UK Energy Choices - by Neil Crumpton, energy campaigner and member of the DECC-NGO nuclear Forum September 2015

This briefing discusses some major points in favour of a nuclear-free (renewable) UK energy policy.

Building a fully decarbonised electricity sector by 2030 using renewables-only and renewables+(BE)CCS pathways (on course for a predominantly renewably-energised UK by 2050) are contrasted with pathways in which nuclear power is seen as 'crucial', 'key' or ‘absolute’. Significantly more fossil gas based electricity system (be it shale or imported LNG) is also a possibility. A nuclear+shale gas pathway appears to be the current direction of the Tory government and others.

This briefing :

* focusses on UK electricity policy and decarbonisation pathways by 2030 and beyond

* aims to show how absolutely central the role of new-nuclear is in current Tory policy and others

* shows how renewables, nuclear, CCS, BECCS and fossil fuels either displace or compliment each other, which could see renewables decline steeply from 2020

* explains why new nuclear technologies are nowhere near ‘crucial’ or ‘key’ at UK or global level and opposes nuclear power for several stand-alone reasons (proliferation, waste, safety, security)

* suggests that Renewables + CCS (preferably BECCS on biomass) would decarbonise the Grid by 2030, compared to a renewable-only policy which would be a stretch

* explains that the gas-fired ‘back-up’ needed for ‘unreliable’ renewables is a major strength not a fatal weakness - ie decentralised Grid resilience + national security benefit, and starts local heat networks vs centralised nuclear

* suggests that a decentralised back-up roll-out would be very low-cost (15 x cheaper than nuclear per GW) and could / should be owned by the public, and operated by Local Authorities / National Grid

* suggests a preferred role for coal CCS if it were to play a role ie producing Synthetic NaturalGas (SNG) and a (re)demonstration of the world-leading British Gas-Lurgi SNG gasifier technology + integrated CCS

* explains that the production of SNG made from biomass, wastes and or coal with CCS would be ‘low-carbon’ to ‘carbon-negative’ and would fuel the decentralised gas-fired back-up (ie SNG-fired)

* suggests a public debate on the planned £ 11 billion electricity + gas Smart Meter roll-out (which benefits big utilities + threat to privacy and UK security) and £ 1 b/y Capacity Mechanism policy vs a £ 6 billion roll-out of decentralised gas-fired back-up needed for the additional renewables needed to avoid the current 2030 nuclear plan

* suggests that the current nuclear policy is 1950s centralised thinking and that a renewables + BECCS / SNG plan is looking to the future and to an essentially renewably-energised and decentralised UK by 2050

Introduction

The forthcoming decisions about energy policy, particularly of nuclear new-build, would have significant consequences long after the politics and personalities of recent years have passed into history. New nuclear stations may run from 2025 to 2085, their 'high burn-up' waste would likely remain on-site (in 'Interim' Stores') until around 2140, and new-build waste in one or more Geological Disposal Facilities would be another feature in geological time.

The wider ramifications for non-proliferation (more genie out the bottle) and the increased potential for uranium or plutonium reaching terrorist hands, could also feature significantly in the history of the next few centuries.

Yet many politicians have little interest in complex nuclear matters, and exposure to nuclear PR can be very persuasive. Those ministers who make major decisions on energy issues may have little technical background or even pre-interest in energy issues. They may well be exposed to family members or others lobbying or working for nuclear companies. The DECC-NGO Forum has had five energy secretaries in five years. Top civil servants who may advise get most of their information from newspapers apparently, not forgetting that the BBC Trust included two EdF advisors, chair and vice-chair until recently. Even chief scientific advisers are not necessarily versed in the relevant issues and yet are away from scrutiny.

A sustainable no-nuclear UK energy policy

However, this situation provides opportunities for those who are interested. A basic grasp of the subject can go a long way. This briefing goes a bit further to point out some fuels, systems and ideas which may be of value. It may hopefully accurately show the scale and consequence of the Coalition's and new Government's strongly nuclear vision or that of their chief scientific and senior civil service advisers.

I have heard numerous people say that we (the public, and even many politicians) 'have been led down the garden path on nuclear power'. An instance springs to my mind, Ed Davey at the 2013 Glasgow Lib Dem conference professed, and policy documents stated, that [my emphasis] : '*nuclear power stations COULD play a LIMITED ROLE in decarbonising the UK's electricity supply*'. The party's long-standing no-nuclear policy was fairly narrowly overturned on that basis. Yet just days later Davey flew to China to secure nuclear investment which WOULD see nuclear playing a CENTRAL ROLE in 2030 decarbonisation plans. During another conference Mr Davey took time out to fly to Rome to chair his Green Growth Group which lobbied to undermine EU and UK 2030 renewables targets. For an assessment of the direction Mr Davey was, and Mrs Rudd is, heading see **Nuclear Power, plans and points** section below which puts plans for nuclear power in a UK and global context.

It has been suggested that coal with CCS should be considered. Is there a role for coal ? Even the word 'coal' and indeed 'CCS' will pretty abruptly set many against anyone suggesting such fuel and technology. Even if the policy was caveated on a very small amount of coal-CCS for demonstration reasons, for a possible relatively small role-out post 2025, pending post-2020 renewables progress reviews and the global gas security situation at that time.

