NET ZERO

A global roadmap to 2050

The International Energy Agency (IEA) recently published the world's first comprehensive study to lay out a cost-effective transition to a net zero energy system while ensuring stable and affordable energy supplies, providing universal energy access and enabling robust economic growth. *Laura Cozzi*, Chief Energy Modeller, IEA and *Timur Gül*, Head of the Energy Technology Policy Division, IEA, present some of the key findings of the roadmap.

The energy sector accounts for about two-thirds of the global emissions of greenhouse gases (GHGs), largely in the form of CO_2. Mitigating climate change, perhaps the greatest challenge humankind has faced, requires the net emissions of GHGs to fall to zero. This was recognised in the 2015 Paris Agreement on climate change, which called for achieving a 'balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century'.

Subsequently, the 2018 special report of the Intergovernmental Panel on Climate Change (IPCC) on *Global warming of 1.5°C* detailed the high risks of global warming above 1.5°C. The report also calculated that limiting warming to 1.5°C would require reaching net zero CO_2 emissions globally by 2050.

It is in this context that the International Energy Agency (IEA) decided in 2020 to develop a global roadmap detailing a pathway to net zero emissions in the energy sector by 2050, building on analysis published in its *World Energy Outlook* and *Energy Technology Perspectives*. The special report – *Net zero by 2050: A roadmap for the global energy sector* – was published in May 2021.*

Designing the pathway

The roadmap describes *a* pathway to reaching net zero emissions from the energy and industrial sectors by 2050. It is not *the* pathway. Each country has its own circumstances, resource endowments and cultural preferences that will shape a country's own pathways. Undoubtedly, there will be many surprises along the way. Some technologies or policy options may exceed expectations; others may fall short. Nonetheless, the IEA's net zero emissions (NZE) pathway is designed with certain boundary conditions in mind, including:

- *Comprehensive technology approach*. The pathway is designed to maximise technical feasibility, cost-effectiveness and social acceptance while ensuring continued economic growth and secure energy supplies. It takes a prudent approach to technologies such as bioenergy to take account of biodiversity considerations and possible implications for food. At the same time, it highlights the challenges and risks of reaching net zero emissions without a comprehensive technology portfolio.
- *Orderly transition in the energy sector*. This includes ensuring the security of fuel and electricity supplies at all times, minimising stranded assets where possible and aiming to avoid volatility in energy markets.
- *International co-operation*. The pathway assumes a high degree of international co-operation to ensure that technologies are developed and diffused rapidly, and that developing countries are assisted in undertaking the challenging transition.

The pathway also involves an unprecedented effort to combine the insights of the IEA's two energy models, the *World Energy Model* (WEM) and *Energy Technology Perspectives* (ETP) model. In addition, the IEA collaborated with leading international institutions, including the International Monetary Fund (IMF), to model the macro-economic, and the International Institute for Applied Systems Analysis (IIASA) to model the land-use and air pollution impacts of the transition.

Key results and policy priorities

The resulting pathway is narrow; action over the next decade is critical. But it is also feasible, and allows for continued robust economic growth and the achievement of the United Nation's (UN) energy-related Sustainable Development Goals (SDGs), including universal energy access by 2030.

Short-term action, using commercially-available and proven

technologies, is crucial to the first decade of the NZE pathway. Substantial policy action on energy efficiency across all sectors allows the global economy to grow 40% by 2030, while using 7% less energy. Wind and solar electricity generation scale up dramatically, with 2030 installations reaching four times the record level of 2020. The electrification of energy consumption is accelerated, with electric car sales going from around 5% of the global car market today to more than 60% by 2030. These near-term actions are necessary to bend the rising CO_2 emission trajectory and cut emissions by around 13 Gt.

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However, by 2050 almost half of the emissions reductions achieved in the NZE involve technologies currently at the demonstration or prototype phase. A major innovation push is therefore required to achieve the NZE, with advanced batteries, hydrogen electrolysers and direct air capture (DAC) and storage being key opportunities.

Policies are urgently needed to enhance and strategically direct early-stage R&D, while at the same time completing a portfolio of demonstration projects. We estimate that achieving the NZE requires about $90bn to be spent on technology demonstration to 2030, compared to the $25bn currently budgeted.

