Center on Global Energy Policy at COLUMBIA | SIPA

February 2023

Decarbonizing the Global Buildings Sector: Efficiency, Electrification, and Equity

By **Ian Hamilton**

The importance of decarbonizing the buildings sector is widely recognized now, with 120 countries citing building energy improvements as a way to tackle emissions in their Nationally Determined Contributions (NDCs).[1] To achieve the Paris Agreement goals,[2] the global buildings and construction sector must achieve net-zero emissions by 2050, and all new buildings must be net-zero carbon starting in 2030.[3] But efforts to address buildings sector energy performance and carbon (CO_2) emissions have not kept pace with these high-level targets. In 2022, the International Energy Agency (IEA) described the sector as "not on track."[4]

This sector lags because of low levels of investment in energy efficiency, a lack of improvement in energy intensity over the past decade, and modest growth in renewable energy.[5] Today, only 44 countries have building energy codes that regulate the energy efficiency of buildings. It is estimated that 82 percent of the population to be added by 2030 will be living in countries currently without such energy codes.[6] With floor space expected to grow to more than 286 billion square meters by 2030,[7] which is a growth of 20 percent from 2020, buildings will be among the fastest-growing source of energy demand, particularly among developing economies improving their access to modern energy services, such as cooling.[8]

The challenge for the buildings sector is choosing actions to support rapid decarbonization in the near term, alongside expanding access to sustainable, affordable, and clean energy. This commentary analyzes the pathways for building decarbonization that are focused on increasing energy efficiency through technologies and expanding building electrification and electricity grids to support the transition to clean energy. It considers the impact of multiple ongoing crises, from energy costs to climate change, on buildings sector decarbonization. Finally, it argues that decarbonization of the building stock must be designed to support broader sustainability objectives that go beyond the singular focus on emissions reduction to addressing systemic energy inequities.

Direct and Indirect Emissions from Buildings

The global buildings sector consumes an estimated 30 percent (or 127 exajoules) of global energy in the forms of electricity, fossil (natural) gas, and liquid and solid fuels for heating, cooling, cooking, lighting, and equipment uses. It is responsible for around 27 percent of global energy-related CO_2 emissions, which adds up to 10 metric gigatons of carbon dioxide per year.[9] Of these emissions, 32 percent are directly from fossil gas, fuel oil, kerosene, etc., and 68 percent are indirectly from electricity. When the production of materials used in the construction of buildings is accounted for, the buildings sector's share of energy use and emissions rises to 36 and 37 percent, respectively.[10]

Additionally, the sector will need to address the balance of decarbonization actions between direct and indirect emissions in the near term while not limiting mitigation options or creating path dependencies that result in future problems for the sector or the electricity grid.[11] For example, decarbonizing the electricity supply through renewables will reduce indirect emissions as well as direct emissions through a shift away from fossil fuel gas to electric-based heating in buildings. But this could have a significant impact on the electricity grid load if the energy efficiency of the building fabric is not considered as part of the process.

Reducing direct emissions: The IEA estimates that efficiency could contribute to around 25 percent of the reductions needed to decarbonize the buildings sector to reach net-zero emissions by 2050. Energy efficiency investments can reduce the demand for energy for services such as heating, cooling, lighting, and ventilation. A further 30 percent reduction could come from direct use of renewable energy, such as photovoltaics (PV), solar thermal hot water, and hydrogen. The remaining 45 percent of direct emissions reduction would come through building electrification.[12]

Reducing indirect emissions: According to the IEA, increasing the electrification of buildings using technologies available today, alongside a decarbonizing grid, is the primary solution for addressing building emissions from indirect sources.[13]

The Role of Technology-Driven Energy Efficiency to Achieve Building Decarbonization

Technological options to improve energy efficiency and decarbonize the buildings sector have been available for the last two decades.[14] These include high-performance and low-cost insulation materials, units glazed with solar control films and gases, high-efficiency heating and cooling systems, high-performance appliances and equipment, and smart and digital control systems.[15] However, the diversity and complexity of buildings as systems and their varying uses and ownership structures have resulted in persistently slow adoption of these technologies.

