system reliability, etc).

Goals

There were two specific goals for the charrette. The first goal is to aid Cambridge in identifying, exploring and prioritizing advanced energy efficiency technologies and implementation strategies that will ultimately **reduce the City of Cambridge's peak demand by 50 MW and fossil fuel consumption by 5 percent over 5 years.** Some details about the goals include:

- The 50 MW peak reduction target includes efficiency reductions, demand response, clean distributed generation resources such as combined heat and power, and photovolatics.
- The fossil fuel reduction goal applies to fossil fuels used for transportation and heating oils, but not for fuel used to produce power.
- New construction does not factor into the goal to reduce peak demand 50 MW. As long as there is a reasonable baseline, any reduction can be verified.

The second goal is to **identify an opportunity or challenge in energy efficiency** for the Boston Innovation Challenge. The Challenge will be to solve the identified opportunity or challenge for prize money.

Charrette Participants

RMI, Harvard and MIT invited experts in a wide range of areas relevant to energy and water efficiency, including green architecture, mechanical systems, land and water, corporate finance, facility management, and others to the charrette. The complete list of participants can be found in Appendix A.

RMI would like to thank all of the charrette participants for attending and actively working towards achieving the targeted energy reduction goals. RMI would especially like to thank the Kendall and Barr Foundations and Harvard and MIT for both funding and hosting the charrette.

Report

This report focuses on solutions to reduce peak power consumption for the city of Cambridge and ways to concurrently decrease fuel use. Innovation Prize ideas are also given that will assist in achieving the goals. Finally, next steps are outlined for the Cambridge Energy Alliance and the City to being pursuing.

III. Innovation Challenge Goals

One of the goals of the charrette was to identify an opportunity or challenge in energy efficiency that could become the subject of the Boston Innovation Challenge (BIC). The Challenge is a new initiative designed by the Barr Foundation as an inducement prize to stimulate new ideas and initiatives (rather than rewarding existing efforts). Energy efficiency was chosen as the first topic for the Innovation Challenge because of the synergy with the interests of Barr Foundation and the Kendall Foundation to dramatically reduce energy use in Cambridge. The Boston Innovation Challenge will seek ideas in the early stages of the innovation process, and as we expected, several ideas emerged from the charrette.

The Innovation Challenge was the topic of a breakout group during the third day of the charrette, but there were other ideas for the Innovation Challenge that emerged during other breakout groups throughout the entire charrette. Following is a list of prioritized Innovation Challenge ideas. Priority was given first to ideas having early and significant potential energy-reduction impact followed by ideas that might have the largest energy-reduction impact. While there were many technological or product ideas generated during the workshops, it has been noted that social or behavioral goals have the best energy-impact potential within a one or two-year timeframe and may best be able to help Cambridge Energy Alliance (CEA) meet the 50 MW/5 year goal.

The real key to the success of the energy-focused innovation challenge is the 'design' of the challenge--the framing, scope, marketing and selection process. While broad community energy goals have been loosely defined, specific goals for each innovation idea were not created, but should be developed for each of the following ideas to test the respective effect each idea has toward achieving the overall goals.

The number noted in parenthesis after the prize idea refers to the item number in the Appendix D list of innovation ideas.

Table 1. Innovation Prize Ideas

#	Innovation Prize Idea	Category	Potential Impact / Comments
1.	Implementation prize (14)	Behavior	Because many of the BIC ideas will require time to develop, social or behavioral ideas have the best potential to impact the energy innovation goals sooner. This idea could be combined with the best messaging idea (15).
2.	New financial model (2)	Finance / Barrier	A new financial model has the potential to breakthrough many of the barriers to deeper energy savings. This might be accomplished by using a longer payback period, carbon cost accounting, on-bill financing or other ideas.
3.	"Prius" meter for real-time customer energy consumption information (1)	Product / Behavior	The success of this product will depend on its design and cost. If it is easy to retrofit into existing buildings/homes, and provides useful information looking forward, it will potentially have an impact on energy use behaviors.
4.	Super-efficient rooftop AC system for small commercial applications in humid climates (7)	Product	This idea has excellent potential to contribute toward peak demand reduction, could readily be retrofitted, and would be applicable throughout the eastern and central U.S.
5.	Residential scale desiccant cooling technology (plenary session)	Product	Adoption of this idea could dramatically slow growth of peak electric demand throughout the eastern and central U.S.
6.	Advanced residential solid-state lighting (SSL) (10).	Product	With either a price or technology breakthrough, SSL could provide substantial energy savings in general lighting.
7.	Wireless Demand Response Device (11)	Product	Could control any number of appliances or devices for load shedding and might even be combined with "Prius" meter (#3) for maximum impact.
8.	CO2 sequestration device or system at the local level (residential or building-based) (21)	Strategy / Technology	This kind of idea has the potential to contribute toward the 5% fossil fuel reduction goal while helping to reduce greenhouse gas impacts.

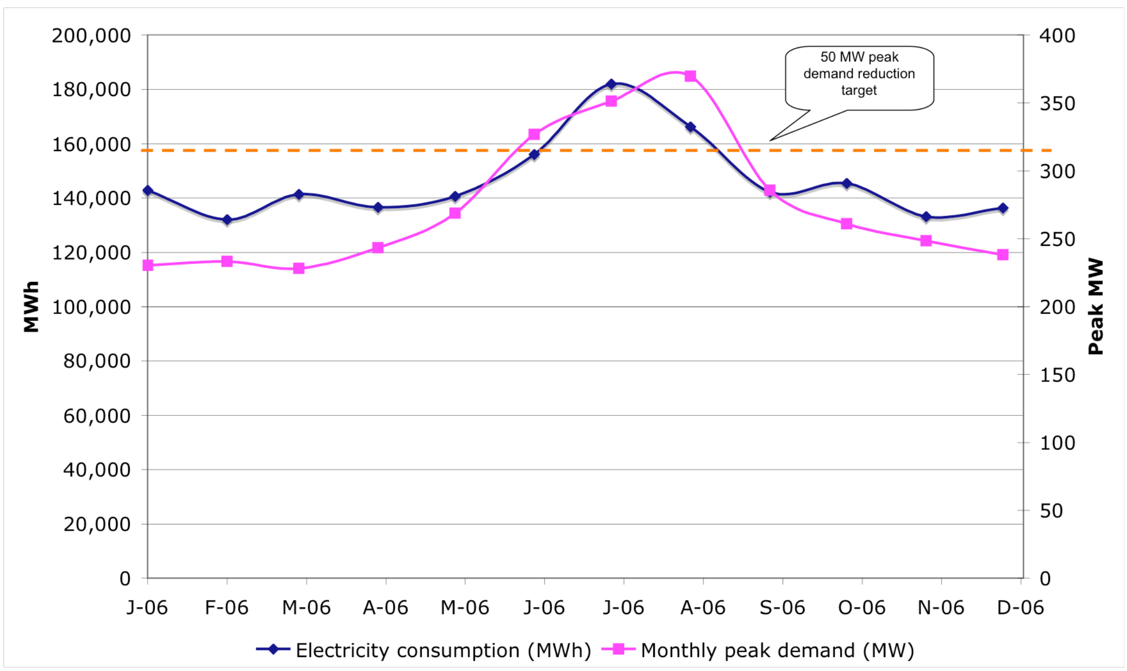
In conclusion, technology breakthroughs and products would likely bring the largest peak energy savings, but these would come at the cost of time. This doesn't mean that products or product barriers should be passed over as an innovation prize opportunities, but rather that they should be selected with the understanding that it will take time to get to market with these ideas. Behavior, social and financial model innovations tend to offer the most opportunity for immediate impact. For example, the Hood River Conservation Project achieved an 85 percent participation rate (by retrofit measures) and therefore it can be interpreted that by increasing the realized market penetration from 10 to 50 percent, through the use of behavior, financial or other social innovations, CEA will greatly improve its chances of achieving and sustaining the energy goals of this project.

IV. How to Achieve Cambridge's Energy Reduction Goals

In order to achieve the goal of a 50 MW peak energy reduction and the five percent reduction in fossil fuels, the Cambridge Energy Alliance needs to simultaneously pursue all available "low hanging fruit" while also working with energy services companies (ESCOs) to implement as many advanced strategies as possible. It is essential that the CEA and the City of Cambridge use the results of the workshop to reduce the current demand to meet goals, and simultaneously work on developing a more comprehensive and accurate baseline to facilitate more demand reductions later.

Below, Figure 1 displays the electricity consumption in Cambridge by month, and the monthly peak demand. In order for Cambridge to meet its goal of reducing electricity peak electricity demand, it is imperative for the City to reduce energy consumption during the summertime months. However, many energy efficiency measures have the potential to reduce the peak demand. For more information on Cambridge's energy supply and demand, see Appendix B.

Figure 1. Cambridge Electricity and Demand, 2006



Cambridge Load Growth

Electricity use in the Boston system sub-area is projected to grow by an average of 1.17% through 2014 (for comparison, the expected growth rate for the full New England region is 1.44%), representing a relatively low level of new development. It is likely that much of the growth projected over the next several years in the Cambridge area will be due to the Northpoint development, which is primarily planned as residential and commercial development. One type of load that may not be included in the baseline forecast for the Boston area is potential development in new high-technology load such as data centers.

