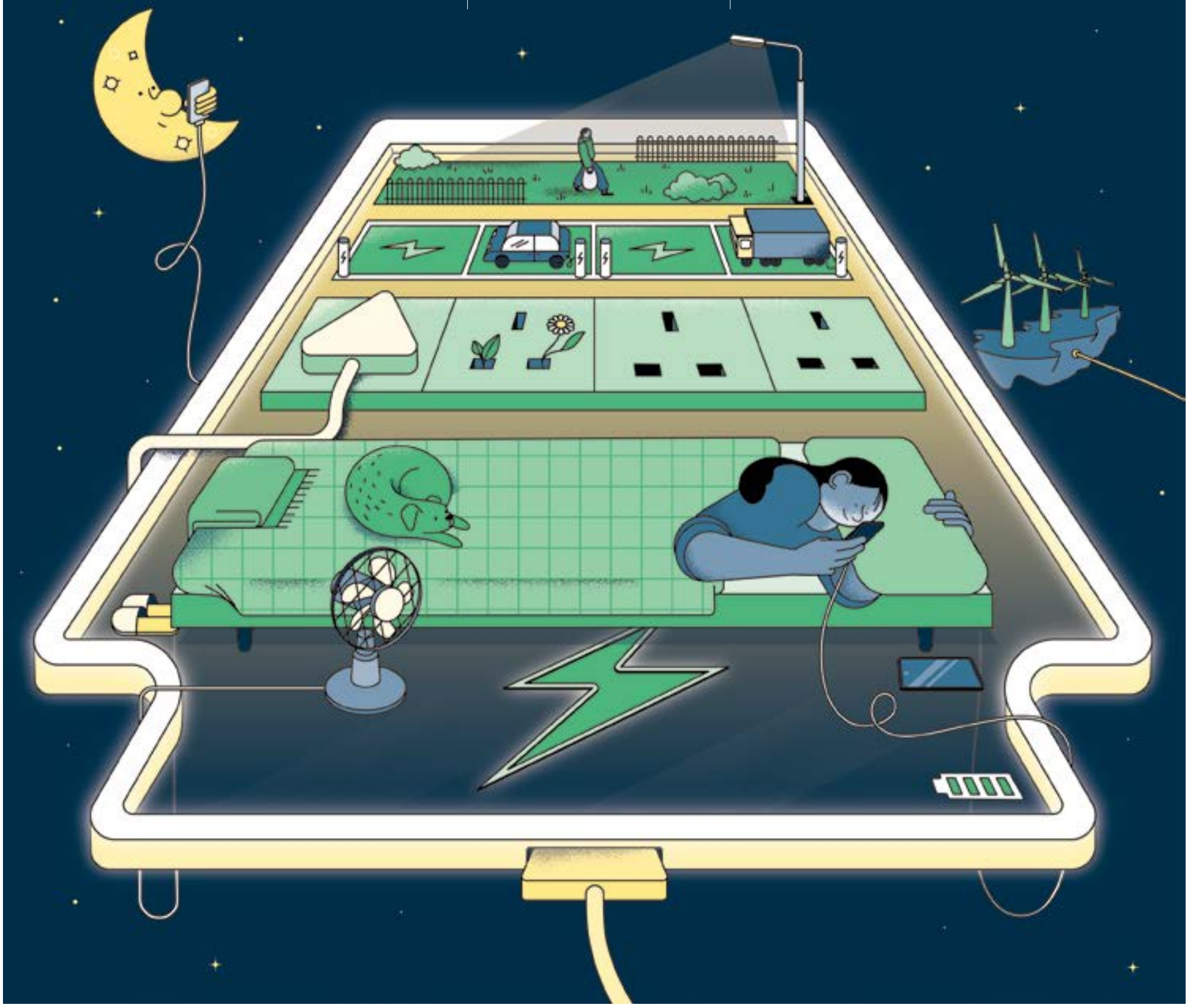
FUTURE OF ENERGY



FUTURE OF ENERGY

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STORAGE

Capacity crowd: who's leading the charge for lasting storage?

While long-duration energy storage has played an inconspicuous role in the net-zero mix so far, it's as important as wind and solar generation – and it's poised to emerge from their shadow

Jim McClelland

Energy storage technologies do attract attention, but this is generally reserved for batteries and their limitations, mostly during discussions about range anxiety relating to electric vehicles. Even though relatively few people are talking about it, long-duration energy storage (LDES) is arguably the most significant technology to monitor in the new power play.

Short-duration storage is measured in minutes, 240 at the most. Medium-duration storage runs from four to 12 hours and LDES covers everything beyond that. It can stretch to weeks, months or even quarters. The tech has become a hotbed of investment and innovation of late. What factors are behind this upsurge in R&D activity?

First and foremost, LDES is seen as vital to energy security and market stability, helping the electricity grid to manage peaks and troughs in supply and demand. It minimises the risk of brownouts – unexpected drops in voltage – and blackouts. Given the proliferation of extreme weather events such as winter storms, such resilience is becoming ever more important.

LDES is also vital for high-volume power users such as heavy industry, as well as for consumers in remote areas where grid connectivity and supply can be limited. In effect, it provides them with a safety net. But the climate emergency means that LDES is more than an insurance policy against shocks to the system. It's become key to the energy transition.

Decarbonising the electricity supply is crucial to achieving net zero, especially with the electrification of transport and heat fuelling global demand for green power. Harnessing the full potential of renewable energy sources such as the Sun and wind requires their variable and intermittent output to be optimised over time.

As a result, storage is booming. Growth in the global market broke records last year, according to BloombergNEF, which reports that capacity was up 68% on 2021 and forecasts that it will grow 15-fold by the end of the decade.

But the demand for long-term storage is growing at an even faster rate. The Long Term Duration Storage Council, an industry body comprising more than 60 members in 19 countries, has forecast that the world's electricity grids will need to deploy 85TWh to 140TWh of LDES by 2040. This growth trajectory places the market's potential value by that year somewhere between £1.2tn and £3.2tn.


Andriy Andriyenko/Getty Images

Potential scenarios explored by National Grid suggest that the UK will require at least 50GW of LDES capacity by 2050, in line with the nation's net-zero aims. To put that number in perspective, there is about 5.3GW of LDES operational in Great Britain today. This comprises roughly 2.8GW of pumped hydro and 2.5GW of newer lithium-ion battery storage. In short, then, there's a lot of work to be done.

But the industry is working hard on the task at hand. As evidenced by the range of projects approved for some of the £69m funding awarded last year under the government's Longer Duration Energy Storage Demonstration (Lodes) competition, the possible solutions take many forms.

The Lodes portfolio contains all of the core technologies with a genuine prospect of working on a commercial scale. These include compressed-air energy storage (CAES), liquid-air energy storage (LAES), thermal energy storage, flow batteries and pumped hydropower; plus power-to-low-carbon gases, developed in conjunction with the production of green hydrogen. The materials in the mix range from metal hydrides to 3D-printed concrete. Some of the more exotic-sounding solutions involve the lifting and lowering of weights in a vertical underground shaft, the use of salt caverns as a hydrogen store and the creation of a 30MWh vanadium flow battery that's set to be one of the largest of its kind in the world.

The newer technologies in particular – including CAES, LAES, flow batteries and hydrogen – have great potential, according to Dr Thomas van Lanschot, director of power and low-carbon energy at Fitch Solutions. He believes that these are likely to dominate the market in the long run.

But he adds: "In the near term, CAES and LAES projects are gaining traction globally and could provide a more rapid solution to our LDES needs."

The real growth opportunity for LDES lies in the property sector, so tapping into the residential market makes sense. That's the view of Lee Fraine, head of building services and sustainability at Rapleys, a property consultancy.

"We should be talking about LDES more in the domestic market," he argues. "At present, there are really only two operational forms: the solar store and the home surplus storage system. But neither is scalable in terms of both space and cost for the vast majority of people."

Some projects have already made it through the demo phase. For instance, the Earba Storage project, which will use two lochs in the Scottish Highlands, is set to provide significant amounts of both power (up to 1.5GW) and stored energy (up to 33GWh), making it the largest pumped-hydro scheme in the UK. And Highview Power is looking to raise £400m, most of which will go towards what's been billed as the first commercial-scale LAES facility near Manchester.