So, in **Annex 1 2030 Electricity Sector Scenarios** I have set out some 2030 electricity supply-demand scenarios (which all meet National Grid's 2030 demand forecast and CCC decarbonisation recommendations). The scenarios, explained below show the likely or possible pathways and options, and how nuclear, renewables, CCS and gas and coal would likely complement or displace each other. Annex 1 is mainly for my reference but the highlighted scenarios are simple enough to glance at, and it provides some scrutiny of my assessment and views set out here.

The Tory, Lib Dem, UKIP and Labour energy policies ALL support the building of a five, possibly six, project '16 GW' new-build nuclear programme by 2025 or as soon thereafter. The five projects would generate around 120 Terra watt-hours per year (TWh/y). A sixth project, Chinese reactors (about 24 TWh per year) on the Bradwell site, may well be strongly-linked to a Chinese investment deal for Hinkley C (25 TWh per year).

The DECC planning consents, CfD agreements and developer's final investment decisions for probably at least three of the projects (Hinkley C + Wylfa B + Moorside = 75 TWh per year) are planned to take place before 2020 and so within the lifetime of this Government. This would mean 75 TWh per year less renewables /BECCS/CCS in the 2020s pretty much guaranteed, rising to probably 120-150 TWh/y by 2030 if all 'first-tranche' projects are consented (if the reactors work properly if completed is another matter).

UK electricity demand is forecast by National Grid to be around 350 TWh/y in 2030 (including about 25 TWh/y transmission losses). So a 120-150 TWh/y new nuclear programme plus Sizewell B (8 TWh/y) would supply about **37-45 %** of such a 2030 electricity demand. Where is the 'balanced' mix ministers have routinely explained is necessary for energy security (and has anyone tried to stop the wind blowing and the sun shining, or the tide rising for that matter) ?

Beyond 2030 Coalition ministers talked of 7 GW of Small Modular Reactors by 2035 which would in theory generate 55 TWh/y of electricity at baseload. The 2013 Pathways report explored 55-75 GW nuclear scenarios by 2050 which would generate somewhere between 400-550 TWh/y and possibly 50+ TWh/y of heat. That's up to 45 % of future UK ENERGY (of possibly 1,300 TWh/y excluding aviation and shipping). For comparison, a renewables/BECCS 2050 energy system could comprise around 600 TWh/y of offshore wind in 2050 or 45 % of demand.

The Climate Change Committee's electricity sector 'decarbonisation' recommendation is to achieve 50 g/kWh by 2030 which may allow just 10 TWh/y of unabated gas-fired generation by that time. The Government may just about honour its 2020 EU renewables commitment which would require at least **110 TWh/y of renewable electricity by 2020** (though it is trying to wriggle it down). It is also possible that the planned five or six new nuclear projects generating 120-150 TWh/y would be operational by 2030 along with 8 TWh/y from Sizewell B. So, it would then require only 70-100 TWh/y of non-nuclear low-carbon electricity (renewables, CCS, BECCS) to be built across the 2020s to achieve electricity sector 'decarbonisation' based on forecast demand (which may be overestimated).

So renewables build in the 2020s is currently planned to fall significantly below that which should be built by 2020, even with no CCS. Furthermore, a realistically buildable gas-CCS programme (generating 40 TWh/y by 2030) sequestrating 18 mt CO2 per year (ie just one or two regional pipelines) could further reduce 2020s renewables deployment to 30-60 TWh/y. Of that, 30 TWh/y or more could come from biomass plus some smaller renewable schemes (tidal / lagoons, hydro, AD bio-gas, wave, geothermal).

So, **offshore wind and PV deployment in the 2020s could fall to near or below that achieved to date in 2015** (about 20 TWh/y). That scenario is what the pro shale gas, pro-nuclear, minded advocates may want. Chancellor Osborne should be questioned on that to show the British public, including Tory voters, the Tory Government's preferred 2030 energy outcome.

The scenarios indicate that if the planned new-build nuclear programme did not proceed, then realistically deployable renewables with some level of CCS included would very probably be able to achieve sector decarbonisation by 2030.

Decarbonisation by renewables alone would be less certain and lacks room for manoeuver. Deployment rates, particularly of offshore wind, would have to be consistently high and costs competitive. IF the deployment rate or cost were not on track to meet 2030 climate or 'levy control' targets then a relatively small amount of gas-CCS, coal-CCS or bio-energy-CCS (BECCS) would be needed.

There are also some large industrial sources of CO2 that could be captured and sequestered, possibly up to 8 mt CO2 per year by 2030. So CO2 pipelines need to be planned and started soon (the White Rose pipeline in Yorkshire could be built by 2021) to open such options.

Would 'greens' oppose any fossil-CCS or BECCS if necessary to achieve 2030 electricity sector decarbonisation while seeing off nuclear new-build ? Much would depend on deployment rates of offshore wind farms and solar PV, additional onshore windfarms, and availability and attitudes to biomass.

Biomass is a key renewable resource for producing aviation fuels, chemical feedstocks (for plastics, paints, oils, etc) and Synthetic Natural Gas (bio-SNG, bio-methane) for use in on-demand electricity and heat production. It is of far more importance than nuclear electricity and UK innovation funders and campaigners should be aware of that. While potentially large supplies could be available if promoted in all the scenarios electricity generated from dry biomass reaches 20 TWh/y by 2020 (eg Drax 11 TWh/y) and deployment is capped at an additional 20 TWh/y in the 2020s. Bio-wastes are considered separately.