The IEA estimates that achieving the net zero by 2050 target would require the buildings sector to realize an average energy intensity improvement of 4–5 percent per year between now and 2050. New buildings need to be built to higher performance standards and through codes aligned with achieving net-zero emissions. For example, the British Columbia Energy Step Code sets out a clear pathway toward net-zero-ready buildings by 2032 and fully zero-carbon buildings by 2050 as the utility grid decarbonizes.[16] However, existing buildings—the majority of the current building stock—also need to be net-zero ready or able to operate at zero emissions as grids decarbonize. This could require installing more than 1.8 billion heat pumps and 1.2 billion solar thermal systems, adding around 7,500 terawatt-hours of building-integrated PV generation, and improving the energy efficiency of household appliances by 40 percent compared to today.[17]

Those working toward building decarbonization face choices.

Buildings can become more energy efficient through either an incremental approach or targeted deep renovations. The former involves adopting retrofits when renovating a building or upgrading to a high-performance system at its end of life. The latter is a multisystem upgrade to achieve a high-performance standard. A deep retrofit is often a high-cost and high-disruption activity, leading most efficiency retrofits to be done with an incremental, piecemeal approach.[18] A way to improve this approach is to upscale the overall activity of retrofitting in buildings in order to reduce costs and improve practice. For example, Europe's Renovation Wave aims to at least double the annual energy renovation rate of buildings by 2030, with a goal of renovating more than 35 million buildings by 2030.[19] Increasing the market activity of energy efficiency renovations in buildings in Europe may bring down technology costs and give installers more experience with these renovations. Likewise, regulators and those implementing standards will better understand where attention is needed to avoid the unintended consequences of poorly implemented renovations.

Technologies should have the effect of reducing energy demand without decreasing a building's productivity, comfort, and use. This requires a focus on the wider benefits and co-benefits that building decarbonization can offer building users, such as bill savings, comfort, and health as well as secure and resilient energy systems. Broader benefits for society (e.g., increasing generational value) and the economy (e.g., jobs, investment, and cost savings) should also be considered.[20]

The Role of Electrification in Achieving Building Decarbonization

The electrification of buildings is a key action that will enable buildings to become zero-carbon-emissions ready by phasing out direct use of fossil fuels alongside adding onsite renewable generation and a renewable-powered electricity grid.

Electrifying buildings means eliminating the use of fossil-fueled gas appliances, such as those used for space and water heating and cooking, in order to reduce direct emissions from oil and fossil gas furnaces used for heating. Many governments are developing bans on fossil fuel appliances and heating systems or are banning connection of new buildings to gas grids. Fossil fuel bans are accelerating a shift toward electrification and alternative renewable fuels, such as hydrogen and renewable heat networks. A number of countries have implemented national, state, and city bans on certain types of heating systems (see Table 1).

Table 1: Governments that have implemented bans on fossil fuel appliances in buildings (select list)

United Kingdom	The UK has set a goal to prohibit the installation of gas heating systems and boilers in new homes starting in 2025, and a ban for all buildings by 2035.[21]
European Union	Germany has implemented an implicit ban on fossil fuel heating by requiring that all newly installed heating systems be at least 65 percent powered by renewable energy starting in 2024.[22]
	Austria has set a ban on fossil fuel boilers from 2023 onward.[23]
	The Netherlands will require that all newly constructed buildings either include a heat pump or be connected to a heat network from 2026 onward.[24]
Canada	The City of Vancouver and province of Quebec have set requirements for new buildings to be zero emissions and have banned the replacement of space heating and hot water systems powered by fossil fuels in new construction.[25]
United States	In California, 50 cities have either banned or discouraged the use of gas in new buildings.[26] In New York, Ithaca has proposed a policy to ban gas by 2030, and New York City has a goal of ending gas use by 2040. Elsewhere, some cities, such as Eugene, Oregon, have already implemented a ban on natural gas in new construction.

Source: Department for Business, Energy and Industrial Strategy (BEIS), UK; Federal Ministry for Economic Affairs and Climate Action (bmwk.de), Germany; Climate Action, Environment, Energy, Mobility, Innovation and Technology (bmk.gv.at), Federal Ministry Republic of Austria; central government, the Netherlands; CBC News; Sierra Club.

The primary technology under consideration for heating and cooling electrification is heat pumps. Alongside heat pumps, district or community heating and cooling networks can also be developed or converted to deliver low- or zero-carbon energy.

Heat pumps

Heat pumps use refrigerant gas to transfer heat from an external source (such as air, water, or the ground) to an internal heating system (such as air or water). They are an efficient way to heat buildings and water because of their ability to achieve a high seasonal coefficient of performance (COP), which is a measure of the average annual energy efficiency of a system and can range from 3.5 to 7 in moderate climates, depending on the system's configuration.[27] By comparison, a typical modern gas boiler will have a COP of around 0.93 at best, meaning that heat pumps can be many times more efficient than traditional boilers under optimal conditions.

