Beyond electrification: ways to tackle difficult to decarbonise sectors

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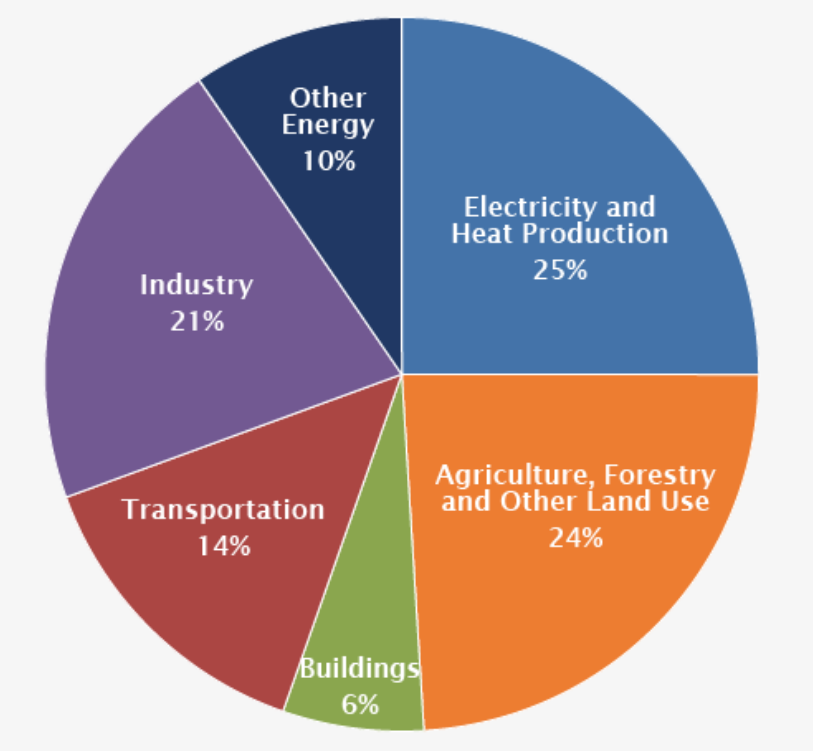
Global GHG emissions



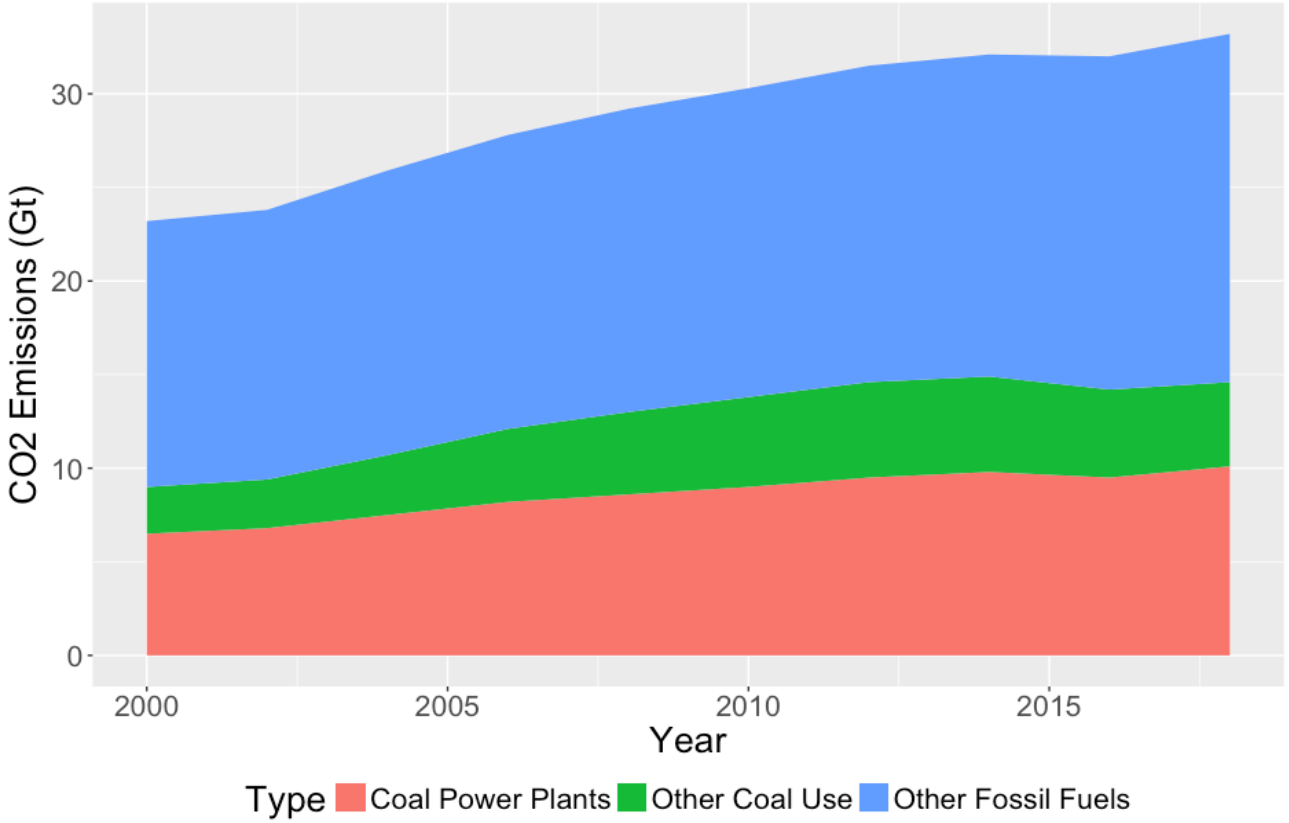
Electricity and Residential Heat – homes, offices and includes electricity demand for industry

