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1. UK Clean Growth Strategy

This is a special issue of nuClear News covering out comments on the UK Government's Clean Growth Strategy, which the Department of Business Energy and Industrial Strategy (BEIS) has called for before the end of December 2017

These comments were produced on behalf of the Stop Hinkley Campaign and the Nuclear Free Local Authorities.

1. Clean Growth Strategy

Executive Summary

The Clean Growth Strategy includes some welcome initiatives, particularly on energy efficiency. But it also includes a commitment to continue with the hugely expensive and discredited Hinkley Point C and to continue discussions with developers on the rest of the proposed 18GW nuclear programme. The Strategy also reaffirms plans to fund R&D on new nuclear technology, including Small Modular Reactors to the tune of around £460m – a figure which dwarfs funding for low carbon heat and energy efficiency.

It is now generally agreed that renewable electricity is much cheaper than nuclear electricity and likely to become more so. But the Government and nuclear industry believe nuclear energy will still be required because renewables are intermittent. But there are plenty of ways of managing intermittency in renewables without resorting to expensive nuclear power. In fact baseload power is not helpful in balancing a variable electricity supply – it simply leads to further overproduction of electricity at times when renewables can meet demand on their own. What is required is flexible electricity supply which can be turned on and off quickly to fill the troughs when renewables aren't able to supply.

And fortuitously there are several methods of dealing with intermittent renewables which will also help to decarbonise heat. By thinking about energy strategy in a much more integrated way, rather than focusing on decarbonising electricity and decarbonising heat and transport as three separate endeavours, we can develop an energy strategy which not only cuts carbon emissions but also cuts costs for consumers, tackles fuel poverty and doesn't produce nuclear waste in the process.

Preface

The UK Government's Clean Growth Strategy (1) is about meeting legally binding commitments to reduce greenhouse gas emissions for the period from 2023 to 2032. In doing this, the Strategy also intends to "increase our economic prosperity" and "lower energy bills".

Yet the Department of Business Energy and Industrial Strategy (BEIS) estimates that top-up payments for Hinkley Point C – a major plank of the Government's energy strategy - will increase electricity bills by adding around £30 billion over the 35-year contract to the costs which must be met by consumers. (2) And this is a discounted figure, as can be seen from the latest National Audit Office report, (3) which means it is not what consumers will actually pay, but the present value of what consumers will pay. The actual number consumers will pay is closer to £59bn.The cost to consumers will go up with inflation just as the guarantee to EDF Energy is index-linked.

Here, we argue that it would be much cheaper to abandon Hinkley Point C. Expenditure on the Hinkley site will be rising as construction work proceeds but while the cost of abandoning the project may be high, it would be much lower than persisting with the project. At the moment it may only cost around £2bn to abandon the project, but this figure is dwarfed by the 'opportunity costs' of the nuclear programme – what options are we not pursuing because we are assuming nuclear power will meet our objectives. Pursuing a consistent policy of energy efficiency measure and promoting renewables would be a much more cost-effective way of meeting our climate change goals. (4)

The Government says achieving clean growth and affordable energy as set out in the Clean Growth Strategy sits at the heart of its recent Industrial Strategy. Part of the Industrial Strategy is to "*explore the long-term options for clean heating and the many potential uses of low carbon hydrogen*." (5) This submission will focus in particular on the role of renewable energy in supplying low carbon heat and the way heat can be used to balance renewable energy.

The Government and pro-nuclear advocates argue that we need nuclear power to provide baseload electricity and that because renewable sources are intermittent they will need back-up. But, there are many ways in which large contributions from variable renewables can be balanced - so it's not a major problem. Moreover it may not cost too much. Indeed some of the balancing options can save money. (6)

Introduction

The Clean Growth Strategy sets out how the Government intends to meet its legally binding commitments to reduce greenhouse gas (GHG) emissions for the period from 2023 to 2032. (7) A 57% cut in greenhouse gas emissions, compared with 1990 levels, has been set as the target for the period 2028-32 in line with advice from the Committee on Climate Change (CCC). However CCC has said we are already off-track to meet that target. (8) The Clean Growth Strategy is intended to get us back on track. Unfortunately though, the quantified parts of the Clean Growth Strategy only add up to a 53% emissions reduction - well short of meeting the 57% target.

We also have to bear in mind that the 80% target for cutting greenhouse gas emissions by 2050 (upon which the 57% cut is based) relates to the pre-Paris Agreement goal of avoiding warming of more than 2^{o}C. The Paris Agreement has set a new goal of aiming for 1.5^{o}C. The CCC says the UK will need to reduce GHG emission "*at least 90% below 1990 levels by 2050*" if it were to meet its fair share of the 1.5^{o}C goal.

So, there are three reasons why there is much more work to be done. Firstly implementing the proposals in the Clean Growth Strategy will be a challenge in itself; secondly the Strategy will only reduce emissions by 53%, not the 57% required. And thirdly, if we are to meet our commitments to the Paris Agreements we will need to set a target which is higher than 57%.

The Government believes the UK has done well in the power and waste sectors and we now need to replicate this success across the economy, particularly in the transport, business and industrial sectors. We also need to reduce the emissions created by heating our homes and businesses, which account for almost a third of UK emissions.

The Clean Growth Strategy

The recognition by the Prime Minister in the introduction to the Strategy that "*Clean growth is not an option, but a duty we owe to the next generation*" is welcome as is the recognition that such a Strategy "*…will improve our quality of life and increase our economic prosperity … mean cleaner air, lower energy bills, greater economic security and a natural environment protected and* *enhanced for the future*." The Industrial Strategy also wants to maximise the advantages for UK industry of the global shift to clean growth.

As Bruce Davis - a member of the Government's new Green Finance Task Force – highlights:

"*Prosperity and low carbon are no longer a compromise but aligned objectives for the economy*." (9)

In other words, the Strategy amounts to an unequivocal statement that tackling climate change and a prosperous economy are one in the same thing. (10)

In his introduction, Greg Clark, the Secretary of State for Business, Energy and Industrial Strategy (BEIS) says: "*The move to cleaner economic growth is one of the greatest industrial opportunities of our time. This strategy will ensure Britain is ready to seize that opportunity*."

However, the strategy does concede that the UK is still not on track to meet its legally binding carbon targets for the late 2020s and early 2030s. (11) It will actually leave the UK significantly off track achieving its targets. (12)

Highlights of the Strategy include:

- A hugely welcome promise of a renewed focus on both domestic and industrial energy efficiency. The new strategy promises around £3.6bn to upgrade the energy efficiency of a million homes, with the Energy Company Obligation (ECO) extended to 2028 at its current level. Homes account for around 13% of the UK's emissions.
- A proposed new target for the business and industry sectors to improve their energy efficiency by "at least" 20% by 2030.
- A welcome aspiration for as many homes as possible to be improved to EPC Band C by 2035, where practical, cost-effective and affordable.
- A welcome reaffirmation of the pledge to phase out unabated coal generation by 2025.
- £557m in low-carbon support will be available for certain renewable technologies to compete for including offshore wind, and onshore wind on Scottish islands (subject to state aid approval from the European Commission). The next auction will be held in spring 2019.
- The strategy repeats a 10 gigawatt (GW) target for new offshore wind in the 2020s and says it will consider going even further "if this is cost-effective and deliverable". The government will provide an update on its approach to small-scale renewables "later this year".
- The transport sector accounts for 24% of UK emissions, with almost zero progress since 1990. The Strategy says almost every car and van will need to be zero emission by 2050, and by 2040 cycling and walking should be the natural choices for shorter journeys, or as part of a longer journey.

