Removal of CO_2 from the Atmosphere

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IMechE reports

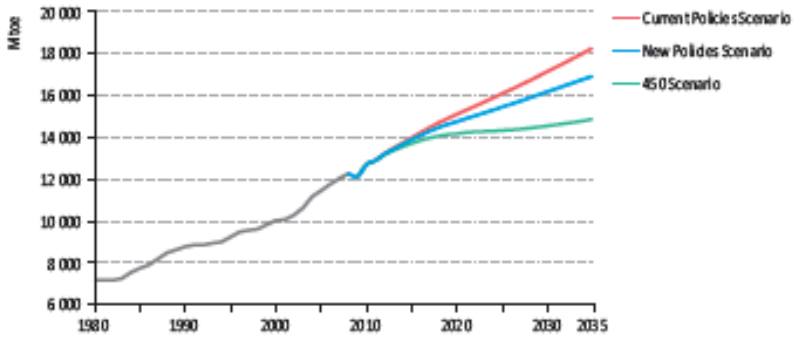
Institution fully engaged in the public debate:

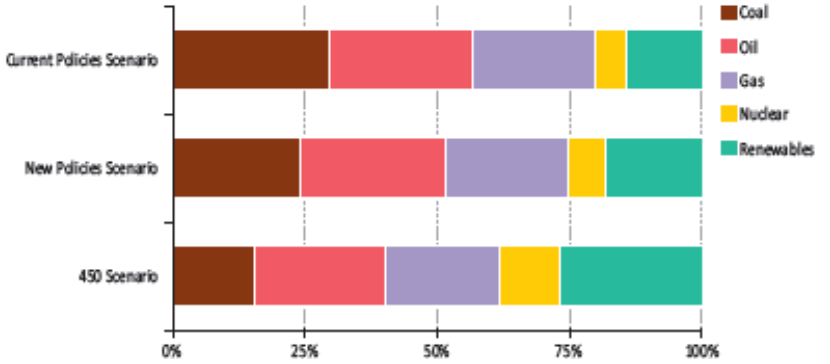
Introduction

- Presentation overview
  - Removing CO_2 from Air
  - Removal techniques
  - Air capture machines
  - State of play
  - CO_2 recycling
  - Carbon pricing
  - Unlocking innovation
  - Conclusions

More energy – mainly fossil

- Global growth
  - IEA predicts 40% increase in primary energy demand by 2035, with 90% of growth in non-OECD.
  - Possible doubling of today's demand by 2050, tripling over 21st century.
  - 81% of primary energy currently from fossil fuels (coal, oil, gas), potentially still 75% in 2035 [IEA].





- On-track for mean global temperature rise of 3.5°C by 2100.

Removing CO_2 from air

- Principal advantages
  - Removes CO_2 regardless of location.
  - Tackles difficult sources (transport, domestic, dispersed industry; circa 50% of global emissions).
  - Enables 'carbon recycling' through 'closed' carbon loops.
  - Puts a credible 'ceiling price' on CO_2 emissions.
  - Can address past emissions (and enable geo-engineering?).

Removal techniques

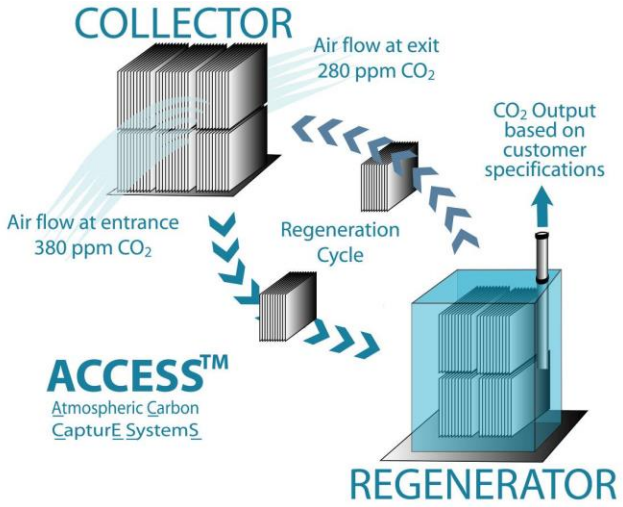
- Top candidates
  - Air capture machines (Direct Air Capture – DAC).
  - Bioenergy with Carbon Capture and Storage (BECCS).
  - Augmented ocean sequestration.
  - Biochar production through pyrolysis.
  - Reforestation and afforestation.
  - Enhanced weathering.

