UK ENERGY SECURITY & RESILIENCE

AND THE CHALLENGES OF DELIVERING NET ZERO

CONTENTS

INTRODUCTION

Back in 2006, as Shadow Defence Secretary, I gave a speech at Chatham House about energy security, subsequently published in a pamphlet entitled "Over a barrel". It is a useful (and sometimes painful) exercise for any politician to look back on their analysis of a problem at a particular point in time and see how it has changed.

In that speech I said that *"In the years ahead energy security, economic security and national security will be inextricably linked. If we want to ensure that we can keep the lights on in Britain then we need to develop a comprehensive energy strategy. It is simply a matter of risk management.* ***Such a strategy will need to have three components: diversity in the type of fuels we use; diversity in the geographical sources of those fuels and the security structures that will guarantee the safe transport of these fuels."***

Most of that analysis is, I believe, equally pertinent today. Some things, however, have changed in the wider political debate about energy. In that same speech I talked about how *"When Churchill switched the navy from running on coal to running on oil, it meant we no longer depended on the Welsh pits but on the Persian oil fields. At that point, energy security became national security. Churchill said that 'safety and certainty in oil lie in variety and variety alone'. It was true then and true now. We need to ensure that a variety of energy sources are available for our economy, be they coal or gas or nuclear or renewables".*

Obviously, with the increased emphasis on dealing with climate change, there has been a move away from coal. Since 2015 the UK has reduced its coal use by 93%, well ahead of any other G 20 country and the British government intends to end its use entirely by the end of 2024. That is the easy part. In its decarbonisation agenda, the UK government also wants to move away from gas although the exact pathway and timetable for this is less clear. Because this will be considerably more difficult than moving away from coal, It means that we will still be dependent on fossil fuels for energy for some time and the strategic considerations which we have become familiar with will remain. On top of these, new vulnerabilities, such as cyber threats, may become of ever greater importance.

This pamphlet is not designed to be a policy statement but to provoke debate about the whole range of issues around energy policy, not simply how we deal with the climate change aspects. Some of the most respected individuals in the industry give their views about the challenges ahead, addressing some of the most important questions about security and resilience in energy: What is Britain's actual starting point on the journey towards decarbonisation? How realistic is our timescale to achieve net zero? How much capital will the decarbonisation agenda require, where will it come from and when? What will be the role of new technologies be in this process? How do we avoid creating the risk of energy poverty amongst the British people? What will be the role of our system of interconnectors in the common energy security of ourselves and our closest allies? What is the wider international geopolitical context of the debate? How do we avoid becoming dependent on potentially hostile states for our energy supplies? What does the increasing cyber threat mean? These are just a few of the questions that we need to be able to answer.

The debate around energy has increasingly become focused on the environmental and economic elements. It is time that we gave the same weight to the security and resilience implications.

I am hugely grateful for the insightful contributions from an expert range of voices in the field. We hope that it will provoke interest and debate.

Liam Fox

AUTHORED BY

LIAM FOX

The Rt Hon Dr Liam Fox MP has been Member of Parliament for North Somerset since 1992. Dr Fox held several roles in John Major's Government, including as a Foreign & Commonwealth Office Minister. Between 1997 and 2010, he held several roles on the Conservative Party Opposition Front Bench such as Constitutional Affairs Spokesman, Shadow Health Secretary, Conservative Party Chairman, Shadow Foreign Secretary and Shadow Defence Secretary. Dr Fox served as Secretary of State for Defence in David Cameron's Government from May 2010 until October 2011. Between July 2016 and July 2019, he served in Theresa May's Government as Secretary of State for International Trade and President of the Board of Trade. As International Trade Secretary he was tasked with creating the UK's first Independent Trade Policy for forty years post-Brexit. Before entering politics, Dr Fox worked as an NHS doctor and then as a family GP. He is also a former Civilian Army Medical Officer and Divisional Surgeon with St John Ambulance. In 2012, he founded the military charity 'Give Us Time'.

TRENDS, FRIENDS AND THREATS

It is worth, at the outset, getting clear in our heads the difference between Britain's total energy requirements and the fuels used in electricity generation. While this difference will be clear to those involved in energy policy and those in the industry, these two elements seem to have a become increasingly conflated in the politics around the energy and environment debates.

UK ENERGY CONSUMPTION

In terms of total energy consumption in the UK in 2019, 44.4% was accounted for by oil (mainly for use in transport), 30.7% was gas (mainly for domestic heating), 17.9% was electricity (used in industry, domestic and service sectors but very little in transport), bioenergy and heat was 5.8% (used across all sectors) while coal and manufactured fuels accounted for only 1.2% (mainly used in industry).

Looking at this consumption the other way round, in terms of sectors, the total energy consumption (measured as million tonnes of oil equivalent) of each sector was: industry 15.7% (mainly gas and oil), domestic use 29.1% (mainly gas), transport 39.9% (mainly oil) and services 15.3% (mainly gas and electricity). It is clear immediately that if decarbonisation is to take place in a massive amount of new electricity generation will be required across all sectors.

UK ELECTRICITY GENERATION

Total electricity generated in 2019 dropped 2.8% compared to 2018, while net imports increased by 11%. Gas accounted for 40.9 % of generation while coal accounted for only 2.1 % (production favoured gas over coal, due to the carbon price per GWh being lower for gas). Low carbon generation (nuclear and renewables) accounted for a record high of 54.2% of generation. This was due to large increases in renewable generation, which was up 8.5%, making up 36.9% of electricity generated. Nuclear generation was down by 13.6 compared to 2018, due to outages. The UK enjoyed its longest run of coal-free power during 2020 with a total of 68 days between 10 April and 16 June – the lengthiest coal-free period since the industrial revolution.

Taking these things together, the size of the decarbonisation challenge becomes clearer. If we are to reduce the transport sector's dependence on oil and the domestic sectors dependence on gas for heating, we will need to generate vastly increased amounts of electricity from other sources. This will require us to accelerate the use of the technologies we currently have in the renewable sector and to turn to new modes of generation, including the small modular reactor capabilities in the nuclear sector. We will need to take difficult, and balanced, decisions about how we will make the transition from our current energy mix without making the UK a client state, dependent on others for an unhealthy proportion of our energy mix (as well as determining how we will find the necessary capital to make this happen). Meantime, we need to deal with the immediate problems of an economy that still imports a great proportion of its energy from overseas.

As Britain's oil and gas fields in the North Sea have gradually become more depleted, the country has grown more reliant on supplies of fuel from other countries. This reliance has been exacerbated by the phasing out of coal as part of the climate change agenda. While the U.K.'s energy dependency peaked at around 48% in 2013, the increased contribution of renewables, including wind, coupled with a reduction in primary energy demand has seen this dependency fall to around 35%.

Despite the fact that Britain's energy dependence is notably lower than

the average of our European Union neighbours, this still means we have to import a substantial proportion of our energy and as we move further into the phase of decarbonisation, and the phasing out of gas, will either have to find new ways of generating more of our own power or become increasingly dependent on others. If we are to avoid becoming a potential client state in energy there are a number of things that we will have to do. The first is, obviously, to find new ways of producing energy domestically; secondly, ensuring that we have a diversity in supply where we need to import rather than becoming too dependent on a single source of energy production and, thirdly, knowing who our friends are so that we build the necessary protections and interdependencies with our most dependable allies. To enter an accelerated phase of decarbonisation without knowing where our energy will come from, the timescale involved in the capital needed would be an act of domestic and security irresponsibility.

WHO DO WE IMPORT FROM?

According to the UK Department for business, energy and industrial strategy (BEIS) the key sources of imports of crude oil have historically been Norway (its share of UK imports was unchanged at 39% in 2019) while OPEC countries, mainly Algeria and Nigeria, accounted for 20%, down from 32% in 2018. Meanwhile, the share of US imports increased from 17% in 2018 to 26% in 2019.

The UK imports a wide variety of petroleum products, while remaining a net exporter of certain fuels including petrol. Traditionally the Netherlands, which acts as a major trading hub, has been the largest source of imports. As such, the Netherlands is the largest supplier of transport fuels with aviation turbine fuel generally sourced from the Middle East.

Norway accounted for 57% of UK gas imports in 2019, with pipelines from Belgium and The Netherlands supplying 1% and 3% respectively. The remaining 39% arrived as Liquefied Natural Gas (LNG), of which 49% was from Qatar. In 2019, Qatari, Russian and US LNG imports accounted for 82% of all LNG imports, while smaller quantities of LNG were received from Angola, Cameroon and The Netherlands for the first time.

INTERCONNECTORS

Electricity interconnectors are high-voltage cables that connect the electricity systems of neighbouring countries. They enable excess power, such as that generated from wind and solar farms, to be traded and shared between countries.

By importing more affordable electricity from Europe, bills are reduced for consumers and by connecting to broader and more diverse sources of energy, interconnectors are an important part of resilience and making the electricity system more secure.

The first subsea electricity interconnector, linking the UK and France, entered operations in 1961. Interconnexion France-Angleterre (IFA), National Grid's first interconnector, went live in 1986 and also links the UK and France.

In 2019, interconnectors supplied 8% (25 TWh) of total electricity consumption in Great Britain, rising to 9% in the first six months of 2020. 66% of this energy in 2019 came from zero-carbon sources.

It is expected that by 2024 at least six interconnectors will be operating between Great Britain and Europe, enough to supply 25% of our electricity requirements. There are also gas interconnectors, which enable the sharing of natural gas in a similar way.

The planned interconnector between the UK and Norway, North Sea Link, will mean that when activity in UK wind farms and solar generation is lower, we can draw on carbon-free Norwegian hydro power, a situation that can be

reversed when circumstances permit.

Norway is, in fact, a key player when it comes to UK energy and is thus a key geopolitical ally.

HM Ambassador Richard Wood spoke about the UK and Norway´s partnership in clean growth, and the importance of the wider relationship at the Diplomatic Gas Forum in January 2019.

He noted the tremendous investment that has gone into Norwegian gas infrastructure, including the expansion at Nyhamna and the new Polarled pipeline. The Aasta Hansteen field which came on stream last month is now producing Arctic gas that reaches the UK market.

TRANSPORT THREATS

One thing that has not changed, in this era of renewables and proposed decarbonisation, is that it is still oil that lubricates the global economy and so safe and unhindered transport is key to its efficient and effective functioning. Worldwide production of crude oil rose from about 3.5 billion metric tons in 1998 to about 4.5 billion metric tons in 2018. Around 60% of oil is transported by maritime routes. As a consequence, oil accounts for about 30% of the world's total maritime trade. The risks of supply are not, however, evenly spread. For example, while Asia-Pacific accounts for less than 10 percent of global oil production, the region is the largest consumer of oil with over a third of global oil consumption occurring there.

Many of these products were transported around the Arabian Peninsula, through the so-called chokepoints of the Suez Canal, the Bab el-Mandeb Strait, the Strait of Hormuz and the SUMED pipeline.

The transportation of oil and gas (including LNG) bring different vulnerabilities at different stages of the process. Tankers and other maritime transportation can be affected by a range of issues such as design issues, weather and piracy while pipelines and other distribution networks face their own dangers.

TANKERS

Tank vessels are classified by the trade in which they routinely operate over a period of time. The three most common categories are crude oil carriers, product carriers: which can carry clean (e.g., gasoline, jet fuel) and dirty (e.g. black oils): and parcel carriers (chemicals).

Crude carriers are classed as either VLCCs (Very Large Crude Carriers) or ULCCs (Ultra Large Crude Carriers) and are designed to transport vast quantities of crude oil over many long sea routes. "Lightering," (the offloading or transferring of oil from large tankers to smaller ones) is used so that the smaller vessels can enter smaller ports that are impossible for larger ones.

Given the unpredictable, and often severe, nature of the high seas, one of the major concerns for the safe transport of bulk liquid cargos by tank vessel is the stress on the hull. The maldistribution of cargo and resultant forces can cause bending (concentration of weight in the mid-section), hogging (concentration of weight at both ends of the vessel) and shear force.
There are extra problems faced in the transportation of LNG with high pressures and the potential for explosions.

Scientific advances have meant that natural gas can be turned to liquid at extremely low temperatures and transported as liquefied natural gas (LNG). LNG tankers are specially designed with double hulls, to allow extra ballast water because LNG is lighter than gasoline, and additional safety features.
While we all expect aviation safety to be constantly improving, it is a remarkable fact that every year, on average, more than two dozen large ships sink, or otherwise go missing, taking their crews along with them.

Adverse weather can cause, in severe conditions, the loss of a vessel but can also result in other forms of damage including vessels running aground or spilling cargoes, sometimes with catastrophic environmental consequences. There can also be political ramifications.
In 2019, the Suezmax crude oil tanker TOUR 2 was beached by storm on Jan 15-16. When the inevitable photos of the incident appeared on social media, it was notable that not only was the name unreadable but there was no AIS (Automatic Identification System) record of any big ship anywhere near the Syrian Latakia coast in the Mediterranean.

It transpired that TOUR 2 had loaded a shipment of crude oil at Kharg Island, Iran, transited the Suez Canal and switched its AIS off around Dec 24-25, shortly after leaving Port Said. Purposefully, given its illegal activity, the tanker had been literally made to disappear from radar. Her illicit cargo had been offloaded at Baniyas Refinery, Syria, and anchored off Latakia. Only the natural risk of bad weather and her subsequent grounding revealed the conspiracy between two of the world's most rogue states.

PIRACY

Piracy is not some romantic idea linked to literature or the cinema. It is a brutal criminal reality that is a constant threat to maritime security.

The permanent threat of maritime piracy, which many hoped had reached its peak, grew again in 2020. While 162 ships were attacked by pirates in 2019, the number of ships attacked grew to 195 last year.

The peak year for contemporary piracy was 2010, with around 445 reported incidents, most commonly in Indonesia, Malaysia, and Nigeria. Strategic passages for oil transport such as Bab-el-Mandeb, near Somalia, or the Strait of Malacca off the Indonesian coast are a strong magnet for maritime crime. The size of the prize is the main driver, despite considerable risk. In 2013, oil tankers shipped 15.2 million barrels of oil each day through the Strait of

Malacca, bigger than the daily volume of oil imported into the whole of the EU. Coupled with the rising price of oil as the decade progressed, the risk-benefit calculation for pirates moved steadily in one direction. Of course, the risk is not only for them but for the crews who can be caught in the crossfire of the crime.

In Somali waters, at least 149 crew members were held hostage in 2011, and over 100 pirates were killed - mostly by naval forces, increasingly important in the international battle against piracy, as part of not only a military response but in response to increasing demands of insurers.

Despite this greater security, the attacks continue. In May 2020, pirates fired at the British-flagged Stolt Apal in the Gulf of Aden, between Yemen and Somalia. The tanker with a carrying capacity of 32798 t DWT was attacked by two skiffs running at high speed containing six armed pirates. Despite multiple warning shots being fired by the armed guard team aboard the Stolt Apal, the skiffs opened fire on the ship. The tanker sustained damage although, thankfully, no one was injured. The armed guard team returned fire, disabling one skiff and ending the pursuit.

On 7 November 2020, two tankers were targeted by pirates in separate incidents off the coast of West Africa, the chemical/product tanker Torm Alexandra, operated by Danish shipping company Torm, and the oil tanker Wesley, controlled by UK's Union Maritime.

Pirates boarded the Torm Alexandra some 162 nautical miles south of Cotonou, Benin but following anti-piracy drills, the crew of 20 Filipinos and 1 Montenegrin — reached the citadel and safety. These are clear warnings that piracy poses to free navigation.

PIPELINES

Pipelines play a critical role in the transportation process because most

oil moves through them for at least part of the route. After the crude oil is separated from natural gas, pipelines transport the oil to another carrier or directly to a refinery. Petroleum products then travel from the refinery to market by tanker, truck, railroad tank car, or further pipeline.

Pipelines face a number of risks and uncertainties including safety, security, design, construction and interruption due to Third Party Disruption (TPD) and acts of terrorism. Since the oil and gas pipelines are flammable, explosive, and toxic, any pipeline leakage can cause catastrophic consequences, such as fire, explosions, and environmental pollution.

In July 2021, nitrogen was used to extinguish a fire, described as "an eye of fire" on the ocean surface west of Mexico's Yucatan Peninsula. According to the state-owned oil company Pemex, which has a long record of major industrial incidents, a gas leak from an underwater pipeline sparked the blaze. It seems likely that the fire began in the pipeline that connects to a platform at Pemex's flagship Ku Maloob Zaap oil development, the company's most important. Poor maintenance and human error continue to contribute to the risks that pipelines can face.

MARITIME CHOKEPOINTS

With around **80%** of global merchandise being shipped by sea, commercial shipping relies on strategic trade routes to move goods efficiently. These can cut thousands of miles and days from travel times but do not come without risks which are particularly present at a number of maritime bottlenecks, or choke points. These are typically narrow natural straits or man-made canals with high traffic volumes because of the economies they bring. While these routes bring increased efficiency they also, almost inevitably, diminish the overall resilience of the system. The sort of structural risks that are associated with narrow passages was amply demonstrated recently in the Suez Canal blockage.

In March 2021, the canal was blocked for six days after the grounding of the 20,000 TEU container ship Ever Given, following a sandstorm where winds exceeding 74 km/h (46 mph) resulted in an inability to steer the ship, whose hull deviated. The obstruction by the vessel, the length of four football pitches, occurred south of the section of the canal that has two channels, so there was no way for other ships to bypass Ever Given.

On 28 March, at least 369 ships were queuing to pass through the canal, preventing an estimated US$9.6 billion worth of trade. The ship was finally freed by Egyptian, Dutch, and Italian tugs and the canal was found to be undamaged.

The blockage temporarily sent oil prices climbing on international markets, a sign of the immediate economic impact that closure of a chokepoint could have.

Chokepoints are also subject to geopolitical risks either through direct targeting by insurgents or because they pass through dangerous or contested territory. Despite these risks, the financial rewards mean that they remain key waterways in the facilitation of international trade.

STRAIT OF HORMUZ

Controlled by Iran and connecting the Gulf to the Gulf of Oman and the Arabian Sea, this is the most important chokepoint in the world. Around 21 million barrels of oil per day pass through here, about 30% of all the oil traded on the world's oceans.

