HyResource

Features article

Net Zero Emissions by 2050 and the Role of Hydrogen

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Introduction

As we approach the mid-way point of 2021 it is useful to reflect on several key reports released in 2021 that deal with the ambition of reaching net zero (CO_2) emissions by 2050, and the role that hydrogen can play in such an ambition.

The two most important 'flagship' reports that discuss the implications of reaching net zero emissions by 2050 for global energy markets are:

- International Renewable Energy Agency (IRENA, March 2021): World Energy Transitions Outlook: 1.5°C Pathway: Preview.
- International Energy Agency (IEA, May 2021): Net Zero by 2050: A Roadmap for the Global Energy Sector.

The IRENA report is a 54 page summary exposition of the 'contours' of an energy pathway and actions required to keep on a 1.5°C climate pathway, which the report highlights as being consistent with reaching net zero emissions by 2050 (p.9).

The IEA report is a detailed 224 page outline of the 'essential conditions' consistent with global energy markets reaching net zero emissions by 2050, as well as describing the sectoral pathways, wider impacts and key uncertainties of such an approach.

Immediately after release of the IEA Roadmap, the G-7 Ministers responsible for Climate and Environment met virtually on 20-21 May 2021 and issued an extensive Communique which included, amongst other things, a commitment '…to submitting long-term strategies (LTSs) that set out concrete pathways to net zero GHG emissions by 2050 as soon as possible, making utmost efforts to do so by COP26.'

Why these net zero emissions by 2050 reports are important

Firstly, it is useful to make clear what these report are not, so as to better understand their real importance. The reports do not purport to show *the* pathway to net zero emissions by 2050 as recommended by IRENA or the IEA. Rather, they present *a* possible pathway, one of many, that these organisations have deemed to present as a 'main scenario' (for want of a better expression).[1]

There is therefore lesser benefit in dissecting the merits or demerits of specific points arising from the individual pathway options presented. The importance of these reports comes in several forms and include:

- Greater clarity on the *practical implications* (not just for the energy sector but for the global economy as a whole) of delivering the ambition of net zero emissions by 2050.
- Greater appreciation of (a) the extent and urgency of the broader set of actions required for an *accelerated* transformation of the energy sector, (b) the types of behavioural changes that society along with the priority actions that governments would need to implement, and (c) the critical path factors that can support or constrain achievement of the ambition.
- Provision of a set of guideposts (or markers) by which performance in reaching the ambition of net zero emissions by 2050 can be judged.

[1] A range of global scenarios consistent with net zero emissions by 2050 are included in the Intergovernmental Panel on Climate Change (IPCC) report Global Warming of 1.5°C. An IPCC Special Report (2018). A recent scenario modelling exercise (as just one other example) focussed on impacts for the oil and gas industry of limiting the global temperature increase to 2°C.

The ambition of the global economy reaching net zero emissions by 2050 should be framed in an historical context.

There is a not inconsiderable amount of academic literature that has examined the speed at which transformation of an energy system can take place, and while it is challenging to summarise this output, a simplistic interpretation suggests that, *based on past experience*, a complete global transition to a low-carbon economy would require in excess of 50 years (at a minimum).[2]

When considered in this historical perspective, acceleration of the global energy system transformation (or, put another way, the time-scale compression of such a transformation) included in these reports is very considerable (unprecedented or unparalleled is probably a more accurate descriptor).

Net zero emissions by 2050 –common threads

Under the IEA and IRENA 'main scenarios', annual global energy-related and industrial process CO_2 emissions, presently at around 35 billion tonnes, fall to between 20-25 billion tonnes by 2030 and to net zero by 2050 (when use of CO_2 removal technologies supports net zero emissions to be reached).[3]

By 2030, annual CO_2 emissions are between 10-15 billion tonnes below present levels*, a reduction of approximately 30-40 per cent in the next decade.* To invoke the historical perspective, this compares with a rise in the annual rate of CO_2 emissions of around 15 per cent since 2010.