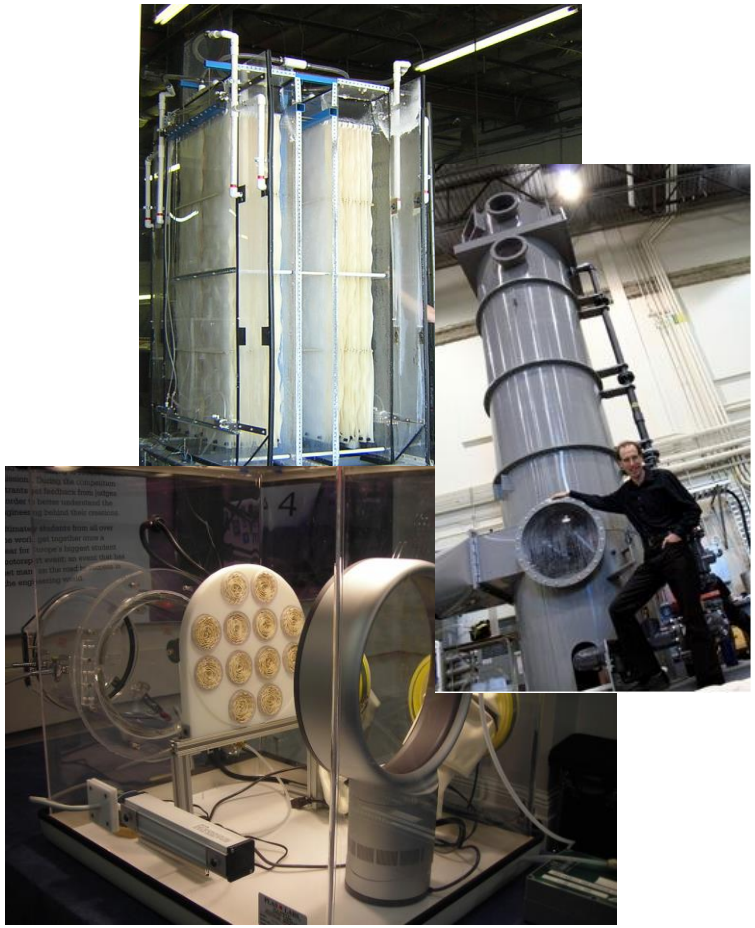





Air capture machines

- Key process steps
  - Capture CO_2 to filter medium.
  - Remove CO_2 from filter.
  - Storage of CO_2 or recycle.





- Early Pioneers
  - Klaus Lackner, Peter Eisenberger, David Keith, Aldo Steinfeld