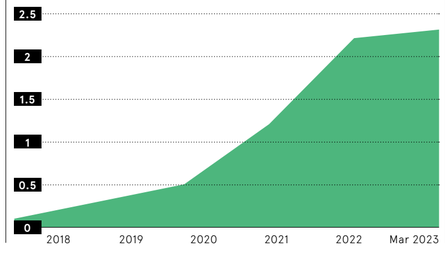
While progress is being achieved, Stuart Murphy, founder of tidal lagoon system TPGen24, believes that wider market cooperation is still required to generate meaningful momentum.

"If the government cannot afford to explore every avenue at this stage, it should open doors for the private sector, whether that's through innovation funds, tax incentives or supporting investor relations," he says.

The stage is set for LDES, then, but any further measures to stimulate this high-potential market would clearly be welcome.

THE LONG GAME IN ENERGY STORAGE *Climate Tech VC, 2023*

Cumulative funding for LDES tech worldwide ($bn)



DISTRICT HEAT NETWORKS

Hot in the city

gkaimoments via Gettyimages

480,000

consumers in the UK have connections to a heat network

Department for Energy Security and Net Zero, 2023

80TWh or 20%

of heat demand for all UK buildings – could be met through heat networks under the Climate Change Committee's pathway to net zero

Climate Change Committee, 2022

District heat networks offer highly efficient technology that could propel the UK towards net zero, but the sector has several hurdles to surmount before it can realise its potential

Helena Pozniak

All of the heat going to waste from sources such as power stations, factories, data centres and even sewage works could meet a significant proportion of the UK's heating and cooling needs, according to a growing number of energy experts.

Researchers at Durham University have estimated that this country generates 391TWh of industrial waste heat a year. District heat networks, widely considered to be the cheapest and cleanest method of heating and cooling cities, are poised to tap into that energy. If the UK were to adopt the technology – which has the potential to bring costs down in the long term – on a large enough scale, it could make serious headway towards honouring its legally binding pledge to become carbon neutral.

"Every building is going to have to decarbonise by 2050," says Toby Heysham, CEO of heat network developer Pinnacle Power. "How else is net zero achievable if not through heat networks?"

For that to happen, the sector will first need to attract more funding, improve its supply chain and win the hearts and minds of consumers.

District heat networks suit heavily built-up areas and are best understood as central heating for cities. They use renewable energy and waste heat from local sources to heat or cool water at a central point and distribute it around the neighbourhood to buildings through a network of insulated pipes.

"Hot water will be piped into your home, just like gas is now for your central heating," Heysham says.

Benefiting from a relatively temperate climate, the UK has been far slower to adopt the technology than most of its northern European neighbours, but it's started to benefit from decades of experience on the continent and is developing its own tech – leak-detecting sensors for instance.

"We're working on innovations that make our systems better and are also great exports," reports James Beal, a specialist in renewable energy who advises the Department for Business, Energy and Industrial Strategy.

The latest networks tend to be compatible with modern systems using solar, wind and geothermal energy. When renewable energy is abundant, it can be used to generate and store heat for later demand and help balance the grid. Networks can also be used for cooling, which is becoming increasingly important given the dangerously high temperatures that many cities have endured in recent summers.

Only about 3% of the nation's buildings use heat networks at present, but that could rise to 20% by 2050, according to the Heat Networks Industry Council. The industry body believes that this amounts to an investment opportunity approaching £80bn over 25 years.

Some pioneering initiatives are already showing how it can be done. The Cambridgeshire village of Swaffham Prior has swapped oil burners for a district heat network powered by large communal pumps, for instance. A scheme in Islington is taking waste heat from the London Underground, but a far larger project combining energy from the Tube and data centres in the borough with solar generation is set to give 33,000 residents and 80 businesses low-carbon electricity and heat. Local authorities in Bristol, Cardiff, Gateshead, Leeds, Manchester, Sheffield and other parts of London are pressing ahead with heat networks too.

Copenhagen's extensive district heating system is based largely on biomass power, but it has been incorporating waste heat from industrial processes in recent years

> **"How else is net zero achievable if not through heat networks?**

The fact that the cost of gas and electricity is so high in the UK is making local energy generation an increasingly attractive option, notes Heysham, who adds: "The more people sign up, the more efficient it becomes."

But, to achieve economies of scale, the industry must first build pipes and other infrastructure, easing the way for consumers to switch when the time is right. Heysham, whose firm has just raised £1bn to invest in heating networks around the country, refers to this task as "getting over that hump in the road before you can see the positive effects".

While it's a relatively straightforward task to introduce heat networks to new developments, retrofitting the nation's notoriously energy-inefficient period buildings is more of a challenge. That's particularly true in the capital, where Westminster alone contains 475 listed buildings per square mile.

As well as attracting private finance, the UK must build supply chains and invest in skills such as design, installation and maintenance. There is a widely acknowledged dearth of civil engineering know-how at a time when the green energy sector as a whole sorely needs it.

Graeme Maidment, professor of mechanical engineering and design at London South Bank University, whose specialisms include the utilisation of waste heat, stresses that concerted action is urgently required to address this shortfall.

"There has to be a concerted effort from a bunch of stakeholders to work together and develop such skills via a spread of technical apprenticeships," he argues.

Trade body the Association for Decentralised Energy has forecast that "the growth in heat networks will contribute to the creation of an estimated 46,400 to 63,400 new jobs annually during the peak employment period".

The energy security bill, currently in the House of Lords, is expected to pass into law late next year. It could stimulate the kind of large-scale collaboration on skills that Maidment believes is necessary. This legislation aims to create heat network zones, in which suitable buildings will be obliged to connect to a network where one is available. This should give developers the confidence to invest in the infrastructure required and the skills to design, build and maintain it.

Beal stresses that both suppliers and users of this emerging technology need some reassurance. Small communal heating networks have not earned the best of reputations in the UK, given that they've typically been powered by a poorly maintained gas boiler, rattling away in the basement of a large block of flats. These may be a world away from the modern systems under development, but British consumers need to know that if they're to embrace the new tech.

"We must be clear about the benefits. The sector has an opportunity to promote and deliver heat networks at pace and scale and so drive down the costs," he says. "It's a challenge, but heat networks will ultimately deliver a better solution."

TRANSPORT

The jet reset: aviation's search for greener fuel

Although biomass-based fuel isn't the perfect long-term solution for an industry under intense pressure to reduce its greenhouse gas emissions, the alternatives have barely got off the ground yet

Bradley Gerrard

With the con trails of jet airliners painting the industry's greenhouse gas emissions across the skies for all to see, aviation is an obvious target for those seeking to decarbonise the global economy.

Its emergence from the Covid crisis is well under way, with global airline traffic last year recovering to more than two-thirds of 2019's total. This has only added to the pressure on the sector to find greener fuels.

Much of the focus to date has been on biomass-derived sustainable aviation fuel (SAF), which is made by converting a natural, notionally sustainable, feedstock into a usable form using various industrial processes. But there's a growing debate, in both the sector and the scientific community, about whether SAF is the best long-term option or whether the research and development effort should move on other fuels with more lasting potential.

Aviation knows it must continually reduce its carbon footprint if it's to hit the 2050 net-zero target set by its industry body, the International Air Transport Association. It is responsible for less than 3% of the world's anthropogenic greenhouse gas output, but its visibility and likely growth in activity means that it holds a prominent position in people's minds as a sector with room for improvement.

Although 60% of Heathrow Airport's airlines by capacity have pledged to turn at least 10% of their fuel supplies to SAF by the end of this decade, there is no guarantee that enough of it will be available.

"It represents only about 1% of consumption at present and we're using all the SAF there is," reports Claudia Galea, a former Boeing manager who is now global sustainability director at US consultancy Kearney. She adds that it's "three times more expensive than conventional jet fuel, which makes it a hard pill for airlines to swallow".

This means that ramping up the production of SAF will be crucial if it's to stand any chance of mitigating the industry's use of fossil fuels. But those seeking to do this will "need to think about the wider ecosystem and the whole value chain", Galea says. "The case for using SAF has been proven. Airlines want it and governments want to make it affordable, so the pendulum has swung towards the production side."

As with every type of fuel, the production of SAF has an impact on the environment and may draw on resources that could be used for other purposes. A policy briefing published by the Royal Society in February discusses the potential constraints of biomass-based fuel solutions, highlighting the fact that they exhibit "significant resourcing implications, particularly energy crops, which would require at least half of all UK agricultural land for their cultivation to supply the whole amount of jet fuel used in the UK".