Transport - ~95% from petroleum based fuels

Industry – emissions primarily from fossil fuels burned onsite

Source IPCC (2014)

Global CO_2 emissions

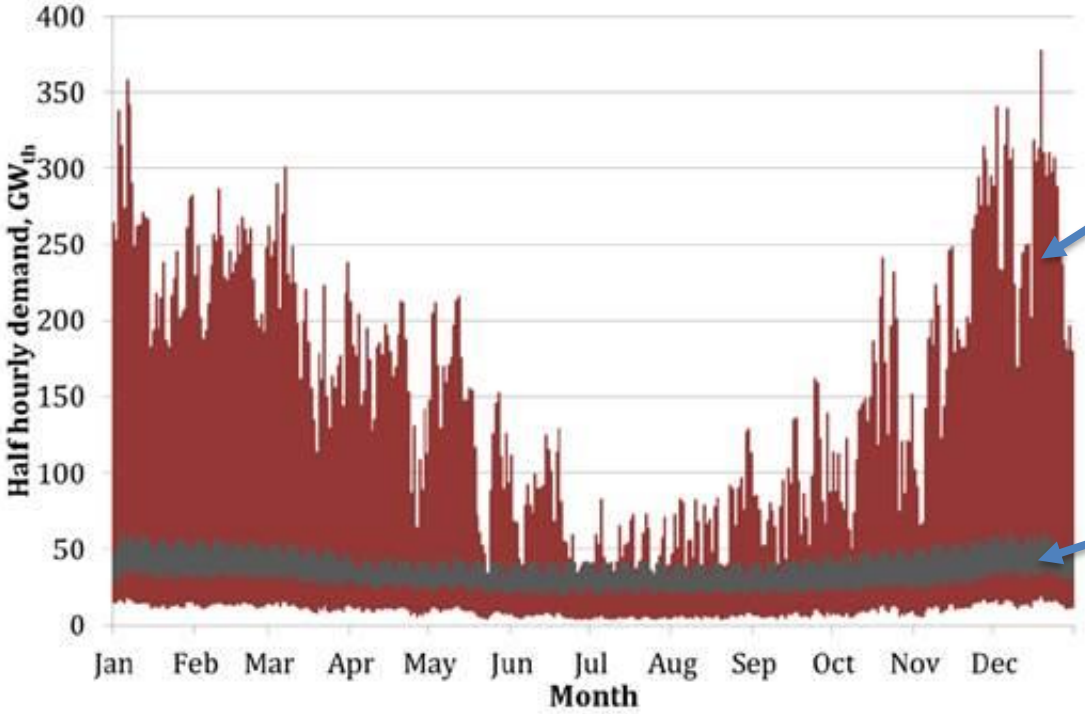


Source: https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions

Electricity and Residential Heat

- There will be a major role for increased electricity use in homes (incl. for heat) and decarbonisation of electricity demand overall
- Electrification of residential heat demand will vary depending on individual countries
- Globally - emissions from electricity sector are rising even as emission intensity reduces (growth outpacing rate of decarbonisation)

