Keeping the lights on at near-zero carbon: Technical companion

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A References and sources of information

[1] Department for Business, Energy and Industrial Strategy (BEIS) https://www.gov.uk/government/statistics/energy-consumption-in-the-uk-2020

[2] BEIS “Greenhouse gases, final figures https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

[3] https://reinvestproject.eu/wp-content/uploads/2019/11/OR_RE-INVEST_Life-cycle-GHG-emissions-of-renewable-and-non-renewable-electricity.pdf

[4] file:///C:/Users/Ellen60/Downloads/20-WWS-UK.pdf

[5] Friends of the Earth Scotland https://foe.scot/resource/offshore-oil-and-gas-workers-views/

[6] Climate Change Committee https://www.theccc.org.uk/publication/sixth-carbon-budget/

[7] Intergovernmental Panel on Climate Change – Special Report on Global Warming of 1.5 degrees Celsius https://www.ipcc.ch/sr15/

[8] Kevin Anderson, John F. Broderick, Isak Stoddard *A factor of two: how the mitigation plans of ‘climate progressive’ nations fall far short of Paris-compliant pathways* https://www.tandfonline.com/doi/full/10.1080/14693062.2020.1728209

[9] BEIS https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877047/Press_Notice_March_2020.pdf

[10] IPCC Climate Change 2021: the Physical Science Basis https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[11] Renewable UK – Wind Energy Statistics https://www.renewableuk.com/page/UKWEDhome

[12] Climate Change Committee – 6th Carbon Budget: Electricity Generation https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf

[13] Clean Technica - https://cleantechnica.com/2021/02/12/vestas-unveils-worlds-most-powerful-offshore-wind-turbine/

[14] https://theconversation.com/floating-wind-farms-how-to-make-them-the-future-of-green-electricity-142847

[15] CleanTechnica - https://cleantechnica.com/2018/10/30/uk-floating-wind-could-support-17000-jobs-generate-33-6-billion-in-value-by-2050/

[16] Vivid Economics - https://www.theccc.org.uk/wp-content/uploads/2019/05/CCC-Accelerated-Electrification-Vivid-Economics-Imperial.pdf

[17] https://www.scotsman.com/news/environment/worlds-tallest-land-wind-farm-planned-scottish-site-3137060

[18] Office of National Statistics (ONS) https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021#:~:text=Employment%20in%20onshore%20wind%20has,most%20jobs%20in%20onshore%20wind.

[19] International Renewable Energy Agency (IRENA) - https://www.irena.org/Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country

[20] Climate Change Committee – 6th Carbon Budget: Electricity Generation https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf

[21] Wikipedia – Solar Cell Efficiency https://en.wikipedia.org/wiki/Solar_cell_efficiency

[22] https://www.azocleantech.com/article.aspx?ArticleID=831

[23] https://www.greenmatch.co.uk/blog/2017/10/the-opportunities-of-solar-panel-recycling

[24] Centre for Alternative Technology: Zero Carbon Britain – Rising to the Climate Emergency https://cat.org.uk/info-resources/zero-carbon-britain/research-reports/zero-carbon-britain-rising-to-the-climate-emergency/

[25] Powerroll (Solar Film) - https://powerroll.solar/unique-solar-film/

[26] ONS https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset

[27] Solar Energy Industries Association: Solar Heating and Cooling - https://www.seia.org/initiatives/solar-heating-cooling

[28] Heat Pump Association - https://www.heatpumps.org.uk/wp-content/uploads/2019/11/A-Roadmap-for-the-Role-of-Heat-Pumps.pdf

[29] https://ore.catapult.org.uk/app/uploads/2018/11/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Industrial-Benefit.pdf

[30] Royal Society Protection of Birds (RSPB) https://www.rspb.org.uk/our-work/policy-insight/climate-change/action-to-tackle-climate-change/uk-energy-policy/wave-and-tidal-power/

[31] Hendry Review: Independent Review of Tidal Lagoons https://hendryreview.wordpress.com/

[32] https://ore.catapult.org.uk/app/uploads/2018/11/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Industrial-Benefit.pdf

[33] https://www.statista.com/statistics/555600/electricity-generation-hydro-uk/

[34] https://www.british-hydro.org/types-of-hydro/

[35] International Hydropower Association (IHA) - https://www.hydropower.org/country-profiles/united-kingdom

[36] Climate Change Committee – 6th Carbon Budget: Electricity Generation https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf

[37] IRENA https://www.irena.org/publications/2015/Apr/Renewable-energy-integration-in-power-grids

[38] Automotive World https://www.automotiveworld.com/articles/risky-business-the-hidden-costs-of-ev-battery-raw-materials/

[39] https://theconversation.com/the-uk-plans-to-build-huge-batteries-to-store-renewable-energy-but-theres-a-much-cheaper-solution-143053

[40] Catapult report for Good Energy https://ge-web-www-cdne-dev01.azureedge.net/static/documents/good-energy-renewable-nation-pathways-to-a-zero-carbon-britain.pdf

[41] Renewable Energy Association (REA) - https://www.r-e-a.net/wp-content/uploads/2019/10/Energy-Storage-FINAL6.pdf

[42] Northern Gas Networks - https://h21.green/

[43] For example, Friends of the Earth - https://policy.friendsoftheearth.uk/insight/role-hydrogen-our-future

[44] https://www.scientificamerican.com/article/how-do-fast-breeder-react/

[45] http://blog.policy.manchester.ac.uk/sci-tech/2016/03/plugging-the-energy-gap-can-extending-nuclear-reactor-lifetimes-help-keep-the-lights-and-heating-on/

[46] Catapult report for Good Energy https://ge-web-www-cdne-dev01.azureedge.net/static/documents/good-energy-renewable-nation-pathways-to-a-zero-carbon-britain.pdf

[47] Jacobson (2019) - https://web.stanford.edu/group/efmh/jacobson/Articles/I/NuclearVsWWS.pdf

[48] Jacobson (2021) - https://eu.boell.org/en/2021/04/26/7-reasons-why-nuclear-energy-not-answer-solve-climate-change