It has long been an area of conflict with tankers and commercial ships being attacked during the Iran-Iraq war in the 1980s. More recently, harassment by Iran of international shipping has increased. With the election of the new hardline President Ebrahim Raisi, this is a situation that is unlikely to improve.

On Jan 4th 2021, Iran's armed seizure of a South Korean tanker, the Hankuk Chemi, added to the list of incidents where civilian ships have been targeted. Iranian forces boarded the vessel in the Strait less than a week after another tanker, Pola, was attacked with a limpet mine. These are the latest in a long line of high profile incidents including the seizure of the British tanker Stena Impero, in 2019. Several tankers have been attacked by limpet mines linked to Iran.

According to the Centre for strategic and International studies in Washington (CSIS) *"Iran is reshaping its military forces to steadily increase the threat to Gulf shipping.*

This increase in Iranian capability is almost certainly not designed to take the form of a major war with the US and Southern Gulf states, which could result from any Iranian effort to truly close the Gulf. It does, however, give Iran the ability to carry out a wide range of much lower level attacks which could sharply raise the risk to Gulf shipping, and either reduce tanker traffic and shipping or sharply raise the insurance cost of such ship movements and put a different kind of pressure on the other Gulf states and world oil prices.

Moreover, Iran's growing long-range missile forces, and movement towards a nuclear weapons capability will give it an increasing capability to compensate for its aging and low capability regular naval and air forces with a far more threatening level of deterrence."

THE SUEZ CANAL

The Suez Canal in Egypt is a long-standing geopolitical prize that links Europe with Asia. Its absence, or lack of availability, would add around seven days to maritime journeys as ships were forced to sail around Africa. In 2019, almost 19,000 vessels with 1 billion tonnes of cargo (including around 4 million barrels per day of crude oil and refined products) sailed through the canal.

The canal has recently been gaining importance as a southbound route for U.S. and Russian crude oil and petroleum products to destinations in Asia and the Middle East. Crude oil shipments, mainly to Asian markets such as Singapore, China, and India, have more than doubled in the past two years. Petroleum exports from Russia accounted for the largest share (24%) of southbound petroleum traffic. Increases in Libya's crude oil production and exports in 2018 also contributed to a rise in Suez southbound shipments. In the past two years, increased production and exports of U.S. crude oil and petroleum products—especially liquefied petroleum gas—have also increased southbound traffic through the canal. Despite the Egyptian government's major expansion project for the canal in 2015, risks remain as the episode of the Ever Given showed.

THE PANAMA CANAL

The magnificent Panama Canal provide a shortcut between the Pacific and Atlantic oceans saving a trip of around 8000 nautical miles, equivalent to around 21 days. The canal underwent a $5.4 billion expansion in 2016 which tripled the size of ships that are able to transit.

In 2019, over $2.6 billion in tolls were generated, while in 2020 12,245 transits carried 255.7 million long tons of cargo through the canal. Of these 2759 were LNG transits, 1305 carry petroleum gas and 712 carried crude products.

The increasing presence of Chinese interests in and around the Canal has made the waterway a flashpoint for U.S.-China competition over spheres of influence with many in Washington seeing the increased Chinese activity as an invasion of "America's backyard". Given the continued trade tensions between the world's two biggest economies, this is not a situation that is likely to be resolved any time soon.

STRAIT OF MALACCA

The Strait of Malacca is 580 miles (930 km) in length, lying between the Malay Peninsula and the Indonesian island of Sumatra. It is one of the world's narrowest choke points with its smallest point being only around 1.5 nautical miles. Despite its size, it is one of Asia's most critical waterways, since it provides a crucial connection between China, India, and Southeast Asia.

Piracy, which was a real problem in the early part of the 21st-century, reduced considerably for a number of years but by 2019 there were, once again, 30 piracy incidents in the strait. The annual haze, the result of seasonal bushfires in Sumatra, can reduce visibility to a mere 200 m, a distance much shorter than many of the longest vehicles transiting the area and represents a major hazard to shipping. One unique historical challenge facing vessels in the area is s that there are around 35 shipwrecks in the TSS (traffic separation scheme) channel. In August 2017, the U.S. Navy destroyer USS John S McCain collided with a merchant ship with the tragic loss of 10 of the ship's crew.

BABEL-MANDEB STRAIT

The Bab el-Mandeb Strait, lying between the Horn of Africa and the Middle East, links the Mediterranean Sea with the Indian Ocean via the Suez Canal. It is both a primary waterway for the world's oil and natural gas transportation and a high-risk area for piracy. In May 2020 a UK chemical tanker was attacked of the Yemeni coast, the ninth such attack in the area in that year. The amount of crude oil and refined petroleum products transported through the waterway rose to about 4.8 million barrels per day in 2016, from about 3.3 million barrels per day in 2011. China has established its first ever foreign military base in Djibouti, lining it up to be yet another area of tension with United States in the ongoing battle for global strategic dominance.

SUMED

It is worth finally mentioning, in the context of choke points, the 200-mile-long SUMED Pipeline which carries oil through Egypt from the Red Sea to the Mediterranean Sea. It runs from the Ain Sokhna terminal in the Gulf of Suez to Alexandria.

The pipeline, with a total capacity of 2.34 million barrels per day, is the only alternate route to transport crude oil, from the Red Sea to the Mediterranean Sea, if the Suez Canal becomes impassable for any reason. The pipeline operators approached a number of oil traders during the recent Ever Given blockage episode but there was little uptake as moving oil through the pipeline can be costly with some traders estimating that it would only be viable for supertankers carrying 2 million barrels.

All of these potential risks that exist across the globe will need to be mitigated for as long as we need to transport fuels across the oceans. Even if we succeed in decarbonising Western economies, we will still be dependent on strong and functioning economies in other parts of the world as our trading partners. Given the huge dependence that China, for example, has on fossil fuels and the huge length of time it is likely to take to reduce its dependence on Gulf oil, it is clear that we are going to require long-term global cooperation in ensuring the security of maritime transport (as well as pipelines). While the model of international integration of operations in dealing with piracy in Somalia is perhaps encouraging, a great deal more must be done to share the burden in a world whose economic interconnections have brought both new opportunities and new vulnerabilities.

Those nations such as the UK who are not only huge trading nations but, in our case an island, are geographically hugely dependent on the free flow of maritime trade and need to ensure that we invest in the necessary capabilities to ensure the security of the high seas. The investment that has been made by the UK in the Royal Navy, particularly the carrier strike capability, needs to be matched in both funding and intent by our major

trading partners if we are to navigate, in every sense, the tricky waters ahead.

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MARK BENTLEY

Mark Bentley became US strategy consulting firm Putnam, Hayes & Bartlett Inc.'s youngest ever partner in 1988. Identified as one of Europe's '30 Under 30' Leaders, he advised on numerous privatisations, regulatory frameworks and industry restructurings. Mark worked closely with Sir Alan Walters, economic adviser to Margaret Thatcher, and was recruited by Professor Tom Copeland to join McKinsey & Company. In 1996 he became an investment banker, holding senior roles at Lehman Brothers, JPMorgan Chase, HSBC, hedge fund CQS, Greenhill & Co., and latterly as a Senior Adviser to Guggenheim Partners, establishing the London Office. He has led or participated in M&A and financing transactions with an aggregate value in excess of US$500 billion. Mark was educated at University College, London, LLB (1st Class Honours), and at New College, Oxford, (BCL).

PETER ATHERTON

Peter Atherton worked on the privatisation of the electricity industry before joining National Grid PLC where he held a number of commercial roles, and served as a member of NG's Corporate Strategy team. Peter then joined Kleinwort Benson as an equity research analyst covering the UK Utility Sector. In 2000, Peter joined Citigroup to head their Pan-European Utility Sector research team, and established and led a similar equity research team at Jefferies, in 2016 Peter left investment banking to pursue a career as an advisor to Governments and Corporates on strategy and related issues. He is a regular public commentator on UK energy, regulatory, and consumer issues, including on the Radio 4 Today Programme and Newsnight.

A REGULATORY FRAMEWORK FOR A DE-CARBONISING ENVIRONMENT

INTRODUCTION

Energy is a component part of everything we produce and consume, and a prerequisite factor to our quality of life. We now need to deliver energy with a view to a carbon-neutral future. Delivering a 'de-carbonized' "Green Industrial Revolution" presents a series of extraordinarily complex challenges which encompass industrial policy, regulation, income distribution, and balancing the trade-offs between different policy objectives. As COP 26 comes into view, there is no better time to start a serious discussion of these issues.

In this paper we focus on electricity, and on three specific questions:

- 'Energy Poverty': delivering de-carbonized power will be (still) more expensive, so how will we will deal Energy Poverty in this rising price environment, particularly when the 'burden of action' for decarbonization's next stage will fall more directly on households?

- What will capital providers require? Given their current financial condition, incumbent energy industry participants can only deliver so much. Investors will have particular requirement before capital flows into decarbonization initiatives.

- Regulatory regime: is the current regulatory regime fit for purpose, or does it require a refocusing in approach?

The objective in this paper is to set out some of the challenges, and start the discussion.

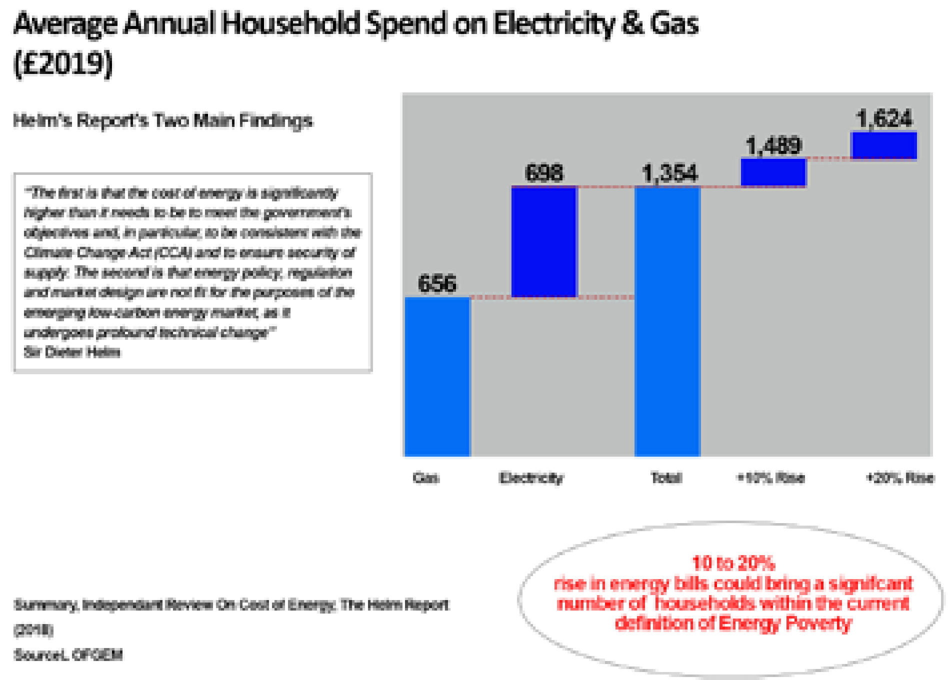
ENERGY POVERTY

Any decarbonising solution that fails to address the question of Energy Poverty is a fools' errand. Any solution which increases the problem raises difficult political issues. Boardman's 1991 definition of 'Energy Poverty', occurring if > 10% of disposable income is spent on heating and lighting, places approximately 3.2 million households in this category; the distribution of disposable household income suggests a small energy price increases can dramatically increase the 'Energy Poor.'

Sir Dieter Helm's Report (2018) found that electricity prices are 20% higher than necessary to meet reliability and Climate Change Act obligations. Compounding the problem, post 2030 households face higher vehicle costs, potentially offset by not having to pay duty and tax on fuel -- but few believe that HM Treasury will be able to resist taxing vehicle miles and, at some point, the extraordinary margins and returns achieved by some renewable generation (literally, taxing the air we breathe(d)). Shifting domestic heating away from natural gas, together with the impact of increased energy costs on food, adds little cheer. If Helm's analysis is correct, the least we can do is avoid repeating regulatory policy mistakes.

There are a number of options to tackle the 'Poverty' part of the problem, including direct income subsidies, or attempting to increase labor prices by restricting supply. How do we tackle the 'Energy' part? We can lower consumption through energy efficiency measures. We can ensure the

correct incentives are there to drive operating costs as low as possible, and push for greater capital efficiency on both the supply and the demand side, including grants to fund energy efficient capital spends, such as insulation. We need to avoid 'mandated' solutions which implement a quasi-industrial policy, rather than letting the market decide the best options: as Helm points out, central planning usually turns out to be expensive. Finally, we need to resist the temptation to try to solve societal problems via utilities, through imposing cross subsidies between consumer classes. This simply destroys the price mechanism; utilities themselves should not be a vehicle for redistributive politics.



WHAT CAN UTILITIES AND CAPITAL MARKETS REASONABLY BE EXPECTED TO DELIVER?

It should be a great time for utilities: electricity demand is growing faster than any other energy type, with the International Energy Agency ("IEA") estimating required capital investments of $7.2 trillion in the sector (2016-2025). The move to decarbonisation requires changes in the production of electric power on a scale not seen since either the 1920s and 1930s, or the 1950s and 60s as power systems were transformed by integrated large-scale generation fleets. Yet financially, most utilities are struggling: McKinsey estimates the total shareholder returns for the decade 2008-2018 average 1%: many utility management teams are struggling to preserve rather than create shareholder value. This is despite the fact that much competition, encouraged by regulatory initiatives, failed to materialize. We've gone from a highly competitive UK generation market (1987 – 2017) to a situation where returns are government-determined. Most utilities have exited from trading and supply, leaving this segment to new entrants, often thinly capitalized (except in optimism.)

Since 2008, capital markets conditions have been extraordinarily favourable, and Quantitative Easing has helped utility share prices and asset values. It will be a serious mistake to believe this 'low interest rate Nirvana' can continue forever: a higher interest rate, or a higher inflationary environment could pose interesting challenges. To date, the sheer volume of capital available for energy transition has been extraordinary, and capital markets are open for financing energy transition, pollution remediation such as carbon capture, digital solutions on the demand side, and energy storage. However, many banks are eliminating lending to hydrocarbon extraction and conversion; one of the hardest energy projects to finance today is a large coal-fired power station.

Decarbonization has delivered incumbent utilities a series of operating challenges. Renewables are inherently intermittent, and this creates significant instability in transmission and distribution systems. The location of many of these renewables has created new system bottlenecks, and new instability dynamics. Renewables cannot provide the ancillary benefits of the large generation stations, such as inertia or reactive power, which now need to be found from other sources. In this new world the "Holy Grail" of technological innovation is long-duration storage, enabling power generated from renewables at unusable times to be taken into storage and used in time of need.

Energy Security has always had many different facets; we must now add 'resilience'. Imagine coping with the Covid 19 pandemic without the Internet? Recent events in Texas provide graphic demonstrations of the modern world consequences of power system failures. Resilience is now the electricity sector's most pressing issue. The US Federal Energy Regulatory Commission (FERC) is currently examining the issue "because affordable and reliable electricity is vital to the country's economic and national security." There's that word again: affordable.

A little history is required. Originally, power systems were built to deliver locally, and the generation fuel could be shipped relatively long distances: coal was shipped from Newcastle to Battersea. Minimum efficient scale rose, first in coal-fired, thereafter in nuclear generation (which was going to be "too cheap to meter"). National co-ordinated systems delivered significant benefits, including the incredible levels of reliability, which we have taken for granted. Some would argue that we are heading back to more local energy systems.

We still need to spend much more capital. There are many detailed attempts to estimate the total needed, but a sense of scale demonstrates the issue:

- Generation (£100bn): The Committee on Climate Change estimates we will need 100-160 GW of installed renewable capacity to generate the 600 TWh we will need in future (versus the 340 TWh we currently consume; 100 GW of installed capacity exists currently; 50 GW will retire; therefore, a new build of 100 GW is required; at average prices of £1bn per GW, a cost of £100bn

- Networks (£50bn): taking RIIO-2 as a guide suggests £50bn, plus a significant amount of technology spend

- Heating (£450-550bn): replacing gas in domestic heating will cost £250bn plus, the similar sum to replace gas in industrial heating

- Domestic Vehicles (£5-800bn): replacing all petrol or diesel cars by the early 2030s will cost somewhere between £500 and £800bn; even replacing a quarter of the vehicle fleet is a significant sum, and much depends on the extent to which petrol and diesel cars' use is allowed post 2030, (a complete ban is inconceivable).

New technologies might lower these costs, and they are 'gross' figures; a significant portion would have to be incurred anyway – – maybe 30 to 40%? In terms of cost performance, much of the 'low hanging fruit' have already been picked, and the industry has, over decades, cut a lot of excess costs: the well is rather dry here.

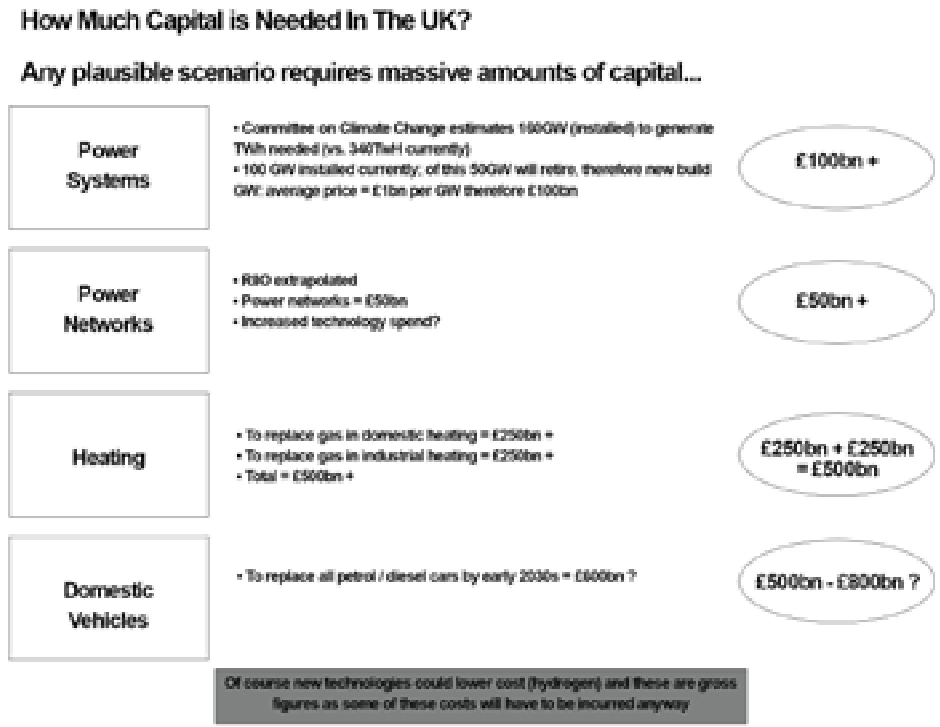
Capital providers will continue to require returns in line with the risks they are being required to absorb. ESG criteria are added in addition to, not as a substitute for, returns. ESG criteria do not escape the Capital Asset Pricing Model's logic. In the past 30 to 40 years, equity and debt capital markets have become ever better at pricing risk by asset class. Large private capital has flowed into regulated industries, displacing publicly traded capital. The increased demand for long-lived yield assets, to match with long-term liabilities has been an important driver.