The global market for space and water heat pumps is rapidly growing. The total number of heat pumps installed in Europe by 2022 is estimated to be 14.9 million units, of which more than 2.2 million units were installed in 2021.[28] Many European countries have plans to further increase the use of heat pumps in their energy mix. France leads with more than 500,000 heat pump units installed in 2021, and France, Italy, and Spain have targets to significantly increase their heat pump capacity by 2030. Heat pumps are commonly used for both heating and cooling in southern Europe, with cooling being their primary function because of the region's warmer summer weather. In other parts of Europe, particularly in northern countries, heat pumps are primarily used for heating.

In the United States, a recent study found that in regions with fewer than 6,000 heating degree days (areas south of Detroit), electric heat pumps are the most cost-effective and low-emission option compared to fossil fuel systems. California has adopted codes that incentivize compliance through both building integrated PVs and the use of electric heat pumps for space and water heating.[29]

As a global market, heat pump installations are expanding. According to the IEA,[30] in 2020, Europe accounted for only 12 percent of total sales, while North America and other developed economies made up 50 percent. Among developing economies, China's share was 33 percent while other developing economies accounted for 4 percent. In the global heat pump market, 83 percent of heat pumps were installed in the residential sector, 14 percent in the commercial sector, and 3 percent in the industrial sector.

To be most effective, the installation of a heat pump should be done alongside improving the energy performance of the building envelope. In well-insulated homes and buildings, heat pumps can be sized to a lower heating design temperature, reducing their size and cost.

Heating and cooling networks

With significant investments in new pipelines and heating and cooling exchange units, buildings can also benefit from converting existing energy networks to zero carbon emissions. For example, the Toronto deep lake water cooling system provides cooling to more than 100 commercial and mixed use buildings and saves an amount of electricity equivalent to that used by a town of 25,000 houses.[31] Similarly, fossil gas infrastructure can be transitioned to hydrogen, with appropriate upgrades to avoid pipeline degradation, challenges with inconsistent metering, and gas leakage.[32] The United Kingdom estimates that blending a mix of up to 20 percent hydrogen into the fossil gas grid would reduce CO_2 emissions by 66 percent compared with 2014 levels.[33] However, to align with the Paris Agreement, the source for the hydrogen must be "green," or derived from renewable and zero-carbon sources.[34]

Electrification and heat pumps also support the global demand for cooling, estimated to increase from 20 percent of all electricity used today to 37 percent by 2050.[35] The number of air conditioners globally is expected to increase 50 percent by 2030 from an estimated 2.2 billion units in 2021,[36] posing the additional challenge of rapidly increasing peak loads on electricity systems. The challenge will be to ensure that the electricity grid is capable of decarbonizing rapidly through technological advancements that ensure variable load demands from increasing cooling and on-site renewable generation are met.[37]

Implications for the Grid

To achieve net-zero emissions globally, the IEA estimates that global investments in electricity grids will need to more than double, from around $300 billion per year in the 2016–2020 period to more than $600 billion per year, on average, during 2026–2030. The increase will need to occur primarily in emerging and developing countries and have a focus on digitalization.[38]

Decarbonizing the grid can enhance energy security, but only with proper planning, investments, and timely actions to avoid a strain on the power system during the transition. Distributed energy resources, such as solar PV panels, batteries, and other major distributed loads like air conditioners, are rapidly expanding. It is crucial to manage their growth to maintain system reliability, control costs, and ensure that utility business models keep pace with these changes.[39]

Moreover, electricity systems are at a high risk of disruptions caused by climate-related events.[40] Climate change is leading to more variable precipitation patterns, rising sea levels, and extreme weather events that have an impact on every aspect of the power system, including the efficiency of generation, resilience of transmission and distribution networks, and demand patterns.

Headwinds for Decarbonizing the Building Stock

There are significant challenges to realizing the ambition of decarbonizing the global buildings sector. These include regulatory and financing barriers and the scale of technological change required in replacing heating and cooling systems and refurbishing hundreds of millions of buildings around the world. Over and above these, rising energy costs and the high burden of energy efficiency investments on consumers present immediate challenges.