- As far as home heating is concerned the Strategy says reducing demand for energy will not be enough. By 2050 home heating will need to be fully decarbonised. There are a number of low carbon heating technologies with the potential to support the scale of change needed, including heat pumps, using hydrogen in our existing gas grid and district heat networks. At present it is not certain which approaches or combination will work best. So the strategy says the groundwork needs laying in this parliament, so decisions can be taken in the early 2020s on the long-term future of heat. Government has commissioned research into different heat demand scenarios, the use of hydrogen, what changes might be needed to the electricity grid in response to large scale uptake of heat pumps, the role that bioenergy might play in decarbonising heat and international activity. It plans to publish initial findings from a number of studies later this year, and a full report by summer 2018.

On the downside the Strategy includes:

- Plans to 'deliver new nuclear power through Hinkley Point C and progress discussions with developers to secure a competitive price for future projects in the pipeline'.

- Of the £900m to be invested in innovation, more than half is to be invested in nuclear power including future nuclear fuels, new nuclear manufacturing techniques, advanced reactor design, and, just when we thought technological disastrous reprocessing was about to end in the UK - recycling and reprocessing. The Strategy reaffirms plans (already announced) to fund for R&D on new nuclear technology, including Small Modular Reactors to the tune of around £460m – a figure which dwarfs, for instance the £20m R&D/innovation funding for low carbon heat and energy efficiency. As part of the BEIS Energy Innovation Programme up to £7 million was announced for development of the capability of nuclear regulators who support and assess advanced nuclear technologies.

- Despite several rumours that onshore wind was about to make a comeback, and climate change minister Clair Perry was reported in Utility Week on 3rd November to be keen to enable onshore wind projects to compete for subsidies in areas where they enjoy public support, there was no new plan to enable new onshore wind farms to get to market.

- There is no mention of replacing the zero-carbon homes standard scrapped in 2015, although the Government will consult on strengthening building regulations for new and existing homes. A report from Frontier Economics argues this standard should be reintroduced, to avoid new homes needing costly retrofits in future. (13)

- On solar the Strategy only said the Government wants to see more people investing in solar without government support and is currently considering options for the approach to small scale low carbon generation beyond 2019, and will provide an update later this year. There was no mention of utility-scale solar

- There was little mention of wave and tidal power apart from mention of the "need to demonstrate how they can compete with other forms of generation." And there was no mention of the Swansea Tidal Lagoon.

Since the Strategy was published, an announcement made alongside the Chancellor's Autumn Statement has been deeply concerning. The Treasury published a document which that suggested there will be no new subsidies for low-carbon electricity generation for another eight years. The £557m pot of funding for the next auction for Contract for Difference payments, which was due to be held in Spring 2019 to support "less established" renewable technologies, including offshore wind, was expected to be used up by 2021 (14) This is now to be spread out to 2025. The government hopes that "*significant cost reductions that were achieved in the last CfD auction indicate that this support could secure far more low carbon electricity than originally anticipated*". (15)

This is a gamble and could lead to an investment hiatus and there is still no clarity on how the cheapest forms of renewables – onshore wind and solar - will get to market. We should be capitalising on the investments already made and building a renewable energy manufacturing base in this country – not pulling the rug out from under companies trying to move towards subsidy-free renewables.

Lowering Energy Bills and Meeting Carbon Targets

The Secretary of State, Greg Clark, says in his introduction to the Strategy "*If we get it right we will not just deliver reduced emissions, but also cleaner air, lower energy bills for households and businesses*."

But the recent House of Commons Public Accounts Committee concluded that:

"*The economics of nuclear power in the UK have deteriorated since the government last formally considered its strategic case for nuclear in 2008. Estimated construction costs have increased while alternative low-carbon technologies have become cheaper*." (16)

This followed on from a National Audit Office report which described Hinkley Point C as a "*risky and expensive project with uncertain strategic and economic benefits*." (17)

Both the NAO and PAC have called on the UK government to prepare a Plan B against the risk that EDF ultimately abandons HPC. Energy Finance Consultant, Gerard Wynn, says

"*…new nuclear power is at odds with some of the main global trends in power generation today: cheaper renewables (wind and solar), digitalisation (solar, smart grids and demand-side response, not spinning turbines), decentralisation (distributed generation, rather than huge, centralised power plants) and flexibility (where nuclear performs worst, even behind coal)*." (18)

Wynn argues that a major UK new-build nuclear programme now looks untenable, unless developers halve their return expectations. He says there are multiple parallels between Hinkley Point C and the recently failed U.S. nuclear power project at SCANA Corporation's VC Summer. Time now for the government to re-double its efforts to drive alternatives before taxpayers and consumers are landed with the same huge cost overruns and delays.

Despite the growing evidence that renewable energy costs are falling rapidly the Government is set to load as much as £50bn or more onto consumers' bills to pay for Hinkley Point C. (19)

A widely-used yearly benchmarking study — the Levelized Cost of Energy Analysis (LCOE) from the financial firm Lazard Ltd – concludes that building and running new renewable energy is now cheaper than just running existing coal and nuclear plants in many areas. Lazard shows, while solar and wind have dropped dramatically in price since 2009 nuclear power has simply priced itself out of the market for new power. (20)

A recent E3G study shows that the cheapest way to decarbonise the power system involves large volumes of variable renewable generation even when taking system integration costs into account. The E3G report says Government needs to deliver new low carbon generation capacity as cheaply as possible. The UK will need new capacity capable of producing around 150TWh (terawatt hours = 1,000 million kWh) per year of electricity by 2030 – around half of all current output. All plausible scenarios imply that this can only be achieved by deploying a significantly increased volume of renewable generation – likely to be around 50GW, predominantly from a combination of onshore and offshore wind and solar PV. (21)

Energy Efficiency

The first step in devising a Plan B would be to focus on implementing energy efficiency measures. In fact when the Government first endorsed Hinkley Point C, (HPC) it was projecting an increase in electricity consumption of 15% by now, whereas in practice we are consuming 15% less than a decade ago. In other words it made a 30% error, yet Hinkley Point C is only due to deliver 7% of UK electricity consumption. This is despite a 13% increase in GDP over the last decade and the increase in the number of gadgets we all own. (22)

This consumption revolution has been prompted by vastly improved electricity efficiency in industry, in consumer white and brown goods, and in areas like lighting, where household consumption has dropped from 20.7 terrawatt hours (TWh) in 2007 to 14.2TWh this year. In 1990 when Compact Fluorescent Lightbulbs (CFLs) were scarce in UK homes 26.6TWh of electricity were consumed in UK domestic properties for lighting. The average household is spending £87.36 per year on lighting, but if consumption levels had remained at 1990 levels that figure would have been £164 per year. This trend is set to continue. By 2025 LEDs will probably have replaced most CFLs and incandescent light bulbs, and LEDs themselves are becoming more efficient. Consumption is expected to fall a total of 89% compared to the year 2000, and annual expenditure will fall to just £16. (23)

