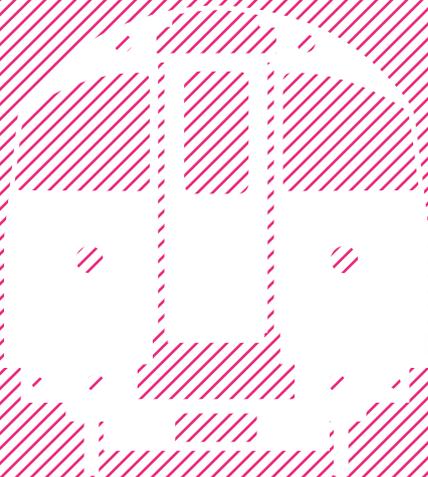


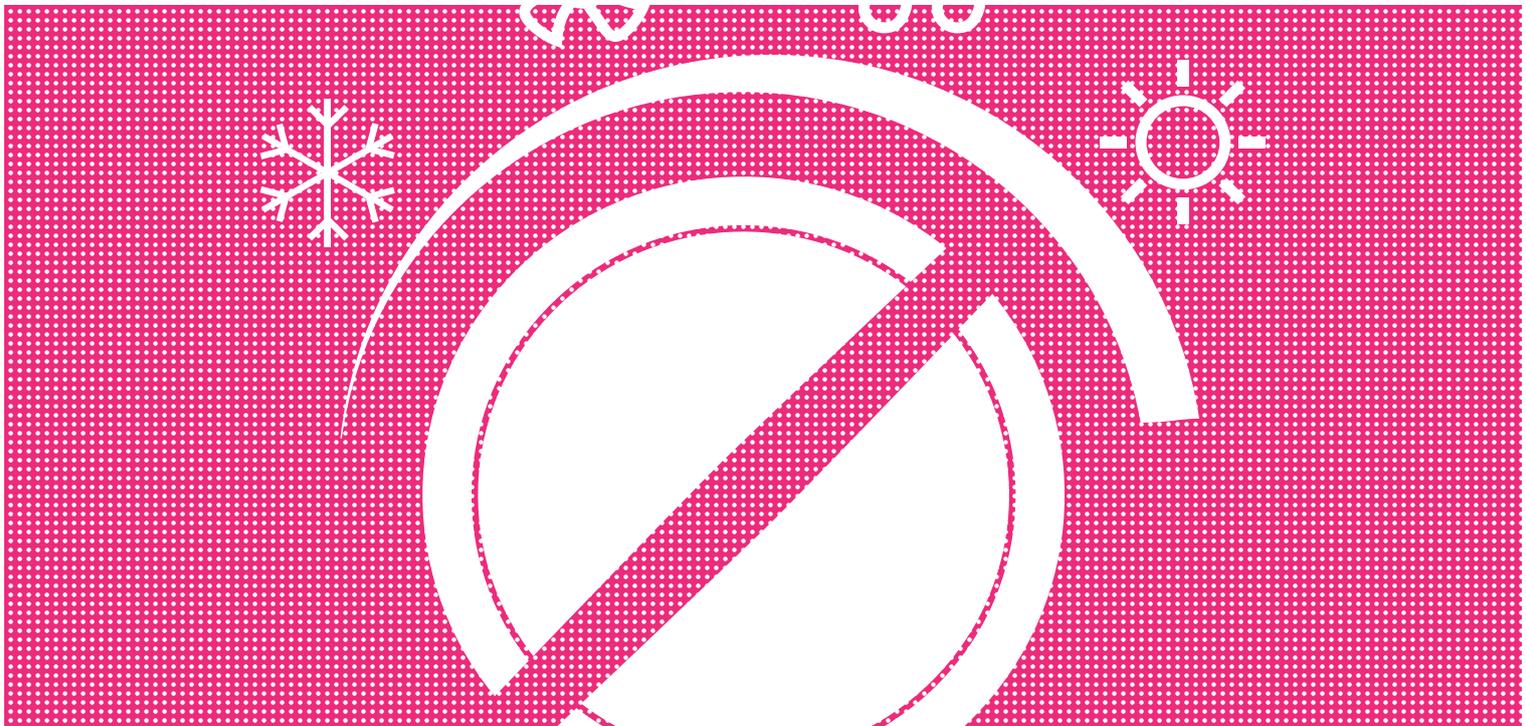
ENERGY FOR
HUMANITY _

ELECTRIFYING HEAT AND TRANSPORT CAPTURE & STORAGE

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A large portion of global CO₂ emissions is created by heating and transport. Electrification of these areas is a leading solution. What are the options?

A low carbon electricity system looks quite plausible. Some combination of nuclear, hydro, gas fired carbon capture, wind, solar and energy storage is practical and reasonably cost effective. Of course there is plenty of room for technology development and policy discussion to determine the optimal combination of technologies and the route to achieve this nirvana. A large portion of global CO₂ emissions is created by heating and transport. Electrification of these areas is a leading solution. What are the options?

Heating creates a large percentage of emissions in countries that have winters, a point often neglected in the focus on low carbon electricity. In UK, for instance, winter gas demand, mostly for heat, is around four times electricity demand. If we electrified space and water heating using conventional 'resistive' heaters, we would need a huge increase in generating capacity, none of which would be solar, since there is very little available in winter.

A portfolio of existing technologies could help to cut demand for fossil fuels in heating, especially natural gas which should be used in higher value applications such as gas fired CCS power generation.

Improved building insulation is critical. Modern regulations mandate high standards, which are generally met, but there is a major need for retrofit technology since buildings have a typical life of 100 years.

Heating and cooling controls must be installed and maintained correctly. This is obvious but does not always happen. Uncomfortable employees are very expensive - energy is not the only cost.