A number of very large-scale dedicated pools of capital focused on infrastructure, in both the private equity, venture and development capital

parts of the capital table have emerged. Infrastructure, has become a distinct asset class. Arguably though, investors have become too used to government guarantees, and too used to settled arrangements rather than market solutions.

As capital providers assess their position, the 'management speak' fashion, to "repurpose the corporation" does little. The nationalized utilities tried this through their mandate to act "in the public interest," which led only to poor consumer service, capital allocation decisions, and inefficiency.

The 'repurposing the corporation' approach is conceptually confused, requiring managements to perform impossible trade-offs: this cannot be good policy. Competitive free markets have produced more wealth than any other form of industrial organization history, and demonstrated an extraordinary capacity to incorporate whatever policy needs society requires, they remain remarkably misunderstood.



WHAT SHOULD WE REQUIRE OF REGULATION?

In the UK and elsewhere the focus is on large-scale, 'big infrastructure', which have evolved financing models dovetailed into regulatory frameworks. The principal policy objective has been to ensure things that otherwise wouldn't happen, get built. To do this, the state socializes the risk and assumes/underpins the economic returns.

Unsurprisingly this is a highly attractive model for private sector capital, particularly so in a world where yield is scarce. Proponents claim these models lower the cost of finance, and therefore benefit consumers: well, possibly.

There are four such financing models:

- Guaranteed Price: such as CFD's, successfully used for renewables. Highly attractive and effective in attracting large-scale capital, but very disruptive to the wholesale price mechanism

- Guaranteed Revenue: the 'RAB'model, used for existing utility networks is very successful at attracting capital (arguably because regulators systemically failed to constrain returns here). It can be adopted for (greenfield financing) -- examples include the Thames Tideway Project, and the proposed Sizewell 'C' project

- Consumer Credit: credit support for households to borrow to improve energy efficiency on their properties. This policy failed, due to can its complexity and also its high interest rates

- Direct Grants: similarly, have been partially successful but the take-up challenge meant that resources of often gone to the middle classes and higher income groups.

All these models raise critical economic moral and political questions around the allocation of risks costs and rewards. We still needed for effective regulation, not just a solution for the climate problem. It needs to also solve for consumer protection and economic efficiency, making sure that prices reflect costs and give the right signals and incentives for consumption. The best regulatory systems recognise that functioning competitive markets are the best solution. The ISO the Independent System Operator model ('ISO') has now become something of a common shibboleth for regulatory frameworks. However, these may destroy wholesale markets, substituting demands of many into the demands of one -- the key buyer, the ISO. The key issue is how we avoid ISOs taking on the central planning role that the former CEGB fulfilled.

The Helm review suggests that our regulatory structures are heading in the wrong direction. Certainly, there has been a wilful reluctance to reach for markets as the solution to problems. The Energy Price Cap is possibly the strongest example; popular, but very bad policy; an interim measure which is beginning to look awfully permanent. In 2001, the then-Labour government made the manifesto claim "We have brought full competition to the gas and electricity markets." Seventeen years later, a Conservative government introduced the Price Cap because the industry is no longer deemed to be 'competitive': what's wrong with this picture?

Regulators' and policymakers' attitudes to markets has shown a peculiar form of 'regulatory schizophrenia', and open fear of using markets to address particular issues. Political fear of high prices compounded this with amnesia: "the best cure for high prices being high prices", which, provided entry is easy, eliminate excessive economic rents.

The problem is deeper than this. Much would have been solved if we had focused on creating a proper market for CO_2 emissions, and used the prices in the market to determine technology choice. The preferred approach was subsidy directed at particular solutions: an industrial policy, with specific direction, for example into offshore wind, and other solutions. As Dieter Helm has highlighted, this government interference has proved to be very expensive for the consumer: the government is supposedly examining fundamental reforms to fix "a broken market." The government has not challenged Helm's diagnosis, and surely his work deserves a response?

Regulation of the UK power industry has also become extraordinarily complex. Regulation has become its own little industry, where many of the players have a vested interest in complexity. As Dieter Helm observes: "The sheer number of interventions in the UK energy market is so great that few if any participants in the markets, few regulators, ministers, or civil servants, can have grasped them all."

What should be the path for future investigation and debate? It seems to the authors that we need discussions on the following:

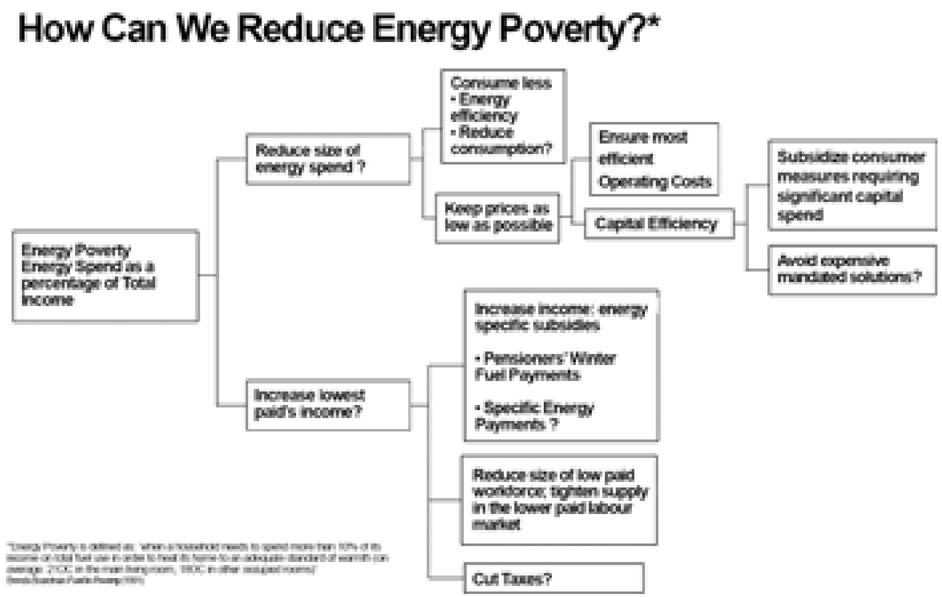
- Energy Poverty: should we should tackle Energy Poverty head on by giving more purchasing power to those who are affected. We should not 'throw the baby out with the bath water' through price caps or forcing artificial cross subsidies between consumer classes

- Regulation or Industrial Policy: are we regulating an industry, or trying to create a regulatory framework to deliver a particular Industrial Policy. For example, many have argued that the UK is better served by adopting, say regarding SMRs in the case of nuclear power. The argument runs that if the UK government wants to see (say) an SMR fleet installed, it needs to kickstart the technology by the award of a series of production contracts to deliver the fleet of these generation types, in much the same way as they might go about procuring say a new destroyer or fighter program. Many an industry argue that is this approach and only this that will make the real economic case for SMRs

- Focus On The 'Platform' Rather Than Picking A Winner? Guggenheim

Partners' Chairman, Alan Schwartz, has framed the problem as follows: rather than trying to make industrial guesses, pick winners or go for a mandated outcome, regulators should focus on open architecture, multiple solution, market-driven world, working on a common platform: much like apps on the iPhone platform do. Innovation can thrive because the rules are largely agreed and will not change: the proper function of regulation is, therefore to provide a platform for the ecosystem within which multiple different solutions can thrive and compete. The Schwartz approach is intriguing

- Let the markets do what they do best: capital markets, whether equity or debt, are extremely good judges of, and extremely efficient at pricing risk. Capital markets most certainly do understand regulated industries, and in particular the strengths and weaknesses of different regulatory frameworks and structures. Risk profiles are not static; they evolve and change. For example, in the construction and development of offshore wind a higher rate of return to account for the construction and execution risks is required, but once these risks are eliminated, the assets can be transferred to those who require a lower return, such as infrastructure funds.



AUTHORED BY

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Ilesh Patel joined Baringa in 2010 and is currently Baringa's global strategy and markets lead for the Energy & Resources industry. He has 25 years of UK and international experience advising utilities companies, regulators, governments, investors and lenders on strategy, regulatory, investment and commercial issues. Recently, he has led work on renewable energy projects, new energy technologies, distributed energy and interconnectors. He has advised on over twenty electricity and gas interconnector projects and over 50 GW of renewable energy, battery and electricity storage projects for renewables developers and power generators across the world. This has included work for renewable energy companies, energy infrastructure investors, power generators and traders, in both Europe and increasingly in other regions around the world, such as South East Asia, UAE, Australia, Africa and South America. He has also led Baringa's work for large energy users, such as Tesco Plc and Transport for London, advising on renewable energy purchasing and sustainability strategies.

DECARBONISING THE GB ENERGY SYSTEM – PATHWAYS, ISSUES, AND CHALLENGES

OVERVIEW OF A NET ZERO ENERGY SYSTEM

The climate change crisis is now widely recognised as one of the most serious long-term threats facing the world, and tackling climate change is the UK Government's top international priority[1].

Recognising this, the UK was the first major developed economy to set a legally binding target of 'net zero' greenhouse gas emissions by 2050. Achieving net zero emissions will require a radical overhaul of our energy system. In 2019, almost 80% of the UK's primary energy consumption was met by fossil fuels[2]; by 2050, this will have to be reduced dramatically, to at most 40% and potentially under 10% of final demand, and almost all the carbon emissions from the remaining combustion of fossil fuels will have to be captured and permanently sequestered.

BEIS analysis[3] suggests that by 2050, 50-60% of final energy demand across the economy will be met by electricity – up from just 17% today – due to the electrification of most light vehicles, heating, and many industrial processes.

1 Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy, HMG, 16 March 2021.
2 Digest of United Kingdom Energy Statistics (DUKES) 2020, BEIS, 30 July 2020.
3 Table 6 in the Impact Assessment for the sixth carbon budget, BEIS, 16 April 2021.

This would represent a near doubling (or more) in annual electricity demand, and a 40% increase in peak demand – even with much greater demand flexibility from 'smart charging' of electric vehicles and heat pumps.

The remaining 50% of energy demand – from industry, heavy vehicles, and some home heating – is expected to be met largely from combustion of natural gas with carbon capture, utilisation and storage (CCUS), or low carbon hydrogen (produced either by electrolysis or from natural gas or biomass reformation with CCUS). Together this is expected to require between 60 and 180 million tonnes of CO_2 to be captured and stored each year by 2050[4] – at the lower end, equivalent to the total emissions from the power sector today, and the upper end equivalent to the emissions from power and road transport combined.

WHAT WILL A NET ZERO ELECTRICITY SYSTEM LOOK LIKE?

With electricity dominating our future energy supply, decarbonising and growing our electricity system is going to be crucial to meeting net zero. Most of the existing GB generating fleet will retire before 2050, both for technical reasons (i.e. assets reaching the end of their design life) and for economic and emissions reasons (e.g. emissions limits forcing plants to close, or high carbon prices making them uneconomic to run).

To replace this and meet growing demand, Baringa estimates that around 150GW of new electricity generating, energy storage, and interconnection capacity will need to be built in GB over the next 30 years – double the previous maximum increase in generating capacity of 57GW between 1944 and 1974[5]. This will require total investment of over £150 bn (capital costs excluding interest, 2020 prices) – equivalent to over £5 bn per year.

4 The UK Carbon Capture Usage and Storage deployment pathway, BEIS, 28 November 2018.
5 BEIS Historical electricity data: 1920 to 2019. Note that this figure is for total capacity, so the build rate may have been higher if there were also retirements.

The vast majority of the new generation will need to be low carbon. Baringa analysis suggests that a cost optimal system would have about 65% of generation from wind and solar, 15% from bioenergy, and 3-7% (each) from nuclear, gas CCS, hydrogen, and storage (see Figure 1). There would also be significant unabated gas capacity (over 20GW), although this would only operate at low load factors to meet demand at times of low wind and solar output.

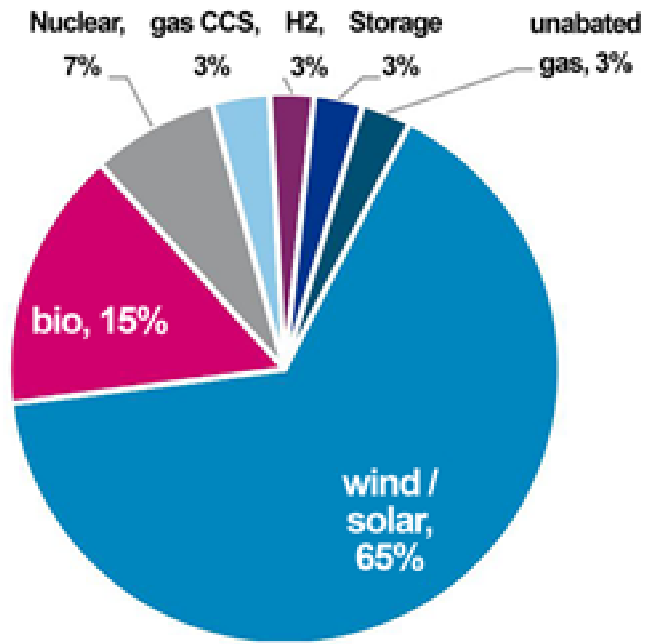

Figure 1: GB generation mix, 2050
Source: Baringa net zero reference case analysis

However, uncertainties over technology costs and development means that focussing too much on a theoretically 'optimal' system is risky. BEIS analysis[6] (Figure 2) shows that a large number of different generation mixes could potentially be 'low cost', ranging from 40% to 80% renewables, 7% to 50% nuclear, and 1% to 10% gas-CCUS.

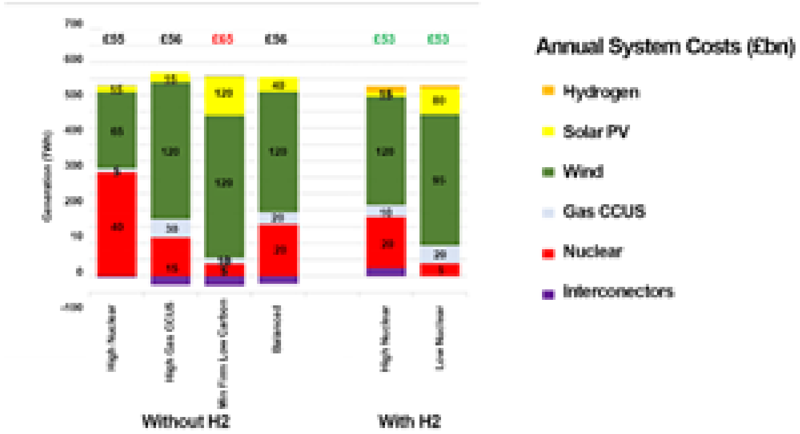

Figure 2: Illustrative 2050 generation mixes
Source: Replotted from BEIS 'Modelling 2050'[6], lower demand
Numbers in bars represent capacity (GW)

Despite the deployment challenges, the steep reduction in the costs of many low carbon technologies over the past 10 years – projected to continue into the future – means that the future energy system need not cost any more than our system today. For example, a recent report from Imperial College London estimated that a net zero electricity system could be around 20% cheaper per unit of electricity than today's system[7].

However, achieving these cost reductions depends on global trends as well as getting domestic policy and market design right.

6 Modelling 2050: Electricity System Analysis, BEIS, December 2020.
7 Net-zero GB electricity: cost-optimal generation and storage mix, Imperial College London, June 2021.

The steep cost reductions in wind and solar technology seen recently have been driven by scaling up of deployment – costs typically fall by 10-20% for each doubling of installed capacity, so continued acceleration of global deployment is key. In addition, many low carbon technologies have high up front capital costs, low operating costs, and long operating lifetimes, so ensuring that investment can be incentivised at a low cost of capital, and amortised over the full asset lifetime, will be key to minimising costs to consumers. The UK has a key role here both in developing effective policy and 'exporting' it to other countries to help drive deployment and hence continued cost reductions.

THE ROLE OF GAS IN A NET ZERO ENERGY SYSTEM

Around 860TWh of natural gas is currently consumed in the UK each year, supplying almost 40% of the UK's primary energy[8]. In a net zero energy system this figure is likely to drop, but there is still a wide range of uncertainty. For example, in a high CCUS scenario total natural gas demand in 2050 could be just 16% down on 2019, to around 750TWh, whereas in a high electrification and green hydrogen scenario, there could be no natural gas consumption at all[9].

Even in the latter scenario, though, gas may still play an important role in the energy system – but low carbon gas, such as biomethane and hydrogen, rather than natural gas. National Grid estimates that demand for low carbon gas could be around 200TWh, meaning that a significant gas transmission and distribution system is still likely to be required in future, albeit potentially smaller than today's.

8 Digest of UK Energy Statistics (DUKES): Energy, BEIS, October 2020.
9 National Grid Future Energy Scenarios, July 2020.

POLICY AND INVESTMENT CHALLENGES

The uncertainty over both the level of future electricity demand and the optimal technology mix for meeting demand and emissions targets creates challenges for both policy makers and investors.

For example, policy makers face the question of whether and how much nuclear and CCUS capacity to support. Given the long development times and complex infrastructure requirements of these assets, we need to start building them now for there to be any realistic prospect of having the tens of GW of capacity we might need operational by 2050 – but this also risks locking consumers into a higher cost energy system if the costs of renewables, energy storage and low carbon hydrogen continue fall far enough.

