TECHNOLOGY

Innovation towards net zero

Huge acceleration of clean energy innovation is required on the road to net zero, according to the International Energy Agency. Looking forward, *Brian Davis* presents a selection of key technologies which are being addressed.

In order to meet the Paris Agreement goals many countries are targeting to curb global warming and reach net zero emissions by the second half of the century. However, in many cases this will only be possible with significant drive and innovation. In a recent report* the International Energy Agency (IEA) analysed over 400 clean energy technologies and commented that: 'Although renewable technologies are in use and can deliver significant emissions reduction, they will not be sufficient on their own to meet the ambitious targets.'

In particular, few technologies are currently available to reduce emissions to zero in sectors such as trucking, shipping, aviation and heavy industries. IEA Executive Director Fatih Birol commented: 'Without decarbonising the transport sector there is no chance whatsoever of meeting climate targets. Around half of emissions reductions that are needed still require major innovation of clean technologies.'

The most critical technologies needing innovation are battery technologies, carbon capture and storage (CCS) and low carbon hydrogen, which are currently mostly in the development phase and/or costly.

In a wide-ranging report the IEA looked at the 'Fastest Innovation Case' and asked: How far could innovation take us? It is an exciting vision, given that the IEA's Sustainable Development Scenario aims to reach net zero emissions from the energy sector within five decades on the back of ambitious technological change, demanding the fastest and most successful energy technology innovation in history to meet the Paris Agreement goals.

Many technologies are still in the laboratory or early prototype stage and will require relatively short and successful routes towards commercialisation, despite risk of market bottlenecks and resource constraints along the supply chain if co-ordination fails during rapid expansion. 'There is little or no precedent for the required pace of innovation', notes the IEA.

The Fastest Innovation Case needs to enable 9 $GtCO_2$ of additional net emissions savings compared to the Sustainable Development Scenario in 2050, which is equivalent to tackling almost 30% of today's energy sector emissions.

Key clean energy technologies at demonstration or large prototype stage today, including hydrogen-based steel production, electrolytics hydrogen-based ammonia-to-fuel vessels, and carbon capture for cement production, are assumed to reach market only six years from now under the Fastest Innovation Case – twice as fast as the IEA's current Sustainable Development Scenario. The only case of such rapid progress historically is LED development, which are small enough to be mass produced and require a relatively low level of capital expenditure during the prototyping and demonstration phase.

Electrification is key

Electrification is a key strategy, which would see the share of electricity in total energy demand reach 45% by 2050 under the Fastest Innovation Case, compared to about 20% today. Transport and electricity will be responsible for about 95% of additional electricity demand. Faster battery manufacture and improved smart charging infrastructure is required. Without advances in alternative chemistries to lithium-ion, the use of batteries for transport to move beyond road vehicles and short-distance shipping and aviation will be difficult.

Gravimetric energy densities (at cell level) will have to triple from current levels. At least two alternative battery chemistries – lithium-sulphur and lithium-air – have the potential to provide such advances, although both are at the small prototype stage today. These developments promise more rapid uptake of electric vehicles (EVs), with potentially 80% and 60% of light- and heavy-duty vehicles on the roads in 2050. Nearly 3.5 times more battery-electric heavy vehicles could be deployed in this scenario.

Electric heating

Large-scale electric heating would also have to penetrate more deeply into the industrial sector under the Fastest Innovation Case. Rapid advances are underway to demonstrate large-scale high-temperature electrical heating for industrial processes, that do not involve electricity-conducive materials. However, most of the electromagnetic technologies are at the concept validation stage and would have to reach markets within a decade, with average deployment maintained at a new 1mn tonne installation (equivalent to half the capacity of a conventional integrated steel mill) every two months up to 2050. In the buildings sector, around 30 GW thermal capacity from integrated heat pumps would need to be installed every month on average from 2030 to 2050, a big challenge.

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Hydrogen and hydrogen-derived synthetic fuels

Meanwhile, demand for hydrogen and hydrogen-derived synthetic fuels (including ammonia) would have to grow by almost 25%, relative to the current Sustainable Development Scenario, with most demand coming from the industry and transport sectors. To put this in perspective, almost two new 1mn tonne steel plants based on full hydrogen reduction would

EI pledged to net zero

The Energy Institute (EI) has pledged to net zero. EI President Steve Holliday FREng FEI says: 'The climate emergency demands changes in behaviour across the board – from governments, businesses and societies. The EI is resolved to end its own impact on the climate and is joining a growing number of organisations on an ambitious but managed journey to net zero. We do not yet have all of the answers, but I hope our members, partners and customers will be inspired to follow.'