Using Energy Service Companies to Meet Reduction Goals

Energy service companies (ESCOs) develop, install and arrange financing for projects designed to improve energy efficiency and maintenance costs for facilities over a seven to twenty year time period.[1] Using ESCOs is a core part of the solution to meeting the City of Cambridge's energy reduction goals, and has been included in the Cambridge Energy Alliance (CEA) plans to meet the City goals. RMI conducted analysis on the potential impact of efficiency measures in the existing residential and commercial sectors. The other sectors (new construction and institutions) could also be implemented by ESCOs, however, RMI has chosen to look at those sectors as separate opportunities that are discussed later in the report.

The energy reduction measures and corresponding potential energy savings that RMI thought ESCOs would implement are shown in Table 2 and
Table 3. The measures that are included only impact peak demand; thus working towards the 50 MW reduction goal. These estimated savings are based on the following assumptions:

- In the residential sector, a seven percent annual penetration rate is assumed,[2]
- In the residential sector, seven percent of the housing stock equates to approximately 3,100 units,
- In the commercial sector, a seven percent annual penetration rate is assumed,[3] and
- In the commercial sector, seven percent of the commercial stock equates to approximately 2,730,000 square feet.

In addition to the energy reduction measures quantified below, additional measures that we have an energy reduction potential are listed below. The City of Cambridge and the CEA should consider the use of these energy reduction measures as well. These measures are:

- Low-flow fixture swap outs
- Storm windows/sealants
- Rigid insulation/exterior siding retrofits
- Electric/tankless water heater
- Water heater blankets
- Spray foam insulation
- Variable speed drives

[1] National Service of Energy Service Companies, available at www.naesco.org/about/esco.htmb
[2] A seven percent annual penetration rate is assumed based on Cambridge Energy Alliance's goal of achieving between one and ten percent annual penetration rate.
[3] A seven percent annual penetration rate is assumed based on Cambridge Energy Alliance's goal of achieving between one and ten percent annual penetration rate

Table 2. Annual Potential Savings from Existing Residential Sector Retrofits

Energy Reduction Measure	Megawatt peak reduction (MW)[4]
Metering/education	0.35
Energy Star appliance replacement	0.17
Incandescent to CFL switch out	0.13
Envelope upgrades	0.10
High efficiency central AC units	0.12
High efficiency window AC units	0.22
Total annual reduction	**1.1**

Table 3. Annual Potential Savings from Existing Commercial Sector Retrofits

Energy Reduction Measure	Megawatt peak reduction (MW)[5]
Dimmable switch/occupancy sensors	0.27
T5 / CFL switch out	1.1
High efficiency central AC units	1.0
Total annual reduction	**2.4**

Using these assumptions, RMI analysis indicates that if the City of Cambridge uses a traditional ESCO model in the existing residential and commercial buildings, there is the potential for approximately 3.44 MW peak load reduction, as shown in Table 4. Over five years, a seven percent annual penetration rate would result in 17.2 MW reduction, which is 34 percent of the 50 MW goal. For illustrative purposes, if a one hundred percent annual penetration rate were used in both existing and commercial buildings, the peak energy reduction could almost be met in just one year just using ESCO implemented measures.

Table 4. Annual ESCO Peak MW reduction

ESCO- only			
Existing residential and commercial sector	Annual penetration rate	Annual peak MW reduction potential	Five-year peak MW reduction potential
	7%	3.4	17
	20%	9.8	49
	100%[6]	49	49

[4] The formula for determining what the megawatt peak reduction for the existing residential sector is: (residential megawatt hours/ 8760)*0.60

[5] The formula for determining what the megawatt peak reduction for the existing commercial sector is: (commercial megawatt hours/ 3000) *0.50

[6] Assuming a linear relationship (0.49 MW peak load reduction per 1% penetration) a 100 percent penetration rate would result in 49 MW of peak reduction.

Additional Measures to Reduce Peak Energy and Fossil Fuel Consumption

As shown in Table 4, the City will have to implement other energy reduction measures besides using an ESCO if it does not achieve more than a twenty percent annual penetration rate. RMI analyzed other energy reduction potential opportunities in the City of Cambridge to offer a variety of options as to how to meet the energy reduction goals:

- **Enhanced ESCO**: This portfolio adds another layer to the traditional ESCO model by including energy reduction measures that a traditional ESCO may not normally use, such as radiant barriers and high performance glazing.
- **New construction**: This portfolio includes energy reduction measures that have the potential make new residential and commercial construction 20-40 percent more efficient than existing code.
- **Institutional**: This portfolio includes energy reduction measures for campuses, data centers and labs.

The options reach across three primary building types: residential,[7] commercial[8] and institutional.[9] Below, Table 5 shows the potential peak megawatt reduction associated with the enhanced ESCO and new construction options, at differing penetration rates. RMI was not able to determine the peak energy reduction from the institutional sector, so it is not included here. The peak megawatt reduction potential listed is additional, meaning that the enhanced ESCO reductions do not include the ESCO-only peak megawatt reductions. Similarly, the ESCO-only portfolio does not include new construction.

If the ESCO-only model can only achieve a seven percent annual penetration rate, it can be combined with the enhanced ESCO model for a variety of measures that can be combined at different penetration rates to meet the 50 MW goal. Each of these options, and the energy reduction measures included in it, are discussed in more detail below.

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[7] For the purposes of this report, a residential building is a single family, attached or multi-family dwelling.
[8] For the purposes of this report, a commercial building is defined as a grocery, office, restaurant, data center, or other place of business.
[9] For the purposes of this report, an institutional building is defined as a university, civic, hospital, laboratory, data center or government owned structure.

Table 5. Annual Potential Energy Savings from Options

Enhanced ESCO			
Existing residential and commercial sector	Penetration rate	Annual peak MW reduction potential	Five-year peak MW reduction potential
	7%	8.4	42
	20%	24	120
	100%[10]	120	120
New construction			
New construction (residential and commercial)	Penetration rate	Annual peak MW reduction potential	Five-year peak MW reduction potential
	100%	5.1	5.1

Enhanced ESCO

As shown in Table 4, even if the ESCOs-only model achieved a one hundred percent penetration rate in the existing residential and commercial sector the City's energy reduction goal would not be met. Thus, additional measures need to be taken by the City and the Cambridge Energy Alliance. Below, Table 6 and Table 7 display the measures and the corresponding assumed energy savings for enhanced existing residential and commercial sector retrofits. The measures that are included either impact peak or thermal demands; thus working towards either of the reduction goals. These estimated savings are based on the following assumptions:

- In the residential sector, a seven percent annual penetration rate is assumed,[11]
- In the residential sector, seven percent of the housing stock equates to approximately 3,100 units,
- In the commercial sector, a seven percent annual penetration rate is assumed,[12] and
- In the commercial sector, seven percent of the commercial stock equates to approximately 2,730,000 square feet.

Using these assumptions, RMI analysis indicates that if the City of Cambridge uses an enhanced ESCO model in the existing residential and commercial buildings, there is the potential for approximately 8.2 MW peak load reduction annually. Over five years, this would achieve 42 MW, or 84 percent of the 50 MW goal.

[10] Assuming a linear relationship (1.2 MW peak load reduction per 1% penetration).
[11] A seven percent annual penetration rate is assumed based on Cambridge Energy Alliance's goal of achieving between one and ten percent annual penetration rate.
[12] A seven percent annual penetration rate is assumed based on Cambridge Energy Alliance's goal of achieving between one and ten percent annual penetration rate

Table 6. Annual Potential Savings from Enhanced Existing Residential Sector Retrofits

Energy Reduction Measure	Megawatt peak reduction (MW)[13]	1000 therms/year reduction
Dispatched Load Shedding	0.18	-
Radiant barrier paint, blower door testing, attic door sealant	0.04	-
High performance glazing	0.43	-
Daylight response dimming sensors	0.11	-
Comprehensive lighting upgrades	0.09	-
Simple Daylighting strategies	0.06	-
Advanced controls	0.15	-
Replacement program for circulating pumps/thermostatic valves	0.03	-
Solar Hot Water	-	43
Boiler/Furnace Replacement (High SEER Rating[14])	-	11
Heat Recovery	-	0.38
Total Annual Reduction	**1.1**	**54**

[13] The formula for determining what the megawatt peak reduction for the existing residential sector is: (residential megawatt hours/8760) *0.50

[14] SEER stands for Seasonal Energy Efficiency Ratio

Table 7. Potential Savings from Enhanced Existing Commercial Sector Retrofits

Energy Reduction Measure	Megawatt peak reduction (MW)[15]	1000 therms/year reduction
Advanced controls/Demand Control Ventilation	1.6	-
High-performance glazing	1.2	0.44
Building Management System	0.49	-
Energy modeling	0.48	
Submetering	0.43	
Continuous Commissioning	-	0.40
Daylighting	0.31	-
Comprehensive lighting strategies	0.37	-
Advanced lighting controls	0.31	-
Measurement and verification	0.29	-
Automated time of day scheduling	0.23	-
Replacement program for circulating pumps/thermostatic valves	0.47	-
Daylight response dimming/photosensors	0.21	-
Simple daylighting strategies	0.15	-
Heat recovery	0.12	0.53
Right size cooling	0.04	-
Marketing and information program for participants	0.05	-
Window retrofits	0.05	-
Dispatched load shedding	0.51	-
Total annual reduction	**7.3**	**1.4**

New Construction

In addition to pursing enhanced energy efficiency measures, the City will also need to aggressively pursue efficiency within the new construction sector. Significant gains can be made in new construction due the incredible potential to maximize efficiency at the initial design or construction phase. RMI conducted analysis on the potential impact of efficiency measures within the new construction sector. Given the size and scale of the newly approved NorthPoint development, (2,700 new residential units and over 2.2 million square feet of commercial space) NorthPoint provides an opportunity for the CEA and the City to work with the development team to implement numerous load reduction strategies. By increasing the efficiency of NorthPoint, and other new developments in Cambridge, the measures implemented by the CEA and the ESCO in the existing building sector will have a greater impact.

