The heating decarbonisation challenge: how electrification and cost-effective insulation can displace fossil fuels

Global emissions and energy use – residential and commercial space and water heating

Emissions today	Energy use today	Energy use in 2050	
		With the electrification of building heating (e.g., heat pumps and electric radiators)	*+ With strong action to improve building insulation and improve the energy efficiency of heat pumps*
4.1 $GtCO_2$ *10% of global emissions*	16,700 TWh *45% of total buildings energy use* *Of which, 2,600 TWh is electricity*	↓ 14,000-15,000 TWh *Of which, 10,000 TWh is electricity*	↓↓ 8,000–13,000 TWh *Of which, 4,500–8,000 TWh is electricity* But relies on strong policies and actions

The critical need to decarbonise building heating:

- 45% of the total energy consumed in buildings globally is used to heat homes and offices and provide hot water for bathing. Today, this is predominately achieved using gas or oil boilers, with heating accounting for 80% of direct fossil use in buildings.[1] While everyone around the world needs to heat water, most heating demand comes from space heating in buildings in northern latitude countries with cold winters.

- A whole-building approach is required to create zero-carbon buildings. This requires home and commercial building owners to adopt three types of technologies:

    1. Clean heating technologies powered by clean electricity (e.g., heat pumps and electric radiators).

    2. Insulating walls and windows.

    3. Smart technologies that enable households and businesses to flex their energy use to different times of day (e.g., smart energy management systems, rooftop solar panels, and batteries).

Electrifying heating is effective and can be cost-effective relative to fossil fuel boilers:

- Building heating can and should be almost entirely electrified, primarily with heat pumps. In most circumstances, heat pumps can provide low-carbon heat at a total cost of ownership comparable, and in many cases lower, than fossil fuels; this is because, while heat pumps cost more than gas boilers upfront, they are 3-4 times more efficient than a gas boiler and will therefore have lower operating costs if electricity costs less than 3-4 times gas. There is, however, no one-size-fits-all solution. A range of technologies (including various district heat network solutions) will be needed to solve the challenges of specific building types and climate variations.

- In some countries, largely in Europe, hydrogen gas is being considered as an alternative to replace natural gas for heating. However, hydrogen is not a viable alternative to replace gas heating at scale; it is much less efficient (e.g., "green hydrogen" produced via electrolysis would require 5-6 times more electricity than heat pumps to produce equivalent heat input); and it would still require substantial retrofit to boilers and the gas network.

There is a huge opportunity for low-cost insulation improvements:

- Insulating the least efficient homes must be a priority, and combined with heat electrification can lower energy bills and improve comfort levels. For those at lower income levels government support is likely to be required. However, for the average home, deep retrofit is not a pre-requisite for installing a heat pump, as long as radiators and heat pumps are appropriately sized.

1 IEA (2022), *World Energy Outlook 2022.*

- While not a pre-requisite for heat pumps, there is a suite of home improvements, many of which are relatively low-cost (e.g., loft insulation and draught proofing) which can greatly improve living standards, and reduce energy bills. Crucially, better insulation can enable households to effectively "pre-heat" their homes ahead of more expensive peak times and ease demand pressures for clean power systems.

It is possible to almost eliminate all fossil fuel use for residential building heating by 2050 through the deployment of heat pumps and improved insulation.

- This will also halve the 2050 final energy demand for residential heating compared to a business-as-usual scenario that maintains existing oil and gas use.

The resulting electricity demand can be more than halved with efficient heat pumps and insulation.

- The electrification of building heating will mean that electricity used to heat buildings could grow 4-fold, creating challenges for a clean power system based on renewable generation which varies over days and years, and for local electricity grids if they are not sufficiently upgraded.

- It is, however, possible to halve 2050 electricity needs for heating from 10,000 to 4,000–5,000 TWh with improvements in the efficiency of heat pumps (e.g., from ~300% today to 400-500% by 2050) and insulation.

Priority policy actions to tip the dial:

1. Ban fossil fuel boilers in new builds immediately and ban sales of new fossil fuel boilers from 2035 in high-income countries and China.

2. Working with energy companies and technology companies, policymakers should develop street-by-street strategies to replace fossil fuel boilers. These strategies should identify the most appropriate technologies locally (e.g., air-to-water heat pumps, networked ground-sourced heat pumps, etc.), gaps in local supply chains and skills, and should include plans for eventually switching off segments of the gas grid.

3. Reduce electricity prices relative to gas via appropriate power market design and a shift of environmental levies from electricity to gas bills.

4. Commit to retrofitting the least efficient energy properties by 2035 by providing low-cost finance, clear guidance, and support for low-income households.