Yet biomass gasifiers / refineries with CCS fitted (ie BECCS) would generate valuable, storable and 'carbon-negatively' produced bio-fuels. This is because not all the bio-carbon atoms in the primary biomass end up in the produced bio-fuel. Many, possibly more than half, end up as CO2. This CO2 byproduct of the bio-fuel/SNG refinery can be sequestered, not least because its already pre-captured within the works, and probably at usefully high pressure and purity.

Biomass is currently a focus of some opposition-campaigning on some justified issues of sustainability. Unfortunately there is little activity on identifying and promoting much-needed potentially major sustainable resources eg from Earth's arid zones : http://www.renewableenergyworld.com/articles/2014/01/pricklypear-cactus-nuisance-or-bioenergy-opportunity.html and http://www.renewableenergyworld.com/articles/2014/06/tequila-sunrise-companies-sign-pact-to-advance-agave-as-aviation-biofuels-feedstock.html. Such potential biomass sources and bio-gasifier technologies should be subject to considerable UK R&D innovation funding. Nuclear research by NIRAB may reach £ 30 million next year. Is bio-energy getting anything like that ? Some UK Innovation funding on growing seaweed biomass under offshore wind farms should be considered too.

Gasification of Bio-Energy with CCS (BECCS), rather than unabated combustion of biomass, to produce 'carbon-negative' bio-SNG for injection into the UK gas network is shown in Scenario 5 (30 TWh/y BECCS). **This pathway has significant infrastructure, energy security and national security benefits in terms of supplying renewable gas to geographically decentralised gas-fired back-up schemes.**

The renewably-fired back-up schemes (tens of GW by 2050) would compliment the intermittent wind and PV deployments and could be easily be configured as CHP to supply local heat networks. The SNG could be stored inter-seasonally at scale eg in the Rough offshore gas-field site (sufficient for 15-20 TWh/y electricity and at least half as much heat) for use in winter.

The decentralised back-up could be state-owned, operated by Local Authorities, and or by National Grid, and would form the basis of localised electricity and heat networks. A 15 GW deployment would cost just £ 6 billion. That's cheap compared to the planned £ 11 billion smart gas and electricity meter rollout (which is likely to supply trouble), or the **£ 1 billion per year 'Capacity Mechanism'** starting 2018 which pays ageing, paid-down nuclear and fossil stations for generating what they were going to generate anyway, if they don't themselves break down (Mr Davey's policy). The numerous benefits of this pathway compared to centralised nuclear generation are set out in **Annex 2 Gas-fired 'back-up' is a major strength not a fatal weakness.**

Use of natural gas (fossil methane) for electricity generation in all the scenarios reduces significantly from current levels (99 TWh/y). It is highest at around 50 TWh/y electricity in (the Government's) pro-nuclear, pro-shale, anti-renewables policies (Scenario 2). A renewables-only policy with CCS demos only (Scenario 3) would see the lowest gas use at 12 TWh/y IF the renewables targets were achieved.

Other more likely scenarios for renewables deployment which include CCS indicate natural gas generating around 25-45 TWh/y. Coal, mixed with other fuels (biomass, wastes, contaminated wastes), **with** CCS could technically play a 15-25 TWh/y role if the price is competitive, and could be used to reduce some marginal gas dependency rather than displacing renewables. In 2014, electricity generated from coal was 95 TWh/y (and nuclear was 58 TWh/y).

Coal could be co-gasified along with biomass and various wastes in CCS-fitted multi-fuel SNG production plants. The high temperature provided by the coal would enable contaminated wastes to be combusted well beyond dioxin-formation temperatures. Such coal-assisted contaminated waste gasification may be the most effective contaminated waste management technology.

The SNG produced would be low-carbon to mildly carbon negative depending on the biogenic content of the fuel mix. The SNG would then be used in back-up plants as described in Annex 2. **The UK taxpayer has already proved a world-leading 76 % efficient SNG production technology at Westfield in Scotland in 2006 in the shape of a British Gas-Lurgi (BGL) slagging gasifier + HICOM methanator :**

see page 12 : http://www.google.co.uk/search?client=safari&rls=en&q=china+building+British+Gas+lurgi+gasifiers+2014&ie=UTF-8&oe=UTF-8&gfe_rd=cr&ei=J_riVZiXGczD8gfvqqCYDQ

Several BGL gasifiers / SNG plants (without CCS) are currently being built in China ! A new demonstration plant, with integrated CCS plant, should be considered for funding and might be demonstrated with CCS by 2025. Decisions on any coal/ multi-fuel-CCS roll-out could then be taken at that time.

Coal supply for 25 TWh/y generation with CCS would amount to nearly 9 million tonnes per year in 2030 (350,000 tonnes per TWh abated coal electricity). For comparison, last year coal used to generate electricity was around 46 million tonnes, down from a 1980s high of around 80 million tonnes per year. The UK imports most of its coal demand currently, recently 40 % from Russia. UK coal production in 2013 was 12.7 million tonnes of which 4 million tonnes was deep-mined.

Some coal could be produced from the South Wales coalfields and Yorkshire depending on prices. Some jobs in coal mining areas may be created though hardly significant in the wider scenario and energy security context, which could see similar job numbers in shale-gas production, or in indigenous biomass supply.