The document adds that this would incur "significant trade-offs with food production", potentially adding to emissions via increased food imports and soil erosion.

SAF might not be the ideal solution, then, but few obvious alternatives to it have emerged so far.

"The development of SAF has gained significant attention as a short-term solution," says Lee Sykes, commercial director at transport engineering firm Drive System Design. "But it's widely recognised that it is a temporary measure while the industry transitions towards more sustainable alternatives."

Broadly speaking, these alternatives include synthetic fuels (sometimes called electrofuels), hydrogen, ammonia and battery power.

Each one, predictably, has its pros and cons, with a common factor being the fact that virtually all are at an early or even hypothetical stage of development.

Professor Nigel Scrutton, the co-founder and chief scientific officer of C3 Biotechnologies, believes that the synthetic fuel his company is developing holds an advantage over SAF in that it relies on "readily available" waste material. He envisages that it could be manufactured on site by users, cutting the financial and environmental costs of transporting it.

"We want to move away from the central refinery model, because the carbon footprint and some of the costs of taking fuel around the world are enormous," Scrutton says.

Battery-powered flights are "still subjects of extensive deliberation and research", while the hydrogen-based systems require sophisticated tech for pumps, fans and thermal management, according to Sykes.

The Royal Society paper notes that the adoption of hydrogen and ammonia would require the "substantial modification of aircraft and infrastructure", which could dampen demand for those fuels.

The Mission Possible Partnership (MPP) is a corporate coalition seeking decarbonisation throughout the value chains of the world's most carbon-intensive sectors. In July 2022, it published an industry-backed strategy entitled *Making Net-Zero Aviation Possible*. This document sets out an optimistic scenario and a more prudent one for aviation's path to carbon neutrality, with the former assuming "a faster cost decline of renewable electricity and hence, more favourable economic conditions for electricity-based technologies". This would bring battery-powered aircraft and those powered by hydrogen fuel cells to market earlier and on a larger scale.

> **SAF will serve as a crucial stopgap solution, providing significant environmental benefits and enabling more immediate emission reductions**

It's notable that even the MPP's "business as usual" scenario (in which no progress is made in these alternative technologies) predicts that continued improvements to the efficiency of existing fuel at historical rates would lead to a 26% reduction in the industry's global greenhouse gas emissions by 2050.

It should also be noted that non-fuel-based innovations can help to reduce the industry's emissions. Iris, the new air-traffic management system created by Inmarsat and the European Space Agency, is helping airlines to take more efficient routes, for instance. Inmarsat predicts that this could save 6.5 million tonnes of CO_2 from European flights each year by 2040.

Policy-makers will also be pivotal in shrinking aviation's carbon footprint, as governments often hold the power to catalyse key industrial developments through taxation and regulation.

Galea believes that the EU's decision to scrap its free emissions permits for airlines may prove "counterproductive", because this could take money away from aviation R&D. She argues that blended tax credits in the US, which offer tax breaks for jet fuel that's a mix of SAF and conventional fuel, are a "very short-term fix" and that changes in how they are administered are needed to better support order visibility for SAF producers.

It's also important that different jurisdictions don't vary too dramatically in their approaches. Aviation is a global industry and aircraft must be able to refuel wherever they are. But some divergence is already happening, with most European investment targeting hydrogen solutions while those in the US tend to favour battery power.

Yet both technologies remain at an experimental stage, whatever commercial potential they might show, Sykes notes.

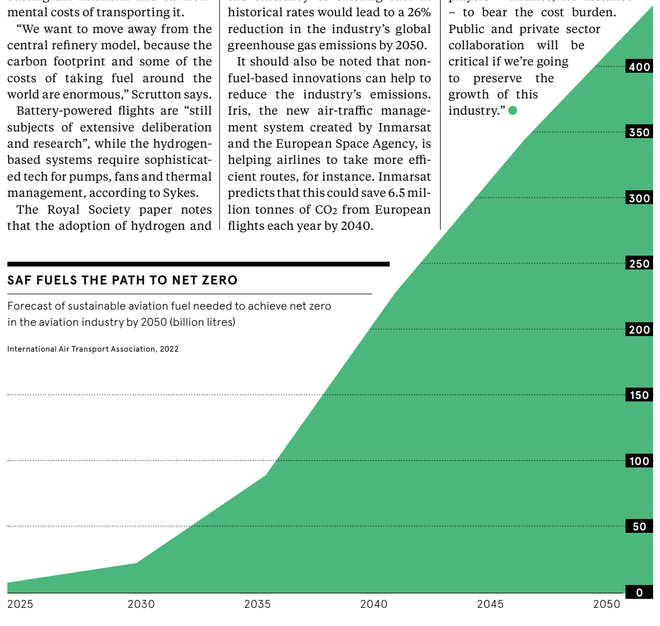
"Designing and certifying new aircraft incorporating these alternative propulsion methods is likely to take until 2030 at the earliest," he says. "In the meantime, SAF will serve as a crucial stopgap solution, providing significant environmental benefits and enabling more immediate emission reductions."

With no easy take-off for any of the alternatives in development, industry-wide teamwork will be vital if it's to stand a chance of meeting its commitments, according to Galea. It will take "an ecosystem effort", she says, arguing that "it should not be falling on one or two players – airlines, for instance – to bear the cost burden. Public and private sector collaboration will be critical if we're going to preserve the growth of this industry."

SAF FUELS THE PATH TO NET ZERO

Forecast of sustainable aviation fuel needed to achieve net zero in the aviation industry by 2050 (billion litres)

International Air Transport Association, 2022



INSIGHT

'We must act now and act together – there is no time to waste'

Sadiq Khan, mayor of London and chair of C40 Cities, explains how cities and national governments can drive the transition to round-the-clock, carbon-free energy

When I promised to make London carbon-neutral by 2030, I knew it was an ambitious target. But the pledge had to be made. Urban areas are responsible for more than two-thirds of the world's energy usage and more than 70% of its carbon emissions. Our dependence on fossil fuels is not only the leading cause of climate change; it's also to blame for the fact that 99% of humans are breathing toxic air.

Making clean energy available every hour of every day is the only way to phase out fossil fuels. Cities are driving forward 24/7 carbon-free energy, but a global transformation is needed to make clean energy a reality. This requires the backing of national governments.

Clean energy must be supplied and consumed 24/7 – no power can be generated by carbon-emitting sources at any point. This goes well beyond buying enough clean energy to match annual electricity demand. True round-the-clock clean energy will require an extensive transformation of urban energy infrastructure, including grid-wide adaptation, electrification and a shift to a range of generation and storage technologies. The scale of these changes is significant, but the benefits will be vast: 24/7 carbon-free energy promises to drive the systemic change needed to rid fossil fuels from global and local systems.

Cities are already working to make 24/7 carbon-free energy a reality. As chair of C40 Cities – a global network of mayors working on climate change mitigation and adaptation – I am dedicated to driving this transformative approach in cities worldwide. C40 Cities has joined forces with Google to launch the 24/7 Carbon-Free Energy for Cities programme, aimed at accelerating the decarbonisation of regional electricity grids for the benefit of city residents. London, Copenhagen and Paris are implementing innovative pilots, creating scalable carbon-free models for other cities to work to.

We have already made huge strides in the transition to round-the-clock clean energy in London. We're pursuing the highest clean energy deployment targets, leading the way alongside 15 other cities by signing up to C40's Renewable Energy Accelerator. Transport for London, the single largest consumer of electricity in the city, is on track to move to 100% renewable electricity by 2030.

London's 24/7 carbon-free energy pilot builds on the success of our FlexLondon programme, which engaged businesses across the capital to advance flexible low-carbon energy, which allows users to choose when and where to use energy.

With global energy prices rocketing and an urgent need to tackle the cost-of-living crisis, clean energy is the cheapest form of energy in most jurisdictions, including the US, China and the EU. That's also true in the UK, where gas is up to nine times more costly than offshore wind. Investing in affordable renewables will protect people from inflation and create millions of green jobs – up to six times as many as those employed in the gas sector.

The interconnected challenges of multiple economic and environmental crises are exacerbating local and global inequalities. That's why I committed to the creation of 50 million green jobs by 2030 across the C40 city communities that need it most, as well as allocating two-thirds of our budget to support cities in the Global South.

As we look ahead to the UN's COP28 climate conference in Dubai, we need bold action from national governments. They must follow cities' lead by investing in 24/7 carbon-free energy and setting national standards and schedules that will drive the market to phase out fossil fuels. And they must do it quickly.