Similarly, although wind and solar are the cheapest generating technologies today, they are 'price takers' in the electricity market which means that their future revenues are almost entirely dependent on the future capacity mix and carbon and gas prices. For example, if new renewables capacity continues to be supported outside of the market, such as through the contracts for difference (CfD) scheme, existing generators could see very low market prices from the mid-2040s (see Figure 3). This uncertainty is likely to increase the cost of capital for any 'merchant' revenues (e.g. for unsubsidised plant, or after the end of any support contracts), which will have the effect of increasing consumer costs and reducing the overall rate of deployment.

Investors in existing and new thermal assets – such as unabated gas CCGTs and peaking plant – also face uncertainty. We are likely to continue to need significant unabated peaking thermal capacity to ensure security of supply at times of low renewable output, but in future the operating hours for these generators will be severely reduced unless they can retrofit CCUS technology or switch to hydrogen. It is not clear today how quickly this reduction in running hours will take place, nor whether the current policy and market arrangements will be sufficient to enable these assets to cover their costs and provide returns to investors.

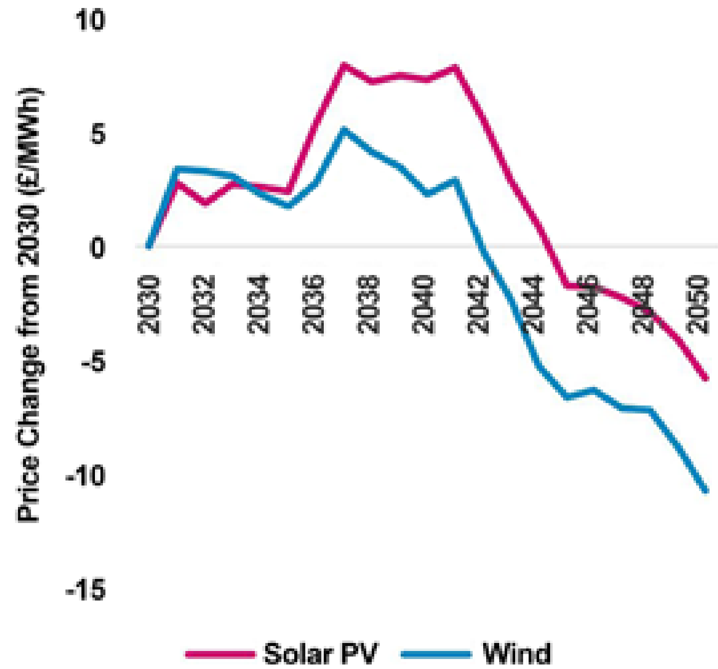

Figure 3: Illustrative renewables capture prices in a net zero scenario
Source: Baringa modelling

Flexibility on both the generation and demand side will be key to a net zero electricity system, but again mobilising the required investment faces challenges. Storage technologies generally rely on price arbitrage – e.g. buying and storing electricity when it is cheap, and exporting it when prices are high – but this revenue stream is inherently volatile and depends on prices being allowed to 'spike' to high levels.

Governments are often uncomfortable with the risk of high market prices (even for short periods of time), so flexibility providers face the risk of political intervention to dampen price volatility, which could undermine their business case. Significant flexibility is also expected to come from domestic assets such as electric vehicles and heat pumps, but these technologies are still nascent and it is unclear whether and how consumers will respond to incentives.

Finally, the uncertainty over the future role of gas has major implications for investors in gas assets – in particular, the transmission and distribution networks. Currently the costs of these networks are spread across a large number of gas users. However, if gas demand falls, and in particular if gas consumers are geographically dispersed across the country, the costs for individual consumers could start to rise rapidly, threatening the long-term viability of the networks. Whilst this drop in methane demand could be partially offset by biomethane and hydrogen, this would require additional investment in network infrastructure, and it remains unclear how significant the role for biomethane and hydrogen will be in a net zero system. Investors will be looking for clarity from regulators and network companies as to how they will be planning for and mitigating these risks.

PRINCIPLES FOR MARKET DESIGN

Significant policy and market changes will clearly be required to address with these challenges. However, the complexity and uncertainty we face make it impossible to identify a single 'big bang' set of reforms that can be guaranteed to work. Policy will need to evolve over time, and investors' attitudes to risk will need to adapt, focussing on the long-term value to the system and to decarbonisation that different assets bring, rather than seeking to accurately forecast different revenue streams far into the future. And of course it is essential that throughout the net zero transition, energy costs remain affordable to consumers (in particular the 'fuel poor' and vulnerable consumers) and ensure that industry remains competitive – otherwise there could be a loss of public support for decarbonisation, and emissions might simply be 'offshored' to higher carbon markets.

Baringa has recently proposed[10] a set of 'guiding principles' that policy makers could adopt to guide policy decisions and encourage long-term investment in the face of uncertainty. These include:

1. Deploying 'whole system' thinking to take account of interdependencies between policies and sectors;

2. Ensuring there are clear roles and responsibilities for decision-making, including considering establishing and giving more authority for ensuring decarbonisation and security of supply to an independent body such as an energy system operator;

3. Providing a consistent carbon signal across markets and policies, to minimise distortions between sectors, fuels, networks, and generation;

4. Using competition where it is most effective, for example in creating new decentralised markets for energy, network access and flexibility, but recognising that it is not optimal in all circumstances and in some cases greater central coordination may be necessary; and

5. Engaging and protecting consumers, enabling them to take advantage of advances in technology to reduce bills and carbon impacts, but also ensuring that vulnerable consumers do not end up with higher bills as a result of engaged consumers paying less.

10 The Journey to Net Zero: Why this is more than just EMR 2.0. https://www.baringa.com/en/insights-news/points-of-view/the-journey-to-net-zero-why-this-is-more-than-just/

IMPLICATIONS FOR ENERGY SECURITY

The net zero transition will change how we think about energy security. The International Energy Agency defines energy security as:

"...the uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance." [11]

Energy security takes into account the sources and diversity of supply, along with a system's ability to deliver energy when required in a safe and reliable way, and has four main components:

The significant reduction in use of fossil fuels means less exposure to international and geopolitical risks from energy imports – as seen recently with Suez canal and tensions in Straits of Hormuz.

The switch to electric vehicles also significantly reduces risks arising from disruption to the refining and transport of liquid fuels around the country – as was seen dramatically in the UK in 2000 with the fuel tanker driver strike, and more recently in the US with a cyber attack on the Colonial fuel pipeline.

11 www.iea.org/topics/energy-security

However, much greater dependency on a single energy vector – electricity – means that the impact of any supply disruptions will be much more profound. We've already seen from the electricity blackouts in Texas last winter how devasting a prolonged shortage of electricity is to a modern economy, and if most transport and heat was also electrified the impacts would have been even more catastrophic.

In principle a more electrified economy could also be vulnerable from a cyber security perspective. The increase in use and value of market data in the operation of the energy sector, increased automation and increased use of digital infrastructure all create new risks. The just-in-time nature of electricity vs. gas means that interruptions to supply have immediate impact, although of course as we have seen cyber attacks on pipelines can also have rapid and significant consequences. The EU Directive on security of network and information systems (NISD), and UK equivalent, provides a baseline level of cyber-security and resilience across the energy sector but a huge amount will depend on how we couple Net Zero thinking with technology resilience.

The uncertainties and policy and investment challenges described above also create a risk that we do not build sufficient capacity and infrastructure to meet increasing electricity demand. For example, if the pace of deployment of renewables slows, and/or there are significant delays in commissioning new nuclear and gas CCUS power stations, whilst at the same time existing gas and nuclear power stations close early, we could find ourselves with tight electricity margins by the mid-2020s and with limited short-term options. It is therefore crucial that the appropriate policy and market signals are in place to incentivise an acceleration of investment in new low carbon capacity, and ensure that security of supply is maintained.

The increase in the proportion of variable renewables will also make operating the electricity system more complex. The GB Electricity System Operator is confident that it will be able to operate a zero carbon system by

2025, and is in the process of procuring new technologies and tools to do so (such as synchronous compensators, flywheels, synthetic inertia, etc.), but by definition these techniques are novel and have not yet been proven in a large-scale system.

But conversely, a more decentralised and flexible system can be more resilient – an outage of any one generator has less impact on overall system, and more households and businesses are likely to have their own forms of generation and storage (e.g. solar panels, batteries, EVs, thermal storage).

CONCLUSIONS

Our Low Carbon Future is here now – 2021 is the inflexion point. One need to look no further than the fresh government commitments from the top emitting countries, China chief amongst them, the imminent approach of COP26, a private sector focus across a variety of industries on embedding climate change into investment decisions, and the increasing and important role of financial regulators in increasing pressure on lenders and investors around climate risk disclosures and capital allocation to industries facing significant physical and transition risk due to climate change.

Our low carbon future must go beyond the power sector and must go beyond renewable energy alone as a solution. 80% of emissions come from outside the power sector. A low carbon future is contingent on decarbonising all four key areas of the energy system - Power, Transport, Buildings, and Industry – backed by the rise of sustainable finance. For each of these sectors there are choices to be made on when, how fast and how to decarbonise – what role will new technologies play, how will carbon pricing influence those choices, how will heat and cooling requirements be met and how can countries, companies and sectors collaborate to achieve more together will all be questions we need to answer as a country.

To make our commitments to 2030 and 2050 happen, 2021 is the year when transition must become transformation, where we must deliver on the promises and commitments we have made to a low carbon future and to "Build Back Greener".

Transitioning to a Net Zero energy system is clearly a huge challenge but there is no reason if well planned that we cannot achieve it and the result need not be any more expensive, less resilient or less secure than our energy system today – indeed, it could even be cheaper, more resilient and more secure if it is well planned and well executed. And of course it is essential that throughout the net zero transition, energy costs remain affordable to consumers and ensure that industry remains competitive – otherwise there could be a loss of public support for decarbonisation, and emissions might simply be 'offshored' to higher carbon markets.

AUTHORED BY

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Michael Hewitt (Rear Admiral - RET.) retired from active duty on 1 January 2014, after 31 years of service in the U.S. Navy. A career naval aviator, RDML Hewitt distinguished himself across a diverse spectrum of defense-related competencies. He is recognized as one of the department's leading experts in strategy-to-task advancing asymmetric warfare, nonkinetic warfare, and sensitive collaboration within the Department of Defense, Interagency, and National Security Staff. Upon his retirement from the military, RDML Hewitt founded HSH Analytics, a company dedicated to providing unmatched expertise in special access program operational employment, future war-fighting scenario development, and emerging technologies aligned to asymmetric warfare. In2016 RDML Hewitt co-founded and is the CEO of International Peace, Power and Prosperity (IP3). IP3 and its affiliate Allied Nuclear Partners (ANP) is a global nuclear energy adviser, a start-up that helps foreign governments procure nuclear technology from American and commercially driven international companies, tailors financing and helps countries start nuclear energy programs. In addition, RDML Hewitt is an advisor for several corporate entities involved in cyber defense, countering weapons of mass destruction, commercial capabilities for USG requirements, and high tech firms supporting advanced warfare concepts.

IP3 PERSPECTIVE ON THE UK ENERGY SECURITY PROJECT

Secure, clean, reliable energy is fundamental to the survival and prosperity of every sovereign country. Without it, nothing grows – not industry, agriculture, education, housing, science, or healthcare. In sum, sovereign control over clean, resilient energy is a leading measure of a country's national security and must be seen as such and not simply as an economic and environmental issue. Reliability has recently become an especially important trait.

Therefore, a nation's first goal must be to build and deploy systems able to deliver baseload power with high-capacity factors (i.e., percentage of round-the-clock delivery of design capacity). These systems must also be capable of powering the unique challenges of each country beyond baseload power, to include district heating, desalination, process heat, and the development of alternative energy sources (e.g., hydrogen). So how should a sovereign country go about assuring that its system is secure, clean, and reliable?

Today, energy sectors are marred by hidden assumptions regarding the levelized cost of electricity, long versus short-term outlooks and the resilience of grid and supply chain infrastructure. This eliminates the possibility of including a more robust selection of investors interested in participating in the sector. However, mechanisms for "third-party finance," developed and refined in defense procurements over the last 40 years, provide examples for modern economic innovation. Government leasing and power purchase agreements offer ways to activate external financing to strengthen construction budgets. Leadership is needed but remains uneven at best. In the battle against time to decarbonize the planetary systems, the United Kingdom has the means at hand to re-frame how national leaders define energy security and activate investment in critical climate solutions.

WHERE WE ARE NOW

Having already weaned itself from coal-fired power generation, London is setting its course on cutting out all fossil fuel-fired generation next. Trying to get ahead of an expected rise in demand for clean energy from the heating and transportation sectors, Britain plans on replacing its eight existing nuclear power plants with new next-generation reactors. While the exit from coal for power generation was relatively simple, the exit from gas will not be.

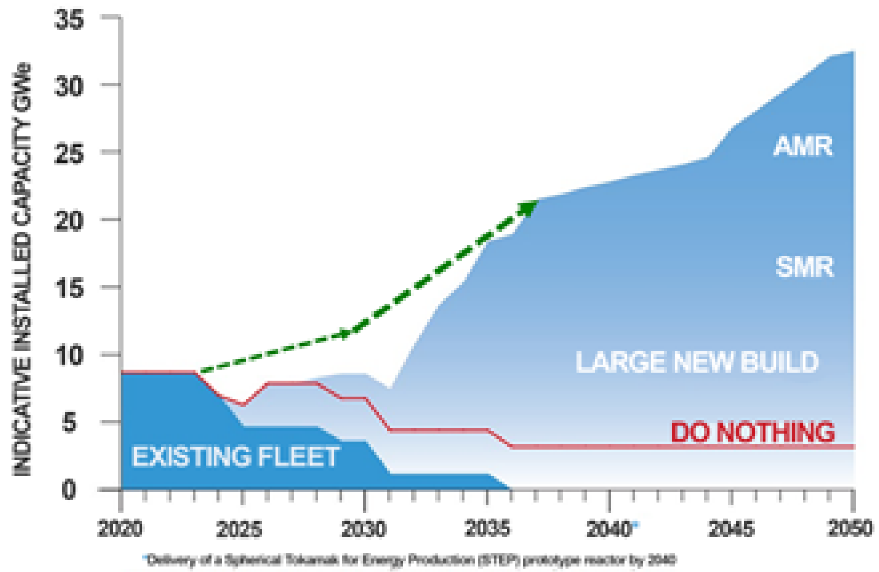
According to a new report by the UK's Nuclear Industry Association, an ambitious buildout of nuclear projects could ensure nuclear continues to provide 40% of Britain's clean power through 2050 and drive deeper decarbonization through district heating and the creation of hydrogen and other clean fuels.

Support for nuclear energy now transcends traditional party politics and speaks to the changes in how energy availability is understood to impact peace and prosperity across societies. In 2018, the NATO Brussels Summit Declaration identified the important role energy security plays in the coalition's common security. Since the early 2000's, NATO has made a priority of its awareness of energy developments and sought to develop its competence in supporting the protection of critical energy infrastructure. In recent years, its focus has moved beyond improving the energy supply for the military to recognizing energy availability for the stability it provides

in society.

Advanced nuclear energy in smaller-scale deployments represents an important market for future nuclear power. Coordinating with major vendors to align with UK goals, HMG can support the growth of an economic ecosystem that can cultivate investor relationships interested in a 16-reactor program for the UK. The UK's commitment to a fleet approach to small modular and advanced reactors is critical to reestablishing the nuclear industrial base and demonstrating leadership at the upcoming COP26. Working together with European allies across 3SI and NATO, the British nuclear industry can modernize and lead the regional clean energy transition that is requisite to meeting the challenges of both energy security and decarbonization.

THE IMPENDING DECLINE IN UK NUCLEAR CAPACITY TO 2050, AND PATH FORWARD WITH SMRS



WORKING WITH OUR ALLIES – NATO AND FIVE EYES

The 3SI and NATO nations recognize the vital importance of energy security as part of collective defense missions. Trusting that commercial interests fuel Russia's energy projects could potentially subjugate the whole of Europe and negatively influence the United Kingdom. Nord Stream 2 represents leverage to price gouge Eastern Europe or even blackmail NATO members into not meeting the alliance's defense spending targets of at least 2% of GDP.

Although Berlin pushes back against nuclear as a clean resource for sustainable investments, most of the other EU countries are taking matters into their own hands. As part of Europe's Green Deal, nuclear energy has been excluded initially from the European Union's drafted taxonomy for sustainable activities. However, several countries continue to lobby the European Commission to consider nuclear as a clean energy resource favored under the new taxing scheme. The Commission will reconsider its exclusion of nuclear - as well as natural gas - in the coming months. Again, leadership is critical for ensuring decarbonization objectives are fused to energy security imperatives.

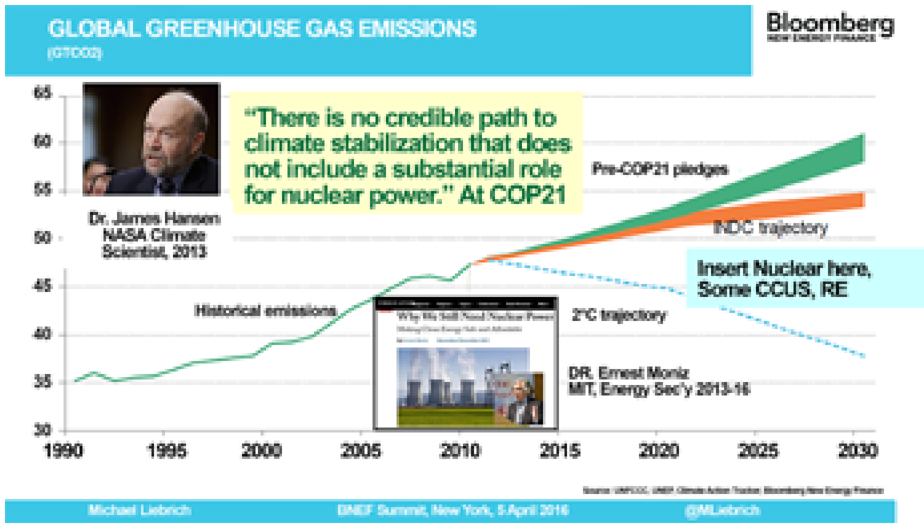
Support for new nuclear energy spans the traditional right-left divide in the United Kingdom as Britain remains committed to meeting its 2050 net-zero emissions target. But investments by Chinese state-owned nuclear firms in UK nuclear projects (at Bradwell, Sizewell) threaten to undermine British sovereignty and collective security among NATO allies. To create a resilient future and to mitigate the burdens of climate change, new priorities must be set in terms of how energy security is defined.