In summary

UK electricity and decarbonisation policy is currently aimed at prioritising significant new nuclear build to 2030 and beyond. If achieved UK electricity supply would become very dependent on large foreign nuclear companies by 2030 with uranium imports coming from declining and possibly increasingly risky sources. That's a very different pathway to UK businesses and collectives harnessing clean renewable electricity from unstoppable indigenous resources to achieve sector decarbonisation.

Some CCS deployment would aid decarbonisation if a policy of renewables-only deployments were falling short. The decentralised benefits of PV and other renewables, working in conjunction to an increasingly renewable gas / SNG -fired decentralised back-up system, could well be lost to centralised nuclear generation and large utilities with internet control of consumers.

In 75 years time numerous toxic waste stores would be dotted around UK coastlines and possibly urban fringes awaiting disposal decades later, while another tranche of nuclear stations is opened. Meanwhile, the UK would be cited as an example by any country trying to build a civil nuclear programme for potential conversion for military purposes at some later point.

The pathway choices are so very different. The Chinese president Jinping is on a state visit to the UK in October, and a Hinkley C deal hangs in the deciding balance at this major watershed in the UK's energy future.

Perhaps the president may return to China with a mind to fit CCS to their BGL> SNG plants and to cancel unfinished nuclear projects.

Author : For information, I am a long-standing avoid-nuclear campaigner, currently representing as best I can a community group opposing the planned Wylfa B nuclear project on Anglesey (Pobol Atal Wylfa-B or PAWB). I worked as a front-line campaigner for Friends of the Earth for 16 years specialising on energy issues, serving on or presenting possible evidence to various committies, etc. Since 2011 I have campaigned independently (on low income, low-corporate interest, and with possible home-town bias).

I am an active member of the DECC-NGO nuclear Forum which meets about three times a year and is usually attended by a minister. My representations focus on energy systems, future energy scenarios and pathways. Most of the points I have set out below have or are being put to OND staff in discussion papers etc. Forum members are currently calling for a review of the National Planning Statement (NPS) 'fast-track' planning policy linked to a wider review of new-build nuclear power. I'm also an active contributor to the Claverton Energy Group an email discussion group and occasionally contribute an article to the Ecologist.

The views set out are my own, based on many years of campaigning from speaking at small public meetings on Anglesey to presenting at major conferences in London. I regularly converse with some leading energy professionals (certainly in the field of synthetic gas production and Carbon Capture & Storage CCS).

I'm not funded by anyone, and not necessarily aligned with ex-colleagues views in FOE or other NGO's particularly on issues of CCS, 'carbon-negative' BECCS (biomass with CCS), and minor coal use. I am very much a supporter of bio-energy with CCS (BECCS) in combination with other renewable technologies. I'm born, bred and part resident in Hull which would thrive on offshore wind manufacture and deployment.

Nuclear Power, plans and points

A fundamental point - nuclear power is NOWHERE near an **'essential', 'key' or 'crucial'** technology to tackle climate change or energy security - at UK level or globally - those two ideas have been very successful sucker-punches by the nuclear PR industry, and those three words routinely repeated by UK ministers since Tony Blair in 2005 (Amber Rudd has recently added **'absolute'**).

Nuclear power is a marginal technology with multiple dangers supplying **just 2.4 % of current global 'final' ENERGY demand**. Global nuclear supply has hovered around 2,450 TWh/y in recent time while global 'final' energy demand has risen over 100,000 TWh/y. The latest IAEA forecast indicate that by 2050 reactors world-wide would produce around just 4 % of 2050 global energy demand at most. Such a small supply would come at a grossly disproportionate dis-benefit to global security and non-proliferation in an age of mass-terrorism and high-tech asymmetric warfare.

At UK level nuclear power supplies around **3.6 % of UK energy**, not over 7 % as G Brown was dis-briefed (that figure includes the waste heat from the power station cooled by the sea !). Worse, many UK media outlets have mistakenly and routinely repeated for two decades figures of around 18 % (confusing energy with electricity) bigging-up the significance of nuclear power to public and politicians alike.

UK energy demand is currently around 1,700 TWh/y and UK reactors have been supplying around 55-65 TWh/y (those who contest - DO the simple maths). UK electricity demand has been hovering around 350 TWh/y so nuclear supplies about 18 % of UK electricity currently.

France currently generates about 24 % of its ENERGY currently and is trying to reduce its uranium dependency (1). In contrast, 2013 HMG's nuclear Pathways report assessed nuclear scenarios supplying up to 30-40 % of 2050 UK ENERGY, possibly more if some Small Modular Reactors (SMRs) were connected to large district heating networks, in what would be a plutonium-based economy.

Several CCS technologies are already proven unlike the current (Generation III+) reactor designs being planned for the UK. A 'syn-fuels' full-chain CCS scheme in Dakota has been sequestering around 3 million tonnes of CO2 per year since 2000 (http://www.dakotagas.com/CO2_Capture_and_Storage/). It is not Scotch mist. Even proponents caution about the unproven benefits of future Small Modular Reactors (SMRs).

The so-called 'waste-burning' future 'fast' reactors (Generation IV, 'burn or breed') like the proposed Hitachi PRISM are far from being commercially or even technically proven at utility-scale, let alone in a 'proliferation-resistant' nationwide deployment. Its about time messers Monbiot and Lynas (self-promoting commentators NOT system-savvy engineers) recovered from such sucker-punch PR.