A crash programme to replace all the lights in the UK with LEDs could cut peak electricity demand by about 8GW, a saving of another 15% of all power consumption. LEDs produce less waste heat and so can sometimes cut the need for air conditioning in places such as hotels and large office buildings. Even a much more restricted national campaign that just focused on domestic houses would have a dramatic impact. If we switched the lights in the parts of the house that are in use in early evening - essentially the kitchen and living areas - we would reduce home demand by more than 50%. Importantly, these rooms are the places where we now often use halogen downlighter bulbs, the most inefficient lights currently on the market. A standard halogen GU10 bulb uses 50W of power. The LED equivalent does the same job with just 5W. We could cut the typical demand for electricity to run lights from today's evening average of 180W to 80W by replacing about 21 bulbs in the typical home. The impact would to reduce electricity demand by 2.7GW – almost the capacity of Hinkley Point C. The payback period of such a scheme is about two years at last year's LED prices. For an expenditure of around £60, the householder would typically save £30 a year (24)

Even a feeble effort to improve energy efficiency could reduce demand even further than the 30% already discussed above.

Cost-effective investments in domestic energy efficiency between now and 2035 could save around 140 terawatt hours (TWh) of energy – roughly equivalent to the output of six power stations the size of Hinkley Point C, according to a report by the UK Energy Research Council. Such a programme could save an average of £270 per household per year at current energy prices. The investments would deliver net benefits worth £7.5bn to the UK, and could reach £47bn, if benefits such as health improvements and additional economic activity are counted. (25)

Domestic energy efficiency alone could save 40TWh/yr by 2030 and help eliminate fuel poverty into the bargain. (26) There are around 100 TWh of electricity savings detailed in a report for the Government by McKinsey for which there are currently no plans to capture. (27) Consultancy firm Utilitywise says Hinkley is an "*unnecessary expense*". Energy efficiency measures could save the equivalent amount of electricity along with £12bn. (28)

Energy Minister Claire Perry told the Tory Party Conference that "*consumers' energy bills have actually gone down, mostly because we are more energy efficient and use more efficient appliances*." Official figures show that the average price of a dual fuel energy bill paid via direct debit has fallen from over £1,000 a year in late 2013 to less around £865 today. This is a welcome recognition that low carbon energy strategies can, actually, reduce consumers' energy costs in contrast to much of the media's focus which has tended to be on the cost of green levies. (29)

Onshore wind

Onshore windfarms could be built in the UK for the same cost as new gas power stations and would be nearly half as expensive as Hinkley Point C, according to engineering consultant, Arup. The technology has become so cheap that developers could deliver turbines for a guaranteed price of power so low that it would be effectively subsidy-free in terms of the impact on household energy bills. Arup's report found that windfarms could be delivered for a maximum of £50-55 per MWh across 15 years. The analysis was commissioned by Scottish Power. Keith Anderson, the firm's chief operating officer, said "*If you want to control the cost of energy, and deliver energy to consumers and to businesses across the UK at the most competitive price, why would you not want to use this technology?*" (30)

The predicted price of onshore wind in Germany is now half the EU's projections for 2030, following a recent auction. The auction results were described as "incredible" by one expert. The average price at which contracts were awarded in the 1GW auction was €38/MWh, the German regulator Bundesnetzagentur announced. Once distribution and transmission costs are factored in, the figure is likely to be closer to €40/MWh – about £35/MWh. (31)

According to Bloomberg New Energy Finance (BNEF) new onshore windfarms were the cheapest way for a power company to produce electricity in Britain by 2015 with costs dropping to £55/MWh. (32) The trade body, Scottish Renewables, has shown that costs could be cut by a further 20% if government, industry and regulators work together to make sure we can use the latest generation of turbines on suitable sites, reduce grid charges, and deploy energy storage technologies. (33) The Bloomberg New Energy Finance (BNEF) outlook says the price of onshore wind has dropped 30% in the past eight years, and is expected to fall another 47% by 2040. (34)

Energy ministers Richard Harrington and Claire Perry both told delegates at the Conservative Party conference that new onshore wind projects could return to play a role depending on whether their costs are competitive and they win the support of local communities. (35) But there was no mention of a plan to bring new onshore wind projects to market. However, at the end of November 2017, Claire Perry confirmed to the House of Commons Business Energy and Industrial Strategy select committee the Government will look to provide support for onshore wind. Officials at the Department for Business, Energy and Industrial Strategy (BEIS) are "actively working" on a plan to allow large onshore wind farms to be built once again in Wales and Scotland. (36)

Offshore wind

The price of £57.50/MWh unveiled recently for two offshore wind projects, off the coast of the UK is almost half the level expected to be paid for Hinkley Point C. What is more the offshore wind payments only continue for 15 years while nuclear payments would continue for 35 years. The UK could theoretically produce up to 595GW from offshore wind at competitive cost, an order of magnitude more than Britain's entire power needs, even at peak times in the dead of winter. (37)

New nuclear power stations in the UK can no longer compete with windfarms on price, according to Hans Bunting, the chief operating officer of renewables at Innogy SE, part of the company that owns npower. He says offshore windfarms will become even cheaper than today and that companies that want to build new reactors in the UK will not be able to compete with windfarms on cost, even when their intermittency was taken into account. Innogy recently secured a subsidy of £74.75 per megawatt hour (MWh) to build an offshore windfarm off the coast of Lincolnshire - £17.75 cheaper than Hinkley. It should be completed at least three years earlier than Hinkley. But by 2025 – 2027 offshore wind will be even cheaper. (38)

The BNEF predicts that offshore wind costs will drop a stunning 71% by 2040. (39)

Solar power

Sustainability expert, Chris Goodall, author of new book called "*The Switch*", says cheap solar panels and advances in storage technology are about to transform the world. By 2030 or 2040 solar will be the cheapest way to generate electricity, indeed any form of energy everywhere. At the rate of growth that we are seeing at the moment of 35-45% per year solar will grow from providing 2% of global electricity to at least 50% by 2030. We can see the cost of batteries coming down in price dramatically. (40)

In October it was reported that Saudi Arabia had received offers to supply solar electricity for the cheapest prices ever recorded, at 1.79 cents per kWh beating the previous record for a solar project in Abu Dhabi at 2.42 cents. (41) Since then Chile has received two bids for electricity from large-scale solar projects, in 20 year contracts, at prices under 2.5¢/kWh in a recent national auction. The lowest bid was 2.148¢/kWh. This represents continued price declines in the solar industry and financial trust in the product from global financial houses. (42)

Solar power, once so costly it only made economic sense in spaceships, is becoming so cheap that it will push coal and even natural-gas plants out of business faster than previously forecast according to the BNEF outlook. The research group estimated solar already rivals the cost of new coal power plants in Germany and the U.S. and by 2021 will do so in quick-growing markets such as China and India. Electricity from photovoltaics costs almost a quarter of what it did in 2009 and is likely to fall another 66% by 2040. (43)

According to the 100% renewable utility, Good Energy, the wholesale price of electricity in the UK is falling, mainly due to the rise in solar photovoltaics (PV) and wind power. (44)

The Government's own projections show that solar and wind power will be cheaper than new nuclear power by the time Hinkley Point C is completed. According to *The Guardian*, an unpublished report by the energy department shows that it expects onshore wind power and large-scale solar to cost around £50-75 per megawatt hour in 2025 (compared to the index-linked guaranteed price of £92.50/MWh that the government has offered EDF Energy). (45)

Renewables vs Nuclear – the fight for market share.