Residential heating in the UK

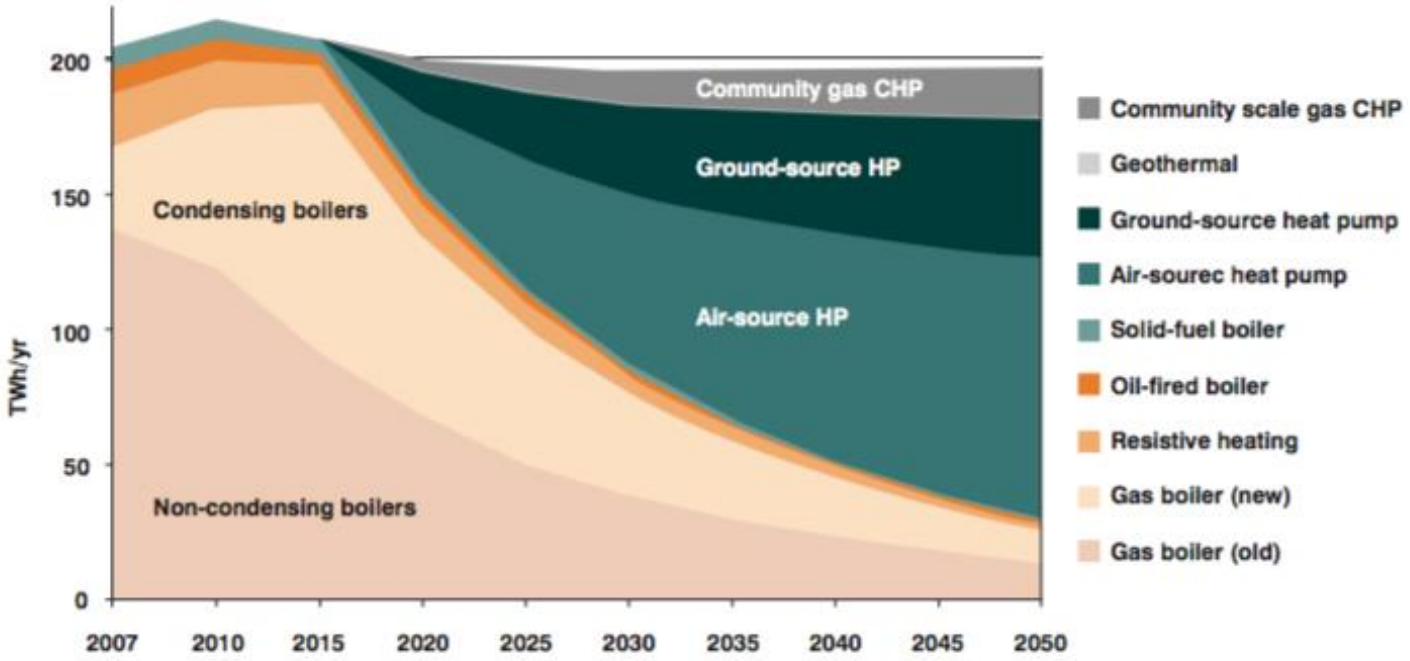


Heat demand (GWth) in UK in 2010

Electricity demand (GWe) in UK in 2010

Source: R. Sansom, “The challenges of decarbonising space and water heating”, UKERC Summer School, July 2015

Previous analysis had focused on heat pumps to decarbonise UK residential heat demand



Source: ERP, “Potential Role of Hydrogen in the UK Energy System”, Energy Research Partnership, October 2011