State of play

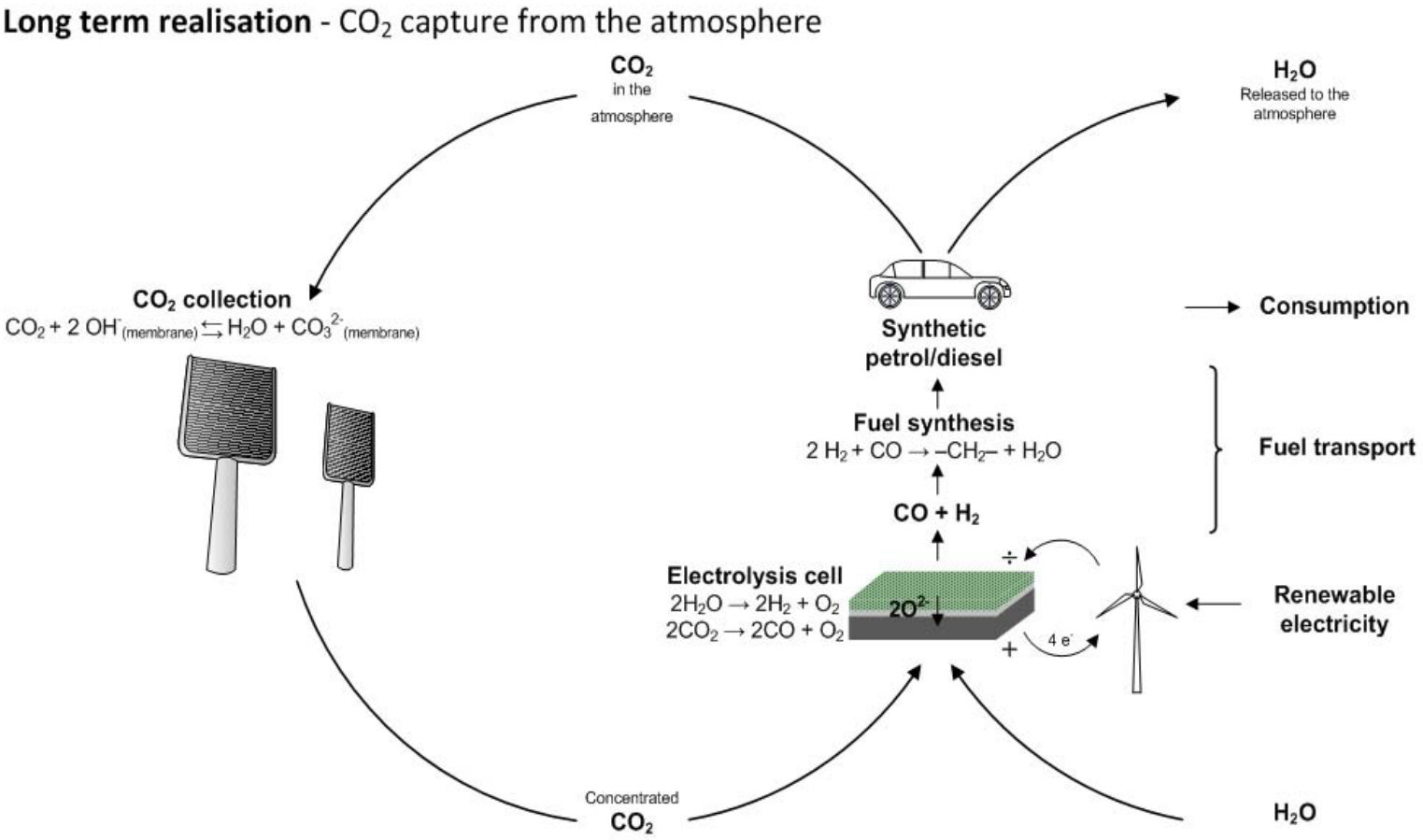
- Entrepreneurial commercial players
  - Carbon Engineering
  - Global Thermostat
  - Kilimanjaro Energy
  - Sapphire Energy
  - Air Fuels Synthesis
  - Climeworks
- CO_2 markets
  - Enhanced Oil Recovery (EOR)
  - Algae for Fuel (Aviation)
  - Synthetic Fuel (Aviation)
  - Chemical processing
  - Horticulture
  - Military

CO_2 recycling - 1

- Challenge of transportation fuels
  - High energy densities found in hydrocarbon liquid fuels.
  - Replacing enormous global infrastructure for liquid fuels.
- Carbon recycling for fuel
  - Captured CO_2 used as feedstock for a biological or chemical process for production of fuels.
  - 'Closed-loop' carbon cycle when CO_2 from air capture.
- Algea based production
  - CO_2 and H_2O as feedstock to algae cultivated in sunlight.