Future generations globally will not thank the mainly English (not British) for promoting nuclear power as a key national or global low-carbon energy and climate 'solution'. The security implications of producing, using and storing large quantities of uranium, plutonium and wastes globally, along with the proliferation consequences, are high and possibly irreversible (like guns in America).

The British public would be paying for the rescue of a dodgy, debt-ridden and 'subsidy-confidence' driven industry (largely foreign) from a justified demise, by turning its back on its considerable renewable energy resources and potentially large and leading UK renewable energy and CCS industries.

Annex 1 2030 Electricity Sector Scenarios

All the scenarios below assume, for the moment, that 110 TWh/y of renewables are built by 2020 as part of the UK commitment to EU renewables policy. That said, on August 26th DECC announced it was looking to see if reductions in renewable electricity could be achieved by energy efficiency improvements ! By 2020, renewable electricity schemes may comprise 10 GW (33 TWh/y) offshore wind, plus 12.5 GW (30 TWh/y) onshore wind, plus 10 GW (9 TWh/y) solar PV, 6 TWh/y hydro + 20 TWh/y from biomass + some bio-wastes, tidal and demo schemes.

The scenarios all include the proposed small CCS White Rose (coal/biomass) demonstration scheme (2 TWh/y) to show context. This scheme would be built adjacent to the huge 4 GW Drax power station (22 TWh/y). National Grid has publicly consulted on the CO2 pipeline route to offshore storage area and which could be built by about 2021. The 'regional' pipeline would be upto about 2 feet diameter so could transport upto a massive 17+ million tonnes of CO2 per year at full capacity from projects in the west Yorkshire area including industrial CO2 sources. The White Rose scheme itself might sequester around 2 mt CO2 per year from mostly coal but possibly up to 30 % from co-fired biomass sources (it would have carbon-negative emissions at about 5 % biomass co-firing). A smallish CCS project around Deeside could re-use (reverse-use) one or two existing natural gas pipelines from/to depleted gas fields in Liverpool Bay (maybe a few mt CO2/y).

A 50 g/kWh electricity sector decarbonisation target would allow some unabated fossil emissions (50 g/kWh = 0.05 mt / TWh). The sector allowance would be **17.5 million tonnes CO2** at an estimated 350 TWh/y demand (0.05 x 350). The scenarios assume average renewables and nuclear CO2 'lifetime emissions' are deemed low eg averaging about 20 g/kWh (0.02 mt/TWh) or around **6 mt CO2** per scenario.

Also, 2030 biomass is assumed to have an average 'life-cycle' (LCA) fossil emissions equivalent to 20 % of its emissions (of about 0.9 mt CO2 per TWh electricity generated). All scenarios include 20 TWh/y from pre-2020 biomass + 20 TWh/y from 2020s biomass. So biomass LCA emissions are assumed to be **7.2 mt CO2** (40 x 0.9 x 20 %) in all scenarios.

Consequently, the 2030 unabated gas allowance may be around 4.3 mt CO2 (17.5 - 7.2 - 6 = 4.3). Emissions from gas-fired back-up schemes would emit around 0.4 mt CO2 per TWh generated (ie just less than 50 % efficiency). So a 4.3 mt/y allowance would allow about **10 TWh/y unabated gas-fired generation**. Note that the LCA emissions from imported biomass may be attributable to the producer country's carbon inventory in the same way uranium yellow-cake imports to the UK may or may not be attributed to the exporting country.

Uranium fuel related CO2 emissions could rise as the higher content rock resources are crushed up and ore quality declines. In contrast, by 2030 some bio-fuel imports could even be carbon-negatively produced abroad (eg liquefied bio-SNG from CCS-fitted SNG plants in Mexico, Middle East or Australia). Such accounting needs to be clear and fair.

Each TWh of gas-CCS (due to a 20 % CCS energy penalty for 90 % capture) would emit 0.5 mt CO2 per TWh supplied, of which 0.45 mt CO2 would be sequestered and 0.05 mt CO2 released to atmosphere. Each TWh of coal CCS would emit 0.09 mt CO2 (reducing to MINUS 0.13 mt at 30 % biomass co-firing) and sequesters 0.81 mt CO2. So broadly each 10 TWh/y from CCS schemes in the scenarios would release about 0.5 mt so reducing the 10 TWh/y unabated gas allowance further by 1.25 TWh/y.

In ALL the scenarios below it may be that, post 2020 and a new government, that some additional onshore wind farms are built to the 12+ GW (30 TWh/y) of schemes built pre-2020. For example an additional 8 GW (20 TWh/y) deployment (inc net re-powering) would be very plausible and 12 GW (30 TWh/y) possible depending on public consent post 2020.