[49] Robert W. Howarth and Mark Z, Jacobson (2021) - https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956

[50] Tyndall Centre - https://foe.scot/wp-content/uploads/2021/01/CCS-Research-Summary-Briefing.pdf

[51] Biofuelwatch https://www.biofuelwatch.org.uk/2018/biomass-basics-2/

[52] https://www.biofuelwatch.org.uk/axedrax-campaign/

[53] World Resources Institute - https://www.wri.org/research/avoiding-bioenergy-competition-food-crops-and-land

[54] https://www.biofuelwatch.org.uk/2021/uk-beccs-ngo-statement/

B How much energy do we need to generate – the target explained

The scale of the challenge

In its 6th Carbon Budget report the government's Climate Change Committee sets out potential pathways to "net zero", including a near-doubling of today's electricity demand by 2050, which must all be from low carbon sources. In addition, the government has committed to a reduction in territorial emissions* of 78% of 1990 levels, by 2035 (ie 68% of 2019 levels). The CCC states that to achieve this target electricity will need to fully decarbonise by 2035, whilst meeting a 50% increase in demand, and that this will require an additional 400TWh of low carbon generation.

In terms of global justice, and even in terms of the possibility of meeting global targets, the goals set by the UK government are far too lax. The IPCC Special Report on Global Warming of 1.5 Degrees, published in 2018, said that, to limit warming since 1850-1900 to 1.5°, the amount of CO2 the world can still emit (the remaining "global carbon budget" is 840 GtCO2 for a 33% chance of hitting the target; 580 GtCO2 for a 50% chance; and 420 GtCO2 for a 67% chance. The CCC takes as a starting-point a global budget that gives humanity a 50% chance of hitting the 1.5 degree target – very poor odds given the catastrophic consequences of breaching that target. This gives rise to a global target of net zero by 2050, whereas a global budget of 420Gt CO2 would mean reaching net zero globally by 2038. These issues are discussed in detail in this article by Peter Somerville.

Furthermore, the "share" of the global carbon budget that the CCC allocates to the UK (9 Gt CO2 from 2018) is argued by climate justice campaigners and scientists (see here and here) to be about twice as generous as it really should be, given its large share of historic emissions and the unequal distribution of wealth which is a barrier to decarbonised development in the global South. *Even if* we ignored these global inequalities and the UK's share was worked out purely on the basis of its share of the global population, the budget would only be 5Gt CO2, not 9Gt. The conclusion must be that we must cut emissions far faster than proposed by the CCC.

A second problem lies in the technological pathways themselves. In the CCC scenario, genuine renewables (ie from wind, water and solar) comprise only 70% of generation in 2035, with the remainder from nuclear) and "dispatchable" sources, ie those which can be stored and utilised according to demand – essentially, gas with carbon capture and storage (CCS), biomass with CCS, and hydrogen produced by methods deemed to be low carbon. Technologies for grid integration, energy storage and reduction of peaks and trough in demand are discussed in far less detail, whilst strategies for changing the way we do things so as to reduce energy demand is allocated only 15% of the hoped-for emissions savings.

*** A footnote on accounting of emissions**
It is important to recognise that these figures account only for emissions actually produced within the borders of the UK, and are highly misleading as to the UK's real contribution to global emissions. A 2020 report from the University of Leeds estimated that when emissions are counted on the basis of consumption of products as well as fuels (and emissions associated with exports excluded), 46% of the UK carbon footprint is associated with emissions from imported manufactured goods and materials. From a global perspective, this is a significant labour rights issue, reflecting the ability of corporate producers to operate

where labour is cheapest and labour rights and environmental standards weakest; conditions which in turn reflect historic colonialist exploitation and the drive by more recently emerging economies to attract inward investment by holding down costs for manufacturers (see eg Malm, 2016).

How much electricity do we need to produce?

According to BEIS (see diagram on page 78) total UK electricity supply in 2019 was 346 TWh, of which 295 TWh (85.4 per cent) was from final consumption, ie excluding energy industry use (24 TWh, or 6.9 per cent of demand) and transmission and distribution losses (26 TWh, or 7.6 per cent of demand). Of this, only 85 TWh was from wind, wave, solar or hydro.

As noted above, total final energy consumption (ie not including energy industry use, or conversion and distribution losses) was 1,651TWh, of which 40% was used in transport, 29% in homes, 15% in industry and 15% in other sectors combined. Add on 15% for energy industry use and transmission and distribution losses, as the proportions may be expected to be roughly the same as for current electricity supply. This gives us 1,651 + 248 = 1,899 TWh . Transmission losses will be less when more energy comes from local and more distributed sources (eg rooftop solar or local generating schemes), but the additional efficiency losses from increased storage need to be taken into account. We therefore go with the same figure of 15% for these losses.

However, this includes each sector's share of the primary fuels used to generate electricity. 438 TWh of this primary energy consists of fossil and other carbon-based fuels combusted for heat. A combined cycle gas-fuelled generating plant has an efficiency of around 60%, meaning that around 40% is wasted. On the other hand, renewably-produced electricity is measured by electricity actually generated, so switching to renewables would mean we could eliminate that 40% energy currently wasted as heat during the electricity generation process .