Last autumn, Michael Grubb, Professor of International Energy and Climate Change Policy at University College London, told the House of Lords Selected Committee on Economic that, although he had supported new nuclear during his time on the Committee on Climate Change, he felt "*times and conditions had substantially changed … renewables are now clearly cheaper. Committing to a 35-year contract at that level was economically inappropriate*" He continued: "*renewable energy costs … appear almost to have halved in the past few years … We now have more than 10 gigawatts of solar, when the cost projections were that we would get 1.5 gigawatts by about this time … It is now clear that in the electricity sector we will be delivering more renewables than the Government planned for or expected by 2020*." (46)

The electricity system has changed radically in the years since the project to build new third generation nuclear in Britain was initiated, says Grubb in a paper he wrote with Andrew ZP Smith, Deputy Director & Academic Head of the RCUK Centre for Energy Epidemiology. National Grid's (NG) Future Energy Scenarios (2016) show a steadily declining need for 'baseload' generation. By 2030 there will be growing periods when wind and solar meet all projected demand. The capacity of 'firm' inputs (like gas, nuclear, biomass, interconnectors, storage etc) required to operate more than half the year is reduced to 20GW overall. (47)

Renewables could soon be producing enough electricity to power the grid from April to October. The implication is that for most of its contracted operating life Hinkley Point C would increasingly be competing with other, lower cost low-carbon sources. For efficient system operation either Hinkley would have increasingly to 'load follow', adjusting its output up and down to follow changes in demand, or alternately, baseload nuclear would displace other and cheaper sources, for example forcing wind and solar off the grid, if it cannot operate flexibly, or if the £92.50/MWh (indexed) contract is allowed to determine its operation (the plant with biggest payment has most incentive to run). Ministers will have to explain to consumers why they were having to pay for expensive nuclear electricity when cheaper renewables are being turned off.

By 2030, around 20GW of capacity would be required for less than 10% of the year, to cover peak net demand, for which nuclear power is manifestly unsuitable. The dominant need in the majority of National Grid scenarios post 2030 will be for adequate responsive capacity displacing coal and gas, and more efficient approaches to balancing demand and supply.

Michael Grubb told the House of Lords: "*If you are worried about how to provide power during winter periods when there is a cold dark windless night, you do not want to build a spanking new plant designed to run 100% of the time; you build something that is cheap to construct and expensive to run.*" (48)

Emeritus Professor Keith Barnham says once operating, a nuclear reactor is expected to run with constant output, 24/7, month to month. But what the UK needs is flexible, not continuous baseload power generation to back up wind and solar, which can vary in less than one hour. Hinkley's power is not only almost irrelevant; its inflexible nature will soon make it redundant. If renewable expansion had continued at the same rate it did between 2010 and 2015 we could have achieved an all-renewable UK electricity supply by 2025. (49)

Intermittent vs baseload

The nuclear industry claims that it doesn't matter how low the price of renewables goes because they are intermittent, nuclear energy would still be needed to provide baseload. (50)

However, Michael Liebreich, CEO of Bloomberg New Energy Finance says "*…there are plenty of ways of managing intermittency in renewables without resorting to expensive backup power. First, you improve your resource forecasting. Second, by interconnecting the grid over larger areas, much of the variability of renewable energy can be evened out. Third, just when an increased proportion of renewable energy means you start losing control over supply, the introduction of digitally controlled smart grids gives you better control of demand. Finally, there is power storage, currently mainly in the form of pumped hydroelectric power but, in future, most likely in the form of batteries for electric vehicles. The cost of each of these techniques is coming down just as rapidly as the cost of renewable energy*." (51)

Emeritus Professor Dave Elliott agrees. He says "*we have the technology to match green power supply and demand at affordable cost without fossil fuels - by deploying the 'smart grid', using 'green gas' made from surplus power, and raising energy efficiency*." (52)

Fortuitously, as we shall see, there are several methods of dealing with intermittent renewables which will also help to decarbonise heat.

"*Large-scale power generation … will be the dinosaur of the future energy system: Too big, too inflexible, not even relevant for backup power in the long run*."

This is according to, not some dangerous radical organisation, but UBS Bank. (53) The bank expects a rapid decline in battery costs of more than 50% by 2020 which will spur not just the sale of electric vehicles, but also lead to an exponential growth in demand for stationary batteries to store excess power. In turn this will lead to a much higher share of renewables in the electricity mix. Similarly HSBC Bank predicts that conventional generators will be the biggest losers from an upcoming energy storage boom. (54)

In fact baseload is not helpful in balancing a variable energy supply – it simply leads to further overproduction of energy at times when renewables can meet demand on their own. In a grid which has a large contribution from variable renewables, what is required is flexible electricity supply which can be turned on and off quickly to fill the troughs when renewables aren't able to supply. Nuclear power is a very poor fit for a 21st century grid system and acts against increasing renewable energy capacity. (55) Gas power stations that can quickly ramp up output, for instance, provide the best solution for this at the moment. These could be made completely carbon neutral by using synthetic gas created with surplus electricity from renewables and UK-grown biomass. (56)

A Renewable Mix to Reduce Intermittency

Researchers at the University of New South Wales (UNSW) have pointed out that the intermittency of different renewable energy technologies like wind, solar, geothermal, etc varies with technology and therefore can be made smoother by selecting the right mix of technologies. Some renewable electricity sources (e.g. bioenergy, solar thermal electricity and geothermal) have identical variability to coal-fired power stations and so they can be used as base-load. (57)

Improved Interconnection

In an energy system with a high penetration of renewables during infrequent periods of high demand and low renewables production, electricity may need to be imported. But during periods of high renewable production and lower demand, it could be helpful to export electricity. An analysis prepared for National Grid's Interconnector business points to benefits for the economy, the consumer and the environment if the UK could double its interconnector capacity by 2020. If interconnector capacity could double to 8-9 GW there are potential savings of £1bn a year. This would also take GB closer to the European benchmark of having interconnectors making up 10% of generation capacity. It is estimated that each 1GW of interconnection could reduce Britain's wholesale power prices by 1-2%. These benefits would be a result of British wholesale prices remaining higher than those in neighbouring countries, which is expected to be the case until the early 2020s. (58)

Electricity Storage

Deep penetration of renewables will be assisted by continued price drops in lithium-ion batteries and explosive growth in electric cars: "*This will help renewable energy reach 74 percent penetration in Germany, 38 percent in the U.S., 55 percent in China, and 49 percent in India by 2040*," according to BNEF. Think Progress website concludes: "*Literally every day we see headlines making the economic case for investing in new clean energy rather old dirty energy*." (59)

The old energy order is drawing to a close as a battery storage revolution takes off, according to *The Telegraph*. Over the last two years, battery costs have fallen 40%, with further falls to come as economies of scale take hold. The great promise of storage is that it should lend renewables the same “always on” characteristics of more conventional forms of power, allowing electricity to be drawn when the wind is blowing, and given out again when it is not. (60)

