City of Cambridge
Getting to Net Zero Action Plan 5-Year Review

Science, Policy and Technology Review for Task Force Members

Introduction

These slides are provided as background material for the Cambridge Net Zero Task Force Members. The information contained herein is intended to provide task force members, city staff and the consulting team a common understanding of the conditions that exist today with respect to:

- The latest **Science** on emissions reductions goals,
- Greenhouse gas (GHG) emissions reduction-related **Policies**,
- **Technological** changes since 2015 that may impact or influence the NZAP Actions

The slides are organized according to the Science, Policy, Technology framework that has been referred to in the first two task force meetings. We expect that task force members will reference these conditions when assessing possible adjustments to the NZAP Actions.

The Science and Policy summary slides are based on the Net Zero Action 5-Year Review: Science and Policy Current Conditions conducted by city staff in 2020. The technology summary was compiled by DNV GL. It is not meant to be an all-encompassing review of changes in NZAP enabling technologies since 2015. The technologies included here are a sampling of some of the more notable changes over the last 5-years that align with the **three pillars of decarbonization: Energy Efficiency, Electrification and Renewable Energy**.

Throughout the slides we make reference to which category of NZAP actions is primarily influenced using the following symbols where applicable:

EE	NC	ES	All
Action 1 – Energy Efficiency in Existing Buildings	Action 2 – Net Zero New Construction	Action 3 – Energy Supply	Applies to all categories

Part 1

SCIENCE

Science

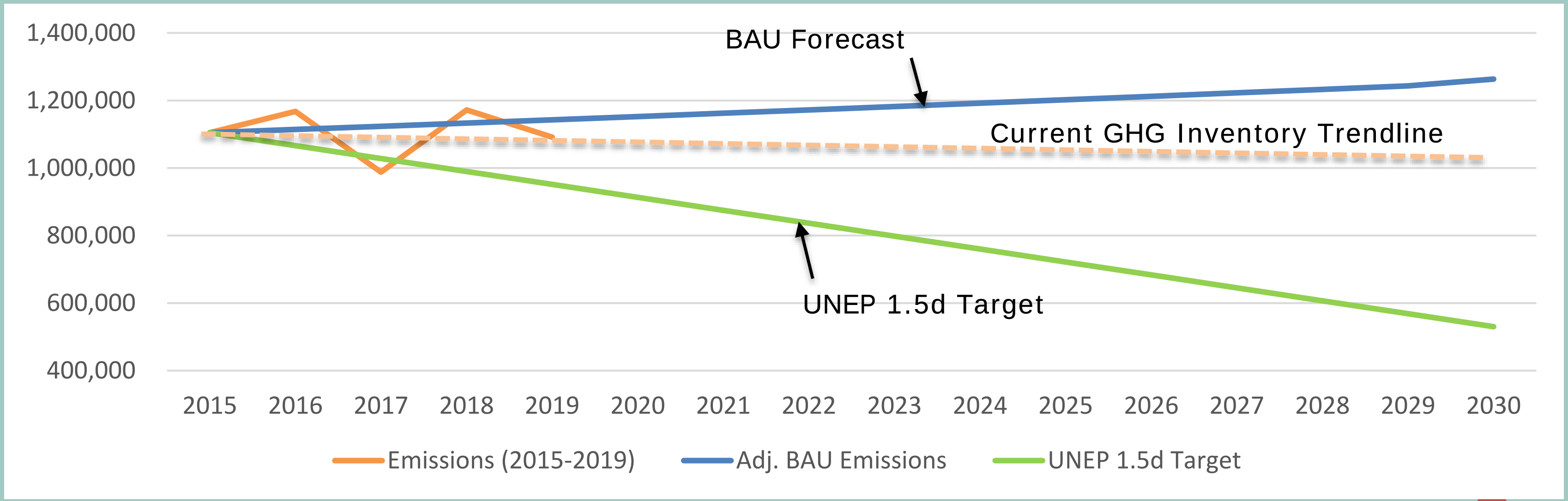
All

Issue:

- Since the adoption of the Net Zero Action Plan in June 2015, the International Panel on Climate Change (IPCC), the United Nations body responsible for assessing the science related to climate change, issued a special report on the impacts of global warming of 1.5 deg C above pre-industrial levels.

