NEW ENERGY WORLD

The magazine of the Energy Institute

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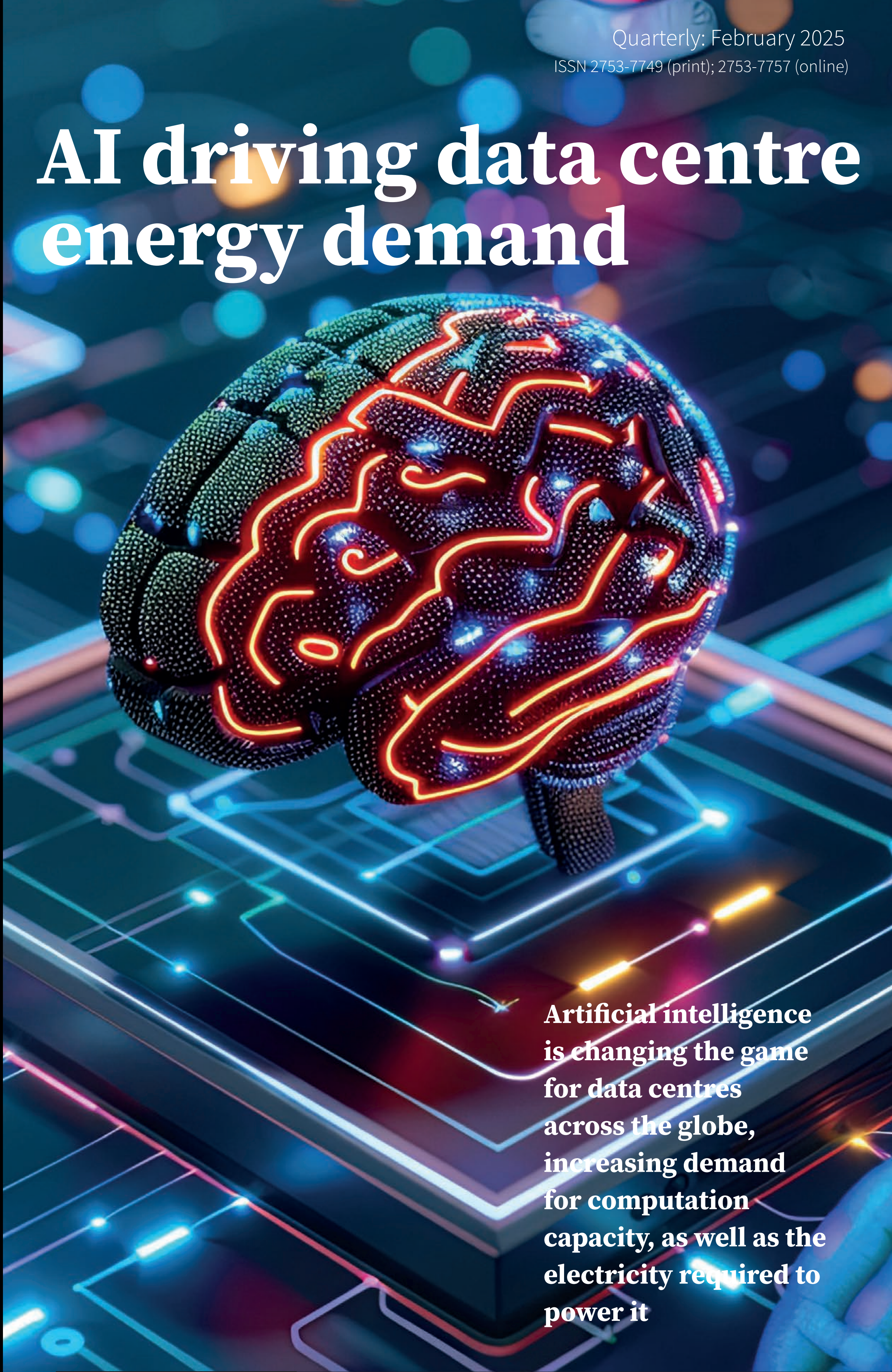

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Artificial intelligence is changing the game for data centres across the globe, increasing demand for computation capacity, as well as the electricity required to power it

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- Fusion – the 21st century's hottest ticket
- How should we account for exported fossil fuel emissions?
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Welcome

Reflecting on my first year in post, it's surprising how quickly the geopolitical situation has shifted since I joined. A new US administration and the (hopefully permanent) cessation of hostilities in the Middle East are dominating headlines at the moment. What will be next?

The drama of today's news does make it more difficult to continue focus on long-term global challenges such as decarbonising electricity, transport and industry. Fortunately, that is what the Energy Institute is for, today and tomorrow.

To that end, CEO Nick Wayth FEI has launched a personal A–Z of the energy transition (A was air source heat pumps; B was biofuels). Updates are available every fortnight on LinkedIn, or read them all via **https://shorturl.at/tkYR1**

For more information about all aspects of the energy transition, read *New Energy World* each week at **knowledge.energyinst.org/new-energy-world**

Will Dalrymple, *Senior Editor*

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What is the potential of hydrogen interconnectors?

HYDROGEN

Electricity interconnectors are expanding and attracting investment. Can the development of hydrogen pipelines be as successful internationally as the energy transition gains momentum, asks Janet Wood.

Development of trading and transport of energy is fundamental to the energy transition because it facilitates optimisation of renewable resources. As a result, electricity interconnectors have recently become a focus for investment.

For some uses we need to transfer 'molecular energy' (currently as natural gas/methane) as well as electrons. Can hydrogen take the place of natural gas to be the world's molecular energy carrier?

The UK is an example of how electricity interconnection has expanded. For around 25 years Great Britain's market (England, Wales and Scotland) had just one link with any other market, the Interconnection France-Angleterre (IFA), a joint venture between French Transmission Operator RTE and the UK's then National Grid (now National Grid Ventures) which started operating in 1986. In 2002, Great Britain was connected to the island of Ireland, linking the Moyle interconnector to the Scottish and Northern Ireland markets.

But it was nearly a decade later that Great Britain's electricity market started to expand links with neighbouring countries. Under EU policy, the EU set an interconnection target to allow at least 15% of the electricity produced on its territory to be transferred across its borders – a step up on the previous interconnection target of 10% by 2020. This will aid efficient power sharing in the EU's Internal Energy Market (IEM). According to the European networks organisation ENTSO-E, interconnection between EU countries had reached 93 GW at the start of 2022.

The EU expects 23 GW of interconnectors will be added by the end of 2025 and a further 12 GW by 2030. This expansion is facilitated by the European Commission, which includes interconnection in its list of 'Projects of Common Interest' for member states (PCIs).

Before the UK left the EU, its push for new interconnectors was partly driven by IEM targets. But even though Great Britain's market is outside the IEM since Brexit, the case for new interconnectors remains strong.

Developers proposing new interconnectors have an option to ask bill

Viking Link is a 1,400 MW high voltage direct current (DC) electricity link between the British and Danish transmission systems

Photo: National Grid

Interconnector	In service
IFA interconnector	1986
500 MW to Northern Ireland (Moyle)	2002
1 GW to the Netherlands (BritNed)	2011
500 MW to the Republic of Ireland (East West)	2012
1 GW to Belgium (Nemo Link)	2019
IFA2 interconnector	2021
1.4 GW to Norway (NSL)	2021
ElecLink	2022
1.4 GW to Denmark (Viking Link)	2023

Table 1: Great Britain's in-service interconnectors

payers to underwrite their investment, in a ‘cap and floor’ mechanism that guarantees a return while capping profit. Great Britain’s energy regulator Ofgem is the gatekeeper on the cap and floor mechanism and recent cost-benefit analyses for new projects concluded that bill payers benefit from underwriting further interconnection. In November 2024, it gave the green light for three new planned interconnectors with neighbouring markets to be underwritten, along with two that would connect via offshore wind farms.

Can hydrogen follow?
Electricity interconnectors are good investments because resources to general electricity are variable and not sited near to users – and importantly, because there is no other option than to transport the necessary electrons at huge scale. Reliance on renewables has increased the drive for interconnectors, both in terms of numbers and of scale, with links now proposed that are thousands of miles long.

What does this tell us about the likely future of an international market in hydrogen? Clearly the same conditions apply.

Green hydrogen is most economically produced where renewable energy resources are abundant, but potential hydrogen buyers are seldom co-located with producers.

A number of countries with abundant renewable resources have announced hydrogen strategies that propose to rely heavily on export markets. Australia, for example, said in a consultation on hydrogen opportunities: ‘The development of a hydrogen export industry will support investment in the sector and also provides at least some offset to the likely reduction in export income derived from fossil fuel exports.’

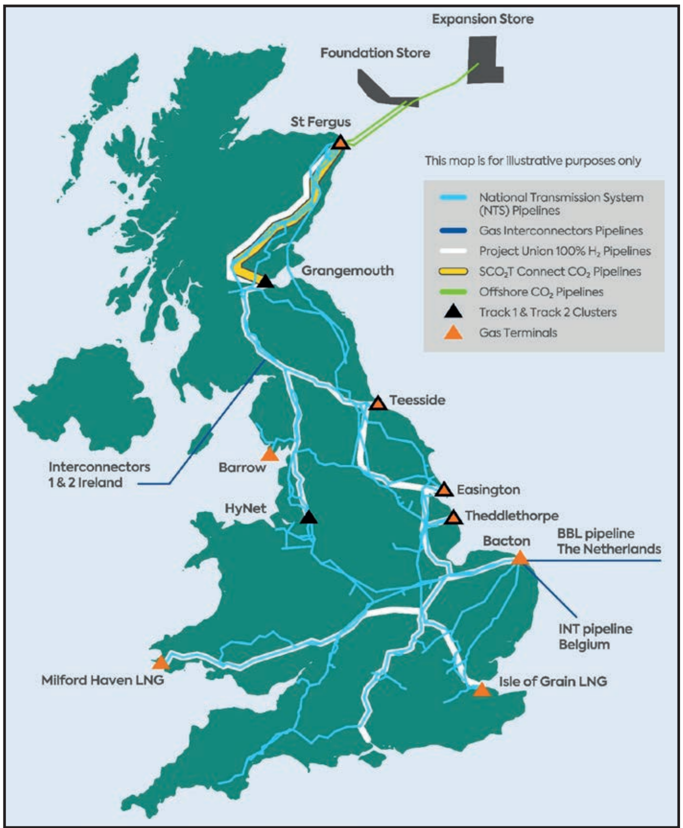


Fig 1: Project Union, mapped on to other UK gas pipeline networks

Source: National Grid

Namibia has also launched a green hydrogen programme, saying its ‘world-class solar and wind resources’ give it ‘a long-term competitive advantage in producing green hydrogen and green ammonia’.

Brazil has a similarly ambitious programme: a Triennial Work Plan for hydrogen, published in mid-2023, said it expects eventually to produce around 35mn t/y of hydrogen from offshore wind-generated electricity. A law enacted in 2024 will provide tax credits for low-carbon hydrogen. Fernanda Delgado, Executive Director of the Brazilian Green Hydrogen Industry Association, said it presented ‘the opportunity to lead the production and export of this essential energy vector for the global energy transition’.

What precedent is there for hydrogen pipelines?
This not the first time a global gas market has been developed. Methane (natural gas) in the past was typically transferred via by pipelines, but this has changed. Since December 1998, InterconnectorUK has been available to move natural gas between Great Britain and Europe (with a terminal in Belgium). In 2006, two new pipelines were added: a second pipeline from Bacton to the Netherlands, and the Langeled link bringing gas from Norway. But gas is often transported by ship, as liquefied natural gas (LNG) and Great Britain has built three terminals to import LNG (located at Grain, South Hook and Dragon).

The LNG industry had been expanding – in 2022, Qatar, Australia and the US were the largest exporters, but other exporters included Malaysia, Indonesia and Nigeria, according to the UK Department for Energy Security and Net Zero (DESNZ). Growth of LNG sped up in 2022 after Russia’s invasion of Ukraine, as European buyers rushed to replace Russian pipeline supplies.

Hydrogen is already transported by pipeline, although there are fewer than 5,000 km of hydrogen pipelines, according to the International Renewable Energy Agency (IRENA). Development of a far larger hydrogen market will require new interconnectors.

A European Hydrogen Backbone (EHB) initiative brings together 33 infrastructure organisations to give impetus to developing the necessary infrastructure in Europe. In Germany, the Federal Network Agency (Bundesnetzagentur) gave go-ahead in October 2024 to a 9,040 km hydrogen pipeline network connecting demand clusters with hydrogen sources. Between 2025 and 2032 methane gas pipelines will be repurposed and new hydrogen pipelines built. The Federal Network Agency will set the fees for the hydrogen core network, and KfW will provide a loan facility of €24bn.

The EU would like to see markets in natural gas and hydrogen develop across the bloc, and in 2024 it passed a new Directive (2024/1788) on common rules for the internal markets for renewable gas, natural gas and hydrogen. Gas projects are included in its PCI process.

Progress on the network for various gases is evaluated every two years by the bloc’s Agency for the Co-operation of Energy Regulators (ACER). Its 2023–2024 gas network planning report increased focus on integrating low-carbon and renewable gases, along with decommissioning and repurposing existing gas infrastructure. Several countries have developed hydrogen strategies, legal frameworks and specific hydrogen planning activities, and EU member states are becoming more consistent in including hydrogen in their plans. ACER recommended that this work should be encouraged.

Hydrogen shipping is also under development, to transport hydrogen over large distances globally.

> ***Reliance on renewables has increased the drive for interconnectors, both in terms of numbers and of scale. Will the same hold true for an international market for hydrogen?***

How can we transport hydrogen?
While the transport infrastructure for hydrogen is in the early development stage, other options may become a *de facto* transport route.