While there may be multiple pathways to reach net zero emissions by 2050, there is convergence on the 'areas of focus' - the major global trends (or key pillars of decarbonisation) are consistent across the 'main scenarios':

- **Improved energy efficiency (and conservation behaviours)**: the IEA 'main scenario' indicates the rate of annual energy intensity improvement for total energy supply would need to rise from 1.6 per cent in recent years to over 4 per cent in the period 2020-2030 to 2.7 per cent in the twenty years thereafter.
- **Renewables deployment**: both 'main scenarios' envisage the share of renewables in total electricity generation globally to be at around 90 per cent in 2050 (versus less than 30 per cent presently).[4] This reflects in part the rapid electrification of end-use applications (see below) and the growth in renewable-based hydrogen production.
- **Electrification of end-use sectors**: electrification intensifies in industry, buildings and transport, especially after 2030 and electricity becomes the main energy carrier; both 'main scenarios' have the electricity share of final energy consumption at around 50 per cent in 2050 (vs 20 per cent at present). In the IEA 'main scenario', by 2050, around 85 per cent of the car fleet is electrified globally (with the remainder being hydrogen-powered vehicles) compared to one per cent at present.
- **Hydrogen (and its derivatives) deployment**[5]: hydrogen has a significant role to play in both 'main scenarios'; it is blended with natural gas in gas networks and offers decarbonisation options for industry and transport not easily met by electrification. By 2050, the combined share of hydrogen and hydrogen-based fuels account for 13 per

[2] *Benjamin K. Sovacool*, '*How long will it take? Conceptualising the temporal dynamics of energy transitions'*, *Energy Research and Social Science, Volume 13, March 2016, Pages 202-215*, undertakes an extensive literature review and examines key issues in energy systems transitions.

[3] Present level emissions is the average of 2019 and 2020 levels (IEA p.199). China, the United States, India and the European Union (EU) 27 plus the United Kingdom account for around 60 per cent of global CO_2 emissions.

[4] The IEA 'main scenario' indicates that the share of renewables in total electricity generation (roughly) doubles to 60 per cent in 2030 from present levels. The IEA 'main scenario' indicates that the share of renewables in global energy supply rises from around 12 per cent in 2020 to around 67 per cent in 2050.

[5] The main derivatives include e-ammonia and e-methanol.

cent of total final energy use worldwide (IEA) / 12 per cent of total final energy consumption globally (IRENA).[6]

- **Bioenergy and carbon capture utilisation and storage (CCS/CCUS) deployment**: both the IEA and ARENA 'main scenarios' suggest a significant role for these CO_2 reduction options in tackling emissions from 'residual' fossil fuel use and industrial processes. These technologies play an important role in power plants, co-generation plants and industry (mainly cement, chemicals, and iron and steel), blue hydrogen production, and with direct air capture, especially after 2030.[7]

It is noteworthy that net zero pathways evaluated for some key economies exhibit broadly similar threads to those noted above.[8] Of course the extent of application of each thread, and the timing of that application, will be dependent in large part on country or region specific circumstances, including economic capacity and natural resource endowment.[9]

Net zero emissions by 2050 – the role of hydrogen

The IRENA *World Energy Transitions Outlook (Preview)* identifies hydrogen and its derivatives as one of its six main components of CO_2 emissions abatement, accounting for 10 per cent of abatement by 2050.[10]

The IEA *Net Zero by 2050 Roadmap*, in its Summary for Policy Makers, stresses that net zero by 2050 requires great leaps in clean energy innovation, with the biggest opportunities being advanced batteries, hydrogen electrolysers, and direct air capture (DAC).

> *"Together, these three technology areas make vital contributions [to] the reductions in CO_2 emissions between 2030 and 2050 in our pathway. Innovation over the next ten years – not only through research and development (R&D) and demonstration but also through deployment – needs to be accompanied by the large-scale construction of the infrastructure the technologies will need. This includes new pipelines to transport captured CO_2 emissions and systems to move hydrogen around and between ports and industrial zones." (IEA, p.15)*[11]

Also in its Summary for Policy Makers, hydrogen 'markers' are clearly identified in graphical representations of key milestones in the presented pathway to net zero emissions by 2050.

The versatility of hydrogen and its derivatives is evident with hydrogen/hydrogen-based fuels included as an important CO_2 emissions mitigant across several sectors – electricity, industry, transport and (to a lesser extent) buildings. In the IEA report, the word hydrogen is mentioned 440 times across all main chapters.[12]

Aggregate deployment milestones for hydrogen and hydrogen-based fuels are shown below. Unless otherwise noted, the subsequent information is based on the *IEA Net Zero by 2050 Roadmap* (which is 'directionally' consistent with key markers identified in the IRENA *World Energy Transitions Outlook: Preview)*.