Making 24/7 carbon-free energy a reality will entail a total shift away from fossil fuels. The gains from such a move will transform our cities and the lives of their residents. It will lead to lower energy bills, more good jobs, less pollution and healthier, more resilient communities. We must act now and act together – there is no time to waste.

Sadiq Khan
Mayor of London

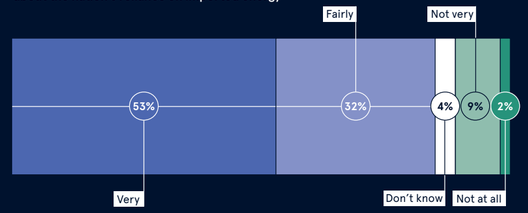
ENERGY SECURITY IN THE UK

Energy security has been a high priority for most European nations since successive political and economic crises culminated in a supply crunch during the winter of 2021-22. According to a recent government report, the UK's overreliance on fuel imports makes it particularly vulnerable to supply shortages and price inflation. While the transition to renewables must play a key role in the nation's quest for long-term energy security, guaranteeing a reliable supply is crucial in the shorter term. How is the UK faring in this respect – and how worried should we be?

THE PUBLIC ARE WORRIED ABOUT ENERGY SECURITY

BEIS, 2022

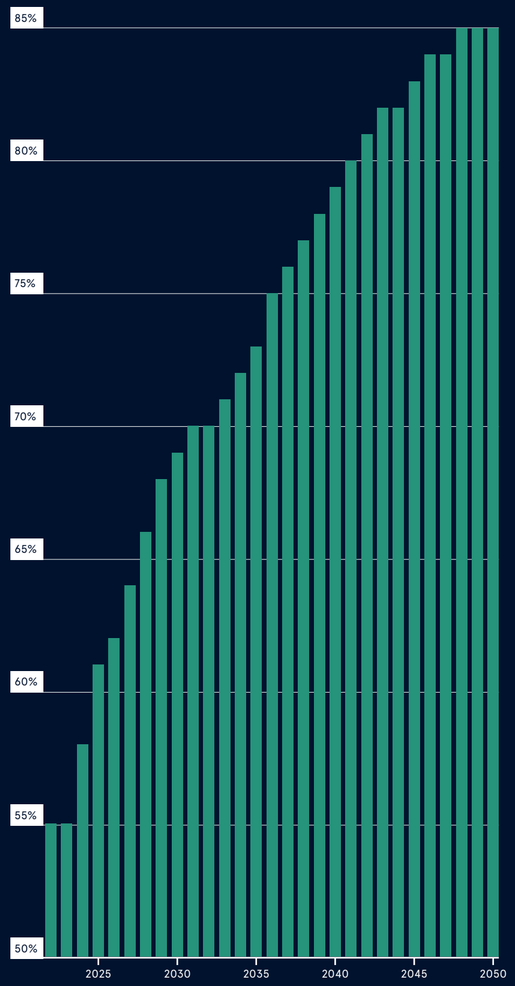
Share of UK adults giving the following responses when asked how concerned they were about the nation's reliance on imported energy



A GROWING RELIANCE ON FOREIGN GAS

North Sea Transition Authority, 2022

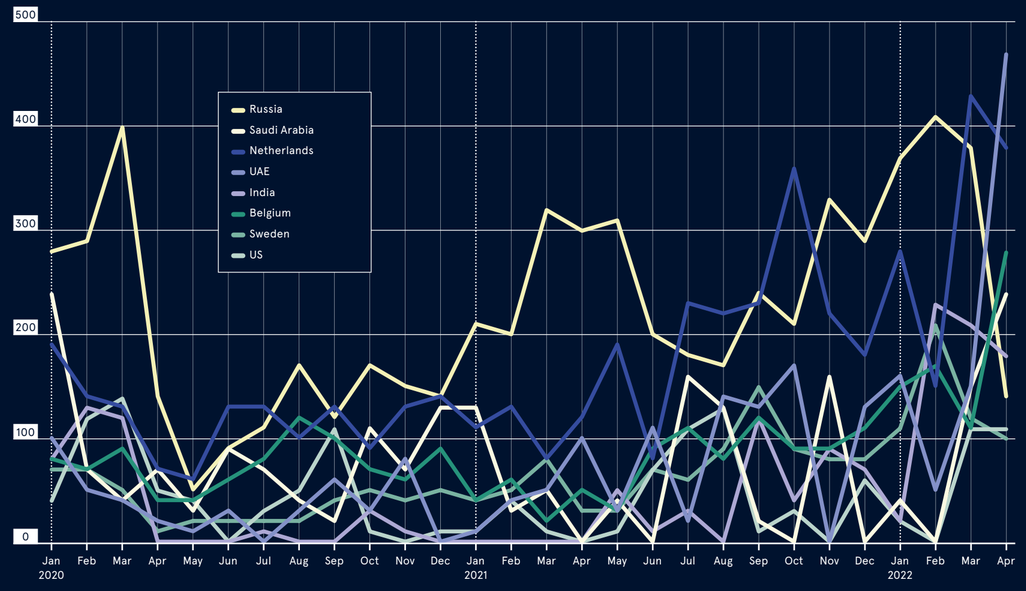
The UK's forecast dependency rate on imported gas from 2022 to 2050



THE UK IMPORTS MUCH OF ITS REFINED OIL FROM OUTSIDE THE EU

Office for National Statistics, 2022

Value of the UK's refined-oil imports from key suppliers from Q1 2020 to Q2 2022 (£m)

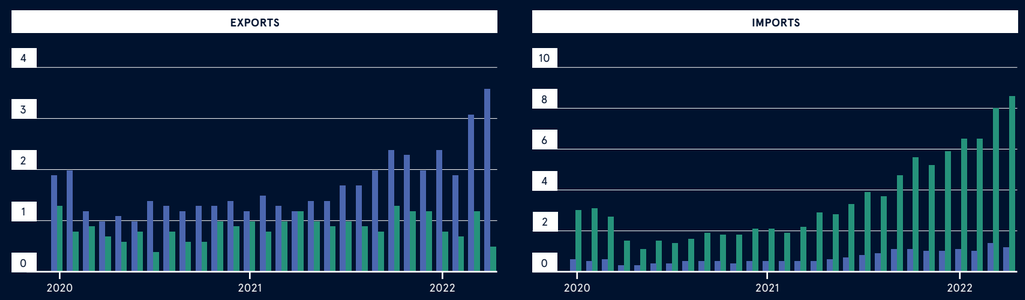


FUEL IMPORTS FROM OUTSIDE THE EU ROSE SHARPLY IN Q4 2021

Office for National Statistics, 2022

The UK's trade in fuels with EU and non-EU countries from Q1 2020 to Q2 2022 (£bn)