Hydrogen has important uses in industry, for example as ammonia for fertiliser. Global production of ammonia for this purpose is 183mn t/y, according to the International Energy Agency (IEA), using dedicated vessels similar to LNG transport. Ammonia has been proposed as an option for transporting hydrogen for other sectors, although there is a hefty energy penalty in converting it at both ends. Ammonia can also be used directly as fuel in gas turbines.

In a report in January 2024, DNV noted that: 'Ammonia is considered a key future storage and long-distance transport medium for hydrogen. While the liquefaction, storage and transport of pure hydrogen requires enormous energy input and is technically complex, handling ammonia is comparatively simple and an established industrial practice. Furthermore, the energy density of liquefied ammonia is higher than that of liquefied hydrogen, making its transport more efficient.'

At the moment, in contrast, hydrogen transport by ship is still problematic. Kawasaki built Japan's first LNG carrier in 1981 and describes itself as 'the rare player who can combine shipbuilding and liquefied hydrogen cryogenic technologies'. But it recently pulled out of a consortium developing LNG-style tankers for hydrogen.

Meanwhile, one LNG tanker maker, GTT, has been awarded Approvals in Principle by accreditation company Bureau Veritas (BV) for a containment system that allows for the conversion of LNG fuel tanks for either ammonia or methanol fuels (methanol is another potential hydrogen product that in current modelling would be largely produced and stored at ports, with some transport required).

It is clear there is more than one option by which hydrogen could become the molecular energy transport medium we need. Diversity of supply routes would be helpful to give customers security of supply. However, it may be less helpful in developing a global market if it reduces the guaranteed volumes that are required to underwrite capital-intensive infrastructure like pipelines and shipping terminals. ■

This article was first published online in *New Energy World* on 8 January 2025.

HYDROGEN

Could Europe be the Saudi Arabia of natural hydrogen?

Hydrogen is an increasingly important component of the energy transition. But where will we get it? The cheapest, cleanest source may turn out to be natural accumulations of hydrogen underground, writes Professor Dave Waltham, Department of Earth Sciences, Royal Holloway University London.

There's a big effort to find new, commercially exploitable deposits of hydrogen. Ongoing exploration stretches across more than 20 countries, from Australia to Spain and on to Canada. One small village in Mali burns 'natural hydrogen' to generate its electricity. But, so far, that's the sole example of real-world exploitation. For now, we don't know whether natural hydrogen fields are large enough, or common enough, to make a significant impact on the developing hydrogen economy.

The Los Mallos de Riglos formation in the European Pyrenees – natural hydrogen deposits have been found in the Pyrenees, but the extent of their distribution, and their size, remain unclear

Photo: Nathalie Grassineau

Investigations so far have been reminiscent of 19th century petroleum exploration – whether in Pennsylvania or Baku, early oil drilling took place near seeps that had been known for centuries. No one had the slightest idea that, in the 20th century, enormous volumes of petroleum would be found in the Arabian peninsula, the North Sea and offshore Brazil. Those discoveries had to await a deeper understanding of how, where and why hydrocarbons accumulate.

Current natural hydrogen exploration is at a similar, early stage of development, as it's based on the equivalent of following oil seeps.

For example, current exploration in Australia and Brazil has looked for hydrogen leaks at the Earth's surface, in the form of 'fairy circles' – km-wide patches of disturbed vegetation which indicate hydrogen accumulating in the soil. Alternatively, previously-drilled oil or water wells were occasionally analysed for the presence of hydrogen. This is how the discovery in Mali was made and is also the basis for current searches in the Pyrenees.

So, for now, we're looking in places where hydrogen has already been detected. This makes sense, but uncovering the hydrogen-equivalent of Saudi Arabia may require a more science-based approach.

Fortunately, the techniques already used for hydrocarbon exploration tell us what a scientific exploration strategy would look like. Whether we're after oil, natural gas or hydrogen, we need a source rock to generate it, a porous rock to hold it and an impermeable cap rock to trap it. A successful accumulation also needs a migration route connecting source to trap and, in addition, everything has to be in place at just the right time. There's no point in having an otherwise fabulous trap that only formed a million years after the oil, gas or hydrogen passed by.

What do we need to find natural hydrogen?
Source rock, reservoir rock, cap rock, a migration pathway and good timing are, therefore, the necessary components for successful hydrocarbon exploration. Hydrogen exploration only really differs when we consider the source.

For oil and gas, our sources are 'dirty rocks' or, in more technical language, organic-rich sediments. Cook these at high temperatures and pressures for a few million years and crude oil or natural gas oozes out. What's the equivalent for hydrogen?

There are several possibilities but the largest potential source, by far, is the Earth's mantle – the 85% of Earth's volume that lies between the core and the crust. Mantle rocks generate hydrogen when they're warm and wet. Warm, here, means in the range 200–600°C. Wet means lots of free water (hydrated minerals don't count as the water is chemically locked up within them). With this combination of temperature and moisture, water oxidises the reduced iron that mantle rocks abundantly contain, and hydrogen is released.

However, most of the mantle is hot and dry rather than warm and wet. Useful source rocks are, therefore, only found in places where geological processes cool down mantle rocks and, simultaneously, expose them to water. Fortunately, there are many plate-tectonic settings where this happens.

The classic example is the mid-ocean ridge system – the 65,000 km long mountain chain that runs along the centre of the world's oceans. This ridge is where new crust is formed as brand-new tectonic plates are pulled apart by powerful convection currents deep within our planet. The resulting thin, fractured crust allows mantle to approach the surface and allows seawater to percolate deep beneath the seafloor. Warm, wet mantle is, therefore, found along much of the ridge's length and this liberates vast quantities of hydrogen.

But this all happens in deep water and a long way from civilization – they're called mid-ocean ridges for a reason! These ridges are unlikely, therefore, to form the basis of a new, clean, energy industry. Ideally, we want a hydrogen source on land and close to industrial centres, so that we can get it out cheaply and don't have to transport it too far.

How do we find natural hydrogen?
There are other ways to moisten and cool the mantle. These generally involve a more complex sequence of geological events than occurs at mid-ocean ridges and, to quantify their potential properly, we need the hydrogen-exploration equivalent of the 'basin modelling' software widely used in hydrocarbon exploration. These are computer models that simulate the formation and deformation of sediments and the associated generation, migration and trapping of fluids. My own Royal Holloway research centre is currently developing basin models of hydrogen energy systems, although this work remains at an early stage.

To focus our minds, we've been thinking about the Pyrenees mountains, where natural hydrogen has been found on both the French and Spanish sides of the range. These accumulations may be independently sourced and entirely unrelated, but it makes sense to begin by assuming a common source somewhere under the central Pyrenees. There are at least a couple of candidates.

Firstly, as tectonic plates collided to form the Pyrenees over the last 40 million years, mantle rocks were pushed upwards by the resulting thrust faults. Thousands of cubic kilometres of thrusted mantle can be seen today on seismic images at depths of only around 10 km (where it should have just the right temperature). And, as this is directly under the highly faulted central Pyrenees, it is likely that rainwater has trickled down to meet it. The hydrogen potentially generated by this much mantle would have the same energy content as a supergiant oil field. Of course, hydrogen generation won't have been 100% effective and not all of the generated hydrogen will have found its way to traps. But even a small fraction of this total would still be commercially attractive.

There is another, even more exciting, possibility. As well as generating thrust faults which pushed rocks upwards to form mountains, the Pyreneean collision also subducted the lower part of the Spanish crust under the French mantle. Think of the Spanish crust as meeting the tectonic equivalent of a fork in a road, so that the top half went up and the bottom half went down. And crustal rocks contain a lot of water. The subducting Iberian crust will have warmed as it was pushed deep into the Earth, and released its water which then buoyantly rose into the overlying Gallic mantle.

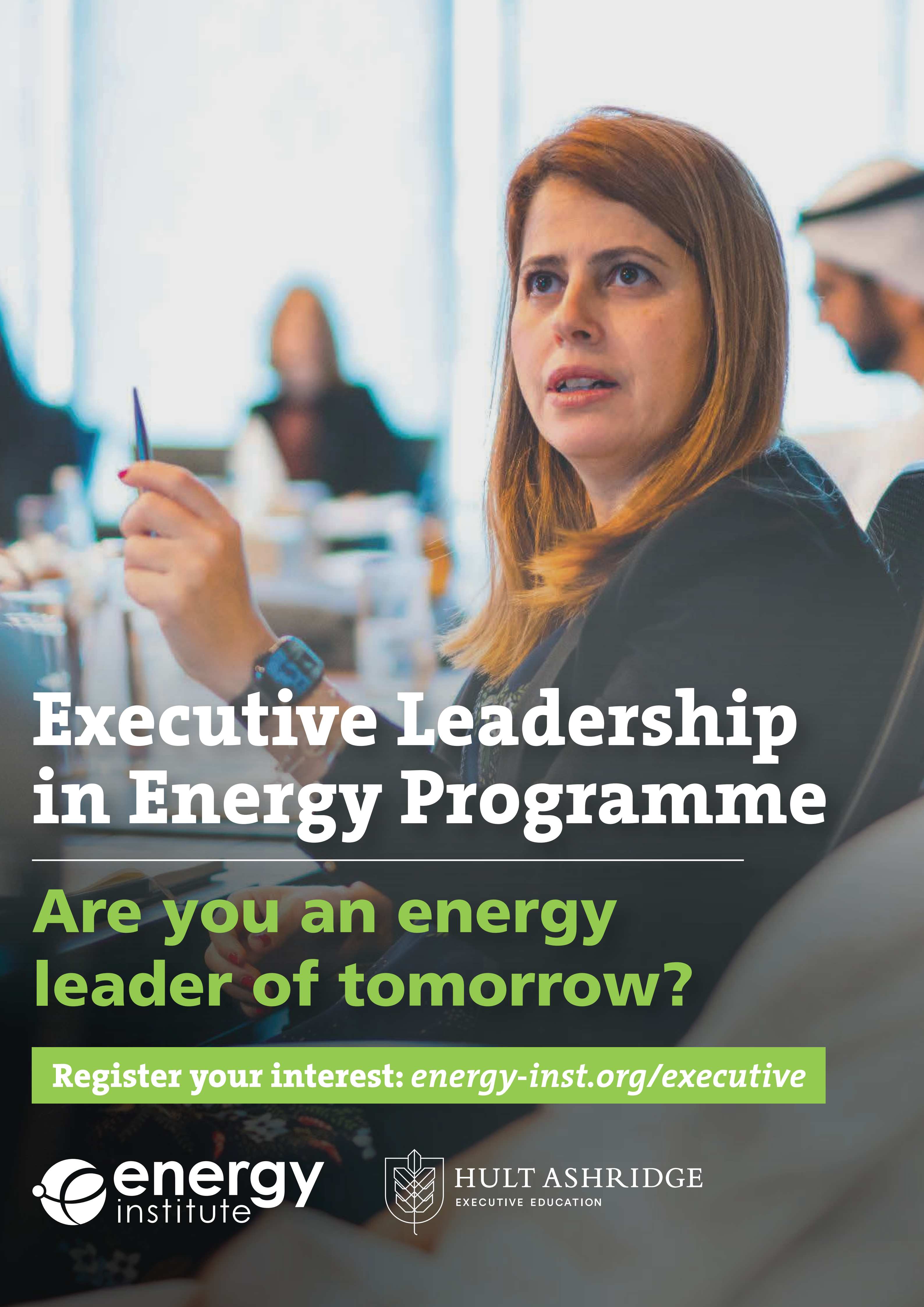
In most such settings, the result is 'arc volcanism' (as seen in the Andes or in Japan) because adding water to hot mantle makes it melt. Mysteriously, in the Pyrenees (and also in the Alps) there has been no such volcanism. Our models suggest that water release was unusually late in the Pyrenees, and that the mantle wedge was cooler than normal by the time water reached it. Could it be that, under these circumstances, water oxidises iron and generates hydrogen rather than producing magma? We don't yet know, but we're working on it.

The potential quantities of hydrogen generated by this scenario are staggering. The mantle wedge could have produced 10–100bn tonnes of hydrogen, containing the energy equivalent of over 10 years of total, global oil consumption. Once again, not all the available hydrogen will have been liberated and not all of that will have been captured in subsurface traps. Even so, if this model turns out to be correct, the implication is that south-west Europe may be the Saudi Arabia of hydrogen I've been after.

Reality check
The current excitement over natural hydrogen may be misplaced. The rosy picture I've painted above is very much a best case. More sceptical views are often based on the observation that, if there's really a lot of subsurface hydrogen around, we should have spotted it decades ago. There is something to this argument, but there are also good reasons why we may have missed it. For example, analyses of gases in oil wells are usually carried out using gas chromatography with hydrogen as the carrier gas. That's like looking for moisture in salt by first dissolving it in a test tube of water!

Natural hydrogen exploration is a classic high-risk/high-returns problem. Hydrogen accumulations large enough to be commercially viable may not exist at all. Or they may be so rare that they don't make much difference. Still, it's worth the risk of looking anyway as the economic and environmental pay-off will be enormous if a significant number of rich hydrogen accumulations really do lie under our feet just waiting to be found. ■

This article was first published online in *New Energy World* on 23 October 2024.



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What did COP29 achieve for climate finance?

FINANCE

The UN Climate Change Conference (COP29) closed on Saturday 23 November 2024 having brokered several new climate finance agreements, including a new finance goal, to help countries to protect their people and economies against climate disasters. Reaction to the agreements has been mixed, reports *New Energy World* Senior Editor Will Dalrymple.