Impact:

- Cambridge has already committed to achieving carbon neutrality by 2050, so setting an intermediate emissions reduction target of at least 45% by 2030 from the 2012 baseline is necessary to maintain a science-based emission target that is consistent with IPCC recommendations.



Note: The Current Trendline above does not consider the impacts of NZAP actions that are underway including the BEUDO Performance Requirements which are expected to have a significant impact going forward.

Science

NC

Issue:

- According to Architecture 2030; The embodied carbon emissions of building products and construction represent a significant portion of global emissions: concrete, iron, and steel alone produce ~9% of annual global GHG emissions; and will likely be responsible for almost half of total new construction emissions by 2050

Impact:

- Embodied carbon is not currently accounted for in the community-wide inventory; if considered, new strategies will need to be developed to address the additional emissions and possibly require other GHG accounting methodologies

Est. Carbon Emissions from the Construction of New Buildings
(Image Source: Greenbuildingadvisor.com)

Part 2

POLICY

Policy

Current City Policy

Cambridge has committed to achieving carbon neutrality by 2050. The faster Cambridge can reduce emissions within its borders, the more the City can lead by example in the global effort to combat climate change

Federal Alignment:

EE
- Slowdown in federal policy for energy efficiency, especially for plug loads has created a gap in behavioral energy use reductions but these are expected to ramp up again under the new administration.

ES
- Federal tax credits will play a role in clean energy procurement for the City

NC
- National building codes such as the 2021 IECC set the baseline for state code updates

Policy

State Alignment:
The current Three-Year Energy Efficiency Plan for gas and electric utilities expires in 2021 and although the Plan is implemented at the state level, the City can advance programs for hard-to-reach sectors like multifamily buildings.

Recent State Activity:

All

- The Baker Administration's Decarbonization Roadmap that was released in December sets a 2050 net-zero greenhouse gas emissions limit and requires at least 85% reduction in gross GHG emissions; In addition, it requires emissions to be reduced by 45% by 2030. The Interim Clean Energy and Climate Plan for 2030 lays out a set of actions for achieving this target, including advancing a net zero stretch code for new construction, retrofitting 1M buildings for energy efficiency and heat pumps, aligning MassSave, the state's energy efficiency program, with GHG –based reduction targets, and increasing renewable electricity supply from off-shore wind and Canadian hydropower.

NC

- Following Brookline's ban on fossil fuel piping in new buildings in November 2019, Cambridge, considered a similar ban; however, the Attorney General's office struck down the ban stating that it conflicted with state laws.

Policy

Local alignment:

NC

- Cambridge voted on the proposed changes to the IECC in December 2019 that would advance EE in new construction. The state building code can have a significant impact on the GHG emissions of new buildings and major renovations in Cambridge. The benefits of a uniform net zero stretch code have to be balanced with possibly giving up local control.

NC

- The City is working with MAPC and other cities to advance a net zero stretch code at the state level to facilitate a uniform approach.

NC

- Envision Cambridge is the citywide plan for development through 2030. A number of the actions and indicators directly relate to building energy use while other actions, like those in the Housing Plan section, could be incorporated into NZAP moving forward (with the additional benefit of already being identified as a citywide priority over the next 10 years).

