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Low Cost, High Security Energy

Preventing the next energy crisis

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Executive Summary

The last year has made the UK's vulnerability on energy terrifyingly clear - prices have rocketed to previously unthinkable levels and National Grid has warned of blackouts being imposed this winter because of uncertainties in gas supplies.

The government has sought to mitigate the immediate bill crisis. But now it must ensure we move to a secure, low-cost energy system. Work to prevent the next energy crisis needs to start today. Having previously been a policy area of interest almost exclusively to sector specialists, energy policy has become a tier one policy issue for the public as a whole.

In this report we investigate what a credible plan might entail. In doing so, we combine new modelling, policy analysis and opinion research to ensure that a plan would work, but also be acceptable to voters in the real world. Amid a cost of living crisis, it is even more important that ordinary families' experiences and attitudes are taken into account; no Government can or would move on energy policy in the face of implacable opposition.

We test public receptiveness to key energy concepts via a poll of 2,000 adults and four focus groups. From this, we draw conclusions about what can - and must - be done now to create a low cost, high security energy system that will protect us from the energy crises of the future.

We then establish five different energy strategy scenarios informed by public opinion and by dozens of interviews with sector experts, MPs and policymakers. We test them against two key criteria - energy security and cost to households - unlike most recent reports on this topic, we do not start with cutting carbon as one of our criteria.

To investigate these scenarios we built a model of the UK's energy system. A model that relies on well-respected industry assumptions from National Grid ESO, that allows us to interrogate the impact of a wide range of possible policy interventions across oil and gas, choices for electricity generation, and different types of household consumption.

The five scenarios we compare were chosen for their ability to test different facets of our political debate about energy and answer questions posed during our interviews with political stakeholders.

We investigate the impact:

1. of taking no action now to change our energy mix
2. of sticking with the Net Zero strategy
3. of trying to be 'even more green'
4. of focussing instead on fracking and nuclear; and
5. of looking to pull every lever available to government

(a full summary of each scenario can be found here).

Having approached the energy challenge from these multiple directions, we conclude the following:

- **The public back a move towards energy independence.** They remain worried about their livelihoods this winter and want to hear a plan to ensure that the current energy crisis never happens again. They also continue to favour renewable technology over coal, oil and fracking - and believe that renewables will be cheaper in the long run as well as reducing our reliance on imports.

- **We must build new energy supply, faster.** If we continue to increase domestic supply at current rates, we will be highly dependent on imports of gas and electricity, and unable to bring down household bills. In the last five years we have added less than 1GW of offshore wind capacity per year. If we accelerate to meet the target in the British Energy Security Strategy of between 4 and 5GW per year, we can reduce household bills and become a net exporter of electricity by 2030.

- **We must act swiftly to reduce domestic demand for gas.** The roll out of heat pumps and energy efficiency measures makes a similar contribution to reduced imports in 2035 as does shale gas in the most optimistic scenario for fracking. However, heat pumps and insulation would reduce energy demand permanently, make bills cheaper and save government money.

- **Wind is cheap and secure and we need more of it.** Any scenario with a rapid increase in wind supply does better – on household cost and on security grounds – than one without. That is also true when we factor in the costs of intermittency (that is, keeping the lights on when the wind doesn't blow): even at 80% reliance on intermittent generation, the cost of generation PLUS intermittency costs is lower than gas generation alone.

- **Changing our energy system protects future bill payers against external shocks.** Reducing gas demand in the power sector and increasing our reliance on home-grown, zero-marginal-cost renewables insulates families from the kind of energy bill shock seen this year as a result of the invasion of Ukraine. Specifically, our modelling finds that should a similar gas price event happen in 2040, a typical household bill (for a household running an EV and an Air-source Heat Pump (ASHP)) would be £1,049 cheaper in the Net Zero Focused scenario than in the Do Nothing scenario.[1] Furthermore, this price shock in which gas prices jump by almost 400% leads to household's bill rising by only £22 in the Net Zero Focused scenario.

- **In order to fully benefit from lower costs, we also need to reform the energy market.** Generating more power from zero-marginal cost wind won't benefit households if wholesale electricity prices continue to be set by high cost gas. The Government is right to recoup some of the excess profits being made now by renewable energy generators. In the longer term, the vast majority of renewable generation will be on contracts for difference (CfDs), removing this distortion. Policy in the near term needs to be well designed so as to understand bidding incentives, not discourage future investment, and not to be punitive to generators who have hedged. Such well-designed market reform has the potential to save households in the region of £400 each year.

In addition to the modelling, we examined the latest research on energy security and the ways in which increasing renewable energy sources both helps and threatens the security of our electricity supply. Combining this with our opinion research, we conclude that:

- **Critics are right to worry about intermittency, and the government should be held accountable for delivering plans to manage it.** A plan on paper – however realistic (and a realistic one exists) – is not sufficient. The government urgently needs to make it easier for projects that enhance power system flexibility to get moving, and should hold itself to account by committing to an annual assessment of what that worst case scenario might be and requiring the System Operator to assess its readiness against that scenario. <u>We recommend that, as a starting point, this should test the ability of the electricity system to cope with maximum wind lull that lasts for two weeks straight.</u> This 'Energy Stress Test' will help to instil confidence as we transition into new energy technologies with which the market is less familiar.

[1] A household still reliant on a gas boiler would still benefit from a significant, albeit lower, saving of £429

- **In the near term, we do need gas storage and gas generation.** In a highly renewable world, gas supply (which could include fracking), and gas storage, is vital for both baseload (permanent power) and flexible capacity (power that switches on and off).

- **In the medium term, we should prioritise diversity of supply and keep our options open.** That means building more nuclear capacity, accelerating the development of green hydrogen so it can be deployed when cheap enough, and increasing market flexibility and keeping our gas storage and generation available. Building a green hydrogen economy would also allow us to capture excess generation - when the wind blows too much - and build up energy stockpiles to insure us against future crises.

Overall, the different strands of our research show that the Net Zero Strategy and British Energy Security Strategy, with an additional focus on energy efficiency, represent our best chance of reducing household bills and ensuring long-term energy security for the UK. The real debate lies not in whether to deviate from this plan but in how the government can accelerate our progress to actually delivering it.

Introduction

In the energy industry it used to be the norm to discuss the energy 'trilemma' of a) security of supply, b) environmental impact and c) affordability.

Over the past decade, the emphasis of debate and Government action on energy has been firmly upon the environment. But even as the COP 26 delegates departed for their own countries last November, attention was switching to price. Gas prices, at double, even triple their historic norms, led to the failure of 30 suppliers in the UK, leaving behind c.£4bn (and rising) of debts. Prices continued to rise through the end of 2021, crossing 200p/therm, a previously unimaginable level, in the days before Christmas. Nonetheless, as prices rose, government and National Grid were expressing confidence that this did not mean a supply shortage that should worry UK consumers.

What is a therm?

Energy policy comes with its own jargon and confusing sets of units. These can be off-putting to the non-specialist. That is especially the case for gas, which in the UK is measured either by its energy content in therms, BTUs or kWh, or by volume in mcm or bcf. Throughout this report we will use therms as we believe they are the easiest to visualise. Technically, a therm is the energy required to raise the temperature of 100,000 pounds of water by one degree Fahrenheit. A more useful visualisation is that a therm is approximately one day of household use. The 'normal' wholesale price of a therm of gas over the last decade has been around 40p.

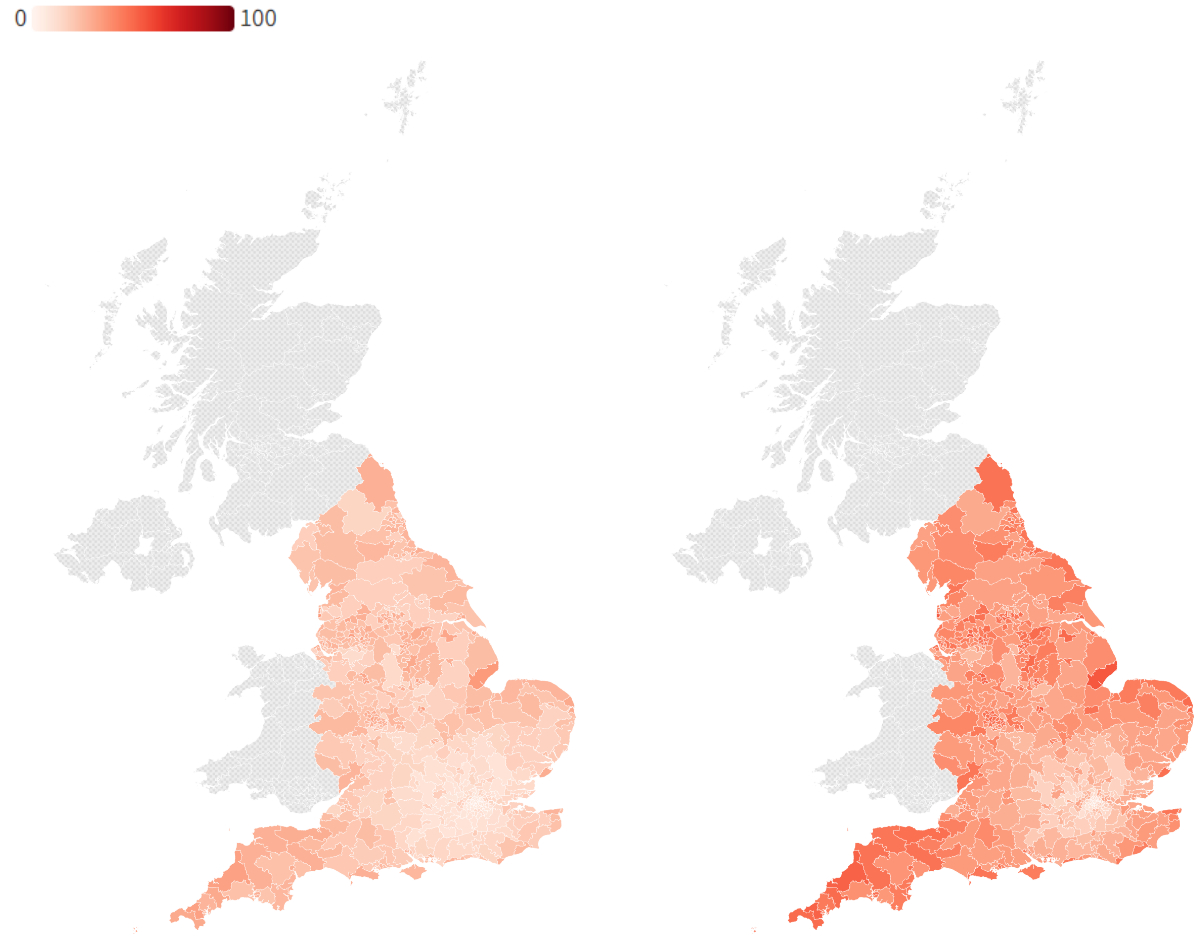
Russia's invasion of Ukraine, and their subsequent constriction of supplies of gas into Europe changed that. In August 2022, gas prices topped 700p/therm - around 17 times their historic level - as European countries rushed to fill their gas storage facilities ahead of winter. This was a market that was now pricing in the risk of supply being unable to meet demand. We have been rudely reminded of the importance of security of supply. The resulting Energy Price Guarantee, which seeks to hold bills for a typical household's consumption to £2,500, being, one of the biggest fiscal commitments in peace-time UK history, with a cost just less than the Covid furlough scheme even now it has been limited to just six months.[2]

[2] House of Commons Library, *Coronavirus Job Retention Scheme: statistics*, December 2021

Figure 1: UK wholesale gas price

Even with this intervention, price increases will have real and devastating impacts on everyday life. Even if the intervention announced by Liz Truss in September 2022 were continued beyond six months, we would see 34% of the UK will be in 'fuel poverty' (defined as spending more than 10 per cent of their household income on energy). And as the new government has committed to a less costly scheme, it can be assumed that this is a lower bound..

Figure 2: Distribution of households in England in fuel poverty summer 2022 and summer 2023



Summer 2022: c.5 million households

Summer 2023: c.8 million households

Layered on top of that financial stress are the diplomatic pressures caused by reliance on foreign energy sources. Russia is harnessing its position as a major supplier of gas to Europe as a tool in their war against Ukraine. By cutting off gas supplies, Putin hopes that either EU decision makers will cave to Russian demands for non-interference in the war, or that the public will rise up to demand the same.

This situation is unlikely to be a temporary phenomenon (even if spot prices fall, futures are likely to continue to price in the risk of further supply squeezes). Prices for UK consumers have risen for a set of complex and interconnected reasons that can be broadly summarised as:

- Increasing demand for oil and gas as the world recovered from the disruption of Covid,
- Failure of producer companies to increase supply due to labour disputes, bad weather, and dwindling stocks, and
- Disruption to Russian supply caused by sanctions linked to the Ukraine war.

While a global recession might drive down demand, that is an unsustainable solution to high energy prices. Meanwhile, uncertainty over the quantity of supply seems set to continue and recent damage to the Nordstream pipelines means we won't soon be seeing major inputs of Russian gas, even if the Ukraine war were to come to an end swiftly. The world is a more tense and turbulent place than it was before Putin's tanks rolled across the border.

This is a very different world to a decade ago, when we debated long and hard about how to make sure that customers who did not regularly change their energy supplier didn't suffer from a 'loyalty penalty' of £110[3] and it makes political battles over whether to build our own renewable energy sources (especially offshore wind) look myopic at best.

Our report is in two parts:

Part One asks the British public what they think.

Policy decisions in energy are frequently technocratic rather than being based on what the public wants. We used a nationally representative poll and focus groups to ensure that those making policy decisions can see what the public cares about and how they value different trade offs.

In the past decade, the UK's electricity system has altered radically but it has largely been out of the sight of the public. Sky high costs will mean far more scrutiny of energy policy over the next few years and politicians must be prepared for that. We find rising concern about the apparent lack of a plan from Government to make our energy cheaper and less dependent on imports. The public also remains fairly committed to energy policy that fulfils environmental goals, expecting either that renewable energy will be cheaper than fossil fuels or that the government must deal with the problem otherwise. Fracking remains unpopular among British adults. We use these insights in considering the political viability of different energy scenarios in Part Two.

Part Two considers the policy choices ahead.

In Chapter 2.1 we offer an initial attempt - which we hope others will build on - to analyse decisions on energy supply in terms of cost and security. Policymakers are still scrambling to catch up with the dramatic change of situation over the past year. This is reflected in the fact that while the sophisticated, existing models of the UK energy system - used by policymakers to test ideas before they are announced - do require a certain reliability in the electricity system, few offer any energy security measure as a standard output.

Our model shows the outcomes of decisions about our energy mix in terms of the future costs to households and the proportion of that energy that is produced within the UK. It is immediately clear that speed is key. Without major investment in the UK's energy generation, and a rapid increase from current trends, we will be ever more exposed to gas imports.

[3] Citizens Advice, *The Cost of Loyalty: Table 1*, February 2018

In Chapter 2.2 we discuss two discrete elements of energy security: independence from imports, and reliability of generation. These are *our* measures, picked after dozens of conversations with MPs, commentators, and energy experts to understand their concerns and offering insight into the needs of a resilient future.

Chapter 2.3 examines how domestic energy costs (including heating, power and transport bills) can be reduced for the whole of the UK using market reform.

We hope we, and others, will build on this analysis – looking at overall energy use (including industry for example); at dynamic effects; at the implications for jobs; and at other measures that can accelerate our transition to lower cost, more secure energy. In the meantime, we hope this report provides a nudge to the debate: we need, once again, to explicitly consider security and cost in our energy choices.

This is an explanation of what such an approach should look like.

1.1: Talking to the Public about Energy

Our opinion research shows that:

- 78% of British adults said that the cost of living was one of the most important issues facing the country at this time and 59% were worried about their ability to pay their energy bills this winter.

- Potential Tory voters had some sympathy for the scale of the crisis the Government is facing but they also didn't feel that the government had planned well to avert it.

- Our focus groups viewed energy independence as something that the UK should be striving to achieve. They did not see independence as cutting the UK off from our neighbours - they wanted to maintain import routes - but were keen on the idea that we produced our own energy and were confident this would lower bills.

- Renewable energies are by far the most positively received: wind, solar and hydro gain high levels of support with remarkably little opposition. Oil, fracking and coal are the least popular sources of power.

- For each source of energy supply, we presented for and against arguments to test their relative power to sway opinion: for solar and wind, baseline opinion remained strongly supportive regardless of the arguments made. For fracking, our results indicate that making arguments about the greenhouse gas emissions of fracking significantly reduces support. For nuclear, concerns about safety were by far the most damaging arguments. Coal suffers the opposite fate to wind and solar energy, being so unpopular a source of energy that no argument for it performed well - even energy security.

- At the moment, just over a third of Britons (35%) support fracking, just under a half (48%) oppose it, and 17% do not know. These are not good numbers if you are keen to roll out fracking and if that 17% swing behind the opponents, all hope for fracking will be gone (and other polls show support is even lower in areas where fracking might take place).

- Environmental concerns were important to "swing voters" (those who live in the Red or Blue Wall and are open to voting Conservative) and the public in general. Though a few agree that green projects may need to take a back seat while we get through the cost of living crisis, most expect environmentally friendly solutions to be cheaper - at least in the long-term. We found net agreement of 54% for the statement "I would prefer the rising cost of living to be addressed without compromising the UK's plan to reach Net Zero by 2050" - with a consistent 52% in the Blue Wall and 49% in the Red Wall - voters don't want Governments to force them to choose between these two priorities.

- Overall, swing voters were desperate to hear the plan that will get us out of the current energy crisis and stop it from happening again. Perhaps even more importantly, they wanted to know that the Government was doing something to make that plan a reality.

Testing Public Opinion

Successful policies in a democracy must be effective in principle, deliverable, and maintain public consent. To ensure that the policies we have recommended are acceptable to the voting public, Public First conducted a poll between 27 September and 2 October 2022 with a sample of 2,000 British adults. Fieldwork took place online and results were weighted to be nationally representative.

We also ran four focus groups with swing voters who were willing to vote Conservative at the next General Election, but were yet to be persuaded to do so. These people lived either in Oldham East and Saddleworth - in the Red Wall[4] - or in the constituency of Wimbledon - in the Blue Wall[5] - and were split between those from professional (social grade B and C1) and manual worker (social grade C2 and D) households.

Our groups took place on 6 October 2022; the Thursday immediately after Conservative Party Conference and the day on which National Grid ESO published its Winter Outlook, warning of possible planned outages if certain worst case scenarios occurred over the winter of 2022-23.

[4] For the purposes of this research we used the definition of the Red Wall coined by James Kanagasooriam and Elizabeth Simons, which uses as its basis the observation that "The Red Wall exists because for a highly geographically concentrated cluster of people, living across the Midlands and North, the Conservative Party no longer seems unappealing." - James Kanagasooriam, Elizabeth Simon, *Red Wall: The Definitive Description,* 2021

[5] For the Blue Wall we have adopted YouGov's definition: "constituencies which are currently held by the Conservatives; voted to Remain in 2016; and have a higher-than-average concentration of degree holders in the population (25%+) - YouGov, *Conservative vote share down 8pts in 'Blue Wall',* 2021

How important are the security and cost of our energy to the public?

Energy bills remain a cause of deep concern for many: 78% of British adults said that the cost of living was one of the most important issues facing the country at this time and 59% were worried about their ability to pay their energy bills this winter.

This is important to understand - despite the enormous price intervention by the government, bills are still a challenge to pay.

In our focus groups with marginal seat voters these concerns arose unprompted and had meshed together with inflation and strikes (both planned and threatened) as "the mess that the economy is in". Conducted when Liz Truss was Prime Minister, participants in both Oldham and Wimbledon were perhaps prepared to accept that the PM and cabinet were trying to deal with the mess but it didn't seem to be going terribly well.

So all-encompassing were these worries about the cost of living that the NHS was the only other issue that participants thought the Government should be concentrating upon any time soon. Without prompting, respondents told us about their newfound enthusiasm for turning off lights and everyone was trying to keep the heating off until November. One fitness instructor in Wimbledon told us that her home energy bill had trebled to £600 a month, while a soft play manager in Oldham told us that their workplace's energy bill had hit £10,000, prompting a host of behaviour changes among staff who were all worried about their jobs.