The energy needed to compensate for switching fossil fuelled generation to renewables is then 263 TWh, and the total amount we need to find is 175 kWh less (on business as usual consumption levels). That is 1724 TWh

In addition, in the transport sector full electrification would eliminate a lot of the waste heat energy from the internal combustion engine (an electric vehicle can typically travel three times as far as an ICE vehicle on an equivalent amount of energy input – or to put it another way, the energy efficiency is about 33%). Based on the above figures, we can estimate that around 30% of *final* energy consumption is fuel for running cars and other small ICE vehicles (ie about 500TWh/yr) and that this could be reduced, at a conservative estimate, by about 60% or about 300 TWh, leaving us with about 1,424 TWh of renewably-produced electricity to find, *on a business as usual basis.*

An alternative approach to energy requirement of EV cars, based on total mileage driven and electricity input required per mile, puts the amount of electricity needed to run the current UK car fleet at as little as 75 TWh/yr – far less than the 200 TWh allowed for here. We think this is overoptimistic, but as a cautious compromise between the two approaches we reduce our estimate somewhat, to 150 TWh, giving us a saving of 350 TWh, and leaving us with 1,374 TWh to find, *for the business as usual scenario.*

However, it is very evident from these figures that, even assuming a doubling of total electricity supply to around 700TWh, with all electricity supplied by renewables, we will still need to cut demand drastically across the whole economy (by around 50% on these estimates), through a combination of technological efficiency improvements and some deep changes in the way we do things *as described in other chapters.* Higher levels of generation might be technically feasible, but undesirable in light of the emissions costs and impacts on the environment.

In addition, given the shortcomings we have identified in the CCC targets, and the rapid approach of climate tipping points identified in 2021 by the IPCC, we should be aiming to achieve this by 2038, not 2050, and the government target of 78% emissions cuts by 2035 should be regarded as inadequate; hence, we need to be far more ambitious in the pace of electrification.

C The technologies – potentials and barriers, targets and job-numbers

In this section we present an expanded version of the section dealing with the proposed technologies, including some of the factors taken into account in setting targets, and the reasoning behind our estimates job numbers.

Windpower

By the end of May 2021, the UK had 10,961 wind turbines with a total installed capacity of over 24 GW, consisting of 13.7 GW of onshore capacity and 10.4 GW of offshore capacity, and delivering an estimated total of 66TWh/yr. Wind power contributed 24.8% of UK electricity supplied in 2020 (see RenewableUK for statistics).

The CCC's "balanced pathway" sees wind providing 430 TWh by 2050 from a generating capacity of 125 GW – a five-fold increase – with 95 GW of this being from a ten-fold growth in offshore capacity. In the shorter term, the goal is 40 GW of offshore capacity installed by 2030.

To meet our own suggested targets, we agree that offshore wind will contribute the most, and that given the rapid technological developments outlined below, we should be able to reach 100GW by our target date of 2038. For onshore wind, we will need to increase installation far faster than suggested by the CCC – we suggest 96 GW by 2038.

Given the significance of windpower in our proposals, we offer here some deeper analysis of potentials and limitations as well as the basis for estimates of job numbers, beginning with offshore wind.

Offshore wind

To get from to 10.4 GW to 100 GW offshore wind by 2038 – and increase of around 90 GW over 16 years (allowing for a slower start in 2022) – we would need to install an average of about 5.6 GW per year.

This may seem ambitious; however, two major trends in turbine development will make this feasible. Firstly, turbine capacity is increasing rapidly; the average power rating of a turbine increased from 2.5MW in 2012 to over 7MW in 2019, and there are now turbines in development rated at up to 15MW and with capacity factors of over 60% (compared with about 40% for those currently in operation).

Whilst increased power ratings obviously mean increased size, larger turbines are a more efficient use of space and materials. The increase in power squares with an increase in length of the blade and cubes with the increase in wind speed, so the gains from building higher and larger are very significant. In addition, because more power can be produced from fewer turbines the need for foundations and inter-platform cabling for a wind farm is reduced.

Deep water floating turbines.

The second major development is the use of floating turbines. Reliance on fixed bottom turbines would mean that the space constraints and impacts on the marine environment of operating 100GW of capacity would be severe, especially given the demands for North Sea space from other energy hungry countries. The EU alone is planning for 60GW by 2030 although not all in the North Sea. Many thousands more turbines will be competing for shallow waters.

Floating turbines in deeper water have a number of advantages: they save on the steel required for fixed bottom turbines, their installation may be less disruptive to the ocean bed, and because they would be more widely spaced and away from areas used by high bird populations, there would be far less bird strike. They can be deployed over a far wider range, in waters up to 1,000m deep (compared with a limit of 60m for fixed bottom turbines).

Because they are deployed far out at sea where wind speeds are greater and more constant, they achieve a higher capacity factor (currently, up to 57% over a year compared with around 40% for fixed bottom turbines), and can be built much larger and higher (potentially, up to 333m with 113m blades). A 2018 report claims that, with the right investment, the UK could install 50GW of floating wind power supporting 17,000 jobs, by 2050; however, these technologies are hugely expensive to develop, and held back by difficulty finding investors for the early projects which can provide the practical experience needed to get these vital technologies scaled up quickly. That is one reason why a National Climate Service is needed to eliminate the market considerations which create these barriers.

Resources and construction emissions

The environmental impact of the production, installation and maintenance of a vast number of turbines needs to be taken into account. This must include infrastructure such as submarine power cabling and on shore grid work. To give a sense of the challenge, materials required for the CCC's 2030 target of 40GW amount to about 4 million tonnes of steel, 125,000 tonnes of copper, 40,000 tonnes of pre stressed concrete and many other materials. The power transmission cables use large amounts of lead, steel and copper for sheathing against salt water penetration. Production of these materials generates large amounts of GHGs, for example:

One tonne of copper generates 4 tonnes of CO2 in mining and production, and 125,000 tonnes of copper generates 500,000 tonnes of CO2.

One tonne of mixed grade steel generates about 3 tonnes of CO2, and 4 million tonnes of steel generates 12 million tonnes of CO2.

One tonne of conventionally produced concrete generates about 180kg of CO2 – mainly from the cement.

Even so, taking into account their projected lifespan, wind turbines have much lower lifetime emissions than any other form of energy production; and emissions from extraction and manufacture of these materials will decline steeply as more renewables are used and production processes become more efficient. For example, concretes are being developed with much lower proportions of cement or with the cement replaced by other materials. Similar considerations will of course apply to other types of installations requiring these materials, including onshore wind farms and the water-based technologies discussed below.

Jobs potential

In 2019 the UK added 2.4 GW of windpower, comprising 1.6 GW offshore and 0.8 GW onshore.