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[6] This compares with a negligible amount at present.

[7] The IEA report notes that fossil fuel-based CCS/CCUS projects face deployment challenges and has evaluated a low CCUS case (150 million tonnes capture of emissions from fossil fuels in 2050 vs 3,600 million tonnes capture in the 'main scenario'); it is estimated that an additional cumulative investment of US$15 trillion would be needed to reach net zero emissions by 2050 in this low CCUS case (compared to the 'main scenario').

[8] In the case of the US, for example, a notable recent examination of pathways to net zero emissions by 2050 is the Princeton University Net Zero America study (December 2020).

[9] There is less consensus in national pathways on the role of bioenergy and CCS/CCUS technologies in reducing emissions.

[10] Compared to the IRENA reference Planned Energy Scenario (PES) where global CO_2 emissions are at around 37 billion tonnes in 2050.

[11] The IEA Roadmap notes that that the three technologies of advanced high-energy density batteries, hydrogen electrolysers and DAC are critical in enabling around 15 per cent of the cumulative emissions reductions between 2030 and 2050. (p.186)

[12] This compares with 336 for renewable/renewables, 74 for electrification, 83 for nuclear, and between 200-250 for each of bioenergy and CCUS.

Key deployment milestones for hydrogen and hydrogen-related fuels

	2020	2030	2050
PRODUCTION PROFILE			
Total production (million tonnes - Mt)	87	212	528
Low-carbon hydrogen production	9	150	520
share fossil-based with CCUS	*95%*	*46%*	*38%*
share electrolysis-based	*5%*	*54%*	*62%*
Merchant production	15	127	414
Onsite production	73	85	114
CONSUMPTION PROFILE			
Total consumption (Mt)	87	212	528
Transport, of which	0	25	207
hydrogen	*0*	*11*	*106*
ammonia	*0*	*5*	*56*
synthetic fuels	*0*	*8*	*44*
Industry	51	93	187
Electricity, of which	0	52	102
hydrogen	*0*	*43*	*88*
ammonia	*0*	*8*	*13*
Buildings & agriculture	0	17	23
Refineries	36	25	8
PLANT AND INFRASTRUCTURE PROFILE			
Electrolyser capacity (GW)	<1	850	3,585
Electricity demand for hydrogen-related production (TWh)	1	3,850	14,500
CO_2 captured from hydrogen production (Mt CO_2)	135	680	1,800
No. of export terminal at ports for hydrogen/ammonia trade	-	60	150
Average cost of producing hydrogen from renewables (US$/kg)	3.5-7.5	1.5-3.5	1-2.5
KEY SECTORAL INDICATORS			
Hydrogen-based electricity generation (TWh)	-	875	1,713
Hydrogen-based fuel share of global transport demand	-	<5%*	28%
Hydrogen refuelling units	540	18,000	90,000
Industry hydrogen demand (Mt), of which	51	93	187
Chemicals	*46*	*63*	*83*
Steel	*5*	*19*	*54*
Cement	*0*	*2*	*12*

Note: Hydrogen-based fuels are reported in million tonnes of hydrogen required to produce them

** This number is an interpolation based on graphical information in Figure 3.22, p.133*

Source: IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, 2021, various pages

The global hydrogen production ambition in a net zero by 2050 pathway represents a massive increase in production capability from the present megawatt levels, and even from recently announced targets; for example, in A Hydrogen Strategy for a Climate-Neutral Europe (July 2020), the European Commission includes a strategic objective of at least 40 GW of renewable hydrogen electrolysers installed in the EU by 2030 (and the production of up to ten million tonnes of renewable hydrogen).