Policy

EE

ES

Role of Local Institutions: Many organizations across Cambridge have instituted aggressive climate or emissions reductions plans. For example:

- **MIT's** current goal is 32% reduction by 2030 with a commitment to carbon neutrality. They are in the process of setting a new goal to be announced in Spring 2021. Approximately 97% of MIT's emissions scope 1&2 emissions comes from building use. Their stated top priorities include maximizing energy efficiency, optimization of the central utilities plant followed by reducing the use of fossil fuels on campus.
- **Harvard's** climate goals are focused on addressing the full impacts of fossil fuels, including health, climate change, and equity issues, and translating research into action. Harvard met its first 30% net GHG reduction goal in 2016 (while the campus grew by 11%) and in Feb 2018 set 2nd generation climate goals to be **fossil fuel-free by 2050** and **fossil fuel-neutral by 2026**.
    - This means the eventual elimination of fossil fuels for heating, cooling, and powering buildings and vehicles, and the 2026 fossil fuel-neutral goal is a bridging strategy of investing in new, off-campus renewable energy projects to offset both the GHG emissions and the health impacts of air pollution from fossil fuels.

In addition, the Cambridge Compact for a Sustainable Future was created to provide a forum for collaboration between the City, and local companies and institutions including Harvard, MIT, and 15 businesses.

Part 3

TECHNOLOGY

Achieving Carbon Emissions Reductions

There are three primary ways to reduce emissions from buildings. These are known as the 3 pillars of decarbonization:

ENERGY EFFICIENCY

ELECTRICIFICATION (FUEL SWITCHING)

RENEWABLE ENERGY SUPPLY

NZAP Enabling Technologies

The technologies shown below are included because they align with the three pillars of decarbonization and are recognized as having more notable changes over the last 5-years. This graphic shows how they map to each of the main NZAP Action Categories.

NZAP Action Category 1: Existing buildings (EE)

Thermal Tech

- Heat Pumps
- Smart T-Stats

Energy Efficiency

- Lighting
- Demand flexibility

NZAP Action Category 2: New Construction (NC)

Thermal Tech

- Electrification

Materials

- Thermal Storage/Phase Chance Materials (PCM)
- Cement Alternatives
- Glass

Renewable Energy

- Energy Storage
- Solar PV
- Fuel Cell

NZAP Action 3: Energy Supply (ES)

Thermal Energy

- Hydrogen-blending
- Geothermal

Grid-scale RE

- Wind Turbines
- Microgrids
- Off-site Renewable Procurement

Map of Decarbonization Technologies to NZAP Action Categories

Notable Changes in Technologies by NZAP Action Category

			Relevant Action Category		
Tech Category	**Purpose**	**NZAP Enabling Technologies**	**Energy Efficiency in Existing Buildings**	**Net Zero New Construction**	**Energy Supply**
Thermal Tech	Foster Fossil Fuel Free Heat/AC	Air / Water Source Heat Pumps	●	●	
		Ground Source Heat Pumps	●	●	
DER	Increase Integrated Renewable Energy	Rooftop PV	●	●	
		Solar Thermal	●	●	
		Fuel Cells	●	●	
Energy Efficiency	Reduce energy demand or consumption	Lighting Systems	●	●	
		Demand Flexibility	●	●	
Materials	Reduce energy consumption or embodied carbon	PCM / Thermal Storage		●	
		Cement Alternatives		●	
		Glass		●	
Thermal Energy Supply	Reduce fossil fuel based heating	Electrolysis / Hydrogen Blending			●
		Geothermal Districts			●
Grid-scale Renewables	Enhance or manage clean energy supply	Wind			●
		Microgrids			●
		Off-site RE Procurement			●

Technologies Covered by NZAP Action Category

Note: Further information on each of the technologies listed here is provided in Appendix A, Technology Details