Scaling up directly from that, we would need to add around 5.6 GW each year to get to 100 GW offshore wind by 2038 – around 3.5 times as much as in 2019.

We would need to add around 5 GW per year of onshore wind – about 5 times as much as in 2019.

We include here a detailed discussion of approaches to job numbers for offshore wind, since this is expected to be the biggest element in the renewable energy mix. Some of the considerations regarding method with be similar for the other technologies, which we consider more briefly.

Jobs potential in offshore wind

Estimating jobs potentials is a difficult and necessarily inexact exercise. Different sources give widely different figures even for existing job number, reflecting different methodologies and different ways of defining the scope of what jobs are included. Lower figures will obviously be obtained if estimates are confined to people working directly in manufacture, installation and operation than if those working in project planning, procurement of materials and other roles are included.

According to figures from the industry body IRENA, in 2019 UK employment in wind power was 44,000, including both offshore and onshore wind. However, according to the ONS (Office of National Statistics) the 2019 figures were 7,200 in offshore and 4,400 in onshore wind. Both these widely differing estimates encompass jobs in construction and installation, operation and maintenance, as well as a wide variety of jobs in planning, design, procurement and administrative support.

The Offshore Wind Industry Council published a market research report in February 2021, which estimated an increase from 26,000 in 2020 to a peak of nearly 70,000 jobs by 2026, comprising 40,700 direct jobs and 29,148 indirect jobs If we assume about half as many jobs in onshore wind in 2020, this would be 39,000 in total – much closer to the IRENA figures but again much higher than the ONS figures. However, we treat the IRENA and OWIC estimates with caution given that these are both industry bodies.

According to industry organisation Wind Europe the UK only installed 483 MW of offshore wind in 2020. However, if we take the 2019 ONS figure of 1.6 GW, we may contrast it with the average build rate of 5.6 GW per year that we would need to get to 100 GW by 2038 – about 3.5 times the 2019 rate.

The ONS figures for 2019 are broken down into categories of job roles, and though these are not easy to interpret, it can be seen that of the 7,200 jobs, 2,500 are in manufacturing and 700 in construction, to which we can add perhaps another thousand for the professional, scientific, technical and support services involved in the deployment phase – making around 4,200. So to deploy 3.5 times that amount of installed capacity per year would require around 14,700 continuous jobs.

We can estimate the jobs in operation and maintenance, then to be around 3,000 in 2019, but these would include the operation and maintenance for all the existing wind farms as well as those newly deployed in that year. So we can take the total installed capacity in 2019 – which was 9.7 GW – and scale that up to an installed capacity of 100 GW, giving us 29,000 jobs in O and M by 2038.

Adding jobs in the deployment phase to jobs in operation and maintenance, we reach **33,700 jobs by 2038.**

The wind sectors as defined for the purposes of the ONS report include "the production of electricity and the design, production, and installation of infrastructure for wind power, including operations and maintenance". It would appear, therefore, that these figures only include manufacture of the wind farm components themselves, and not the ancillary equipment such as specialist boats, trucks and machinery, nor the supply chain jobs producing materials and components which may be common to other construction and engineering and not only wind farms.

An alternative approach (Mika Minio-Paluello, personal communication) is to assume that a new windfarm – let's say 1.5 GW – will have around 200 people employed in direct operation and maintenance. Double that again and you get 800 operation and maintenance jobs per wind farm. That would need to be tripled or quadrupled to reach 5.6 GW per year – adding 2,800 jobs in operation and maintenance every year. This would give us very roughly 45,000 jobs in operation and maintenance by 2038.

Adding that to the 14,700 continuous jobs in the installation phase gives **about 59,700 jobs in total by 2038.** Again, that is direct jobs in production and installation, operations and maintenance, and not indirect and supply chain jobs.

Of course, increased efficiencies will mean that the direct and indirect workforce may be less than projected; larger turbines with larger installed capacity require less labour than the same installed capacity from a number of smaller turbines, especially for operation and maintenance, and in addition operation and maintenance is becoming less labour intensive due to increased automation .

In contrast, figures from IRENA and from the Offshore Wind Industry Council suggest this is a considerable underestimate. Based on other estimates by IRENA (2018) reaching an installed capacity of 100GW of offshore wind could mean building up to a workforce of anywhere between about 70,000 and 200,000 *in direct jobs* (this would include those already employed in this sector). The numbers will depend on how well established the industry is, and on the development of technologies; and given that this is expected to be rapid, an estimate of no more than 100,000 would seem sensible.

However, drilling down more deeply, estimates are also given for the lifetime labour requirements for a 500MW windfarm, with conventional 8MW turbines, sited 40km offshore in 45m water depth.

The total estimated direct employment is 2.1 million person days, or 8,203 job years, including operation and maintenance through the lifetime of the installation, though the jobs would mostly be concentrated in the planning and construction phases. A direct scale up to 100GW gives 1,640,600 job years, or an average of around 100,000 over 16 years (to 2018) - but in practice the jobs numbers would begin in the tens of thousands and grow to well over 100,000 as more and more installations came onstream. In addition, older installations will by then need replacing (given an average lifetime of 25 years), meaning significantly more jobs than those needed just to add to the stock.

Using this logic, a direct scale-up would allow us to guess at 150,000 jobs by 2038; however, taking into account that this modelling is based on a small installation with modestly-sized turbines and that scaling up both in numbers and in size would mean considerable efficiencies of scale, and further taking into account efficiencies from technological developments over that time period, we would have to assume far fewer – say**, 100,000 jobs by 2038** which would square with the IRENA projection above.

Overseen by a National Climate Service supporting the training and (re)deployment of workers, the rate of increase can be rapid; we believe the 100GW target should be met by 2038. But of course the jobs will not stop once the target capacity Is reached; as well as operation and maintenance, there will always be work to do in decommissioning and replacement of the older installations, and all the jobs in manufacturing and procurement, recycling, research, development and planning associated with this.