> *"Energy prices affect everyone"* Sasha, Account Manager, Oldham

> *"You see it every day, every time you go past the petrol pumps you remember and it matters - you dread the letters through the door telling you how much your bills are this month."* Mike, Sales Executive, Oldham

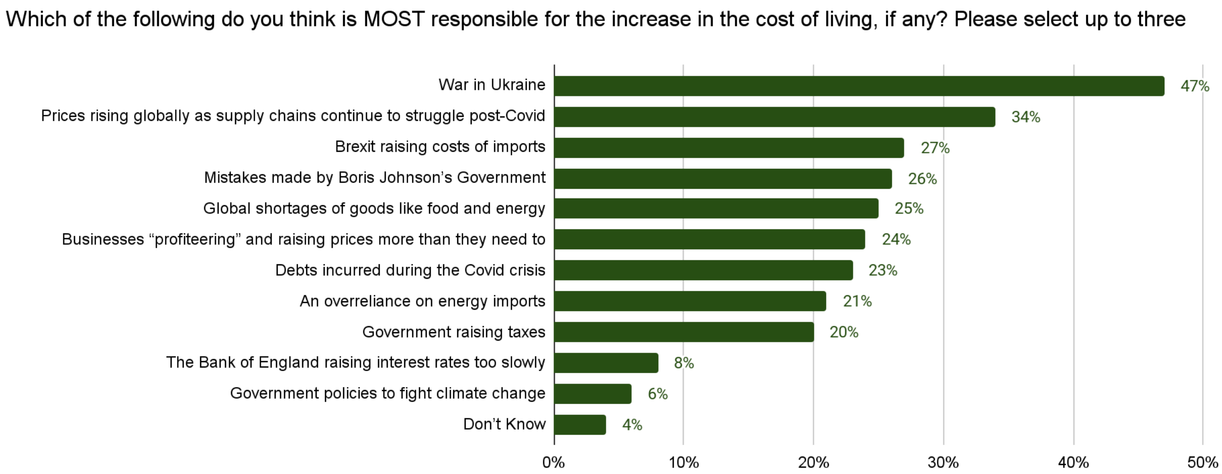
Our professional group in Oldham had noticed that conversations with both friends and colleagues now referenced their smart meter data with alarming regularity and wondered how it would impact the country's mental health to stare obsessively at our smart meters all winter. In Wimbledon, participants tried to articulate the centrality of energy to our way of life: the C2Ds believed that energy should be a human right, while one BC1 participant placed energy in the essential foundation of Maslow's hierarchy of needs.

> *"Without sort of being an amateur psychologist... in that pyramid of Maslow's hierarchy of needs, that's at the core that's at the baseline."* Bill, Social Worker, Wimbledon

How well has the Government handled the crisis so far?

Our potential Tory voters had some sympathy for the scale of the crisis the Government is facing. Reflecting the findings of our poll, they blamed the war in Ukraine - first and foremost - for rising living costs, with honourable mentions for the after-effects of Brexit and Covid. Only 26% blamed mistakes made by Boris Johnson's Government and just 6% blamed government policies to fight climate change.

Figure 3: UK perception of causes for cost of living increase



But while most of these swing voters weren't blaming the government for their climbing cost-of-living, they also didn't feel that the government had planned well to avert it. The Wimbledon professionals noted the closure of gas holders (now used for flats), while in Oldham they told us that anyone knows you shouldn't source too many of your essentials from one place - that would be a real risk.

Respondents wondered aloud at why the Government wasn't putting solar panels on the roofs of all our homes. Even some new houses didn't seem to come equipped with them and this puzzled Oldham in particular: "In Spain all the houses have them - they're miles ahead of us on this stuff." The lack of action on solar rollout chafed even more when other respondents recounted tales of their relatives who not only saved money on their bills but were paid to put power back into the grid "Why can't the Government help us all to do that?"

For the most part, voters were glad to know there was some help coming for their exorbitant bills but even if they were getting help - and the 45p tax cut had been reversed, which they raised positively without prompting - what about the punishment for the bad guys? These voters were more worried about the impact of strikes on the economy, and how businesses would survive rising costs, with little rancour towards energy companies. However, we detected possible early signs of a shift in broader attitudes indicated by some discussion of companies raising prices more than was justifiable given inflation: "like when decimalisation happened and everyone took advantage."

Energy security

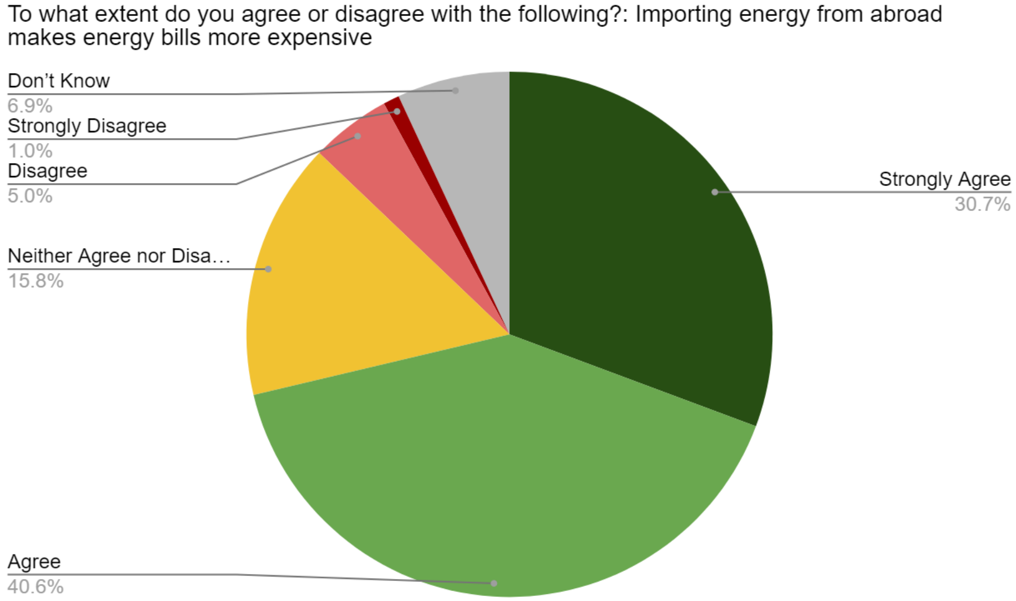
Most participants had not heard the term "Energy Security" before but some could take a (fairly accurate) guess at what it might mean and the rest got the gist pretty quickly. Nonetheless, they found the idea vague or abstract. The concepts of "energy independence", "self-reliance", "self-sufficiency" and "homegrown energy" were much more tangible and easily understood. In fact, each of these terms was coined by the respondents themselves.

On this issue, Wimbledon respondents were far more informed and opinionated than their Oldham counterparts: the conversation was noticeably longer and more detailed in London. This was true even comparing our professional Red Wall seat to the manual Blue Wall. Nonetheless, the four focus groups agreed entirely on their conclusion: that energy independence was implicitly a positive thing that the UK should strive to achieve. They did not see independence as cutting the UK off from our neighbours - they wanted to maintain import routes - but were keen on the idea that we produced our own energy and were confident this would lower bills. In Oldham, participants had the distinct impression that other European nations had done a better job of this than the UK.

Whether or not they use the terminology of energy security, it is evident that the public is worried about the topic. Even before recent headlines about blackouts, 80% of Britons said they were somewhat or very concerned about "the ability of the Government and energy providers to provide all the energy that businesses and households need". And voters clearly link the issues of cost and security. When asked how, in the longer term, what we could change about our energy system to bring down costs, one respondent from Oldham chimed in: "Be more self-sufficient," while another offered: "Reduce how much we use at home," neatly covering both the demand and supply aspects of energy security. The same opinion was evident in Wimbledon:

> *"For me, I don't know the ins and outs of energy and the background. But if the government found ways to source their own energies on our own turf, then I would expect then a drop in price, because then you're cutting out all the other costs of transportation and tax and everything else. So just from coming from no knowledge, I would hope they were promoting self sufficiency as a country"* Remi, Occupational Therapist, Wimbledon

Figure 4: UK perception of impact of importing energy on energy bills



The focus groups had been planned about a fortnight in advance, to take place after both the Labour and Conservative Party Conferences. As it happened, they occurred only hours after the release of National Grid ESO's Winter Outlook Report which presents the System Operator's view of security of supply for the electricity systems for the winter ahead. The press had naturally run with the worst case scenario presented by ESO - one in which supply of gas from the EU was significantly curtailed over the coldest parts of winter and no reduction in domestic demand was achieved - resulting in planned regional blackouts. Blackouts were mentioned in three of four groups with all of them recalling the possibility of "3 hour" cut offs.

> *"I think they have totally under invested in the last two decades. And now we are feeling the pinch... We're in 2022, we're not in a war situation in the UK and it makes you think what is going on? How on earth could we cope with three blackouts?"* Paul, Manager in Drinks Manufacturing, Oldham

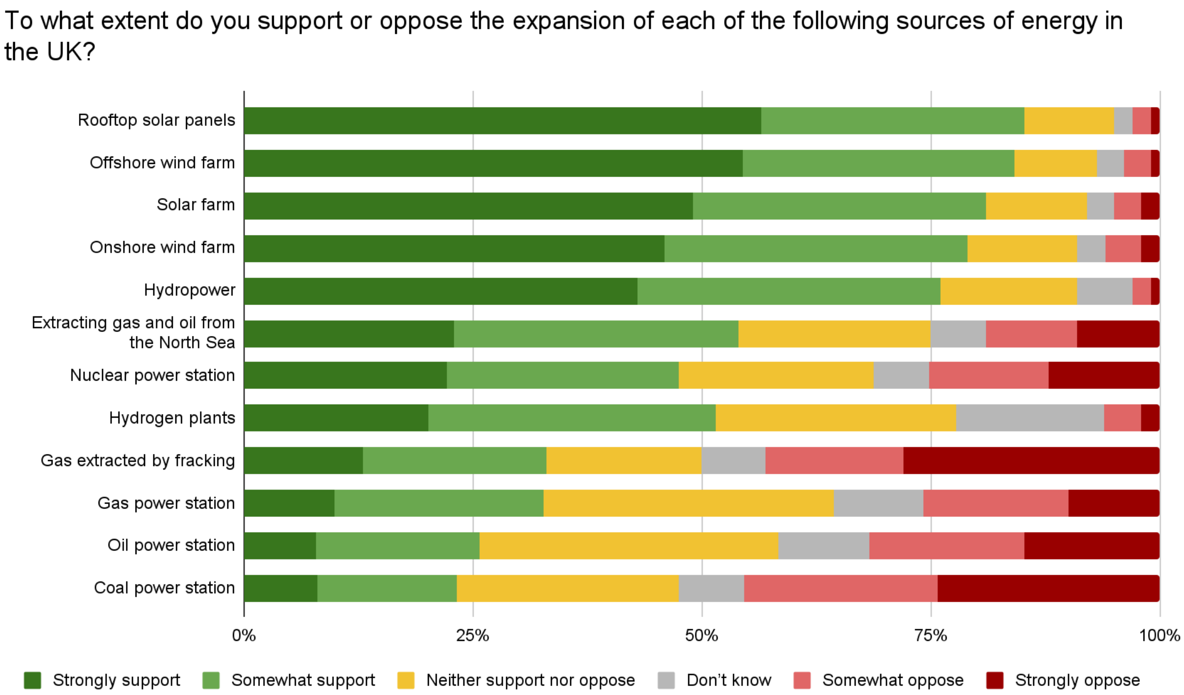
> *"For those businesses that are going to struggle, for those families that have got people at home that rely on you know, equipment, that are carers that rely on equipment to keep their loved ones, you know, what's gonna happen to them if we start having three hour power cuts? What's gonna happen to those people? There should have been something in place so that if something like this did happen"* Victoria, Fitness Instructor, Wimbledon

Policy decisions

Our respondents had some very specific ideas about how to help ease their household bills now - not least a big cut in petrol duties and maybe more bill subsidies - but were much less certain of the wisdom of competing plans for our energy system.

They felt underqualified to make choices between technologies without really understanding the costs and benefits of each. Participants didn't know how nuclear power stations worked, how expensive wind turbines were, or how much output could be produced from solar panels. They wanted more information before making choices between technologies or wanted people more expert than them to help. However, our polling reveals their underlying preferences before furnishing any such information and tallies well with the comments that our focus groupers did feel able to make:

Figure 5: UK support for expansion of energy sources



Renewable energies are by far the most positively received: wind, solar and hydro gain high levels of support with remarkably little opposition. Hydrogen is less well understood than other forms of energy storage and therefore has the largest share of 'Don't knows'. Nuclear and gas are next, though in each focus group one person noted "I know it's meant to be safe but we don't want to end up like Japan." Oil, fracking and coal are the least popular sources of power.

Fracking was not seen positively nor well understood. While some focus group participants were willing to give fracking an opportunity if it cut bills or reduced imports, it was agreed that earthquakes were not an acceptable price to pay for either.

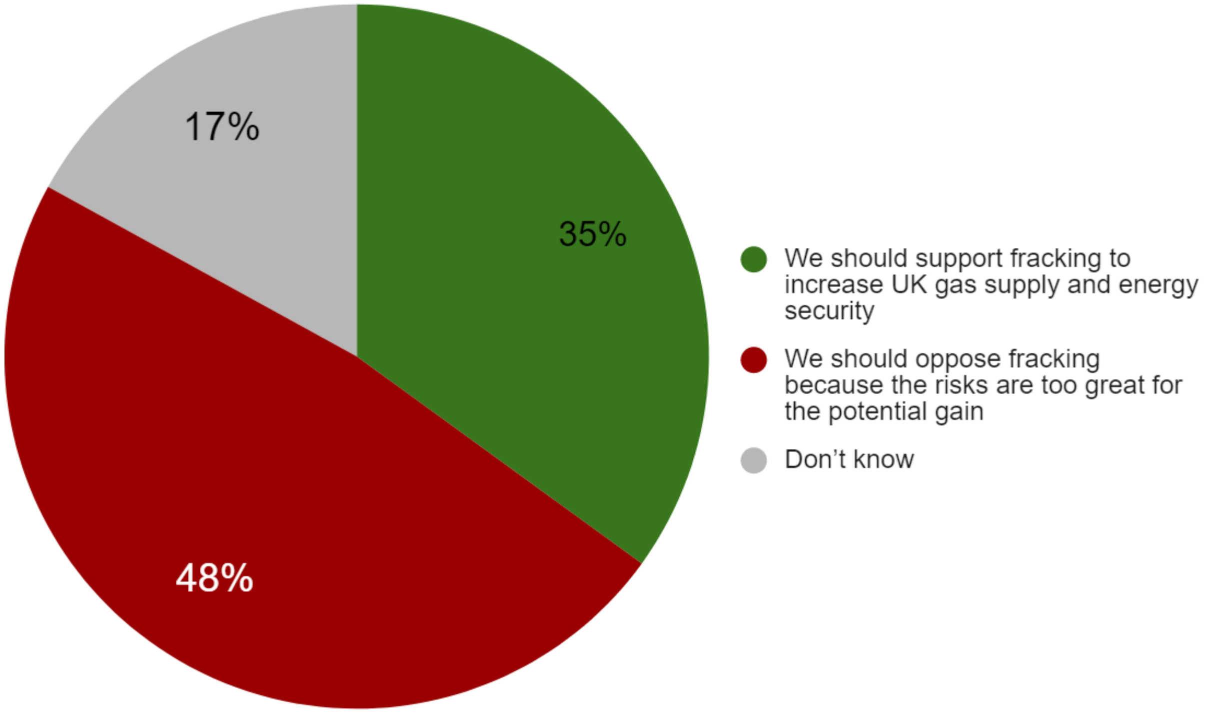
> *"Fracking is a big no for me, because I just think sustainability... can we do this viably for the next 200, 300, 500 years? And if the answer is no, then I don't think we should be doing it"* Jack, Production Planner, Oldham

> *"I don't think anything that makes your house shake is good"* Victoria, Fitness Instructor, Wimbledon

Our nationally representative poll agreed, on balance. 88% told us they had heard of fracking but we offered everyone a neutral explanation before asking their thoughts, just in case: "'Fracking' is a way of extracting natural gas from the ground. It involves drilling into the earth and directing a high-pressure mixture of water, sand and chemicals at a layer of rock in order to release hard-to-reach gas deposits. Fracking could provide the UK with a new source of natural gas, but releases greenhouse gas emissions and can cause local tremors (said to be equivalent to heavy traffic). Which is closest to your own view?" At the moment, just over a third of Britons (35%) support fracking, just under a half (48%) oppose it, and 17% do not know. These are not good numbers if you are keen to roll out fracking.

That 17% who are on the fence are crucial. If the Government can find areas of the country that are viable for fracking and happen to be close to enough of the 35% who support this technique, fracking may still be feasible. But if that 17% swing behind the opponents, all hope for fracking will be gone.

Figure 5: UK support for fracking

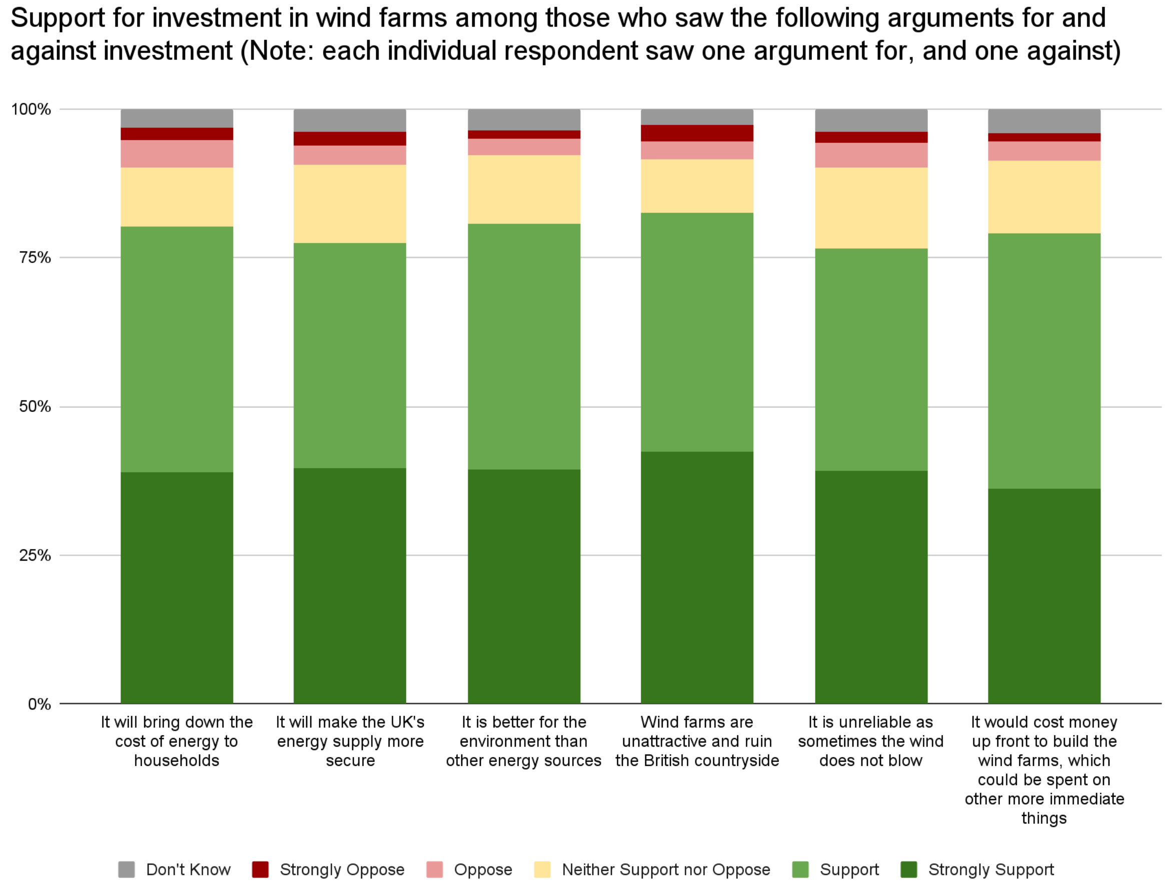


Effective arguments for energy policy

In order to better understand how flexible public opinion is on each energy source, we tested a range of arguments for Wind, Solar, Fracking, Nuclear and Coal. Each poll participant saw one argument made in support of increasing investment in a particular energy source, and one argument against (the full list can be seen in the poll tables). Afterwards they were asked to select which argument was strongest, and then indicate their support for greater investment in the energy source.

For both solar and wind, baseline opinion is so supportive of investment in these energy sources that arguments have little effect on levels of support. Regardless of the arguments for and against investment which we showed respondents, support for both solar and wind was over three-quarters.

Figure 6: UK support for investment in wind farms



To illustrate this, we can examine the argument around the appearance of wind farms destroying the British countryside. Only a fifth of people felt this argument was a strong argument, but within that group only 17% went on to say they would oppose investment in wind. In the end, this means that only around 4% of the public is likely to feel both that this is a strong argument, and oppose investment. Even among those inclined to agree with this argument, a majority still support investment.