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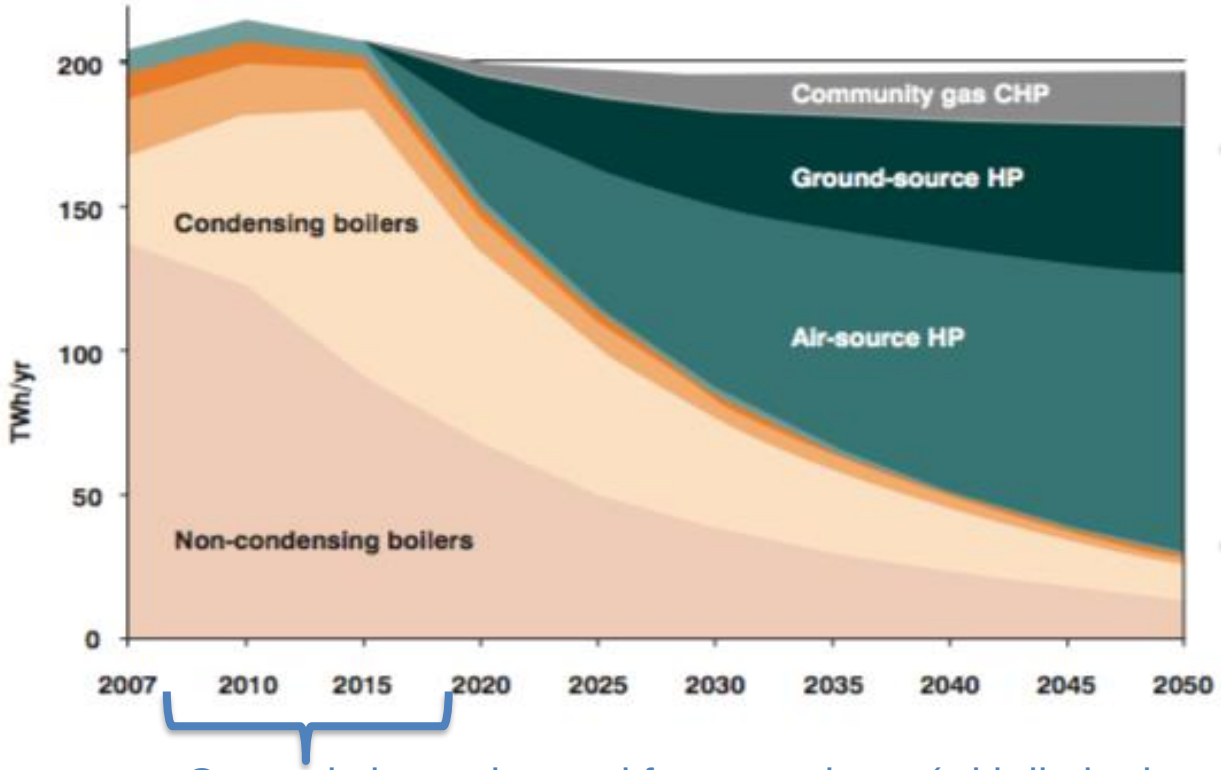


Had been an interest in moving towards heat pumps – however can create significant peak demand on coldest days

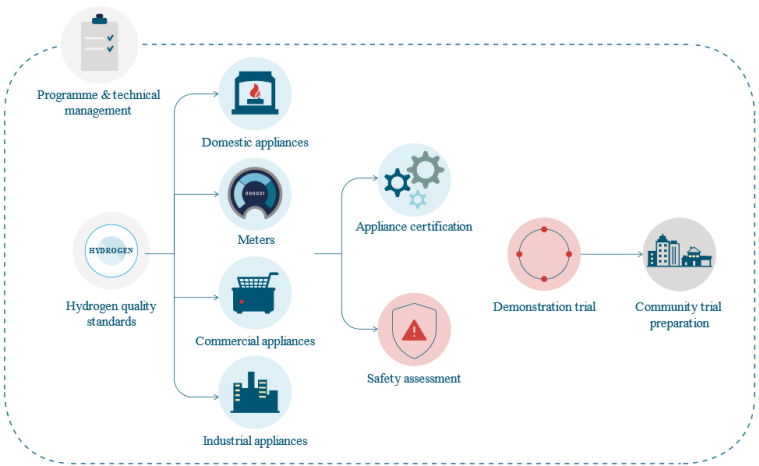
Currently large demand for natural gas (with limited district heating – unlike other European countries)

Recent interest in the following technologies for heating

- District heating (potential to utilise nuclear heat - several examples including in China and Sweden - but generally need plant close to demand)
- Large (MW) scale heat pumps connected to a heat network
- Hybrid heat pumps (minimises electricity demand at most challenging times)
- Hydrogen

Sources: BEIS, “Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report”, November 2016; Royal Society, “Nuclear cogeneration: civil nuclear energy in a low-carbon future”, October 2020

Hydrogen for residential and commercial heat



Hy4Heat project explores the potential use of hydrogen gas for heating UK homes and businesses.