At the core of the largest COP29 agreement is $300bn of finance per year led by developed countries, with developing countries encouraged to contribute voluntarily. That is three times larger than the previous total, and represents a $50bn increase on the previous draft text, said to have been the product of 48 hours of intensive diplomacy by the COP29 Presidency. Beyond the $300bn figure is a much larger ambition to scale up a combination of public and private finance to reach $1.3tn/y by 2035. Together, these make up the so-called New Collective Quantified Goal on Climate Finance (NCQG).

Demonstrations played a bigger role at COP29 than previous gatherings, and mirrored the event theme of climate finance

Photo: UN Climate Change/Kiara Worth CC BY-NC-SA 2.0

COP29 President Mukhtar Babayev said: 'The Baku Finance Goal represents the best possible deal we could reach. In a year of geopolitical fragmentation, people doubted that Azerbaijan could deliver. They doubted that everyone could agree. They were wrong on both counts.'

Is the COP29 NCQG figure large enough?

Opinion differs about whether the agreed sum is sufficient. Ani Dasgupta, President and CEO of the US-based think tank World Resources Institute, reacted with muted positivity. He says: 'Despite major headwinds, negotiators in Baku eked out a deal that at least triples climate finance flowing to developing countries. The $300bn goal is not enough, but is an important downpayment toward a safer, more equitable future. The agreement recognises how critical it is for vulnerable countries to have better access to finance that does not burden them with unsustainable debt. And it opens the door for a broader set of countries to contribute.'

'The poorest and most vulnerable nations are rightfully disappointed that wealthier countries didn't put more money on the table when billions of [lives] are at stake. According to leading economists, $300bn by 2035 does not meet the scale of what developing countries need to pursue a low-carbon economy and protect their citizens from mounting droughts, floods, and wildfires.'

'This deal gets us off the starting block. Now the race is on to raise much more climate finance from a range of public and private sources, putting the whole financial system to work behind developing countries' transitions.'

His nuanced reaction was echoed by commentators in the UK. For example, at the University of Exeter, Professor Peter Cox, Director of the Global Systems Institute, says: 'It is absolutely fair that developing countries should receive money from the developed world to help them adapt to climate change. It seems that some progress has been made on that, but the sum agreed ($300bn/y) still falls well short of the climate change damages that developing countries suffer.'

On the other hand, Exeter Professor of Physical Geography Stephen Sitch adopts a more positive tone. 'Given the geopolitical realities, the $300bn represents a foundation that can be built upon. Also, there is an important agreement on carbon markets which will open up further opportunities for expansion of nature-based solutions.'

Carbon market developments at COP29

Sitch was referring to agreement on provisions in Article 6 of the Paris Agreement, which governs the international trade of carbon credits, upon which recent COPs have been unable to reach a consensus. Carbon trading has been a controversial part of the international response to climate change, with little trust in the efficacy of some schemes. According to the Environmental Defence Fund, Article 6.2 now covers the transfer of carbon between two countries (bilaterally). Trades from domestic systems or linked emissions markets can now be officially recognised, and those trades are reflected in their official decarbonisation plans. Transparency requirements, rather than a global watchdog, regulate the system.

On day one of COP29, countries agreed standards for a centralised carbon market under the UN Article 6.4 mechanism. The Paris Agreement Crediting Mechanism includes environmental and human rights protection, and the right of appeal by anyone affected by a project. The agreements also mandate that the carbon market supervisory body should consider the best available scientific evidence, according to an official statement by UN Framework Convention on Climate Change (UNFCCC).

The Environmental Defence Fund also pointed out that Article 6.4 covers the transfer of carbon credits from the older Clean Development Mechanism to the Paris Agreement Crediting Mechanism.

Reviewing Article 6 as a whole, it says: 'Altogether these two mechanisms have the potential to lead to a marked improvement in carbon markets under the UNFCCC. However, much depends on two factors: progress on defining further several standards under Article 6.4, and the proper scrutiny of standards and approaches used under Article 6.2.'

In the organisers' official press release, COP29 Lead Negotiator Yalchin Rafiyev commented: 'Today, we have unlocked one of the most complex and technical challenges in climate diplomacy. Article 6 is hard to understand, but its impacts will be clear in our everyday lives. It means coal plants decommissioned, wind farms

Other COP29 news

- On the sidelines, the UK, New Zealand, and Colombia joined the international Coalition on Phasing Out Fossil Fuel Incentives Including Subsidies (COFFIS).
- TotalEnergies and Oil India Limited (OIL) signed a cooperation agreement to carry out methane emissions detection and measurement campaigns using TotalEnergies' drone-based AUSEA technology. State-owned enterprise OIL recently joined the Oil and Gas Decarbonization Charter (OGDC).
- The Industrial Transition Accelerator (ITA) urged governments to use proven policy measures to stimulate demand for green products and better seize the potential of industrial decarbonisation. It says that uncertain demand and a lack of incentives to buy green products is stalling industrial decarbonisation progress, with producers and customers at a stalemate due to lower price of higher-carbon products.
- Companies are eyeing more business opportunities from tackling climate change than ever before, with the world's biggest businesses now identifying nearly $5tn in potential gains, according to data released by global disclosure watchdog CDP. Expectations have increased substantially, with the world's largest 500 businesses raising the potential financial benefits they see from $2.1tn in 2018 to $4.8tn in 2023.
- The European Commission and the Beyond Oil and Gas Alliance (BOGA) announced a new partnership to accelerate a just, orderly and equitable transition away from fossil fuels in Europe and globally.
- The European Commission launched the Methane Abatement Partnership Roadmap, which aims to minimise emissions of methane throughout the oil and natural gas supply chain and establish cooperation frameworks between countries either importing or exporting fossil fuels.
- Fortescue and other global shipping industry leaders signed an agreement, 'Green Hydrogen and Green Shipping: Amplifying the Power of Hydrogen in a Just and Equitable Transition,' calling for greater action on zero emissions fuel standards and related investments for international shipping.
- The Coal Transition Commission, which brings together governments, international organisations and financial institutions, published its first report laying out actionable recommendations to accelerate the coal-to-clean energy transition. It says accelerating coal transitions will depend on bold and effective domestic policy and planning and the support of a broad range of international partners.
- Masdar and Albanian Power Corp (KESH) signed a joint venture agreement to explore GW-scale renewable energy projects in Albania, and export to neighbouring countries.
- Masdar and the Ministry of Energy Uzbekistan signed an agreement to develop a 1 GW wind farm in the Mingbulak region of the country.

built and forests planted. It means a new wave of investment in the developing world.'

What about loss and damage?
Steps were also taken at COP29 to begin operations of the Loss and Damage Fund, intended to provide financial assistance to countries vulnerable to the impacts of climate change. Its establishment was agreed in COP27 in Egypt, and progressed at COP28. A board meeting held in Baku ahead of COP29 in September saw the appointment of a Senegalese-US banker, Ibrahima Cheikh Diong, as Executive Director for an initial four-year term.

At COP29, host country the Philippines signed an agreement with the Fund's board. Other agreements between the Fund's board and the World Bank were also signed.

To date, the total pledged financial support for the Fund exceeds $730mn. According to the COP29 organisers, the Fund will be able to finance projects as soon as 2025.

More reaction
A dissenting view of the success of the event comes from the Least Developed Countries (LDC) Group negotiating for 45 countries across Africa, the Asia-Pacific and the Caribbean, whose joint population numbers over one billion people. It says: 'The LDC Group is outraged and deeply hurt by the outcome of COP29. Once again, the countries most responsible for the climate crisis have failed us. We leave Baku without an ambitious climate finance goal, without concrete plans to limit global temperature rise to 1.5°C, and without the comprehensive support desperately needed for adaptation and loss and damage. This is not just a failure; it is a betrayal.'

It characterised the NCQG as a 'glaring symbol' of this failure. It, they said, ignores the needs of LDCs and SIDS [small island developing states] by offering no minimum allocation, lack of 'meaningful support' in loss and damage, and 'weak and vague' commitments for climate finance, whose lack of clear definitions 'undermines transparency, leaving the door open for manipulation and inaction.'

A scrum of participants at the COP29 closing plenary session in Baku, Azerbaijan
Photo: UN Climate Change/Vugar Ibadov CC BY-NC-SA 2.0

Nick Wayth, CEO of the Energy Institute, offered a wider assessment of the significance of this year's achievement. He says: 'It was great to be at COP to speak about the challenges of the global energy transition as well as gender diversity. In Baku, I saw first-hand the need for an inclusive approach to this process – so the progress made in increasing the availability of climate finance for vulnerable people around the world is very welcome.'

'However, the Energy Institute's *Statistical Review of World Energy* tells us that the world's progress in the energy transition remains slow. Until we can reverse the trend of increasing global emissions – which in 2024 reached an all-time high of 40Gt CO_2 – more and more of the world's population will be adversely affected by climate change.'

'Independent, non-partisan organisations like the EI play a vital role in providing objective, unbiased and trustworthy information about the energy transition to governments, companies and individuals.'

UN Climate Change Executive Secretary Simon Stiell summed up the two-week-plus event in a short phrase: 'It has been a difficult journey, but we've delivered a deal.'

He continues: 'No country got everything they wanted, and we leave Baku with a mountain of work to do. The many other issues we need to progress may not be headlines but they are lifelines for billions of people. So this is no time for victory laps, we need to set our sights and redouble our efforts on the road to Belém [Brazil, hosts of COP30].'

'Even so, we've shown the UN Paris Agreement is delivering, but governments still need to pick up the pace. Let's not forget, without this UN-convened global cooperation, we'd be headed towards five degrees of global warming.'

'But we are still a long way off course. Bold new climate plans on the way to Belém will be crucial to getting us back in the race. They must embed the targets we agreed in Dubai, including to rapidly ramp up renewables, transition away from fossil fuels, and transform societies, making them more resilient.'

Stronger national climate plans (Nationally Determined Contributions, or NDCs) become due from all countries next year. These new climate plans must cover all greenhouse (GHG) gases and all sectors, to keep the 1.5°C warming limit within reach. At COP29 two G20 countries – the UK and Brazil – signalled clearly that they plan to ramp up climate action in their NDCs 3.0. The UK's plan is to reduce economy-wide GHG emissions by at least 81% by 2035, compared to 1990 levels, excluding emissions from international aviation and shipping. The Brazilian government said it would reduce net GHG emissions by 59% to 67% by 2035, relative to 2005.

COP30 begins on 10 November 2025, only time will tell what gets done by then.

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COMMENT

Carbon taxes – a catalyst for decarbonisation

The effectiveness of carbon credits in mitigating climate change has come under increasing scrutiny, suggesting they may not deliver the intended environmental benefits. Carbon taxes might be a better alternative, write Kavita Gandhi, Executive Director, Sustainable Energy Association of Singapore (SEAS) and Vinod Kesava, Chairman of Carbon Working Group, SEAS.

In 2024, global CO_2 emissions from fossil fuel use were projected to increase by 0.8%, reaching a record 37.4 Gt. This trend highlights the need for more robust mechanisms to drive the transition to low-carbon technologies.

By imposing a fee on CO_2 emissions, carbon taxes create strong economic incentives for businesses to adopt low-carbon technologies, thereby reducing their emissions. This strategy not only encourages direct decarbonisation but also addresses the limitations associated with carbon credits, ensuring that financial incentives align with environmental goals.

In 2023, global carbon pricing revenues reached a record $104bn, reflecting the growing adoption of such measures worldwide. However, to effectively drive the energy transition, it is crucial to set carbon tax rates at levels that significantly impact business decisions, compelling a shift towards sustainable practices.

A carbon tax directly targets the financial foundation of emissions-intensive industries by increasing the cost of emitting CO_2. Businesses are charged a fee for each tonne of CO_2 they emit, effectively making pollution more expensive. Companies relying on carbon-intensive processes will find that this additional cost erodes profit margins and are therefore compelled to innovate or adapt to avoid additional cost.

To escape the financial burden of carbon taxes, companies have a clear incentive to transition to low-carbon or carbon-neutral technologies. These include renewable energy solutions such as wind and solar power, energy-efficient machinery and advanced carbon capture and storage systems. By adopting these technologies, businesses can dramatically cut their CO_2 emissions to reduce their tax liabilities. This shift would not only help companies save money but also contribute to a broader societal transition toward sustainable energy and practices.

Kavita Gandhi, Executive Director, Sustainable Energy Association of Singapore (SEAS)

Photo: K Gandhi

A bad reputation?

Critics often argue that carbon credits are ineffective, claiming that they merely allow companies to continue emitting CO_2 while offsetting those emissions through purchased credits. Even as a global carbon markets framework is being formulated post-COP29, the effectiveness of carbon credits as a tool for genuine emission reductions remains a topic of debate.

Critics argue that this enables major polluters to avoid making substantial changes to their operations, relying instead on purchased credits to offset emissions. Concerns have been raised about the potential for greenwashing and the adequacy of oversight to prevent double counting of emission cuts. While this criticism may hold in poorly regulated markets, it overlooks the critical role of a robust carbon tax in ensuring that the balance favours decarbonisation.

A higher carbon tax creates a powerful incentive for businesses to adopt cleaner technologies rather than rely solely on offsets. Carbon credits are not merely a way to maintain the *status quo* – they represent measurable reductions in emissions. By tying carbon credits to stringent certification standards and increasing the cost of emissions through taxation, governments can ensure that the balance leads to a net reduction in CO_2 and a significant push toward the energy transition.

As one of the few countries in the Asia-Pacific region with an operational carbon tax, Singapore has set an example by incrementally increasing its tax rate, which is expected to reach S$50–80/t (US$37–59) by 2030. It was raised from S$5 to S$25 last year. This approach aims to drive emissions reductions domestically while fostering a robust carbon trading ecosystem. Singapore's carbon markets also enable companies to trade offsets and credits, ensuring that businesses unable to fully decarbonise can still contribute to global emission reductions.

By aligning its carbon tax with international trading standards, Singapore maximises the impact of both mechanisms, promoting transparency, accountability, and innovation in emissions reduction strategies.