The public is more divided on both fracking and nuclear, and we find evidence that the arguments made for and against both can shift levels of public support for investment. We find that energy security is perceived to be a relatively strong argument for investing in fracking, however counter arguments around the greenhouse gas release of fracking and local tremors were perceived to be stronger. Messages against fracking investment which focus on how long it would take to yield results is likely to be less successful than focussing on these environmental angles. 46% who saw the green-house gas argument oppose fracking investment, compared to 40% who saw the yield time argument. The difference is small but statistically significant.

For nuclear, an argument focusing on concerns about safety clearly beats other counter arguments, even when phrased loosely ("some are concerned about…").

Generally the public leans towards support for nuclear investment, but the arguments made for and against it would have an impact. We find support for nuclear investment at 45% among those who see the argument about safety, compared to 53% if the argument made against investment focussed on the unattractiveness of nuclear power stations.

Finally, for coal investment, the unpopularity of this as an energy source means the arguments for it saw little cut-through. In contrast to wind and solar, opposition to coal is strong and minds appear made up, such that it is unlikely even the stronger arguments for coal investment would swing the debate.

Figure 7: UK perception of fracking as an energy source

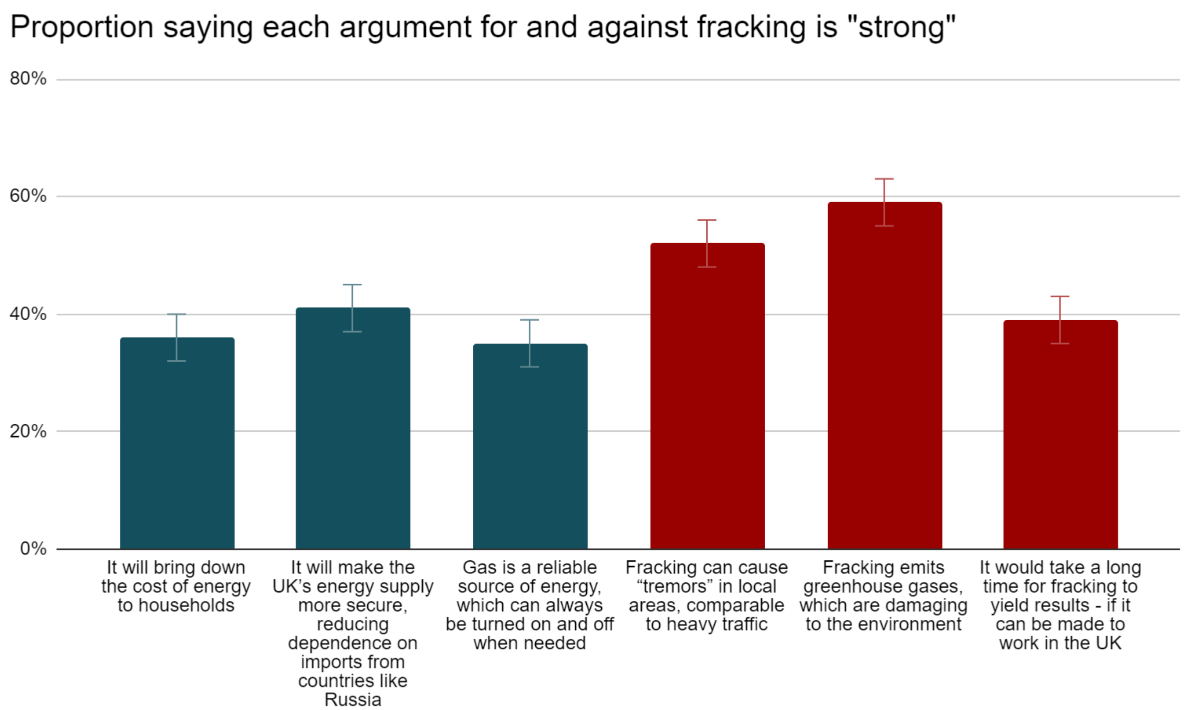


Figure 8: UK perception of nuclear as an energy source

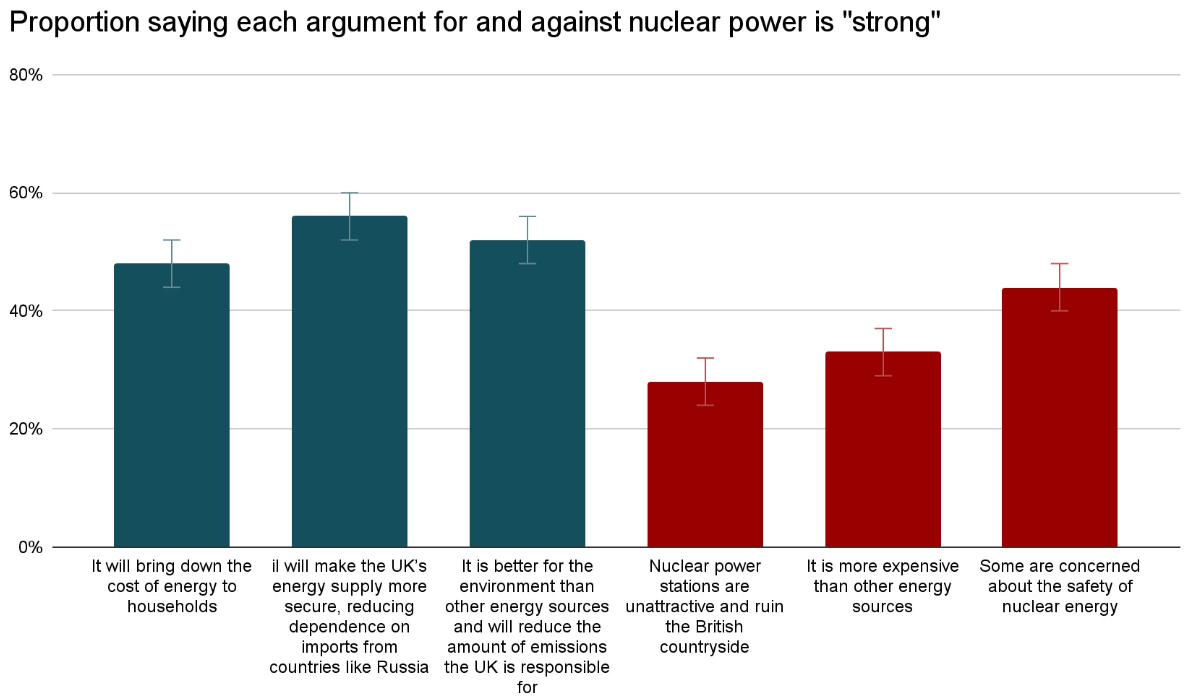
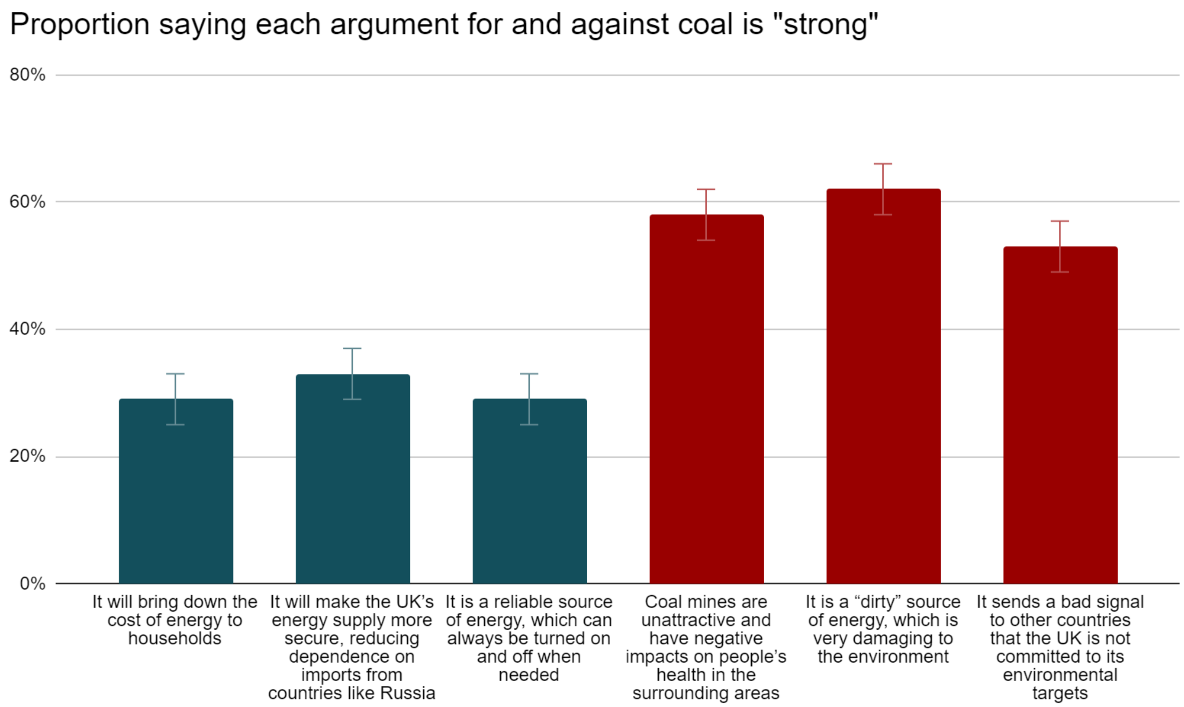


Figure 9: UK perception of coal as an energy source



Energy and the environment

Environmental concerns were important in all four focus groups but there was variation in how this should be prioritised. In the Wimbledon professional group, environmental priorities survived the cost of living crisis better, with participants taking away from the conversation the question of whether they should vote green next time.

> *"I've never voted Green before but it might be might make me go down that avenue at the next election"* Bill, Social Worker, Wimbledon

> *"It's made me think that possibly… the Greens might come to the forefront"* Dermot, Business Owner, Wimbledon

This was also true for the majority of Oldham respondents. These swing voters also pointed out that less environmentally friendly solutions came with their own costs. In fact, most of them expected environmentally friendly solutions to be cheaper - at least in the long-term.

> *"Wind turbines, obviously there's a cost to get them in place. But that sort of energy will be here forever. So it would make it cheaper if we made enough of it, if we made it efficient enough, we would bring the cost down"* Amy, Soft Play Assistant, Oldham

> *"Also [fossil fuels are] not a long term solution, either, because it's gonna run out. And I don't know how much it costs, I don't know how much one of those drills costs. But to me, there's more like economically viable options that are more renewable"* Ollie, Tech Retail Assistant, Wimbledon

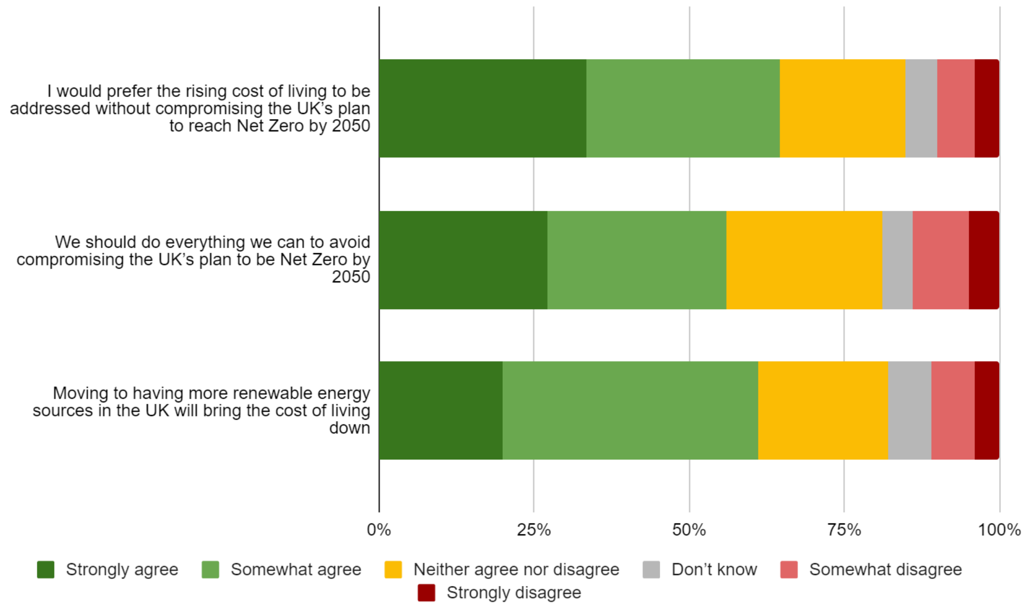
But for the Wimbledon C2D group and one respondent in each of the Oldham sessions the ability to pay their bills came first and, if environmental goals were undermining that, they were prepared to reduce green spending for a few years until the crisis was over.

> *"I think [environment is] really important. But, at the same time, I think a lot of money would have to go into making us environmentally friendly. And I don't know, right now, is that a good idea?"* Annabelle, Personal Trainer, Wimbledon

> *"I think the priority for people is cost over environmental disadvantages. Personally, I think in the current situation, which we've never sort of seen in our lifetime, the cost is more important for me at this moment in time. The environment does play a part but I think in the next 6 to 12 months people are focusing on how much it's costing per month, they're not thinking about the environment as much"* Ollie, Tech Retail Assistant, Wimbledon

Nor are the views of our groups at all unusual: the wider public demonstrates a net agreement of 54% for the statement "I would prefer the rising cost of living to be addressed without compromising the UK's plan to reach Net Zero by 2050." Climate change and other environmental issues remain important to the public despite rising concern about the economy. 21% of the public say that climate change is one of the most important issues facing the country at this time - the fifth most popular answer to this question and significantly higher than taxation (12%), immigration (14%), crime (9%) or housing (9%). The majority of the public do not see environmental policy as something to trade off against the cost of living: 61% expect that moving to more renewable energy, for example, would bring down the cost of energy, while others expect the government to resolve any inherent cost conflict by finding savings elsewhere to protect environmental commitments.

Figure 10: Public opinion on cost of living crisis and Net Zero



In search of a plan

While the public are very aware of the limitations of their own knowledge of the energy system, our Red and Blue Wall residents very much hoped that someone better informed had a plan. An overwhelming 89% of the public agreed that "This energy crisis shows that the Government needs to make energy security a much higher priority" and our groups echoed that sentiment. Unfortunately, they certainly hadn't heard about a plan and weren't assuming that one existed.

> *"I don't think they know what they're doing. I think they hope that we've got enough to get us through winter and then they'll sort it out next year"* Alex, Staff Nurse, Oldham

Perhaps even more importantly, they wanted to know that the Government was doing something to make that plan a reality. It is a regular feature of energy research - and inevitable given how far away many wind turbines are from the general public - that respondents tell us that they never see any of these changes being made. If the Government wants the public to give it credit for making real change, it was made clear again in these groups that they will have to become far more effective storytellers and cheerleaders for the work that has already been done.

> *"I think we've spent a lot of time talking about these renewable sources of energy. And we hear the government speaking about it, but never actually taking any action. I think one point which is paramount now is that someone close to these MPs needs to actually push them on it, because it feels like we're just going round and round in circles. It's just getting delayed and delayed and delayed. There actually has to be a clear plan of what we're doing in the next sort of 12 months, 5 years, 10 years"* Ollie, Tech Retail Assistant, Wimbledon

This impatience pervaded our focus groups. Many of the policies that we tested seemed 'common sense' to participants, who wondered why their government wasn't just getting on with it. In the next chapter, we'll show that the modelling outputs agree with the public.

2.1: Modelling the UK Energy System

In this chapter, the outputs of our modelling work show that:

- Making no choice about which technology to back would be, effectively, to choose gas, which means increasing the security risk of relying on imported energy.
- We must build new energy generation, faster. Despite extraordinary achievements in this field, we are currently not meeting our ambitions to deliver additional wind generation - which is cheap and secure.
- We should act swiftly to reduce domestic demand for gas in order to drive down our reliance on foreign imports.
- Fracking could improve energy security by the late 2030s, but would make no difference to costs. Given our public opinion results in Part One - and the recent evidence of parliamentary risk - fracking will likely cause more political pain that it would cure.
- The name of the Net Zero Strategy disguises its potential. To call it this undersells its potential for delivering Low Cost, High Security energy. We have stripped away environmental factors and find that the Net Zero Strategy remains the best plan - though it can be augmented to accelerate progress.
- The new Prime Minister should resist calls to deviate from the plan and instead concentrate on finding ways to accelerate the energy transition.

Introducing the model

The charts in this chapter show how the energy mix will vary between 2025 and 2040 across five policy scenarios. As well as these long-range projections, you will see headline figures for the average household energy bill (including transport, heat and power) in 2035, and the year by which each energy mix results in the UK reaching energy independence. Outcomes over the next two decades vary dramatically depending on policies set now.

Our model is based on data from National Grid ESO's industry standard-setting Future Energy Scenarios. We start with their estimates of energy demand and how that will be met by supply. It then allows us to see the impacts of adjusting for different choices - such as different generation technologies or altered rates of consumer uptake for electric vehicles, heat pumps, thermal storage and insulation. By using our own model we are able to make detailed examinations of these choices for outputs such as energy bills and energy security.

The five scenarios we examine are:

- Do Nothing - in which there is no change to our current energy generation mix;
- Not Net Zero - an approach that very deliberately turns away from Net Zero and, while delivering significantly more renewable generation, slows the growth of renewables relative to the previous government's ambitions in favour of more nuclear and fracking;
- Net Zero Focused - an outline of the Net Zero Strategy (NZS) plus the British Energy Security Strategy;
- Do Everything - a scenario in which we follow the NZS but augment it with additional fracking and nuclear, and
- Full Green - in which we seek to accelerate progress towards a fully decarbonised energy system

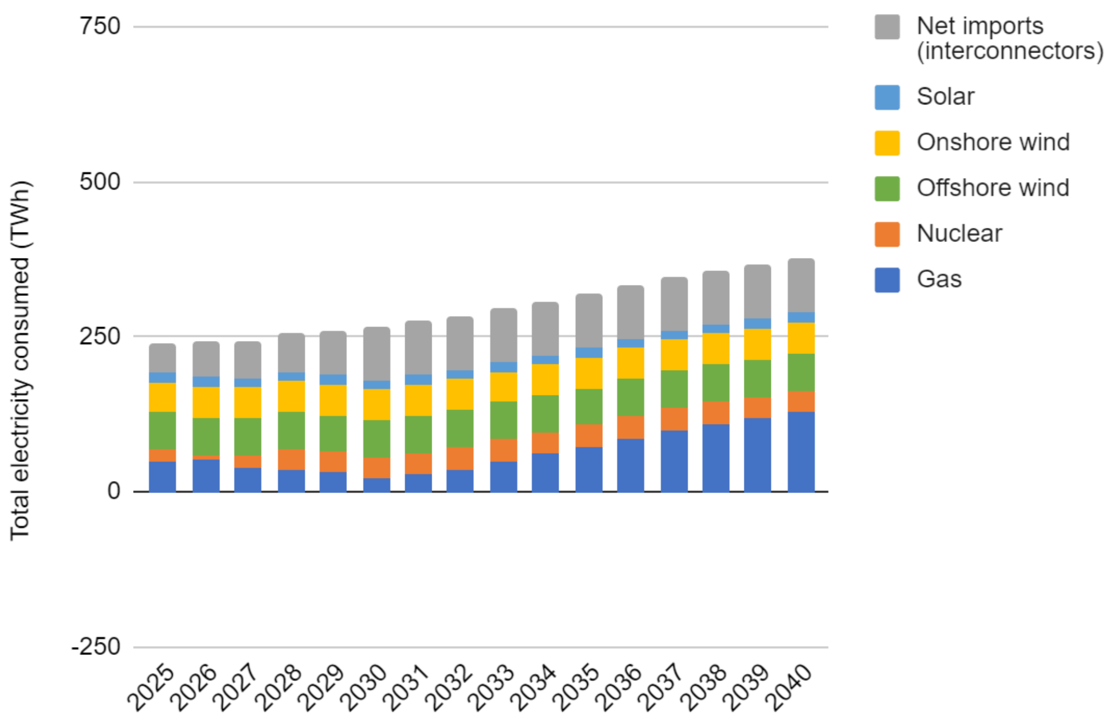
Clearly, there could be five hundred scenarios, and we had to make choices about our assumptions. To refine our choices, we conducted many interviews with MPs, advisors and commentators with an interest in energy to stress-test our initial outputs and narrow down the five scenarios most illustrative of the choices facing policymakers today. We have summarised these, the assumptions we made in each, and our results in the table at the end of the chapter but first we'll take you through them in turn.

The Five Scenarios

In **SCENARIO ONE - "Do Nothing"** we show the result of making no change to our current energy mix. In this scenario we also assume slow uptake of electric vehicles (EVs) and heat pumps, and no change in the rate of energy efficiency improvements, be they insulation or boiler optimisation.