[15] The formula for determining what the megawatt peak reduction for the existing commercial sector is: (commercial megawatt hours/ 3000) *0.50

Below, Table 8 and Table 9 display the measures and the corresponding assumed energy savings for new construction in the residential and commercial sector. These estimated savings are based on the following assumptions:

- In the new construction sector, a 100 percent penetration rate is assumed.[16]
- NorthPoint has reported a build-out of 2,700 residential units and 2.2 million square feet of commercial space.

Using these assumptions, RMI analysis indicates that if the City of Cambridge requires stringent new construction standards for residential and commercial buildings, approximately 5.1 MW of peak load reduction is achievable on an annual basis. However, it is important to note that as mentioned in the "Load Growth" section, the NorthPoint development is likely going to be the majority of the new construction in the Cambridge area for several years. Thus, it may be overly optimistic to project that the City will be able to achieve 5.1 MW of peak load reduction on an annual basis. However, if the City did, new construction could meet 10 percent of the 50 MW goal annually.

Table 8. Potential Savings from New Residential Construction Efficiency

Energy Reduction Measure	Megawatt peak reduction (MW)
Ultra Efficient House: measures include eliminate heating systems, passive cooling, advanced daylighting controls, Energy Star appliances, variable speed ECM, solar water heating	1.71
High Efficient House: measures include variable speed fan furnace, passive cooling, advanced daylighting controls, Energy Star appliances, variable speed ECM, solar water heating	0.97
Occupant training	0.40
Total annual reduction	**3.1**

Table 9. Potential Savings from New Commercial Construction Efficiency

Energy Reduction Measure	Megawatt peak reduction (MW)	1000 therms/year reduction
Higher EER-rating equipment	0.85	-
Improved envelope	0.38	0.86
Advanced daylighting controls	0.31	
District heating and cooling (CHP)	0.24	1.1
Building Automation system	0.18	-
Total annual reduction	**1.2**	**2.0**

There are additional measures that do not contribute to peak load reduction, but do increase the over all efficiency of new residential and commercial buildings, and thus reduce demand that the

[16] A 100 percent penetration rate is assumed because in order to implement the New Construction portfolio, citywide code changes/standards will need to be implemented..

City should consider when crafting energy codes. Examples include variable speed fans and pumps and passive measures (daylighting, natural ventilation).

Institutional Efficiency and Programs

Pursuing institutional efficiency can offer further reductions in peak load energy use. Strategies discussed in this section would contribute to reduce load growth in the future, as well as reducing the current peak load. Many of the institutional measures discussed here are energy efficiency measures. However, these measures do offer the opportunity to reduce peak load because so many of the institutional energy reduction measures are geared at energy efficiency.

The measures discussed are:

- Co-generation and tri-generation
- HVAC improvements
- Data centers
- Lab buildings
- Behavioral changes
- Water conservation
- Distributed/renewable power generation

In addition to discussing energy reduction measures that will help the City meet it's energy reduction goals, this section also discusses institutional programs that will also facilitate energy reduction. The institutional programs discussed are:

- Cross pollination
- Carbon offsets program
- Peer-to-peer training program
- Design team incentives
- Building potential rating systems
- Owner services program

Institutional Efficiency Measures

Co-generation and Tri-generation: Energy reduction opportunities through co-generation and tri-generation exist for many types of institutions found in Cambridge, including: universities, hospitals, large apartment buildings, and hotels. Co-and tri-generation have the potential to double the efficiency of the existing prime movers in Cambridge from thirty-five percent efficiency to approximately seventy percent efficiency. The Cambridge Energy Alliance and their ESCO partners could help identify institutions that could take advantage of this opportunity, and address the regulatory challenges that could arise with this technology. Small and large-scale systems in various types of institutions could be sized from 60 kW – 50 MW, and cost roughly $250,000 to $10 million.

HVAC Improvements: Heating, ventilation and air conditioning (HVAC) offers significant energy savings on an institutional level and for the City of Cambridge as a whole. Increasing the efficiency of several components of the HVAC system can result in energy savings of 30-50 percent:

- 15 percent saving from commissioning/retro-commissioning with Demand Control Ventilation,
- Two percent savings from free cooling,
- Three percent savings from efficient light fixtures, and
- Reductions in water use

While a 30-50 percent reduction in building energy consumption is a large saving, if these measures are applied in thousands of buildings in the City, the energy savings could begin to approach twenty-five percent of Cambridge's total energy use.

Commissioning: In terms of commissioning at a campus level, a range of four steps to present more options for institutions is given. They recognize the different entry levels that each may have.

- Controls: The implementation and correct calibration of controls can make existing building systems perform to their fullest potential.
- Retro - Commissioning: Retro or re-commissioning would identify opportunities for improvement, above and beyond just controls adjustments.
- Continuous Commissioning: Constant monitoring of buildings and their systems would ensure the most efficient operation over the life of the building.
- LEED for Existing Buildings: An institution could require every existing building to go through the LEED for Existing Buildings Certification process. A minimum level of achievement could be mandated, as well as requiring the completion of optional LEED-EB credits, thus making certain steps mandatory.

Data Centers: In the next ten years, Cambridge could easily expect to see a 10 – 50 MW of peak power demand increase caused by data centers. With proper design and smart choices in computing equipment, 50 percent of that energy could be saved (in cooling and computing energy). This could result in a peak demand reduction upwards of 12 MW after a growth of 24 MW of peak power demand.

Lab Buildings: Harvard cited that out of a stock of 600 buildings, 30 large lab buildings account for 40 percent of Harvard's greenhouse gas emissions, which has a direct correlation with energy use. Improvements and renovations to lab buildings and their operations could save significant amount of energy. This could be accomplished by installing low flow hoods, initializing night time setbacks, demand controlled ventilation/reductions in air changes per hour, and by changing behavior to reduce the increased airflows designed in for unnecessary safety measures. This strategy may also require a change in lab design airflow standards.

Behavioral Changes: If universities or other institutions are able to encourage the identification of "phantom loads" in campus buildings and residences, they may use the findings to encourage behavioral change (i.e. using power strips and turning the entire power strip off). Also, other institutions and the City of Cambridge could build off of the recent Harvard success of realizing a 10 – 15 percent reduction in electricity use can be achieved in dorms through a social marketing campaign.

Water Conservation: Reducing water use also presents an opportunity for energy reductions because of the embodied energy in every drop of water used in the City, particularly because the

Walter J. Sullivan Water Treatment Facility for the City is the single largest energy user.[17] For example, a 30 percent energy reduction can be achieved by replacing all water fixtures with low flow equipment. Institutions in Cambridge currently use 19 percent of the City's water, thus, efficiency from this sector along could result in a six percent reduction in total water use. The energy savings associated with this volume of water efficiency is approximately 600 MWh.[18]

Distributed Generation and Renewable Power Generation: Distributed generation and renewable power generation offer the universities in Cambridge the ability to avoid building a new campus central plant, which would ultimately lead to peak reductions, as well as considerable energy savings at all times.

Institutional Programs

Though the following programs can less be analyzed for impact at this time, their effect on the reduction of energy use for institutions should not be ignored. These ideas represent more ways for institutions to operate more efficiently and improve their sustainability efforts.

Cross Pollination: The Cambridge Energy Alliance could identify opportunities in institutions with a more developed energy reduction plan, and create a "cross pollinator" position to help other institutions benefit from the knowledge gained at institutions further along in the process.

Carbon Offsets Program: The more developed institution could fund another institution's energy savings measures through interest free financing, which would reduce emissions for the institution granted the funding, and allow the giving institution to claim the CO_2 assets.

Peer-to-peer Training Model: Similar professionals within institutions can hold workshops that allow attendees to share knowledge of a certain profession as it pertains to the institution. This creates content experts out of all attendees. Though this model requires a sizeable investment, the returns are also significant. This model can also be extrapolated to the Cambridge community at large.

Design Team Incentives: Performance and integration based incentives could ensure that the project design teams develop the most efficient design and that actual building resource use is measured after occupation. The incentive would be in the form of fees paid out depending on how well the building performs.