Authoritarian state-owned firms prioritize politics and foreign policy over commercial interests and costs. A "best-in-class" model counters this by bringing together investors, developers, vendors, and contractors. Only by strengthening customers' buy-side leverage and extending the horizon

of their procurement processes, can the UK be assured both financial and security interests are served. To keep the lights on, we must use reliable sources and ensure energy prices make our economy competitive.

THE GLOBAL ENVIRONMENTAL AND ENERGY IMPERATIVES FOR NUCLEAR POWER

The twin pressures of carbon mitigation and long-term rising global energy demand necessitate broad and significant deployments of nuclear energy worldwide. From 2000 to 2050, three billion more people will move to cities. In a world nearing 10 billion people, more than 6 billion will live in urban areas (UN population data). This massive scale of urbanization – with more and more electric cars and buses, demands for clean water, and high-rise apartments and office towers – cannot be met without nuclear power, say prominent climate scientists.



Near the end of the year, COP26 will entail a "five-year checkup" on progress since the historic COP21 Paris Accord. Importantly, at that Paris meeting, Dr. James Hansen, formerly the leading climate scientist at NASA, very clearly stated, "There is no credible path to climate stabilization that does not include a substantial role for nuclear power." And he chastised many Environmental NGOs on their impractical "100% Renewable" campaigns in doing so. For six billion urban residents in 2050, wind and solar and biomass or geothermal power are impractical for large urban power loads that must be available 24/7, even with batteries. Hansen and several of his colleagues have called for a stronger profile of Nuclear Power at the COP26 in Nov. 2020.

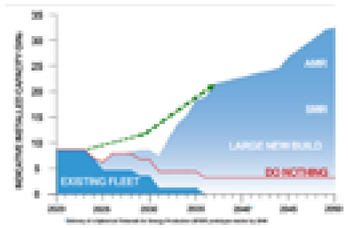
Nuclear power, with a very small footprint per MW, is ideally suited for cities in any climate. In Jan. 2019 during a Polar Vortex spell, the leading power utility in Michigan, CMS, suffered a gas compressor station explosion, and gas supply was not available for two weeks. The icy conditions and overcast skies eliminated wind and solar. Fortunately, the Fermi 2 nuclear plant was running to sustain Detroit, MI and Toledo, OH under the severe weather. With droughts in western states, hydropower is dimmed. Running more transmission lines all over the landscape for wind and solar farms increases wildfire hazards, which California has seen four years in a row. The PG&E utility is bankrupt a second time. The "100% Renewable" Campaign - some use "A Green New Deal" as the rhetoric - poses a dangerous, ideological campaign with little grounding in physical reality. Faced with climate change, the worst strategy is to make your entire power system more vulnerable to severe weather for millions of people dependent on reliable power in major cities.

THE ROLE OF NEW NUCLEAR ENERGY TECHNOLOGIES

New technologies will play an essential role in the transition to a low-carbon future. In the case of nuclear energy, preservation of the existing fleet of carbon-free generators is a prerequisite to new and improved designs. Accelerating the deployment of Small Modular Reactors (SMRs, sub 500 MWs) and integration of nuclear energy for hydrogen production represent critical means to meet climate goals. Advanced Nuclear Technologies (AMRs) provide for greater flexibility domestically and create new export options.

The first three of Britain's next-gen reactors - the licensed Hinkley C, planned Sizewell C, and proposed Bradwell B projects - have worrying degrees of ownership by Chinese state-owned nuclear energy companies, from 20% to 67% stakes. As Chinese developers have noted, the proposed Bradwell B reactor offers Beijing the opportunity to build the first Chinese reactor in a developed Western "P5" country. The US, UK, and other member states of the NATO alliance have good reason to be concerned.

MIND THE GAP: THE SHIFT TO SMRS CAN HELP THE UK OVERCOME A DECLINE IN NUCLEAR FLEET CAPACITY

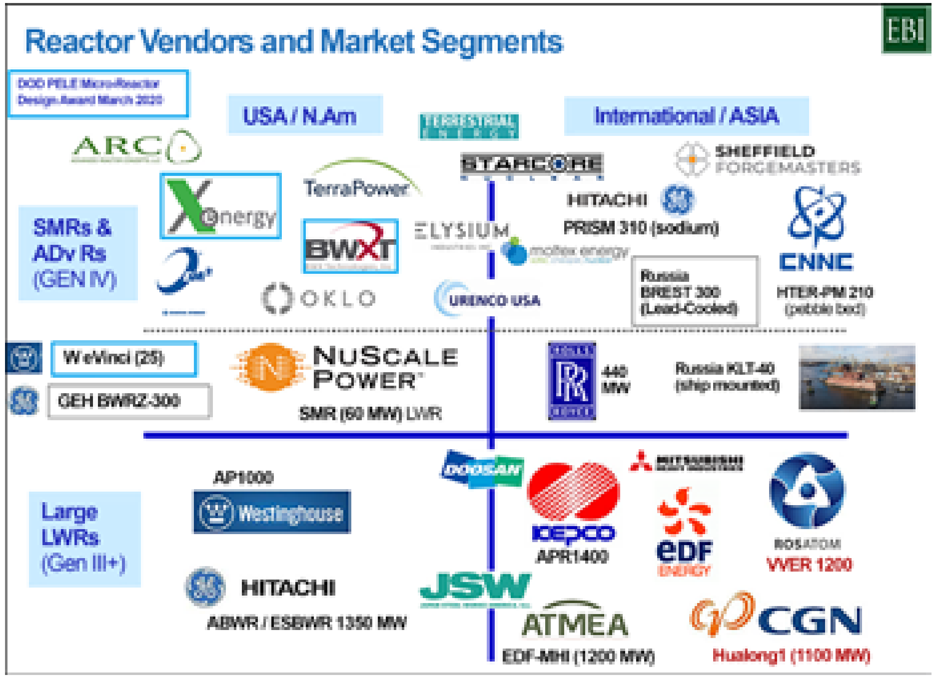


UK Winter Storms – 2011, 2018

- Much smaller financing packages: £1.5- £3.0 billion [440 MW] per project versus >£ 20 billion
- Dramatically reduced "stick-build" at a reactor site, reducing construction time, aiming for <£4M per MW.
- High quality assurance with most of the reactor system built inside a controlled factory
- **Much less land use than wind farms**, and slimmer plant profile with native environment overall

- Revenues and cash flow can be earned sooner, while some installation continues at each site
- Stronger safety envelope at the fuel level with some designs, not only at the reactor level
- Many more passive safety features (no active pumping required), incorporating lessons learned
- Greater power flexibility, or tailoring for areas with smaller and weaker grids
- Hybrids: Adaptation of reactors into desalination, chemical or fuels refining, metallurgy, hydrogen fuel
- Less need for cooling water with some installations. Useful in areas with water stress
- Advanced fuel designs improve the overall waste profile of the operation
- Safer plant profile option in bunker reduces exposure to drone strikes or outside attack.

REACTOR VENDORS: SMRS VS LARGE REACTORS (NORTH AMERICAN AND INTERNATIONAL)



Compiled by ADPaterson, Rob Sweeney for IP3

To protect British industry and ensure the reliability and resilience of critical infrastructure, the UK must consider how best to develop and maintain a robust allied industrial base, include the energy industry, and provide cyber defense infrastructure. A ***BUY-SIDE*** strategy for nuclear energy projects and hybrid nuclear systems can be delivered without sacrificing the host country's sovereignty. Regulatory integrity as well as oversight of construction costs and safety standards stand preserved in a competitive, commercial context. (Allied Nuclear Partners, https://alliednuclear.com)

We must ensure we do not increase strategic dependence. Russia's weaponization of natural gas in Eastern Europe and China's effort to entangle CCP-dominated state-owned firms in Western nuclear development constitute a geopolitical pincer that cannot be underestimated and certainly not dismissed. Unless the international community limits the industrial policies of China and Russia from having an impact around the world, energy investments will increasingly represent vulnerabilities in the defense of nations.

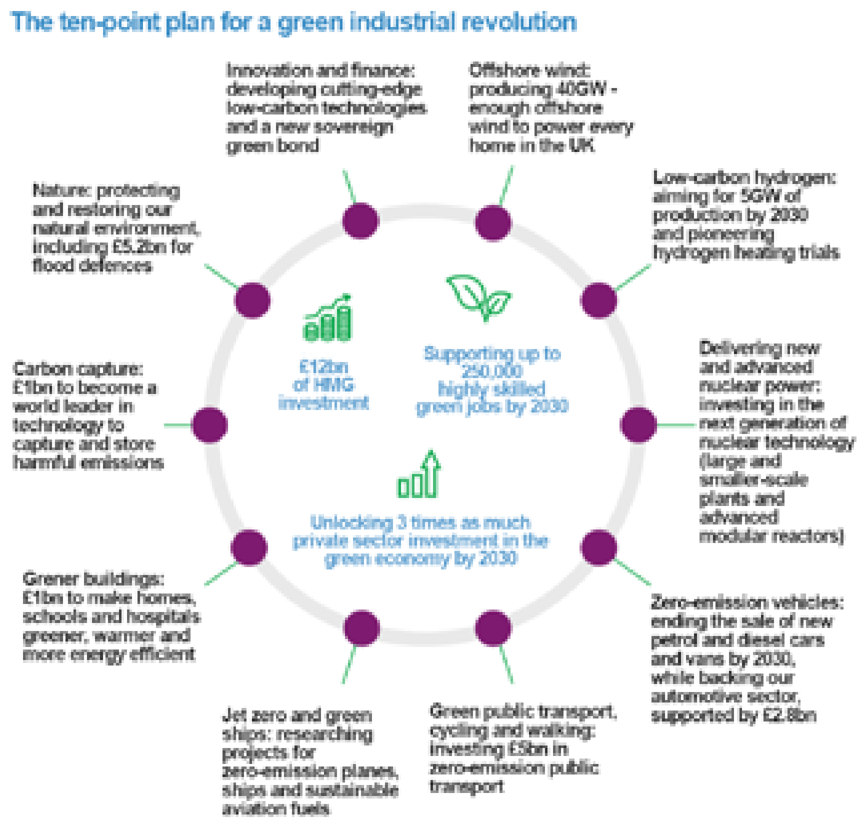
PARTNERSHIP AND THE PATH TO DECARBONIZATION

The UK has made great strides to advance an allied approach to climate change. Powerful alliances among the UK, Canada and the US can meet global challenges with integrative solutions. The challenges of climate change and foreign resource competition are among the defining issues in our respective countries. In the UK, the recent TEN-Point Plan and the Energy White Paper outline a strategy for a domestic and international plan to decarbonize, as well as reestablish the British leadership role going into COP 26 and as a P5 nuclear power.

The inclusion of nuclear energy in ESG criteria will be accelerated by the UNFCCC Framework and NDCs goals for Net Zero by 2050. To accelerate emission reductions by 2030 and reduce climate risk, new nuclear will play an essential role. Carbon-free baseload power to complement renewable energy stocks will become a fiduciary duty to responsibly meet global energy demand, electrify transportation, and protect the environment.

Sovereign wealth funds, corporations, and wealthy family offices are shifting to divest or invest based on climate change criteria[1].   This movement represents more than $14.1 trillion in combined assets (www.divestinvest.org). New nuclear energy will emerge as part of the energy mix because it delivers reliable returns while meeting conservation goals and poverty reduction needs in emerging economies.

1 $Trillions in investment for de-carbonization   www.reuters.com/article/us-climatechange-investment-letter-exclu/exclusive-investors-with-34-trillion-demand-urgent-climate-change-action-idUSKCN1TQ31X



Few other energy sources can scale as effectively to address water scarcity, protect natural resources, and preserve national sovereignty. Innovation and renewables have brought us far, but new nuclear will be necessary for countries to reach longer-term net-zero goals.

British and American pioneers can together reclaim a comprehensive, industrial base-approach to build low-carbon technology. Small Modular Reactors and the UK fleet approach to SMRs provide a meaningful template for economic growth and environmental protection. A comprehensive set of offerings and models can complement and enhance the Prime Minister's goals. Salient elements in the Prime Minister's plan include his underscoring new nuclear power and SMRs as the foundational platforms critical to reaching global decarbonization goals.

We must ensure policy decisions are taken in a way compatible with our environmental targets. Too often, the "clean energy" characterization still seems to be a proxy for renewables. With continued dependence on natural gas, the commitment to net-zero emissions remains conflicting. The UK government published its security review, promising defense and security renewal while temporizing with China in order to secure co-operation on climate change. In 2021 and beyond, Her Majesty's Government will make climate change and biodiversity loss international priorities.

RUSSIA & CHINA – AN APPETITE FOR DISRUPTION AND "LIMINAL WARFARE" BEYOND MILITARY MEANS

Strategic perspective on energy security and resilience, be it in the UK or anywhere else, would not be complete without comment regarding the role of two principle, destablising players on the global energy stage:

RUSSIA:

A study by Rice University's Baker Institute for Public Policy, shows Moscow has cut off crude oil and natural gas supplies to (or price gouged) neighboring countries at least 15 times from 1990 to 2015 amid political tensions. In bypassing Eastern Europe, the planned undersea Nord Stream 2 will enable Moscow to "freeze out" Eastern Europe at a moment's notice without cutting off energy supplies to Germany.

NATO members Poland, Estonia, Latvia and Lithuania, non-aligned Ukraine, and even Russian ally Belarus, have good reason to fear the 1,200-km pipeline through the Baltic Sea. Afterall, Russia has a track record of weaponizing energy exports for political ends since it attempted to crush the Baltic States' independence bids with an oil blockade in 1990 and restricted gas exports through Ukraine off and on for decades. Buying Russian gas through Germany via Nord Stream 1 and 2 does not remove those risks.

Once in service, Nord Stream 2 will be capable of transporting 55 billion cubic metres of gas per year, doubling the capacity of the existing Nord Stream pipeline. This will no doubt make Europe's largest economy (and polluter), Germany, become more addicted to Russian energy as natural gas fills the void of retiring generation capacity from Germany's nuclear and coal-fired power plants.

The Nord Stream 2 energy project highlights the need for nuclear energy in critical infrastructure and national security. Russia's politically driven natural gas pipeline aims to bypass Eastern Europe and get Germany even more dependent on Russian energy imports - and fossil fuels - taking advantage of Berlin's unnecessary shutdown of its nuclear power plants.

Through cheap gas or gas cutoffs, Russia aims to increase its leverage over Germany, neighboring countries, and by extension NATO. The North Atlantic Treaty Organization cannot afford to allow its member states to fall under Moscow's sway or become vassal states again. The undermining of the energy security and national sovereignty of NATO allies will make collective defense more difficult. Russia isn't just selling natural gas—Russia is purchasing power and advantage in a calculated effort to disrupt the allied system.

Not all nations need to be energy independent to preserve their energy sovereignty, but they must have access to energy on commercial terms unencumbered by geopolitical motives rather than become dependent upon potential or actual adversaries for energy supplies. A Europe dependent upon Russia for its energy supplies is the antithesis of energy sovereignty – a danger not only to Europe, but also to the US and its other allies.

CHINA:

China well understands both that armed warfare is to be avoided if possible and that resilient baseload energy is perhaps the most salient vulnerability of free-world countries. Currently it is well along in penetrating country after country using seemingly benign offers to build various pieces of heavy infrastructure (e.g., ports, pipelines, highways, and power plants) relying on their own state-owned and heavily subsidized industries and predatory lending. In addition to its focus on energy, China's Belt & Road Initiative (BRI) also seeks to capture critical resources (e.g., cobalt and lithium), strategic terrain (i.e., ports, straits, and military basing rights) and assured access to the world's leading markets (i.e., Western Europe and the United States).

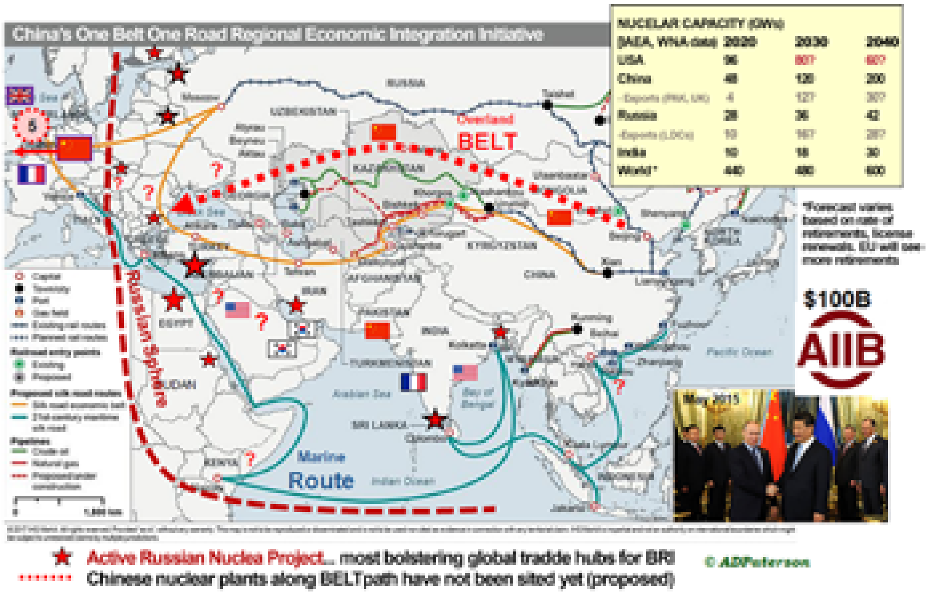
Focusing on China's energy strategy, Beijing understands that if it can gain control over the supply of a country's energy, it will control that country. In pursuit of global dominance, China has adopted a two-dimensional strategy: first weaken a given country's energy resilience by, for example, encouraging an over-reliance on renewable sources. Wind and solar surely have a place in every country's energy mix, but not at the expense of reliability and resilience.