As you can see in the chart below, in this scenario gas generation grows significantly through the 2030s as demand increases and all other options (including imports) are maxed out.. This level of underinvestment, and consequent reliance on global energy supply is deeply unrealistic but it is a helpful starting point, clearly demonstrating that without major investment into the UK's energy generation, we will default to using ever more gas over the next few decades. Making no choice about which technology to back would be, effectively, to choose gas.

Figure 11: Generation mix in the "Do Nothing" scenario

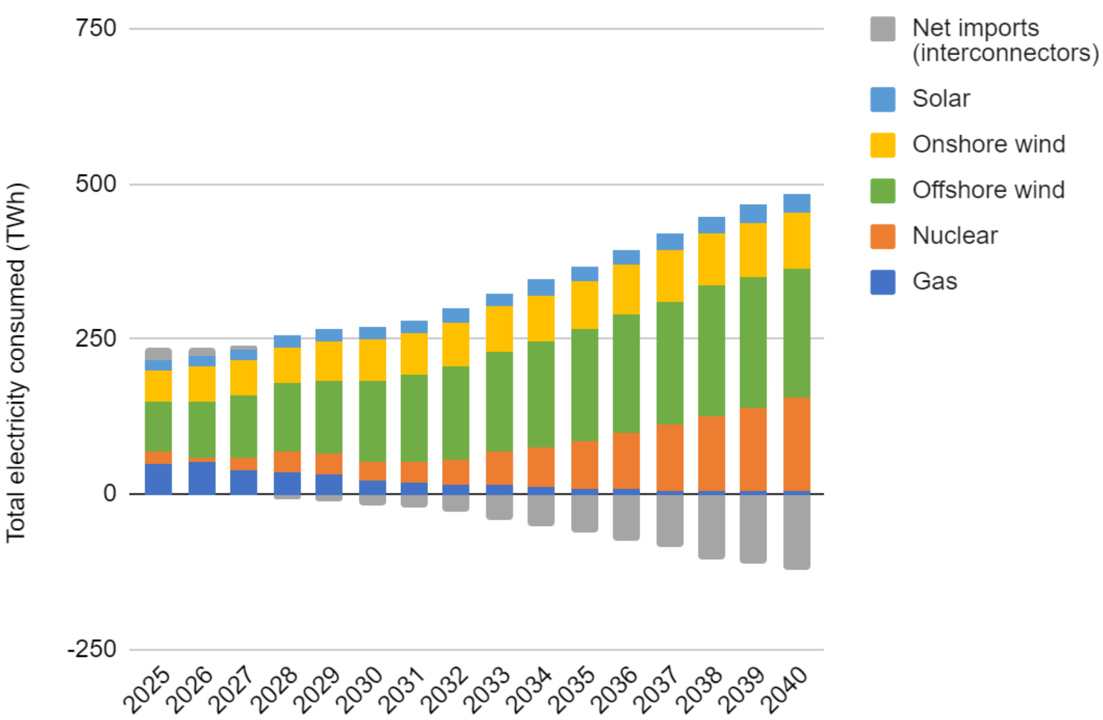


SCENARIO TWO - "Not Net Zero" shows a world in which the government pursues fracking and nuclear, but fails to accelerate renewable generation: we continue to build at the same rate for wind and solar. In this scenario we again assume slow uptake of EVs and heat pumps, and no change in the rate of energy efficiency improvements.

What is Fracking?

Hydraulic fracturing, or fracking, is a method used to extract petroleum (oil) or natural gas from sites where the supply is distributed in smaller pockets and cannot be extracted by drilling alone. In the fracking process, cracks in and below the Earth's surface are opened and widened by injecting water, chemicals, and sand at high pressure. This helps to release the oil or gas which can then be pumped to the surface. This method for extracting 'shale gas' is used widely in the United States and in offshore facilities but exploratory work to understand how feasible this will be onshore in the UK was halted in 2019 due to public disquiet over the tremors that can result from this method of extraction.

Figure 12: Generation mix in the "Not Net Zero" scenario



In this scenario, offshore and onshore wind continue to rise, but offshore wind plateaus from 2037 onwards. Nuclear, on the other hand, rises to meet more than a third of demand by 2040. Meanwhile, some of our gas use switches from imports to domestic shale gas - allowing up to 95% of our demand to be met domestically.

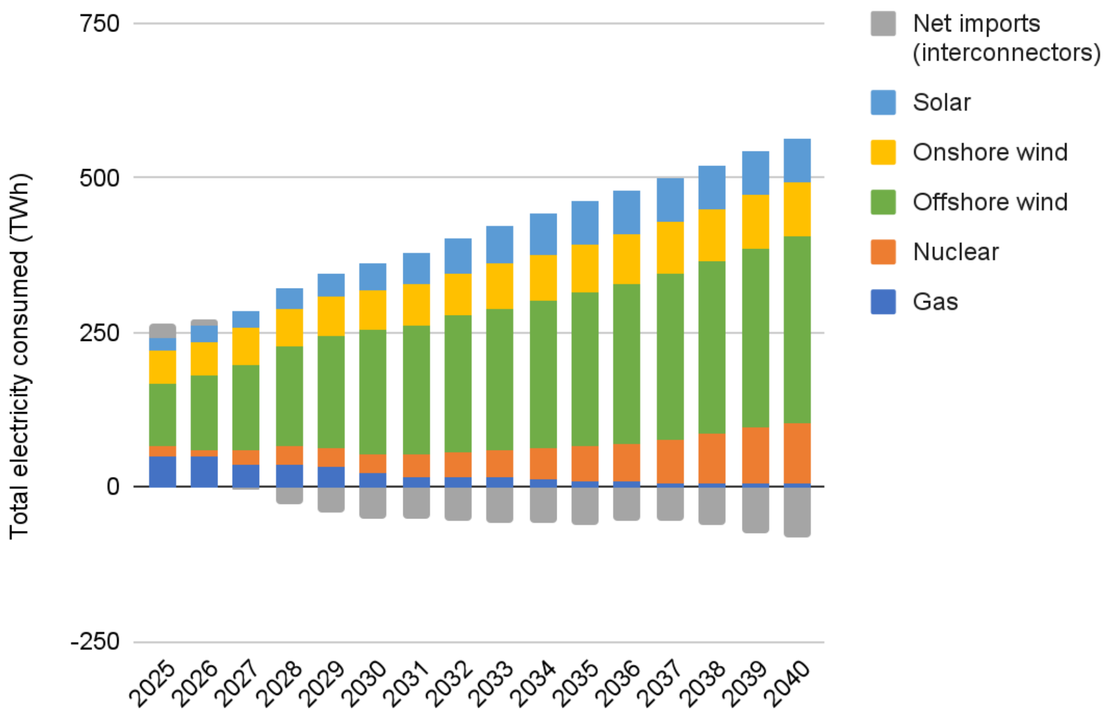
This scenario is likely from a policy desirability point of view but, as our evidence in Part One shows, unlikely from a political point of view. Under Liz Truss, the Government sought to lift the moratorium on fracking and floated the idea of designating fracking sites as nationally important infrastructure, in order to reduce the capacity for local objections. Both Liz Truss and Rishi Sunak spoke during the leadership campaign in the summer about the importance of building new nuclear, including Small Modular Reactors. However, headwinds remain: when we explore public attitudes to different types of generation and find that nuclear and fracking remain among the least popular. Fracking has caused political problems for governments in the past - and a parliamentary vote on fracking contributed to the last Prime Minister's downfall - as a result, some potential exploration companies have also stated that they don't believe the UK market will ever produce significant volumes of shale gas.[6]

Sharp-eyed analysts may ask why this scenario still involves such large amounts of wind power if it examines a turning away from renewables. The answer is that in our first iteration of the model, we showed expert interviewees a version of this scenario that stripped out many of current plans for wind power and this was considered very unlikely, especially by policy makers who have called for this Government to concentrate less on net zero. We therefore, re-introduced wind at the current level of planning but assumed no further push to increase renewable energy.

In **SCENARIO THREE - "Net Zero Focused"** we model the impact of changes that are similar to the Net Zero Strategy from a renewables point of view– a rapid acceleration of our existing shift to renewable energy, underpinned by a baseload of nuclear and gas. The main difference is that we haven't added the decarbonisation technology required to meet net zero. In this scenario we assume medium take up of EVs and heat pumps, and also increased energy efficiency measures.

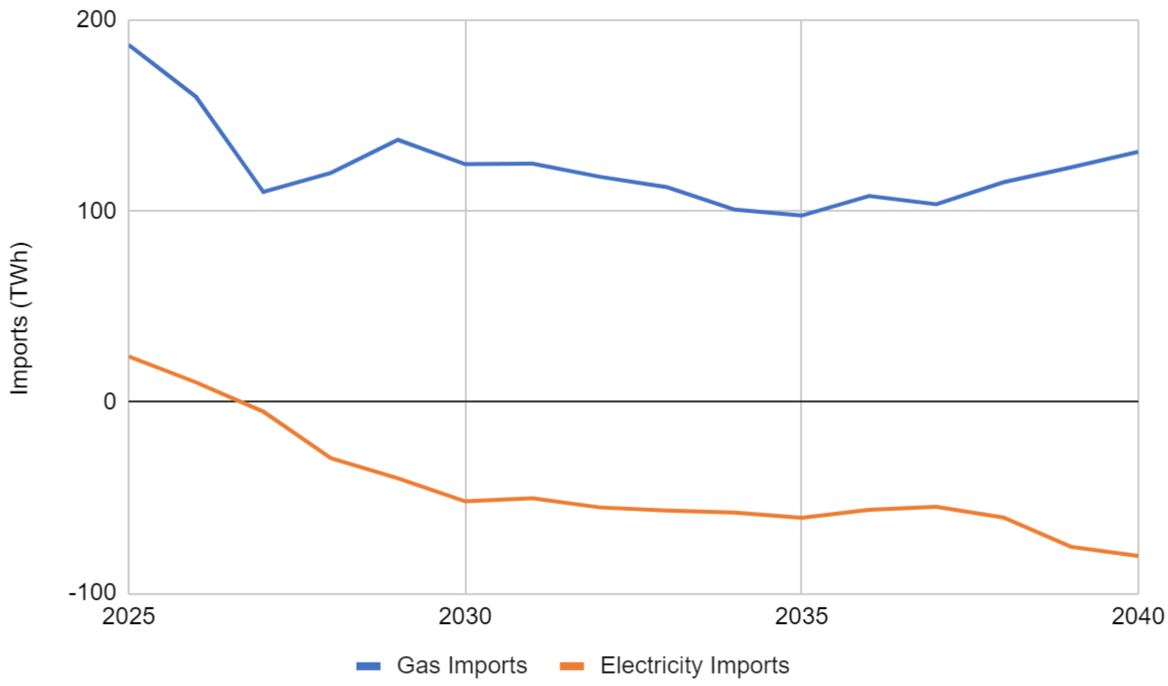
[6] *The Guardian* *Fracking won't work in UK* September 2022

Figure 13: Generation mix in the “Net Zero Focused” scenario



There are two striking features to note in this scenario: the first is the impact of accelerating energy efficiency measures. This can be seen in the energy imports chart below, with the lines for gas and electricity both sinking satisfyingly southwards, denoting a reduction of imports but also - in the case of electricity - an increase in the times during which we export our energy over the interconnectors in the channel and North Sea.

Figure 14: Gas and Electricity imports/exports in the “Net Zero Focused” scenario



This effect demonstrates the importance of acting swiftly to reduce domestic demand for gas and the quickest and easiest way to do that while preserving quality of life is to insulate more homes. In 2021, the ONS estimated that only 42% of English homes and 37% of Welsh homes qualify for an EPC rating of Band C or above.[7] According to analysis by the Energy & Climate Intelligence Unit, moving the average EPC rating of households from D to C would reduce UK gas imports by 15%.[8]

[7] ONS, *Energy efficiency of Housing, England and Wales Table 1f*, 2021,

[8] Applying the 21% saving in domestic demand equates to 7.4% of total UK demand. Assuming that this would be entirely deducted from net imports, this would equate to a 15.2% cut in net imports.
ECIU: *Reheating the shale gas debate will not solve the gas crunch* October 2021

What is an EPC rating?

Energy Performance Certificates (EPCs) rate how energy efficient a building is and give it a score from A (very efficient) to G (very inefficient). EPCs give consumers a guide to how costly any property will be to heat and light, and what its carbon dioxide emissions are likely to be. The certification also includes information on what the energy efficiency rating could be if recommended improvements were made and highlights cost effective ways to achieve a better rating. An EPC needs to be available as soon as you start to market your property for sale or rent and they remain valid for 10 years from the date of issue.

It is likely that this figure actually overestimates the energy efficiency of Britain's homes because the houses least likely to have had an energy efficiency assessment are the oldest and least well maintained. Including all homes in the data would therefore be likely to pull down the percentage of adequately insulated dwelling. BEIS Household Energy Efficiency statistics show that 8 million homes in the UK lack loft insulation and cavity wall insulation is missing from 6 million relevant properties. Solid wall insulation is very much a minority sport, with only 9% of properties having it, leaving 7 million uninsulated.[9] Insulating Britain's draughty homes makes bills cheaper, saves households and government money, and reduces our dependence on imported gas.

The second important finding demonstrated by this scenario, is the impact of building more wind energy. In fact, in our modelling, any scenario with a rapid increase in wind supply does better – on household cost and on security grounds – than one without. Wind is cheap and secure and we need more of it. That is also true when we factor in the costs of intermittency (that is, keeping the lights on when the wind doesn't blow - see Chapter 2.2 for more details on this).

The problem is, we are not currently building fast enough. In the last five years we have added less than 1GW of offshore wind per year - to meet the target in the British Energy Security Strategy we need to up that to between 4 and 5GW per year. Our Net Zero Focused scenario shows that if we accelerate supply to this rate we can reduce household bills and become a net exporter of electricity by 2030.

Offshore wind has been a UK success story. As a result of a predictable regulatory framework incentivising private sector investment, the UK has the second largest installed capacity of offshore wind of any country, having only recently been overtaken by China. And in building our >11GW of offshore wind, we have seen the cost of the technology fall dramatically. Nonetheless, our ambitions outstrip even these achievements and more needs to be done if

[9] BEIS, Household Energy Efficiency detailed release: Great Britain Data to December 2020 March 2021

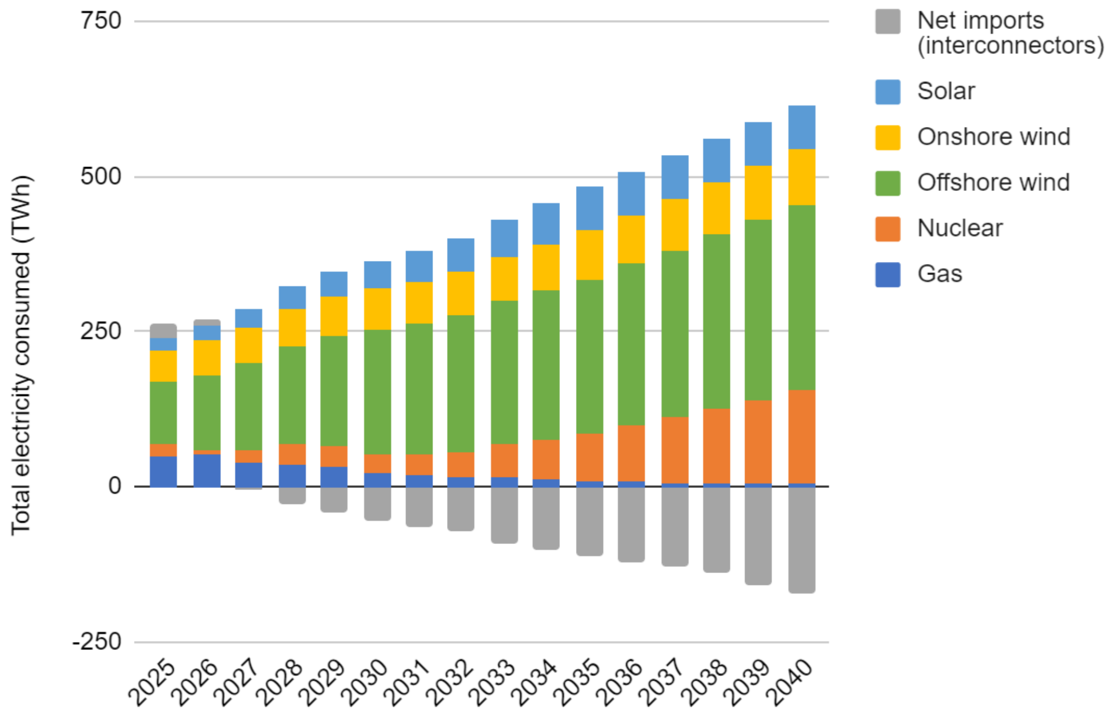
we want to realise the security, cost and export benefits of becoming the 'Saudi Arabia of Wind,' as a former PM colourfully described it.

In **SCENARIO FOUR - "Do Everything"** we include the same amount of fracking and nuclear as in our "Not Net Zero" scenario, and the same high ambition for offshore wind as in the "Net Zero Focused" scenario, in an attempt to see what the 'best of both worlds' might look like. This scenario also has gas and biomass CCS in the power generation mix. We also assume medium uptake of EVs and heat pumps and, again, increased energy efficiency measures.

In this scenario, we source more of our gas domestically - from shale gas - which allows us to get closer to energy independence. However, bills remain slightly higher than under net zero as we incur expense from additional nuclear plants.

What we learn from this is that attempts to optimise further almost inevitably involve trade-offs. For example, here we gain in security but costs rise.

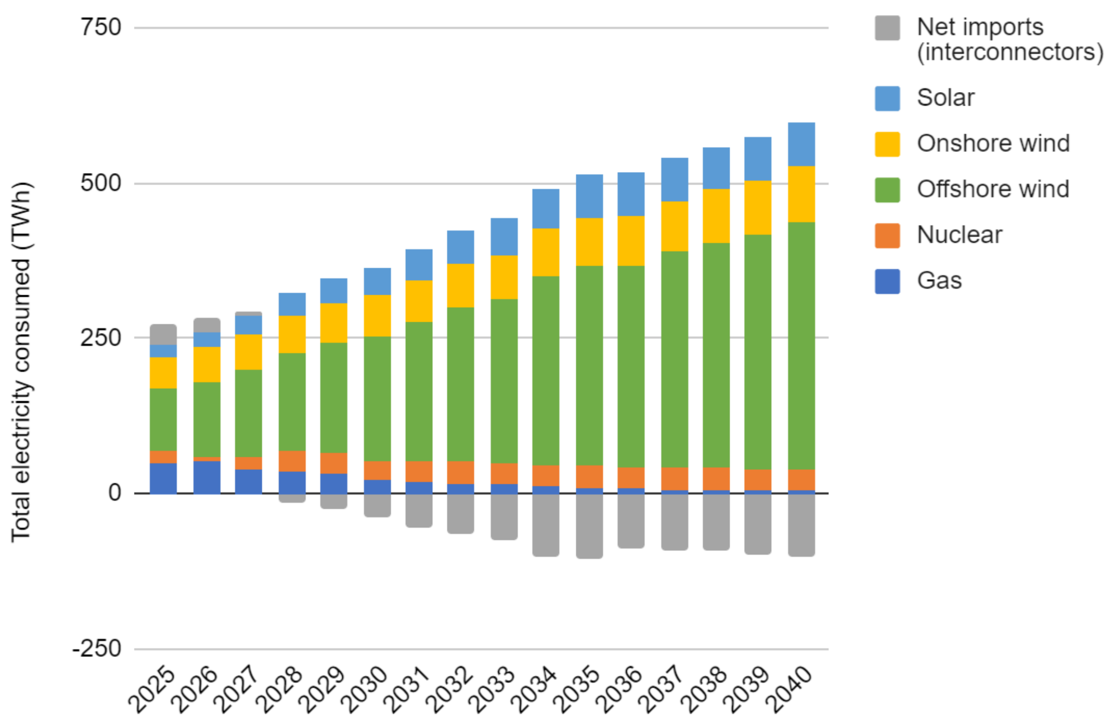
Figure 15: Generation mix in the "Do Everything" scenario



And finally, we offer **SCENARIO FIVE - "Full Green",** which represents a more radical view of the role of renewables, does away with most new nuclear, and underpins renewables with peaking plants compatible with net zero (BECCS; Hydrogen; CCUS; etc). Here, we assume slightly better energy efficiency than in the Net Zero Strategy and high take up of EVs and heat pumps.

This demonstrates that there is scope for doing even more on renewables if there were political will, but it doesn't materially change the cost of living or change the date by which we become a net exporter of power. This scenario would thus only be favoured if you were minded to take carbon footprint into account. It might also make it harder to manage the increased levels of intermittency - for more on which, see Chapter Two.