Notable Changes in Technologies by Target Emissions Sector

			Target Emissions Sector			
Tech Category	**Purpose**	**NZAP Enabling Technologies**	**Residential**	**Comm. & Inst.**	**Manuf. & Const. Industry**	**Energy Industries**
Thermal Tech	Foster Fossil Fuel Free Heat/AC	Air / Water Source Heat Pumps	●	●		
		Ground Source Heat Pumps	●	●		
DER	Increase Integrated Renewable Energy	Rooftop PV	●	●		
		Energy Storage	●	●	●	●
		Fuel Cells		●	●	●
Energy Efficiency	Reduce energy demand or consumption	Lighting Systems	●	●	●	
		Demand Flexibility	●	●	●	
Materials	Reduce energy consumption or embodied carbon	PCM / Thermal Storage	●	●		
		Cement Alternatives	●	●	●	
		Glass	●	●	●	
Thermal Energy Supply	Reduce fossil fuel based heating	Electrolysis / Hydrogen Blending	●	●	●	●
		Geothermal Districts	●	●	●	●
Grid-scale Renewables	Enhance or manage clean energy supply	Wind	●	●	●	
		Microgrids	●	●	●	●
		Off-site RE Procurement	●	●	●	

Technologies Covered by Target Emissions Sector

Considered Potential & Relative Impact of NZAP Enabling Technologies on Future CO2 Emissions

Tech Category	NZAP Enabling Technologies	Energy Efficiency in Existing Buildings		Net Zero New Construction		Energy Supply		Relative Impact on Overall Future Cambridge Emissions
		Economic	Technical	Economic	Technical	Economic	Technical	
Thermal Tech	Air / Water Source Heat Pumps	■	⇧	⇧	⇧	n/a	n/a	+++
	Ground Source Heat Pumps	■	⇧	■	⇧	n/a	n/a	++
DER	Rooftop PV	⇧	⇧	⇧	⇧	n/a	n/a	+++
	Solar Thermal	■	■	■	■	n/a	n/a	+
	Fuel Cells	■	⇧	■	⇧	n/a	n/a	+
Energy Efficiency	Lighting Systems	⇧	⇧	⇧	⇧	n/a	n/a	++
	Demand Flexibility	■	⇧	⇧	⇧	n/a	n/a	+++
Materials	PCM / Thermal Storage	●	■	■	⇧	n/a	n/a	+
	Cement Alternatives	●	●	■	⇧	n/a	n/a	++
	Glass	●	●	■	⇧	n/a	n/a	++
Thermal Energy Supply	Electrolysis / Hydrogen Blending	n/a	n/a	n/a	n/a	■	■	++
	Geothermal Districts	n/a	n/a	n/a	n/a	■	■	++
Grid-scale Renewables	Wind	n/a	n/a	n/a	n/a	⇧	⇧	+++
	Microgrids	n/a	n/a	n/a	n/a	■	■	+
	Off-site RE Procurement	n/a	n/a	n/a	n/a	⇧	⇧	+++

Estimated Level of Feasibility:

● Low ■ Moderate ⇧ Strong

Scale of Estimated Potential Impact on Overall Future Emissions:

\+ Minor ++ Moderate +++ Significant

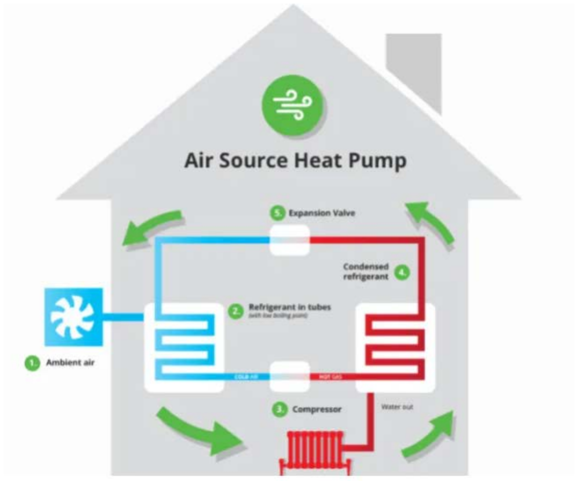
Appendix A

TECHNOLOGY DETAILS

NZAP Enabling Technology Review

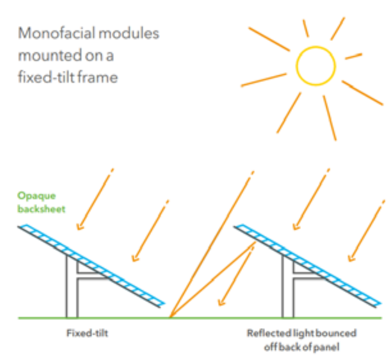
EE

NC

Thermal Technologies		
Summary:	Thermal Technologies include those systems that provide space or water heating for residences and businesses. With respect to the NZAP, heat pump systems are considered supportive of emissions reduction goals because of their efficiency and because they primarily use only electricity to concentrate and move heat to where it is needed. Mitigating carbon emissions associated with space heating and cooling will depend largely on electrification of space heat, yet customer acceptance of heat pump technology is lagging the pace needed to meet emission-reduction goals. This category includes Air Source and Water Source Heat Pumps (ductless mini-split heat pumps, centrally ducted ASHPs, air-to-water heat pumps, heat pump water heaters, and variable refrigerant flow (VRF) systems) as well as Geothermal or Ground Source Heat Pumps (GSHPs).	
Notable Change:	Since 2015, Cold Climate Heat Pump technologies have greatly improved. Cost competitive ASHP units that provide efficient heating (COP ≥ 1.75) at 5°F are now much more widely available.	
Applications:	Fuel switching / Electrification - may be used as primary source of space and water heat for residential, multifamily, and small commercial businesses.	
Benefits:	• High degree of flexibility, from supplemental systems to whole-building systems • Provide both heating and cooling • Low maintenance	
Other Considerations:	• Space and location of outdoor units • Installation - ductless units best option when no existing ductwork. • Appearance could be an issue for ductless unit heads. • Cost of switching from Gas heating to Electric • Contractor and occupant desire to have a backup heating system for coldest days of the year	
Alternatives:	Alternatives heating options for homes and businesses include individual gas- or oil-based furnaces and boilers. District energy may also provide an alternative source of heating.	Image Source: RemodelingCalculator.org

NZAP Enabling Technology Review

EE NC

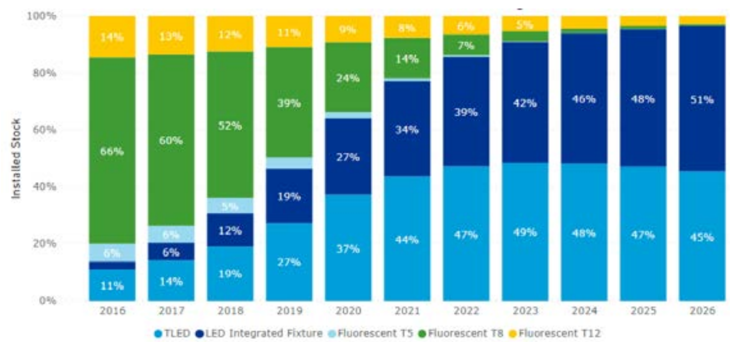
Distributed Energy Resources		
Summary:	The Distributed Energy Resources (DERs) covered here include rooftop photovoltaics (PV), solar thermal, energy storage systems, and fuel cell technologies. While PV and Fuel Cells provide an on-site renewable source of electricity, energy storage systems provide capacity to store energy and use it for back-up power, or for storing clean energy and for use when the emissions intensity of grid-supplied energy is at its highest. These technologies are considered essential building-level technologies to support the NZAP goals.	
Notable Change:	Notable changes in these technologies since 2015 include: • PV - average cost of installing solar for residences and businesses has decreased (current range $2.51 - $3.31/W in MA according to EnergySage); there continues to be advance in technologies and panel efficiency (shifts from multi-crystalline to monocrystalline silicon wafers, and eventually from p-type to n-type wafers, will achieve higher efficiencies and better power-to-cost ratios) • Fuel cells: According to DOE, market continues to grow and could reach maturity in next 10-years; hydrogen fuels have received increased attention in recent years • Energy Storage: Market has seen considerable growth; Cost for batteries will continue to drop driven by greater production capacity; Improvements in energy density, weight and volume of electric batteries will enable wider use of battery-storage systems.	
Applications:	• PV: Supplemental on-site power for buildings and homes • Fuel cells: Supplemental or primary stationary on-site power for buildings and homes (as well as transport power for buses and fleet vehicles) • Energy storage: Building and utility-scale storage, EVs, back-up for information and communications technologies	
Benefits:	• On-site clean renewable source of electricity • Increased reliability and resilience • High degree of flexibility • Low maintenance	 Image Source: DNV GL Energy Transition Outlook
Other Considerations:	• Space and location of systems (other rooftop equipment, building orientation and roof angle will effect capacity and performance) • Location of storage units with respect to building sand fire codes	
Alternatives:	Grid-supplied electricity and fossil-fuel based back-up generators	