Building Potential Rating System: Valuing the existing building stock potential to save energy may help campuses capitalize on energy savings to be had. A rating system could be created, which values the potential savings, so that the least efficient building would be rated the highest. Identifying "resource mines" in this way can have a variety of benefits, such as inciting student competition, creating a marketing opportunity, and helping ESCOs in choosing potential projects.

Owner Services Program: To ensure a smooth transition between construction, commissioning and owner occupation, a process could be implemented to assist in handing off the building to its

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[17] From pre-read
[18] If 9.25 GWh of energy is used to pump and purify Cambridge's water, a 6% reduction would yield 600 MWh of energy savings

end users. This way the operations managers can be fully educated on how the building is intended to operate.

With improved operations and the implementation of programs that support efficiency at various institutions and institutional levels, resource savings can happen dramatically, quickly, and be of a great magnitude.

Combined Solutions Total Potential

A portfolio of scenarios are presented that combine the solutions presented above. They are intended to serve as examples of potential ways to achieve the stated peak demand reduction goal. Also shown is a baseline strategy that gives the total reductions possible with a pure ESCO strategy at a penetration rate of 7%. This rate was chosen in order to illustrate that without higher participation goals, the outcomes fall short of the goal.

Table 10: Annual Peak Load Reduction Scenarios

Combined Solutions Potential	Baseline	Scenario 1	Scenario 2	Scenario 3
	Penetration Rate (%)			
ESCO model 0.49 MW reduction per 1% penetration	7	50	27	20
Enhanced ESCO model 1.2 MW reduction per 1% penetration	-	33	27	25
New Construction 5.1 MW reduction for 100% penetration	-	-	100	100
Institutions Unknown	-	-	-	20
Total peak load reductions	**3.4 MW**	**50 MW**	**50 MW**	**50 + MW**

The ESCO- only model will achieve a 49 MW reduction in peak load at a 100% penetration rate. A mix of ESCO and enhanced ESCO models will achieve the 50 MW peak reduction load. However, these penetration rates are quite high, thus RMI has compiled other strategies that will allow the City of Cambridge to meet their reduction goals. All scenarios are summarized below.

1) ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at very high penetration rates.

2) Aggressive new residential construction efficiency requirements approaching 100% participation + a mix of regular ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at higher participation rates.

3) Institutional efficiencies + aggressive new residential construction efficiency requirements approaching 100% participation + regular ESCO in existing residential and commercial sectors + enhanced ESCO in existing residential and commercial sectors at lower participation rates.

Table 10 represents examples of penetration rates coupled with strategies that will achieve a 50 MW reduction in peak energy use. Depending on which strategies are pursued and the amount of aggression in which they are pursued, the penetration rates can be adjusted for each strategy and the total peak load reduction can change.

The peak load reductions possible in the institutional level are large though unknown at this time. It is recommended that more analysis be completed and discussion undertaken with Harvard, MIT, and others to determine their roles in the resulting strategy.

Ultimately, a combination of strategies will provide the most robust strategy for achieving a peak load reduction of 50 MW and beyond. By diversifying the ways in which efficiency is achieved, lower penetration rates for each sector are permissible, and more opportunities for energy savings can be pursued.

Increasing Efficiency Potential through Utility Programs and Policy

In addition to using ESCOs and other energy reduction strategies, there are two enabling options that have significant potential to reduce peak energy consumption and reduce fossil fuel use across all sectors: working with the utility to establish more energy efficiency programs and incentives, and working with the City to change policies that will mandate more efficiency. These additional options are not grouped in with the enhanced ESCO, new construction or institutional options because of the cross-sectoral nature of the options.

Utility Programs

NSTAR, as the utility serving Cambridge, could increase the amount of efficiency incentives available to its customers through a number of initiatives and programs identified at the charrette. A complete list of the utility initiatives and programs identified at the charrette is available in Appendix C, and RMI has prioritized these initiatives and programs in Table 11 below.

RMI prioritized the utility initiatives and programs identified at the workshop based on the:

- Likely impact of program or initiative to meet City of Cambridge goals,
- Ease of implementation of program or initiative, and
- How innovative the policy is.

Table 11. Top Ten Utility Programs/Initiatives from Charrette

Sector	Initiative or Program	Description
Community	On-bill financing	The water bill for the City of Cambridge is being re-done, and this provides an opportunity for the water utility to add an on-bill financing mechanism. This mechanism would allow the City to pursue a Pay-As-You-Save type program.
Existing residential and new commercial	Programmable, communicating thermostat	Retrofit existing residential and commercial buildings with programmable, communicating thermostats so the consumer and the utility can see energy use and plan to reduce energy when the consumer is not home.
Existing and new commercial	Real-time two-way monitoring and display	New buildings would all have real-time two way monitoring to allow the utility and the consumer to see energy use or reduction in real-time. This allows the utility to verify that peak reductions have been made.
New commercial	District heating and cooling	District heating and cooling would significantly reduce electric demand for air-conditioning, subsequently reducing the peak demand. Due to high capital costs, it is most cost-effective to plan for a district system during the planning stage of new construction.
Community	Off-peak water pumping	Water pumping represents a significant portion of energy use in the City of Cambridge and shifting water pumping to off-peak presents a valuable opportunity to reduce peak demand.
Institutional and Community	Co-generation and tri-generation	Implementing existing prime movers to increase the efficiency of current use
Institution	Retrofit campus buildings as model	Use a high energy consuming building for a retrofit opportunity that would raise awareness of energy efficiency potential and encourage additional building retrofits
Existing residential	Demonstration retrofit to serve as model	Use a high energy consuming house for a retrofit opportunity that would raise awareness of energy efficiency potential and encourage additional building retrofits
All	Renewables	Distributed renewable energy generation

Policy

The City of Cambridge could enact many policies that would mandate greater savings within each sector. There were a variety of ideas that were introduced at the charrette, many of which have significant energy reduction potential. The top ten policies are listed in Table 12 below, and all of the policy suggestions are listed in a table in Appendix C.

RMI prioritized the policy ideas identified at the workshop based on the:

- Impact of program or initiative to meet City of Cambridge goals,
- Ease of implementation of program or initiative, and
- Innovative aspects of the policy itself.

Table 12. Top Ten Policy Ideas from Charrette

Sector	Initiative or Program	Description
All	New building codes, including lighting codes	Create stricter building code standards, including lab and data center standards, to increase efficiency
All	Coordinate fire code with EE strategies	When the fire code is updated, ensure that there are energy efficiency measures coupled with the update
All	Permit expedition	Expedite building or renovation permits for buildings that are "green"
All	Operations and Maintenance training	Provide classes and information on the energy value of keep equipment maintained, and how to maintain equipment
Existing residential and commercial	Green design assistance	Provide assistance to interested parties on how to do "green" design, common errors and ways to tunnel through the cost barrier for maximum efficiency potential
Institutional	Comprehensive city audit	A comprehensive city audit will provide the City with accurate baseline numbers from which it can subtract its energy reductions
Institutional	LEED for new construction	Require LEED for new construction
Community	Water utility revenue decoupling	Decouple water utility profits from water sales
Institutional	CEA identify co-generation and tri-generation	Task the Cambridge Energy Alliance with identifying strong co-generation and tri-generation opportunities in the institutions in Cambridge
Existing residential and commercial	Building energy use disclosure	Require landlords/rental property managers/building owners to disclose the last twelve months of energy consumption data when new tenants/owners are looking at house.

Together, utility programs and initiatives coupled with strong policy can create a very supportive environment for energy efficiency. Each sector will be positively impacted by any, or all, of the utility programs or policies suggested in the tables above. The City of Cambridge and the CEA may want to further prioritize the policies by which are the easiest to implement and begin changing codes or setting standards to realize immediate savings. The City and the CEA would also benefit from establishing a strong relationship with NSTAR and determining what the most mutually beneficial situation there is where NSTAR can help the City achieve its goals.

V. Transportation Fuel Use Reduction Strategies

Along with the decrease in fuel use due to strategies discussed in the last section, transportation represents a large opportunity to meet and exceed a 5% reduction in fuel use. More analysis should be undertaken to establish the actual benefits from implementing the strategies given in Table 13.

Table 13. Strategies to Decrease Transportation Fuel Use

Solution	Strategy
Integrate Existing Private Shuttle Routes	Publish route info, coordinate schedules, open buses to the public
Promote City and Institutional Leadership	Encourage programs to specify cleaner fleet vehicles and reduce vehicle miles traveled
Transportation Auditing	ESCO style audits to identify opportunities to reduce auto use
Parking	Use parking rates, new construction space requirements, and cash-out programs as tools to reduce the convenience of driving everywhere
Real-Time Information	Provide user-friendly schedule and route information for public transit options though the wireless mesh network
Encourage Walking and Biking	Close streets to cars and improve bike paths
Decrease Convenience of Driving	HOV lanes and congestion charges
One Payer System	Improve convenience of public transit options
Improve Existing Vehicle Efficiency	Properly inflated tires and real-time MPG display
Identify Freight Opportunities	Potential for bicycle use

A few areas were identified where transit opportunities overlapped with building sites. One idea was to tie a transportation audit to the building energy efficiency program. This ESCO style audit would help residents identify opportunities to use public transportation or carpooling options. Working with business to explore opportunities for local bicycle freight deliveries also offers potential cost savings, with a fraction potentially going to Cambridge Energy Alliance or a partner.