Bloomberg New Energy Finance (BNEF) predicts a six-fold increase in investment in energy storage to $8.2bn (£6.7bn) by 2024, and to $250bn (£197bn) by 2040. This massive growth in energy storage will create a "fundamentally different" global power system. This energy storage ‘megashift’ is already beginning to gather pace. The battery market has seen breath-taking levels of growth from utilities over the past 12 months, while non-utilities are increasingly realising that lithium-ion or flow storage systems can act as the perfect accompaniment to on-site renewable energy installation. (61)

Cheap, ubiquitous electrical energy storage will lead to a very different world and may change the focus of many of today’s energy policy debates, according to Matthew Lockwood at the Exeter University Department of Energy Policy. It is likely to help reduce peak demand, and allow renewables to provide a much higher percentage of electricity demand, especially if they are cheaper than alternative forms of low carbon electricity such as nuclear or fossil fuel with carbon capture and storage. (62)

North Star Solar has set up a joint scheme with the former colliery town of Stanley in Co Durham to offer in-home batteries and solar panels for free to all the town’s 35,000 households. The combination of rooftop panels, a lithium battery and energy-efficient LED light bulbs will immediately cut power bills by 20%. (63) Camden Council has teamed up with Islington and Waltham Forest Councils to deliver a pilot programme to test the potential benefits of solar panels and energy storage systems for residents at risk of fuel poverty. The '24/7 Solar' initiative is being part-funded by national fuel poverty charity National Energy Action. The aim of the trial is to see if there is evidence that integrated solar and storage technologies can effectively reduce the energy bills of fuel poor households. (64)

The £19m 'Big Battery' installed at a sub-station in Leighton Buzzard, Bedfordshire has completed a two-year trial and successfully shown that power storage has the potential to be both technically and commercially viable. (65)

There have also been calls for more Pumped Hydro Electricity Storage (PHES). Professor Phil Taylor of Newcastle University and Dave Holmes of the Quarry Battery Company say that grid-scale storage could obviate the need for back-up fossil fuel power plants and effectively make wind and solar power baseload generation. If the surplus electricity from renewables can be captured for use later when the sun fails to shine or the wind fails to blow then we could manage without conventional baseload generating stations. At the moment we are stuck with a wasteful system which pays renewable generators to reduce output when there is a surplus, and then we have to use fossil fuels to meet demand when weather conditions result in low renewable generation. Britain already has 2.8GW of pumped hydro electricity storage (PHES). Increasing the PHES capacity would be part of a more flexible grid system which exploited other storage technologies as well as demand management techniques. A UK survey has identified suitable locations with low planning risk for 10-50GWh of PHES. (66)

Smart Energy

The community at Garmony on the Isle of Mull is an example of how things might look in the future, and it illustrates how providing decarbonised heat can be part of the win-win solution to living with intermittent renewables. It's not just that the community is running a new 400-kilowatt hydro power plant on an east coast hillside that will plough £2 million into local projects. It's what they are doing about using the electricity. If the river is flowing fast and full and electricity demand is low, there's nowhere for the power to go. There's a limit to how much can be transmitted to the mainland, and no easy way of storing it. The same applies to wind turbines when the wind is blowing hard but homes and factories aren't hungry for power, at night for example. It's why electricity consumers have to fund "constraint payments" to compensate generators forced to turn off turbines to avoid overloading the national grid.

What the Mull and Iona Community Trust are trying to do is to develop a much smarter local grid that will enable electricity to be stored rather than wasted. It's called the ACCESS project – Assisting Communities to Connect to Electric Sustainable Sources. It means that electric storage heaters in homes can be automatically switched on and off in order to match the amount of power being generated by the hydro plant. This type of decentralised, locally owned, community-scale scheme for using renewable energy has real potential to revolutionise the energy system.

The Orkney isles and Community Energy Scotland (CES) are taking the lead for the whole UK as the European Union explores ways for islands to capitalise upon their energy resources with a new £14 million smart grid project. The SMILE project (SMart IsLand Energy systems) will see Orkney collaborate with technical, grid and academic partners across Europe and fellow island communities of Samso in Denmark and Portuguese Madeira, to investigate how electricity producers, consumers and the grid that links them, should tackle energy storage and other challenges raised by renewables and electric transport. In light of Scottish and UK government proposals for significant moves away from petrol and diesel vehicles, SMILE helps to address how battery-powered vehicles (BPVs) will be re-charged in future to maximise electricity generation from renewable sources and not over-burden the grid.

For independent energy charity CES, SMILE joins a suite of projects across Scotland where they are working with partners to overcome grid constraints so that community owned renewables can create local confidence and value, help people reduce their energy costs, strengthen local services, and promote skills and employment. With over 50MW of installed wind energy capacity generating over 46GWh per year of renewable power, Orkney has been a net exporter of electricity since 2013. Many of the islands' wind turbines are often 'curtailed' due to local grid capacity restrictions, resulting in loss of significant proportions of their annual output; estimated to be between 30% and 70% of potential production for the worst affected. Smart grids are part of the answer for the need to flexibly, stably and reliably accommodate in the energy system the increasing share of distributed energy generation, increasing demands for energy and changes to the pattern of this demand. Through smart grids, peak generation and demand can be controlled, matched and the electricity system stabilized. (67)

The Isles of Scilly, an archipelago located 28 miles off the Cornish coast, can't export its excess solar power onto the mainland grid. But earlier this year, the Scillies launched a three-year, £10.8m Smart Islands project to trial the new technologies that can help the Scillies become an independent hub for green energy, no longer reliant on its single, unreliable interconnector cable and back-up diesel generators, but instead a kind of future community of electric vehicles, heat pumps, solar panels, energy storage, electric vehicles and an internet of things platform all working in harmony. The Cornwall and Isles of Scilly Local Enterprise Partnership (LEP) will contribute an extra £2.95m to the scheme to fund an anaerobic digestion plant, energy efficiency work with island businesses, and the deployment of a complete EV infrastructure including bi-directional chargers and 'solar canopies' for clean refuelling. (68) The landmark project aims to double the renewables capacity of the Isles through the addition of new solar. The Smart Energy Islands project was announced earlier this year, using around £8.6 million from the European Union's Regional Development Fund (ERDF) alongside over £2.1 million from technology providers Hitachi Europe, Moixa and PassivSystems. (69)

Andy Kerr, director of the Edinburgh Centre for Carbon Innovation argues that the old, inflexible and top-heavy electricity distribution system is going to disintegrate. He says "*we need to get away from thinking of green energy just as a bunch of subsidised windmills or wave or tidal turbines, or thinking only about electricity. Green energy in its widest sense includes energy generation technologies, but also heat pumps, energy efficiency, low emission vehicles and smart meters*." (70)

Decarbonising Heat

Heating homes, businesses and industry consumes nearly half of all energy used in the UK – and produces a third of carbon emissions. There are also around 4.5 million UK households suffering from fuel poverty to take into consideration. The Clean Growth Strategy says the groundwork needs laying in this parliament, so decisions can be taken in the early 2020s on the long-term future of heat. It will assess a range of options for decarbonising heat, including electric heat pumps, using hydrogen or biogas in the gas grid and heat networks. Initial findings will be published soon, with a full report following by summer 2018. It's worth noting the CCC has said UK heating must be virtually zero-carbon by 2050.

