18 priority next-generation climate mitigation technologies

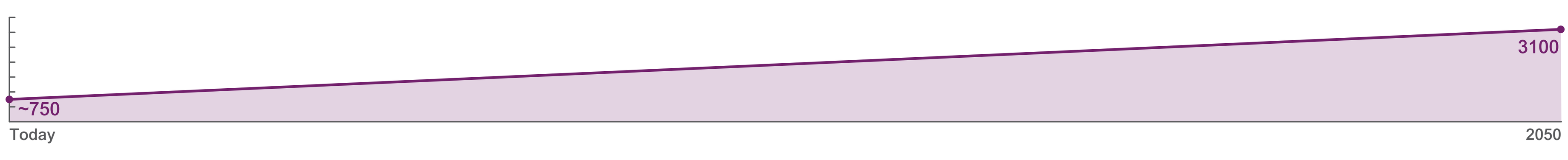
These 18 technologies all have the potential to make significant contributions to reducing greenhouse gas emissions, and are at the earliest stages of development. In some cases, they offer the only known way to reduce emissions in a given sector. Funders need to invest in early stage research and development of these technologies now. These new technologies are essential to stay well below a 2°C temperature rise compared to pre-industrial times, as stipulated in the Paris Agreement.

For some of the more mature technologies, early demonstration is now vital to show that commercialisation and roll out at scale is possible. This research must start without delay. While government and industry should continue to deploy proven technologies, such as solar PV, heat networks and biomass, simultaneous investment in early-stage new mitigation technologies will ensure that there are affordable options to help us reach net zero greenhouse emissions in the long term.

TECHNOLOGY READINESS LEVEL (TRL)
Ranking technologies based on their level of maturity

- 1–3: Basic research at the lab-scale
- 4–6: Technology development and small-scale demonstration
- 7–9: Large-scale operational demonstration and commercialisation of the full system

Aviation



Unchecked, global emissions from aviation could rise from ~750 $MtCO_2$ today to 3,100 $MtCO_2$ by 2050. (ATAG, 2014)

Biojet

TRL: 7–9

20–95%

POTENTIAL
Can reduce life-cycle emissions by 20–95%. (E4tech, 2009)

NEXT STEPS
- Efficiency improvements in production process to reduce costs
- New engine designs to cope with low aromatics could open up cheaper biofuel supply options

Hydrogen aircraft

TRL: 1–3

100%

POTENTIAL
Can reduce direct emissions from aviation by 100%.

NEXT STEPS
- Research into cost-effective hydrogen production processes
- Hydrogen supply infrastructure

Industrial sector

Industry accounts for 30% of global greenhouse gas (GHG) emissions. Of this, 70% is from the steel, cement and chemicals industries. (IEA, 2010)

Carbon capture and storage

TRL: 4–6

30%

POTENTIAL
30% of all CO_2 captured will be from industrial sources by 2050. (IEA, 2016)

NEXT STEPS
- Large-scale demonstration
- Whole-systems integration
- Government-backed transport and storage infrastructure

Hydrogen in steelmaking

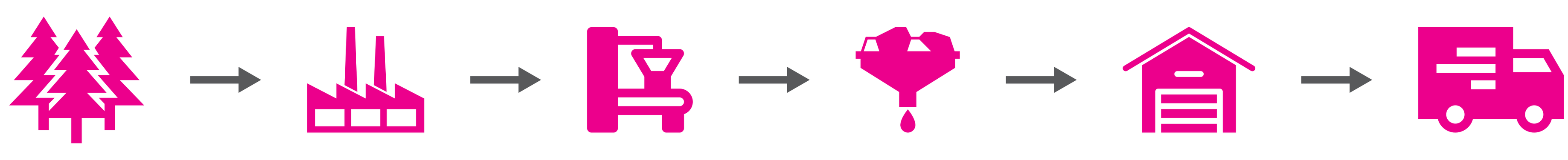
TRL: 1–3

80%

POTENTIAL
Could reduce emissions in steel industry by up to 80%. (Abdul Quader et al., 2016)

NEXT STEPS
- Currently demonstrated at lab scale
- Significant R&D required to take it to commercialisation

Advanced biofuel supply



Finding cost-effective and sustainable sources of biomass is crucial to the success of biofuels.

Artificial photosynthesis for biofuel production

TRL: 1–3

POTENTIAL
Has the potential to produce biofuels more efficiently than growing and processing biomass.

NEXT STEPS
- Development of novel catalysts and organisms to speed up fuel production

Algae for bioethanol production

TRL: 4–6

1.5
1

POTENTIAL
1.5 tonnes of CO_2 is saved for every 1 tonne of algae oil used in place of crude oil. (Malik and Tamburic, n.d.)

NEXT STEPS
- Innovative harvesting methods to reduce energy inputs and costs
- Genetic engineering of algae strains optimised for biofuels production

Energy storage

For every 1 gigawatt of intermittent renewable energy generation, we need 1 gigawatt hour of storage capacity. (Budischak et al., 2013)

Thermal cycle

TRL: 4–6

hours

POTENTIAL
Storage over period of hours.