Rising costs: Since the start of 2022, energy costs have been highly volatile, accelerating and declining at rates not seen since the global financial crisis of 2008 and the Organization of the Petroleum Exporting Countries (OPEC) oil crises in the 1970s.[41] Steep rises in energy costs have been a shock to monthly energy expenditures at a time when inflation overall is eroding purchasing power.[42] The effects of the COVID-19 pandemic on supply chains have also made it more costly to transport materials and goods to building construction and renovation markets.

In their reaction to these challenge conditions, central banks across the Organisation for Economic Co-operation and Development (OECD) are addressing inflation by raising interest rates. By December 2022, the US Treasury, for example, has seen the short-term interest rate increase to 4.44 percent from 0.22 percent in January 2022; the eurozone has increased rates from 0.50 percent to 2.75 percent during the same period.[43] Increasing borrowing costs will have a dampening effect on overall expenditure—including energy efficiency investment—on top of the higher cost-of-living that's constraining spending on energy and other household goods.

An energy affordability crisis: Typically, investments in large-scale efficiency programs or utility decarbonization are secured at low credit costs, but building energy efficiency investments are borne by households and energy consumers, often at high costs of credit, because these types of loans are not securitized. The European Investment Bank estimates that around 70 percent of the investment in energy efficiency by 2030 is expected to come from final energy consumers, with future investments coming from energy suppliers.[44] In most European and North American economies, households face both higher energy prices and higher borrowing costs for energy-efficient renovations, leaving many without the means to reduce their energy costs. The United Kingdom, for example, risks seeing more than half of all households falling into fuel poverty by January 2023, despite a fuel price cap that aimed to limit bill increases, while businesses have almost no protection against these rising costs.[45]

Even before interest rates began to increase, however, energy efficiency investments were typically seen as more risky. Energy efficiency investments should reduce individual loan interest rates due to their effect on lowering energy costs, and therefore increasing available savings that lower risk of default.[46] Yet this benefit is often not realized in the buildings sector because these loans are grouped with more volatile investments.[47] With credit becoming more expensive, energy efficiency investments could be delayed, hindering the decarbonization of building stock.

Toward Equitable Building Decarbonization

Who benefits from building decarbonization is a critical question policy makers must address. In 2015, the rate of energy poverty or energy insecurity in the United States was estimated at nearly one-third of all households.[48] This is likely to be higher than ever in the current cost-of-living crisis, especially among low-income households that identify as Black and Hispanic.[49] Policies and programs will need to be designed so that the ownership of the low-carbon future is reflective of the diversity of the wider community. The European Renovation Wave is prioritizing efforts to lower energy bills, particularly among low income households, as part of improving housing energy performance.[50] The United Kingdom's Energy Company Obligation seeks to simultaneously reduce carbon emissions and energy poverty through targeted fabric and heating system retrofit measures for households with means-tested benefits and in poverty conditions.[51]

Improving energy and building system quality and resilience in the face of climate change and more intense weather patterns is vital, particularly for households living in poor quality buildings facing higher risk of poverty and poor health.[52] In the United States, the risk of flooding among low-income and affordable housing is likely to triple by 2050.[53] Developing programs that reduce risks of disruption and enhance energy security need to be a part of the decarbonization transition.

The question of who will take part in delivering the decarbonization agenda needs to be addressed so that workers from various skills and backgrounds will be enabled to join the low-carbon workforce. The installation of high-performance systems and advanced building systems will require a significant increase in skilled labor. For example, the European Renovation Wave estimates that 160,000 additional workers are needed to meet the target of 32 million buildings refurbished by 2030. The United Kingdom may need more than 350,000 additional full-time jobs to achieve the 2050 net-zero goals for the buildings sector,[54] and similar numbers are required for decarbonizing the energy grid.[55] This workforce needs to reflect the broader community who will share in the benefits that the decarbonization agenda will realize.

A concerted effort to lower borrowing costs for energy-efficient investments will help consumers, particularly those from marginalized communities, with the transition. These efforts could include expanding government and utility programs that provide energy as a service or lower the cost of financing for energy efficiency.

Conclusion

The technology and financing solutions needed to decarbonize the global building stock are available today. However, to truly realize a sustainable transformation, equity needs to be at the heart of the transition toward net-zero-carbon buildings, whether through addressing fuel poverty, investing in marginalized communities, upgrading infrastructure, or reducing costs to support greater clean energy access for marginalized communities. Now is the time for policies and programs to push forward an agenda that enables the decarbonization transition toward an equitable built environment.

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