Rather than looking at decarbonising heat as somehow a separate endeavour to decarbonising electricity we should be looking at both as an opportunity to develop an integrated energy system which makes use of surplus renewable electricity, currently being wasted, and provides new opportunities for energy storage, makes the most of the recently modernised gas grid and tackles fuel poverty into the bargain. A combination of new district heating networks and green gas could help balance renewable electricity and reduce emissions from the heat and transport sectors at an affordable cost. In combination with energy efficiency programmes we could solve several problems at the same time. The alternative option of hoping against all the evidence that we can get the exorbitantly expensive nuclear programme up and running in time to start replacing fossil-fuel powered domestic heating systems is unlikely to succeed.

The Clean Growth Strategy presents three illustrative pathways. Firstly, an electricity pathway which replaces gas boilers with electric heating and uses around 80% more electricity than today, coming mainly from renewables and nuclear. Secondly a hydrogen pathway in which the gas grid is adapted to provide hydrogen to heat our buildings, as well as to fuel many of the vehicles we drive in 2050. A third pathway uses biomass and carbon capture.

An electric pathway

The National Policy Statement on Energy (July 2011) says much of our heating will need to be electrified if we are to reduce emissions of greenhouse gases by 80% by 2050. (71)

Section 2.2.22 says: "*Looking further ahead, the 2050 pathways show that the need to electrify large parts of the industrial and domestic heat and transport sectors could double demand for electricity over the next forty years*."

Section 3.3.14 says: "*As a result of this electrification of demand, total electricity consumption (measured in terawatt hours over a year) could double by 2050. Depending on the choice of how electricity is supplied, the total capacity of electricity generation (measured in GW) may need to more than double to be robust to all weather conditions. In some outer most circumstances, for example if there was very strong electrification of energy demand and a high level of dependence on intermittent electricity generation, then the capacity of electricity generation could need to triple. The Government therefore anticipates a substantial amount of new generation will be needed*."

But according to Iain Conn, chief executive of Centrica, Government plans to electrify domestic heating and encourage a switch away from gas-fired boilers and radiators are "*mad*". He told the Utility Week Energy Summit conference in 2016: "This whole idea of electrifying everything is mad. We shouldn't allow government to chase after the electrification of heat too quickly. They [will] get it wrong." (72)

Nearly 70% of all of the UK's space heating comes from natural gas, contributing about a third of the nation's total greenhouse gas emissions. The majority of domestic heating is provided by gas-fired boilers, with only 7% of homes using electric heating. Mr Conn said that there were better alternatives available and suggested that more money should be channelled into research to find new ways of tackling the problem.

Why would we want to ditch the UK's gas distribution grid, developed over many years and only recently upgraded with new pipes. Surely it makes more sense to see how we can make the gas "green". The additional electricity capacity required to electrify heating would be enormous. And there would be huge variation in the daily and seasonal demand. Peak heat demand could require the equivalent of an additional 30 nuclear power stations and the UK's current distribution network would require a significant upgrade. Jo Abbess, author of "Renewable Gas: The Transition to Low Carbon Energy Fuels" agrees that switching from gas to electric heating would put a huge strain on the power transmission and distribution system and entail constructing a large number of new power stations in a short space of time that would only be used for a few months of the year. Converting to renewable gas means we can continue to make good use of the gas grid. (73)

If we can't decarbonise gas, a large proportion of households with gas central heating could be expected to rip out their boilers and radiators and install a completely new system probably using ground or air-source heat pumps or other forms of electric heating. This would be extremely expensive for each individual consumer and most people probably couldn't afford it without massive subsidies. Studies suggest that around 80% of households would require financial assistance to change their heating system. (74)

Isabelle Kocher, Chief Executive of the French utility Engie, says the world has been focused on decarbonising electricity via renewable energy, but electricity only accounts for a minor part of total energy demand. The company, which was once part of a consortium to build nuclear reactors at Moorside in Cumbria, now plans to switch all of its gas operations to biogas and renewable hydrogen by 2050, making it 100% green. The power and gas group already has some 70 biogas projects worldwide, including 40 in France, and says that if all its projects get approval its annual investment in biogas could soar tenfold to hundreds of millions of euros per year. Engie is looking to invest in industrial-scale hydrogen production by electrolysis of water in places where solar energy is cheap. It wants to produce hydrogen at a price that would make it more competitive with steam reforming of hydrocarbons, which accounts for 95% of hydrogen produced today and costs about 2 euros per kilo, compared to 6 euros/kilo for electrolysis. (75)

A biogas and hydrogen pathway

The National Grid says green gas could produce 30-50% of domestic gas demand in future. Biomethane produced by anaerobic digestion (AD) is the main current source of green gas, and more of it could be injected into the gas grid rather than wastefully being used to generate electricity. Nearly a third more biogas was being produced in the UK in 2016 compared to 2015, according to the Anaerobic Digestion and Bioresources Association (ADBA). The UK had 617MW of biogas capacity - enough to power 800,000 homes. But growth in the industry has slowed due to government policy decisions and investment uncertainty. (76) The bio-methane sector has only just started to develop and has significant scope to increase the production of green gas. National Grid highlights the potential for a 10-fold increase in the number of green gas connections with approximately 40TWh/year of green gas from AD injected to the grid by 2035 – around 5% of UK gas demand or around 10% of UK domestic gas demand.

Hydrogen

Hydrogen is one of the most abundant elements on the planet, and can be used as an energy source, but it does not exist in the natural world on its own. First it must be separated from a compound that contains it. There are three main ways to separate hydrogen. Steam reforming is the most common method which involves extracting hydrogen from methane – a process which produces carbon dioxide. Secondly coal gasification involves the heating of coal at high temperatures but this process releases carbon monoxide. Finally electrolysis uses electricity to split water into hydrogen and oxygen. Although electrolysis is the cleanest way to produce hydrogen up until recently it has been the most costly method – perhaps four times more expensive than steam reforming. (77)

Now breakthroughs with electrolysis technology and cheap solar energy are beginning to change that. The technology for producing renewable hydrogen is known as power-to-gas (P2G), and it is quickly improving. P2G is primed for significant growth in coming years as demand for clean hydrogen grows, electrolyser capital costs fall, and cheap renewable energy bathes the grid. Many commentators believe it will be the key to grid stabilisation in systems with an increasing contribution from intermittent renewables. Research and development into using hydrogen an energy source and storage medium which allows electricity to be stored for weeks and months beyond what lithium-ion batteries can manage is being backed by some big energy companies including Shell and Uniper (formerly part of Eon) as well as carmakers BMW and Audi. (78)

The Hydrogen Council is a new coalition of companies, including 3 oil majors, which published a report at the Climate Conference in Bonn on the value of using surplus electricity (through water electrolysis) as a source of hydrogen, and then using it as energy for cars and for making renewable chemicals and fuels. As well as being a key pillar in of the energy transition, the study shows that hydrogen has the potential to develop US $2.5tn of business, creating more than 30 million jobs by 2050. The study entitled Hydrogen, Scaling up outlines a comprehensive and quantified roadmap to scale deployment and its enabling impact on the energy transition. Deployed at scale, hydrogen could account for almost one-fifth of total final energy consumed by 2050. (79)