The overall breakdown of job roles is given in IRENA (2018) as:
Manufacturing and procurement – 59%
Operation and maintenance – 24%
Installation and grid connections – 11%
Decommissioning – 5%
Project planning – 1%
Transport - 0.1%

Note that in the IRENA analysis, these are direct jobs only – for example, "manufacture" includes only components of the turbines, and does not include the manufacture of specialist trucks, boats, cranes and other equipment, nor the materials needed to construct the turbines, cables, substations and associated machinery. "Transport" consists mainly of specialist truck drivers and ships' crew.

A further report from 2018 projects a possible 36,000 direct jobs in 2032. This research is from Catapult, which is a private organisation doing commissioned research work and operating research and development facilities for the industry. Given its reliance on academic credibility, its work may be considered a reasonably reliable resource.

Although this particular report is based on a projection of only 35 GW by 2032, it is useful for our purposes because the modelling takes into account probable advances in efficiency through increased size and capacity of turbines, the development of floating turbines, new technologies and better locations and opportunities for clustering of sites. It projects far enough into the future to make a direct scale-up to our own target seem more plausible. Remaining on the cautious side, it allows us to hope that we might see double this number of jobs to increase capacity to 100 GW by 2038, ie **72,000 direct jobs.**

Indirect jobs are also difficult to estimate, but given the amount of associated infrastructure and equipment needed to support the installation and operation of offshore wind, the numbers are very high. For example, a blade manufacturing factory planned on the site of an old steel works on Teesside expects to provide 750 direct jobs and 1500 (ie twice the number) indirect jobs in the supply chain. The survey by the Offshore Wind Industry Council projects 69,848 jobs in offshore wind by 2026, including 40,700 direct jobs and 29,148 indirect jobs (defined in this report as jobs in the supply chain where products are not solely for wind industry use) – a ratio of 0.83 indirect jobs for every direct job.

Extrapolating this to the estimate of 100GW installed by 2038, we get a possible 83,000 indirect jobs in the supply chain for offshore wind, starting from a low base and building at a rate dependent on the integration of the supply chain made possible by National Climate Service planning. The definition of direct and indirect jobs varies somewhat between different studies, but it is clear that the potential is very large.

We now have estimates of 33,700, 59,700, 72,000 and 100,000 direct jobs, depending on source and methodology. Accepting a multiplier of 0.83, that gives us 27,971, 49,551, 59,760 or 83,000 indirect jobs.

Taking the estimate which is around mid-way, but allowing that exact numbers cannot be determined, we conclude that 70,000 direct and 60,000 indirect jobs is a reasonable estimate.

But the actual number of local indirect jobs, and of local direct jobs in manufacture, will depend on procurement and investment decisions, essentially political decisions, which once again underlines the importance of the joined-up planning that can be carried out by a National Climate Service, to ensure that such a workforce can be mobilised and anticipate and prevent the bottlenecks in the supply chain which are inevitable when the process is left to “the market”. Worries that have emerged in some parts of the trade union movement about the offshoring of work in the supply chain are misplaced, not only because they rest on a narrowly nationalistic view of the challenge ahead, but also because the needed expansion of supply chains to support direct jobs in offshore windpower is so large and the timescale so short.

Nevertheless, there is enormous scope here, and indeed an urgent necessity, not only to establish supply chain industries but also to rebuild industries such as shipbuilding for the specialised craft needed to support offshore wind, as well as the specialised land vehicles and other equipment. The challenge is to build the supply chain and ancillary industries rapidly enough to make feasible the much faster roll-out of renewable generation, as well as supporting a far greater number of jobs. And this becomes even more important in view of the “induced” jobs, ie jobs in a wide range of sectors that follow from the increased spending power of workers gaining secure well-paid employment in previously economically depressed regions.

Onshore wind

What is a practical target?

At 14 GW, onshore wind currently takes up 2,700 km2 of land. To deploy 30 GW of onshore wind could need an additional 3,300 km2 of land. (For comparison, Wales has an area of about 21,000km2). However, the height of onshore wind turbines has been growing; in 2012 the average height was 75m and the average capacity was 2.5 MW, whilst turbines of up to 260m are currently being planned, with an installed capacity of up to 6 MW each. Larger turbines not only produce far more power due to large rotor spans, but the greater vertical reach enables them to access higher and more consistent wind currents, increasing the turbines capacity factor, potentially making for a more efficient use of land, and increasing the number of sites where sufficiently high wind speeds are available.

The Vivid Economics report for the government's Climate Change Committee finds that the Great Britain onshore wind resource could increase to 96 -214 GW, with 8-19% of GB land area potentially suitable for development when factors such as slope, type of ground cover, distance from settlements etc are taken into account, along with the higher wind speeds which can be captured with the newer, taller turbines.

This is a lot of land, which needs to be balanced with other desirable land uses, eg reforestation, peatland restoration, and solar PV farms (see below), as well as production of food and other crops useful for carbon sequestration and uses in construction (eg hemp). Many of these activities can be carried out around the bases of the wind turbines, so a wind farm does not necessarily exclude other land uses, but the disruption caused by the installation must also be taken into account. We therefore take the lower estimate of a potential 96 GW from the Vivid Economics report as a basis for estimating the potential number of jobs.

Jobs in onshore wind power

According to the Office for National Statistics there were 4,4000 people employed in onshore wind in 2019, although the figures from IRENA point to a much larger number. The UK currently has around 14GW installed capacity, with 600 MW of new capacity added in 2019.

Given that the current rate of installation is so low, it is difficult to estimate how many jobs are needed to install at a suggested rate of around 5 GW/yr, to grow from 14GW in 2021 to around 96 GW in 2038. 5 GW/yr is around 8 times the rate in 2019 (which appears to have remained stable since then).

However, using the same logic as for onshore wind, and using the ONS figures, we can estimate that of the 4,400 workers in 2019, 2,200 might have been employed in the planning, procurement, manufacture and construction phases – ie the work involved in deploying the 600 MW of new capacity – whilst the remaining 2,000 might have been working in operations and maintenance of a total 10 GW of capacity installed cumulatively by 2019.