Other metrics that illustrate the extent of uptake of hydrogen (and derivative fuels) in a net zero by 2050 pathway are scattered throughout the IEA Roadmap and include:

- The increase in gaseous hydrogen production between 2020 and 2030 is twice as fast as the fastest ten-year increase in shale gas production in the US (p.59)
- Merchant hydrogen produced using electrolysis requires around 12,000 TWh in 2050, which is greater than present total annual electricity demand of China and the US combined. (p.71)
- Hydrogen is increasingly blended with natural gas in gas networks; the global average blend in 2030 includes 15 per cent of hydrogen in volume terms. (p.75)
- There is a large increase in the installation of end-use equipment for hydrogen during the 2020s, including more than 15 million hydrogen fuel cell vehicles on the road by 2030. (p.75)
- Although hydrogen-based fuels provide only around 2 per cent of global electricity generation in 2050, this translates into very large volumes of hydrogen and makes the electricity sector an important driver of hydrogen demand. (p.76)
- Hydrogen provides around one-third of fuel use in trucks in 2050 (contingent on incentivisation/development of the necessary infrastructure by 2030) and hydrogen-based fuels provide more than 60 per cent of total fuel consumption in shipping. (p.76)
- In industry, around 60 per cent of heavy industry emissions reductions in 2050 is from technologies that are not ready for market today: many of these use hydrogen or CCUS. Each month from 2030, the world equips 10 new and existing heavy industry plants with CCUS, adds three new hydrogen-based industrial plants and adds 2 GW of electrolyser capacity at industrial sites. (p.99)
- By 2025, any gas boilers sold are capable of burning 100% hydrogen and the share of low-carbon gases (hydrogen, biomethane, synthetic methane) in gas distributed to buildings rises from almost zero to 10 per cent by 2030 to above 75 per cent by 2050. (p.146)
- Nearly 40 per cent of hydrogen production in 2050 is from natural gas in facilities equipped with CCUS. (p.161)

In terms of uptake profile, the initial focus is to convert existing uses to low-carbon hydrogen – noteworthy is use in gas blending and electricity, which together approach 100 million tonnes global use in 2030 from a negligible amount in 2020. After 2030, low-carbon hydrogen expands rapidly across a broader group of sectors. (p.75)

This expansion after 2030 is in large part dependent on a major acceleration in clean energy innovation. More than 75 per cent of the cumulative emissions reduction in the IEA 'main scenario' related to hydrogen is from demand technologies not presently on the market. (p.96) This is especially relevant for emissions reduction in heavy industry.

Making the practical happen

Such a heading for the subject matter under consideration offers potential for a thesis-length discourse. Abstracting for the moment from the obvious funding/investment aspects (see IEA pp.81-82 and 153-155 and below for related reports), a few points related to the above metrics are worth noting:

- Manufacturing electrolysers at the rate required in the IEA 'main scenario' (an average annual capacity addition of around 80 GW per annum during the 2020s, higher after 2030) is a particular challenge given current manufacturing capacity, as is installing the associated electricity generation capacity.

- Historical cycles in innovation, on average, must be accelerated, considerably.[13]
- International cooperation across a range of aspects is a necessary condition for emissions to fall to net zero by 2050, including enabling cost reductions through the creation of international demand signals and economies of scale, in managing trade and competitiveness, supporting innovation, demonstration and diffusion, and funding and certifying CO_2 removal programs (such as bioenergy and DAC equipped with CCUS).[14]

Related reports

Recently released reports by the IEA build on, or have considerable bearing on, key aspects of reaching net zero emissions by 2050. These reports include:

- The Role of Critical Materials in Clean Energy Transitions (May 2021) – reviews the complex links between these minerals and the prospects for a rapid transformation of the energy sector, and examines whether today's mineral investments can meet the needs of a swiftly changing energy sector.
- World Energy Investment 2021 (June 2021) - amongst other things, focusses on whether the growing momentum among governments and investors to accelerate clean energy transitions is translating into an actual uptick in capital expenditures on clean energy projects.
- Financing Clean Energy Transitions in Emerging and Developing Economies (June 2021 in collaboration with the World Bank and World Economic Forum) - drawing on nearly 50 case studies, addresses the challenge of accelerating investment for clean energy transitions in emerging and developing economies.

[13] By way of example, the time from first prototype to market introduction would need to be around 40 per cent faster than was the case for solar PV; technology to enable low-emissions ammonia-fuelled ships and hydrogen-based steel production would need to reach market in the next 3-6 years. (IEA p.185)

[14] The importance of international cooperation in reaching net zero emissions by 2050 and the implications of failing to achieve such cooperation is discussed in the IEA Roadmap (pp187-189).