P2G has already surpassed its 2020 cost reduction target set by the European Union. Sheffield-based ITM Power has been quietly building a global market in hydrogen technology, making electrolysers that convert electricity to hydrogen. The Company says its P2G product is now half the price it was just a few years ago. The firm's work in Germany – where it has two groundbreaking projects – shows that not only is the process possible, it's pretty much commercially viable. P2G can turn surplus renewable electricity, which would otherwise go to waste into hydrogen, which can be used at anytime in a number of ways. (80)

The hydrogen gas produced can be used as it is - to fuel vehicles for instance or it could also be turned back into electricity and fed into the grid when demand is high. This would allow solar electricity to be used at night or in the winter for instance. Alternatively hydrogen could be injected it into the gas grid, as has been done in Germany for years, but there are technical limits to how much hydrogen can be added to the natural gas network – currently about 5 to 10%. Finally hydrogen can be mixed with carbon dioxide (captured from industrial or fossil fuel facilities even) to make a synthetic natural gas. This can also be done by feeding the hydrogen to microbes which then combine it with carbon dioxide and excrete methane. (81)

Hydrogen energy storage systems can have lower capital costs than lithium-ion batteries for discharge durations of more than about 20 hours. Electrolysers can also ramp production up or down quickly – ideal for a system with lots of intermittent energy. Electric utilities are gradually beginning to recognise the value P2G can bring to their grid, and gas utilities are beginning to recognize hydrogen as a potentially significant fuel of the low carbon future. The longer-term vision of companies like Engie and others is to generate hydrogen where cheap renewables exist, and export it to demand centres. Generating hydrogen from renewables can be a win-win for energy systems across the globe. (82)

A vital step towards commercialisation of P2G has been announced by the French manufacturer McPhy which has won a €1.3m contract with the Austrian gas storage specialist RAG. RAG will install an electrolyser and pump hydrogen into a sealed underground cavern alongside CO_2 from a biogas plant. Microbes in the cavern will absorb the H_2 and CO_2, exuding methane (natural gas) as the waste product. The methane will then be injected into the gas grid. The electrolyzer can respond within 30 seconds to instructions to take less or more electric power. And methane-generating microbes have been shown to respond similarly quickly to enhanced availability of hydrogen. (83)

In Germany, Uniper (formerly part of Eon) has been testing a P2G plant at Falkenhagen. The plant feeds small amounts of pure hydrogen (so-called "WindGas") directly into the natural gas network. (84) Because of the technical limits on how much hydrogen and can added to the natural gas network, it is now building a methanation plant which is scheduled to be completed in the spring of 2018. (85)

Germany company – Electrochaea – has developed a commercially viable process which converts low-cost and stranded electricity and carbon dioxide into pipeline-grade renewable gas for direct injection into the existing natural gas grid. The core of this power-to-gas system is a selectively evolved microorganism – a methanogenic archaea. The technical advantages of this biocatalyst mean the technology can operate at lower capital and operating costs and with greater flexibility than conventional thermochemical methanation processes. In November 2017 a company called Caloric won the tender for engineering and construction of a biomethanation pilot & demonstration plant in Solothurn, Switzerland using the Electrochaea system (86)

Also in Germany, Wiesbaden-based project developer ABO Wind has partnered with the H2BZ Initiative Hessen eV, the Regionalmanagement Nordhessen / MoWiN.net and the petrol station operator Frank Roth. ABO Wind is currently commissioning a wind farm in neighbouring Kirchheim with a total rated output of 9.9 megawatts. The electricity could be used to supply all Kirchheim households and additionally an electrolyzer for a wind-hydrogen filling station. It will be capable of fuelling two to four cars a day. ABO Wind hopes funding will be made available from the National Organization for Hydrogen and Fuel Cell Technology to increase fuel cell output to 2MW, which would raise the daily fuelling capacity to 200 cars a day. (87)

Emeritus Professor of Renewable Energy, Dave Elliott, writes that the UK Government's new Clean Growth Strategy includes amongst other things, a £20m R&D/innovation funding for low carbon heat and energy efficiency, but that is dwarfed by the £480m proposed for nuclear R&D, on Small Modular Reactors and the like. It is much more urgent to explore Power to Gas (P2G) which can be used to generate hydrogen and methane. (88)

Hydrogen in the UK

Closer to home, in Methil in Fife, the Levenmouth Community Energy Project – led by Bright Green Hydrogen (BGH) – is a collaborative initiative supported by Fife Council and Toshiba. This is the world's foremost facility demonstrating hydrogen derived from a renewable turbine and solar resources. It is the first project of its kind in Scotland to use green hydrogen to fuel a fleet of hybrid/electric vans. (89) Some of the hydrogen is used to run a fleet of 17 low-emission refuse trucks and vans, while the rest is stored in fuel cells and can be called upon to generate low-carbon electricity when output from the renewables devices is poor. A 'smart' microgrid controls how much hydrogen gets stored and how much is converted into power to supply businesses. As well as commissioning two specially adapted dual-fuel bin lorries, the scheme aims to help local firms boost their environmental credentials by offering a range of hydrogen-powered vehicles for hire. (90)

In February 2017, an international summit on hydrogen was held in Aberdeen to bring together bus operators and re-fuelling companies to present study findings of large scale hydrogen re-fuelling. The event showed the economic benefits of hydrogen to the area. (91)

The Orkney island of Eday will draw excess power from a community wind turbine and surplus tidal power from Orkney's European Marine Energy Centre to produce hydrogen to provide auxiliary power for vessels in Kirkwall harbour and ultimately CalMac ferries serving Scotland's islands. The hydrogen will be shipped to Kirkwall harbour – a distance of about 20 miles – where it will be fed into a hydrogen fuel cell and used to provide auxiliary power for vessels in the harbour. (92)

Island Energy

A project relevant to Scottish Islands is being run by Engie and Schneider Electric on Semekau Island south of Singapore. The two companies have installed a microgrid on the island. The network uses a 100 kW turbine, a large PV array, batteries and an electrolyser to produce hydrogen during periods of surplus electricity. The gas will be used both for vehicles and to produce electricity from static fuel cells. (93)

Hydrogen-powered vehicles

ITM Power is installing hydrogen filling stations in the UK with Shell. While carmakers have been slower to produce hydrogen models than electric ones, bus companies and even hauliers, which return to a fixed point, are beginning to embrace it. Compared with electric motors, the range is better and refuelling – around six minutes. Electrolysers reduce the climate impact of making the gas. Creating a ton of hydrogen by traditional methods creates 12-16 tonnes of carbon dioxide. Using renewable electricity cuts that to zero. (94)

One of the world's first hydrogen-powered cars is the Toyata Mirai. These have two main advantages over electric vehicles. They can travel 500 kilometres before they require refuelling and it takes only 3 to 5 minutes to refuel. At the moment these cars are expensive but by the early 2020s Toyota aims to half the price. (95)

The Green Gas Alternative to Hinkley Point C

If the UK really wants 3.2GW of 'baseload' power in Somerset, then the Hinkley Point C nuclear power station is not the only way. Wind power with 'wind to gas' plant and CCGT gas power stations could do the same - faster, cheaper, more flexibily, and at much lower technical and financial risk, according to the Energy Brainpool, in a report for Greenpeace Energy.