Scenario 1 : a five project 120 TWh/y new nuclear programme plus three small CCS demo schemes (including White Rose coal-biomass at 2 TWh/y) could reduce renewables deployment in the 2020s to 92 TWh/y (down from 110 TWh/y pre 2020) or much less if the relatively small CCS deployment was increased eg by 30 TWh/y :

1) 110 renewables-to-2020 + 120 nuclear new-build + 8 Sizewell B + 77 big-renewables-in-2020s + 15 small-renewables-in-2020s + 9 unabated gas + 9 gas CCS + 2 coal CCS + 0 BECCS = 350 TWh/y demand in 2030

Below, a six project 150 TWh/y new nuclear programme plus a large 45 TWh/y gas-CCS programme on about 6.5 GW of large CCGT stations could minimise renewables deployment. The scenario would sequester about 21 mt CO2/y (eg two regional pipelines, one large eg Yorkshire + one small eg Deeside). This high nuclear+gas could reduce renewables deployment in the 2020s to just 30 TWh/y (just 27 % of pre-2020 deployment) and 20 TWh/y of that could be biomass:

2) 110 renewables-to-2020 + 150 nuclear new-build + 8 Sizewell B + 20 big-renewables-in-2020s + 10 small-renewables-in-2020s + 5 unabated gas + 45 gas CCS + 2 coal CCS + 0 BECCS = 350 TWh/y

A renewables-only scenario (no new nuclear and just two small CCS demos sequestering around 3 mt CO2/y at Peterhead and Drax each 2 TWh/y) could look like the scenario below :

3) 110 renewables-to-2020 + 0 nuclear new-build + 8 Sizewell B + 195 big-renewables-in-2020s + 23 small-renewables-in-2020s + 10 unabated gas + 2 gas CCS + 2 coal CCS + 0 BECCS = 350 TWh/y

The big renewables (offshore wind, onshore wind, PV, biomass capped at 20 TWh/y) constructed in the 2020s would have to supply 195 TWh/y by 2030. That would be a big stretch but just plausible if everything went right and better still if National Grid's estimated 2030 electricity demand fell. Assuming 20 TWh/y biomass, and a major 60 TWh/y PV (6.8 GW per year) deployment then wind, mostly offshore, would have to supply 115 TWh/y. It would probably need to include 20-30 TWh/y from additional onshore wind farms (including re-powering).

With no further onshore wind farms it would require 33 GW (115 TWh/y) of offshore wind farms requiring an unlikely deployment rate of 3.3 GW per year (compared to a pre-2020 rate of about 1 GW per year). If a 3.3 GW per year offshore wind deployment rate is considered unlikely a more achievable 2 GW per year deployment would generate 70 TWh/y and onshore wind add what it might. RenewableUK may have a view what a credible 2020s deployment rate would be (including floating schemes).

Offshore wind costs and CfDs are reducing and some estimates indicate that the technology, including floating designs, plus related system costs, would probably be very similar to the Hinkley C index-linked deal, now around £ 94 /MWh (and its system costs) by the time a Hinkley C opened in about 2025 or by 2030 : http://www.eti.co.uk/wp-content/uploads/2014/03/PelaStar-LCOE-Paper-21-Jan-2014.pdf. Offshore wind scenario costs could even be much lower than new nuclear if considering time periods to 2060 (Hinkley C CfD is 35 years) and beyond.

If the comparative costs of offshore wind and nuclear scenarios are anywhere near similar (and they would probable be so) then the considerable benefits of non-proliferation, avoided radio-active wastes, and avoided safety and security risks, of offshore wind should surely be persuasive to the public and policy-makers. There would probably be net job and UK industry benefits too (eg Hull, Grimsby, Teeside, Holyhead).

A more CCS-inclusive renewable / fossil-CCS scenario would be more like Scenario 4 below. The degree of fossil CCS would be depend mainly on relative costs and relative deployment progress of offshore wind farms and PV arrays in particular, and some onshore wind, by the mid 2020s. Here a 170 TWh/y 2020s renewables deployment could comprise 70 offshore wind + 55 PV + 20 biomass + 25 from onshore wind.

A predominantly gas-CCS deployment is shown, sequestering about 17 mt CO2 per year by 2030 eg from two regional pipelines (eg Yorkshire and Teeside and or Deeside). A predominantly coal-CCS scenario would need considerable additional CO2 pipeline and storage infrastructure as coal has nearly double the emissions of natural gas :

4) 110 renewables-to-2020 + 0 nuclear new-build + 8 Sizewell B + 170 big-renewables-in-2020s + 20 small-renewables-in-2020s + 5 unabated gas + 35 gas CCS + 2 coal CCS + 0 BECCS = 350 TWh/y

An alternative to gas CCS and coal-combustion CCS is to gasify biomass with CCS (BECCS) for conversion to strongly carbon-negative bio-methane (bio-Synthetic Natural Gas 'bio-SNG'). The bio-SNG would be injected into the existing UK gas network, which has considerable (short and inter-seasonal) storage potential for subsequent use in gas-fired back-up plants.

These plants need to be built anyway even in a renewables-only scenario (to meet peak demands on windless winter evenings). The carbon-negative 'credit' would allow considerably more unabated fossil gas to be burnt (so usefully avoiding the fitting of expensive CCS plant and cross-countryside pipelines to decentralised low-usage gas-fired plants).

1 TWh/y of electricity from unabated biomass combustion would release around 0.9 mt CO2 at 38 % efficiency. Bio-gasification>SNG>CCGT may have a similar 38 % overall efficiency. If gasified to 'carbon-neutral' bio-SNG (ie emitting 0.4 mt bio-CO2 per TWh electricity when subsequently burnt) then the BECCS plant could capture and sequestrate up to about 0.5 mt CO2 (ie 0.9 - 0.4) excluding any gasifier related emissions.

