It's Electric!

The objective of this challenge is to increase electrification of U.S. buildings (residential, commercial, new, or existing). Student team solutions should lead to reductions in energy use and carbon emissions through electrification solutions, and students should emphasize reducing inequalities in obtaining technologies for identified stakeholder groups.

Background

The United States has a long-term goal to decarbonize the electric grid.[1] This will require several market transformations across multiple sectors, including renewable power generation and storage options, increased energy efficiency adoption and timely use of energy across homes and places of work, and a shift away from burning fossil fuels for all appliances and equipment. Buildings will play an integral role in achieving decarbonization objectives, and eliminating the burning of fossil fuels, also known as electrification, will be a crucial step.

Buildings directly burn fossil fuels, such as natural gas and propane, often for space heating and water heating, as well as various appliances (e.g., cooking, clothes drying). In 2021, nearly 48% of energy consumed by the combined residential and commercial building sectors came from directly burning fossil fuels.[2] This represents almost one-fifth of all energy consumed by the United States each year.[3] In 2020, the residential and commercial sectors were the main consumers of energy, accounting for 40% (i.e., 22% and 18%, respectively) of the total U.S. energy consumption.[4] Space heating accounted for 43% of total energy in residential buildings in 2015, where 69% of energy for the space heating was provided by the natural gas.[5] Only 14% of energy for space heating is provided by electricity.[5]

Natural gas is the primary space heating and water heating fuel source for nearly half of all commercial buildings and is the main commercial fuel source in the Northeast, Midwest, and West.[6] In addition to natural gas, nearly 10% of commercial buildings report using propane and fuel oils for space heating, leaving approximately 30% currently utilizing electricity as the primary source for space heating.[3]

Such a substantial transformation across the residential and commercial building sectors will require innovative solutions, as well as widespread adoption of both new and existing technologies. An example technology requiring both innovation and increased adoption is heat pumps. Heat pumps are an efficient and effective electrification option for both space heating and water heating. It is estimated that less than 15% of commercial buildings utilize heat pumps as heating equipment,[6] and when they are in use, heat pumps are more commonly found in warmer regions of the U.S. There is an opportunity to solve market barriers that limit more widespread adoption of heat pumps in warmer climates, but

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[1] The White House. 2021. "President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability." https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

[2] U.S. Energy Information Administration. 2022. "Natural Gas." https://www.eia.gov/naturalgas/.

[3] U.S. Energy Information Administration. 2022. "Use of Energy Explained." https://www.eia.gov/energyexplained/use-of-energy/.

[4] U.S. Energy Information Administration. 2021. "Monthly Energy Review." https://www.eia.gov/totalenergy/data/monthly/previous.php.

[5] U.S. Energy Information Administration. 2018. "2015 Residential Energy Consumption Survey (RECS) Data." https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce3.1.pdf.

[6] U.S. Energy Information Administration. 2021. "2018 Commercial Buildings Energy Consumption Survey: Building Characteristics Results." https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS_2018_Building_Characteristics_Flipbook.pdf.

also to advance the technology to improve operation and ultimately market transformation in colder climates.

Research has also documented large upfront costs associated with the installation of heat pumps compared to traditional central air conditioning and furnace systems. The New York State Energy Research and Development Authority (NYSERDA) reported that based on 2018 prices, the installation cost of a residential air-source heat pump ranged between 50% and 200% more than conventional central air conditioning systems with a natural gas furnace for heating.[7] This significant increase in costs may limit adoption potential, especially in lower socioeconomic communities.

In addition to high-performance electric technologies that replace fuel-fired equipment, other solutions such as those addressing electrical infrastructure will be required. Consider that almost half of the U.S. housing stock was built before 1970.[8] Unless a home has had a substantial electrical infrastructure upgrade, most of these homes have electrical breaker panels with 100-amp service or less.[9] As appliances and equipment shift away from fossil fuels such as natural gas or propane, new electrical infrastructure will be needed in order to support electrification technologies—at an average cost of $1,300–$2,500 per home to upgrade to 200-amp service,[10] not to mention additional constraints and implications from charging electric vehicles.

The Challenge

This topic challenges student teams to develop an innovative solution that will address electrification in buildings. Students can focus on any aspect related to this transition away from directly burning fossil fuels on-site. Solutions can be considered at the individual building and multibuilding scale. Student teams should first develop a focused problem statement for a specific stakeholder group and then develop a technical solution or process to solve the chosen problem.

Suggestions for student teams include (but are not limited to) the following:

- Develop new equipment or technologies to replace fuel-fired equipment or appliances with high-performance electric options.
- Improve existing electrification equipment or technologies to significantly increase capabilities.
- Develop technologies or processes for right-sizing heat pumps, including technologies or processes that combine right-sizing of heat pumps with other envelope upgrade packages.
- Develop technologies or processes to identify optimal combinations of heat pump equipment and building envelope system upgrades.
- Develop new equipment, technologies, or processes to address electrical infrastructure for homes and commercial spaces to allow electrification of building loads.
- Develop solutions that include advanced controls with specific intent to optimize existing electrical infrastructure to accommodate new electrical loads.

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[7] The New York State Energy Research and Development Authority. 2019. “Analysis of Residential Heat Pump Potential and Economics.” https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/PPSER/NYSERDA/18-44-HeatPump.pdf.

[8] Sarkar, Mousumi. 2011. *How American Homes Vary by the Year They Were Built*. Washington, D.C.: U.S. Census Bureau. Working Paper No. 2011-18. https://www.census.gov/content/dam/Census/programs-surveys/ahs/working-papers/Housing-by-Year-Built.pdf.

[9] Thiele, Timothy. 2022. “How Electrical Service Panels Have Evolved.” The Spruce. https://www.thespruce.com/service-panels-changed-in-the-1900s-1152732.

[10] The Home Guide. 2022. “How Much Does It Cost to Upgrade or Replace An Electrical Panel?” https://homeguide.com/costs/cost-to-replace-electrical-panel.

Student submissions must:

- Describe the scope and context of the chosen problem.
- Identify affected stakeholders, making sure to consider socioeconomically vulnerable and historically excluded, underserved, and frontline communities (communities at the "front line" of pollution and climate change[11]).
- Develop a technical solution to the chosen problem for the targeted stakeholder group. The solution may also include policy solutions, supply chain and manufacturing processes, economic solutions, or other aspects critical to identified stakeholder barriers, but a technical solution must be proposed.
- Discuss appropriate and expected impacts and benefits of the proposed solution. This should include a cost/benefit analysis, a market adoption analysis, and should also consider non-economic costs and benefits, such as occupant health, productivity, and well-being.[12]
- Develop a plan that describes how the team envisions bringing its idea to scale in the market, including sales or distribution channels, outreach mechanisms, stakeholder engagement, and other relevant details.

[11] Initiative for Energy Justice. 2022. https://iejusa.org.

[12] Whole Building Design Guide. 2020. "Consider Non-Quantifiable Benefits." https://www.wbdg.org/design-objectives/cost-effective/consider-non-monetary-benefits.