Because of the low cost and relative convenience of driving personal vehicles, it was difficult to find pathways for Cambridge Energy Alliance to achieve a return on investment while improving transportation efficiency. However, many ways are presented to reduce the carbon footprint of the transportation sector by discouraging auto use.

Another key idea was to increase the availability of private shuttle bus systems, including Harvard and MIT's transit systems and the EZ Ride commuter shuttle. It was agreed that by coordinating schedules, routes, and advertising, these existing systems could be useful alternatives for local residents and workers. MBTA's new Charlie Card payment program also helps to make public transit more convenient. It was suggested to institute a broader one payer system, which would allow access to various modes of public transit, shuttle buses, and even parking payments though a single card or school ID. Real-time information on bus locations and schedules accessible through the wireless mesh network would also increase ridership on public transit.

A key opportunity is the imminent replacement of the BU and Longfellow Bridges. During the construction, commuters will have to find alternative routes or modes of transit, and Cambridge has the chance to apply for "Mitigation Money" from the state to help reduce congestion. The transportation group recommended that the city of Cambridge develop a plan to use this funding for comprehensive alternative transportation and public transit schemes. Other city policies discussed included a proposal to issue T passes to new condo owners or to require monthly parking passes for on-street parking that would function as T passes for a month after they expired as parking passes.

An additional suggestion was to allow residents to charge market prices for parking spaces in front of their houses, thus making driving more costly and neighbors less likely to oppose new zero parking developments

VI. Next Steps

There are a variety of options that will move the City of Cambridge towards its goals to reduce peak energy load by 50 MW and reduce fossil fuel consumption by five percent in the next five years. There are four "next steps" that RMI believes that the City of Cambridge and the CEA should follow to begin moving towards meeting their goals:

1) Implement now
2) Seek additional funding options
3) Simultaneously establish baseline
4) Develop new goals for after five years.

Each of these steps will be discussed in more detail below.

1) Implement Now

The City of Cambridge only has five years to meet their goals, so it is important that implementation begin immediately. The first steps are to use the ESCO model to achieve all of the low-hanging fruit first and achieve the easier reductions as fast as possible. As shown in Table 4, it is likely that the City will need at least twenty percent annual penetration rate to meet its goals only using the ESCO.

2) Seek Additional Funding Options

Currently, the CEA's plan does not include additional funding for the enhanced ESCO, new construction and institution options that will be necessary if the City cannot achieve high enough penetration rates to meet the goal with only the ESCO. The CEA and the City should begin looking for other funding sources to ensure there is enough money to install more energy reduction measures than what the typical ESCO implements.

3) Maintain Baseline

While the City and the CEA are actively working towards reducing peak energy consumption and fossil fuel consumption, it is imperative that they also maintain the baseline energy consumption that the City and Peregrine are working on establishing. Peregrine's access to NSTAR data pre and post work should provide an excellent source from which the City may measure its successes.

4) Develop New Goals for After Five Years

While the City of Cambridge's current goals require an aggressive peak reduction and fossil fuel use reduction over the next five years, it is important to also consider extending and enhancing those goals after the 5-year time horizon. Beginning to consider new goals now and setting those goals prior to the end of the 5-year time horizon is critical in ensuring continuity of efforts, providing advanced notice to key players such as ESCOs, campuses, foundations, and city government, and maintaining momentum.

Possible considerations for extending and enhancing Cambridge's goals include:

- **Electricity consumption reduction**—In addition to the existing peak reduction and fossil fuel reduction goals, Cambridge should consider implementing an electricity consumption reduction target. That is, while reducing the peak will likely reduce total electricity consumption to some degree, demand response could result in peak reduction without accompanying electricity reduction. However, as Cambridge looks forward to continuing its sustainability efforts and reducing the financial burden of energy to its community members, electricity reduction through end use efficiency should be seriously considered. End use efficiency is typically one of the most cost-effective means of reducing both climate impact and cost.

- **Clean, distributed resources**—Consider clarifying the peak demand reduction goal or supplementing with a goal of meeting some percentage of remaining energy demand by using clean, distributed resources such as combined heat & power or solar photovoltaics.
- **Extend existing goals**—Maintain and expand Cambridge's existing peak reduction and fossil fuel reduction goals.

Appendix A: Charrette Participants

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3. Allison Rutter, RMI
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12. Dan Sosland, Environment Northeast
13. Daniel Katz, Overbrook Foundation
14. Dave Dayton, Clean Energy Solutions
15. Don Fudge, NEEP
16. Doug Garron, Harvard University - Engineering & Utilities
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18. Greg Franta, RMI
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29. Leith Sharp, Harvard Green Campus Initiative
30. Lisa Reinhold, Innocentive
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32. Marilyne Andersen, MIT - Architecture Dept.
33. Marion Kane, Barr Foundation
34. Mark Farber, Evergreen Solar
35. Marsha Gorden, The Resource Technologies Group
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44. Phil Giudice, MA Division of Energy Resources
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49. Sharmy Altshuler, RMI Board
50. Stephanie Pollack, Blue Wave Strategies
51. Steve Cowell, CSG
52. Steve Morgan, CESI/Ameresco
53. Steven Lanou, MIT - Environmental Programs
54. Susanne Rasmussen, City of Cambridge
55. Tim Stout, National Grid
56. Tom Vautin, Harvard University Operations Services
57. Tomakin Archambault, MAP, Inc.
58. Victor Olgyay, RMI
59. Walt Henry, MIT - Dept. of Facilities

Appendix B: Energy Supply and Use in Cambridge

The discussion of energy efficiency potential must be informed by a clear picture of not only how *much* energy is currently demanded, but *when* and *how* it is used. This section provides this basic information, and is summarized in the following table and list:

Table 14. Overview Energy Statistics

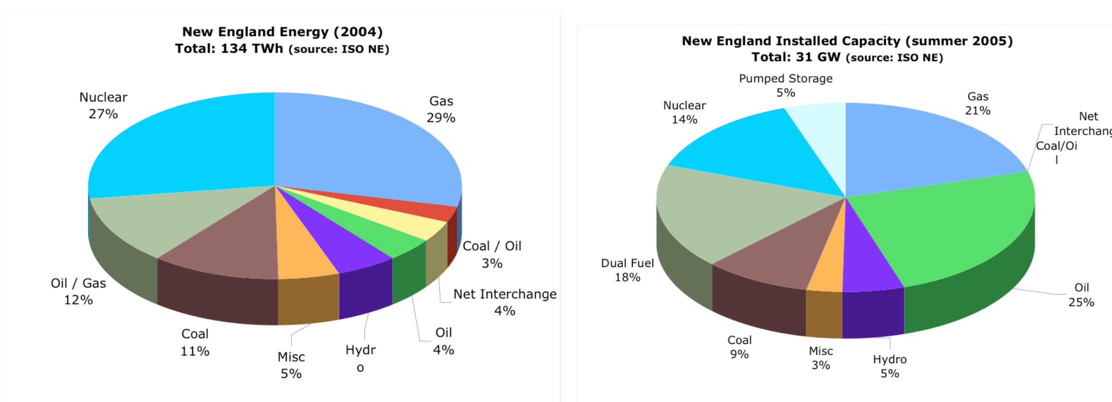
Cambridge Energy Statistics	
Annual electricity consumption (2006)	1.8 million MWh
Peak demand (2006)	370 MW
ESTIMATED gasoline consumption for personal vehicles (gallons/year)	22 million gallons

- Cambridge has few local generation resources; electricity comes from the New England regional grid;
- Natural gas and nuclear plants provide >55% of the region's annual energy;
- The average carbon intensity of its energy is 0.1 metric tons carbon-equivalent per megawatt-hour (MTCE/MWh), or 0.4 short tons CO_2-equivalent per MWh (tCO2e/MWh);
- Approximately 1,600 megawatts (MW) of the region's load are available for demand response (~5.7% of historical peak demand); and
- Existing supply projected to fall short of demand in Boston area by 2014.

The Regional System's Fuel Mix

Over 90% of the electricity consumed in Cambridge comes from the New England regional grid.[19] In 2004, over half of the energy generated within this region came from nuclear and natural gas-fired power plants (see Figure 2). The region's reliance on gas is a source of concern, according to Independent System Operator (ISO) New England's 2005 Regional System Plan. Gas's price volatility is high, and during winter months when heating increases the demand for gas, the lack of fuel diversity could be a risk to reliable electric supply.

Figure 2: New England Installed Capacity and Sources of Energy



[19] The remaining 10% is primarily made up of several small on-site generation units.

The region's average carbon intensity in 2002 was 0.1 MTCE/MWh (0.4 tCO2e/MWh) of electricity generated.[20] For comparison, the carbon intensity of direct natural gas use is 0.014 MTCE (0.058 tCO2e) per million Btu.

Supply Infrastructure

The ISO projects peak demand in New England to grow by 1.5% annually, and electricity consumption to grow by ~1.1% annually in the greater Boston area. Existing peaking capacity is projected to be insufficient to meet demand in the greater Boston area by 2014, and the ISO describes transmission infrastructure to import more as "limited." [21] Therefore, costly upgrades to infrastructure will be needed, or efficiency must be improved to reduce this growth.