NZAP Enabling Technology Review

EE

NC

<table>
<tr><th colspan="3">Energy Efficiency</th></tr>
<tr><td>Summary:</td><td colspan="2">Energy efficiency in buildings will continue to be a key and issue and strategy for helping to achieve the NZAP goals. Space cooling is expected to be one the fastest growing end uses along with plug- and other process type loads. With respect to notable changes over the last 5-years there are 2 energy efficiency technologies we cover here: Lighting systems, and Demand Flexibility</td></tr>
<tr><td>Notable Change:</td><td colspan="2">Notable changes in these technologies since 2015 include:
• Lighting: Over the last 5-year lighting retrofits have been a reliable source of energy savings, but the availability of lighting as an energy reduction measure is rapidly decreasing because of the rate of adoption in recent years. LED integrated fixtures have continued to replace fluorescent technologies with the estimated saturation of ambient linear LED technologies in MA being 48% for commercial businesses as of 2019.
• Demand flexibility: Greater proliferation of smart thermostats and building automation systems is enabling building owners to access value streams offered by demand response. Facility owners receive payment for load reduction, which is automatically controlled by power suppliers or aggregators, in response to signals from the grid</td></tr>
<tr><td>Applications:</td><td colspan="2">• Lighting: Linear lights are most common in office, laboratory and classroom and other commercial spaces whereas residential buildings tend to rely more on screw-based lamps
• Smart Thermostats: Most common in single family and small commercial settings
• Advanced building controls and Energy Managements Systems: Used for energy management but offer opportunities for remote load control. Most common in mid- to large-size facilities, and campuses</td></tr>
<tr><td>Benefits:</td><td>LED Lighting:
• Efficiency / Load Reduction
• Integrated controls offer greater flexibility and additional savings
Demand Flexibility:
• Decreased reliance on emissions intensive electricity during peak periods
• Flexible controls with respect to availability of renewable energy resources</td><td rowspan="3">



Model forecasted saturation of ambient linear technologies (MA)
MA C&I Lighting Inventory and Market Model (DNV GL 2019)</td></tr>
<tr><td>Other Considerations:</td><td>LED Lighting:
• Concerns with light quality, colors and angle
• Impact on heating and cooling demand</td></tr>
<tr><td>Alternatives:</td><td>N/A</td></tr>
</table>