Figure 16: Generation mix in the "Full Green" scenario



Applying our findings

Above we present five scenarios to show a range of possible futures - and learn some key lessons. Full comparative charts are available in Appendix A but for the decisions that need to be made in the next few weeks it is perhaps most instructive to compare the "Not Net Zero" scenario with the "Net Zero Focused" scenario. Specifically this comparison looks at the decision to be made by the new government between the path laid down by Boris Johnson's administration and the calls from some to jettison the focus on net zero in favour of a resurgence of nuclear and fracking. We don't believe that the voices in the Conservative Party favouring the latter approach want to eschew offshore wind where it is cost effective, and so our "Not Net Zero" scenario still sees this grow to become the single biggest source of electricity, it just grows more slowly than was envisioned by Boris Johnson.

As described earlier, we explicitly measure scenarios on the basis of cost and security and not environmental performance. Comparing these two scenarios head-to-head we find that the "Net Zero Focused" - which is set out in the Net Zero Strategy and British Energy Security Strategy - reduces import dependence by almost a quarter (in 2035) relative to the strategy being pushed by some net zero-sceptic elements of the Conservative Party. By 2040, the "Net Zero Focused" scenario imports a third less energy. Household bills are (as described elsewhere) somewhat similar across all scenarios due to the embedded costs (like networks).

But for a typical household still running a gas boiler and a petrol or diesel car in 2040, the Boris scenario cuts household bills by more than £30 a year. And for a household that has switched to an EV and heat pump the benefit is £74 a year.

With no consideration of the environment whatsoever, the approach set out by the former PM in the Net Zero Strategy and British Energy Security Strategy is both cheaper and more secure/independent than the approach currently being proposed that relies more heavily on nuclear and fracking. In fact, we would argue that to call this a Net Zero Strategy undersells it: this is the plan for Low cost, High security energy.

Figure 17: Average annual household bills (£) for a home with a gas boiler and an ICE vehicle (left) and a home with an Air Source Heat Pump and an Electric Vehicle (right)

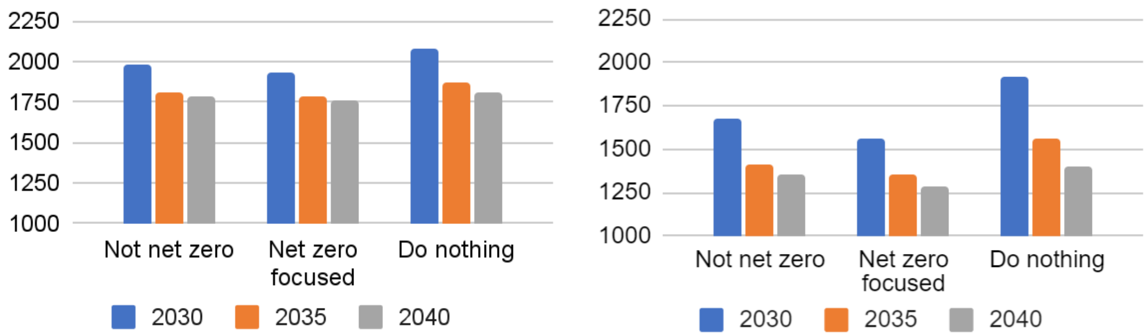


Figure 18: % of electricity produced domestically

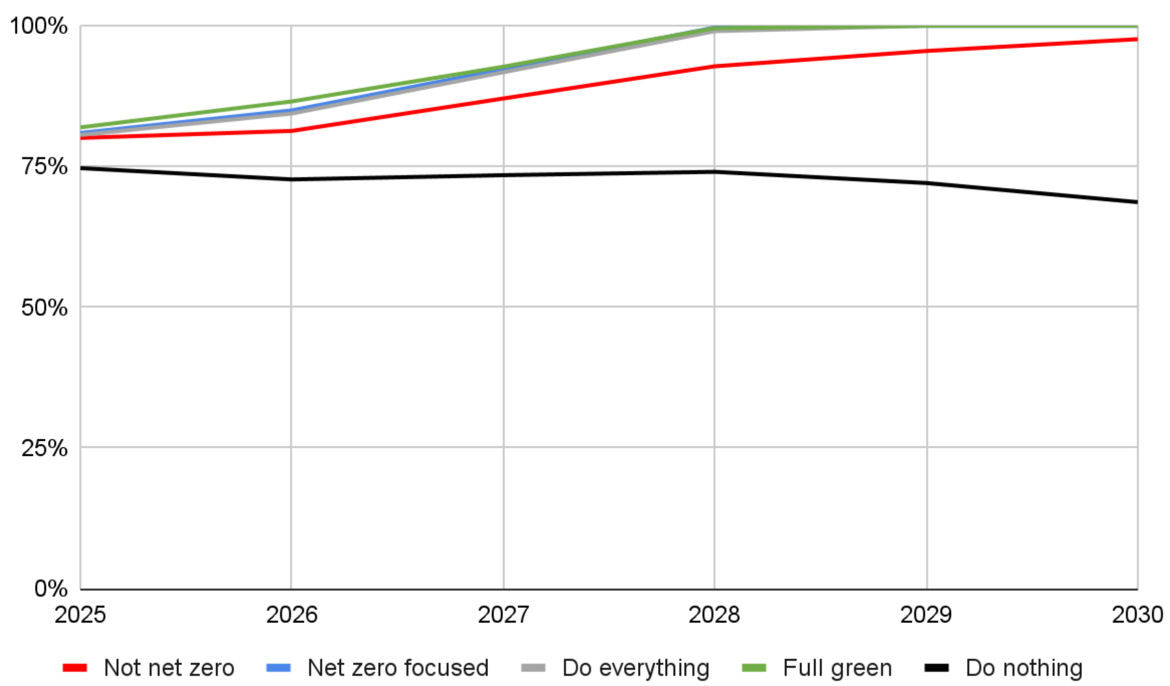


Figure 19: % of gas produced domestically

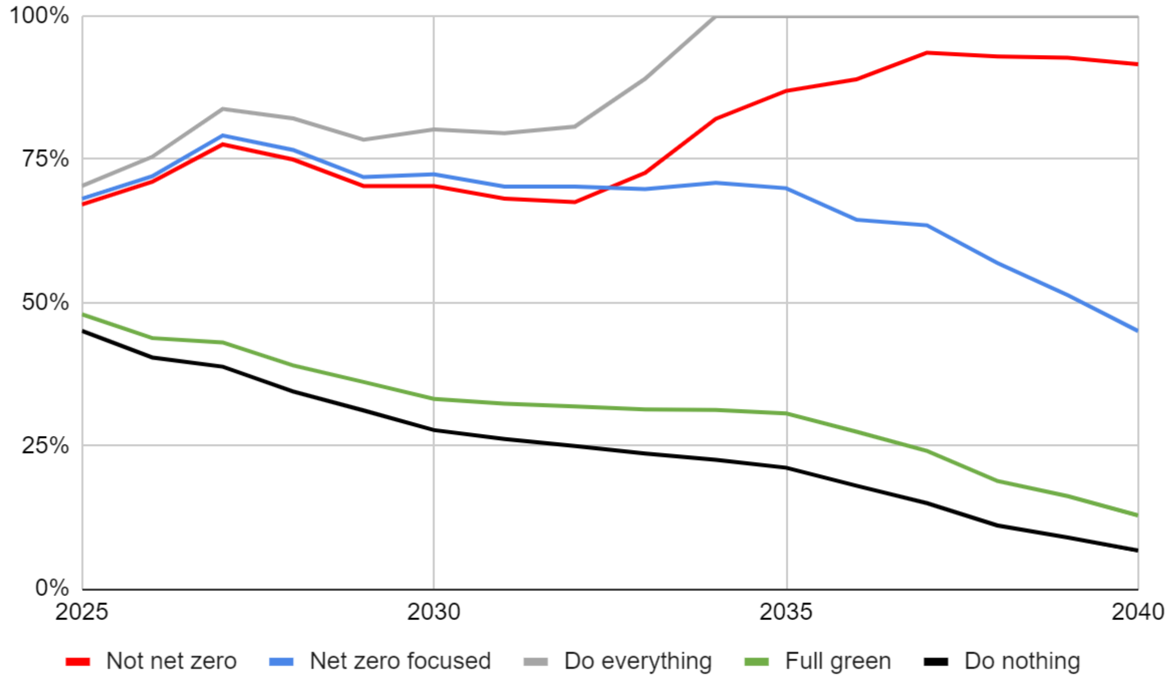
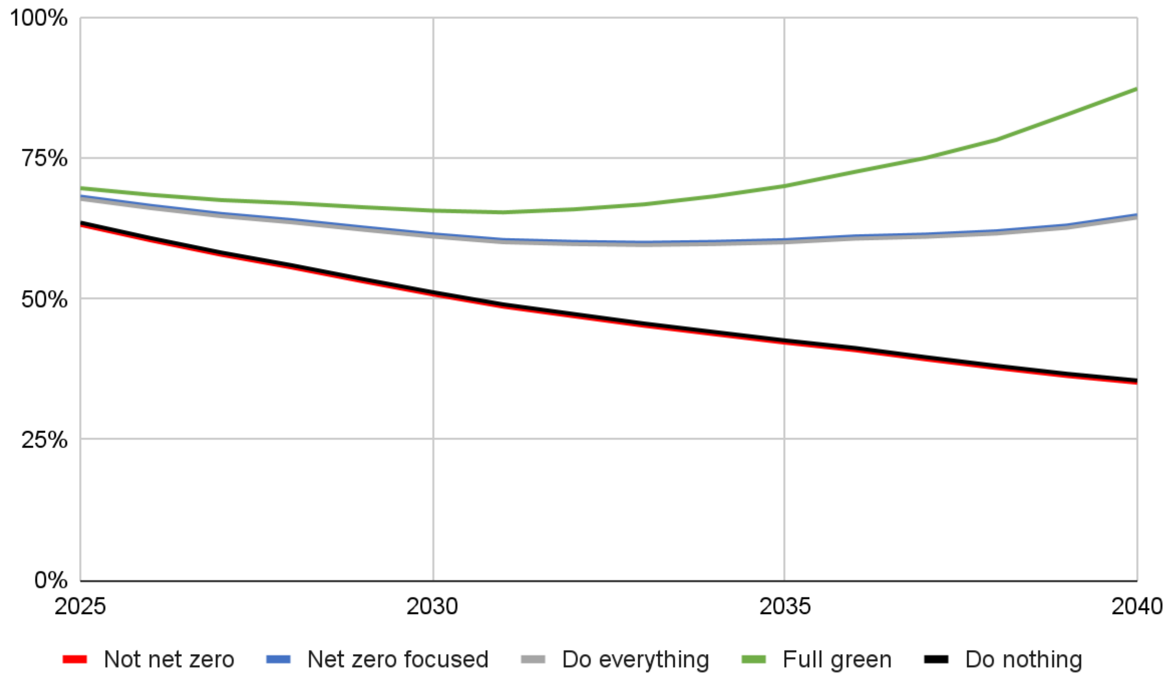


Figure 20: % of oil produced domestically



Summarising the model outputs

Table 1: model output summary

Scenario	Description	Annual energy bill in household with ICE car and gas heating in 2035	Annual energy bill in household with electric vehicle and air source heat pump in 2035	Total imported energy in 2035 [10]	Summary findings
Do nothing	No change to our current energy generation. Slow uptake of electric vehicles (EVs), heat pumps and energy efficiency improvements	£1877	£1560	48 million households equivalent	Sees the UK becoming more dependent on gas for electricity generation and more dependent on imports of oil, gas and power.
Not net zero	Ramps down renewable ambitions in favour of more nuclear and fracking. Slow uptake of EVs, heat pumps and energy efficiency.	£60 cheaper (than the 'Do nothing' scenario)	£145 cheaper (than the 'Do nothing' scenario)	20 million households equivalent	Reduces dependence on imported gas, though oil imports rise. New sources of power generation achieve independence in electricity. Bills are lower than in "Do Nothing" but higher than in "Net Zero Focused."
Net zero focused	Follows the Net Zero Strategy (NZS) plus the British Energy Security Strategy.	£85 cheaper (than the 'Do nothing' scenario)	£206 cheaper (than the 'Do nothing' scenario)	12 million households equivalent	Rapid increase in offshore wind leads to independence in electricity. Oil and Gas imports are lower in 2040 than today. Achieves lower bills than all other

[10] Equivalent of annual median household gas and electricity consumption (15,400kWh), taken from BEIS, *Energy Follow Up Survey: Household Energy Consumption & Affordability Final report*, 2021

	Medium take up of EVs, heat pumps and energy efficiency.				scenarios in 2035 and remains joint lowest (with "Full Green") in 2040.
Do everything	We follow the NZS but augment it with additional fracking and nuclear. Medium uptake of EVs, heat pumps and energy efficiency.	£52 cheaper (than the 'Do nothing' scenario)	£127 cheaper (than the 'Do nothing' scenario)	-0.3 million households equivalent [net exporter]	Achieves overall energy independence (residual net oil imports lower than net exports of gas and power). Bills fall relative to doing nothing, but not by as much as in "Net Zero Focused" or "Full Green" (due to additional cost of nuclear).
Full green	In which we press towards a fully renewable grid at pace. Strong uptake of EVs, heat pumps and energy efficiency.	£72 cheaper (than the 'Do nothing' scenario)	£176 cheaper (than the 'Do nothing' scenario)	13 million households equivalent	Additional uptake of EVs leads to lower oil demand. But gas imports are higher than most other scenarios. Slightly more expensive than "Net Zero Focused" in 2035, but catches up to be joint cheapest in 2040.

2.2: Ensuring Energy Security

In this chapter, we find that:

- In the near term, we need gas storage and generation as an important tool in the stability of our grid. That role may one day be taken up by hydrogen or another technology but in the medium term, we should follow Churchill's edict, prioritise diversity of supply and keep our options open.

  .
- Any sensible energy strategy would speed up the build out of offshore wind: even at 80% reliance on intermittent generation, the cost of generation PLUS intermittency costs of gas back up is still lower than gas generation alone. A mix that got closer to 80% renewables and 20% nuclear, backed up with storage and perhaps hydrogen generation, would cost little more and would deliver energy independence and a net export outcome.

- But critics are right to worry about plans to manage intermittency. Government has created a credible plan for the transition: Government must now be held accountable for delivering the plan and explaining the insurance that is in place should these overlapping redundancies fail.

- The government should annually prepare an assessment of what that worst case scenario might be and require the System Operator to assess its readiness against that scenario. We recommend that, as a starting point, this should test the ability of the electricity system to cope with maximum wind lull that lasts for two weeks straight.

Energy security

Given the extreme political risk of interruptions to our energy supply, it is perhaps surprising that energy security has been allowed, by successive governments, to sink down the list of priorities. It was similarly surprising, when we looked at the sophisticated energy system models used in government and academia, that these largely ignored energy security. In this chapter we aim to correct this omission.

In order to do that, we need to consider two discrete elements of energy security: independence from imports, and reliability of generation. These are our measures, picked after dozens of conversations with MPs, commentators, and energy experts to understand their concerns and insight into the needs of a resilient future.

Defining security

Energy Independence: In this report, we use independence to mean producing enough for your own needs. An energy independent UK would continue to have interconnectors with the continent that allow power to be traded across borders, would continue to use its LNG terminals and pipelines, and would continue to trade petroleum products with our neighbours to match refinery capacity to fuel demand. But overall, an energy independent UK would not be a net importer of energy in any given year.

Energy Reliability: By reliability we mean the fundamental ability to trust that when you flick on a light switch or plug socket, electricity will flow.

Energy Independence

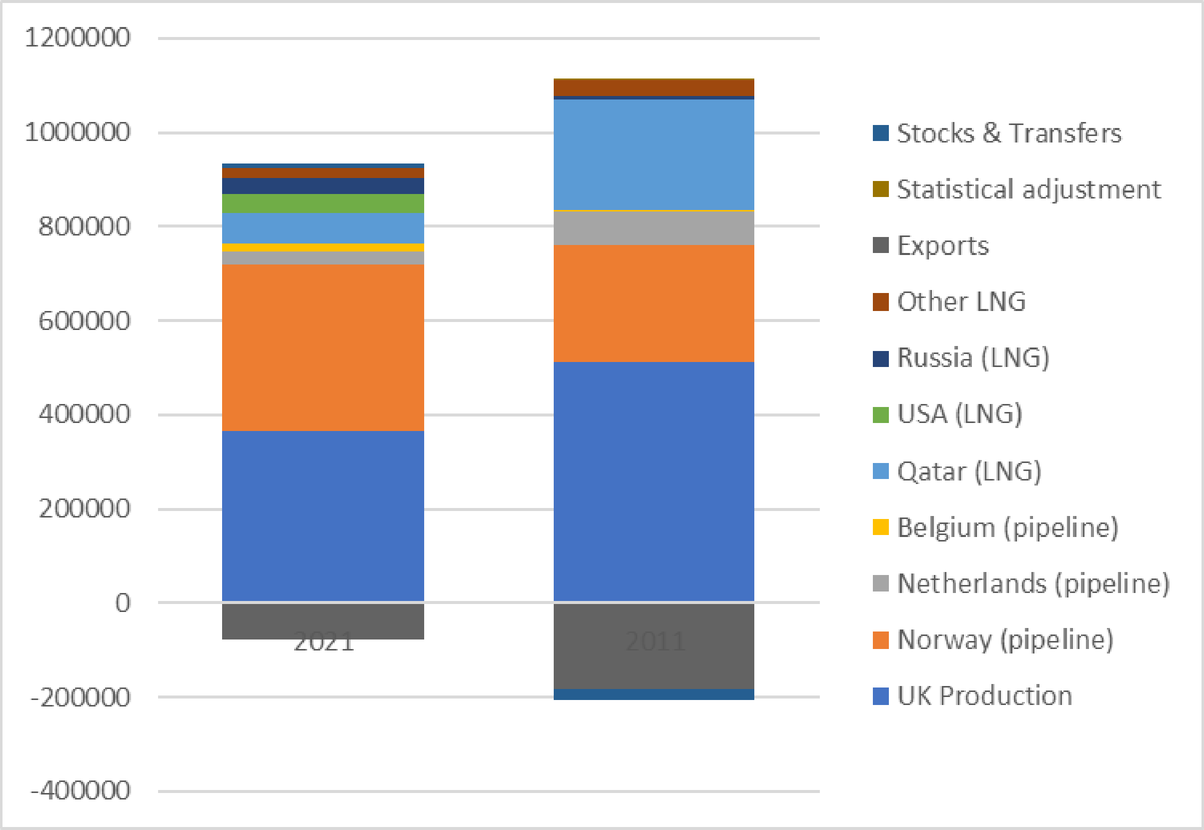
The UK has been a net importer of energy since 2005. And in 2021 our net dependence on imports was 38%.[11]

Historically the UK needed to be self sufficient in electricity as imports of electricity were simply not available. But since Interconnexion France-Angleterre (IFA) opened in 1986, the UK has had increasing access to two-way flow of power. This should be a positive for both increasing security and lowering costs, but instead the UK has become increasingly dependent on imports through the interconnectors - with imports being almost seven times greater than exports. In 2021 net imports hit a record high of 24.6 TWh - more than 7% of total electricity supplied.[12]

But it is in oil and gas that the UK's dependence on imports really shows. In 2021 the UK imported 57% of its gas needs[13] and 25% of its oil.[14] As Figure 21 below shows, the UK has become increasingly reliant on imported fuel.