The energy security risks posed by Chinese ventures in building nuclear plants in NATO countries continue to accumulate. Already notorious for industrial espionage and skirting international rules and norms, Beijing-ruled China, in recent years, has been leveraging infrastructure financing to gain political influence over foreign countries. For instance, when Sri Lanka was unable to pay Beijing back on a loan financing a port, the island nation fell victim to China's "debt trap" and in 2017 China's Navy took ownership of the seaport in lieu of payments – the project became an entry point for China's military.

Trade pressures have already provoked threats of retaliation by Beijing. For instance, plans for Britain's 5G telecommunications network demonstrate the perils of Chinese involvement. When the UK government reversed its decision on allowing Chinese state-owned firms dominance in building the nation's 5G network, the authoritarian regime threatened to pull out from British nuclear projects. London's efforts to safeguard its telecommunications network from the possibility of becoming dependent on Beijing-made telecommunications gear triggered far-reaching repercussions for national security and geopolitics.

The larger issue at play in the 5G equipment debate relates to the security of the core devices that control our networks and provide for the function of our critical infrastructure. Recent events have demonstrated the vulnerability of allied critical infrastructure to potential cybersecurity threats levied by nation-states and other sophisticated actors. Whether one looks at the recent ransomware attacks that threatened Colonial Pipeline and JBS in the US; the massive access Russians and Chinese were able to obtain to US government and industry networks through the recent SolarStorm and Microsoft Exchange hacks; the North Korean Wannacry attack that hit the globe in 2017 and took down the UK NHS for several days; or the Russia NotPetya attack which caused massive collateral damage to the tune of $10B globally, it is hard to underestimate the threats in this domain. These types of cybersecurity vulnerabilities, particularly for our critical infrastructure, as in the energy sector, become even more challenging if the underlying infrastructure is provided by non-allied nations, such as China. The Five Eyes nations (US, UK, Canada, Australia, and New Zealand) are uniquely positioned to address these threats.

China and Russia continue to use nuclear power projects to broaden their territorial command.

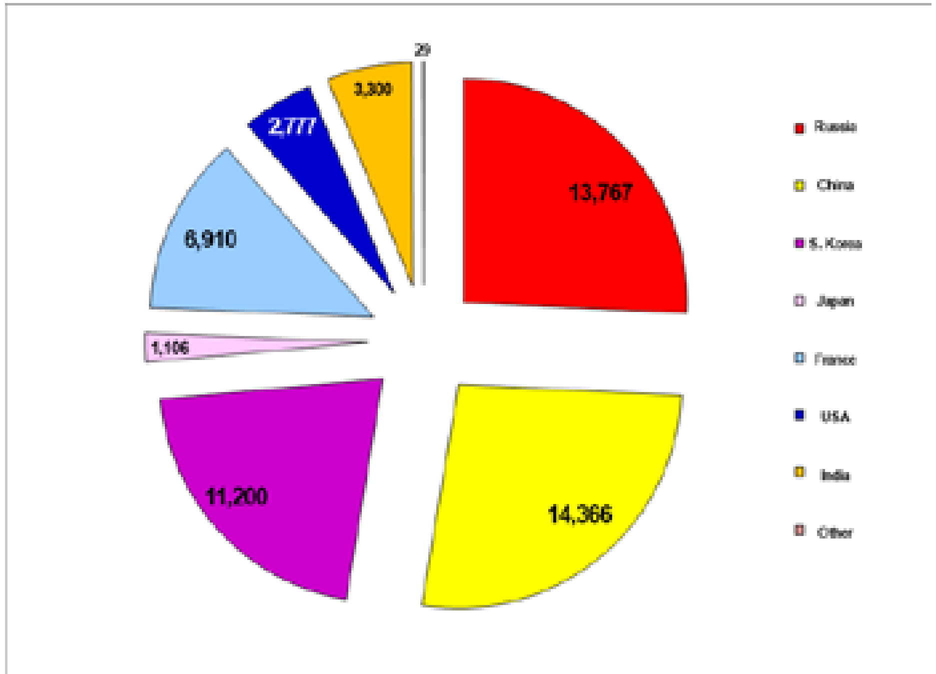


THE GLOBAL ARENA: NEW REACTOR CONSTRUCTION NOW DOMINATED BY RUSSIA & CHINA

Currently, as shown on the below graph, Russian (Rosatom) and Chinese (CGN) state-owned companies lead more than half of the world's nuclear new build. Russia and China, individually, are formidable competitors in the global arena and other energy industries. The "Overland Belt and Marine Route Initiative" (BRI) proposed by China in 2013 directly implements this strategy across Eurasia and into Europe. Moreover, China now owns several ports in Europe under BRI. Russia has expanded a stranglehold on the Suez Canal and the Eastern Mediterranean with nuclear projects in Turkey and in Egypt, and a proposal in Sudan for a floating reactor. Both China and Russia are expanding into Africa and South America by buying up substantial stakes in mineral resources and forging alliances in energy. China's takeover of Chile in the last decade is shocking - primarily to dominate 40% of the world's lithium supply for batteries (Chile has 8 million tons in reserves). China already dominates more than 70% of global solar panel production with the US now making less than 5% of PV panels after leading the world in 1990.

WNA: NUCLEAR PROJECTS CURRENTLY UNDER CONSTRUCTION BY VENDOR (54 GWS; 2018)

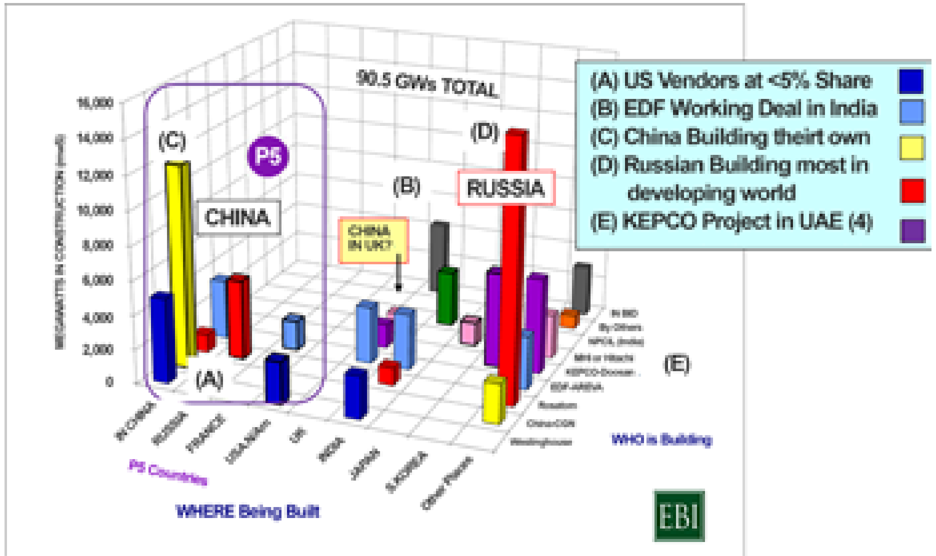
China and Russia now wield the majority of new reactor construction worldwide.



WNA, data analyzed by ADPaterson: www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx

LANDSCAPE FOR CURRENT NUCLEAR POWER PROJECTS – WHO IS BUILDING AND WHERE

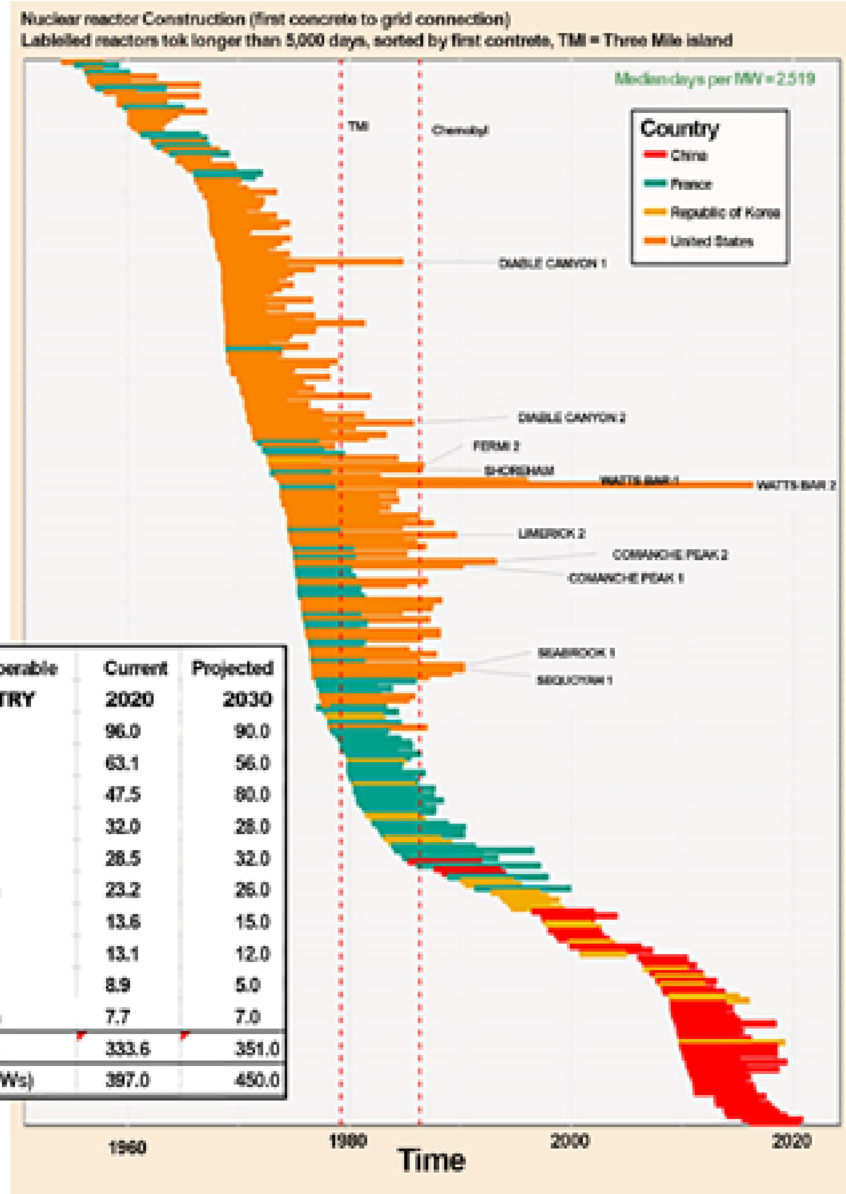
The diagram below is built up from the WNA listing of projects (2018-2025; analysis by EBI), with trade press reports on projects that are sited and very close to a financing agreement, but not yet under construction. This constitutes a broader base of projects (90 GWs) beyond those being built (54 GWs).



WNA: [Data updated and analyzed by Andrew D. Paterson, IP3 team]
www.world-nuclear.org/information-library/current-and-future-generation/plans-for-new-reactors-worldwide.aspx

IAEA Data [PRIS]: Global Nuclear Capacity built up since the 1950s by reactor project and owner.

The length of each bar runs from "first concrete" pour to "grid connection, and the height of each bar is capacity (MWs) to dramatize the timing of historical build out of new reactors and shifts over time.

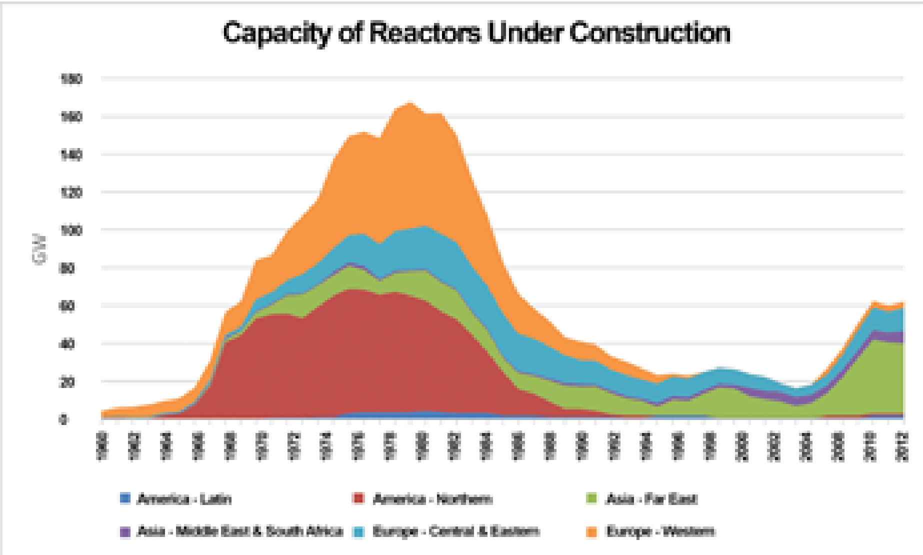


GWs Operable COUNTRY	Current 2020	Projected 2030
USA	96.0	90.0
France	63.1	56.0
China	47.5	80.0
Japan	32.0	28.0
Russia	28.5	32.0
S.Korea	23.2	26.0
Canada	13.6	15.0
Ukraine	13.1	12.0
UK	8.9	5.0
Sweden	7.7	7.0
Top Ten	333.6	351.0
Total (GWs)	397.0	450.0

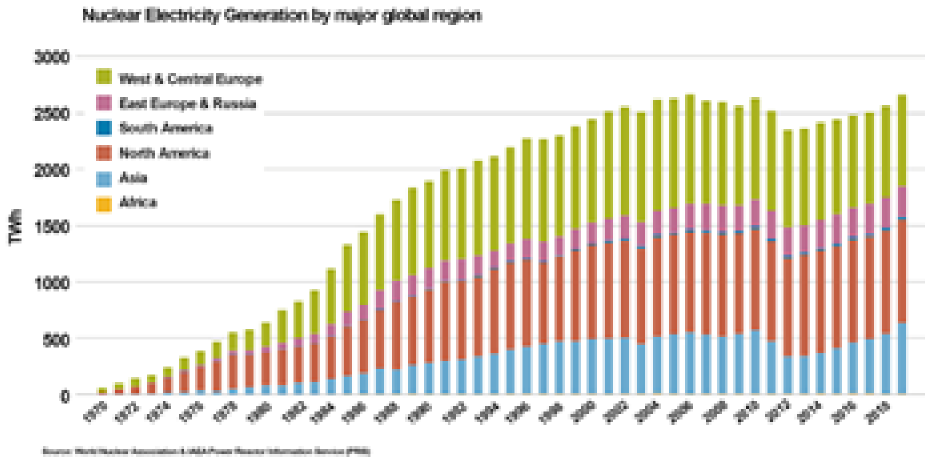
Annual Capacity additions by Major Region [Grant Chalmers, using IAEA data. Table by ADPaterson, IP3]The advent of Russia and China, since 1990 shows markedly in the bottom later portion of the graph. USA and France figure most prominently early on (1960s-70s), then tapered new build.

APPENDIX – HISTORY OF NUCLEAR CONSTRUCTION

WNN: Nuclear Energy Capacity by major global region.



WNN: Nuclear Electricity Generation by major global region.



www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

AUTHORED BY

JASON MANN

Jason Mann leads FTI Consulting's Regulated Industries and Energy Markets group. With 25 years' experience of working in energy markets, Jason has worked extensively in the British energy market from the commencement of the liberalisation process to the current day. He has worked closely with regulated companies such as National Grid, the energy market regulator, Ofgem and wholesale market participants on the design and operation of the wholesale gas and power market. He also has extensive experience of network regulation and tariff setting – being closely involved since the 1990s in the development of regulatory regimes for gas and electricity networks. Jason is a leading advisor on the development and operation of cross border electricity transmission assets (known as interconnectors) – having advised more than 20 different projects throughout Europe, Australia and Southern Africa on a range of market, regulatory and valuation issues.

CONTRIBUTION OF INTERCONNECTORS TO DELIVERING SECURITY OF SUPPLY IN GREAT BRITAIN

UK REQUIRES MORE RENEWABLE GENERATION TO DELIVER NET ZERO

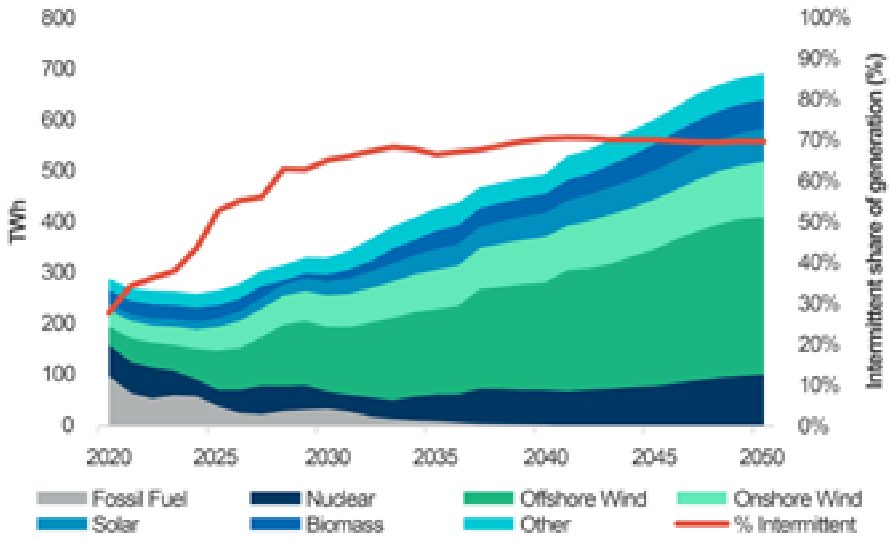
In 2019, the UK Government introduced legislation that requires the country to "end its contribution to global warming" and "bring all greenhouse gas emissions to net zero by 2050"[1]. The recent Energy White Paper set out the Government's vision for making this transition a reality and outlined a pathway for the UK to meet its Net Zero commitments[2].

The White Paper recognised that delivering the Net Zero commitment would require a fundamental transition in the electricity generation mix away from traditional thermal generation (including coal and gas) and towards renewable generation (such as wind and solar). The Government's 'Ten Point Plan for a Green Industrial Revolution' emphasized the need to increase renewable wind generation in particular, and set a target of 40GW of off-shore wind capacity in Great Britain ("GB") by 2030[3].