NZAP Enabling Technology Review

EE

NC

Materials	
Summary:	The material category is most applicable to new construction projects although the items covered here may also be used as retrofits for new buildings. These items include Phase Change Materials (PCM) / Thermal Energy Storage, Cement Alternatives, and Advanced Glazing. While there have been many advancements to materials technologies in recent years, these three were chosen because of their potential for emissions and energy demand reduction, and their support of net zero energy goals.
Notable Change:	Notable changes in these technologies since 2015 include: • Increased interest in passive design strategies driven by Passive House and ZNE design goals • Phase Change Materials / Thermals Energy Storage – PCMs continue to gain attention as solution for balancing heating and cooling loads and supporting passive building design and net zero energy initiatives • Cement Alternatives – Recent initiatives have been undertaken to significantly reduce the emissions intensity associated with the production of cement and also develop materials that have carbon storage properties. • Advanced Glazing Systems – Glazing is one of the primary sources of energy loss within a building, and electrochromic glass technologies are a possible solution. While costs have been a barrier to wider adoption of these systems, electrochromic glass is expected to account for a larger share of the market in the coming years.
Applications:	• Phase Change Materials: New commercial buildings, exterior wall construction • Cement alternatives: New commercial buildings • Advanced Glazing: New commercial building (corporate and government buildings likely to be earliest adopters)
Benefits:	• Efficiency / Load Reduction • Emissions reductions (including embodied carbon) • Long-term cost savings • Increased occupant comfort
Other Considerations:	• Initial cost will be of primary concern for each
Alternatives:	Traditional materials, increased insulation and thermal mass to support passive design strategies. Additional strategies for addressing embodied carbon may include: • Use of durable and long-lived materials • Design for disassembly and reuse • Use of and multi-attribute Environmental Product Declarations

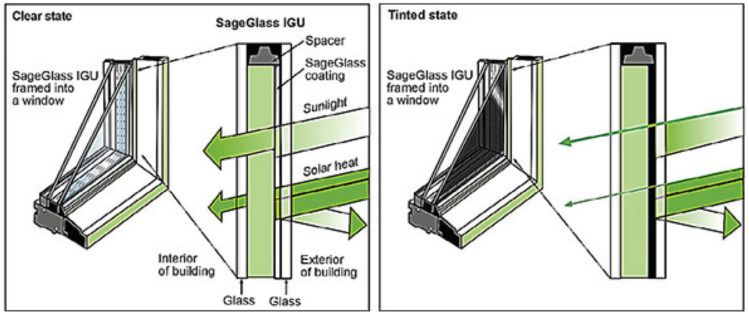


Image Source: Energy.Gov / SAGE Electrochromics

NZAP Enabling Technology Review

ES

Thermal Energy Supply	
Summary:	Emissions from natural gas consumption make up the largest portion of community-wide GHG emissions in Cambridge next to grid-supplied electricity. While there continues to be emphasis on increasing the amount of renewable generation resources used for electricity supply, until recently, less focus has been given to use of alternative fuels in the natural gas supply. Two strategies that have been discussed as viable solutions are the blending of green hydrogen with natural gas to reduce the emissions intensity of gas supply and the creation of geomicrodistricts which are scalable geothermal systems that provide ground-tempered fluid to GSHP units at multiple buildings, along a street or in a neighborhood for heating and cooling.
Notable Change:	Notable changes in these technologies since 2015 include: • There is significant momentum now within the major natural gas utilities to develop cleaner gas supply strategies and alternatives to natural gas including producing hydrogen from renewable energy resources and blending that within natural gas and scalable geothermal systems. • Hydrogen has received more attention recently as a viable fuel when generated from renewable electricity resources.
Applications:	• In addition to supplementing natural gas, Hydrogen may be used to heat buildings, fuel transport, provide heat to industry, and be a medium to capture value from surplus renewables • Geomicrodistricts are best suited for low and medium density residential and mixed-use neighborhoods.
Benefits:	• Diversify heating options for homes and businesses • More efficient use of thermal energy with lower emissions • GSHPs more cost-effective for building owners to install district interconnect is available
Other Considerations:	Green Hydrogen: • Impacts of blending hydrogen with natural gas on building equipment not well understood Geomicrodistricts: • Site constraints may limit feasibility • Not able to meet all heating and cooling loads of all customers • Environmental permitting needs • Cost to owner depends on the existing heating and cooling systems of buildings
Alternatives:	Electrification and reliance on RECs or offsets to achieve carbon neutrality