On this basis, to reach our target we would need an average of 17,600 people working continuously on jobs related to new installation, and a workforce reaching 19,200 by 2038 for operation and maintenance. That's a total of about **37,000 by 2038.**

We again need to recognise that, one the one hand, this is a high-end estimate given that the technologies are improving rapidly and our proposed fast rate of deployment would inevitably mean economies of scale. Nevertheless, there is a large amount of ancillary work which would be needed, which would be additional to the numbers included in the ONS figures and therefore in these estimates – work on roads, manufacture of machinery and vehicles etc.

For an alternative approach, we consider figures given by IRENA (2017) based on 2016 figures – admittedly somewhat out of date given the rapid technological advances. They give the following job figures for a 50 MW installation consisting of 2 MW turbines:

- Project planning - 2,580 person days (about 10 job years)
- Manufacture – 18,967 person days (about 74 job years)
- Transport – 875 person days (3.4 job years)
- Installing and connecting – 35,480 person days (138.6 job years)
- Operation and maintenance – 2,665 person days *per year* (10.4 jobs lasting 25 years)
- Decommissioning – 8,420 person days

Total job years (excluding operation and maintenance) are about 226.

Assuming that production of a new wind farm takes on average 6 months for a 50 MW wind farm, and we need to install an average of 5 GW (ie 100 times 50 MW) per year, each worker does 2 a year and we'd need 50 times that many workers to reach 5 GW a year. That's **11,300** – working continuously to install more wind farms every year.

In terms of operation and maintenance, that's 10.4 times 100 = 1,040 in the first year, 2,080 in the second year and so on – up to a maximum of **16,640**

This suggests that over our 16 year timescale we would build up from a low base to around 16,660 people working continuously in operation and maintenance - jobs that would of course continue for the foreseeable future. And we might guess at 11,300 more continuous jobs more or less *throughout that period* once we make a serious start, in planning, manufacturing and installing the new windfarms. That's about **28,000 jobs.**

So, our estimates range from 28,000 jobs to 37,000 by 2038, and given the difficulties we can expect in getting this work to a rapid start, it would seem prudent to go with the lower figure of **28,000**

Applying the same 0.83 multiplier as for offshore wind, the number of indirect jobs would be 23,240. However, given the lesser technical difficulty and lesser requirement for specialist equipment (specialist boats, cabling etc) we could reduce that multiplier to 0.5, giving **14,000 indirect jobs**. As with offshore wind, we could also expect a large number of induced jobs due to the increased spending in the wider economy.

Solar energy

The two main technologies for electricity generation from solar energy are solar photovoltaic (solar PV – the solar panels commonly seen on domestic roofs), and concentrated solar power. The latter is more suited to regions where there is a lot of strong sunshine, so the focus of this section on UK solar energy is solar PV. However, we also note the direct use of solar energy, eg to warm water for domestic use, thereby significantly contributing to reduced demand on electricity supplies. We return to this in our section on managing the grid.

In 2019 in the UK, 10,911 people were employed in solar PV, and 9,497 in solar heating and cooling.

At the end of 2020, 13.9GW of solar PV capacity had been installed in the UK, generating a total of 12.8 TWh (down from 13.7TWh in 2019; the capacity factor of solar PV is given as 11.2% in 2019 but this will obviously vary from one year to another depending on the amount of sunshine).

The CCC says there is potential for 130-540 TWh (from 145-615 GW of installed capacity) of solar power in the UK, but the Sixth Carbon Budget sets targets of only 60TWh in 2035 and 85TWh in 2050. They envisage 22GW of installed capacity by 2025 and 54 GW by 2035, meaning that around 3GW (between 2.7 and 3.7 GW) per year would have be installed. In 2020, about 545 MW were deployed – less than a fifth of the annual increase required in the CCC projections.

Land use implications

Large-scale solar of 13 GW installed capacity requires 290 square km. 54 GW (2035 target) would be about 4 times that much – 1,160 square km. On the face of it this is much less than for an equivalent amount of onshore wind generating capacity, but given that the capacity factor for onshore wind is much greater - 26.6 in 2019 – we can assume at least twice as much generating capacity is needed for a similar amount of energy produced. Even so, on the basis of land use alone, solar PV compares favourably. Furthermore, the energy conversion efficiency of solar cells – currently typically below 20% - is increasing rapidly with new cell technologies, which means that the same land area will eventually support twice the installed capacity as it currently does.

The Vivid Economics report for the CCC finds that practical solar PV potential is 616 – 1,102 GW large scale and 37GW rooftop, using 6 – 11% of potentially suitable land and around 25% of rooftops (ie those that are south-facing). The more conservative estimate excludes peat bogs (to avoid releasing methane) and high grade agricultural land. However, even now 25% of solar farms are on high grade agricultural land, so again we must consider this in the context of how we prioritise land use.

Resource use and lifecycle emissions

On the face of it, the carbon intensity of solar PV is considerably higher than for wind power, with available figures up to 2017 giving an average of 50.9g CO2/kWh [17] as compared with 14.4g/kWh for onshore wind and 18.4g/kWh for offshore wind.

The emissions per kWh decline with the capacity of the installation. However, there is wide variation depending on the energy mix used in the manufacturing process, the energy conversion efficiency and the device lifetime. Steel and aluminium production play a large role in the infrastructure contribution, and as with windpower, the emissions produced in their manufacture will decline as the transition to renewables progresses. The same is true of the refining of silicon (the commonest material for PV cells) which involves high temperature processes. Lifecycle costs also include the emissions generated during transportation, meaning that domestic production would be more energy efficient.

Advances in cell technologies are likely to reduce rapidly the lifecycle emissions of solar cells; the mean value for monocrystalline silicon (Si), polycrystalline Si and amorphous thin-film silicon (a-Si) have been estimated in the order of **61.8, 52.2 and 35.5** g CO2-equivalent per kWh, respectively, in large part due to differences in the energy requirement for manufacture; A new generation of perovskite cell technology should reduce emissions intensity further by significantly improving the efficiency of the cell, and also requiring less energy in the production process.

