

How Buildings in the USA are Evolving with Energy Efficiency

Jack Mayernik

The energy system in the USA and the buildings connected to it are evolving to take advantage of an array of technological advancements, helping to ensure a dynamic, sustainable, resilient, economically productive and affordable energy future.

As the United States' economy has shifted away from highly energy-intensive industries, the share has grown of energy used by the US' 127 million residential and commercial buildings. Fortunately, multiple technological advancements and policies have continued to inject energy efficiency, which is keeping America's pace of energy demand from marching in lockstep with its population and economic growth. Yet buildings - places in which we spend close to 90% of our lives - still use a disproportionate share of the nation's energy.

Characteristics and energy use of buildings

Today, US buildings use more energy than any other sector in the country and account for nearly 40% of the nation's total energy use, almost 75% of its electricity, and in some regions for some 80% of peak electric power demand. This results in an annual energy bill of \$415 billion USD, plus America's households and commercial buildings are the source of 36% of US CO₂ emissions. Of course, there is great diversity within this: for residences, space heating (23%), cooling (13%), and water heating (13%) together account for almost half the energy people use, while for commercial buildings, heating, ventilation, air conditioning, refrigeration (HVACR) (38%) and lighting (16%) represent just over half the energy use.

The sheer size of the USA means these consumption patterns vary considerably by building type, construction materials and across eight different climate zones. Unfortunately, much of this energy is wasted – estimates of energy inefficiency are in the double digits of percentage and range widely depending on technical and economic assumptions; for example the US Lawrence Livermore National Laboratory has estimated that 35% of energy in buildings is rejected, not counting upstream losses in the power sector. This level of waste is not surprising, especially when considering that the average American building is over 40 years old and was built before more stringent buildings codes and practices were in place.

Energy is changing in the US

There are many changes taking place regarding energy in the US. On the supply side, the US is projected to be a net energy exporter by 2020, largely due to the shale gas and oil revolution and increased export of liquefied natural gas. In the power sector, over 75% of electricity comes from fossil fuels (57%) and nuclear power (20%). But that is changing in that utilities used 34% less coal in 2018 than they did in 2010, and coal's share of the US generation mix is expected to continue shrinking from its peak in 2005. Hydropower (9%) has been surpassed by other renewables (13%), and these trends are expected to continue.

The ability to store this electricity is also changing rapidly, as it is around the world. Since 2014, utility-scale battery storage power capacity has more than quadrupled in the US. Once every facility planned as of 2019 comes online by 2023, US capacity will have tripled to over 2500 MW. And this is only half of the story. Throughout 2018 and continuing into 2019, about half of the US' total new capacity came online behind-the-meter in building-sited batteries, for instance, and these trends are only expected to accelerate as battery costs halve over the next ten years. And that

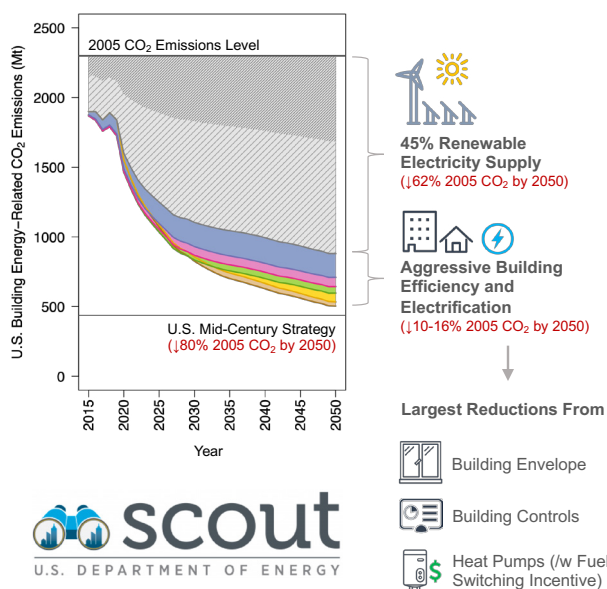
does not consider the enormous potential in building and equipment-level thermal energy storage, which is an exciting opportunity for buildings, particularly regarding peak power reductions and other load-shaping in areas with sharp peaks (usually due to air conditioning) and / or steep afternoon ramps due to highly variable renewables generation.

American energy policy and research strengthen the building-energy relationship

Since buildings use more energy than any other US sector, they have an enormous opportunity to influence America's energy sector as a whole. New analysis confirms this, with researchers at US DOE's Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory finding that by using aggressive efficiency measures, electrification, and high renewable energy penetration, US buildings could reduce their share of CO₂ emissions (currently about 36% of the nation's total) by between 72% to 78% by mid-century, relative to 2005 levels. They identified the necessary steps to meet that huge potential, including: efficiency and low-carbon electrification are required to achieve this impact; reductions are driven by heating energy use in existing residential buildings; envelope, controls, and fuel-switching measures drive cost-effective reductions. While this analysis provides a path for how buildings

can leverage the increasing share of renewables, connected devices, electric vehicles, batteries across a modernizing grid, how is this unfolding here today? Before answering this, it is important to know that energy policies are made and administered across various jurisdictions in the US, at the national, state, and local / municipal levels as follows:

- At the national level the US Department of Energy (DOE) sets minimum energy performance standards for a large variety of appliances and equipment. DOE regulates over 60 different product classes, which cover about 90% of energy use in homes and 60% of commercial building energy use. These minimum standards have been enormously successful, saving US consumers over \$63 billion USD in 2015 alone and more than \$1 trillion USD cumulatively, and have cumulatively helped the country avoid 2.6 billion tons of CO₂ emissions. The majority of publicly funded R&D into energy efficiency in the US is done by the Federal Government, including my office, the US Building Technologies Office (BTO), which works with National Laboratories, academic institutions, corporate research centers and others to conduct R&D on energy efficient lighting, HVAC, sensors and controls, windows and building envelopes, building energy modeling, building design, indoor air quality, thermal energy storage, and much more. The Federal Government is also active in creating voluntary industry efficiency standards and providing reliable labelling of energy use, including through the EnergyStar label.
- Building energy codes and standards are principally set in the US at the State level (excepting manufactured housing and federal housing), with nearly all State amending and adopting their energy codes based on national model energy codes developed by the ICC and ASHRAE. Most demand-side and efficiency-related utility regulation in the US is also done at the State level, typically via public utility commissions that regulate the conduct of utilities. Key measures such as energy efficiency incentives, rebates and programs, Energy Efficiency Resource Standards, and renewable portfolio standards are established at state-level, either by the commissions or state law.
- Local jurisdictions, namely cities and counties, are increasingly involved in energy efficiency. They are usually responsible for enforcing (state-adopted) building energy codes and in recent years US cities have adopted energy disclosure ordinances and set



The US mid-century strategy for reducing building energy-related CO₂ emissions based on a renewable electricity supply and aggressive building efficiency improvements and electrification. Source: US Department of Energy

aggressive energy goals, for example as New York City did in early 2019 by requiring owners of its largest buildings to slash their carbon emissions 40% by 2030 and 80% by 2050.

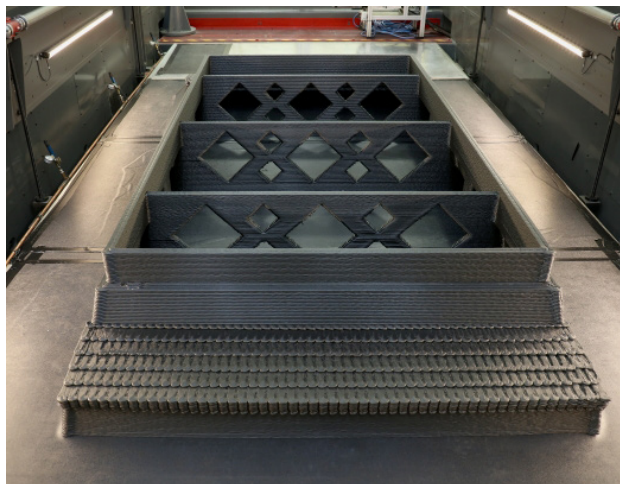
Within the US Department of Energy, BTO has numerous initiatives focused on advancing energy efficiency. I am excited in particular by two cross-cutting initiatives, 'Grid-interactive Efficient Buildings' and 'Advanced Building Construction', which truly align with EBC's mission to develop and facilitate the integration of technologies and processes for energy efficiency.

BTO's Grid-interactive Efficient Buildings and Advanced Building Construction initiatives

As a critical mass of next-generation building technologies comes to market, buildings no longer need to be static consumers of energy. Rather, they can be, and are increasingly active participants in the electrical grid, providing many grid services that utilities typically get from traditional supply-side assets. But we are not yet at the scales needed to truly transform the energy sector. So BTO and our partners are working to advance the existing technical capabilities of buildings so they can optimize the interplay between energy efficiency, demand response, building-sited PV, energy storage, electric vehicles and other distributed energy resources. Simply put, efficiency in buildings can reduce, shed and / or shift, their electricity demands to become truly grid-interactive, while also being energy efficient, affordable and comfortable.

Two sets of grid-interactive efficient buildings, known as Smart Neighborhoods, recently opened, the result of a collaboration of DOE, the Oak Ridge National Laboratory, Southern Company (a major utility company), two homebuilders, and others. In 2019, a neighborhood of 46 highly efficient, PV-enabled, smart and connected townhomes (row houses) opened in Atlanta, Georgia, joining its 'sister' neighborhood of 62 homes outside Birmingham, Alabama. These are both living laboratories where we are evaluating how these technologies and control systems are optimizing each neighborhood's energy performance. They are among 49 planned or operational smart and connected communities in the US today.

Our other principal initiative, Advanced Building Construction, is trying to tackle two stubborn, related problems in our field: The first of these is how to increase the use of energy efficiency retrofits in existing



A 3D-printed mold used for manufacturing precast concrete façade panels at the redeveloped former Domino Sugar Refinery in Brooklyn, New York.

Source: Oak Ridge National Laboratory, US Department of Energy

buildings and, the second is how to modernize the technologies used by the construction industry for both new construction and retrofits. After all, if innovations such as additive manufacturing (3-D printing), offsite manufacturing, modularization, robotics, and digitization are revolutionizing manufacturing in the US and around the industrial world, is there a role for them in construction and retrofits, and in making energy efficiency in buildings more productive and affordable, and less disruptive to occupants? Recently, one of our related projects bore fruit, using 3-D printing to more affordably and sustainably manufacture molds for precast concrete panels that line the textured façades of the redeveloped former Domino Sugar Refinery in Brooklyn, New York. This not only led to greater construction productivity, but also enabled allow new concrete panel designs that are more energy efficient and passive solar-capable. And while both of these initiatives support DOE's RD&D priorities, together they also align closely with EBC's strategic objectives.

Further information

<https://flowcharts.llnl.gov/>

[https://www.energycodes.gov/](https://www.energycodes.gov/status-state-energy-code-adoption)

[status-state-energy-code-adoption](https://www.nrel.gov/state-local-tribal/basics-portfolio-standards.html)

<https://www.nrel.gov/state-local-tribal/basics-portfolio-standards.html>

<https://www.energy.gov/eere/buildings/>

John (Jack) Mayernik is the Alternate EBC Executive Committee Member for the USA.