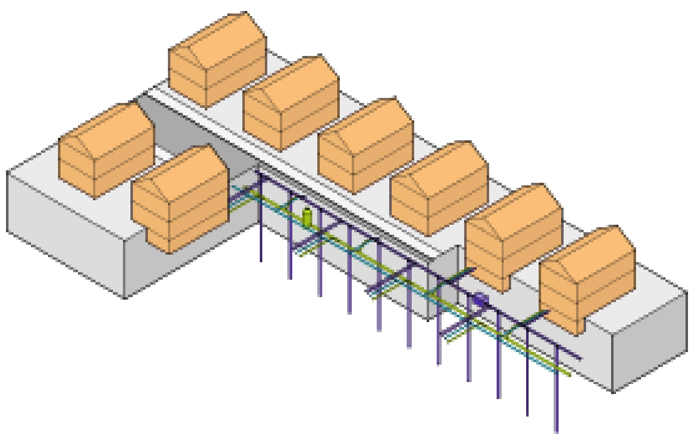


Image Source: HEET / Geo Micro District Feasibility Study

NZAP Enabling Technology Review

ES

Grid-scale Renewables	
Summary:	Within this category we cover power from wind, microgrids, and off-site renewables as the markets for these have continued to evolve over the last 5-years. For wind, significant movement has occurred in the development of offshore windfarms along the East Coast including New England. This development will be relevant to Cambridge with respect to the RPS and electricity generation fuel mix in the coming years. The market for microgrids has also continued to develop and the role of microgrids in energy supply and management will likely expand in the future. We expect to see more small-scale local microgrids in communities taking advantage of decentralized power generation opportunities, such as community solar systems. And since 2015, numerous potential pathways for building owners to purchase off-site renewables have opened including Self-own options, community projects, PPAs and Virtual PPAs, Unbundled RECS, Wholesale markets, investment funds, and aggregation programs.
Notable Change:	Notable changes in these technologies since 2015 include: • Offshore wind farms along the east coast are now nearing the construction and build-out phase with major portions of the build-out occurring over the next 10-years. According to ISO New England 68% of interconnection proposals relate to wind (over 14,000 MW). • To assist with Off-site renewables procurement, the city is considering a form of aggregation or a renewable energy investment fund in which building owners could participate in that would simplify off-site RE purchases for building owners and ensure the generation sources meet city criteria. • The microgrid market and deployment continues to mature driven by demand for uninterrupted, reliable power supply needs and interest in electrification.
Applications:	• Offshore wind will factor into the RPS and may influence the emissions intensity of grid supplied electricity. • Any building owner in the city looking to achieve net zero energy status • Microgrids are most common for campuses (see MIT), but “virtual” microgrids are more flexible and can serve a variety of customers.
Benefits:	• Wind resources provide an emissions-free source of electricity • Off-site renewable is seen as a significant strategy for achieving NZAP goals • Microgrids can provide a reliable and resilient solution in times of main-grid instability or outages
Other Considerations:	For microgrids: • Neighborhoods may seem appropriate setting, but conflicts with utility laws and providing electricity across property line needs to be considered Offshore wind: • Development depends on permitting, demand and available shoreside infrastructure

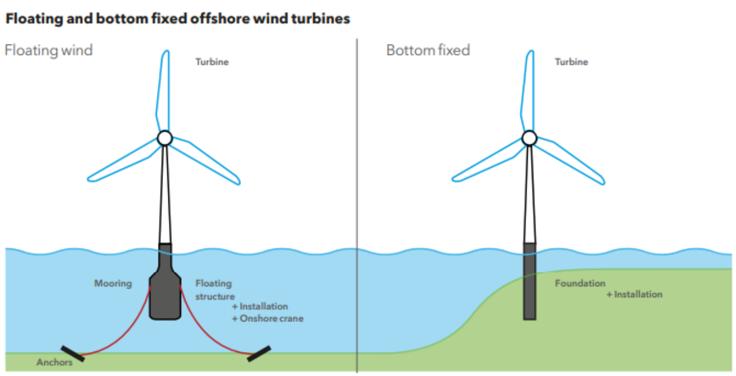


Image Source: DNV GL Energy Transition Outlook

Thank You!

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