Work to date

Apostolos Gkrimpas, EI Training Manager, explains: 'Following the successful submission of our science-based targets at the end of May 2020 as one of the signatories of the "Pledge to Net Zero" scheme, we are now working closely with our topic experts and our internal team in formulating our carbon reduction plan moving forward.'

'The initial focus will be on i) setting up the required procedures to be able to capture data efficiently and ii) carrying out behaviour change and building control optimisation activities. A particular area of focus will be the reduction of carbon emissions through our flights by setting up carbon budgets for our relevant teams/departments.' ●

More information on the EI's journey to net zero can be found at **https://www.pledgetonetzero.org/case-studies-energy-institute**

need to be installed every month from today to 2050. This would call for radical changes to existing steelmaking capacity. While in transport, over 60 ammonia-fuelled large vessels will need to be put into service every month on average until 2050.

Bioenergy

The share of bioenergy in total final energy demand would have to increase by about 25% under the Fastest Innovation Case, driven mostly by industrial and transport-related applications.

Fortunately, such an increase would not present a technical challenge on the demand side, as biofuels are drop-in fuels for most applications. But such growth in demand would put additional stress on biomass supply chains.

Rapid innovation in biofuel conversion technologies and agricultural practices is essential. Algae-based biofuels, for example, are currently only at the small prototype stage. Rapid development is required of advanced biofuels production technologies for biodiesel and bio-jet through gasification and Fischer-Tropsch, to boost aggregated production capacity by an average rate of 40% through to 2050.

Carbon capture and storage

Deployment of carbon capture and storage (CCS) will also have to be boosted by 50%, with the amount of CO_2 stored almost 200 times greater than today, according to IEA estimates. Negative emissions technologies, such as direct air capture (DAC) and bioenergy CCS, would account for the bulk of this. Both technologies would likely become critical in offsetting residual emissions from long-distance transport and heavy industry. Almost 16 DAC facilities of 1mn tonnes capture capacity would need to be commissioned every year on average to 2050, compared with about five such facilities in the current Sustainable Development Scenario. The largest DAC plant currently being designed is of 1mn tonne capacity, and only pilot-scale plants less than half that size have been demonstrated so far.

Opportunities at laboratory scale

There are also opportunities for development of innovative technologies which are still at the laboratory or small prototype stage today. The IEA maintains that focus should be on technologies that are modular and small enough to be mass produced and have potential for 'high spill-overs' from and to other net zero emissions technologies.

Furthermore, technologies should be addressed that have a high potential to unlock supply constraints, such as those impacting bioenergy and rare or higher demand materials. Several such technologies are considered important, including advanced battery chemistries and battery recycling technologies; innovative practices to boost biomass resources; iron ore electrolysis for making steel; and advanced cooling.

Decarbonising transport

Decarbonising transport relies heavily on electromobility and installed battery capacity for these applications increases 500-fold by 2070 in the IEA's Sustainability Development Scenario. But in grid-scale applications, the capacity of the battery fleet increases 260-fold from today over the same period. This level of deployment assumes ambitious innovation efforts to maintain cost and performance trajectories, with the cost of an average battery dropping 68% in the Sustainable Development Scenario, while gravimetric energy densities at cell level increase by 160% compared with current levels.

From a current perspective, electric aircraft of the size and range needed for commercial passenger aviation are still not practical on a significant scale by 2070, mainly due to the high power density required during take-off. With current battery technology, an Airbus 380 would need batteries with an overall weight 30 times greater than its current fuel intake, making lift-off impossible. But early concepts for 10-seaters and electric taxis, including electrical vertical take-off and landing aircraft, have been developed by Rolls Royce, Uber and a number of start-ups. An all-electric commercial passenger aircraft capable of operating over 750–1,100 km would require battery cells with densities of 800 Wh/kg, more than three times the current performance of lithium-ion batteries.

Innovative battery recycling could also be commercialised over the next decade, reducing demand for primary lithium and accelerating the electrification of the transport sector by lowering costs.

Indeed, accelerated innovation could reduce the gap between theoretical and current performance in many areas of technology on the road to net zero. ●

**Energy Technology Perspectives 2020: Special Report on Clean Energy Innovation*; IEA July 2020.