Solar panels have a lifetime of up to 30 years, and almost all the silicon, as well as the glass and metal, can recycled. The rate of recycling of all materials involved in PV cell technology is currently a question of profitability; a situation which clearly could be overcome if managed by a National Climate Service. As more solar PV installations reach the end of their life the recovery and recycling of materials from solar panels will become a significant industry in its own right, employing thousands of people.

Solar technologies and dispersed generation

One advantage of solar PV is its potential for domestic and onsite generation, which means that some homes and businesses can be self-sufficient in energy, reducing the load on the grid; or can even supply energy to the grid, and when used in conjunction with small-scale battery storage, can contribute to levelling out supply and demand. And of course small installations can be other other places than rooftops – basically, anywhere that gets enough direct sunlight (the efficiency and cost per kW of energy is higher for smaller installations, but the additional output is needed and there are advantages in a proportion of energy being generated close to where it is consumed).

Estimates vary widely, but the Centre for Alternative Technology suggests that covering 15 – 20% of the UK's roof area could provide 90 GW of capacity (whilst the conservative estimate from Vivid Economics is 37 GW from 25% of UK rooftops). The manufacturers of an innovative solar pv film (https://powerroll.solar/unique-solar-film/) suggest that covering 25% of industrial rooftops could provide 37 GW of capacity. And of course small installations can be other places than rooftops – basically, anywhere that gets enough direct sunlight.

On any scenario, it is clear that currently a large proportion of the solar resource is owned by private householders, businesses, community groups or local authorities, and a high proportion is installed by workers who are self-employed or employed in small to medium businesses. A lot, of course, is owned by social housing providers (including councils) who claw back the capital cost through rents, whilst ensuring that the rent increase is less than the amount saved on energy bills.

It is easy to envisage local authorities bringing the necessary labour inhouse, with negotiated wages and conditions, and ensuring that any commissioned work was subject to similar conditions. But a public consensus would need to be reached on the relationship between a publicly-owned energy system and the energy generation that is currently in dispersed private ownership; and it would be vital to have a National Climate Service capable of integrating these large and small electricity sources as well as ensuring consistent standards of training and unionised employment.

In the future, it is likely that both energy generation and storage will need to be more dispersed than it is now, to assist with the flexibility needed in a fully decarbonised energy system. However, this does not mean it needs to be in the hands of individual homeowners and businesses. Autogeneration (that is, generating the electricity needed for their own activities) by businesses can, of course, help significantly in limiting the demands made on the grid and on the larger generating installations; and intuitively it perhaps makes sense for businesses to pay for and own these rooftop installations. Self-sufficiency in energy can also make sense for small isolated communities or households.

But it would be equally possible for such installations to be publicly owned, installed by directly-employed workers as public works paid for, like other parts of the climate service, through progressive (redistributive) taxation. The same could apply to rooftop solar, doing away with the need for the ineffective and badly targeted small grants and incentives to homeowners, the complex market system currently envisaged to encourage home-owners and community groups to generate, store and sell back to the grid (which is currently failing anyway due to the removal of the feed-in-tariff subsidy). It could end the time and resources wasted by councils forced to scrabble to compete for different pots of government funding for social homes. It could also help solve the problem of getting the work done in the private rented housing sector, as well as helping to regularise pay, conditions and standards across a publicly-employed workforce.

Jobs potential in solar PV

It has been claimed by industry sources that solar can supply 200,000 new jobs in the U.K. and 80 GW of power generation capacity by 2030. However, due to the land use constraints, we take the much more conservative scenario of the CCC – 60 GW to be installed at an average rate of 3 GW per year – as a realistic target for utility-scale solar farms. Added to this, we take the fairly conservative estimate of Vivid Economics, of 37GW capacity from rooftops, making a total of 97 GW.

Since the amount installed already is small, and solar panels need little maintenance during their lifetime, we can assume that the majority of jobs are in installation during the period we are concerned with. On that basis we could scale up the job numbers from 11,000 (installing 545 MW in 2019) to an average of about 90,000 continuous jobs between now and 2035, in good time for our target date of 2038. The expected improvements in cell efficiency between now and then would suggest a significant reduction in labour intensity; however, this would be balanced to some extent by the greater labour intensity involved in a higher proportion of dispersed installation, where there are fewer efficiencies of scale and workers' actual time on site may be less.

Over time, of course, jobs numbers in repair and maintenance, and especially in recycling, would grow rapidly, as would further jobs in manufacturing if huge supply chain problems are to be avoided. We therefore think the estimate **of 90,000 jobs** by 2038 remains reasonable if it is taken to include these ancillary jobs.

Solar thermal, heat pumps and thermal storage.

Solar thermal technologies have not been considered in detail as they are – like heat pumps – ways of utilising ambient heat rather than generating electricity, However, using solar collectors on rooftops to pre-heat water for washing and heating can significantly cut the energy required by a home or business. Combined with heat pumps – which essentially concentrate low-level warmth collected from the air, ground or a nearby watercourse, and can deliver about three times as much energy in the form of heat as the electrical energy needed to run them -- they can virtually eliminate the need for additional heating in a well-insulated building, not only reducing overall energy demand but also helping eliminate the large peaks in energy demand that occur during winter evenings (see section on managing the grid).

Given that well-insulated water tanks can store heat for a good three hours, such systems can also play a major role in flattening the evening peak in demand. However, the space requirements for hot water tanks are an obstacle for many modern homes, and the future solution is likely to be in thermal stores, also called thermal batteries, which use phase change materials to store large amounts of heat in a smaller space as illustrated in this manufacturer's website.

In 2019 9,497 people were employed in solar heating and cooling. It is unclear how these numbers might scale up if the full potential of these systems was exploited, but we can assume that it would need to be at least doubled to **20,000 jobs.**

NB in the jobs scenario developed for the chapter on “Buildings”, the jobs involved in installing heat pumps, solar pv and solar collectors are not included in the lighter package of work which we envisage for most homes in the first phase of ten years, so these jobs would be mostly **additional** to the 2 million needed for the buildings upgrades ; however, for the deep retrofit work, which we envisage as 2 million homes in the first phase and the remainder thereafter, the full retrofit includes all suitable micro generating and passive heating technologies to make the building as near zero carbon as possible. This might absorb a large proportion of the workforce built up over the next decade to install heating and solar systems.