The group performed a simulation of electricity production during August 2025, which showed that surplus wind power above the 3.2GW equivalent to Hinkley Point C is used in windgas facilities first to produce hydrogen (H_2), then convert it to methane (CH_4). This is then fed into the conventional gas distribution system or stored in existing gas storage facilities and later reconverted into electricity in combined-cycle gas turbine (CCGT) power plants when the need arises.

The cost of the wind power and windgas alternative amounts to €101.4 billion; this figure is €7.2 billion lower than the subsidy cost of €108.6 billion that would accrue during the 35 years following the start of operations at Hinkley Point C in 2025. The cost calculation for the wind power and windgas alternative includes the construction and operation of all wind turbines as well as all electrolysers and CCGT (combined cycle) power plants. (96)

A district heating pathway

Combined heat and power (CHP) generators could be the backbone technology in an energy system dominated by renewables. These can produce both saleable heat and electricity and can rapidly ramp up and down over short periods of time. This means they can be used to balance power grids in order to compensate for fluctuating renewables like wind and solar power. (97) In Germany, for instance, as wind and solar PV take on a greater proportion of total electricity production, CHP plants are expected to take on the role of providing more flexible electricity generation. At the moment CHP plants focus on meeting the demand for heat. Electricity production is seen as a useful by-product. In future the focus will switch to providing electricity when the output from wind and solar is low. (98)

A report by SSE makes the case for increased use of district heating to help combat heating efficiency and affordability. The report – 'Sustainable Heating: Reducing Costs, Improving Comfort and Lowering Carbon Emissions' – found that one retrofit project at the Wyndford housing scheme in Glasgow has delivered a 62% reduction in CO2 emissions since it was installed in 2012. (99) The results also show that lives have significantly improved, comfort has increased, and jobs and economic value have been created. (100) In the UK currently only about two per cent of heat is supplied via heating networks - in comparison, in Denmark 60 per cent of the population is connected to a heat network. As well as delivering significant carbon savings, district heating systems can also cut energy costs for billpayers – heating a flat via a gas-fired district heating system costs around 30% less than it would be using individual gas-fired boilers. (101)

District heating networks can be fed with heat from a range of sources from gas-fired and biomass-fired Combined Heat and Power (CHP) stations which also generate electricity, to deep boreholes which extract geothermal heat from underground. In Glasgow and Fife heat is being captured from trapped water in old flooded coal mines. (102) In Lerwick Shetland Heat and Power is hoping to extend its heat network by installing a 2MW heat pump made by Star Renewables in Glasgow to abstract heat from Lerwick Harbour. (103) In the London Borough of Newham there are plans to harness the energy from "fatbergs", the bus-size balls of grease which cost Thames Water an estimated £1 million a month to remove from its sewers. (104)

Illustrating the potential role of combined heat and power in balancing variable renewables an arms-length council-owed district heating company in Gateshead is set to boost its projected life-time income by nearly £1m after signing up to a power demand-response scheme run by Flextricity based in Edinburgh. The Gateshead District Energy Scheme has become part of Flexitricity's demand response network netting the company more than £60,000 per year over the next 15 years for smoothing out peaks and troughs in national electricity demand. (105)

The advantage of using a CHP station to produce electricity quickly when fluctuating renewables like wind and solar power are not able to supply, rather than using a combined cycle gas turbine for instance, is that a CHP plant can reach an efficiency of 80% plus. This compares with the efficiency of CCGTs, which in the UK which range between 49% and 52%. CHP stations could feed their heat into storage facilities when demand for heat from the district heating systems is low. In five years' time, Germany expects a quarter of its electricity to be provided by CHP generation.

The use of surplus renewable electricity to produce heat for storage

The successful combination of CHP and renewables elsewhere in Europe has been attracting increasing attention. (106) For instance Denmark currently relies on wind power for nearly 30% of its electricity and combined heat and power (CHP) plants supply 50%. Plans are in place to increase wind power up to 50% by 2050. The challenge associated with this system is that as the share of wind power rises, there will be less demand for electricity from CHP plants, meaning that this energy could be wasted. A 'smart' solution would require flexible energy conversion and storage technologies to be incorporated. CHP plants could be provided with heat pumps and additional storage capacity to store additional energy on windy days. (107) So district heating systems could absorb large quantities of surplus wind-generated electricity by using heat pumps and electric heaters for heating water. When demand for electricity is high, but the wind is low, CHP plants could sell electricity but store heat if there is no demand for it at the time. (108)

Micro-CHP (mCHP) could also play a similar role as a grid support mechanism to cope with capacity constraints and short-term spikes in demand and meet the electrical requirements of other new technologies which require electricity such as electric vehicles and heat pumps. mCHP is an innovative new technology, which has significant potential to reduce carbon emissions. There are several competing technologies, but all would replace a conventional domestic central heating boiler, and produce electricity as well as hot water for heating. (109)

In Germany Lichtblick, an energy supplier, is already implementing a novel commercialisation model for mCHP with a view to creating a 'virtual power station' of mCHP units to balance wind in the network. LichtBlick has announced its goal to place 100,000 micro CHP systems with an electric output of 20 kW each into homes and buildings in Germany. The property owner will be provided with the cogeneration unit and a heat storage unit and be guaranteed that the home will be supplied with heat as required. LichtBlick would maintain ultimate control over the cogeneration unit with remote capability to manage the unit. A large heat store decouples the production of heat from that of electricity when necessary. The multiple small units give a sensitive and responsive network of immediate capacity to create a supply of up to 2 GW. (110)

Similarly, in areas not connected to district heating networks, Air Source Heat Pumps (ASHP) could be used to generate heat. But if used in conjunction with heat stores the heat pumps could be operated when electricity demand is low, and therefore cheap rather than at peak times. East Lothian-based company Sunamp has installed its heat batteries in seven homes owned by Berwickshire Housing Association (mostly electric heated) and three staff homes. The goal was to shift 100% of the electricity demand to power an ASHP heating system to off-peak electricity. Because Sunamp heat batteries are compact they are practical to use in ordinary homes. Initial results are showing significant savings to householders. (111)

City-scale Heat Pumps

Star Renewable Energy, based in Glasgow, is the first company to offer a city-scale heat pump. This is being used in Drammen, in Norway, to harvest heat from a fjord and deliver it to a district heating network which is heating 6,000 houses. The project has successfully delivered 85% of the heat required by the district heating scheme at one seventh of the cost of gas.

Director Dave Pearson says the notion that new district heating networks need to start off based on gas is a colossal mistake that will consign a generation to burning fossil fuels. (112)

Conclusions

Solar power, offshore wind and onshore wind costs are falling. By making the most of renewable technologies, along with a combination of energy efficiency, battery storage, hydrogen, combined heat and power and district heating networks, we should be developing an integrated energy strategy which not only cuts carbon emissions but also cuts costs for consumers, tackles fuel poverty and doesn't produce nuclear waste in the process.

Hinkley Point C can still be cancelled more cheaply than continuing with this folly. R&D funding should be directed away from the idea of reviving the old, outdated ideas of small modular reactors and reprocessing and redirected at technologies for the future such as P2G and developing district heating networks with heat storage.

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