How carbon credits change markets

The ripple effects of a higher carbon tax extend beyond individual companies. As carbon-intensive practices become increasingly uncompetitive, entire industries are nudged towards cleaner energy sources and sustainable practices. Over time, this could lead to a market-wide transformation, spurring innovation in green technologies and driving down the cost of sustainable solutions. Industries that once relied on fossil fuels are gradually replaced by those aligned with a low-carbon future.

Consider a manufacturing company emitting 10,000 t/y of CO_2. With a carbon

> *A higher carbon tax creates a powerful incentive for businesses to adopt cleaner technologies rather than rely solely on offsets.*

tax of $100/t, its tax liability would be $1mn/y. To reduce this burden, the company might take the following steps:

- *Invest in renewable energy*: install solar panels or wind turbines to cut emissions by 4,000 tonnes.
- *Upgrade to energy-efficient equipment*: new machinery reduces emissions by an additional 2,000 tonnes.
- *Purchase carbon credits*: the remaining 4,000 tonnes of emissions are offset by buying carbon credits at $50/t, costing $200,000.

By reducing emissions and using carbon credits, the company's tax liability drops from $1mn to $200,000. This significant cost saving demonstrates how higher carbon taxes can drive businesses toward greener solutions.

A higher carbon tax is more than just a financial penalty; it is a catalyst for change. By making CO_2 emissions increasingly expensive, it pushes businesses to adopt clean technologies, drives innovation and fosters a thriving carbon market. Combined with stringent standards for carbon credits and the leadership of hubs like Singapore, this approach ensures that financial incentives favour decarbonisation rather than perpetuating emissions.

The views and opinions expressed in this article are strictly those of the author only and are not necessarily given or endorsed by or on behalf of the Energy Institute.

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COMMENT

How to account for exported fossil fuel emissions

How are fossil fuel-exporting countries incentivised to cut emissions associated with their fuel exports? They are not, but they ought to be, argues Chris Hilson, Professor of Law at the University of Reading and Director of the Reading Centre for Climate and Justice, UK.

COP29 in Baku concluded by reaffirming the agreed call on all parties at the previous UAE COP28 to contribute, *inter alia*, to 'Transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science.'

A key issue raised by the transition away from fossil fuels is where the responsibility lies between fossil fuel exporting and importing countries. Who bears the responsibility to do the transitioning? There is a significant divide here between the climate movement and the fossil fuel industry and producing states.

The former advocates supply-side production cuts in export countries, arguing that the remaining global carbon budget allows for no new oil and gas fields to be explored and developed.

The latter argue that they are merely meeting existing consumer demand and that with greater electrification of the economy, production will naturally fall as demand falls. To cut supplies independently would, they argue, make for a disorderly transition because of the threat to short-term energy security. In any event, there is a risk that other companies or countries would simply step in to replace that supply. (That final argument has been labelled, somewhat caustically, by the climate movement as the 'drug dealer's defence'.)

Chris Hilson, Professor of Law at the University of Reading and Director of the Reading Centre for Climate and Justice, UK

Photo: C Hilson

What does the Paris Agreement say about exported emissions?

The Paris Agreement's greenhouse gas accounting rules do not help. They provide little incentive for exporting states to take action to reduce their emissions by curbing their exports of fossil fuels. These rules mean that major exporting countries – including Russia, the US, Saudi Arabia, Norway, Qatar and Australia – do not have to account for their Scope 3 emissions from exports. Instead, those emissions show up in the accounts of the importing countries where the fuels are consumed.

Of course, the export countries have to account for their domestic *production* emissions – those that arise from vented and fugitive methane at production wells, and CO_2 from flaring and from power used in drilling, transport and LNG liquefaction.

While reducing the 'emissions intensity' of production sites is also important for climate change, by far the greatest climate impact comes from consumption emissions when fossil fuels are burned.

The Paris accounting rules for states are out of step with the way companies are increasingly being held to account for their emissions, with most now being pushed to include their customers' Scope 3 emissions under corporate climate disclosure rules and in Paris-aligned corporate climate targets.

Not all companies are on board. Saudi Aramco has failed to set Scope 3 net zero targets. And some, like Shell and BP, have rowed back on theirs. But there is at least pressure for companies to play their part in reducing global emissions across their value chains. They are increasingly having to account for those emissions, and not just Scope 1 and 2 emissions associated with their own operations.

The question thus remains after recent COPs: why are we lacking such pressure on fossil fuel exporting countries, which are conveniently offshoring their emissions while reaping the economic benefits? Until they have a proper incentive to reduce those export emissions, because they will show up on their own Paris nationally determined contribution (NDC) pledges rather than someone else's, COPs are likely to continue to disappoint on the mitigation of emissions from fossil fuels.

Accounting and disclosure matter. If companies are obliged to account for their

> ***The question thus remains after recent COPs: why are we lacking such pressure on fossil fuel exporting countries, which are conveniently offshoring their emissions while reaping the economic benefits?***

Scope 3 emissions and consider measures they can take to reduce them, states must be too. Very few producer NDCs currently contain such information. We should not be in a position where countries can trumpet reduced domestic emissions in their NDCs while their exported emissions remain high.

Why shouldn't exporters report their Scope 3 emissions?

What are the possible downsides of this approach? One is a risk of double counting of emissions. We need the combustion emissions in importing states to show up still, because that helps to incentivise energy efficiency measures and decarbonisation of their economies. A way forward would be to require exporting countries to report their exported emissions in their NDCs and, like companies with Scope 3 declarations, to have a target and plan for reducing them.

That would make these export emissions visible and hold countries to account for them without the figures necessarily needing to be counted as such for the purposes of capturing total global emissions (where you do want a single measure).

The second is the need to ensure a just transition. The economies of some low-income countries are heavily reliant on fossil fuel exports. When it comes to supply cuts, the principle of common but differentiated responsibilities (CBDR) in the Paris Agreement means that richer exporting countries should take on the lion's share, leaving low-income countries longer to transition.

But the 'common' part of CBDR matters as much as the differentiation part: all exporting countries should be obliged to disclose their exported emissions and have a target and plan for how they intend to reduce them.

This is all the more timely in light of the current International Court of Justice Advisory Opinion proceedings on climate change. Requested in April 2023, the Hague, Netherlands-based Court began deliberations on 13 December last year after a two-week public hearing. That day, Judge Cleveland asked state participants: 'What are the specific obligations under international law of States within whose jurisdiction fossil fuels are produced to ensure protection of the climate system and other parts of the environment from anthropogenic emissions of greenhouse gases, if any?'

Mandatory requirements on disclosure and targets for exported emissions may well end up in the answers. ■

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WIND

Extending the life of onshore wind turbines

As onshore wind turbines age and rotor size and power grows, the SafetyOn forum, in partnership with the Energy Institute, is focused on delivering good practice guides and resources for effective life extension management, explains Bruce Henry, Head of Engineering, EDF Renewables, UK & Ireland.

The Delabole wind farm in Cornwall, England, was the UK's first commercial scale wind farm, closely followed by the nearby Carland Cross wind farm. These pioneering wind turbines were small structures generating 400 kW with 34-metre rotor diameter. Nevertheless, they kickstarted a wind turbine revolution that has since expanded to an impressive 16 GW of installed onshore capacity across the UK – a figure that continues to climb.

The first wind farms were constructed around 1991. So modern wind farms can draw on more than three decades of UK development expertise in design, construction and operation. The most obvious developments were in the wind turbine design: reducing weight, improving control strategies, with better computational modelling, new manufacturing techniques and materials. All of these developments culminate in much larger wind turbines, that are currently in the region of 170-metre rotor and ~7 MW available onshore in the UK today.

Offshore, wind turbines are now offered with ~240-metre rotor diameter and 15 MW, and larger turbines are approaching due to the economic reward and competitive energy contract auctions, not to mention the sustainability benefits of fewer, larger turbines.

While this article focuses on the immediate need for life extension management of onshore wind turbines, offshore wind turbines will become the next, more challenging, topic for study, due to the complex interaction between the wind turbine, foundation, seabed and the force of tides and waves combined with wind.

Life expectation

Although less complex than offshore, onshore wind turbines by their very nature are exposed to extreme climatic conditions. They have to be designed to meet well-developed international standards to ensure they can withstand the forces they are subjected to. And they must include an appropriate safety factor, which ensures that all of that previous learning and development is incorporated into the design.

A prudent wind farm developer makes sure that the wind turbine is certified against these standards. The certification process evaluates wind turbines against many different load cases and scenarios, but importantly

As a new generation of taller, more powerful onshore wind turbines are introduced, SafetyOn, in partnership with the Energy Institute, is examining the safety and operational implications for life extension management of onshore wind turbines. Pictured here: EDF Renewables' Kirkheaton wind farm in the UK.

Photo: EDF Renewables

must guarantee that the wind turbine has a nominal design life of 20 years against a specified classification of wind conditions. Although in recent years, certified design lives have been increasing to 25 or 30 years.

As the certified design life is a 'minimum' threshold, and the wind conditions in situ will likely be less onerous than those used in certification, an opportunity exists to extend the safe operational life – much the same as many other industries do with their assets.

There are significant benefits of extending the life, from both a commercial perspective as you have effectively 'paid off the mortgage', and from an environmental perspective as green electricity is continuing to be generated with no new raw materials or carbon having to be invested.

An alternative strategy would be to 'repower' the wind farm and start again, reusing whatever infrastructure is available. However, as wind turbine technology has moved on, some sites simply can't accommodate larger modern wind turbines within the site constraints.

Extending the life of a wind turbine does come at a cost though, as wind turbine lives are predominantly driven by fatigue, which is a degradation of material strength through constant load cycling. If left to run unchecked, fatigue can start to form cracks which then grow over time, leading to overall failure of the asset. Therefore, it is the responsibility of operators' engineers to manage this degradation, ensuring the wind turbine operation is safe and structural risks are identified, managed and mitigated.

Ultimately there will be a point where the wind turbine will have to be decommissioned due to reaching the end of its structural life, maintenance becoming uneconomical, or the increasing strategic benefit of repowering. Life extension management is, therefore, a balance to ensure safe operation until decommissioning.

Managing safety

There are various methods engineers can employ to assist with understanding the fatigue failure risk of wind turbines to identify high-risk areas. Techniques range from theoretical, such as modelling techniques which give confidence that there is adequate operating life headroom, through to non-destructive testing (NDT) to determine if micro-cracks are forming in the structures. A rigorous maintenance regime will incorporate these types of analysis and investigation, based on risk, to ensure that the assets are serviceable.

One challenge faced by operators is the lack of availability of original detailed design information required by the analytical models, as these were not normally supplied with the wind turbines. Data such as dimensions, plate thicknesses, welds and geometry details are required. Models have to be re-developed and validated with measurement and conservative assumptions being made. This may add to uncertainty and require extra inspections, in case component life may be shorter than anticipated.

As well as the structural issues, there are other issues relating to life extension which must be managed, such as reduced reliability of equipment (rotating and electrical), as well as obsolescence of components, which must all be managed as part of an effective asset management programme.

Due to the timeframes of the first wind farms in the UK and the subsequent growth of wind turbine numbers, many operators now have assets that are just moving into life extension. The numbers of turbines needing to be managed are increasing year on year.

Therefore, the industry is learning as a whole, and international standards relating to management of life extension of wind turbines are still in draft form. Some countries are further along in the journey, such as Germany and Denmark, where there are now statutory requirements to demonstrate the integrity of the wind turbines. But no life-extension-specific statutory requirement currently exists in the UK, beyond normal 'duty of care' and the Health and Safety at Work Act.

The onshore wind industry in the UK does, however, have the SafetyOn forum, which runs in partnership with the Energy Institute. This forum allows onshore wind turbine operators to work together on safety initiatives. Since 2020, a Life Extension Working Group within the forum has pulled together expertise from across the industry on life extension, sharing safety concerns and approaches to life extension.

What do we need to know?

Having researched the highest-priority topics in the sector, the SafetyOn forum has funded the production of some good practice guides and resources, which are now in the process of being drafted. They are introduced below.

Aeroelastic modelling: These computational models look at the interaction between the wind and the structure to predict loading, but are very sensitive to their inputs. Most operators rely on third parties for this type of modelling. A guide on this subject will help ensure that the right data is captured and supplied to make the model as accurate as possible. It will also try to explain uncertainties in the modelling and how to reduce them.

Non-Destructive Testing (NDT): As wind turbine operators look to implement risk-based inspection regimes, this guide will cover what types of NDT are available for different parts of the wind turbine and outline the benefits and limitations of each. From external welds far up a wind turbine tower, where access may be difficult, to inspecting hundreds of blade bolts, the guide will give operators a steer as to what safe and effective methods are available for incorporation into inspection regimes.

Cross-industry signposting: Our industry is aware that there is a plethora of guidance from long-established assets that have been operating safely into life extension. This exercise will set up a website that points to useful guidance from elsewhere, such as corrosion management from offshore oil and gas, to fatigue management from naval applications. The resource links will include other Energy Institute life extension working groups.

The SafetyOn working group will continue to work on improving the understanding and safety of wind turbine life extension across the UK. It has aspirations to centralise databases of life extension failure modes and lessons learned, for the benefit of engineers looking to design their own asset management programme for life extension.

Those currently navigating the complexities of wind turbine life extension find themselves in a fortunate position. Wind turbines designed over two decades ago were typically over-engineered, incorporating levels of redundancy that allow for reasonable life extension in many cases. However, since then, computational modelling has improved, turbine control has become more site-specific and designs have become leaner to manage costs. More attention will be required earlier in modern wind turbines' life cycle.