CO_2 recycling - 2

Carbon recycling and synthetic fuels

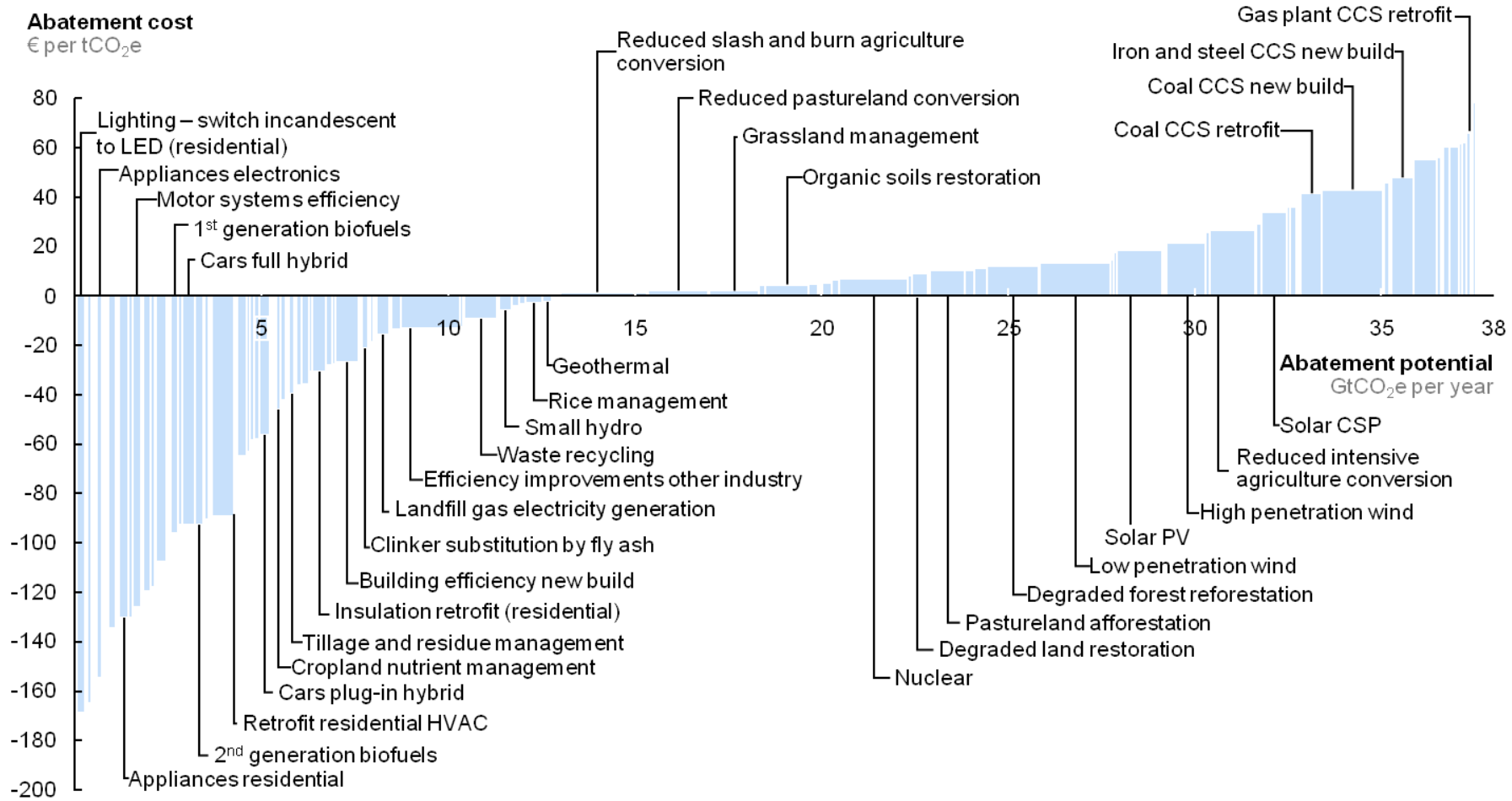


From Mogen Morgensen, DTU Energy Conversion, Technical University of Denmark

Carbon price challenge

- Emitting greenhouse gases is largely cost-free
  - Challenge is setting a credible, meaningful penalty and creating a mechanism to apply it.
- Two choices
  - Regulate for outright global emissions ban; eg HFCs, CFCs.
  - Economic instruments that create a cost for emitting.
- Challenge for economic instruments
  - Direct carbon tax or tradable permits scheme?
  - Price setting clear for tax, opaque for tradable permits.
  - Setting the price is highly problematic; future energy price sensitivity, unforeseen consequences, hypothecation.
  - Need credible, logical, tenable, justifiable price applied through transparent, legitimate mechanisms.

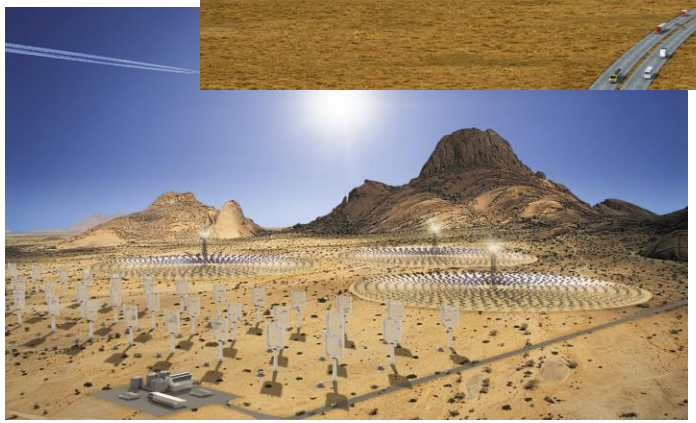
Setting the carbon price



McKinsey & Co., 2010, Impact of the financial crisis on carbon economics: Version 2.1 of the Global Greenhouse Gas Abatement Cost Curve.

Unlocking innovation

- How to levy price and drive innovation?
  - Requirement to abate emissions, or undertake air capture and CO_2 sequestration through own machines, or pay third party machine fleet operators to create 'negative emissions'.
  - Requirement could be applied initially to the G20 nations, who collectively account for 80% of global emissions.
- Price competition
  - Competition amongst fleet operators would innovate the costs out and drive the 'ceiling price' down.
  - Drive Cleantech innovation.



Chances of success?

- Using air capture to set carbon price satisfies three rules for successful technology fixes to social problems.
  - Embodies cause-effect relationship connecting problem to solution.
  - Effects of fix are assessable using relatively unambiguous criteria.
  - R&D necessary to realise the technology improves an established core that already exists.