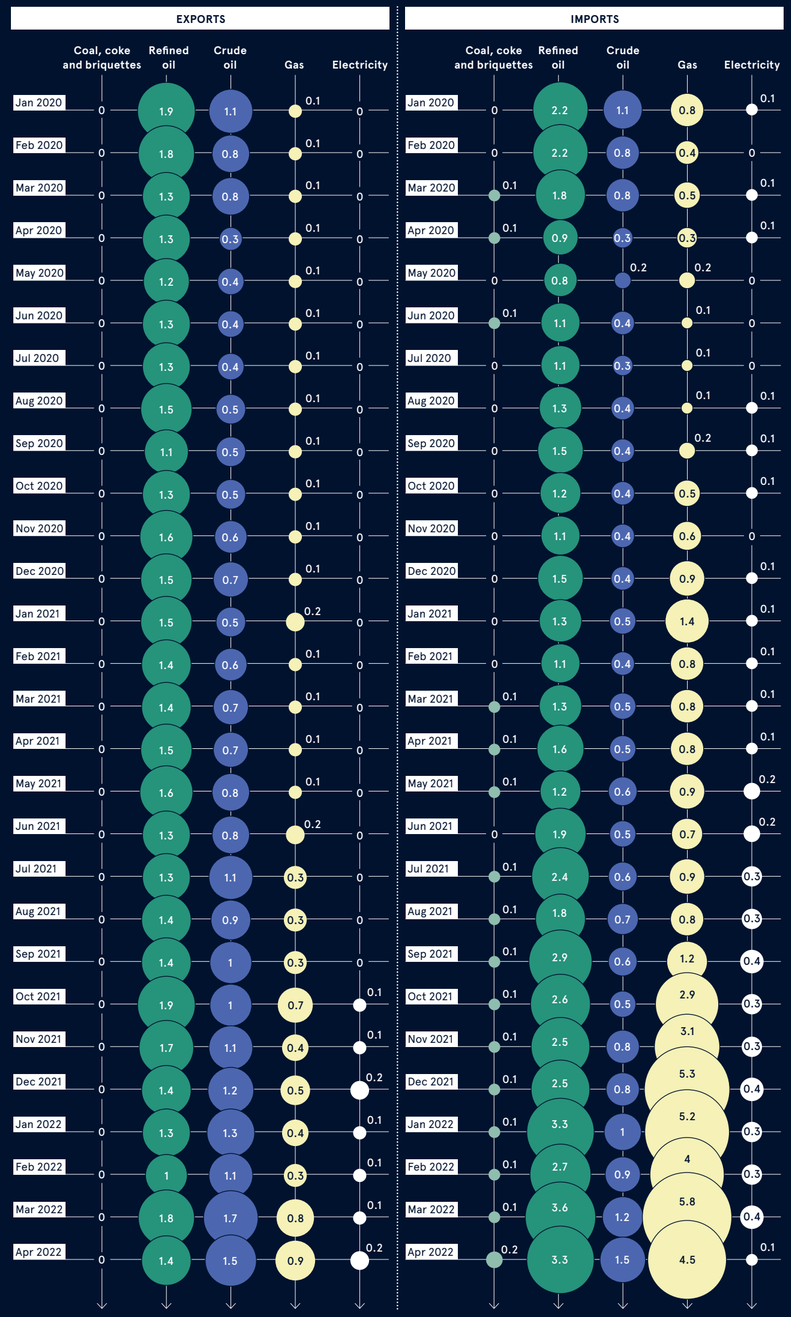
EU Non-EU



THE SHIFTING BALANCE OF TRADE IN ENERGY COMMODITIES

Office for National Statistics, 2022

UK imports and exports of energy commodities (£bn) from Q1 2020 to Q2 2022



Alberto Novo via Getty

RENEWABLE POWER

Going with the Flow

Floating offshore wind (Flow) energy generation could play a key role in global decarbonisation. Realising the full potential of this method is unlikely to be plain sailing, though

Jon Axworthy

"Dogger: south-westerly, veering westerly, six to seven, perhaps gale eight later..."

Such words will be familiar to anyone who listens to BBC Radio 4's *Shipping Forecast* for warnings of high winds and rough waters around the British Isles. "Dogger" refers to the Dogger Bank, a massive sandbank under the North Sea starting about 80 miles off the Yorkshire coast. The broadcast also offers a regular reminder that this area is the chosen site for one of the world's largest offshore wind farms, part of the UK's planned transition from fossil fuels.

Once it's fully operational, the array will be able to power more than 6 million homes annually. But, unlike the monopile turbines we can typically see from the UK's shores, the Dogger turbines will be mounted on floating foundations rather than fixed to the seabed. The term for this type of arrangement is floating offshore wind (Flow).

A report published by the Global Wind Energy Council has estimated that 80% of the world's offshore wind resource potential lies in waters deeper than 60m, beyond the reach of traditional fixed turbines. The water is only about 35m deep at most over the Dogger Bank, but the Flow architecture allows for bigger blades to take advantage of the stronger winds way out in the middle of the North Sea.

Gavin Watson, renewable energy specialist and partner at law firm Pillsbury, explains: "The further from shore and the deeper the water, the stronger and more consistent the wind. Considering one of renewable power's biggest challenges is intermittency, the ability to smooth the peaks and troughs of generation is a huge benefit. The foundations for Flow turbines are more costly than the pylons for their fixed equivalents, but the wind's greater strength and consistency far offshore, combined with the size of turbines that can be installed, significantly offsets the initial outlay."

Moreover, small increases in wind speed translate to big ones in energy production. A turbine in a 15mph wind will generate twice as much electricity as it does in a 12mph wind, for instance.

But the ability to harness the strongest winds isn't the only benefit offered by Flow.

"Rather than being constructed in situ on fixed pylons, Flow turbines can be assembled quayside and floated into place before being anchored to the seabed with cables. This makes them quicker and easier to install," Watson says. "Because they're further from the coast, planning permission is easier to obtain and visual impact problems are less acute. There are also potential biodiversity benefits: there is some evidence that fish stocks regenerate when protected from trawling by the floating structures."

The EU has already set an ambitious goal of producing half of its electricity from Flow arrays by 2050, while it's been estimated that the technology could eventually meet half of the combined energy needs of the east and west coasts of the US.

One of the biggest obstacles to achieving such ambitions is the challenge of rolling the technology out on a large enough scale. When it comes to building a turbine hundreds of metres tall atop a large floating platform, there is no standard design solution that will suit every operational condition possible. This is one of the reasons why only 50 Flow turbines had been commissioned by the end of last year, even though the global stock is expected to exceed 5GW by 2030 and 25GW by 2035.

A floating turbine installed in the Atlantic off the west coast of Portugal

Gabriel Davies is the senior director who heads the floating wind programme at Ørsted, a Danish multinational energy company that develops and operates wind farms. She believes that there is "a need to reduce the number of floating-foundation concepts to enable industrialisation to happen at pace. While innovation is important, the sector needs to converge on a small number of designs to drive and clarify government targets and help provide focus."

> **While innovation is important, the sector needs to converge on a small number of designs to drive and clarify government targets and help provide focus**

The consensus among analysts is that the deep-sea wind industry also lacks a robust supply chain for both turbines and foundations, which is also restricting its growth.

That said, the UK is installing more offshore turbines than any other country except China. In doing so, it's building a valuable blueprint for the Flow sector to follow.

"We've seen that support from the government has been pivotal, with the UK offshore wind sector benefiting from a stable policy regime and continued support from successive administrations," Davies says. "In partnership with government, the sector has flourished."

But the costs of producing floating turbines are still rising, thanks to the continued scarcity of high-quality steel and price inflation affecting other components. Such factors discourage manufacturers from committing to big investments in the materials they need. Developers could offer them more certainty that a reassuring number of orders are on the way, but they in turn need to know they can be guaranteed building permits, which is a governmental matter.

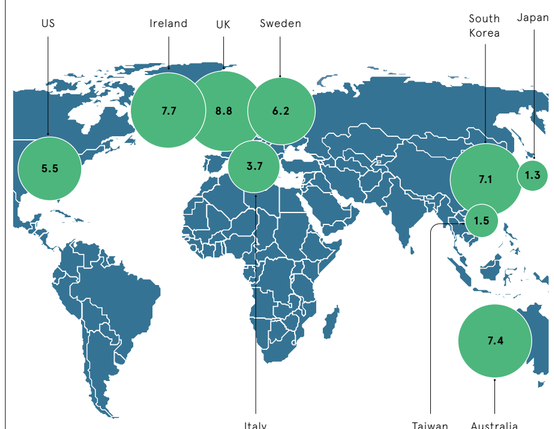
Davies acknowledges that developers ought to be working more closely with policy-makers "to agree supply chain plans that play to the strengths of their territories and make sure that these maximise the economic opportunities for the businesses in them. We must also ensure that planning decisions can be made on schedule and that we build the infrastructure required for the transmission of renewable electricity on a large scale."

The future success of Flow depends heavily on how policy-makers understand the sector and respond to the issues it's facing. For instance, they need to show enough confidence in its potential to encourage private investors to give it their backing too.

"Providing a clear view of future opportunities will give the supply chain the assurance to invest in expanding its operations to meet demand and create economies of scale," Davies says. "That will help to ensure that floating projects are investable and will provide value for all stakeholders, from consumers and governments to owners, operators and investors."