Energy Efficiency

Energy efficiency programs run by utilities in the New England region have achieved savings of approximately 8,000 GWh per year, along with 1,600 MW of controllable load (see Table 15). NSTAR, the delivery utility for Cambridge, currently offers efficiency programs for both gas and electricity, and for both residences and businesses. In addition, NSTAR offers a load response program to its business customers. A list of these programs is included in Appendix C.

Table 15: Demand Response and Efficiency Savings Achieved in New England

Year	Summer Peak Demand Response (MW)	Energy (GWh/yr)
2004	1,507	7,590
2005	1,552	7,909
2006	1,603	8,078
Avg forecast 2007-2014	1,597	8,205

Renewable Energy

Massachusetts currently has approximately 837 MW of installed renewable energy (see Table 16) capacity that has been approved as counting towards the state's renewable portfolio standard (RPS). See "Regulatory and Policy Context for Cambridge" for more on Massachusetts' RPS.

[20] www.newenglandclimate.org/files/climatechange03.pdf
[21] http://www.iso-ne.com/nwsiss/grid_mkts/key_facts/ma_profile.pdf

Table 16: Units Qualifying for Massachusetts RPS

Technology	Nameplate Capacity (MW)[22]
Anerobic Digester	20
Biomass	204
Landfill Gas	133
Photovoltaic	2
Wind	478
Total	837 MW

Energy Use

Summary

- NEEP's 2005 study identified significant potential for increasing the efficiency of energy use;
- Fuel oil used for heating is a significant contributor to Cambridge's CO_2 emissions; and
- Targeted 50 MW peak demand reduction is 13.5% of Cambridge's 2006 peak (370 MW).

Electricity use in the Boston system sub-area is projected to grow by an average of 1.17% through 2014 (for comparison, the expected growth rate for the full New England region is 1.44%).

The division of energy use by major sector across Massachusetts is shown in Figure 3.[23] Figure 3 shows RMI's approximation of total energy consumed within Cambridge, by type of energy.[24] Further information on electric rates is available in Appendix D.

Figure 3: Massachusetts Energy Use by Sector (2001)

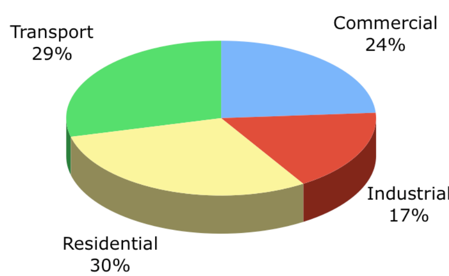
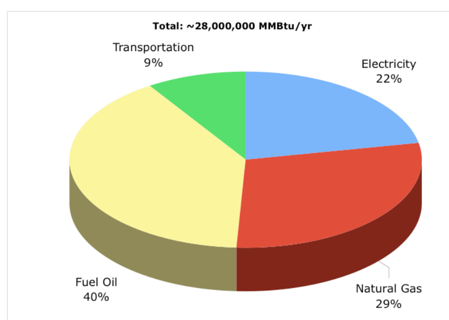


Figure 4: Estimate of Cambridge Energy Use



22 http://www.mass.gov/doer/rps/approved.htm
23 http://www.eere.energy.gov/states/state_specific_statistics.cfm/state=MA
24 The values shown in Figure 4 are rough approximations only, based on New England-wide ratios of electricity-to-natural gas and electricity-to-fuel oil consumption, as well as non-Cambridge-specific values for vehicle miles traveled per car. Additionally, the transportation sector shown here includes ONLY personal vehicle use.

Energy Use for Transportation

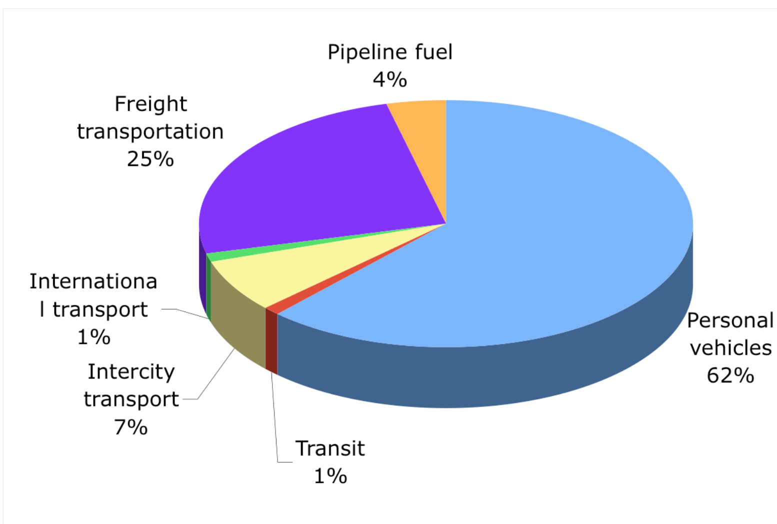
Table 17 shows the estimated number of cars per family in Cambridge, approximately 41,000. Using the Energy Information Administration (EIA)'s value of 535 gallons of fuel per year, per car,[25] annual gasoline consumption in Cambridge is approximately 22 million gallons, or 2.75 million MMBtu per year. This is approx. ½ the total electrical energy consumed in Cambridge in 2006.[26]

Personal vehicles are not the only way in which energy is used in the transportation sector. While Cambridge-specific data was unavailable, Figure 5 shows the breakdown of transportation-related energy end uses for all of New England.

Table 17: Vehicles available per residence in Cambridge[1]

Vehicles per household	# of households
No vehicles available	12,608
1 vehicle available	21,367
2 vehicles available	5,677
3 or more vehicles available	1,324
Total vehicles ~41,000	

Figure 5: Transportation Energy End Uses (New England)



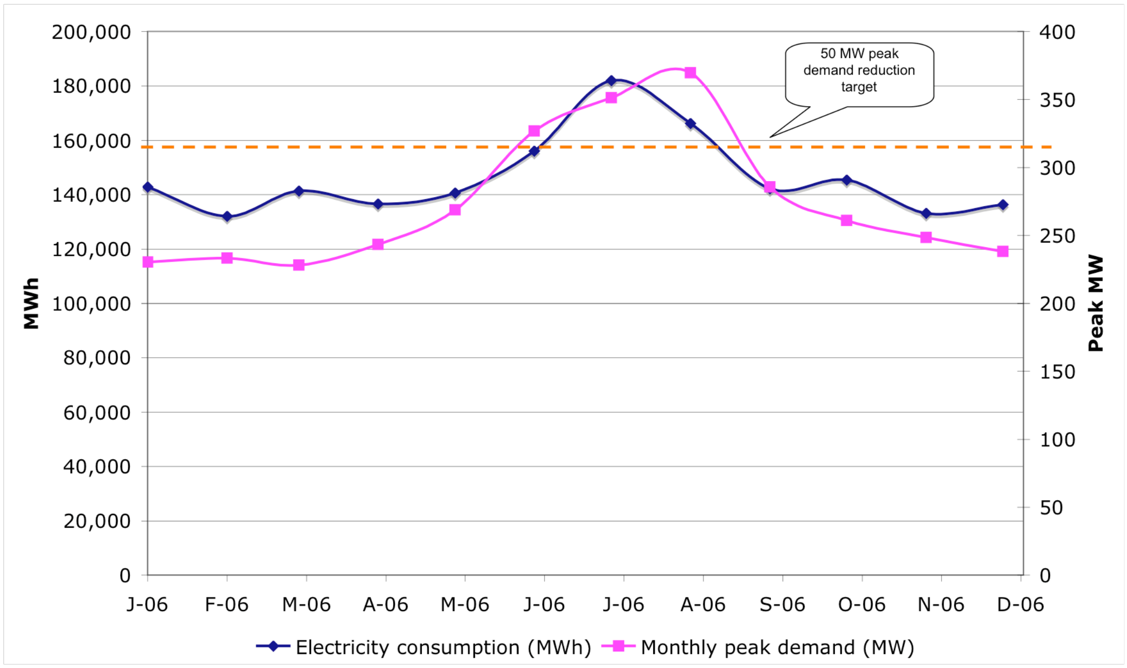
Energy Use for Buildings

Cambridge's 2006 monthly peak demand and electricity consumption values are shown in Figure 6. Peak demand occurs during the summer, when air conditioning systems face high temperatures and humidity. Figure 6 also shows the Cambridge Energy Alliance's targeted 50 MW reduction, which in 2006 would have yielded a peak of 320 MW.

25 This value is the average fuel consumption for urban / central city areas. ftp://ftp.eia.doe.gov/pub/consumption/transportation/tab3_94.pdf

26 Total 2006 electricity consumption was 1,755 GWh, or 6 million MMBtu.

Figure 6: Cambridge Electricity and Demand, 2006



Fuels for Heating

New England is unusual within the United States for the relatively high percentage of buildings heated with fuel oil (25% of commercial sector buildings, 14% of residences). The burning of fuel oil emits considerably more greenhouse gases (CO_2) and local pollutants (NOx and SOx) than does the burning of natural gas (see Table 18).