Runs from 2017 – 2021, with £25 million allocated by UK Government

https://www.gov.uk/government/publications/hydrogen-for-heating-project

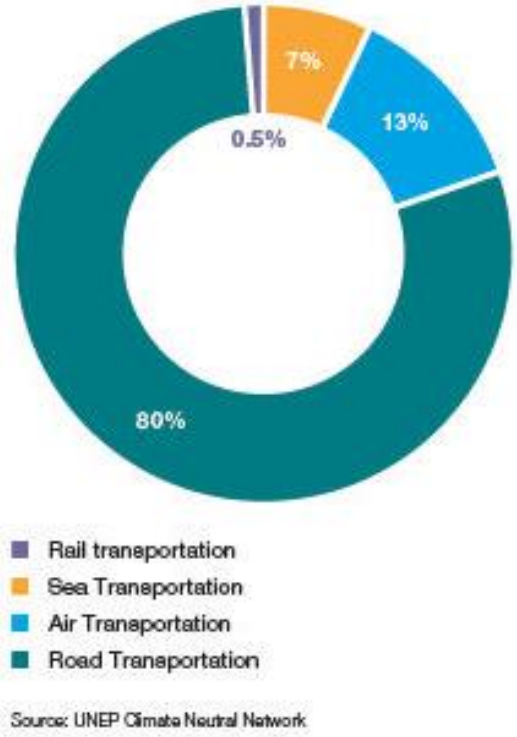
https://www.hy4heat.info/

Hydrogen could play a central role in decarbonising heat (particularly for those countries currently reliant on gas infrastructure)

UK currently investigating as part of Hy4Heat project (includes distribution, industrial trials and investigating safety aspects)

Potential to use Gen-III and Gen-IV reactors for H_2 production

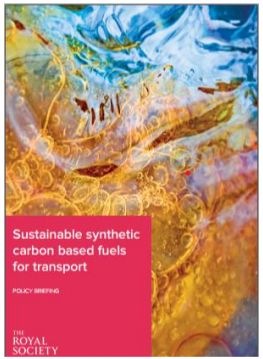
Transport (global breakdown)

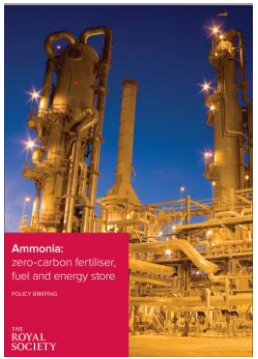


- Road (~60%) is primarily from light vehicles
- Electrification is only part of solution (e.g. difficult with respect to shipping, air and some heavy goods vehicle demand)
- Air transport emissions growing rapidly
- Synthetic fuels

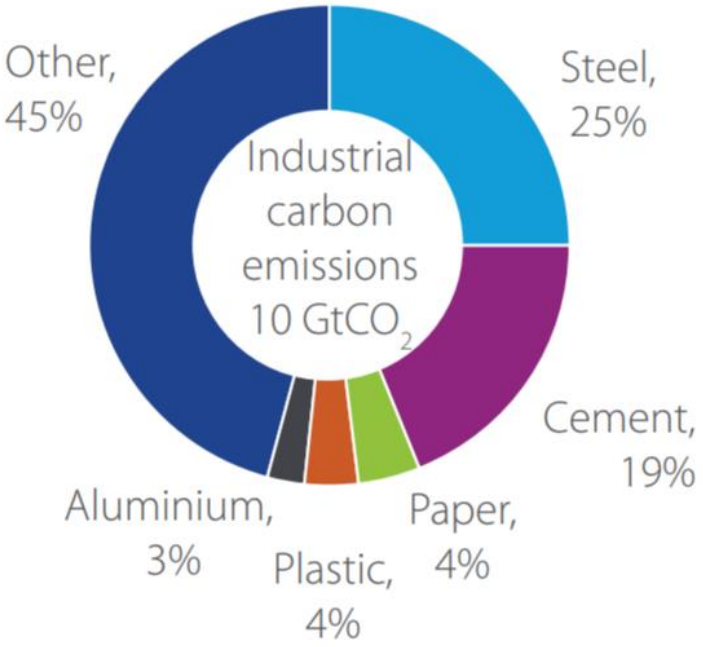
Synthetic fuels and green ammonia

- Synthetic fuels have the advantage:
  - High energy density
  - Tap into existing infrastructure
  - Tackle difficult to decarbonise sectors (e.g. marine and aviation)
- Need to be mindful of overall efficiencies (e.g. 13% for diesel engine synfuel vs 69% for battery electric vehicles)
- Also interest in green ammonia for fuel, storage and low-carbon chemical feedstock