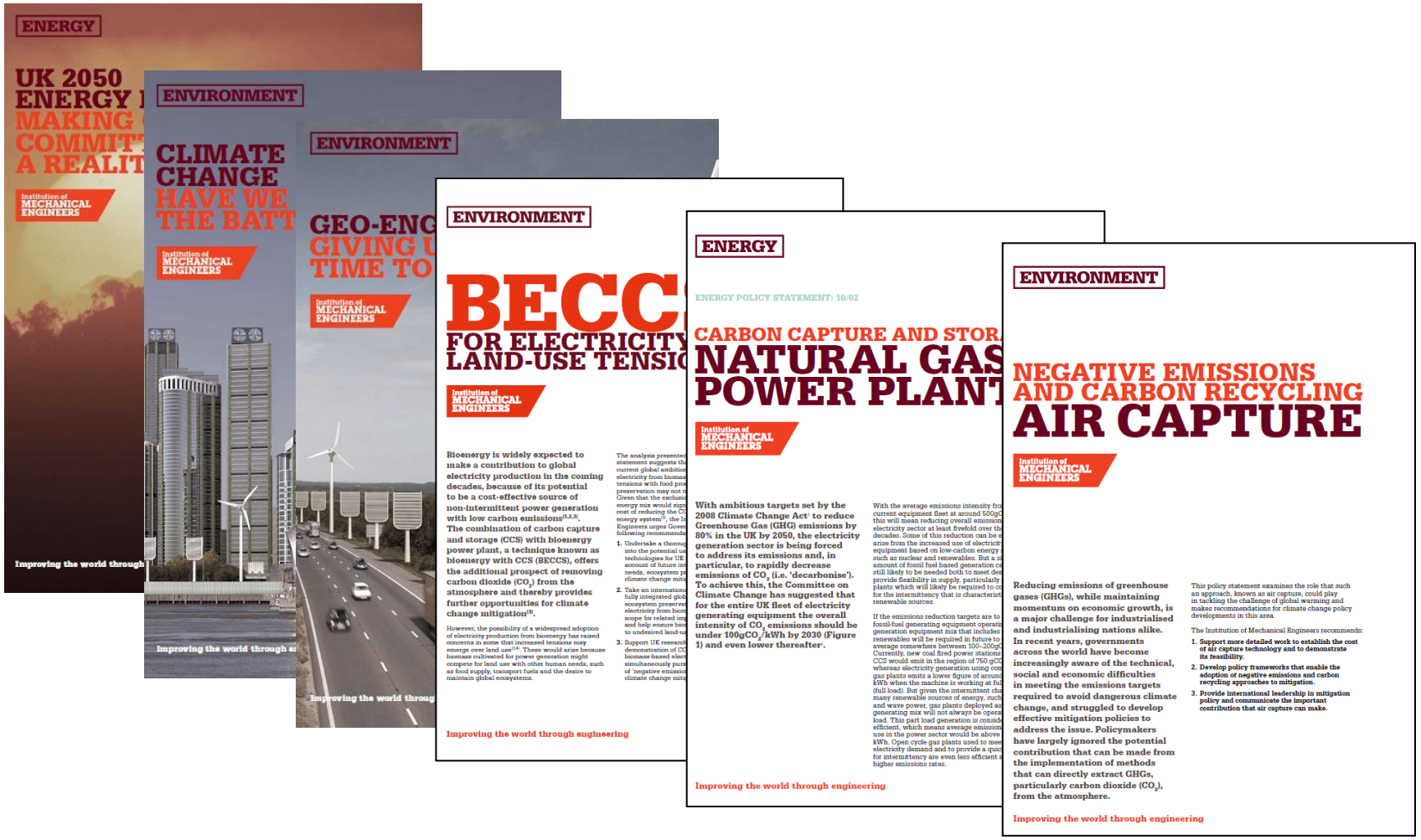
Conclusions

- Access to secure and affordable energy crucial
  - Essential to human progress and increased well-being.
  - Demand expected to increase substantially in 21st century.
  - Continued fossil fuel usage threatened by environmental risk.
- Removal of CO2 from the atmosphere
  - Removal can take place anywhere independent of source.
  - Several technologies available and in development.
  - Enables negative emissions and carbon recycling.
- Direction of travel
  - Entrepreneurs stepping into niche markets
  - Potential to fix market failures and drive innovation to reduce costs of clean technologies.
  - Secures continued exploitation of affordable fossil fuels and embedded infrastructure while reducing environmental risk.

Conclusions

- Air capture technology
  - Several machines in (commercial) development.
  - Enables negative emissions and carbon recycling.
  - Potentially helps secure continued exploitation of embedded infrastructure while reducing environmental risk.
  - Potential to fix market failures and drive innovation to reduce costs of clean technologies.
- Direction of travel
  - Entrepreneurs stepping into niche markets.

Thank you



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