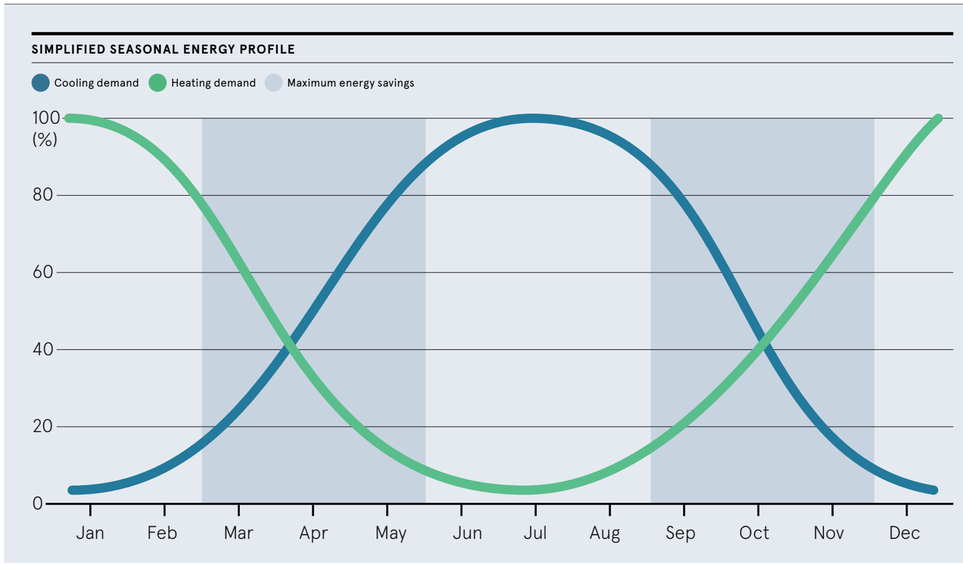
THE UK LEADS THE WAY IN FLOW PIPELINE CAPACITY

Offshore floating wind project pipeline capacity in selected countries (GW)



ReNews.biz, 2021

Commercial feature



The system has led to savings of over

€1m

a year on the diesel fuel needed to power a boiler. This also prevents almost

3,000t

of CO2 equivalent each year

Why breaking down energy silos is the key to decarbonisation

Innovative heat pump technology and electrified thermal management systems are set to become game-changers in the way commercial buildings are managed. But to get the most out of these technologies, the mindset that places heating and cooling in separate silos needs to change

On the face of it, we are in a Catch-22 situation. As global warming leads to a hotter world, there will be greater need for more cooling and more air conditioning than ever before. But this means more energy use, often through burning fossil fuels, which simply exacerbates climate change.

Heating, ventilation and air-conditioning (HVAC) can be part of the solution. The key to this, says Jose La Loggia, president, commercial HVAC EMEA at Trane, a strategic brand of Trane Technologies. Trane Technologies, is to stop seeing heating and cooling as separate entities.

"The heating and cooling requirements of a building have historically existed in silos," he says. "But this is a way of thinking that needs disrupting.

"You have this absurd situation where on the one side you are using fossil fuels to create heat, and then on the other, you're using electricity to reject heat from the same building."

This inefficient use of energy means that in Europe, buildings are responsible for 40% of energy consumption and 36% of greenhouse gas emissions. Almost half of the energy used in buildings is on heating and cooling.

A thermal management system combines the ability to chill and heat by recovering energy that would otherwise be wasted. When powered by renewable electricity, they can play a crucial role in decarbonising buildings and cities, helping to remove the need for fossil fuels and reduce greenhouse-gas emissions.

This innovative and proven approach to heating and cooling has seen Trane partner with a growing number of organisations that are looking to decarbonise their operations and enhance a building's efficiency and sustainability.

Hospitals are a classic example of where both a chilling load and a heating load overlap at the same time. At the Mater Dei Hospital in Malta, when the time came to replace the existing chillers, the hospital opted for a new thermal management system that produces both chilled and hot water at the same time, helping to meet heating, cooling and dehumidification needs across the hospital.

The system has led to savings of over €1m a year on the diesel fuel needed to power a boiler, and also prevents almost 3,000 tonnes of CO2 equivalent each year. But in addition to these savings, Ramon Tabone, senior mechanical engineer at the hospital, believes that improved air quality is another important benefit of the Trane system.

> **In Europe, buildings are responsible for 40% of energy consumption and 36% of greenhouse gas emissions**

"We forget the direct impact on the health of the citizens when burning fossil fuels in densely populated city and village centres," he says. "There is no doubt that health-related pollutants have reduced dramatically as a consequence of this project."

Around 80% of the work Trane carries out is retrofit, and while the initial outlay may be higher than simply replacing like-for-like, once savings in fuel costs are factored in, "the system is in some cases better than free," says La Loggia. "They start saving money immediately."

Trane, has also worked on the installation of a low-carbon heating system at Derby College's Broomfield Hall Campus, with the new highly efficient thermal system replacing fossil-fuelled boilers.

According to Iain Baldwin, the college's director of estates: "Relying on a carbon-based heating system was outdated and unacceptable in today's society. This installation is a step in the right direction for the college and is a great example of how green, clean energy provision can be utilised on a greenfield site."

Using the total-efficiency ratio (TER), an industry approach championed by Trane, the company has shown that the new thermal units have brought about a 400% improvement in efficiency and cut annual CO2 emissions by 160 tonnes. TER is based on the calculation that with separate heating and cooling systems, for every two units of energy that are introduced, the best outcome is four units of heating and cooling. A thermal unit boosts this to eight units for every one that is put in.

The Derby project is also comes as part of Trane Technologies Gigaton Challenge, the company's commitment to help reduce 1 billion metric tons of CO2 equivalent from its customers' footprint by 2030, a figure roughly equal to the annual emissions of Italy, France and the UK combined.

The company is also working internally to reduce its own carbon footprint. At the end of last year, it installed an electrified thermal-management system at its manufacturing facility in Charmes, France. The new system is expected to cut out 1,800 tonnes of carbon emissions annually. The company has committed to reach net-zero greenhouse gas emissions across its value chain by 2050 with its emission-reduction targets validated by the Science Based Targets Initiative (SBTi).

The growth of new technologies is also playing a key role in the rise of the new combined system. In 2019, a new district heating system – the first of its kind in the UK – buzzed into life in Stirling, Scotland. It uses Trane's heat-pump technology to extract heat from sewage and wastewater. The technology has the potential to save over 380 tonnes of carbon a year, says Donald MacBrayne, business development manager for Scottish Water Horizons.

The network, which is operated by Stirling Council, supports a number of key public buildings including a leisure centre and high school. Such has been the success of the project that the council is now looking to expand the network and connect more customers to low-carbon heat. Four similar projects have since been launched in Scotland and there has also been interest from across Europe.

Innovation is part of the solution, says La Loggia, "but we need to change the traditional way of thinking that says heating and cooling are separate things."

By creating better connections between the grid and the entities that use electricity, from cooling systems to transportation, and with the increasing efficiency of battery storage, the amount of energy that needs to be generated in the future may be far less than is needed to power today's less-efficient systems, he explains.

"The future is where infrastructure is no longer siloed but seen as one organism. Cities will become better inter-connected, so that everything is electric and fossil fuels become a thing of the past."

For more information please visit www.tranetechnologies.com

TRANE TECHNOLOGIES

INTERVIEW

‘It’s a bit like an internal combustion engine’

Recent breakthroughs suggest that commercially viable nuclear fusion is achievable. First Light Fusion’s **Nicholas Hawker** explains how a shrimp that punched well above its weight inspired his firm’s R&D efforts

Sean Hargrave

When Dr Nicholas Hawker was at the University of Oxford studying how pistol shrimps take down their prey, he was more interested in physics than biology. Could the diminutive crustacean’s ability to produce a high-energy shockwave help him to create an affordable nuclear fusion power source that would enable the world to wean itself off fossil fuels?

“The shrimp has one outsized claw that it can snap really fast to make a shockwave strong enough to stun its prey. This also produces bubbles,” Hawker explains. “As the shockwave passes over the bubbles, it makes them collapse, which releases energy in the form of bright flashes of light. A big part of my PhD was studying that process of cavity collapse with fusion in mind. I wondered whether it could be applied to generate power. The answer was ‘probably not’, but it did help us to set up simulations to see how the principle could be adapted for use in fusion.”

Those simulations proved promising enough for him to co-found First Light Fusion in 2011 and, as its CEO and technology chief, attract more than £70m in funding for the business. At the end of 2021, the firm demonstrated that fusion was feasible, but its next big challenge is to achieve ‘gain’ – that is, create a reaction that produces more energy than it requires to get started. To this end, it has announced plans for a new demonstrator facility to be constructed at the UK Atomic Energy Authority’s research base at Culham, Oxfordshire.

Scientists pursuing fusion believe that the process could play a vital role in meeting the world’s zero-carbon energy needs without also producing significant amounts of radioactive waste.