1 BEIS (2019)***, UK becomes first major economy to pass net zero emissions law***
2 BEIS (2020), ***Energy White Paper: Powering our Net Zero Future***, page 3
3 HM Government (2020), ***The Ten Point Plan for a Green Industrial Revolution***

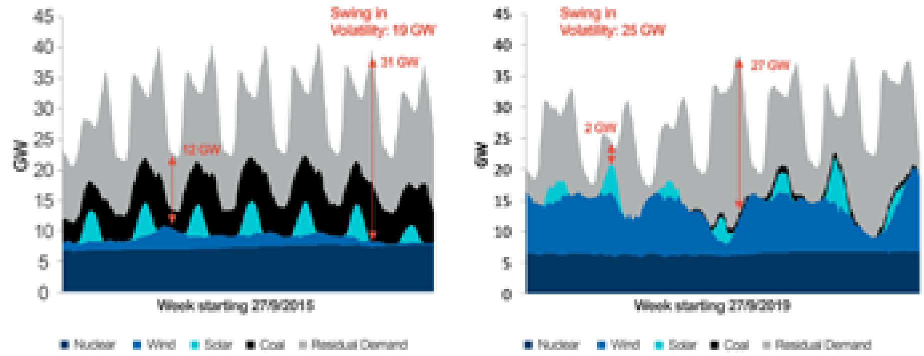
As a result, the share of power produced from renewable sources is expected to increase dramatically in the period to 2050, as set out in Figure 1-1.

Figure 1-1: Anticipated GB generation mix to 2050



Such a shift in the generation mix is unprecedented and is widely expected to pose significant challenges to the smooth operation of the electricity system, which needs to balance the supply and demand for electricity on a second-by-second basis. Specifically, growth in intermittent renewable generation is expected to lead to increasingly frequent periods with either "too much" or "too little" generation relative to demand, as set out in Figure 1-2

Figure 1-2: Imbalances between supply and demand in GB



Source: National Grid ESO; Elexon Balancing Mechanism Reports, FTI analysis.

As illustrated in Figure 1 2 above, large variations in what is referred to as "residual demand" will pose challenges for balancing the electricity system and maintaining what is generally referred to as "security of supply". The challenge is likely to become more acute as ageing coal and nuclear plants are due to be closed down in the next few years. Seasonal supply risks are also likely to exacerbate the challenge of maintaining security of supply during sustained periods of low wind speeds (e.g. during the summer).

Additional sources of flexible supply and/or demand will be required to help mitigate these challenges and help balance the electricity system.

INTERCONNECTORS CAN HELP TO ENHANCE THE SECURITY OF SUPPLY

Electricity interconnectors are cross-border transmission links that enable electricity to flow between two regions or countries. Interconnectors are one potential source of greater flexibility and can help to address what is often referred to as the "energy trilemma" (that is, improving security of supply while also reducing costs and carbon emissions).

Interconnectors help to address the energy trilemma (and, indeed support the transition towards Net Zero) by:

- acting as sources of flexibility and enhancing security of supply by connecting GB with multiple European regions;
- reducing carbon emissions by enabling exports of renewable generation from one region to displace thermal generation in another region; and
- enabling cost savings for consumers by transporting lower-cost electricity to regions of high demand and through their participation in "capacity mechanisms"[4].

Specifically, interconnectors can help to improve security of supply in GB by diversifying the electricity sources that the GB energy system relies on. This is because interconnectors provide greater access to other energy resources, particularly at times of "system stress". This might be, for example, when there is insufficient generation available to meet electricity demand (or, indeed, when there is too much generation for a given level of demand).

Interconnectors already provide GB with access to a broad range of energy resources by interlinking GB with neighbouring European regions, as set out in Figure 2-1. A recent Network Options Assessment by National Grid found that additional interconnection capacity between GB and European markets of 18-23 GW "would provide the maximum benefit for GB consumers".[5][6]

4 See section **Capacity mechanisms reward suppliers for being available**
5 National Grid ESO (2020), **Network Options Assessment.**
6 This is in line with a recent assessment by the European Commission's Expert Group on electricity interconnection that in countries where *"[interconnection] capacity is below 30% of their peak load… [or] below 30% of their renewable installed generation capacity, options for further interconnectors should be urgently investigated" to ensure that "electricity demand… can be met in all conditions… [and enable] export potential of excess renewable production"* (see: Commission Expert Group on electricity interconnection targets (2017), Towards a sustainable and integrated Europe).

Figure 2 1: Map of GB interconnection projects (operational and in planning)

Note: Operational projects illustrated with solid black lines; planned projects illustrated with dashed blue lines. Locations are indicative.
Source: FTI Consulting.

One feature of interconnectors is that they increase the extent to which the GB electricity system is reliant on external sources of supply. The availability of interconnectors is also dependent on external factors, such as the technical availability of the asset and the source country of imports.

Specifically, an interconnector would be unable to contribute to security of supply in the event of a technical outage. Technical faults on interconnectors are very rare but might happen, for example, if a shipping container or anchor displaced or interfered with the operation of a sub-sea cable. Managing such technical risks requires engineering solutions to make interconnectors more resilient to damage.

An interconnector would also be unable to contribute to security of supply in the event of simultaneous system stress in multiple regions. In this case, there might well be available capacity on the interconnector, but insufficient generation in the neighbouring system.

However, concerns regarding the availability and reliability of generation assets are by no means limited to interconnectors. Indeed, no source of supply is fully reliable, and all types of generation assets are prone to breakdown and outage from time to time. As we explain below, policymakers have recognised the nature of these challenges for some time and developed bespoke mechanisms to ensure that suppliers have strong incentives to be available to support system needs as much as possible in moments when supplies are short.

CAPACITY MECHANISMS REWARD SUPPLIERS FOR BEING AVAILABLE

In 2014, policymakers in GB (in common with many other European governments) introduced a capacity mechanism known as the GB Capacity Market ("CM") to mitigate concerns regarding the security of supply in the context of a rapidly decarbonising electricity sector.[7]

The CM operates alongside the wholesale electricity market and rewards providers of generation capacity for being available to generate electricity at time of system stress or scarcity, while the wholesale electricity market continues to reward generators for the actual output generated. Interconnectors were incorporated into the CM in 2015.

The CM operates in the form of an auction where the overall amount

7 DECC (2014), ***Capacity Market Rules.***

of capacity that is required is set by the UK Government. This "target capacity" is expressed as a range, and represents the demand curve for the CM[8]. Providers of generation capacity then bid into the market until the auction clears. Generators who are successful in their bids are awarded the auction clearing price for providing generation capacity and, in turn, have an obligation to be available to generate electricity in the event of system stress or scarcity.

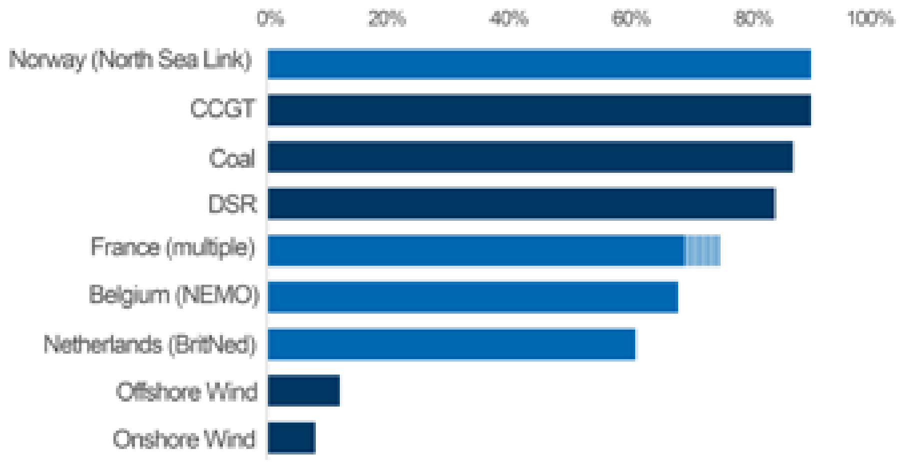
One proxy measure of an asset's ability to contribute to security of supply is its CM "de-rating factor" – which an estimate of the *"realistic long-run expectation of imports at times of system stress"*.[9] De-rating factors determine the share of capacity that generation and interconnector assets can be committed to be available at times of system stress in return for capacity payments, with more reliable assets receiving higher de-rating factors.

The latest modelling from National Grid, summarised in Figure 3-1, suggests that existing and proposed GB interconnectors can provide a similarly secure supply of power to the coal and combined cycle gas turbine ("CCGT") plants that have been traditionally used to maintain security of supply. Policy Exchange, a UK-based think-tank, also considers that *"existing interconnectors have demonstrated a greater level of reliability than Ofgem assumes for almost all forms of generation. They are very reliable"*.[10]

8 For example, in the T-4 auction for Delivery Year 2023/24 (held in 2020), the target capacity (corresponding to the demand curve) was set between 42.1 GW and 44.1 GW. See NG ESO, Capacity Market Auction Guide lines (2020), page 4

9 DECC (2015), ***Announcement of de-rating methodology for interconnectors in the Capacity Market.***

10 Policy Exchange (2014) ***Getting Interconnected: How can interconnectors compete to help lower bills and cut carbon?***



Note: De-rating factors for generation assets are illustrated in navy while de-rating factors for interconnector assets are illustrated in blue. De-rating factors for interconnectors between GB and France are in a range which is represented by a dashed bar. De-rating factors are re-estimated annually, and interconnector de-rating factors in particular have varied from year to year.

Source: National Grid ESO (2019), Electricity Capacity Report; National Grid ESO (2020), Interconnector De-Rating Analysis.

The reliability of interconnectors varies across borders and the de-rating factors for individual interconnectors reflect the technical and market risks for each specific interconnection asset. For example, the reliability of North Sea Link, which connects GB to Norway, is very high at c. 90%, while the reliability of interconnectors between GB and France is in the range of c. 69-75%. Ultimately, the reliability of any particular interconnector is determined by the availability of generation in the source country of imports. (In the case of Norway, hydro generation is very reliable and frequently available. In comparison, the generation mix in Ireland is heavily skewed towards wind and gas and not always readily available when the GB market is experiencing system stress or scarcity.)

OPPORTUNITY COST OF NOT USING INTERCONNECTORS IS HIGH

Interconnectors, by their design, help to maintain security of supply by connecting GB with other European markets. They also help to reduce carbon emissions by enabling imports of renewable generation into GB, and deliver cost-savings to consumers (thus ensuring the affordability of customer bills). Nevertheless, they increase the dependency of the GB electricity system on external sources of supply.

It is reasonable to consider and to 'weigh up' the benefits and costs of interconnectors relative to other types of generation assets in terms of their contribution to security of supply in GB and the UK's ability to deliver on its commitment to Net Zero. However, it is widely accepted that delivering Net Zero without relying on interconnectors as a source of flexibility could be extremely costly. This is because, in the absence of sufficient interconnection, GB would need to rely much more heavily on other types of generation technologies, including thermal generation, pumped hydro, battery storage, and demand-side response ("DSR").

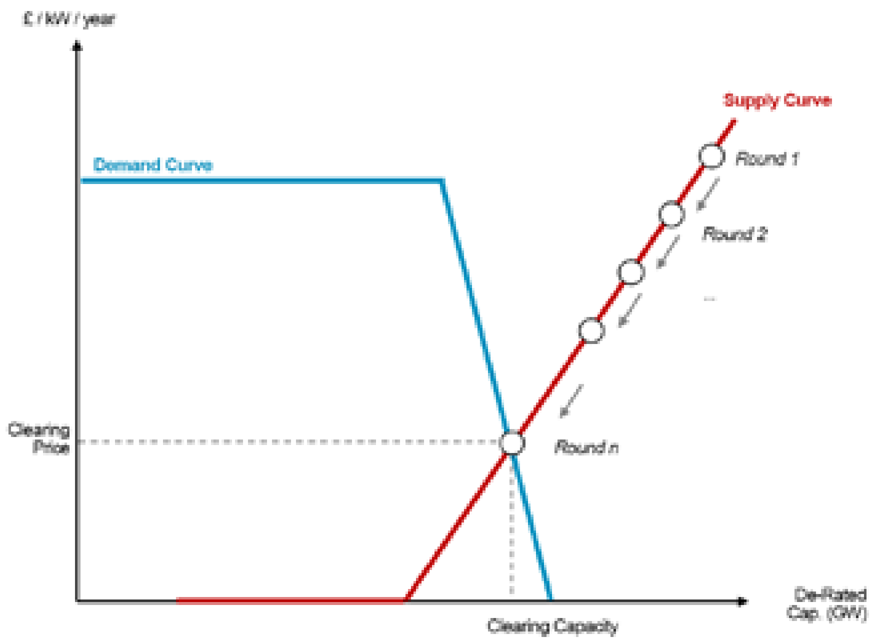
We have considered and estimated the cost to GB consumers of not using interconnectors to maintain current levels of security of supply with reference to the performance of interconnectors in recent CM auctions.[11] Overall, we estimate that the absence of 5.3GW of interconnector capacity would increase the cost of ensuring security of supply to customers by as much as £456 million per year. This is significant and suggests that not employing interconnectors as part of the package of measures to deliver Net Zero could potentially create risks for the delivery of that commitment.

11 See next section **Analysis: Cost of not using interconnectors**

ANALYSIS: COST OF NOT USING INTERCONNECTORS

The GB CM operates as a descending price auction. Prices start at a pre-determined cap (which in recent years has been set at £75 per kW per year), and are progressively reduced, moving down the supply curve. As prices fall, an increasing volume of capacity 'drops out' of the auction, reducing the total capacity remaining. The auction clears when the total remaining capacity is equal to the Target Capacity. This is illustrated in Figure 5-1 below.

Figure 5-1: Illustration of GB CM auction

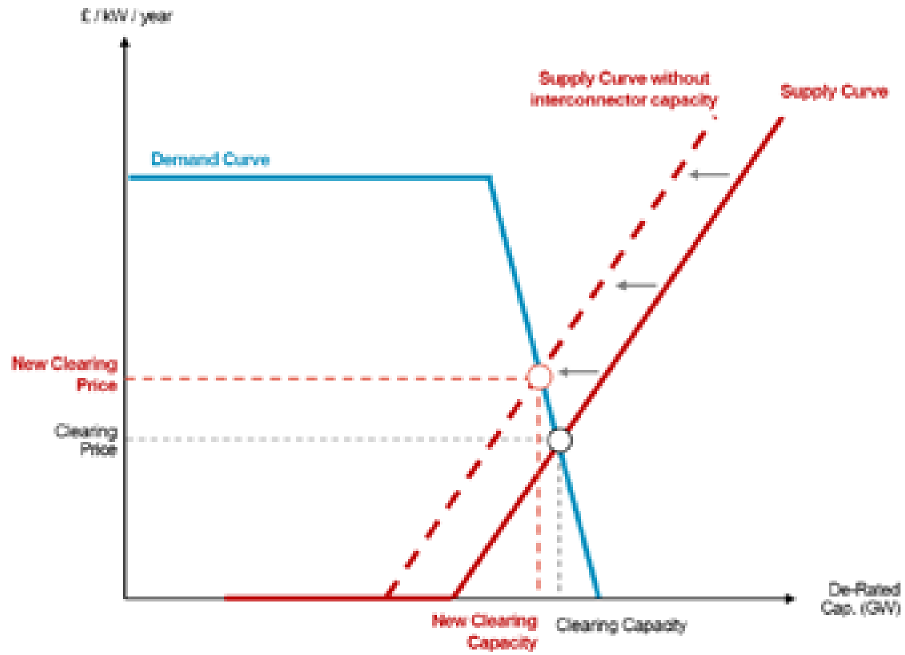


GB CM intersect, the auction clears at the "Clearing Price", and a certain volume of "Clearing Capacity" is procured.

By participating in the GB CM, interconnectors have an impact on the auction clearing price, and therefore the price paid by consumers for GB security of supply.

All else equal, reduced interconnector capacity is likely to result in a rise in the GB CM clearing price, thus increasing the cost paid by consumers for security of supply. In the absence of interconnectors in the CM, the supply curve would shift inwards, causing the point of intersection between the supply and demand curves (that is, the Clearing Price) to rise. This is illustrated in Figure 5-2 below.

Figure 5 2: Illustration of GB CM auction with a 1GW increase in de-rated capacity



In this way, the impact of the absence of GB interconnectors' additional interconnection capacity on GB CM clearing prices, and subsequently the total cost paid by consumers for security of supply, can be estimated. In the

T-4 Auction for Delivery Year 2023/24, held in early 2020, the GB CM cleared at **£15.97/kW/year**, with a total of **43.7GW** procured.[12] This gives a total cost of £699 million per year, funded through customer electricity bills, paid for security of supply.[13]

Assuming linear supply and demand curves, we can estimate the effect of the absence of GB interconnectors on the GB CM clearing price. In the T-4 Auction for Delivery Year 2023/24, around 5.3GW of (de-rated) interconnector capacity participated in the GB CM.

By calculating an inward shift in the GB CM supply curve, we estimate that the absence of 5.3GW of de-rated interconnector capacity could have caused the GB CM clearing price to rise to as much as **£26.51/kW/year**, with a total of **43.6GW** procured. This gives a total cost of **£1,155 million** paid for security of supply, per year.[14] That is, the absence of 5.3GW of interconnection capacity could have increased the cost of security of supply for consumers by as much as **£456 million per year**.[15]

12 National Grid ESO (2020), T-4 Auction (Delivery Year: 2023-24) - Published Round Results.
13 Calculated as the CM clearing price multiplied by the total GW procured: £15.97/kw/year x 43.7 GW.
14 Calculated as above: £26.51/kw/year x 43.6 GW.
15 Calculated as the difference between the two totals: £1,155m - £699m.