Table 18: Heating Fuel Use and Emissions Comparison

Heating fuel use in Cambridge's commercial sector[27]	
Electric	5%
Natural Gas	69.7%
Fuel Oil	25.3%

Heating fuel use in Cambridge's residential sector[28]	
Utility gas	67%
Bottled, tank, or LP gas	3%
Electricity	14%
Fuel oil, kerosene, etc.	14%
Coal or coke	0%
Wood	0%
Solar energy	0%
Other fuel	1%
No fuel used	1%

Fossil Fuel Emission Levels[29] (pounds per MMBtu output)		
Pollutant	Natural Gas	Oil
CO_2	117	164
CO	40	33
NO_x	92	448
SO_x	1	1,122

27 http://www.eia.doe.gov/emeu/reps/abstracts/new_eng.html#consumption
28 US Census, Cambridge, Massachusetts
29 http://www.naturalgas.org/environment/naturalgas.asp

Residential Sector

The residential building stock in Cambridge is notable for its large numbers of multi-family buildings and for the high percentage of pre-1940 construction. Table 19 and Table 20 describe the residential building stock by size and number of buildings, and construction year.

Table 19: Cambridge residential buildings

Dwelling type	Number of buildings [1]	Total sq. footage
Residential Single unit	3,960	8,712,454
Residential 2-4 units	5,096	16,294,463
Residential >8 units	11,990	29,630,774
Total	21,046	54,637,691

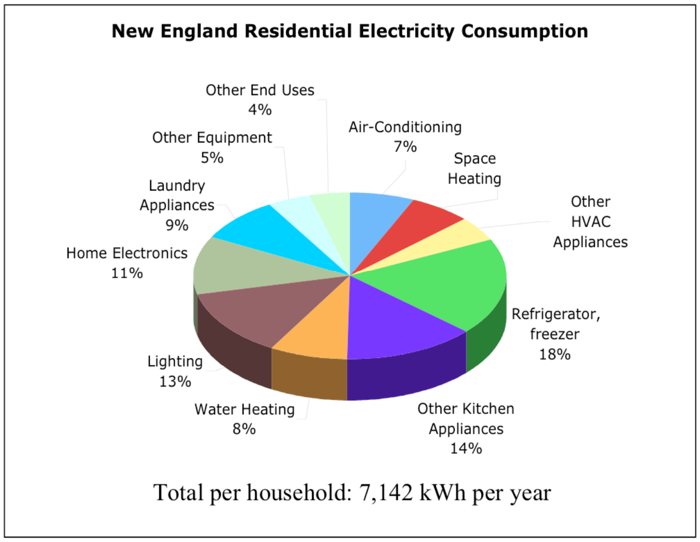
Table 20: Age of Cambridge Residential Buildings

Cambridge residential buildings Year structure built[30]	
Built 2005 or later	1%
Built 2000 to 2004	5%
Built 1990 to 1999	5%
Built 1980 to 1989	7%
Built 1970 to 1979	5%
Built 1960 to 1969	7%
Built 1950 to 1959	3%
Built 1940 to 1949	4%
Built 1939 or earlier	63%
Total	45,006

While space heating consumes over half of total residential sector energy in New England,[31] Figure 7[32] shows that electricity use is distributed nearly evenly amongst a several end uses, with refrigeration and other kitchen appliances comprising a total of 32% of residential energy in New England. While air conditioning consumes only 7% of annual electrical energy, it is the primary driver of summer demand peak in the region.[33]

[30] US Census, Cambridge, Massachusetts
[31] www.newenglandclimate.org/reports/Tommorow'sEnergyTodayME.pdf
[32] http://www.eia.doe.gov/emeu/reps/enduse/er01_new-eng_tab1.html
[33] http://tdworld.com/customer_service/iso-new-england-2007-forecast/

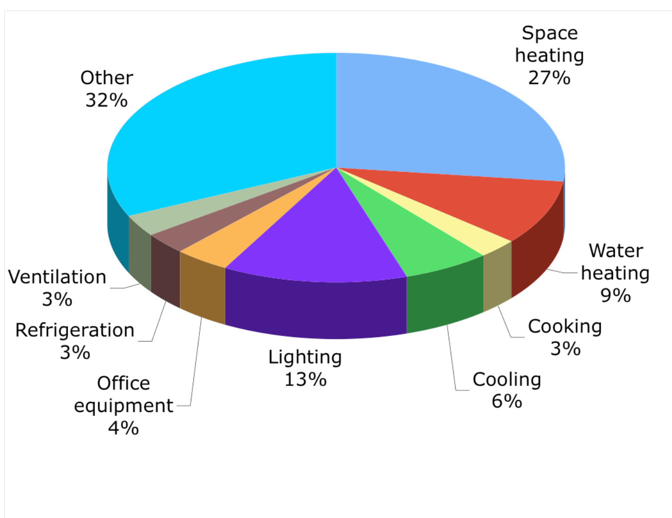
Figure 7: Residential Electricity End Use Breakdown



Commercial Sector

A detailed breakdown of Cambridge's commercial building types was not available, but Figure 8[34] gives the overall breakdown of energy use within all building types across New England. The charts below[35] provide total energy end use breakdowns for major commercial building types for the Cambridge's climate zone. A more detailed breakdown of commercial end-use demand is in Appendix F.

Figure 8: Commercial Energy End Use Breakdown (New England)



34 www.newenglandclimate.org/reports/Tommorow'sEnergyTodayME.pdf
35 Platts data, available through http://www.pnm.com and www.nationalgridus.com

Appendix C: Utility and Policy Ideas from the Charrette

Utility initiatives and programs that were suggested at the charrette are:

- Existing residential
    - Programmable Communicating Thermostat
    - Real-time monitor /display two-way
    - Conversional direct load control
    - Critical peak pricing
    - Demonstration retrofit to serve a model
    - Utility program defense to not commit to future big loads (like plasma tvs)- Vendors
    - Renewables
- Existing commercial
    - Design assistance
    - Real-time monitor/ display two-way
    - Super-efficient chilled water (large commercial)
    - Demonstration retrofit to serve as model
    - Renewables
- New Commercial
    - Super-efficiency chilled water plants
    - District heating and cooling (future Northpoint community)
    - Programmable communicating thermostat
    - Real-time monitor /display two-way
    - Use summer steam from Morant Plant for absorption cooling
    - Renewables
- Institutional/Hospital
    - Water treatment
    - Co-generation
    - District heating and cooling use and efficiency
    - Summer steam in Morant Plant
    - Super-efficient chilled water plants
    - Avoid new central plants
    - Existing campus buildings could be retrofitted and used as models for the rest of Cambridge/other institutes
    - Renewables
- Community
    - AC Load Shedding
    - Water Billing for On-Bill Financing: tie financing for efficiency measures to a building instead of a customer's personal credit
    - Water utility revenue decoupling - remove incentives for utility to discourage efficiency so it can sell more water to pay off debts
    - Water conservation and re-use program
    - Draw from MWRA Water Supply - potentially less energy intensive system could supply Cambridge at peak times
    - Off-Peak water pumping - use Payson Park capacity during the day
    - Cambridge Wi-Fi network used as platform for demand response
    - Co-gen and tri-gen reuse waste heat from distributed power generation

- Neighborhood customer aggregation to facillitate residential demand/response and smooth instantaneous demand on grid
- Fuel Oil efficiency package - couple aggressive efficiency programs to fuel oil sales or fuel oil distributor financing.
- Public Lighting: Wireless, dimmable street lamps
- District Heating and cooling
- District energy systems that eliminate individual building chillers and boilers
- Renewables
- Better scheduling of mass transit
- Integrate existing private shuttle routes (publish route info, coordinate schedules, open private buses to public)
- Auditing – to identify opportunities to reduce automobile use
- Use parking rates, new construction space requirements and cash-out programs, HOV lanes, and congestion charges as tools as disincentives for driving (or incentives for car-pooling)
- Real-time information: provide user friendly schedule and route information for public transit options through Cambridge wireless mesh network
- Close streets to cars and improve bike paths (to encourage walking and biking)
- One-card/One-payer system to improve convenience of public transit options

Policy ideas that were discussed at the charrette were:

- Existing Residential
    - New Codes - performance based
    - New Lighting Code: Performance standards, metrics, equilvalence sphere illuminance, kWh metrics over LPD, require labelled products (LCA, toxicity, recyclability)
    - Coordinate fire code with energy-efficiency strategies
    - Trade in program for upgrade to more energy efficient appliances/holiday lights/etc. Trade ins de-manufactured to reclaim metals and other valuable materials.
    - Operations and Maintenance Training
    - "Green assistance" program to help people through the process of retrofits
    - Building Energy Use Disclosure - provide energy use information at time of sale to give landlord benefit of efficiency improvements
    - Certification program for contractors
    - Potential to override historical precedent for design standards if 3x efficiency can be achieved
    - Permit prioritizing/expediting for efficient designs (retrofits)
    - Financial incentives - design $ award for confirmed performance
    - Utility Program Defense to not commit to future big loads (like plasma tvs) - Incentive
- Existing Commercial
    - Conduct audits and occupancy surveys
    - New Codes - performance-based
    - Coordinate fire code with energy-efficiency strategies
    - Permit prioritizing/expediting for efficient designs (retrofits)
    - Operations and Maintenance Training
    - "Green assistance" program to help people through the process of retrofits