Today’s nuclear reactors rely on fission, the process in which energy is created when atoms are fired at each other so that they split. In essence, fusion is the opposite approach. What First Light Fusion has done is fire a projectile into a target with such force that its atoms are crushed together. The target contains the separate fuel sources of hydrogen-2 and hydrogen-3, which collide to become helium-5 for a tiny fraction of a second at the start of the reaction. The helium-5 atom is unstable, so it naturally decays into helium-4, emitting a neutron from its nucleus. That process generates energy.

“It’s Einstein’s famous E = mc² equation,” Hawker explains. “When helium-5 becomes helium-4 the mass is slightly reduced, so energy is released.”

To achieve this reaction on a large scale, researchers are broadly exploring two approaches. In one, a ball of plasma is heated to a temperature hotter than the Sun in a reactor called a tokamak. The plasma is held in suspension by huge superconductive magnets so that it doesn’t melt the reactor. The other approach, favoured by First Light Fusion, is known as inertial fusion.

The finer details of First Light Fusion’s approach are a closely guarded secret. In essence, though, the process involves firing a projectile along a cylinder at several times the speed of sound and using an “amplifier” to increase the force of its impact on the target hydrogen isotopes. This technology applies the science of cavitation (the formation and collapse of bubbles) – hence Hawker’s early interest in the pistol shrimp.

> **We think our technology will make the existing process much simpler and generate clean energy at a lower cost**

“The core process is not new; it’s the amplifier that’s unique to our approach,” he says. “The projectile hits the front of the amplifier, which focuses the energy of the projectile on to the fuel to create what’s needed for inertial fusion. We think our technology will make the existing process much simpler and generate clean energy at a lower cost.”

Cost is a key concern. Global investments in fusion research have run into billions of pounds already and the tech, if and when it becomes commercially viable, is likely to be hugely expensive to set up and run. In fact, the R&D costs are so colossal that nations are pooling their resources. For instance, the International Thermonuclear Experimental Reactor is a multinational collaboration – involving the US, China and Russia among several other stakeholders – to build and test a tokamak in the south of France. The project had an original budget of €6bn (£5.2bn) in 2012, but it’s expected to cost several times that amount before it can demonstrate ‘gain’ and be developed into a commercially viable power source.

At Culham, a trial tokamak called the Joint European Torus set a world record at the end of 2022 by generating 11MW of energy in a five-second burst – enough to power 11,000 homes for that period. Its ability to produce that much energy for that length of time was hailed as a major advance, yet creating the reaction still required more energy than it generated. This is why the aim for scientists is to prove their approach not only works but can produce more energy than that needed to initiate and maintain the reaction.

A research team at the Lawrence Livermore National Laboratory in California claims to have done exactly that. At the end of last year it announced that its technique, which uses lasers, had produced a fusion reaction generating 50% more energy than it consumed.

Jennifer Granholm the US secretary of energy, has hailed this as “one of the most impressive scientific feats of the 21st century”. Hawker is similarly impressed, believing that it highlights the potential of the inertial approach.

First Light Fusion is aiming to emulate the Livermore team’s breakthrough with a demonstrator reactor called Machine 4, which is set to be the world’s largest pulsed power facility. Construction will start next year. If all goes to plan, the reactor could achieve gain before the end of the decade.

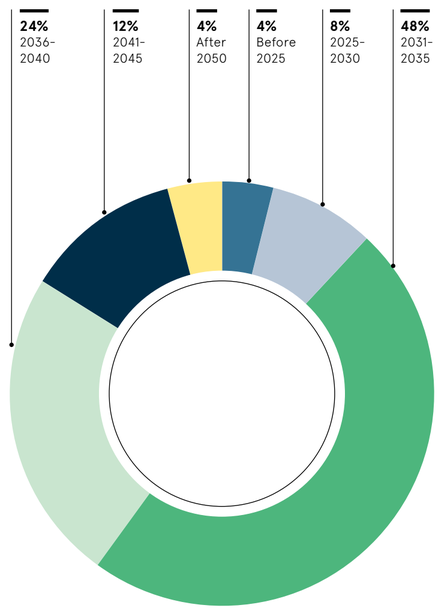
> **The core process is not new; it’s the amplifier that’s unique to our approach**

“Our pilot plant design will fire a projectile every 90 seconds,” Hawker says. “You use one target for one shot and it releases one big pulse of energy. Then you repeat the process. It’s a bit like an internal combustion engine, where the projectile serves as the spark plug – the part that puts in the energy that triggers the reaction. Each target should release about the same amount of energy as that produced by a barrel of oil.”

Hawker thinks that this approach is likely to be the most affordable way for any country to achieve fusion. If it proves too costly, the real fear is that developing nations will have to keep burning fossil fuels – and that a golden opportunity to move the whole world on to clean renewable energy will be missed. ●

WHEN WILL NUCLEAR FUSION BECOME VIABLE AT SCALE?

Share of industry experts expecting the first fusion plant to become commercially viable, by year range



Fusion Industry Association, 2022

Serg Myshkovskyi/Getty Images

SECURITY

Deep trouble: the lurking threat of subsea sabotage

The bombing of the Nord Stream gas pipelines under the Baltic last year has underlined the clear and present danger posed by nation-state attacks on offshore energy infrastructure

Emma Woollacott

On 26 September 2022, a series of explosions ruptured three of the four Nord Stream pipes that had been built to transport gas from Russia to Germany beneath the Baltic Sea. Swedish investigators found traces of explosive at all of the sites, which are in international waters.

While no pipeline was in operation at the time, it had been expected that Germany would soon be receiving gas through the A and B pipes of the Nord Stream 1 line. Their bombing has put paid to that plan, potentially leading to a reduction in the availability of gas in Europe and further price inflation. The incident has raised serious questions about energy security in several countries.

An investigation by the Swedish Security Service is ongoing, with public prosecutor Mats Ljungqvist saying: "We don't rule out anything. But that it's a state actor who is behind this is, of course, our absolute main scenario."

Russia's state-owned energy company, Gazprom, has a controlling stake in Nord Stream, the constructor and operator of the pipelines. Moscow has suggested that the US and its Nato allies, including the UK, might have been involved in the attack. Its allegation has been roundly dismissed. Poland's foreign minister, Zbigniew Rau, has accused the Putin regime of orchestrating the bombings, as have many other politicians.

It's not only gas pipelines that are at risk. There are more than 550 existing and planned subsea cables carrying electricity and telecoms around the world, collectively covering 870,000 miles. Power cables are just as vulnerable to a nation-state attack, notes Dr Dwayne Ryan Menezes, founder and MD of the Polar Research and Policy Initiative, a think-tank with interests in the Nordic region.

"The interconnectors that link the electricity systems of neighbouring countries, as well as offshore wind farms and wave and tidal power generation projects, depend on high-voltage submarine power cables, so these play a key role in ensuring the security of energy supply," he says.

National Grid operates five interconnectors, which link the UK to Belgium, the Netherlands, Norway and France (at two points). A sixth, to Denmark, is under construction.

"Damaging subsea power cables would be particularly disruptive in the countries surrounding the North Sea, causing huge outages that would effectively paralyse their societies and economies," Menezes warns.

The effects on the UK could be particularly severe, given that the country has 44 operational offshore wind farms and is expected to generate one-third of its electricity this way by 2030. It imports 60% of its gas from Norway.

In light of the Nord Stream sabotage and Russia's weaponisation of energy as part of its war on Ukraine, Nato and the EU recently created a joint task force to work on ways to manage the infrastructural risks more effectively. Announcing the move in January, Nato's secretary-general, Jens Stoltenberg, said: "We want to look together at how to make our critical infrastructure, technology and supply chains more resilient to potential threats, and to take action to mitigate potential vulnerabilities."