Industry global emissions



- Much of industrial energy demand is for process heat (for example in UK ~75% of industrial energy demand is for heat)
- Electrification is one option but already widely deployed where economical
- Majority of current temperature demand below 500°C (many reactor systems can achieve this temperature)
- Will likely also be a need for CCUS (to capture CO_2 from industrial process emissions)
- Potential application of H_2 for novel production routes and as a heat source

Sources: https://www.hy4heat.info/s/WP6-Industrial-Heating-Equipment.pdf
J. Allwood et al, “Sustainable materials with both eyes open, Cambridge UIT (2012)

Previous examples of nuclear process heat applications

Include:

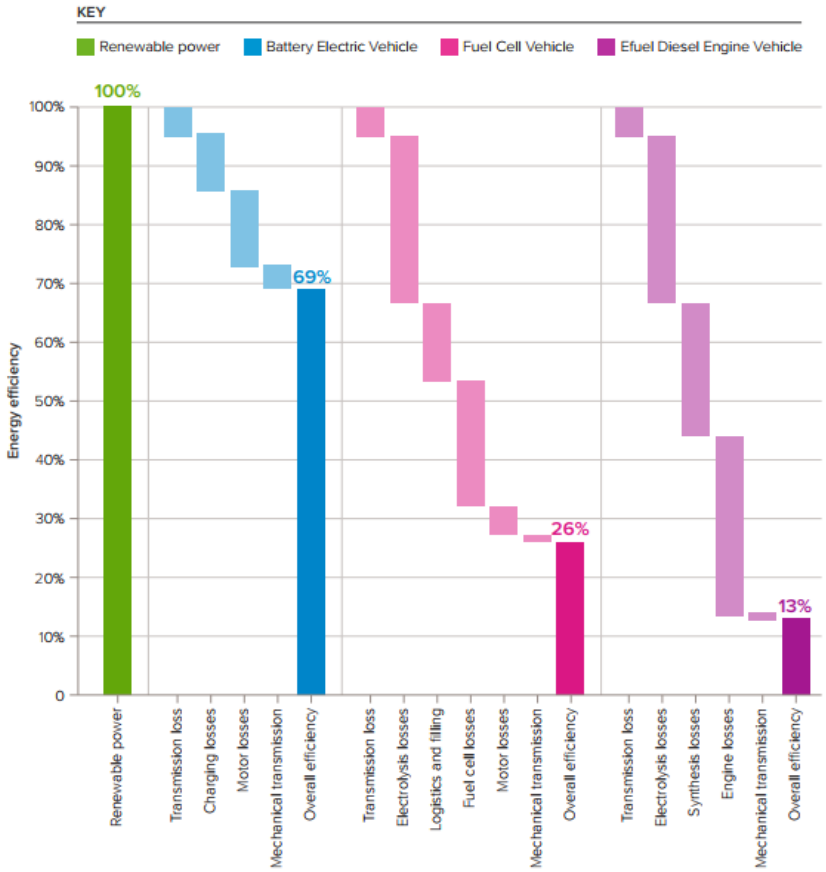
- Canada – large network of heat supplied to chemical industry (heavy water) and nearby industrial park (food & beverage and plastic production)
- UK – Heat used for onsite purposes at Calder Hall
- Norway – Halden reactor for paper/pulp production
- Kazakhstan – BN-350 liquid metal fast reactor used for desalination
- Germany – Stade nuclear plant supplied process heat to salt refinery
- Switzerland – Gösgen nuclear plant supplied heat to cardboard factory

Sources: IAEA, “Opportunities for Cogeneration with Nuclear Energy”, IAEA Nuclear Energy Series, NP-T-4.1, 2017; and IAEA, “Industrial Applications of Nuclear Energy”, IAEA Nuclear Energy Series, NP-T-4.3, 2017

Conclusions

- Electrification will play a major role – however we have a long way to go (need to deploy low-carbon generation much faster)
- For transport, homes, buildings and industry (~60% of emissions) will need to employ options besides electricity and push for greater efficiency
- Potentially significant role for synthetic fuels, hydrogen and direct applications of low-carbon heat (incl. nuclear)
- Significant experience with direct nuclear heat applications
- Nuclear can also play a role in synthetic fuels and hydrogen (indirect applications of nuclear heat) - potentially creates a further large demand for low-carbon energy

Appendix



Source: Royal Society, “Sustainable synthetic carbon based fuels for transport” (2020)