Seasonal storage of heat/cold in subsurface aquifers has been trialled and found effective at larger than residential scale. This can be effective for heating and air conditioning in combination with heat pumps.



Tesla have shown that an electric vehicle (EV) can be a fundamentally better drive, and will add dispatchable demand to the grid.

Heat pumps can, if deployed correctly, provide around 4 units of low grade heat for every unit of electrical energy. The warmer the 'cold' source for the heat pump, and the lower the heat delivery temperature, the higher the efficiency. Air source heat pumps can be effective in areas with temperate winters, but colder regions need ground or water heat sources. Heat can be stored, so heat pumps can be switched on and off to match electrical supply, assisting the integration of inflexible generation such as renewables and nuclear.

All the technologies mentioned exist so the challenge in one sense is 'merely' one of cost reduction and implementation. Lower cost and more effective heat pumps are most desirable.

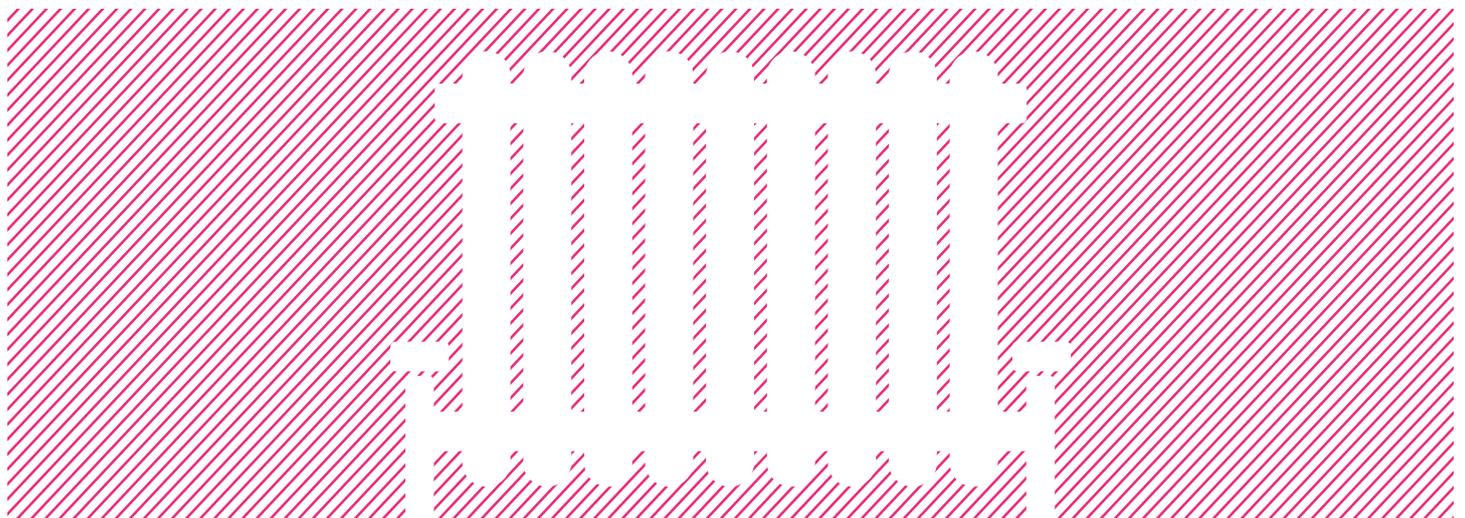
Decarbonising transport is a great challenge, and one we do not need to undertake while there are many opportunities to reduce emissions in other areas at lower cost. There are, however, options for emission reductions which should be pursued, even if they do not lead directly to a zero CO₂ solution.

Liquid biofuels are the most obvious option and one that would apply to all modes of transport if sustainable and cost effective. [See biofuels note.]

Aircraft are rather intractable if sustainable biofuels are not available. More efficient engines, better aerodynamics and advanced route planning / optimisation can cut emissions per trip, but probably not by enough to create absolute reductions in the face of ever escalating demand. Only higher prices are likely to constrain growth.

Ships are already very efficient and weight is not the issue that it is for aircraft. Liquid natural gas creates less CO₂ than heavy fuel oil. Economics plus sulphur emissions regulations are pushing the industry in that direction. Other than biofuels, the only other options seem to be on board CCS (with disposal at destination) or kite wind power, both quite 'original'.

Railways are electrifiable, so not a problem. Long distance trucks and buses may be able to use a combination of batteries, overhead pantographs for recharging and back up engines, perhaps running on sustainable biofuels.



Cars and light trucks can clearly be electrified and Tesla have shown that an EV can be a fundamentally better drive. Reductions in battery cost and weight, preferably brought about in part by elimination of strategic minerals, are necessary and seem to be in progress. EVs will add dispatchable demand to the grid. Given typical vehicle lives of 10+ years, it will take a long time for EVs to become a substantial portion of the global light vehicle fleet, after they begin to form a large proportion of sales.

Hydrogen fuel cells may become economic but there are some of issues that need to be solved: Hydrogen storage and distribution is expensive since it has one third the energy density of natural gas (three times the volume at any given pressure).

Hydrogen filling stations appear to cost order of ten times that required for electric recharge facilities, and no one can refuel at home.

Hydrogen is usually made from natural gas. Unless the CO₂ is captured, the total CO₂ emissions of hydrogen fuel cell vehicles are pretty close to those of a hybrid vehicle running on natural gas. So why bother? Hydrogen can be made by electrolysis of water, but that electricity could, in most circumstances be displacing fossil fuelled power. Hence the effective emissions are that of the displaced power. This also applies to EVs but they use electricity twice as efficiently, so it is less of an issue.