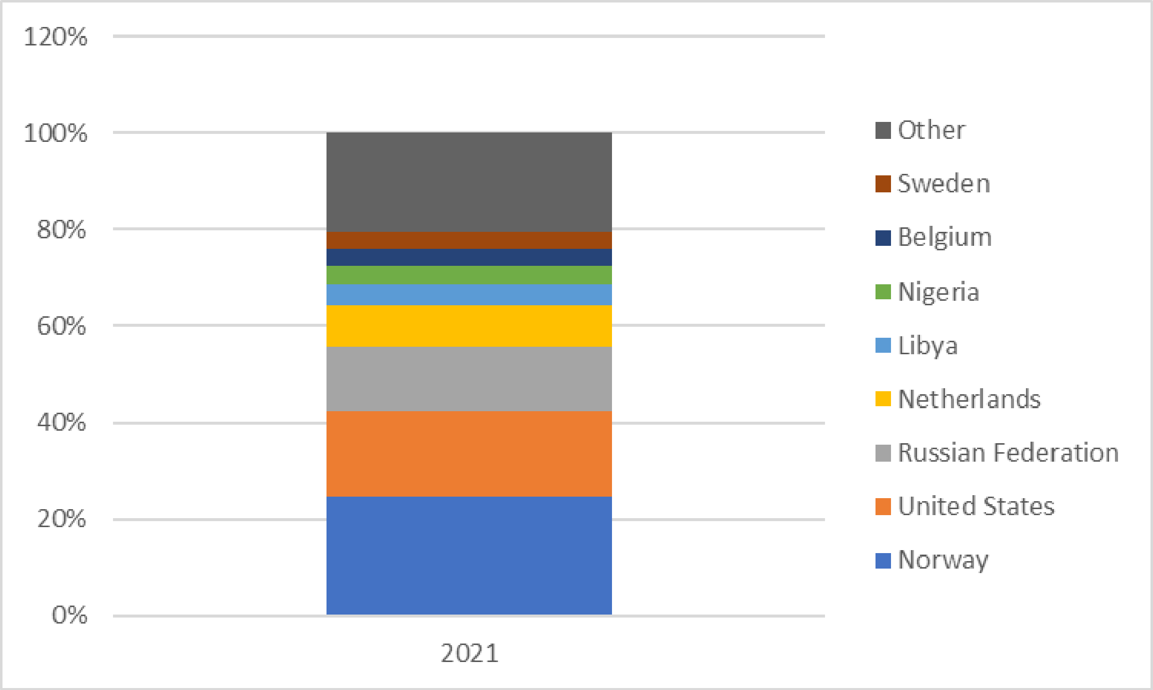
[11] BEIS, *Digest of UK Energy Statistics,* July 2022
[12] BEIS, *Digest of UK Energy Statistics,* July 2022
[13] BEIS, *UK Energy in Brief 2022,* July 2022
[14] BEIS, *Digest of UK Energy Statistics,* July 2022

Figure 21: Sources of UK natural gas supply[15]



[15] BEIS, *Digest of UK Energy Statistics,* July 2022, Table 4.1 and Table 4.5

Figure 22: Sources of oil imports[16]



As Russia's brutal invasion of Ukraine has made clear, over-reliance on imported energy means significant risks for the economy and for household bills. The idea of energy independence has long been discussed in a US context and is gaining momentum here in the UK.

Independence does not mean ceasing to trade in energy, it means producing enough for your own needs. An energy independent UK would continue to have interconnectors with the continent that allow power to be traded across borders, would continue to use its LNG terminals and pipelines, and would continue to trade petroleum products with our neighbours to match refinery capacity to fuel demand. But overall, an energy independent UK would not be a net importer of energy in any given year. As a starting point we show here how each of our energy scenarios performs against this criterion:

Table 2: Scenarios considering energy independence

Scenario	Gas	Electricity	Oil	Total
Do nothing	334TWh imported in 2035	88TWh imported in 2035	311TWh imported in 2035	733TWh imported in 2035
Not net zero	55TWh imported in 2035	Independent from 2028	311TWh imported in 2035	305TWh imported in 2035

[16] BEIS, *Digest of UK Energy Statistics 2022*, July 2022, Table 3.7

Net zero focused	98TWh imported in 2035	Independent from 2027	151TWh imported in 2035	189TWh imported in 2035
Do everything	Independent from 2034	Independent from 2027	151TWh imported in 2035	5 TWh exported in 2035
Full green	203TWh imported in 2035	Independent from 2028	98TWh imported in 2035	196TWh imported in 2035

For electricity - all scenarios that expand offshore wind see the UK becoming a net exporter of power in the late 2020s. This reflects the huge potential the UK has for offshore wind and its low costs.

For gas, continued exploration in the North Sea - as announced by Boris Johnson in the British Energy Security Strategy - makes a significant difference to import dependency. Fracking can make a significant contribution too, but it takes time to ramp up, meaning it is only material from the mid 2030s. Demand is key too - the roll out of heat pumps and energy efficiency measures makes a similar contribution to reduced imports as fracking in 2035.

Energy Reliability

As desirable as it is to be a net exporter of energy, it is even more important for our domestic energy to be reliable. We have grown accustomed to the lights turning on when we flick a switch and no solution that compromises this will be accepted by the British public or business community - no matter how much it may benefit our balance of trade.

In the years before the First World War, Winston Churchill converted the Royal Navy from coal to oil to make the fleet faster. This created an import dependence and thus a vulnerability which Churchill recognised. His answer:

> *"Safety and certainty lie in variety, and in variety alone."*

Churchill was right, of course, and diversity of generation still represents an important pillar of energy reliability. What he could not foresee was that new sources of power would emerge that create a second vulnerability: intermittency.

Intermittent vs Dispatchable energy generation

Throughout this report you will see us describe different types of electricity generation as either 'dispatchable' or 'intermittent'. This difference is crucial to discussions of cost and security in chapter 2.1 and 2.2, so it is important to explain what we mean by these terms. Dispatchable generation refers to sources of power that are made available to the grid on a permanent basis and can be easily turned on and off. Gas power is the classic example of this: as long as a gas plant is staffed and running at a minimum load already, the power station can be swiftly ramped up to produce significantly more electricity for the grid and then turned down again swiftly if required.

In contrast nuclear, for example, cannot be swiftly turned up and down - once operational, today's nuclear plants run at a consistent level and cannot be changed without substantial warning periods.

'Intermittent' generation, on the other hand, cannot be switched on at will. Instead intermittent sources, such as wind and solar, produce power proportionate to how much the sun is shining or how hard the wind is blowing. The system operator's only option in these cases is that they may ask for these generators to turn off the assets if there is too much power on the grid. Not all renewable power is intermittent - hydro and BECCS are generally considered dispatchable, for example. Solar and wind can also be dispatchable if bundled with storage assets like batteries.

The electricity system has always had to balance supply and demand in real time. Historically this required the System Operator (SO) to make projections about patterns of demand - for example, having generation on stand-by to meet a peak caused by kettles being turned on in the advert break in Coronation Street. Increasingly, the SO has also had to make predictions about the output from intermittent renewables such as wind and solar.

Some commentators are, understandably, concerned that as the proportion of electricity produced from intermittent renewables increases it will become harder, and more costly, for the SO to balance the system. Some see this as a reason not to deploy further renewables. But as the costs of wind and solar have fallen rapidly in recent years, this would be a choice to ignore the cheapest forms of generation, as well as the rapidly changing economics and geopolitics of the situation. Certainly, before doing so, it makes sense to explore whether we have adequate tools to manage that intermittency and ascertain the additional cost created by those tools. The remainder of this chapter is, perhaps necessarily, more detailed than the rest of this report, but we still seek to make it approachable for the non-specialist.

Managing intermittency

It is worth noting that the grid has always required balancing, and this has always cost money. In 2016-17 balancing system costs amounted to £1.1bn.[17] This includes, for example, payments to generators for 'black start' services (to allow for the recovery of the system after a loss of power), for 'start up' (where generating units are paid to warm up to a state of readiness to run), and for 'constraints' (where generators are asked to reduce output due to the network being physically unable to transfer the power from one region to another). Balancing costs arise even in a world without renewables, and we have long had systems - often markets run by the SO - to procure services to maintain a secure electricity system.

[17] National Grid, *Electricity Storage and Renewables - Costs and Markets to 2030*, October 2017

Three layers of electricity supply

Every day, in fact every second of every day, electricity generation needs to perfectly match electricity demand. Later in this report we explain who is responsible for this and the tools available to achieve this 'balance'. But before we get into that, we think it useful to think about the supply of electricity, and why we see this in three layers.

First there is "baseload". This is generation that is always on, running at a pretty steady level. Nuclear power is a good example. Many gas-fired power stations were built to run this way, though most now run far more flexibly. Coal historically provided baseload.

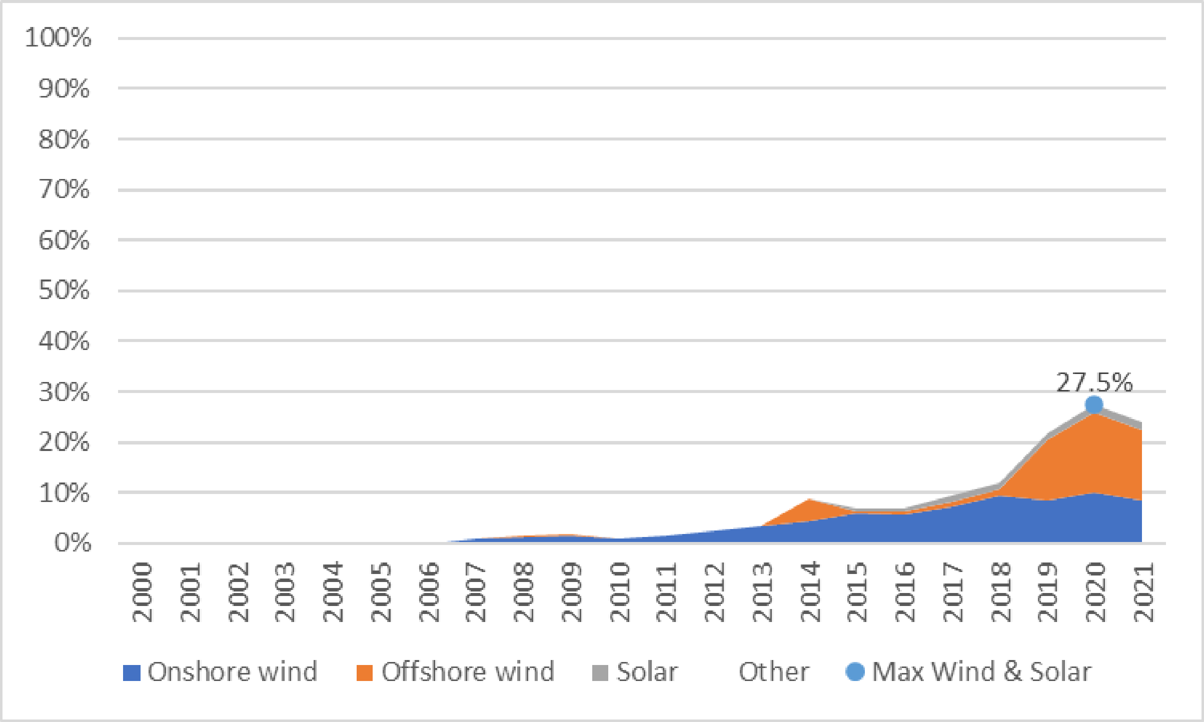
Second there are the generators that cost nothing to run. These are things like wind and solar. They cost money to build and to maintain, but when the wind blows or the sun shines each additional unit of generation doesn't add cost.

Sometimes these two layers are sufficient to meet demand. Sometimes indeed they produce too much and some wind/solar generation gets 'curtailed' (cut off and not used). But most of the time a third layer is needed.

Third is the "peaking" layer. This is generation that can be turned up or down in order to match supply to demand, and is typically the most expensive layer. On a typical day it generates a fraction of what it is capable of producing, and therefore needs to be rewarded with higher prices to account for limited running hours and the costs of being available even when not called to generate. Today this layer is typically a mix of gas-fired turbines, diesel-fired reciprocating engines, batteries, and pumped hydro. In future new peaking options will include new energy storage technologies (e.g. liquid air), hydrogen-fired generation, and fossil fuel based generation fitted with Carbon Capture technology.

In recent years there has been an interesting shift in fossil fuel based generation away from building large power stations and towards much smaller-scale, distributed plants. When the Government began running auctions for additional capacity, it anticipated one or two new large gas power plants being commissioned each year. Instead the gap was filled by many smaller generating units: 70 in 2017, for example. This shift - from large, centralised power stations to smaller scale units, distributed around the country - is already being managed by the UK's grid.

Figure 23: Increasing share of wind and solar generation[18]

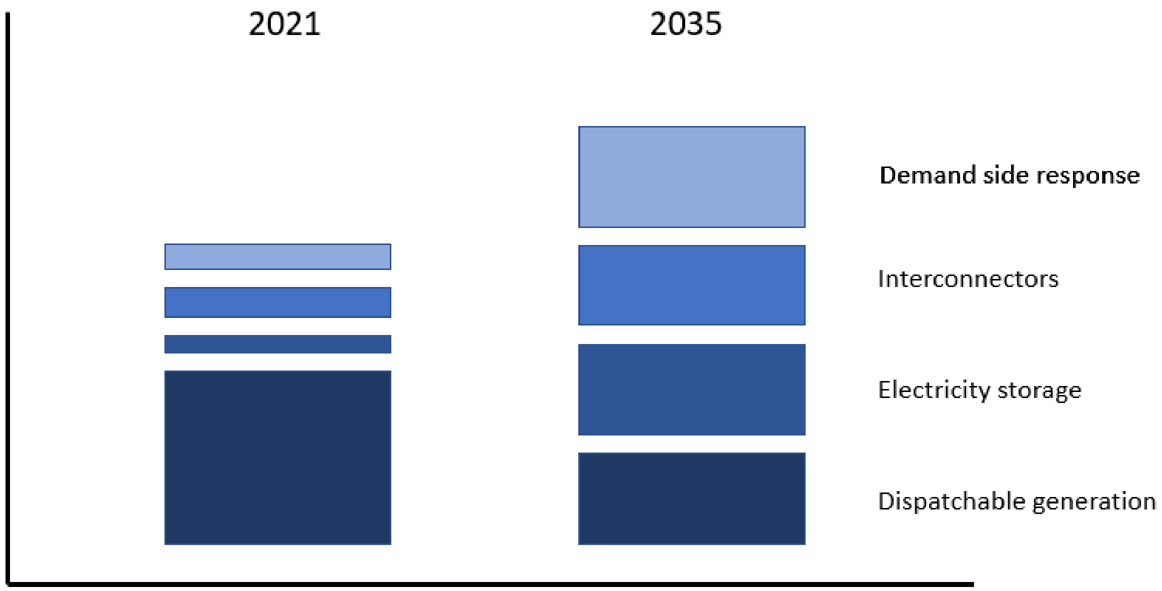


As well as managing this increasing flotilla of small dispatchable generators, the grid has also been getting to grips with how to manage a growing share of intermittent resources. The chart above shows how intermittent renewables account for around one quarter of total generation, and rising. When it comes to how to manage this, it turns out that the tools used are the same.

In the diagram below, we show the scale of tools currently used by the System Operator to manage flexibility in the grid. Next to it is their projection for what will be required to do the same job in 2035 while meeting the targets of the Net Zero Strategy.

[18] BEIS, *Digest of UK Energy Statistics*, July 2022, Table 5.6

Figure 24: Flexibility capacity[19]

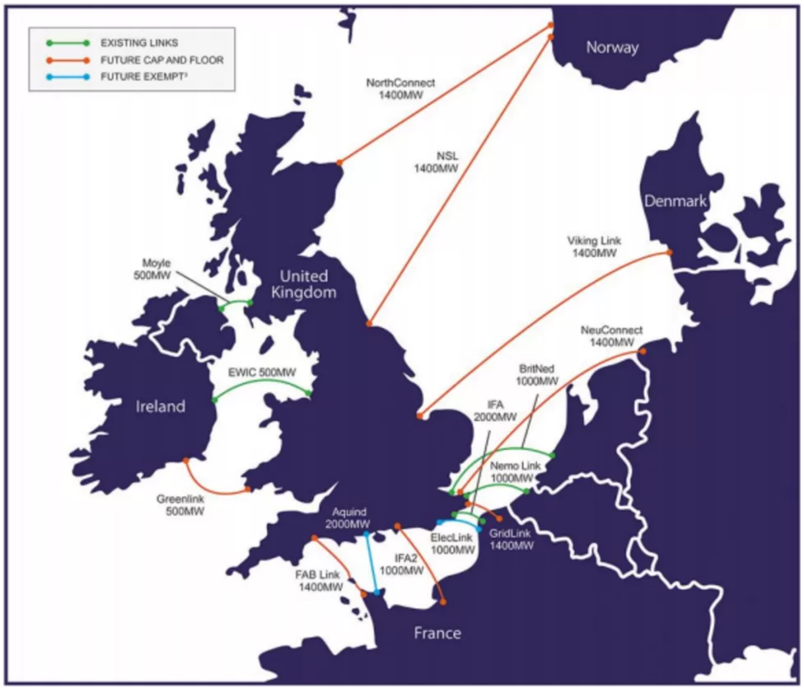


The foundation of each tool kit is dispatchable power - generation that the System Operator can turn on and off at will. At the moment, this is provided by gas and we could continue to use that, although that would make it harder to achieve energy independence. In the future, hydrogen may offer an alternative, British-made, fuel source for seasonal intermittency, allowing us to store power when the wind blows fiercely and release it many months in the future if required. This would also help the grid to manage when the intermittent renewables produce far more power than we demand. Right now, we are nowhere near producing sufficient hydrogen to fulfil this need. Therefore, in the near term, we need gas storage and gas generation.

Interconnectors will also remain an important failsafe. We currently have 8.4GW of interconnector capacity and there are plans for a further six interconnectors which will almost double that, bringing us close to the SO's target well before 2035.[20]

[19] National Grid ESO, *Future Energy Scenarios 2022*, and National Grid ESO, *A Day in the Life 2035*
[20] Ofgem website, *Interconnectors | Ofgem*, accessed 29 September 2022

Figure 25: Existing and planned interconnectors[21]



Demand-side flexibility is the area where today's plans rely the most on new technology. In 2022, demand side response largely means paying big businesses to reduce their power demand but current trends show the potential for the future.

For example, Ofgem expects that electric vehicle (EV) batteries alone will provide 30GW of storage to the grid in 2050 - far more than the system operator expects to require. These numbers are based on electric car uptake figures that are now proving to be conservative. High petrol/diesel costs and falling EV prices, as well as interventions such as London's Ultra Low Emission Zone have driven faster uptake of Electric Vehicles than most models predicted.

Price isn't just an important lever for convincing the public to buy EVs: studies so far suggest that EV drivers become (understandably) more sensitive to electricity prices and can then be incentivised to shift demand from peak hours to cheaper, off-peak electricity very simply using time-of-use tariffs. Octopus's initial results show that simply by showing consumers their energy prices in half hour increments, the average customer shifted their electricity consumption out of peak periods by 28%. Electric vehicle drivers reduced peak consumption even further by 47%. That not only meant that 95% of consumers paid lower energy bills but, if scaled up, would mean spending billions of pounds less of electricity generation - because load would never get quite so high.[22] The System Operator is also taking steps this winter to make cheaper off-peak energy available to a wider audience so that it can spread demand more evenly across the day and thus make it cheaper to run the grid. Newer forms of electric heating can also fulfil this role of shifting demand into off-peak hours.

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[21] BBC News, *Cross-channel electricity link goes live in tests,* October 2020
[22] Octopus Energy, *Agile Octopus - A consumer-led shift to a low carbon future,* October 2018

"Vehicle batteries can play an active role in the energy system of the future. Vehicle-to-X (V2X) technologies allow [users] to export electricity during periods of high demand and/or low electricity supply. V2X's potential goes beyond reducing peak demand, as it is capable of providing a temporary source of energy supply. By 2050, the capacity of V2X could significantly exceed 30GW. By providing power to the grid or buildings, they have the potential to provide further benefits to the energy system, and to EV owners providing that flexibility, as they earn money or reduce their own energy consumption from exporting power. If appropriately integrated, these technologies can lower the overall generation capacity required on the system and also avoid additional network costs." Ofgem[23]

Finally, there is storage. The System Operator is agnostic about what form storage takes but right now it exists primarily in the form of pumped hydro power and some battery systems.

Dedicated batteries have already been built to charge up when power is cheap and discharge back to the grid when power is expensive. By 2035, the System Operator expects over 20 GW of battery storage to be available on the grid. These units will have an average storage duration of at least three hours. But we note that battery use is naturally limited by "cannibalisation" - that is the phenomenon where each additional battery reduces the price differential between high and low prices on which the case for investment in new batteries depends. In National Grid's scenario, dedicated battery use grows rapidly from less than 1TWh in 2022 to over 6TWh in 2026, after which it plateaus.[24] Other forms of longer-duration storage will also be needed and it is not clear which technologies will be most successful but options include liquid air, sand and salt batteries, as well as gravity-based storage, alongside additional pumped hydro. New storage is also likely to be in different locations: next to wind farms or solar or close to major sources of demand - like data centres.