Fortunately, as life extension practices become more standardised, life extension can be planned for from day one. By providing appropriate information and recording accurate data over the course of the operational life, we can achieve more precise predictions of their remaining lifespan. ■

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How AI fuels data centre energy demand

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is changing the game for data centres across the globe. However, its adoption is not simply about handling complex tasks faster, but consumes far more power and creates a surge in greenhouse gas (GHG) emissions. Tech giants are under pressure to make their vast data centres more energy efficient and sustainable. *New Energy World* Features Editor Brian Davis reports.

AI is a two-edged sword, while handling a vast range of tasks far faster, it is extremely power hungry and creates a surge in greenhouse gas emissions from data centres worldwide
Photo: Adobe Stock/Login

At the start of the year, the International Energy Agency (IEA) forecast that global electricity demand is expected to more than double from 2022 to 2026, with AI (and cryptocurrency) playing a significant part in that rise – given global electricity consumption of 460 TWh.

The IEA predicts that electricity consumption by data centres in the European Union (EU) will be 30% higher than 2023 levels (about 100 TWh), as new data facilities are commissioned in line with increased digitalisation and AI in particular. Ireland and Denmark alone make up 20% of the expected increase in EU data centre demand to 2026. And there are moves by the European Commission towards regulating data centre sustainability across the EU. Specific action is underway in some regions, such as the *ad hoc* moratorium on building new data centres in Dublin.

There are currently over 8,000 data centres globally, with about 33% located in the US, 16% in Europe and about 10% in China. Some 1,240 data centres were located in Europe (as of 2022), mostly concentrated in major financial centres including London, Frankfurt, Amsterdam, Paris and Dublin. With significant additional data centres planned, electricity consumption in the

EU is expected to reach 150 TWh by 2026.

US data centre electricity demand is forecast to grow rapidly in coming years, rising from 200 TWh in 2022 to about 260 TWh in 2026 – accounting for 6% of US electricity demand.

China's State Grid Energy Research Institute estimates that electricity demand in the country's data centres could double to 400 TWh by 2030, compared to 2020. To meet this rocketing demand, regulations are being updated to promote sustainable practices in current and future data centres, aligned with decarbonisation strategies.

Why are data centres expanding so fast?

We all play a part. Every time phone data is backed up to the cloud it is stored in data centres. Moreover, 5G, cloud-based storage, Big Data and the Internet of Things (IoT) play a vital role in essential infrastructure worldwide, supporting everything from financial transactions to social media, industry and government operations. Indeed, the IEA estimates that data centres account for over 1% of global electricity utilisation.

As mentioned, both AI and blockchain technologies such as cryptocurrency are power-hungry operations. The US Energy Information Administration calculated that bitcoin mining accounted for 2% of US electricity demand in 2023 – and that figure is climbing rapidly.

What's more, it is very energy-intensive to 'train' AI models. For example, a ChatGPT query uses 10 times more energy than a Google enquiry, David Proctor, a Vice President at the Electric Power Research Institute told *Time* magazine. He reckons that 10–20% of data centre energy in the US is currently used by AI, with a 'significant increase' on the horizon.

More and more powerful generative AI models are being developed, and

> **The IEA predicts that within two years, data centres could consume the same amount of energy as Sweden or Germany's total electricity demand.**

researchers estimate that the computational power required to train these models is doubling every nine months.

The IEA predicts that within two years, data centres could consume the same amount of energy as Sweden or Germany's total electricity demand. This voracious appetite for energy by AI is not just a matter of vast power consumption and GHG emissions – depending on whether the power is sourced from traditional fossil fuels (commonly) or renewables – but also consumes massive reservoirs of fresh water. A study published by UC Riverside estimates that global AI demand could cause data centres to use 1tn gallons of fresh water by 2027 for cooling purposes.

According to analysis by *The Guardian* (15.9.2024), tech giant GHG emissions may be 7.6 times higher than official figures on account of AI-led data centres.

Despite the likes of Google and Microsoft pledging to run 'carbon-free by 2030' in 2020, they and other tech giants, like AWS, have taken a step backwards. Microsoft actually increased GHG emissions by a third last year in pursuit of its AI development programme, and plans to double its data centre capacity, having invested billions in OpenAI.

In 2023, Google's total data centre electricity consumption grew by 17%, despite an express strategy to maintain a 100% global renewable energy match. Google's 24/7 Carbon Energy Pledge clearly states: 'From 2010 to 2023, we signed more than 115 agreements totalling over 14 GW of clean energy generation capacity… now we've set a goal to run on 24/7 carbon-free energy on every grid where we operate by 2030'. This involves cutting 50% of its Scope 1, 2 and 3 emissions by 2030, investing in nature-based and technology-based carbon removals.

Indeed, environmental concerns about data centres are rising around the world as more people, industries and governments look to house an ever-growing mountain of data. The UK recently declared data centres as 'critical infrastructure' – a vital part of modern digital economies.

However, there are concerns that there isn't sufficient power generation or transmission capacity in the pipeline to fuel all the data centres under development. There is a suspicion that the tech giants are gambling on sufficient build-up of the necessary infrastructure to satisfy their escalating data centre needs. Moreover, better transparency will be vital, as there is still a lack of understanding of the environmental impacts of AI.

Improving data centre sustainability

Currently the data centres rely heavily on fossil fuelled power generation, although many companies are negotiating power purchase agreements with renewable energy suppliers, where possible. AI promoters and entrepreneurs suggest that 'innovative technology' will play a vital role for combatting climate change.

For example, Google claims that its DeepMind AI helped reduce the company's data centre cooling by up to 40%. Furthermore, efficiency improvements in chip hardware are set to have a big impact. The world's largest chipmaker NVIDIA recently launched a new line of graphics processing units (GPUs) with 25 times lower energy consumption than previous models.

Digital technology may hold the key to more sustainability in this sector. Steven Brown, Vice President of Digital Energy Solutions at Schneider Electric told *Data Centre Magazine*: 'At Schneider Electric, we call it Electricity 4.0, using digital technology to become more efficient and then electrifying where we haven't yet to decarbonise… helping microgrid infrastructure and smart grid infrastructure.'

Brown suggests there will be a re-emergence of 'edge infrastructure', where data centres will deploy workloads close to where they are being used. 'Once a model is trained, that has to be deployed as an inference model where you get much more agility – such as for cloud AI. Building at the edge requires the kind of critical infrastructure to protect it that you might expect in a data centre environment,' he says. Indeed, the edge computing model can reduce power demand significantly.

On the road towards better sustainability, Dave King, Principal Senior Product Engineer at Cadence, suggests that 'digital twin technology' has a key role to play in developing more energy-efficient and sustainable data centres. 'Using virtual digital replicas of physical data centres, more efficient power management and optimisation of operating systems, such as cooling, can be implemented, helping facility managers reduce the carbon footprint of AI,' he says.

Companies like CyrusOne are designing projects to scale AI infrastructure effectively. According to Tom Kingham, Design Lead Europe & Japan at CyrusOne: 'We see a stronger focus on sustainability, with innovations reducing physical space requirements and carbon footprints, reflecting a broader trend towards greener data centre operations,' he told *Data Centre Magazine*.

According to the IEA's 2024 *Electricity Report*, the primary drivers of data centre electricity demand are the cooling systems and the servers themselves, which each typically account for 40% of the total consumption. The remaining 20% is consumed by the power supply system, storage devices and communication equipment. Adoption of high-efficiency cooling systems has the potential to reduce electricity demand in data centres by 10%. A further 20% reduction in consumption can be achieved with 'direct-to-chip' water cooling and low viscous fluids to cool all other components.

Looking longer term, quantum computers (which deliver faster processing power than supercomputers, while consuming less energy) could reduce electricity demand of the sector if supported by efficient cooling systems. But they need to be cooled to temperatures at absolute zero (–273°C), while supercomputers can operate at 21°C.

Data centres are also becoming more sustainable and their operations more efficient with the move towards hyperscale data centres (exceeding 5,000 servers and 10,000 sq ft), without a significant increase in electricity consumption. The global market for hyperscale data centres is projected to be $212bn by 2026 (double that of 2023).

In 2023, Sweden announced plans for a nuclear-powered data centre using small modular reactors (SMRs).

Another promising area of research for decarbonising data centre operations involves 'time and location shifting' of electricity demand, using new software to temporarily shift power loads with 'carbon-aware' models that relocate data centre workloads to regions with lower carbon intensity at selected times – while also increasing operational affordability and lowering emissions by 34% round the clock. Research shows that this approach, along with other on-site energy efficiency measures, can help data centres achieve 64% carbon-free energy consumption, says the IEA.

Indeed, there is an argument that there is a need for data centre operators to optimise and fine-tune AI models as well as invest in more energy efficient AI accelerator hardware, so AI becomes a *more effective solution* rather than a *challenge* to the environment and climate change. ■

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COMMENT

Financial muscle to push renewable energy into 2030

Renewable energy is competitive, but 2030 targets are challenging. Coordinated action, including continuing political support, will be essential if these are to be met, writes Michiel de Haan, Global Head of Energy Sector at Netherlands-based ING bank, which aims to play its part in accelerating the energy transition through financing.

"There are two ways of approaching the bumpy road ahead: either navigate around obstacles or find the smoothest possible path forward.

For renewable energy investment in 2024, a wide road heads toward 2030 and beyond, but new challenges still lie over the horizon. The social and environmental need for green energy remains crucial, yet political headwinds could slow progress.

Decarbonisation is essential in fighting climate change – not only by phasing out fossil fuels but by expanding affordable green energy access for heating, transport and industry. Meeting the 1.5°C climate target requires renewable energy capacity to triple by 2030. There's a clear call for governments, industries, financial institutions and civil society to scale renewables and make progress on key climate challenges.

At ING, we want to play a leading role in accelerating the transition to a low-carbon economy. By 2025, we're committing €7.5bn annually to wind, solar and battery storage investments – tripling our 2022 target. We've already supported landmark projects, including a €570mn loan for an 842 MW solar project in Spain and a €674mn credit for solar and battery projects across Europe. This underscores our ambition to lead in renewable energy, despite recent sector challenges.

Why isn't renewable energy straightforward?

The early 2020s showed that renewable energy's journey isn't a straightforward one. The 2010s ended on a wave of optimism, with rising investments, cheaper financing and stronger corporate sustainability commitments. But the COVID-19 pandemic disrupted supply chains, raised costs and, following Russia's invasion of Ukraine in 2022,

Michiel de Haan, Global Head of Energy Sector, ING

Photo: ING

created an energy price shock that directly impacted renewables.

Greater financing costs became a challenge for the capital-intensive renewable sector. Trade barriers, local content requirements and political scepticism about environmental, social and governance (ESG) investments added complications. Additionally, issues such as grid capacity constraints and the risk of 'price cannibalisation' – as more renewable energy entered the grid – added to the sector's hurdles.

Renewable finance track record

Those issues have not been enough to halt the global momentum of renewables. In 2023, global renewable energy investment surpassed $620bn – a record, spearheaded by China. It was 8% up on 2022, and nearly double the figure for 2015. Several factors are driving growth.

Renewable energy, especially wind, solar and batteries, remains cost competitive. Corporate energy users are increasingly adopting power purchase agreements (PPAs) with renewable providers to manage electricity costs amid fossil fuel price volatility. This trend, initially popular in the US, is now expanding across sectors like aluminium, automotive and telecommunications in Europe.

Political support has also been instrumental, with initiatives like the US Inflation Reduction Act (IRA) extending tax credits for renewables and the European Union's binding 42.5% goal for renewables by 2030. However, it remains to be seen what the impact of the outcome of the US election will be on US initiatives like the IRA. As inflationary pressures ease and central banks begin reducing interest rates, the financing cost issue that emerged in 2021–2023 may be past its worst.

Looking ahead, renewable energy will see global expansion, but specific investors and lenders will focus on their areas of expertise. The US is a prime destination, driven by available land, rising electricity demand and government incentives. Europe, though with less land and slower demand growth, boasts a strong pipeline of offshore wind projects. Australia needs new renewable capacity to replace retiring coal plants.

Solar energy is particularly attractive due to its steep cost reductions and quick build times, making it a compelling option for utilities and developers. Although issues like the 'duck curve' – where peak solar generation doesn't align with demand – may create overcapacity in certain markets, solar's overall potential remains strong.

Wind offers the advantage of diversified generation across various locations and times, with large-scale offshore wind projects providing significant financing opportunities that support debt providers.

Reaching 2030 goals

While renewable energy has significant growth potential, reaching ambitious 2030 government targets remain challenging. Offshore wind projects require substantial infrastructure; solar projects face network limitations; and onshore wind developments often encounter lengthy permitting processes.

Governments can and must do more if 2030 climate targets are to be met. Their actions send the strongest signal of support for green power. By streamlining permitting processes, adjusting auction models, and maintaining political stability, governments can help pave the way for a thriving renewables sector and reinforce investor confidence.

Reaching 2030 targets will require coordinated action to overcome these obstacles. The renewable energy sector and its investors must continue to advocate for government support, ensuring the path ahead is smooth for green power's transformative potential. ■

The views and opinions expressed in this article are strictly those of the author only and are not necessarily given or endorsed by or on behalf of the Energy Institute.