The NZE pathway is very capital intensive. From a recent annual average of around $2tn, global energy investment is forecast to surge to $5tn by 2030. This would add, according to joint analysis with IMF, an extra 0.4% to global annual GDP growth between now and 2030, resulting in a global economy that is larger by the equivalent of the economic size of Japan today.

Policy makers will need to support developing countries in accessing large amounts of low-cost capital, both from public and private sources.

Implications for the global energy industry

By 2050 in the NZE, the global energy sector looks quite different compared to today. Renewables rise to cover two-thirds of global energy supply, while fossil fuels decline from four-fifths today to one-fifth of global energy supply by 2050. Electricity rises to account for almost 50% of total final consumption, and is deployed across all end-use sectors from buildings, to industry, to transport. Fuel production becomes dominated by advanced biofuels and hydrogen-based fuels, which are crucial to decarbonising parts of energy consumption that electricity cannot reach. Globally, around 7.6bn tonnes of CO_2 are captured, largely in industry and biofuel and hydrogen production. This is much less than typically envisaged by other comparable scenarios, but a very substantial industrial challenge nonetheless.

In the NZE, energy security concerns change, but they do not disappear. The contraction of the global oil market, falling to 24mn b/d by 2050, leaves the lowest cost oil producers with a growing market share. The OPEC share in a much-reduced global oil supply rises to 52% by 2050, higher than ever observed in the history of global oil markets. At the same time, producer economies' per capita revenues from oil and gas sales fall 75% by the 2030s, with substantial implications for fiscal and social policy in these economies. No new investments in fossil fuel production are required in the NZE, beyond projects already committed as of 2021. For producer economies, structural reforms and economic diversification will be critical.

At the same time, new opportunities emerge for the global energy sector. The net zero emissions energy system is intensive in critical minerals, with the market size of minerals like copper, cobalt, manganese and various rare earth metals growing seven-fold between 2020 and 2030. Diversified global mining companies, and countries with resource bases in these critical minerals, will be well-placed to benefit. Concurrently, the growing importance of critical minerals creates new energy security concerns around price volatility and supply diversity.

Global demand for oil and gas contracts substantially in the NZE, with gas demand falling to 1,750bn cm by 2050, accompanying the decline of oil demand discussed above. However, there are a number of growing energy-sector activities in the NZE, which are well aligned with the existing technical and managerial competences of the global oil and gas industries. These include bio-refining, low-carbon hydrogen production from natural gas combined with carbon capture, use and storage (CCUS), offshore wind, and geothermal to name a few. Total investment in these technologies reaches almost $400bn by the 2030s in the NZE, and rise further thereafter.

In the NZE, the business of 'wires and electrons' is huge by 2050. Total annual consumer spending on electricity exceeds $8tn by 2050 (more than twice the retail market for oil products over the last decade). Investment in grids reaches more than $800bn by the 2030s.

Electricity is the key fuel across many parts of the energy sector in a net zero world. But the use and treatment of solid, liquid and gaseous fuels – a core competency of fossil fuel industries – continues to play an important role in the NZE – and electricity accounts for about half of final energy demand only by 2050. For example, modern forms of solid biomass, which can be used to reduce emissions in both the electricity and industry sectors, rise from 32 EJ in 2020 to 75 EJ in 2050, offsetting a large portion of a drop in coal demand. The use of low-emissions liquid fuels, such as ammonia, synthetic fuels and liquid biofuels, increases from 1.6mn boe/d in 2020 to just above 12.5mn boe/d in 2050. The supply of low-emissions gases, such as hydrogen, synthetic methane, biogas and biomethane rises from 2 EJ in 2020 to 50 EJ in 2050. The increase in gaseous hydrogen production between 2020 and 2030 in the NZE is twice as fast as the fastest 10-year increase in shale gas production in the US.

Near-term milestones and stable public policy

Change in the scale and speed that aligns with a transition of the energy sector to net zero emissions by 2050 worldwide will require long-term policy frameworks and clear intermediate targets, allowing industries and investors to adapt their strategies and future expectations.

The IEA's NZE pathway sets out more than 400 milestones detailing how at the global level to reach net zero emissions by 2050 could be achieved in practice. The vast majority of these milestones suggest significant changes in energy demand as a means to trigger the necessary transformation.

It is clear that public policy is more critical than ever to guide investments and strategic expectations in the global energy sector. The IEA's NZE report is *a* roadmap – not *the* roadmap – that can help navigating the changes ahead. ●

*See **www.bit.ly/IEANetZero**