- Certification program for contractors
- Inspector Training
- Building Energy Use Disclosure - provide energy use information at time of sale to give landlord benefit of efficiency improvements
- Potential to override historical precedent for design standards if 3x efficiency can be achieved
- Reconcile existing historic building preservation standards with energy efficient retrofits.
- Establish an "Energy Efficiency Gap Financing" pool
- Financial incentives - design $ award for confirmed performance

- New Construction
    - New Codes - performance-based
    - Set standards for NorthPoint to Option A at minimum. Huge opportunity here (~2,500 homes in the next 10 years; a few million square feet of commercial) to reduce future loads
    - Coordinate fire code with energy-efficiency strategies
    - Permit prioritizing/expediting for efficient designs
    - Leasing structure to align incentives between builders, developers, owners, renters to be energy efficient. Design awards; performance awards ($ awarded to confirmed performance)
    - Financial incentives - design $ award for confirmed performance
    - Metrics: Daylight autonomy, btu/square feet
    - Programmable Communicating Thermostat
    - Reconcile existing historic building preservation standards with energy efficient retrofits.
- Campus/Institution/Hospital
    - Comprehensive city audit on use/opportunities (inspired by carma.org) - where are the big hot spots?
    - **Lab Building Standards:** Low-flow hoods, reduced ACH, night-time setbacks, Demand-controlled ventilation
    - **Data Center Standards:** best current design practice (i.e. separation between hot and cold isles, VSD on fans, water/air-side economizers), most efficient computing equipment, revamp standards to reflect actual energy needs, research of new design methods
    - LEED for new construction or EB, with certain current optional credits instituted as required credits.
    - Create position responsible for coordinating knowledge sharing between institutions (i.e. sharing Harvard University expertise)
    - CEA charged with task to identify institutions for co-gen/tri-gen
    - Policy for co-gen/tri-gen: Interconnection between buildings/institutions/utility/other parties; Decoupling
    - Student participation to disseminate information
    - Carbon credit financing program: One institution provides interest-free financing to another institution to provide carbon reductions so that the investing institution owns the CO2 assets
    - Campus goals/LDRSP/2-30
    - LCA requirements for design/purchasing decisions
    - Building owner readiness/acceptance programs

- Community/Infrastructure
    - Water utility revenue decoupling - remove incentives for utility to discourage efficiency so it can sell more water to pay off debts
    - Water conservation and re-use program
    - Online listserves to share information about energy efficiency retrofits. Use existing social networks and communities: (rotary, churches chamber of commerce, etc.)
    - City could finance retrofits on citizen's tax bills.
    - Develop landlord/tenant process and sample contracts to align incentives for energy efficiency
    - Public light pollution standards
    - Bring in retail establishments (Best Buy, Home Depot, Sears, Lowe's, Target, Bed Bath and Beyond) to emphasize efficiency and to offer affordable energy efficient selection of products, with possible incentives for swapping appliances
    - Labeling and recognition for participants (ads in newspapers, plaques in houses, etc.)
    - Establish an "Energy Efficiency Gap Financing Pool"
    - Building owner readiness/acceptance programs

Appendix D: Boston Innovation Challenge Breakout Group Ideas

The Boston Innovation Challenge conducted a group brainstorm during which participants offered ideas for prize innovations. The following is a list of the ideas generated in chronological order. The final report on this charrette, to be finalized in early December, will include a prioritization and further discussion of these ideas.

At the end of the breakout group, participants were each given three votes to assign to the three ideas on the list we thought were most applicable, achievable, and worth pursuing for the innovation prize. Votes were cast with the understanding that this was only an initial brainstorm, and intended as a starting point for thinking about the prize. The # of votes awarded to each idea (if any) are recorded in parentheses next to the prize idea.

1) "Prius" Meter (6)
A "dashboard" interface displaying real-time feedback of building systems and appliances. Allows a person to see what appliances and systems are currently "turned on" and the resulting impact on their individual energy/electricity use. Would also easily allow people to adjust the status of their appliances/systems for demand/response and other personal controls.
Meter could incorporate wireless monitoring
Should be technically deployable on existing building stock as well as new construction
For residential & commercial applications
Should be affordable (for existing stock as well as new construction)

2) New Economic Model (1)
A new economic model that accounts for the value of wellness, occupant satisfaction, and health benefits (or detriments) tied to energy efficiency.
Places an economic value to the "soft benefits" (wellness, satisfaction) of energy efficiency
Perhaps could present a convincing argument to pursue improved design measures for the sake of better health, satisfaction and productivity. Energy efficiency would then be a result of better design measures in the spaces we occupy, not the driver.

3) Materials that change (6)
Materials that change properties (i.e. seasonally, diurnally, or per zircadian cycle or light levels (chronobiologically) or based on temperature, humidity changes, or other climate-responsive changes).
Example: phase-change materials
Example: could be incorporated in sidings, rooftops, etc.
Example: could have climate-moderating elements, like wind blockers or rain screens

4) Accounting system of CO2 footprint for *individuals* (4)
Individuals can accumulate and own carbon credits; individuals can do personal accounting and reap the rewards of CO2 reduction.
"Investment vehicles" could, for example, take the form of an IRS of carbon credits that allows the individual to earn or pay "micro-payments"
Could integrate social networks/gaming networks for competitive load reduction

Innovations could include carbon-efficient personal mobility/transportation "broker"

5) Demand control system that incorporates individuals (1)
A system that allows individuals to get paid for reducing energy demand, just businesses are paid.
Could incorporate wireless controls
Example: demand control of window units

6) More efficient window AC units (2)
Perhaps w/ desiccants add-ons
For retrofits as well as new construction

7) Super-efficient rooftop AC units for small commercial application
For new construction and retrofits
EE (energy efficient) air conditioning technologies

8) Economically affordable insulation materials that are easily retrofit-able (2)
Innovative, easy installation for retrofits
Address building stock in Cambridge that may not take conventional retrofits as easily, such as existing masonry construction

9) Better building wiring systems (versus knob and tube wiring)
For retrofits in existing building stocks (as well as new construction)

10) Cost effective solid-state lighting (SSL) for residential application (1)
Skip over CFL technologies and go right to solid-state lighting that works for residential buildings

11) Wireless system for demand/response controls

12) "Smart" refrigerators, chargers, power strips, etc.
Could be programmable or respond to reduce (parasitic) loads when needed.
Refrigerators could be "zoned" – not all products need to be kept at the same temperatures
Could work with the "Prius" meter (prize idea #1)
Could be designed for retrofit opportunities

13) "Performance Prize" (1)
Pose the question: What is the innovation that is going to save the most energy?
Don't limit the "category" for the prize, but instead use the contest to really push the Cambridge energy reduction initiative. Turn the energy reduction challenge onto the audience, and reward the most compelling idea.

14) "Implementation/Change Agent" Prize
An implementation plan to really incentivize Cambridge's youth to practice energy efficiency.
A plan for execution.

15) Best messaging
How do we market or package energy efficiency to Cambridge? What is the best messaging strategy? What kind of communications make people act? What kind of messaging do people respond to?

16) Rethink public lighting realm (6)
Sidewalks that light when tread upon
Dynamic, more effective outdoor lighting (the right feel, adjustable for the right amount and for outdoor end uses)
Better define and eliminate light trespass (obnoxious glare)

17) Cambridge as a lighting center
This is a throwback to a suggestion Amory Lovins made to the Lighting and Electricity breakout group on Day One of the charrette. He suggested that one possibility was to really push Cambridge to be a pioneer in beautiful energy-efficient lighting, and to become a landmark "lighting center" that demonstrates break-through lighting for all end-user needs.

18) Design/shape buildings to enhance wind power generation
Mini turbines integrated into buildings
Wind tunnel turbines

19) Innovative BIPV materials
Could be low-cost retrofits for existing building stock

20) Energy collection from other diffuse sources of energy
Example: PVs embedded into sidewalks, parking lot structures
Example: Energy collected from people walking on sidewalks and subway stations

21) CO_2 sequestration strategies/technologies at local level (residential or building-based) (8)
Example: taking concentrated source of CO_2 and growing algae to sequester it
Example: at residential scale, could run greenhouse off the boiler exhaust, etc.)

22) Shuttle transportation coordination
Maximize efficiency of transportation
Logistic management of buses (some buses only have 5 people in them!)

23) Extracting energy from sewage system

24) "Acceptable" mandate strategy for energy efficiency retrofits
How can we make mandates that accepted by the community?

25) Carbon nanotube or lattice electrical system
For electrical distribution
Could be integrated with solid state lighting
Could replace copper system in place

28) Carbon efficient personal mobility broker

29) Single family house designed to eliminate mechanical system (1)
Could be a design that incorporates daylight and natural ventilation for use in dense urban areas and specific to Cambridge.
No heating system in the design

30) Re-engineer federal funding system
Re-design how money is spent and distributed
Efficient implementation

31) Coordination of fire code with energy-efficiency strategies