There is a very healthy pipeline of battery projects. Indeed, in April this year, it was reported that the total pipeline of battery projects has doubled from 16.1GW a year ago to 32.1GW. - more than enough to meet 2035 requirements. Operational battery storage project capacity had grown by 45%, from 1.1GW to 1.6GW, over the previous year, a further 10.4GW has received consent, 7.7GW has been submitted in the planning system and 10.9GW is in development but yet to be submitted.[25]

These data are extremely reassuring but obscure a series of important challenges for batteries and for longer duration storage technologies. First, while planning permission was

[23] Ofgem, *Enabling the transition to electric vehicles,* September 2021
[24] National Grid ESO, *Future Energy Scenarios 2022, "Consumer Transformation" scenario,* March 2022
[25] RenewableUK, *Pipeline of UK energy storage projects doubles within 12 months,* April 2022

eased in 2020 to allow local authorities to grant permission for larger storage developments, those limits are still restricting market growth in England. Second, storage developers report significant problems with getting permission to connect to the grid. And third, as with several elements of the infrastructure envisaged in the Net Zero Strategy, the Government has yet to confirm essential elements of the business model - in this case, whether battery owners will have to rely purely on being able to capture the difference between the low price when they charge up and the high price when they feed power back or whether they would be able to stack multiple revenue streams by, for example, offering that 'charging up' as a service, being paid to absorb excess power when we have far more electricity than we need.

In these last two elements - battery storage and demand side response - it is clear that there remains some uncertainty. That grey area is unfortunate, given the strategic importance of our electricity network and critics are right to worry about plans to manage intermittency. Government agencies have created a credible plan for the transition - the analysis above shows that there are multiple redundancies and they are based on technology or behavioural patterns that are already proven to work but a plan on paper is not the same as real resilience.

Government must be held accountable for delivering the plan and explaining the insurance that is in place should these overlapping redundancies fail. We recommend that the government should hold itself to account with an electricity reliability standard. For example, If the UK is to adopt an approach based on a significant proportion of intermittent renewables it should set a target to have storage and backup capacity such that it can continue to meet electricity demand in a "once in a century scenario" where wind output and solar generation is minimal. This is likely to be a moving target given the changes that we have seen in our generation capacity, and our weather, over the past two decades. Therefore, the government should annually prepare an assessment of what that worst case scenario might be and require the System Operator to assess its readiness against that scenario, much as is now the norm in the banking sector. The annual report should also give a transparent assessment of the costs of this insurance policy, which could be met using a strategic reserve of gas, for example, or other viable generation capacity if it emerges.

For example, detailed analysis by Regen, generously shared with the authors, suggests that the maximum lull (with renewables generating approximately 20% of capacity) that we could expect within a 100-year period would be around 200 hours - or just over 8 days. If we were exceedingly conservative and prepared for a lull to 30% capacity, that would bring our once-in-a-century exposure to two weeks. The Government should therefore ensure that the current technology in our system could cope in that lull scenario for two weeks. Right now, existing gas plants, perhaps combined with a greater volume of gas storage, would be the most plausible way of accomplishing that.

Costs of Intermittency

As we have shown above, managing the system to achieve balance day-in-day-out costs money whatever the generation mix. When we have too much power and not enough demand, the system operator must pay some generators to turn off their equipment. When demand outstrips supply, the SO instead must incentivise generators to start up. In the year before the pandemic, balancing system costs amounted to £1,317m[26]compared with a total value of electricity sold of £39,781m.[27] In other words, balancing costs accounted for 3% of final electricity costs.

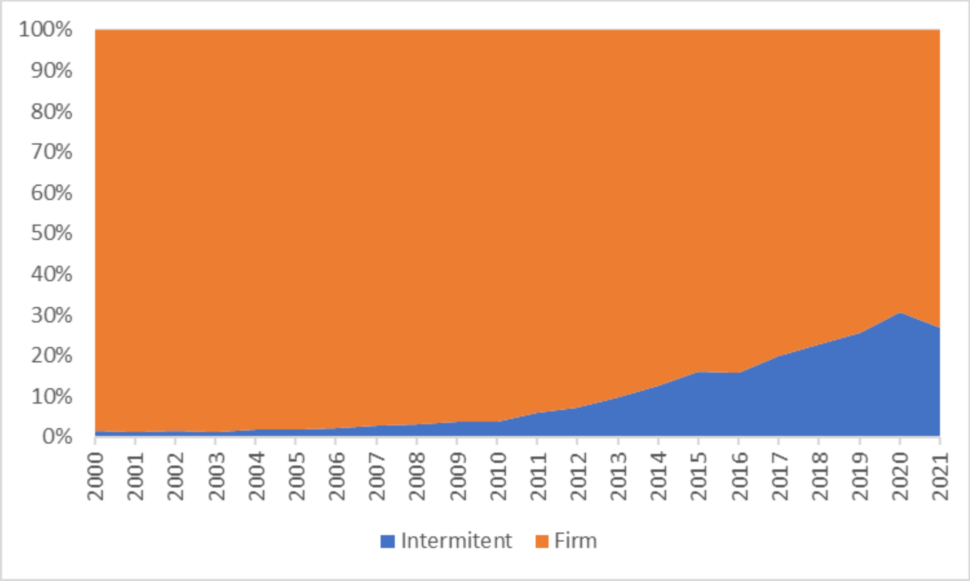
But we are increasing the volumes of intermittent renewables (such as wind and solar PV) being built and this increases the need for active management. This includes the need to meet peak demand at times when output from wind and solar may be low, as well as the need for additional grid infrastructure to transport electricity from point of generation to point of demand.

The electricity system has already become more flexible to meet these needs, with a general move away from large-scale power stations to smaller, more distributed sources of supply. This has been combined with the growth of demand side response and the rapidly falling costs of battery storage.

Flexibility can be deployed to accommodate a growing share of intermittent generation. When demand is high and output is low, demand-side response can be used to shift some load, interconnectors will be in import mode and electricity storage will be discharged into the grid. When demand is low and intermittent output is high, demand can be increased (including the charging of EVs), interconnectors will export, and electricity storage can be charged up.

[26] National Grid Electricity System Operator Limited, *Annual Report and Accounts* 2019/20
[27] BEIS, *Digest of UK Energy Statistics:Table 1.3A,* July 2022,

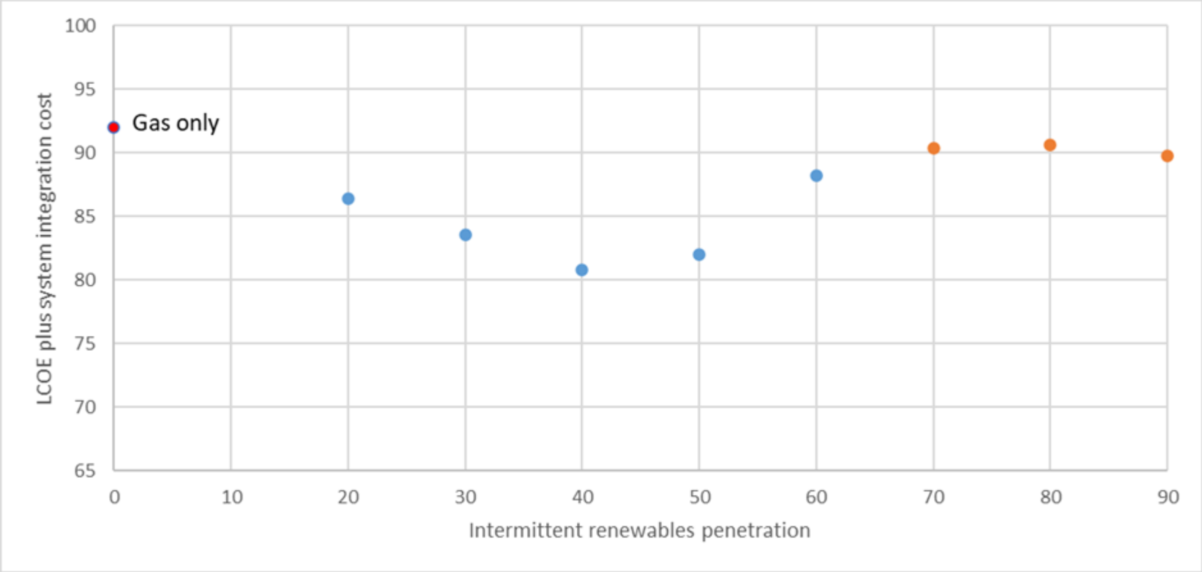
Figure 26: Growing share of intermittent generation[28]



Substantial research has been done in recent years to examine the technical potential for integrating intermittent generation into the electricity mix as well as to estimate the integration cost. These studies typically show integration costs around £10-25/MWh for systems with 50-65% renewables. For higher renewable penetration these costs are higher. Modelling undertaken for the preparation of the Sixth Carbon Budget shows that integration costs could be £25-30/MWh for a system with 75% to 90% of variable renewables. Of this, between £5 and £10/MWh is the cost to ensure the availability of backup generation capacity required to meet peak demand - a cost that is not expected to change significantly as renewables penetration rises.[29] Overall integration costs can, however, be reduced by greater system flexibility (as discussed above: increased battery storage or demand-side response).

[28] BEIS, *Digest of UK Energy Statistics*, July 2022, Table 5.1A
[29] *CCC analysis based on Imperial College* (2015), *Value of flexibility in a decarbonised grid and system externalities of low-carbon generation technologies and UKERC* (2016), *The costs and impacts of intermittency* (2016 update)

Figure 27: Example costs of generation, including the system integration costs, of rising penetrations of intermittent renewables[30]



There is, of course, an effective economic limit to the penetration of intermittent renewables. Some recent studies suggest this limit is very high. But even a 2018 analysis by Aurora shows that overall system costs continue to decline until penetrations reach over 80%.[31] That means that even at 80% reliance on intermittent generation, the cost of generation PLUS intermittency costs is still lower than gas generation alone.

If we were aiming to construct a generation mix solely to optimise for cost - ignoring import dependence or climate change entirely - then, based on these data, that might look something like 45-50% wind/solar, 20-25% nuclear and 25-35% gas generation. But such a mix would involve substantial gas imports and thus exposure to global gas market prices. A mix that got closer to 80% renewables and 20% nuclear, backed up with some electricity storage and perhaps hydrogen, would cost little more and would deliver energy independence and a net export outcome.

[30] Author's calculations. Blue dots based on levelised costs from BEIS, *Electricity Generations Costs 2020*, August 2020 and system integration costs from the 'fast progress' scenario in Imperial College London, *Whole-system cost of variable renewables in future GB electricity system*, 2016. Orange dots use system integration costs from CCC, *Sixth Carbon Budget – The path to Net Zero*, December 2020

[31] Aurora, *System cost impact of renewables*, 2018

Net Zero Intermittency?

So we've concluded that offshore wind generation is cheaper than gas-fired generation, even after including the costs of managing intermittency, and that it reduces dependence on imported gas. That means any sensible energy strategy would speed up the build out of offshore wind. But there are choices as to how to manage the intermittency.

If there were no climate constraint, the System Operator could continue to flex the output of gas-fired plants (and diesel generators). But, given this approach would rely on imported gas, and given the likely continuation of the government's commitment to net zero, we think it is worth exploring how intermittency can be managed in a net zero way.

This net zero toolkit has three parts - load shifting, dispatchable generation, and electricity storage - all of which will be familiar from earlier in this chapter.

First, not all use of electricity is time-sensitive. Some demand can be moved to times when overall demand is lower. There has recently been a newspaper reporting that this means turning on your washing machine in the middle of the night.[32] In practice a much bigger contribution will be made by EVs being plugged in and programmed to charge when power is cheapest. This would smooth out the traditional pattern of daily demand (low use overnight, big peak in the early evening). This effect reduces the peak demand that our electricity system needs to meet.

Second, those flexible gas plants can be replaced by low carbon alternatives. For example, hydrogen-fuelled turbines could provide a reliable source of power that can be switched on and off when needed. These plants would likely be located in areas with plentiful renewable generation that can be used to produce the hydrogen at times of the year when supply exceeds demand. Bioenergy (with or without CCS) could be an alternative form of low carbon generation. This source of flexibility is especially important for dealing with seasonal mismatches of demand and supply, rather than mismatches across the span of a day.

Third, electricity storage becomes increasingly important. This essentially charges up at times when supply is abundant and thus prices are low, and supplies power back to the grid when prices are high. We discussed above how batteries would typically charge overnight and provide a few hours of power, and how technologies like pumped hydro or liquid air can provide longer duration storage.

National Grid ESO has modelled in detail its ability to meet winter demand during a period of low wind speeds and very little sunshine. It has concluded that, with the right plans and strategies in place, this is achievable by 2035. That is great news as it offers us a faster route to energy independence. Nonetheless, we return to Churchill's point: in the medium term, we should prioritise diversity of supply and keep our options open.

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[32] Daily Star, *"Wash your grundies at midnight"*, 7 October 2022

In order to provide reliability as well as independence, we must also a) build more nuclear capacity to ensure our baseload is certain, b) increase market flexibility and c) keep our gas storage and gas generation available as an insurance policy, as well as d) accelerating the development of green hydrogen so it can be deployed when cheap enough. Building a green hydrogen economy would also allow us to capture excess generation - when the wind blows too much - and build up energy stockpiles to insure us against future crises. It would also allow us to achieve energy independence faster.

2.3: Keeping Energy Affordable

In this chapter, we find that:

- Our model shows that household bills in 2040 will be at least £400 lower for families that electrify their cars and heating - no matter which energy mix the government chooses.

- Across the life-cycle, the cost of generation from renewables is (significantly) cheaper than relying on gas. Our model relies on technology cost estimates made before the Russian invasion of Ukraine and assumes a normalisation of gas prices - and yet the cost advantage of renewables is clear. And obviously, this is even more true today when gas prices are seven times the price seen at the start of 2021.

- Reducing gas demand in the power sector and increasing our reliance on home-grown, zero-marginal-cost renewables insulates families from the kind of energy bill shock seen this year as a result of the invasion of Ukraine.

- If new wind generators want to come into the market - and are permitted to do so by the government - they are hindered by long planning lead times, long grid connection lead times and other barriers that mean prices would take several years to reflect the lower cost of renewables.

- Even if new wind generation comes onto the market, expensive gas acts as the marginal good meaning that the wholesale price depends upon how often renewables (and near zero marginal cost nuclear) are able to meet demand on their own, compared to how often gas is needed. Put bluntly: the moment we switch on the gas, expensive gas sets the price.

- Therefore, in order to fully benefit from lower costs in the near term, we do need to reform the energy market.

- The Government should therefore consider a short-term stopgap measure such as a tax on the recent extraordinary profits in the renewables sector, whilst simultaneously accelerating the timeline of consultations to reform the UK's energy market to prevent such actions from being necessary in the future.

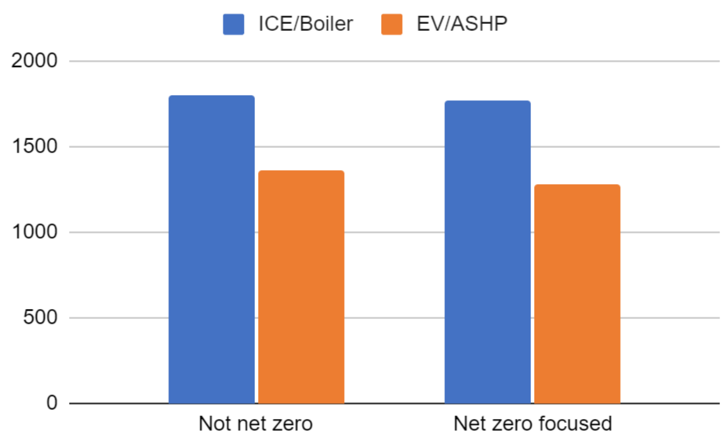
Household costs

In 2.1 we showed the difference in energy bills between scenarios. The beady eyed may have noticed even more significant differences between projected bills for different household types - those equipped with ICE cars and gas boilers vs those with electric cars and air source heat pumps. Clearly, we could have modelled many variations on this theme but have opted for two distinct exemplars that again shine a light upon a live political debate.

Across all our scenarios we find that in 2040 household bills are lower for those that have switched to electric vehicles and a heat pump relative to those still using an ICE vehicle and a gas boiler. This effect is not marginal: by 2040 bills in the electrified household are at least £400 lower across ALL energy mix scenarios.

Moreover, as discussed in 2.2, heat pumps and electric vehicles can also act as tools for shifting electricity demand away from peak periods, and thus rendering our grid more stable and cheaper to run.

Figure 28: Comparison of household bills in 2040



We also considered the impact of a gas price shock similar to the one we are currently experiencing. We found that reducing gas demand in the power sector and increasing our reliance on home-grown, zero-marginal-cost renewables insulates families from the kind of energy bill shock seen this year as a result of the invasion of Ukraine.

Specifically, our modelling shows that should a similar gas price event happen in 2040, a typical household bill for a household running an EV and an Air-source Heat Pump (ASHP) would be £1,049 cheaper in the "Net Zero Focused" scenario than in the "Do Nothing" scenario.[33]

Furthermore, this price shock, which sees gas prices jump by almost 400% sees this household's bill rise by only £22 in the "Net Zero Focused" scenario.

[33] A household still reliant on a gas boiler would still benefit from a significant, albeit lower, saving of £429

Technology costs

Our model shows the potential for wind generation to lower household energy bills. This is intuitive in one sense - wind is free, whereas generation from gas must at the very least cover the cost of the fuel to be burned and the present situation has heightened that difference. In pre-crisis days, assuming all else were equal, the cost of gas needed to produce enough electricity for a typical family would be £80 per year. Using November 2022 gas prices, that cost would be £777.[34]

This is obviously a gross simplification as it does not include the cost of financing and building either the gas plant or the wind turbines, so a measure called the Levelised Cost of Electricity (LCOE) is used, including by the Department for Business, Energy & Industrial Strategy (BEIS). The LCOE is the average cost per unit generated over the full lifetime of a plant, including planning, construction, operation, fueling, maintenance, and decommissioning. It's not a perfect measure but this approach provides a straightforward way of comparing different technologies in a consistent way. Levelised costs are a valuable tool in making choices about what types of plant to build and the relative costs of different generation mixes for a country.

The latest BEIS estimates on levelised cost for new generation assets commissioning in 2025 and 2030 are presented in the table below.

Table 3: Levelised cost of generation technologies commissioning in 2025 and 2030[35]

Technology	2025 cost (£/MWh)	2030 cost (£/MWh)
Gas CCGT	85	99
Offshore Wind	57	47
Onshore Wind	46	45
Nuclear	101	83
Solar (large scale)	44	39

It is clear from the table that across the life-cycle, the cost of generation from renewables is (significantly) cheaper than relying on gas or nuclear. And these costs in the table rely on a

[34] We can estimate this difference for a typical household - say one using 2,900kWh of electricity a year. If we assume the input price of gas is 40p/therm (typical over recent years until spring 2021) and assume a plant efficiency of 49.13% (the figure normally used for this calculation. Then the difference between a gas generation system and a renewables one is £80. At recent gas prices (the price on 26 August for gas delivered in November was 386p/therm) the fuel cost difference would be £777 a year for a typical household.
[35] BEIS, *Electricity Generation Costs 2020*, August 2020 for gas and wind. BEIS, *Electricity Generation Costs*, November 2016. All values are presented in 2018 real prices. Nuclear prices have been calculated from the source material using GDP deflators published March 2022

trajectory of gas prices from well before the Russian invasion of Ukraine - current prices for gas are seven times higher than when these LCOEs were calculated.[36]

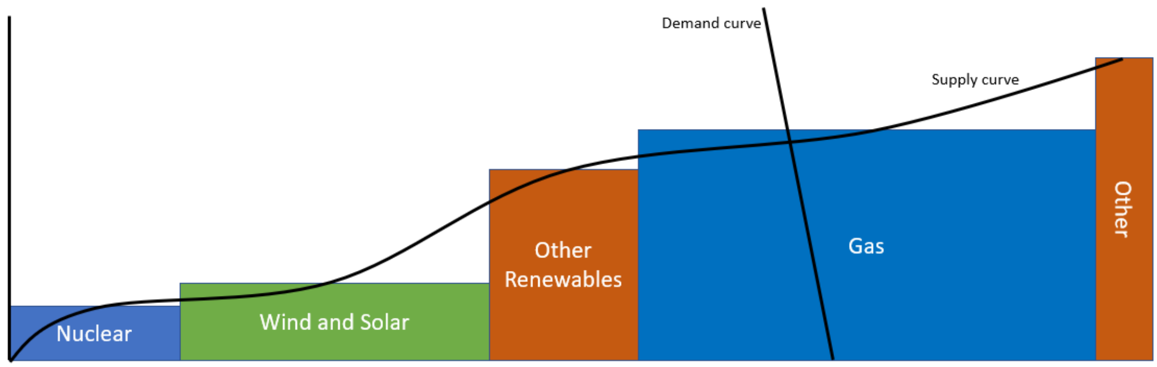
Market reform

This disparity in costs explains why both major political parties back a massive increase in wind power, and why there are many firms willing to invest capital in building them. In recent years the UK has built more offshore wind than any country other than China and earlier this year the government signed contracts to deliver a further 7GW of capacity. But if all of this wind power is so cheap, why is anyone against wind power as a solution for our energy woes, why isn't energy cheaper now, and why doesn't our model show prices dropping more rapidly in the 2030s as more wind comes on stream?