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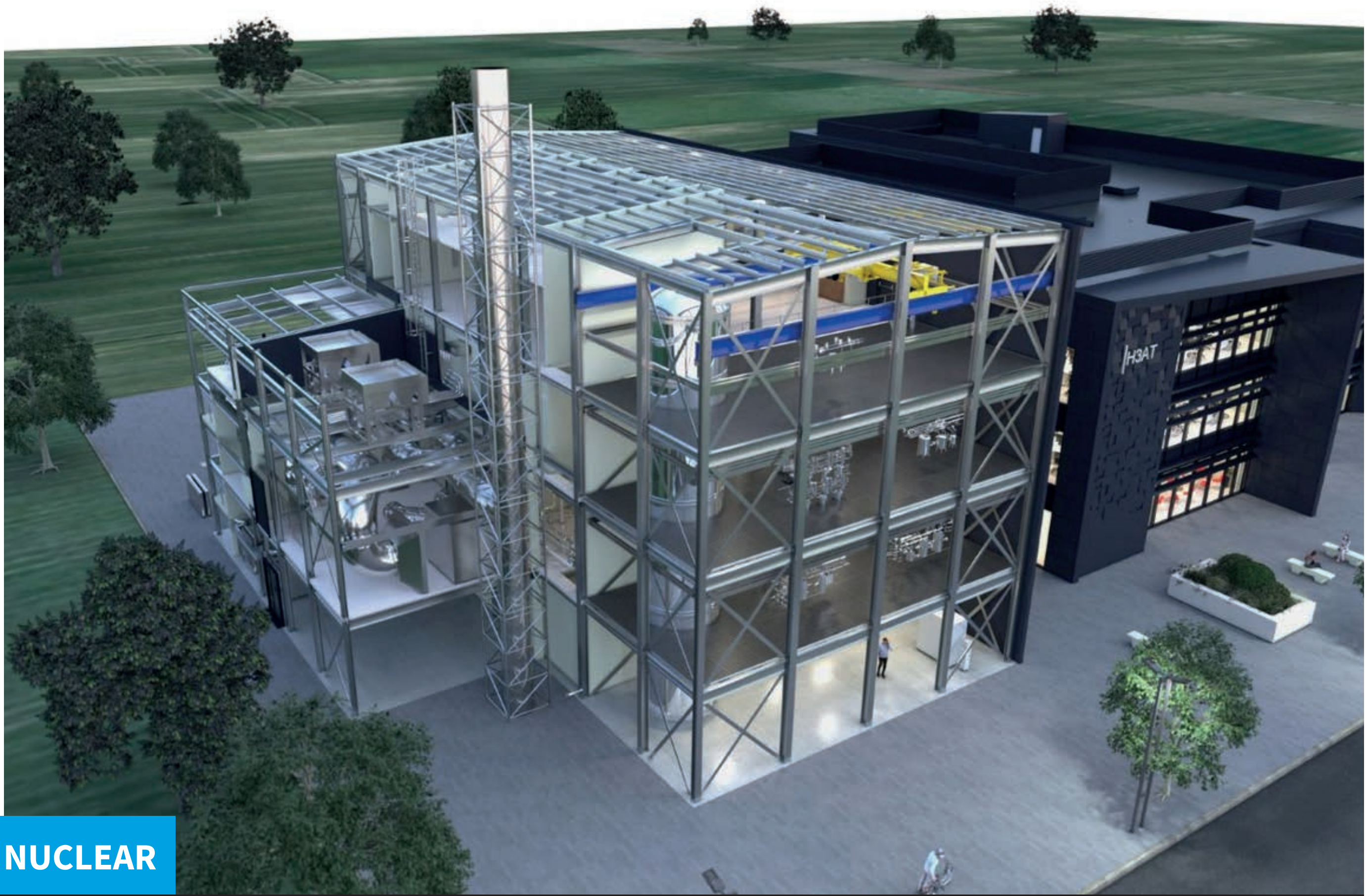

NUCLEAR

Fusion – the 21st century's hottest energy ticket

The UK's 2022 fusion strategy sketched out a vision of building a prototype fusion reactor using a domestic design, along with fuel cycle facilities, proposals which won more than £400mn of public funding in 2025. A panel from the UK Atomic Energy Authority (UKAEA) presented the topic to Energy Institute Fellows in September 2024. *New Energy World* Senior Editor Will Dalrymple reports.

Artist's impression of the H3AT facility, with the R&D hall in the foreground
Photo: UKAEA

Government could do worse than by following the advice of Stephen Hawking, contended Ian Chapman, UKAEA CEO at the Energy Institute Fellows event. 'When asked for a world-changing idea, Hawking said, "I'd like to see the development of fusion".' It is low-carbon; inherently safe – you can't have a chain reaction; half of its fuel is readily available; it has little land use requirements and requires few natural resources; nor does it produce long-lasting radioactive waste.

But, he continued, 'fusion is hard'. To create it on Earth, temperatures have to reach 100mn °C, generating the most intense source of neutrons that fly out everywhere and damage whatever is used to make the reactor. The reactor encounters incredible heat gradients, from the plasma, which can't touch the wall-to-wall temperatures of 2,000°C, to nearby magnets cryogenically cooled to 4°C above absolute zero. This unforgiving environment is not safe for people, so robots must be used for maintenance and ongoing repairs. And the reactor needs enough fuel to keep going.

This process was explored at the European fusion research facility JET in Culham, Oxfordshire, which broke records in terms of the energy it produced last year, and then shut down after 21 years of operation. Chapman called it the largest operating fusion facility in the world; a big industrial plant, with a high quantity of tritium, the same mix of metals as a power plant and the largest-scale robotic maintenance.

Now, plans are taking shape for a prototype powerplant called STEP (but this time funded not by the EU but only the UK) to be located at the site of the former West Burton coal-fired power plant in Nottinghamshire. The reactor will be designed, built and operated by a public-private partnership under UKAEA called UK Industrial Fusion Solutions. A shortlist of industry partners for the one engineering and one construction partners is expected to be published before the end of the year. As the decades-long process of construction begins, vital enabling work is taking place in Oxfordshire, with a focus on its fuel.

Like its nuclear colleague fission, fusion deals in subatomic particles. But rather than splitting a huge atom of uranium, fusion aims to combine some of the smallest. Hydrogen has one proton and one electron, and different isotopes have one neutron (protium), two neutrons (deuterium) or three neutrons (tritium). In the right conditions, a deuterium atom and a tritium atom fuse to create helium, and energetic neutrons.

Unfortunately, while deuterium can be synthesised from seawater, tritium is much harder to come by. For that reason, once they start up, most fusion reactor designs 'breed' tritium by exposing a suitable material, such as lithium-6, to neutrons emitted from the fusion reaction. Their interaction with the material at a molecular level forms tritium atoms, which in theory can be harvested, processed and injected back into the reactor as fuel. This is the province of UKAEA's new H3AT tritium fuel cycle R&D facility in Culham.

How does it work?

At a 1/20th scale, the H3AT facility will study the steps involved in processing tritium generated in a fusion reactor. There are two inputs: gas pumped out of the reactor, consisting of unused fuel and impurities, plus tritium, deuterium and impurities released from the lithium bed (that process is being studied at a sister project, LIBRTI). Second, the resulting gas is purified to remove everything but the hydrogen. Next is to separate each of the hydrogen isotopes. Then they are processed to make new fuel and stored. Those last steps are supported by secondary processes that further remove tritium from intermediate process steps. Waste material is sent out via the exhaust stack.

It sounds straightforward. The only problem is that it hasn't been done before. 'Many of the proposed processes have been demonstrated at the lab scale or experimental scale, and for JET we ran many of these, but we did them in batch configuration. Now we need to do them continuously. And understand how the processes behave when coupled in a closed loop. This hasn't been done at prototype scale,' said Steve Wheeler, Executive Director for Fusion Tech, Fuel Cycle and ITER components, after the event.

He said: 'We will have a default loop with the most robust candidates, but will configure the loop to bring in other candidate systems at a meaningful scale.'

Wheeler did not downplay the difficulty of the task ahead. 'This is a challenging project,' he said, but credits the expertise developed at Culham with the ideal mix of skills to tackle it. He commented: 'If you just focus on physics or engineering, it's easy to throw the problem to another team… Being able to work across boundaries is really important. That's one of the areas where UKAEA has a real advantage through running JET; with decades of activity in fusion, the majority of the disciplines are here in one organisation.'

In terms of physical plant, the building has already been constructed, a four-floor, 2,300 m^2 engineering hall and office space. And there will be a supply of real tritium; the site will be licenced to work with a total of 100 grammes – the same quantity as the JET facility, that will be transferred to the H3AT site.

Wheeler explained: 'The 100 grammes inventory for the loop was chosen very carefully, to be representative of a power plant-scale process. Hardware, software, chemistry, process control – the whole loop as an integrated system is represented. And it is large enough in scale for the data produced to be valuable for power plant scale. But the inventory is kept as low as possible to ensure it is as efficient as possible.'

Building a supply chain from nothing

'An important part of the fusion mission for UKAEA is not STEP and H3AT alone, but developing and building a supply chain based on the legacy of its expertise with JET,' Wheeler remarked.

So far, one big H3AT contract let is to Canadian engineering contractor Atkins Realis, for detailed design of the isotope separation plant.

Wheeler emphasised that this is not just another civil nuclear project. Unlike fission, fusion is likely to be regulated with a lighter touch than the Office of Nuclear Regulation by the HSE and the Environment Agency.

'Fusion is very keen to develop best practice with other industries, in terms of qualifying engineering systems, manufacturing technology, fabrication technologies. We are eager to learn best practices from aerospace, offshore engineering, space, or other industries where the verification and validation of engineering systems is very important, but which aren't following fission codes or regulatory practices.' ■

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Long-term hydrogen storage using metal hydrides

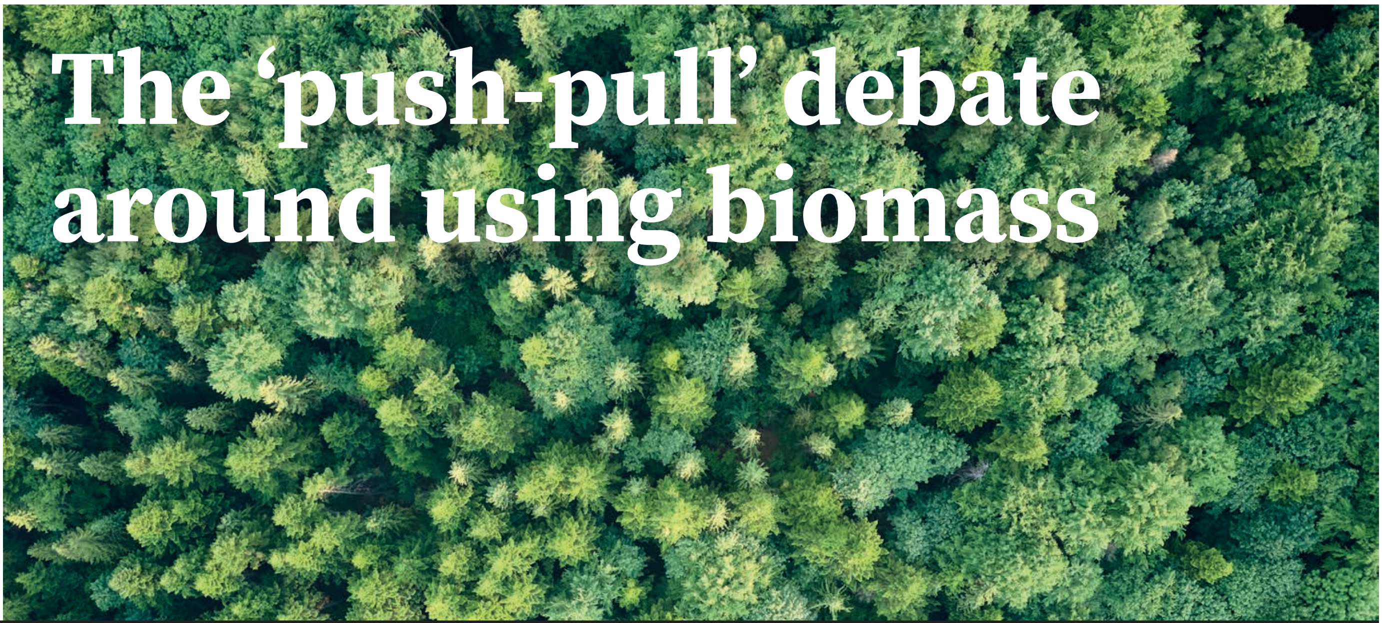
'Fusion's delivery journey is not particularly fast. It is only really going to have a major impact in the second half of the century. We are keen to show benefits in the shorter term where we can, and demonstrate spin-out benefits from technical development of fusion,' according to Steve Wheeler, Executive Director for Fusion Tech, Fuel Cycle and ITER components.

In early 2025, there are plans for UKAEA, with Bristol University and URENCO, to show off the Hydus pilot project prior to building an industrial-scale demonstrator of a hydrogen storage system using depleted uranium. The UK has huge stocks of this heavy metal after processing for nuclear enrichment. It is an extremely dense carrier of hydrogen and naturally reactive, so spontaneously bonds with hydrogen atoms, but releases them when heated.

The demonstrator could potentially power an electrolyser from the grid to generate hydrogen, which can be soaked up in the material and stored indefinitely, providing it is kept dry and away from oxygen. Once power is required, the material is heated, and the hydrogen produced is run through a fuel cell to generate electricity.

'The exciting challenge is to improve the efficiency, so it's as efficient as putting it in a tank' – as Wheeler put it. A key research output will be to measure the system's storage efficiency. To gather data, the demonstrator will be highly instrumented.

The ‘push-pull’ debate around using biomass



BIOMASS

Is biomass an environmentally-friendly component of the energy transition amid net zero targets or adding to emissions? There’s no simple answer, explains sustainability consultant Michelle Meineke.

Biomass is a fuel that has been a key component of human evolution for millennia, and is considered by some parties to be ‘integral’ to a net zero future. It is a renewable fuel source. Biomass exists because plants were able to extract carbon from the atmosphere and fix it into their cells in the form of cellulose and lignin. However, it is shadowed by controversy. As demand for the biomass market grows, so do the worries voiced over subsidies and land management, amongst other issues of concern from highly vocal environmental and regulatory groups.