NEXT STEPS
- Development of new/improved materials for storage of heat

Flywheels

TRL: 4–6

~15 mins

POTENTIAL
Flexible supply for short periods. Important role in frequency response.

NEXT STEPS
- Currently expensive technology
- Improved flywheel material could reduce costs

Power-to-gas

TRL: 4–6

months

POTENTIAL
Storage over seasonal timescales.

NEXT STEPS
- Cost reduction could be achieved by technical improvements such as reducing catalyst loadings, operating at higher temperatures or developing higher or differential pressure systems

Lithium-ion battery

TRL: 4–6

hours/days

POTENTIAL
Storage over period of hours/days.

NEXT STEPS
- Development of new materials
- New processing techniques
- Better understanding of the behaviour and degradation processes

Redox-flow battery

TRL: 4–6

hours

POTENTIAL
Storage over period of hours.

NEXT STEPS
- Understanding flow and material behaviour
- Understanding performance degradation
- Corrosion-resistant materials

High-temperature, sodium-based batteries

TRL: 4–6

hours/days

POTENTIAL
Storage over period of hours/days. Grid-scale balancing of intermittent supply.

NEXT STEPS
- Understanding flow and material behavior
- Understanding performance degradation
- Selection of corrosion-resistant materials for pumps, pipes, etc.

Negative emissions technology

By 2070 we need to be removing at least 10Gt of CO_2 from the atmosphere each year. (AVOID2, 2015)

Direct air capture

TRL: 1–3

~95
1

POTENTIAL
The artifical tree concept, an early example of direct air capture technology, is estimated to cost ~95 $/tCO_2e$. (McGlashan et al., 2012)

NEXT STEPS
- Development of novel sorbents to reduce energy input for regeneration

Bioenergy with CCS (Bio-CCS)

TRL: 4–6

~59–111
1

POTENTIAL
Currently the closest to commercialisation of the various negative emissions technologies. Bio-CCS is estimated to cost ~59–111 $/tCO_2e$. (McGlashan et al., 2012)

NEXT STEPS
- Integration of biomass combustion with CCS technologies
- Demonstration of the whole system process at scale, from capture and transport to storage

Biochar

TRL: 1–3

~135
1

POTENTIAL
Partial combustion of biomass creates biochar. When buried, the carbon previously absorbed from the air is fixed. Biochar is estimated to cost ~135 $/tCO_2e$. (McGlashan et al., 2012)

NEXT STEPS
- Understanding the interaction of biochar with soils
- Calculating the techno-economic benefits of biochar as a fuel or as a soil-enhancement product

Ocean liming

TRL: 1–3

~90
1

POTENTIAL
Involves seeding oceans with lime to trap CO_2 in a stable mineral form and is estimated to cost ~90 $/tCO_2e$. (McGlashan et al., 2012)

NEXT STEPS
- Research into the calcination processes to optimise and reduce costs
- Improved understanding of the full effect of a limited scale deployment of this technology on ocean acidification and the disturbance of ecosystems

Soda/lime process

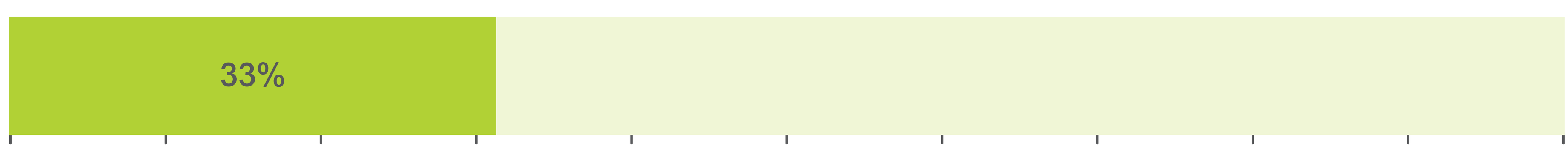
TRL: 1–3

~155
1

POTENTIAL
Based on well-understood processes of calcination and causticisation. Due to high energy inputs, it is estimated to cost ~155 $/tCO_2e$. (McGlashan et al., 2012)

NEXT STEPS
- Development of novel sorbents to reduce energy input for regeneration
- Further studies on process optimisation and energy integration to reduce costs

Built environment



Steel and cement are responsible for a third of the energy use associated with building structures. (Zabalza Bribian et al., 2011)

Alternative materials to steel and cement

TRL: 4–6

POTENTIAL
The construction industry accounts for around half of steel demand and almost all demand for cement.

NEXT STEPS
- Long-term tests of any replacements for traditional building materials are necessary to increase confidence in their performance

For more information, please visit
www.oecd.org/environment/cc/g20-climate/collapsecontents/Imperial-College-London-innovation-for-the-low-carbon-economy.pdf

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