Assuming 0.5 mt CO2 is sequestrated per TWh of electricity generated. If the biomass is assessed to have 'life-cycle' fossil emissions of say 20 % (0.18 mt) then the carbon-negative credit would be 0.32 mt per TWh of SNG electricity (0.9 - 0.4 - 0.18 = 0.32).

So in Scenario 5 below, a 30 TWh/y BECCS deployment would have a carbon-negative credit of around 9.6 mt CO2 (30 x 0.32) which would allow an extra 24 TWh of unabated gas-fired electricity (9.6 / 0.4) as shown below. As the LCA emissions of the biomass used in BECCS have been accounted for in the carbon-negative calculation then to avoid double-counting the unabated gas-fired allowance rises by 0.18 mt per TWh of BECCS or 5.4 mt (30 x 0.18) in the scenario below. This would allow 13.5 TWh/y (5.4/0.4) of additional unabated natural gas use. Note 20 TWh/y of biomass is moved from 'big-renewables' to the 'BECCS' column and 'big-renewables' becomes 'wind+PV-in-2020s' and 10 TWh/y of pre-2020s biomass schemes are decommissioned and the biomass is reassigned to 2020s (gasification) schemes :

5) 100 renewables-to-2020 + 0 nuclear new-build + 8 Sizewell B + 150 wind+PV-in-2020s + 14 small-renewables-in-2020s + (9 + 24 +13) unabated gas + 0 gas CCS + 2 coal CCS + 30 BECCS = 350 TWh/y

In the above scenario 2020s renewables deployment amounts to 184 TWh/y, an increase of just 67 % on pre-2020s deployment and natural gas generates 46 TWh/y. Note also that CCS could be fitted any higher load-factor bio-SNG-fired CCGTs for additional carbon-negative credits. Natural gas-fired generation is high at 46 TWh/y

Another pathway is increasing coal with CCS use (indigenous or imported). Generating 1 TWh of electricity by latest 44 % high-efficiency coal combustion power stations would release 0.75 mt CO2 (0.33 mt per TWh primary coal x 100/44) assuming efficient high if not baseload operation. Underground coal gasification emissions would be similar. Adding CCS (at 90 % capture) would result in about 37 % efficiency with emissions of 0.9 mt CO2 (0.335 x 100/37) comprising emissions to air of 0.09 mt per TWh electricity and sequestration of 0.81 mt CO2 per TWh electricity.

The power stations could be co-fired with dry biomass at possibly 30 % maximum. At 30 % co-firing the emissions would be slightly higher than coal at 0.93 mt CO2 per TWh of which 0.3 mt would be from the biomass. Assuming biomass has 20 % fossil LCA then bio-CO2 content is 0.24 mt. So the 0.093 mt emissions to air would be carbon-neutral and the CCS-fitted station would be generating carbon-negative electricity at around 0.15 mt CO2 per TWh generated (0.24 - 0.09).

So a 33 TWh/y co-fired coal CCS deployment scenario (comprising 23 TWh/y from coal and 10 TWh/y from co-fired pre-2020s biomass eg Drax) would have a 5 mt carbon-negative credit (33 x 0.15). This credit would allow an additional 12 TWh/y from unabated gas (5 mt / 0.4 mt). To avoid double-counting the non-BECCS biomass LCA reduces to 5.4 mt CO2 (30 x 0.9 x 20 %) down from 7.2 mt. So, the unabated gas-fired allowance rises by about 4 TWh/y (1.8/0.4) :

6) 100 renewables-to-2020 + 0 nuclear new-build + 8 Sizewell B + 170 big-renewables-in-2020s + 16 small-renewables-in-2020s + (5 + 12 + 4) unabated gas + 0 gas CCS + (2 + 23) coal CCS + 10 BECCS = 350 TWh/y demand

In the above scenario the 2020s renewables deployment is 186 TWh/y (excluding 10 TWh/y redeployment of pre-2020s biomass), natural gas generates 21 TWh/y, and coal generates 25 TWh/y (much like the 4 GW

Drax station did). The sequestration rate would be about 29 mt CO2 per year (20.25 mt from coal + 8.9 mt from biomass). This would require two large regional CO2 pipelines to offshore storage sites.

However, a much more flexible option if any coal is to be used is 'multi-fuel'-gasification with CCS to produce SNG which would be injected into the gas network. From there the SNG can be stored inter-seasonally and used in decentralised gas back-up plants (this option facilitates linking to local CHP heat networks compared to large rural combustion plants).

The multi-fuel comprises coal, dry biomass and wastes (municipal, commercial and industrial wastes containing both fossil and biogenic materials). Depending on the ratios of fuels the SNG produced would be classed as low-carbon to mildly carbon-negative (at highest proven bio-inputs to date comprising 40 % coal by energy + 30 % biomass + 30 % wastes). Costs would be partially dependent on Landfill Tax benefits.

This multi-fuel gasification to SNG technology has already been proven, at the British taxpayers expense, in 2006 by the British Gas-Lurgi gasifier>methanator schemes at Westfield in Scotland and Schwarze Pumpe in Germany, albeit without CCS. Engineers who pioneered the world-leading 76 % efficiency SNG technology have drawn up plans to fit an integrated CCS plant which compresses the already pre-captured CO2 ready for sequestration via pipeline to offshore storage sites. The high temperature process can also deal with contaminated wastes. DECC is now well aware of this technology.