Bioenergy, produced by combustion biomass, is already a huge player in the global energy transition. It accounts for 55% of renewable energy worldwide and more than 6% of the global energy supply, according to the International Energy Agency (IEA).

Power production and transport fuels are among the primary end markets, where bioenergy is not only key to meeting rising demand, but also to supporting a greener supply chain, such as for production of sustainable aviation fuel (SAF).

Overall, bioenergy’s contribution to final energy demand across all sectors is five times higher than wind and solar PV combined, according to the IEA.

But market growth, with ‘well-defined’ environmental rules and reporting, needs to accelerate. The 3% growth rate between 2010–2022 must nearly triple to 8% per year up to 2030 for bioenergy deployment to get on track with the IEA’s Net Zero Emissions (NZE) by 2050 Scenario.

The future of biomass as a source of renewable energy is hotly debated. Worries over land use are escalating. Deforestation, biodiversity damage and the establishment and opaque monitoring of forestry regulations are some of the main pressure points cited by environmentalists.
Photo: Adobe Stock/bilanol

Political support for biomass is strong in some quarters – but by no means universal. ‘Extraordinary’ is how Graham Stuart, the Minister of State for Energy Security and Net Zero in the UK’s previous Conservative government described the market’s future in the country’s eagerly anticipated Biomass Strategy last year. Nevertheless, the future is unclear under the current Labour government Secretary of State for Energy Security and Net Zero Ed Milliband.

The biomass sector employs 765,000 people worldwide, half of whom are in Europe, making it the world’s fifth largest employer in renewable energy, according to the International Renewable Energy Agency (IRENA).

Clearly, biomass has significant potential. But no market is perfect and challenges must be addressed.

What’s bad about biomass?
Subsidies are a major sore point amongst environmentalists. In the EU, biomass received the joint second-highest subsidy (with wind) at €15bn each amongst EU member states in 2022, (solar took the top spot with €25bn), according to the European Commission. In the UK, the National Audit Office (NAO) reported that £22bn of government subsidies have been provided to the biomass industry so far. As the largest biomass electricity generator by some distance, 36% of the Renewables Obligation funding (£14bn) went to Drax.

However, there are detractors. ‘A carbon accounting loophole created before the Kyoto Protocol in the 1990s has crept into energy policy over the years, enabling energy companies to say biomass is zero carbon because they don’t have to account for the emissions,’ explains Almuth Ernsting, Co-Founder of advocacy group Biofuelwatch. ‘Subsidies should not be spent on burning biomass wood whatsoever, and forest wood is the top priority.’

The IEA claims that burning biomass (wood) creates more CO_2 than burning fossil fuels. And four British power plants now burn the equivalent of 27 million trees in wood pellets every year, almost all of which are imported. Plus, environmental reporting doesn’t always take the fuel footprint of importing large quantities of wood that has travelled – by road and then

> ***It's hard to see how large-scale biomass can exist without significant damage to the climate. The pieces don't fit.***
>
> **Almuth Ernsting, Co-Founder of advocacy group Biofuelwatch**

shipped across the Atlantic from the US and Canada into the UK, or any destinations – into consideration. This all fans the momentum against subsidies.

Increased stringency worldwide is also needed for conversion of thermal power plants from coal to biomass. This is a route many governments and electricity suppliers are exploring, as fossil fuels and biomass can utilise similar infrastructure. This is especially attractive when the estimated global net present value of stranded assets in coal power generation up to 2050 could reach \$2.3tn, according to a study led by researchers at the MIT Joint Program on the Science and Policy of Global Change.

However, redirecting subsidies or 'conversion money' into scaling-up infrastructure for clean, non-emissive renewable energy options, such as wind and solar power generation, is a popular option amongst environmentalists. The IEA estimates that \$4.5tn/y is needed by the early 2030s to accelerate deployment across all clean energy technologies and infrastructure – nearly triple the \$1.tn invested in 2023.

Others are also calling for greater accountability of sustainability regulations worldwide.

Among them is the UK's NAO. 'If biomass is going to play a key role in the transition to net zero, the [UK] government needs to be confident that the industry is meeting high sustainability standards. However, government has been unable to demonstrate its current assurances are adequate to provide confidence in this regard,' said Gareth Davies, Head of the NAO. 'Government must review the assurance arrangements for these schemes, including ensuring that it has provided adequate resources to give it assurance over the billions of pounds involved.'

Power of trees

Worries over land use are also escalating. Deforestation, biodiversity damage and the establishment and opaque monitoring of forestry regulations are some of the main pressure points highlighted by environmentalists.

For example, 41 environmental organisations from the Western Balkans and across Europe called on KfW, a German state-owned development bank, in July to stop financing wood biomass energy in Serbia to avoid forest degradation risks.

Data also recently showed that Germany's forest has been a net source of CO_2 emissions since 2017, when 'everyone thought it was an important carbon sink', says Biofuelwatch's Ernsting. 'The combination of more extreme droughts and intensified logging is devastating Germany's forest, yet the demands for biomass in the country could double in coming years.'

He also warns of 'large scale rainforest clearance' in parts of south-east Asia and Indonesia. The latter is already home to the world's second highest rate of deforestation, according to the World Population Review (WPR).

Forecasting re-growth rates for 50-year-old trees that have been cut down is not a linear process, according to Biofuelwatch. One can't assume that a 50-year-old cut tree will return to its current state in 50 years, due to the unpredictability of accelerated climate change. Plus, we have lost decades of environmental potential from the downed tree and the 'waiting game' to recover it. According to Oxfam, the number of climate-related disasters has been tripling in the last 30 years and there simply isn't time for a 'wait and see' approach to forest recovery. The accuracy of environmental reporting for each tree must improve exponentially worldwide, the NGO suggests.

What's next?

Interest in carbon sequestration linked to biomass is building, says William Perritt, Senior Editor of Forest Products at *Fastmarkets*. Drax's recently announced potential plans to spend up to \$12.5bn up to 2034 building wood pellet-fuelled power plants in the US, equipped with carbon capture systems. This speaks volumes, as do other mega projects in the pipeline worldwide.

It remains to be seen if the new UK Labour government will approve more subsidies for Drax and Czech energy company EPH, which operates a biomass power station in Lynemouth. There is also debate about the viability of using biomass to generate renewable energy in Europe. The Netherlands has ruled against providing future subsidies for biomass plants, which Ernsting calls a 'positive blueprint for other European countries'. Meanwhile, Germany has proposed two coal-to-biomass conversions and several new dedicated biomass plants.

Biomass has the potential to make net zero a reality, but the guesswork and 'murky' reporting must be tackled with urgency on a global scale. ■

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Pendulum could swing against biomass since the US election

Where the needle points for biomass in the US should be clearer in the coming months of the new Trump Administration. Biomass only provided about 5% of the country's energy in 2023, according to the US Energy Information Administration (EIA), so there is huge potential in what the IEA calls the world's second largest energy consumer.

On 22 January 2025, President Trump signed an executive order to freeze funding of climate-based investment under the Inflation Reduction Act (IRA).

However, there is a surge of project announcements to produce biofuels in the US, with many focusing on the SAF market. 'Most are in the US South, with its enormous forest base and less stringent government regulations. To date, the commercial-scale wood-based production of SAF is not readily available – as is true for other biofuel products. We will wait and see on that front,' says *Fastmarkets*' Perritt.

ENERGY TRANSITION

A tale of two transitions

The Energy Institute's *Country Transition Tracker*, produced alongside the *Statistical Review of World Energy*, highlights the disparity of energy challenges faced oss the world. While the various metrics published highlight the extent of 80 countries' progress towards net zero, they do not tell the whole story. Here, Senior Energy Project Lead Gemma Fox discusses two countries that appear to stand at opposite ends of the energy transition spectrum: Iceland and Bangladesh.

There are some stark geographic and economic differences between Bangladesh and Iceland, not least their population sizes and density. Bangladesh has a population of over 172 million, compared to Iceland's 375,000, which is roughly the size of Bangladesh's sixth biggest city. Iceland and Bangladesh have roughly similar land mass and consequently their population densities differ significantly, with Iceland having four people per km^2 and Bangladesh 1,330 people per km^2. Iceland's economy is predominantly sustained on its renewable energy network, tourism and fishing, which generates a GDP per capita of \$70,000, while Bangladesh has a GDP per capita of \$9,400, mainly driven by its garment industry.

The differences between these nations are further amplified by their climates. Bangladesh is characterised by a tropical climate, experiencing frequent monsoons. Its low-lying geography is dominated by the Ganges Delta, and flooding which poses a continual challenge to its infrastructure. In fact, this, combined with its low-lying geography, makes Bangladesh one of the most climate-vulnerable countries globally.

In contrast, Iceland has a sub-Arctic climate, with abundant geothermal and hydropower resources, and offers entirely different energy potential.

These factors all contribute to the starkly different energy systems in Bangladesh and Iceland, and consequently they face very different challenges and opportunities for their energy transition pathways.

Harnessing Iceland's natural resources

Iceland has established itself as a global leader in renewable energy. As much as 83% of its primary energy consumption is derived from renewable resources. This figure makes Iceland the highest-ranked country globally in the *Country Transition Tracker* for proportional renewable energy consumption.

Blessed by its geological location a-top the Mid-Atlantic Ridge, the Scandinavian nation has exceptional access to geothermal power, which generates 23% of its electricity. Iceland also has an abundance of glacial rivers which are leveraged for hydropower, generating 60% of its energy. The remainder is made up of a small amount

Bangladesh's Solar Home Systems programme has brought off-grid power to millions

Photo: World Bank

of imported fossil fuels to support the transportation and fishing industry. As a result, Iceland emits around 2.5mn t/y of CO_2.

Iceland's unique access to great sources of renewable energy has enabled it to successfully decarbonise much of its energy system. As such, the country has been able to switch focus to the decarbonisation of the hard-to-abate sectors and invest in innovative technologies in this area. Iceland is home to the largest operational direct air carbon capture (DAC) storage system, storing the CO_2 emissions from a geothermal power station in basalt rock formations, with zero carbon emissions.

Iceland has become a remarkable example of how harnessing natural resources with technological innovation and strong policy commitments can enable the transition to net zero. However, a notable new development in the country's energy transition is its emergence as a hub for data centres. As the global digital economy expands, fuelled by demand for cloud computing, artificial intelligence and cryptocurrency mining, the need for energy-intensive data centres has grown exponentially (see p16).

Iceland's cheap and renewable electricity has made it an attractive destination for companies such as Verne Global and Advania Data Centres, which have set up massive facilities in the country. For example, Verne Global' s flagship data centre has a power consumption capacity of 140 MW, which is sourced solely from geothermal and hydroelectric power.

Although this shift brings economic benefit to Iceland, it also raises questions about sustainability. Growth in data centres has propelled Iceland to become one of the world's largest energy consumers, relative to its population. The country's energy consumption of 602 GJ per capita ranks second globally; while its energy intensity of 11 MJ/$GDP ranks fourth globally. In addition, the environmental impact of the infrastructure demanded by Iceland's data centres, power plants and connectors is very significant.

Even though Iceland's renewable energy capacity is vast, it is not endless, and the strain on its resources is increasing as demand for data processing grows. The country's new energy challenge is ensuring that the growth of these energy-intensive industries, and the need to expand geothermal energy and hydropower, does not comprise Iceland's sustainability goals or the needs of the local population.

> ***Bangladesh and Iceland have starkly different energy systems and consequently face very different challenges and opportunities for the energy transition pathways of these nations.***

Bangladesh's energy priorities

Bangladesh's energy transition is shaped by a very different set of challenges. According to the World Bank, around 99% of the population now has access to electricity. This figure is up from only 20% in 2000, and is reflected in the *Statistical Review of World Energy*, which shows Bangladesh's energy consumption has grown 273% since 2000.

Despite this huge increase, in the league tables of the *Country Transition Tracker*, Bangladesh still has the lowest energy consumption per capita, at 11 GJ, and consumes only 1.8 MJ/$GDP, the third lowest energy intensity globally. As such, the government's primary goal has been, and continues to be, ensuring widespread, affordable and reliable energy to its citizens.

Currently, Bangladesh relies heavily on fossil fuels, with 28% of primary energy consumption sourced from oil, 55% from natural gas and 15% from coal, making up 98% of the total energy mix. Domestic gas supplies are depleting, and the government has turned to imported LNG and coal to make up for this shortfall as it navigates solutions to its citizens' increasing energy demand. Even though emissions of CO_2 have increased 25% from 2017 to 2024, the raw figure of 125mn t/y of CO_2 emissions ranks Bangladesh within the lower two quartiles of nations, among the lower half of countries which is reflective of their relatively low rates of energy consumption.

Renewables

Despite the current low renewable energy consumption of only 1.8% of its total primary energy consumption, Bangladesh is making efforts to embrace renewable energy. Partly that comes from awareness of the vulnerability of its population to the consequences of climate change, in terms of flooding and sea level rises.

Climeworks' Mammoth direct air carbon capture plant in Olfus, south-west Iceland

Photo: Climeworks

As one of the most climate-vulnerable countries in the world, the Bangladeshi government is hyperaware of the consequences of climate change and sea level rise on the nation.

Bangladesh's energy transition is underpinned by the government's Vision 2041, which envisages significant advancements in the energy sector, including a target of generating 10% of the country's electricity from renewable sources by 2025.

International collaborations, such as those with the Asian Development Bank and World Bank, have been instrumental in funding renewable energy projects and modernising the grid infrastructure.

The government's Solar Home Systems programme has been a groundbreaking initiative. It is the world's largest off-grid solar programme, and provides electricity to around 20 million rural households. The project highlights the success of Bangladesh's mission to supply electricity access across the population.