> **Damaging subsea power cables would be particularly disruptive in the countries surrounding the North Sea, causing huge outages**

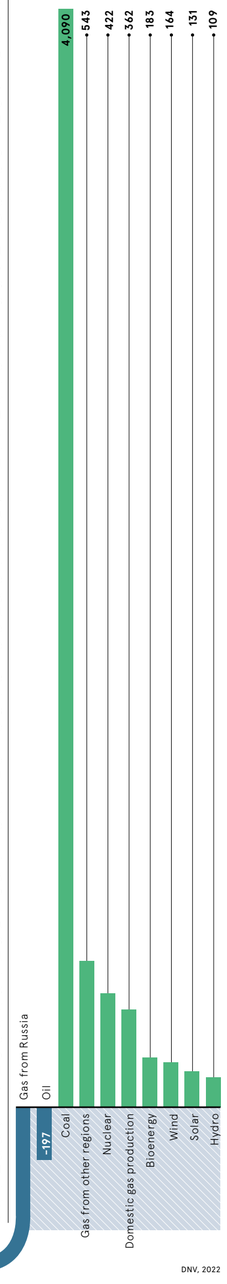
The UK has been concerned about the threat for some time. Indeed, while serving as a backbencher in 2017, Rishi Sunak wrote a report on the subject for the Policy Exchange think-tank after US intelligence officials had declared Russian submarines to be "aggressively operating" near cables in the Atlantic.

The Ministry of Defence has begun taking countermeasures. It shadows vessels transiting the UK's territorial waters and has commissioned two multi-role ocean surveillance ships for subsea protection. These are due to enter service later this year, operated by the Royal Fleet Auxiliary (RFA).

The first, originally a civilian vessel named Topaz Tangaroa, was built four years ago to support a range of underwater operations. Now it's being refitted as the RFA Proteus at the Cammell Laird shipyard in Birkenhead at a cost of £65m, with the installation of equipment including remote and autonomous offboard systems for surveillance and seabed warfare.

EUROPE IS SHUNNING RUSSIAN ENERGY – IS SABOTAGE MOSCOW'S RETALIATION?

Forecast change of primary energy consumption in Europe between 2022 and 2024 owing to the Russia-Ukraine war (petajoules per year)



The government says that its priority "will always be maintaining national security – and our networks are inherently designed to be resilient. We take the safety of current and future systems exceptionally seriously."

Late last year, after drones were sighted flying near its offshore oil and gas facilities, Norway raised its emergency preparedness, citing a risk of "deliberate attacks". Several people have since been arrested for possessing drones and showing an unusual interest in such infrastructure. In May, the UK and Norway signed a statement of intent to collaborate on protecting critical energy infrastructure.

Sweden and Denmark have also increased their alert levels since the Nord Stream attacks, dispatching ships to the explosion sites, while France has allocated €3.1m (£2.7bn) to seabed defence this year.

Sabotage can also come in digital form, of course. Ukraine's energy supplies have been disrupted as much by cyber attacks as by bombs and missiles, for instance.

As long ago as 2015, a cyber attack on a Ukranian power station caused a blackout that's estimated to have affected more than 200,000 consumers for up to six hours. A year later, malware targeting electrical safety relays disrupted the power supply to Kyiv. If it had gone undetected for much longer, it could have destroyed power equipment.

"Physical and cyber attacks aren't a separate issue, particularly when it comes to sabotage," says Steve Gyurindak, chief technology officer at security firm Armis. "Geopolitical tensions have created a hostile environment in which war is being waged in both the physical and digital realms. Malicious actors are using every avenue to damage critical infrastructure."

According to Armis's data on the types of organisations being targeted by cyber attacks, operators of critical infrastructure were the worst hit in H2 2022.

"Hybrid warfare could enable attackers to both physically and digitally incapacitate entire networks of infrastructure," Gyurindak warns. "These attacks could have dreadful consequences."

Several nations have strong reasons to suspect that Russia is using research vessels and trawlers to locate cables for saboteurs to target.

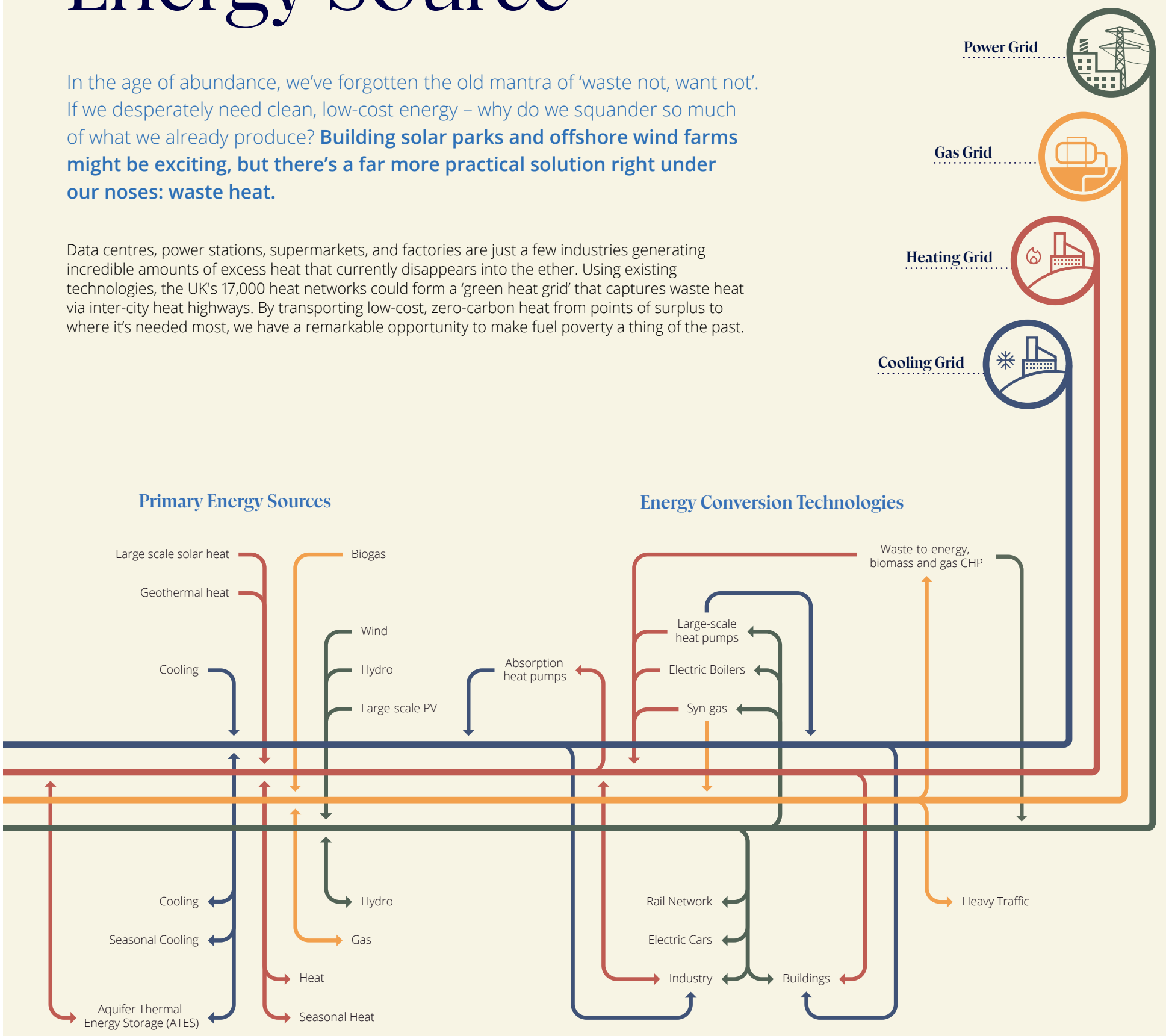
"Such suspicions were raised again in April by the public broadcasters of Denmark, Norway, Sweden and Finland. They corroborated concerns long held in the UK," Menenez says. "These ships turned their transmitters off so as to make their locations undetectable. They were carrying surveillance equipment to assist with undersea mapping and they slowed down as they passed by wind farms."

The recently formed Nato-EU task force is focused mainly on sharing intelligence at present, meaning that the onus remains on individual nations to protect their own infrastructure from sabotage. Whether their defences are strong enough remains to be seen.

Our Greatest Untapped Energy Source

In the age of abundance, we've forgotten the old mantra of 'waste not, want not'. If we desperately need clean, low-cost energy – why do we squander so much of what we already produce? **Building solar parks and offshore wind farms might be exciting, but there's a far more practical solution right under our noses: waste heat.**

Data centres, power stations, supermarkets, and factories are just a few industries generating incredible amounts of excess heat that currently disappears into the ether. Using existing technologies, the UK's 17,000 heat networks could form a 'green heat grid' that captures waste heat via inter-city heat highways. By transporting low-cost, zero-carbon heat from points of surplus to where it's needed most, we have a remarkable opportunity to make fuel poverty a thing of the past.



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Acknowledgment: Smart Energy System diagram originally produced by The Rambøll Group