There has in the past been much debate around the intermittency costs of renewables that are not captured in levelised costs, but as we showed in the previous chapter, this is not the issue here. Instead the cause is the manner in which the market for electricity currently works.

The key point is that wholesale electricity prices are not set on the basis of the costs of the individual technologies used in a given period. We don't add up all the costs and then take an average. Instead - like most markets - the wholesale price is set by the marginal source of production. In other words, the most expensive source of generation used in a given period sets the price for all generators used in that period.

Figure 29: Stylised supply and demand diagram



In recent months, a number of commentators have described it as an "absurd" situation. Why should zero-marginal cost wind generation get paid more for its output when the gas price goes up?

In a normal market the ability for lower-cost units of supply to capture high marginal prices acts as an incentive to invest, bringing new, cheaper units of production into the market. Those

[36] Specifically a gas price of 53p/therm in 2025 and 59p/therm in 2030. This compares to the 386p/therm price on 26 August for gas delivered in November 2022. BEIS, *Fossil Fuel Price Assumptions*, 2019, Table 3

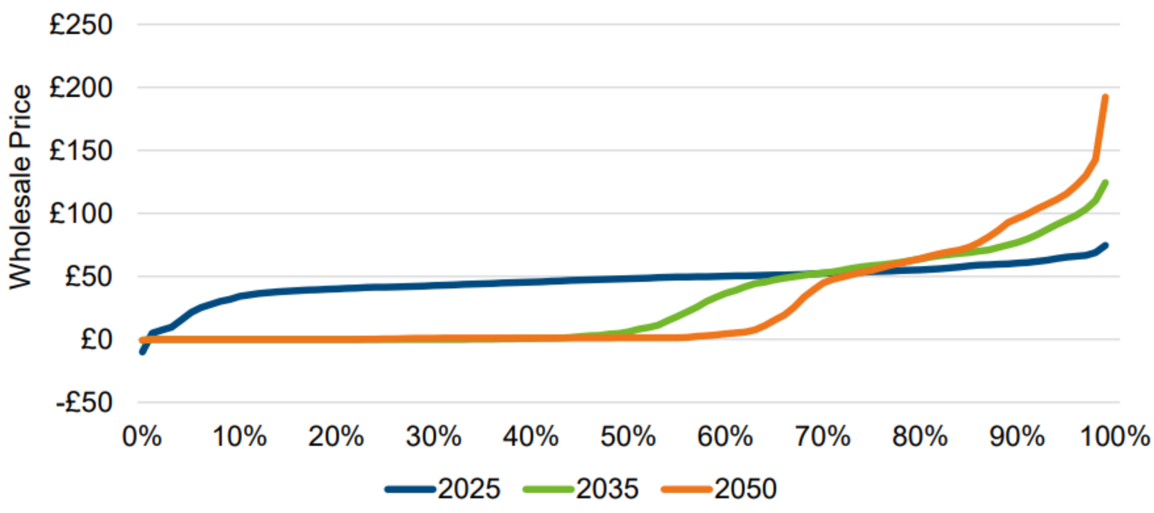
investors continue to make additional profit (known as 'rents') until there is sufficient cheap production that effectively drives the expensive forms of production from the market.

The electricity market is not normal. For many reasons. But in particular because new generation is rarely financed on the basis of the 'merchant' prices, but instead through long-term central contracts with the UK government. The availability of such contracts is limited by government and even if new wind generators wanted to come into the market without a contract they are limited by long planning lead times, long grid connection lead times and other barriers that mean prices would take several years to reflect the lower cost of renewables. All of this slows down the self-regulating nature of a market and the ability of cheap wind power to reduce prices overall. But even if more wind power could be built, it would not necessarily become the marginal generator, and might not impact wholesale prices.

The wholesale price, therefore, depends upon how often renewables (and near zero marginal cost nuclear) are able to meet demand on their own, compared to how often gas is needed. Put bluntly: the moment we switch on the gas, expensive gas sets the price.

As a greater renewable generation capacity is connected, there will be more frequent periods where prices are set at (or near) zero (by renewables), but also more periods where renewable output is low and marginal prices are high. The most recent estimates from BEIS of this pattern of low and high priced periods can be seen in figure 30 below.

Figure 30: cumulative distribution of wholesale prices (£/MWh)[37]



As can be seen, around 50% of the time the electricity wholesale price should be zero by 2035. Even including the effect of some higher wholesale price periods at the right of the chart, this would still see average prices fall from around £50/MWh (5p/kWh) to around £30/MWh (3p/kWh).

[37] BEIS, *Review of Electricity Market Arrangements Consultation Document*, July 2022

In the near term, the fact that gas sets the wholesale price around 80% of the time[38] means that the lower cost of renewables does not feed through to wholesale prices or household bills. This has led many to argue for some reform of the market to prevent low-cost generators from reaping windfall gains from the current extreme gas prices and to allow households to benefit from lower prices.

In the second half of October the government passed legislation, the Energy Prices Act, to essentially recover these windfall gains into a fund to help reduce the cost of electricity. But, especially given the emergency timetable on which this legislation was passed, it is worth considering the options that government had available to it to reform the market.:

- One proposal discussed was to move to **pay-as-bid pricing** - the idea being that each generator would offer to provide power at a price that covered its own costs without reference to other generators. We dismiss this idea. There is a significant body of academic evidence that this would lead to low cost generators gaming their bids and no overall saving.

- An alternative is **a split market**, in which two wholesale prices co-exist. One wholesale price, set as today, for peaking generators including gas-fired plants. And one wholesale price for renewables set in a different way. This approach has some precedent. The Contracts for Difference (CfD) support scheme for newer renewables pays them a fixed price for their energy - a price set through an auction that is designed to reflect their real costs. There are certainly advantages to this kind of scheme, including the incentive for consumers to shift their behaviour (ie when they use power) to maximise their use of the low cost market and minimise their use of the peaking market. It is complex though to see how the new (lower) wholesale price would be imposed on renewable generators.

- **A new regulator** (Of-cost?) could be employed to analyse the 'real' costs of each form of generation and to determine the 'right' level of remuneration for each. But this would involve a marked shift away from markets and competition, which we judge would be complex, bureaucratic and unappealing to the present government.

- The government announced in September that its preference was for **a voluntary CfD contract** to be offered to older renewable generators. While this would reduce bills in the short-run, it also risks locking in higher prices in the long run. Generators are only likely to agree to a voluntary CfD if the expected future gains are greater than the lost revenue in the near term.[39] Compulsion (a stick) of some sort would be needed to require generators to accept a CfD contract with lower expected returns.

[38] UCL Institute for Sustainable Resources, *The Role of Natural Gas in Electricity Prices in Europe*, July 2022
[39] See for example the argument made by Tim Lord, Twitter, 7 September 2022, *https://twitter.com/timbolord/status/1567555327607951365?s=46&t=H8jtr5qYAjR7Q35CIlNo5g*

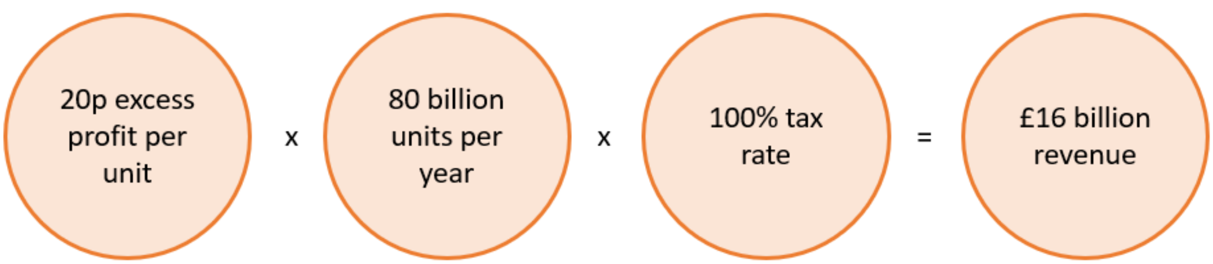
- The remaining alternative is in essence to tax away the gains. The Energy Prices Act, which received Royal Assent on 25 October, provided the required stick by way of a "**temporary Cost-Plus Revenue Limit**" designed to allow "generators to cover their costs and receive an appropriate revenue that reflects their investment commitment and risk".[40] This is a windfall tax in all but name. With perhaps the benefit that unlike some other windfall taxes it should not deter new investment, as the way newer renewables are remunerated prevents such future windfalls occurring anyway.

While the legislation is now on the statute book, it is in the form of providing powers to ministers rather than providing details on how it will work. There is not yet clarity on which generators it will apply to, nor the price limit that it will set. Instead the government has said there will be a consultation "launched shortly" to determine these details. So it is impossible to know how much it will raise beyond the government's vague language that it "has the potential to save billions of pounds".

We think it would be useful to provide an estimate here of how much this effective windfall tax could raise / save for billpayers. Not least because an effective windfall tax allows for a more straightforward way to estimate the impacts than recontracting onto CfDs

In the last year around 80TWh (80 billion kWh) of generation was supported by the Renewables Obligation.[41] This scheme pays a premium on top of wholesale prices to eligible renewable generators. Assume we expropriated revenues above 10p/kWh for each of these generators and assume a wholesale price over the next year equal to the simple mean of the 12 monthly forward prices for 2023.[42] This simplified scenario raises £16 billion. If this were simply divided between households it would save £571 per household, or the dividend could be shared with businesses also.

Figure 31: Estimated annual savings from windfall tax



This is inherently a simplified calculation. The scope and level of the 'temporary revenue limit' are to be determined. Nonetheless, it shows the potential for this to be a significant source of

[40] Energy Prices Act 2022, Explanatory Notes, October 2022
[41] BEIS, *Energy Trends: UK renewables* - Renewables obligation: certificates and generation, September 2022
[42] On 1 October this simple average of prices taken from theice.com was £337/MWh, so to be conservative we assume 30p/kWh for the next year

revenue for the exchequer - of at least the magnitude of the oil and gas windfall tax announced in May 2022 - to offset against the cost of energy bill support schemes.

In the short term, we favour this effective windfall tax option, because it is simple to implement and would not interfere with other market reforms currently under consultation. These include, for example, locational marginal pricing - which could offer stronger market signals to help the SO balance the grid as it grows more complex and thus save a predicted £3bn a year from electricity system costs.[43] Perhaps more important for a government that cares about functioning markets, a windfall tax is preferable to a new round of CfDs because it can be framed as a one-off reaction to extraordinary circumstances, rather than a rebasing of the norm. But whichever approach one chooses, it is clear that in order to fully benefit from lower costs in the near term, we do need to reform the energy market. Generating more power from zero-marginal cost wind won't benefit households if wholesale electricity prices continue to be set by high-cost gas.

[43] Energy Systems Catapult, *Location, Location, Location- Reforming wholesale electricity markets to meet Net Zero*, May 2022

Appendix A

Charts comparing all modelled scenarios

Table 4: Comparison of modelled scenarios - inputs

Inputs					
	Scenario	**Generation constraints**	**Vehicle assumptions**	**Energy efficiency assumption**	**Heat assumption?**
1	Do Nothing	No new generation infrastructure	20% of Consumer Transformation scenario EV uptake	20% of Consumer Transformation efficiency uptake	20% of Consumer Transformation scenario heat pump uptake
2	Not Net Zero	Offshore wind growth capped at 10TWh/yr additional	20% of Consumer Transformation scenario EV uptake	20% of Consumer Transformation efficiency uptake	20% of Consumer Transformation scenario heat pump uptake
3	Net Zero Focused	Offshore wind growth capped at 20TWh/yr additional to 2030 then 10TWh/yr	80% of Consumer Transformation scenario EV uptake	80% of Consumer Transformation efficiency uptake	80% of Consumer Transformation scenario heat pump uptake
4	Do Everything	Offshore wind growth capped at 20TWh/yr additional to 2030 then 10TWh/yr	80% of Consumer Transformation scenario EV uptake	80% of Consumer Transformation efficiency uptake	80% of Consumer Transformation scenario heat pump uptake
5	Full Green	Offshore wind growth capped at 20TWh/yr additional to 2030 the	100% of Consumer Transformation scenario EV uptake	100% of Consumer Transformation efficiency uptake	100% of Consumer Transformation scenario heat pump uptake

		Consumer Transformation scenario			

Table 5: Comparison of modelled scenarios - outputs

	Outputs					
	Scenario	**Gas**	**Electricity**	**Oil**	**Average household bill ICE/Gas boiler 2040**	**Average household bill EV/ASHP 2040**
1	Do nothing	7% domestic in 2040	79% domestic in 2040	35% domestic in 2040	£1,812	£1,401
2	Not net zero	92% domestic in 2040	Independent from 2028	35% domestic in 2040	£1,794	£1,357
3	Net zero focused	45% domestic in 2040	Independent from 2027	65% domestic in 2040	£1,764	£1,283
4	Do everything	Independent from 2034	Independent from 2027	65% domestic in 2040	£1,804	£1,381
5	Full green	13% domestic in 2040	Independent from 2028	87% domestic in 2040	£1,763	£1,282

Figure 32: Average Household (gas boiler, ICE car) - Total energy bill

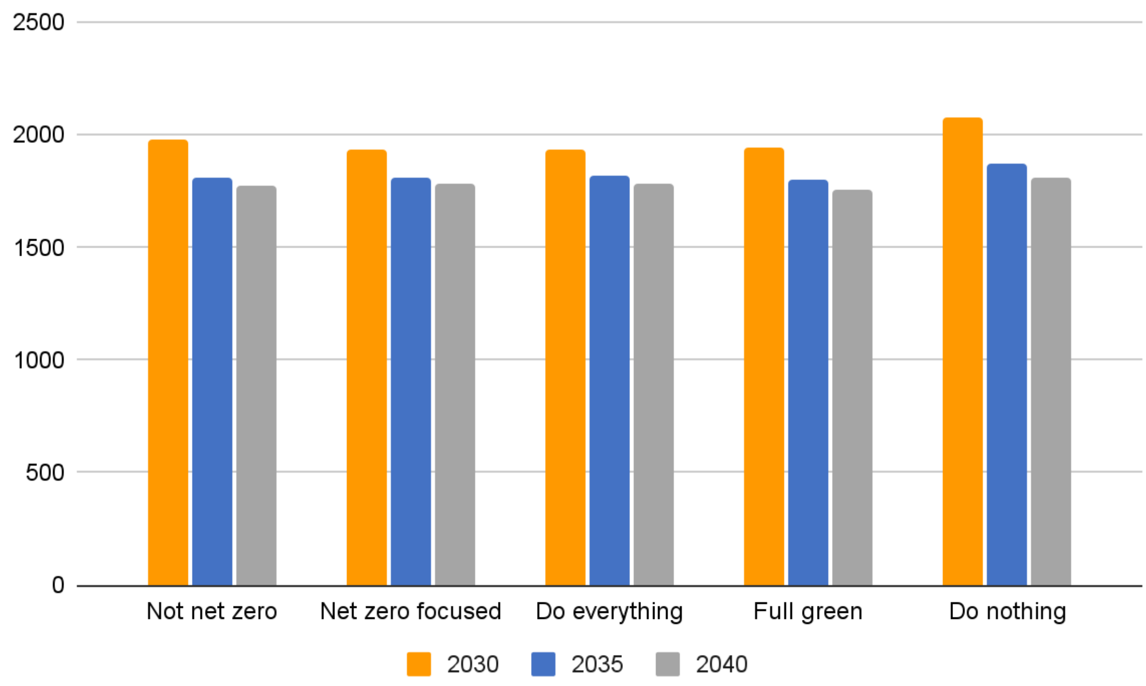
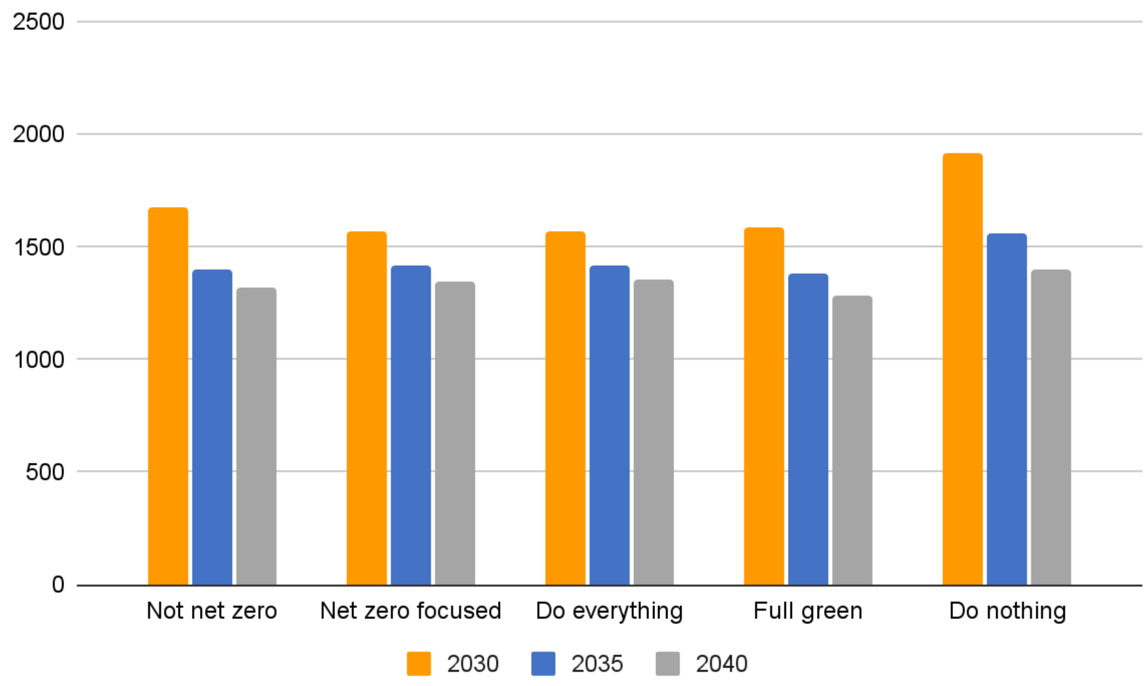


Figure 33: Average Household (gas boiler, ICE car) - Total energy bill



Appendix B

About the model and our data sources

In order to estimate the cost and security implications of different generation mixes:

- Created four scenarios for future electricity generation supply mix, domestic oil supply and gas supply.
- Drew on National Grid's Consumer Transformation Future Energy Scenario to estimate future electricity, gas and oil demand, adjusting this in our own scenarios based on our assumed speed of relative uptake of electric vehicles and non gas forms of heating.
- Drew on data from the last year to estimate a typical seasonal and daily pattern for energy demand and supply by electricity source, using this to understand which source of generation is likely to be at the margin and thus setting the wholesale electricity cost.
- Estimating the likely per kWh cost of ROCs, FiTs, and CfDs, alongside other non wholesale costs on retail bills.

While our model is not a complete dispatch model, we believe it gives a reasonable view of the overall trade offs policymakers face in cost and security between different options for the energy supply.

Table 6: Key Data Sources and Assumption

Item	Source
Baseline energy generation by source	National Grid's *Consumer Transformation* Future Energy Scenario, adjusted in line with our own assumptions per scenario over generation mix
Wholesale gas price	• Taper off current highs in 2020s • Merge to BEIS forecast for 2030s
Average spark spread	Estimated from Ofgem Market Indicators
Gas supply by source	Based on National Grid's *Consumer Transformation* and Falling Short Future Energy Scenarios
Domestic oil production	North Sea Transition Authority projections

LCOE for electricity generation	Extrapolated from BEIS Energy Generation Costs for 2025
LCOE for electricity storage	Extrapolated from Schmidt et al (2019)
Wholesale electricity cost	Estimated off marginal cost of each generation source, and the proportion of the year they are assumed to be marginal
ROCs and FiTs - generation amount	• Ofgem, Feed-in Tariff Annual Report 2020-21 • BEIS, The Renewable Obligation for 2022/23
CfD costs	Estimated as difference between wholesale price and estimated strike price per technology
Other non wholesale costs on electricity + gas bills	Extrapolated from CCC (2017)
Average transport energy consumption by type of vehicle + fuel	Extrapolated from National Grid's *Consumer Transformation* Future Energy Scenarios
Average heating energy consumption by sector + fuel	Extrapolated from National Grid's *Consumer Transformation* Future Energy Scenarios

Appendix C

Items for further research

1. Jobs implications of the model
2. Replicating this analysis for industrial energy use
3. A targeted 'to do' list for creating capacity on the grid and specifically for incentivising battery capacity

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We would like to thank all the energy experts, politicians and commentators who agreed to be interviewed as part of this project, and all those who gave comments. We are particularly grateful to ECF who kindly supported this project.