Having done so without needing to connect the whole population to the grid, this scheme is a model of insights into how developing off-grid electricity systems in developing nations can supply electricity access to remote, underserved areas where traditional grid expansion is logistically challenging and costly. These decentralised energy systems also offer greater resilience, helping communities recover faster from natural disasters such as the monsoons and flooding common in Bangladesh.

Additionally, Bangladesh has invested in energy efficiency improvements and also explored the potential of other renewable energy sources such as wind and biomass, with some pilot projects underway. For example, construction has begun of a two-unit civil nuclear power plant in Rooppur, 160 km north-west of capital Dhaka.

Although progress is slow when compared to other nations, Bangladesh's initiatives and ambitions to address its complex energy challenges sustainably, indicates a growing recognition of the need for a diversified and sustainable energy mix.

Contrasting pictures

While Iceland is frequently portrayed as the benchmark in the transition to net zero, its unique circumstances make it somewhat of an 'outlier'. The more archetypal situation of Bangladesh, looking to provide for a large population, with a low budget and without the benefit of a sophisticated energy infrastructure, offers valuable lessons that are better shared with other nations as they strive to achieve universal energy access.

Divergent paths, shared goals

The energy transitions of Iceland and Bangladesh highlight how geography, resources, and economic and social conditions shape national energy policies and priorities. Iceland has been successful in harnessing its abundant renewable resources, but is now challenged as the home of energy-intensive industry. Meanwhile, Bangladesh is striving to provide energy access to millions who still lack reliable and safe power.

Both countries' transitions underscore the importance of balancing development with environmental sustainability and the ambition to reach net zero. They are navigating their respective paths through the global energy transition, each dealing with unique challenges and opportunities. However, they also share a common goal: to secure a more reliable, sustainable energy future for their citizens.

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COMMENT

How UK nuclear and renewable energy could work together

Nuclear reactors could generate useful heat and produce green hydrogen as well as electricity – and thus play a major role in decarbonisation efforts – if the role of civil nuclear power in the UK's energy mix could be reconsidered. Professor Zara Hodgson, Director of the Dalton Nuclear Institute at the University of Manchester, explains how.

"Getting to net zero by 2050 is going to rely upon a Herculean effort in every part of our energy system. The recent National Energy System Operator (NESO) report shows that fact very clearly, highlighting the step changes needed across all parts of the UK energy landscape to get to a clean electricity grid by the end of this decade, with decarbonisation of other sectors to follow.

For a long while, nuclear and renewables have been seen as competing for policy attention, funding and resources, yet their trajectories in recent decades have been markedly different.

The expansion of renewable energy in the UK has successfully displaced fossil fuel-burning power plants, bringing the ambition of reaching entirely clean electricity production within the next decade within the realms of possibility. On the other hand, we have seen only one new nuclear plant brought online since the 1980s (Sizewell B), with only one other (Hinkley Point C) under construction today. The nation's share of nuclear electricity has declined – and will continue to do so for a while to come.

To the modern observer, nuclear power has become associated not only with its baseload generation, but also high capital costs and construction delays. These attributes have made it appear inflexible in balancing the variable demands of the grid. It's equally well established that renewables embody an element of variability and unpredictability. After all, weather forecasting is a stereotypically British hobby! These issues bring challenges relating to financing, building and operation of our overall energy system.

To date, the back-up plan for our changeable weather has been the installation of natural gas-burning power plants and energy storage. This is despite the drawbacks of high-cost electricity from gas plants only used at peak times, wasted energy from curtailment of renewables, and the continued generation of CO_2 emissions.

Professor Zara Hodgson, Director, Dalton Nuclear Institute at the University of Manchester

Photo: Z Hodgson

Look again at nuclear?

We at the Dalton Nuclear Institute asked ourselves if there was a way for Great Britain to look again at how nuclear electricity – and importantly also nuclear heat – could help to accelerate the renewable energy technology-led transition to net zero, whilst also underpinning UK leadership in combatting climate change.

The work done by my colleagues – involving detailed modelling of a potential 2050 UK energy system – has illustrated that there is a more efficient way to address the challenge of meeting the variable demands of a carbon-free economy than the current approach. Furthermore, this can be achieved at lower overall cost and with more UK jobs than currently envisaged – and without resorting to the use of fossil fuels for back-up power.

This is achieved by exploring a fundamental change in how nuclear energy is modelled to operate in the system. Instead of simply being used for baseload production of electricity, a fleet of nuclear reactors – large, small and advanced – is envisaged as producing a flexible combination of high-quality heat, hydrogen and electricity, along with deployment of associated energy storage.

We put forward a different potential energy future, to spark further discussion. Our proposal is a maximal scenario for electrification – over 840 TWh total supply – three-quarters of which is supplied by renewable energy, just 10% by nuclear plants and zero from fossil fuels. Clearly, such a large-scale approach to clean energy requires a hugely demanding build programme of both new renewable and nuclear infrastructure, in terms of pace and scale.

Much of the nuclear capacity would also likely have to be sited closer to energy end users, to enable co-generation to be effective.

There would also need to be developments in grid design and management to trade and balance the supply and demand of electricity, heat and hydrogen. Along with the development of more sophisticated markets for heat and hydrogen as energy vectors, alongside electricity.

However, the benefits that could be realised – not least energy independence and savings of up to £14bn/y on the current UK energy system scenario – merit attention and analysis. Importantly, these benefits are scalable; the full implementation of this very ambitious approach is not required to make it financially and environmentally attractive.

The full picture

We have recommended that, instead of modelling renewables, nuclear, heat and hydrogen in siloed or outdated strategies, government take more holistic and innovative approaches to energy systems modelling – looking at the full picture.

Capitalising on the flexibility of nuclear energy to contribute more than just low-carbon electricity is a key innovation opportunity for Great Britain. A transition to net zero that integrates electricity generation, from both renewables and nuclear, along with nuclear-enabled heat and hydrogen production, must be explored.

The time to research, evaluate and plan for the delivery of Great Britain's clean energy future is now. ■

The views and opinions expressed in this article are strictly those of the author only and are not necessarily given or endorsed by or on behalf of the Energy Institute.

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COMMENT

Generation 2050: When work isn't enough

In 2021, when the UK hosted COP26, the Energy Institute (EI) launched the 'Generation 2050' campaign to capture the perspectives of those just starting out in industry, some of whom would be in senior leadership positions at the time the UK officially becomes net zero. Now, we continue the initiative by exploring the issues faced by young professionals working in the energy sector. Three prominent members of the EI's Young Professionals Networks (YPNs) explain why they volunteer.

Balancing the stresses of a first or second job, settling into a new city or country in unfamiliar living conditions, might be all too much for many young professionals.

But some have found that by taking on an additional activity that at first sight might seem unexpected – volunteering for a professional association – they have gained work-related insight, new contacts and even a group of ready-made friends.

It was particularly the latter for Karolina Zieba AMEI, now the Vice-Chair of Community Partnerships for the London YPN (her day job is Offshore Wind Associate at the Carbon Trust). She recalls her situation before joining the London YPN: 'I moved to London for my job and it was the first time as an adult that I had to make friends, which was hard.'

It was this or competitive sport, she added, for active people like her looking to do something in the evenings after work (although she adds that it is possible to do both).

Her enthusiasm led her to take an officer role (definitely not a requirement of joining the association). Reflecting on her personal case, she says: 'I like the committee, I like the community, I like taking initiative. You can really make of it what you want. If you put the work in, you won't find any barriers.'

Nicolas Manea started attending YPN events while still a student at Cardiff University. Now Vice President of the South Western and South Wales YPN (while working full time as Distributed

Some young professionals have found that by volunteering for a professional association they have gained work-related insight, new contacts and even a group of ready-made friends.

Photo: Adobe Stock/Nicholas Felix – peopleimages.com

Flexibility Strategy Lead at NESO), he remembered what attracted him initially was learning about a different side of energy to what came up in the classroom. 'At university, if a classmate had asked me to differentiate between a DNO and a supplier, I couldn't [have].'

'But having an environment like the YPN, if you give us that hour of your time, you will get insight equal to many hours of learning. Maybe the information you gathered in the first meeting doesn't make much sense now, but if you go back to the second meeting, and you continuously engage with us, you will realise that after some time you will know a lot about the energy sector,' he adds.

Today, Nicolas frames attending a YPN event in terms of 'training' his curiosity while always keeping the conversation going. That means prioritising listening to an energy podcast, watching an energy related YouTube video, or catching up with an energy friend instead of watching television in the evening.

A further advantage of the meetings is the opportunity for interaction. 'We have a topic, followed by a conversation and a debate about a subject where we all have complementary expertise. I don't think any one person knows from beginning to end exactly how reaching net zero is going to play out. Scarier than not knowing the pathway is not talking about it. And this is what we do at YPN, we are learning from each other, and we always keep the conversation going.'

It was the potential to meet like-minded people that attracted Marta Oliveira to the London YPN. She now Chairs it, alongside her work as a Senior Associate at Ikigai Capital. She says: 'I have a good network from my masters [degree]. But I felt I needed more. The industry is so dynamic. I meet investors, people across the value chain, truck drivers, but I rarely meet YPs [young professionals]. It's usually senior people.'

She continues: 'I wanted more exposure to friends in industry. I wanted other people who I could ask for help if I had an issue. My focus is on delivering bankable net zero solutions to infrastructure asset owners (airports, ports water/waste, etc). I don't have a specialism in any particular energy technology, I don't understand everything about batteries, or solar, or carbon capture. I wanted to have a network of specialists with technical, regulatory and investment perspectives to jointly deliver successful projects.'

'People who I know invited me 2–3 years ago, and when I started there, I thought, this is exactly what I want. It's a very good community; the best possible mix between slightly geeky and slightly friendly. I can get so much from areas I don't necessarily work in because of the experts and events that we put together.'

The Energy Institute Young Professionals Network has 10 branches around the UK, and three in the world (Africa, Middle East, Hong Kong).
To get involved, go to
https://www.energyinst.org/ei-near-me

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Your Energy Institute

New Year's honour for PfW head

The head of POWERful Women (PfW), the professional initiative based at the Energy Institute, was awarded with an OBE for services to diversity and inclusion in the energy sector. Below, Georgina Worrall reflects on the achievement in conversation with New Energy World *Senior Editor Will Dalrymple.*

Georgina Worrall OBE, Head of POWERful Women (PfW)

Q: What does receiving the honour mean to you, personally and professionally, and what do you think it means for POWERful Women?

A: Receiving the honour is really humbling. To receive it at the end of POWERful Women's 10th anniversary is a lovely culmination to what has been a great year for the initiative. From a personal perspective, my nine-year-old daughter is absolutely ecstatic about being able to get married at St Paul's Cathedral!

Q: In 2024, POWERful Women reported that progress in diversity and inclusion in the energy industry had stalled, particularly in terms of board representation. What do you think the industry should be doing that it isn't, currently?

A: There is still a lot that needs to be done around gender parity within the workplace, but here are just a couple of my thoughts:

- Don't be afraid to set bold and ambitious targets. Change only happens when we take brave steps forward.
- Gather and report on comprehensive diversity data – you can't act on what you can't see.
- Pull up a chair for a colleague who should be at the discussion table but hasn't been invited – progress comes about by having diversity of thought around the table.
- Ensure there is a ladder available for your future female leaders to climb. If your future leaders feel listened to and valued, then they will stay and give back to the company.

Q: Seeing the numbers going the wrong way must be a difficult thing to respond to. How do you keep yourself and the team motivated and focused in the face of challenges that must seem insurmountable at times?

A: I am very mindful that POWERful Women only has five years left to achieve its target (at least 40% of leadership and middle management roles in the UK energy industry to be held by women by 2030) and there is still a lot to do. We have a small backroom team, but we are mighty and all passionate about the cause, which definitely helps morale when we see disappointing news around gender diversity.

When it comes to facing the challenges within the sector, POWERful Women is all about providing suggestible actions that if implemented will deliver change, as can be seen in our various reports (*Cultivating Female Talent in Energy, 2024 Annual State of the Nation Report* and our 40 by 30 manifesto, see **https://www.powerfulwomen.org.uk**). We use these reports to stay positive as we know we are providing companies with the tools for them to make the decision needed to implement change.

Big Bang winner drew on craft and chemical skills for environmental project win

The 17-year-old winner of the 2024 Energy Institute Climate Change Special Award is already a committed environmentalist.

On a recent visit to the Energy Institute offices at 61 New Cavendish Street in London, Albert 'Bertie' Read reflects on the prize-winning project and his future plans.

'I care a lot about the planet and I care about humans. And the way for humans and the planet to coexist is to make sure what we're doing has as little impact as possible,' he says.

With that philosophy in mind, Read built a bicycle accessory from upcycled household items that removes CO_2 from the air.

The device uses an old fish tank air pump to bubble air through limewater. The CO_2 reacts with the calcium hydroxide in the limewater to form calcium carbonate, which gardeners can use as a liming material.

Bertie Read, Photo: Will Dalrymple

Powered by a dynamo and solar panels, the proof-of-concept worked; having extracted and weighed the calcium carbonate, he estimated the device sequestered 6 grammes of CO_2. Further envisioned improvements include a miniaturised version, and another with bottle screw attachment with air bubbler attached so the reservoir can be topped up.

Although the innovative Wallington County Grammar School, Sutton, London, student had seen the chemical reaction in his GCSE chemistry course, it was only when researching environmental projects for the Big Bang competition that he realised its potential use in carbon capture.

Read admits that he originally entered the competition with an eye towards boosting his university applications, to study chemical engineering.

Explaining his choice of course of study, he says: 'I'm hoping to work on things to do with environment, energy or carbon capture, or even simple processes, thinking about efficiency and saving energy. Chemical engineering has a big part to play in sustainability.'