A multi-fuel SNG deployment could comprise schemes generating sufficient SNG to generate 33 TWh/y of electricity in back-up plants. For a fuel mix comprising 13 TWh/y from coal fuel + 10 TWh/y from wastes (5 from pre-2020 bio wastes) + 10 TWh/y from biomass (eg pre-2020 Drax).

So the carbon-negative credit would be in the region of 4.8 mt CO2 (extrapolating from Scenario 5 ie 9.6 mt x15/30 BECCS) so allowing an additional 12 TWh/y of unabated gas. To avoid double-counting the non-BECCS biomass LCA reduces to 5.4 mt CO2 (30 x 0.9 x 20 %) down from 7.2 mt. So, the unabated gas-fired allowance rises by about 4 TWh/y ([7.2 - 5.4]/0.4). :

7) 95 renewables-to-2020 + 0 nuclear new-build + 8 Sizewell B + 170 big-renewables-in-2020s + 20 small-renewables-in-2020s + (5 + 12 + 4) unabated gas + 6 gas CCS + (2 + 13) coal CCS + 15 BECCS = 350 TWh/y

In the above scenario the 2020s renewables deployment is 190 TWh/y (excluding 15 TWh/y redeployment of pre-2020s bio), natural gas generates 27 TWh/y, coal generates 15 TWh/y and fossil wastes generate 5 TWh/y.

Annex 2 Gas-fired 'back-up' is a major strength not a fatal weakness (especially as the gas will increasingly come from renewable sources)

For over two decades opponents of renewable energy have played upon the unreliability of intermittent electricity sources, particularly wind and PV. The presumed need for fossil-fired back-up and nuclear 'baseload' has been used relentlessly to ridicule 'unreliable' renewables.

Yet the decentralised gas-fired back-up needed for intermittent renewables is a source of added strength and security, not weakness. The renewables movement should go on the attack with back-up - not sitting down and getting beaten-up.

The back-up plants needed (gas-turbines, gas-engines and fuel cells which can run for days, or weeks if necessary during a prolonged cold spell) would :

* progressively be supplied with renewable fuels, particularly synthetic methane (from bio-sources) which can be stored inter-seasonally, and green hydrogen - ideal infrastructure for seamless transition to renewable gas and away from fossil gas
* be relatively very cheap (£ 0.4 billion per GW installed compared to £ 7.5 billion per GW for Hinkley C or say 17 x cheaper REPEAT 17 x cheaper, RWE made a similar point recently in the media)

* be relatively small (50-100 MW each), very fast and flexible (10 minutes to full power) and work well in conjunction with latest 'short-duration' storage (batteries etc), enhancing Grid reliability, power-matching and frequency-control
* be built in a physically highly secure decentralised deployment in local Grid's around cities and industrial sites, in contrast to five large 'centralised' terrorist-vulnerable, unsightly coastal nuclear projects at the end of long transmission lines

The back-up would be under-utilised compared to 'baseload' operation but that very geographically-dispersed high-redundancy gives strength and resilience to the Grid and hence UK energy and national security.

The additional Capex cost of gas-fired back-up for PV and offshore wind supplying the same output (120 TWh per year) of a 16 GW nuclear programme would be about £ 6 billion (15 GW x £ 0.4 b per GW) noting that 1.6 GW reactors may need more 'fast' (seconds) back-up than wind and PV. That's close to the £ 5 billion cost of the planned 'smart' gas meter roll-out or the £ 6 billion electricity meter roll-out.

Both these internet-connected meter roll-outs have major questions hanging over them, from technical to privacy to national security, and need urgently to be reviewed :

http://www.scmagazineuk.com/why-smart-meters-need-smarter-security/article/381146/

The very battery technologies that can provide that fast back-up can also store peaks of renewable electricity excess to demand for subsequent supply or conversion by electrolysis to 'green' hydrogen. The reducing costs short-duration storage (hours to day, or days) eg batteries, and 'power-to-gas' (P2G) electrolysers (producing green hydrogen), is reducing the 'system costs' of intermittent renewable energy technologies to marginal amounts (a few £ / MWh by mid 2020s).

The green hydrogen can be stored over days and used in fast-response utility-scale fuel cells ( ) or used to augment bio-SNG production from biomass (more bio-carbon atoms being converted to CH_4 rather than CO_2).

The bio-SNG from whatever gasification processes would be injected into the existing strategic gas network for inter-seasonal storage and subsequent use in the decentralised gas-fired back-up schemes. The relatively small decentralised schemes, sited near urban areas on industrial sites etc, could much more easily be connected into local CHP-heat networks or indeed form a scheme from which a network could grow out from.

With sufficient biomass the bio-SNG used in industry, power and heat generation and in domestic boilers could be carbon-negative (ie the overall BECCS production process geologically sequesters atmospheric carbon dioxide recently breathed in by plants).

Contrary to presumptions, an energy system based on nuclear power may need to store MORE energy **inter-seasonally** over a year than a renewables system. This is because offshore wind farms produce about 60 % of their annual output in the windier winter six months when consumer demand is higher. At best, baseload nuclear stations, even if refuelled only in summer months would generate 55 % of their output in winter.

Nuclear stations could be switched off during summer and some designs may have some degree of load-following capability. Yet the cost of electricity from load-following nuclear reactors would rise significantly as the technology is high in capital cost and for commercial reasons, if not technical reasons, needs to be run at baseload for the quickest return to investors.