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AUTHORED BY

LIAM FOX

The Rt Hon Dr Liam Fox MP has been Member of Parliament for North Somerset since 1992. Dr Fox held several roles in John Major's Government, including as a Foreign & Commonwealth Office Minister. Between 1997 and 2010, he held several roles on the Conservative Party Opposition Front Bench such as Constitutional Affairs Spokesman, Shadow Health Secretary, Conservative Party Chairman, Shadow Foreign Secretary and Shadow Defence Secretary. Dr Fox served as Secretary of State for Defence in David Cameron's Government from May 2010 until October 2011. Between July 2016 and July 2019, he served in Theresa May's Government as Secretary of State for International Trade and President of the Board of Trade. As International Trade Secretary he was tasked with creating the UK's first Independent Trade Policy for forty years post-Brexit. Before entering politics, Dr Fox worked as an NHS doctor and then as a family GP. He is also a former Civilian Army Medical Officer and Divisional Surgeon with St John Ambulance. In 2012, he founded the military charity 'Give Us Time'.

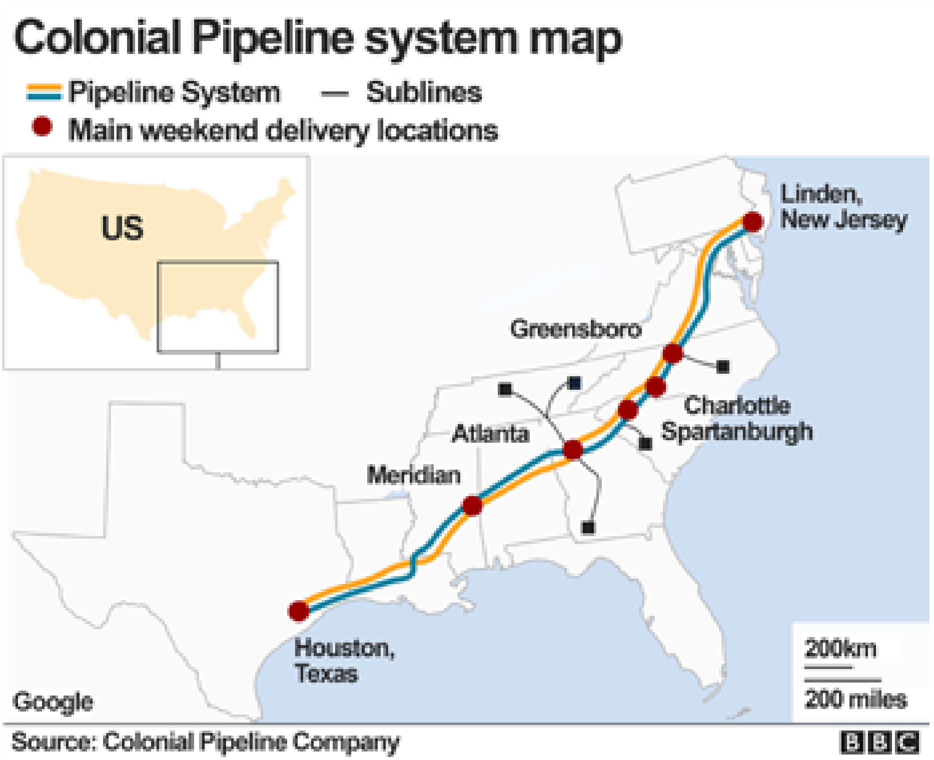
CYBER INTRUSION, STRATEGIC VULNERABILITY

As we have become more dependent on technology to lubricate the wheels of our everyday activities, so we have become more vulnerable to either the failures of the technologies themselves or our ability to access them. As we incorporate greater sophistication, including such elements as artificial intelligence, into our systems there is a real risk that we will sacrifice resilience as we strive for greater efficiency. That will certainly be true if we do not incorporate cyber security as an essential component of our systems.

It is an old adage that crime doesn't pay but we all know that some crimes pay better than others. Cybercrime has at least three elements which make it more attractive to potential criminals: it is generally low risk and high-return, it largely has the advantage of anonymity and it is often goes unreported. While estimates of the cost of cybercrime vary, it is estimated that the annual global cost runs somewhere between hundreds of billions and trillions of dollars. Contrary to the image so often portrayed in our newspapers and broadcast media, cyber criminals are not typically the sad geeky teenagers trying to impress others with their ability to hack into big organisations but veritable armies of terrorists, agents of hostile states or drug cartels. They use fraud and extortion to fund their activities and do so on a truly industrial scale. Essentially, where there is connectivity, there is a risk of cyber-attack and the global energy industry is a prime target.

THE COLONIAL PIPELINE ATTACK

On Friday, 7 May, Colonial Pipeline, a company that supplies nearly half the fuel for the US East Coast, was subject to a ransomware attack. Ransomware is a type of malware that threatens to publish the victim's personal data or perpetually block access to it unless a ransom is paid. On May 10, the FBI confirmed that the attack was the work of DarkSide, a criminal group, possibly based in Russia, which first surfaced in 2020. The Colonial Pipeline attack is being regarded as one of the most significant yet seen on critical national infrastructure. It is reported that DarkSide successfully extorted about 75 Bitcoin (almost US$5 million) from the company. It has not yet been determined whether the attack was an entirely criminal one or whether there might have been any involvement of a state sponsor, such as Russia.



Having locked Colonial Pipeline's computer systems, DarkSide then stole over 100 GB of corporate data. This fits with their known modus operandi of demanding payment to unlock affected computers, payment for the return of captured data and the threat to publish stolen data if victims do not pay. DarkSide double down on their criminality by their willingness to sell information about upcoming victims so that other financial criminals can short the company's stock.

According to security expert Brian Krebs, DarkSide started recruiting new affiliates in April 2021 " mainly seeking network penetration testers who can help turn a single compromised computer into a full-on data breach and ransomware incident".

On 12 May, they announced they announced they had stolen 1.9GB of data from three new victims – a Scottish construction company, a renewable energy product reseller in Brazil and a technology services reseller in the United States. This included client data, financial data, employee passports and contracts.

It is thought that, in common with similar attacks, the administrative side of the business may have been the more vulnerable point of entry for the cyber criminals rather than the better protected operational technology. It is possible that hackers could have been inside Colonial's IT network for some time before launching the ransomware attack. This would be far from unprecedented.

In 2014, for example, the banking giant JP Morgan had cyber criminals sitting on their servers for over two months before being detected – around 76 million personal accounts were compromised along with 7 million business accounts.

Entry may be far from difficult as hackers can get a foothold in a network by something as simple as getting an employee to open an email that results in downloading malware.

The Colonial attack resulted in a swift response from the US federal government. On May 12, President Biden issued an order stating that: "The United States faces persistent and increasingly sophisticated malicious cyber campaigns that threaten the public sector, the private sector, and ultimately the American people's security and privacy. The Federal Government must improve its efforts to identify, deter, protect against, detect, and respond to these actions and actors. The Federal Government must also carefully examine what occurred during any major cyber incident and apply lessons learned. But cybersecurity requires more than government action. Protecting our Nation from malicious cyber actors requires the Federal Government to partner with the private sector. The private sector must adapt to the continuously changing threat environment, ensure its products are built and operate securely, and partner with the Federal Government to foster a more secure cyberspace".

Amongst other things, the presidential order seeks to standardise federal responses to cyber incidents and requires IT service providers to inform the government about cybersecurity breaches that could impact U.S. networks. The order requires upgrading of government services to secure cloud services and other cyber infrastructure, and it mandates the deployment of multifactor authentication and encryption with a specific time period. It also establishes a "Cybersecurity Safety Review Board" made up of both public- and private-sector officials, which can convene after cyber attacks for analytical purposes and to make any necessary recommendations. The Colonial Pipeline, while it has attracted a great deal of political and public attention, is merely the latest in an increasingly long list of attacks on parts of the global energy industry.

ENERGY CYBER ATTACKS

In February 2020, the U.S. Department of Homeland Security issued an alert about a ransomware attack that brought down a U.S. natural gas compressor facility for two days. It appears that hackers used a phishing

attack to gain control of the facility's information technology system. This allowed them to explore the facility's network and disable normal security processes that might prevent malware intrusion.

In November 2019 Petroleos Mexicanos, the Mexican national oil company reported a cyber-attack that crippled its computer systems for several weeks. The hacker (s) tried to extort some $5 million.

In April 2018, several U.S. natural gas pipeline operators including Energy Transfer Partners LP and TransCanada Corp. reported that a third-party electronic communications system had been hit with a cyber-attack. Five of the companies confirmed service disruptions from the hacking.

In August 2017 Saudi Aramco became the target of cyberattacks when the safety system in one of the company's petrochemical plants was hacked. An official at the plant was quoted as saying that the attack was intended, not only to shut down the plant or wipe out data, but also to send a political message. Experts traced the attack to a Russian Government-owned laboratory.

In December 2016, almost a quarter of Ukraine's power grid was taken down by hackers. It was the second attack in less than a year and left customers in parts of Kiev without electricity for an hour. The attack was blamed on Russian hackers who knocked out at least 30 of the country's 135 power substations for about six hours. A year earlier, in Dec 2015, hackers managed to cut off the supply to 225,000 households. A US report into the blackout concluded that a virus was delivered via email through spear-phishing – a technique that sends key employees detailed messages using information gathered from social media. It was a similar type of attack that compromised more than 30, 000 computers at Saudi Aramco in 2012.

In Dec 2014 hackers stole and posted online the plans and manuals for two nuclear reactors, as well as the data of 10,000 employees when the South

Korean nuclear and hydroelectric company Korea Hydro and Nuclear Power (KHNP) was hacked. While the US blamed North Korea, the Koreans claimed the source of the attack was in China.

In May 2020, the U.K.'s grid data system was hacked, although electricity supplies weren't affected.

ENERGY AS A TARGET

In many ways, the threats in the cyber domain to the energy industry are the same as those affecting other sectors – ransomware, billing fraud or theft of data. In other ways, however, there are heightened vulnerabilities as a result of legacy issues, poor design or the increased activity of cyber criminals against utilities. Older generation systems which were designed in an era where the cyber threat was not considered risk disruption of service. Weaknesses in physical security which do not properly safeguard access can make grid control systems vulnerable and so, disruption of transmission. Models of distribution can leave substations vulnerable to attack with consequent disruption of customer services and the large surface area of a modern network produces its own vulnerability.

In an excellent report for McKinsey, Tucker Bailey, Adam Maruyama, and Daniel Wallance set out three characteristics that they believe make the energy sector particularly vulnerable to contemporary cyber threats.
The first threat relates to the "popularity" of energy targets for both cyber criminals and nation state actors seeking to create economic, security and political dislocation. They are also potential targets for extremist environmental activists who wish to disrupt energy supply as part of their wider political agenda.

The second threat is the expansive and increasing surface area of the energy industry related to geographical and organisational complexity, including the decentralised nature of cybersecurity leadership and organisation.

The third threat relates to the unique interdependence between physical and cyber infrastructure that typifies the energy sector. A number of elements may lead to greater exploitation, including the use of smart meters where billing fraud is becoming an increased risk, potential commandeering of operational technology systems to stop multiple wind turbines and even physical destruction.

WHAT CAN BE DONE?

As mentioned earlier, the desire to see increased efficiency in systems can also result in unintentional problems with resilience. In an industry which has moved away from simply being a collection of pipes to an increasingly complex range of thermostats, pressure sensors, valves and pumps that control the flow of fuels across hundreds of miles, the risks to the resilience of the system are obvious. This is particularly so if the threat of cyber intrusion, and the mechanisms to prevent it, were not built into the original design models. In the case of Colonial Pipeline, for example, an inspection gauge robot (the so-called "smart pig") constantly moves through the pipe network checking for anomalies rather than human inspection activity.

Broadly, industry experts suggest three areas where cyber vulnerability can be reduced. There needs to be better strategic intelligence about the type of threats faced by the network including a better understanding of the nature of cyber criminals acting independently or as agents of a hostile state. This implies better information sharing between private industry and government including discussions about where potential witnesses may lie in systems design. Security awareness and protection must be built-in to corporate expansion especially when it involves an increase in infrastructure and geographic complexity.

A culture of security needs to be built-in across the whole of the business. Cyber security cannot simply be the responsibility of an IT department. Company boards must see protection and defence against cyber intrusion as being everybody's business, up to the highest part of the executive chain. There must also be robust processes to determine and report potential vulnerabilities and a willingness to report emerging incidents, early and thoroughly. Technical systems also need to be able to provide a complete picture across geography and business units to ensure an ability to detect coordinated attacks and patterns.

There also needs to be better collaboration across industry to deal with the problems associated with the increasing convergence of physical and virtual threats. The culture of denial of attack must be rooted out as the misplaced notion of protecting corporate reputation can fundamentally undermine the security of the business. This, in turn, affects the service to, and the protection of, customers. The links between physical and virtual infrastructure need to be constantly reviewed as well as IT and OT networks.

THE STRATEGIC UNDERBELLY

Even when energy security and resilience are dealt with through the wide range of issues discussed so far, political and foreign policy considerations can produce new, dangerous and far reaching implications. Probably the best example of this lies in the case of Nord stream where German policy, designed to ensure Russian gas supply for German industry, threatens to become a strategic liability for her allies.

The original Nord Stream is owned and operated by Nord Stream AG, whose majority shareholder is the Russian state company Gazprom. Nord Stream 2 is owned and will be fully operated by Nord Stream 2 AG, which is also a wholly owned subsidiary of Gazprom. Given the close links to the Kremlin, there is no doubt about who pulls the strings.

The laying of the first line was completed on 4 May 2011 and the first gas was pumped into it on 6 September.The pipeline was officially inaugurated in Lubmin, with great fanfare, by the German Chancellor Angela Merkel,

Russian President Dmitry Medvedev, French Prime Minister François Fillon, and Dutch Prime Minister Mark Rutte on 8 November 2011. Completion of the second line occurred in August 2012 with inauguration on 8 October.

Even before the completion of the first and second lines, Nord Stream AG had begun the evaluation of an expansion project consisting of two additional lines (later named Nord Stream 2) to increase the annual capacity up to 110 billion m3 (3.9 trillion cu ft). This coincided with the decision of Chancellor Angela Merkel's coalition, following Japan's Fukushima Daiichi nuclear disaster, that Germany's 17 nuclear power stations would be shut down by 2022.

In 2011, In August 2012, Nord Stream AG applied to the Finnish and Estonian governments for route studies in their underwater exclusive economic zones. Plans to route additional pipelines to the United Kingdom were abandoned as the political relations between London and Moscow soured, a process that has continued to this day.

On 31 January 2018, Germany granted Nord Stream 2 a permit for construction and operation in German waters and landfall areas near Lubmin. In May 2018, construction started at the Greifswald end point. The subsea pipeline is 759 miles (1,222 km) long and Gazprom has also bought an abandoned mine a in Waren, some 160 km north of Berlin, which it plans to convert into the largest underground gas storage in Europe with capacity of 5 billion m3 (180 billion cu ft).

Opponents have seen the pipeline as a move by Russia to bypass traditional transit countries (currently Ukraine, Slovakia, Czech Republic, Belarus and Poland). Some are of these countries, understandably, believe, that this is part of a long-term strategic plan from the Kremlin, designed to exert political influence on them by threatening their gas supply without affecting supplies to Western Europe.

Ukraine, in particular, which has had part of its sovereign territory invaded and occupied by Russia quite reasonably fears that the Moscow leadership will be only too quick to use energy as a political weapon. This fear has been exacerbated by Russia's failure to sign the Energy Charter Treaty, the international agreement that establishes a multilateral framework for cross-border cooperation in the energy industry including transit and investments.

According to the Naftogaz chairman in 2019, Ukraine will lose $3 billion per year of natural gas transit fees from Nord Stream 2. Gazprom itself has clearly indicated that it will divert 20 billion m3 (710 billion cu ft) of natural gas transported through Ukraine to Nord Stream, so it is not difficult to see the direction of travel in Russian policy.

Critics of Nord Stream in other European capitals (as well as the European commission and the European Parliament) believe that Europe could become dangerously dependent on Russian natural gas, particularly since Russia could face problems meeting a surge in domestic as well as foreign demand. This, predictably, has cut no ice in Berlin where the decision to axe the nuclear industry (with no clear plan on how to replace its generation capacity) has left the government there with few policy options. Despite repeated and fervent criticism at the highest political levels, Germany insists on putting its own energy supply for German industry first, even if that means undermining the security of its allies, including NATO members.

The former Swedish Minister for Defence, Mikael Odenberg, has made clear that the pipeline can cause a security policy problem for Sweden as the pipeline could be used as a pretext for a Russian navy presence in the Swedish economic zone (enabling the Russians to use this for military intelligence should they want to). These fears, echoed in neighbouring states, were exacerbated when Vladimir Putin stated that the ecological safety of the pipeline project will be ensured by using the Baltic Fleet of the Russian Navy.

The Nord stream 2 project has also, predictably, increased tensions between Germany and the United States.

In June 2016, a bill passed by US senators 98-2 prompted a joint response from Sigmar Gabriel, Germany's foreign minister, and Christian Kern, Austria's chancellor.

The bill was designed to strengthen sanctions against Russia, given the fear that the incoming Trump administration would soften its stance against Moscow. The bill, which had bipartisan support, would penalize key sectors of Russia's economy, as well as those identified as hackers who carried out cyberattacks on behalf of the Russian government.

The German and Austrian ministers (both left-leaning Social Democrats) wrote that "Europe's energy supply is a matter for Europe, and not for the United States of America!" They continued that to threaten European firms also active in the US with sanctions, if they took part in Nord Stream 2, thrust "a completely new, and very negative dimension into European-American relations,". Even more contentiously, they added "In noticeable frankness, the draft US legislation describes what it's really about: the sale of American liquefied petroleum gas and the squeezing out of Russian natural gas from the European market".

A In short, the view from Berlin and Vienna could be interpreted to read that how American taxpayers' money was spent in the defence of Europe was a matter for them through NATO, but how Germany and Austria behaved in relation to energy security was purely a matter for them, even if it had a strategic impact on the rest of the alliance.

In January 2019, the US ambassador in Germany, Richard Grenell, sent letters to companies involved in the construction of Nord Stream 2 urging them to stop working on the project and threatening them with the possibility of sanctions.

The US Secretary of State, Antony Blinken has reiterated the view of previous US administrations, both Republican and Democrat, that the pipeline is a Russian geopolitical project intended to divide Europe and weaken European energy security.

As President Biden put it "Nord Stream 2 is a bad deal — for Germany, for Ukraine, and for our Central and Eastern European allies and partners". It remains an unresolved, and potentially toxic, issue at the heart of transatlantic, and European, politics and security.

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