Whilst the Heat Pump Association predicts a requirement of 40,000 heat pump installers, we are avoiding the risk of double counting with the “Buildings” chapter by making a very conservative estimate of **20,000 jobs additional to those required for the buildings retrofit programme.**

However, we have not included here jobs in the manufacture, retail and installation of thermal batteries, which we predict to play a major role in demand reduction and load spreading, and which may need to be considered alongside other energy storage systems as an integral part of the task of managing the grid. This is likely to represent a further large source of jobs, especially with the right investment as part of the National Energy Service plan for retrofitting buildings and electrifying the energy system.

Water power technologies

Tides, waves and other types of hydropower figure hardly at all in the current government proposals, despite their potential for helping overcome the unpredictability of other intermittent sources such as wind and solar energy, providing energy either throughout the day or for considerable portions of each day at predictable times.

We look at some of these technologies in turn:

Tidal stream turbines

These are essentially similar to wind turbines, but submerged under the sea in areas where the tides create strong natural currents, especially in areas where the sea flows in a channel between two natural barriers (eg islands/cliffs). Underwater turbines can produce much more energy than wind turbines of similar size, mainly because the density of water is very much greater than that of air. However, water's high density also means that tidal turbines need to be much stronger than wind turbines, making them more expensive to manufacture.

Tidal turbines create relatively little disruption to the ecosystem around them. They could cause collision damage with marine life, but the blades tend to move slowly so collisions are not a major concern. They also emit low level noise, and more research is needed on the extent to which this may be disruptive to marine animals. However, very powerful turbines could alter the water dynamics in a way which causes disturbances to the marine ecology, and more research is needed on the optimum sizes and environmental impacts of such turbines. There is in any case a natural limit to the amount of energy that can be extracted without significantly weakening the strength of the current on which the device relies.

There are a variety of designs for tidal stream turbines; the one which recently became operational in Orkney is a floating barge design, and has an installed capacity of 2 MW, and a capacity factor of around 35 – 40%, yielding up to 7 GWh/yr – a small contribution as it stands, but arguably capable of scaling up to perhaps 2GW of tidal stream power by 2030 and 4GW by 2038, yielding 12.3 TWh/yr. Like floating turbines, these are cases where the difficulty obtaining initial investment and government support acts as an obstacle to the early projects which can lead to rapid technological improvements and an eventual fall in costs – obstacles which could be overcome by a National Climate Service.

A 2018 analysis by energy researchers and consultants Catapult estimated the UK practical resource at 15GW for tidal stream energy, while a recent report from Good Energy proposes a higher figure of 23 GW from tidal. The Catapult report suggest we should see up to 1GW of tidal stream deployed by 2030 at an average rate of 100MW per year, generating almost 4,000 jobs by 2030 and 14,500 by 2040. For the purposes of our estimates we will assume that installations can be scaled up to 4 GW by 2038, with a workforce reaching **16,000 by that year.**

Wave power
Wave energy can be captured by a variety of means, the most common being the wave energy converter – an enclosed chamber with an opening under the surface of the water which allows waves to flow into the chamber and back, compressing and decompressing air in the top of the chamber, which in turn propels the turbine.

Wave energy is reliable and constant (though it does fluctuate according to the weather conditions, with a capacity factor of about 0.3) It will have an important role to play in the renewable energy mix, although it is unlikely to be deployed at scale within the present crucial decade. There are a variety of designs for wave energy, and further research needs to be supported to determine which is the most efficient, and rapidly scale up deployment.

The Good Energy_ report proposes only 2 GW of wave power, whilst Catapult's 2018 analysis estimated the UK practical resource for wave energy at 23 GW These authors project up to 1GW of wave energy deployed by 2040, supporting a total of 8,100 jobs. With the right policy support there is no reason why it could not be twice that much. We therefore estimate 2 GW of wave energy installed by 2038, yielding a by a workforce building to about **16,000 by that date.**

Tidal barrage, with vertical axis turbines:
Often located in estuaries, the barrage is secured to the sea floor, while the top of the barrage is just slightly above where the water level hits during the highest tide. Turbines are located along the bottom of the barrage. During an incoming high tide, water flows over the turbines as the water rises, then flows back through the turbines as the tide goes out.

Tidal barrages are the most efficient way to harness tidal energy, but have a significant impact on the surrounding ecosystem, not only preventing fish and other marine creatures passing through, but possibly also impacting water movement and the amount of suspended sediment, resulting in loss of intertidal habitat. The impacts on marine animals of noise, vibrations and electromagnetic emissions from marine renewable energy are still under-researched

A variation of this is the artificial tidal lagoon, which in appropriate sites would be less disruptive to ecosystems than traditional tidal barrages. The only application so far in the UK (in Swansea Bay) was turned down by the government in 2018, despite the 2017 publication of a report arguing strongly for this technology. According to the Swansea Bay Lagoon’s website, it would have had a 320MW installed capacity yielding over 530 GWh/yr and supporting 2,232 jobs in manufacturing and construction, with further similar projects expected to follow around the Welsh coast.

Tidal fences may have either vertical or horizontal blades, pushed by moving water. They are installed together like a fence, usually in between land masses in places such as inlets and fast-moving streams. They are submerged entirely underwater, and have far less impact on the surrounding ecosystem since most of the water passes through; again, the extent of potential damage to marine life is unknown, but it is likely to be less since there is so little impact on sea levels, sedimentation etc.

Hydroelectric As of 2018, hydroelectric power stations in the UK accounted for 1.87 GW of installed generating capacity. This includes four conventional hydroelectric power stations and run-of-river schemes for which annual electricity production is approximately 5 TWh. There are also pumped-storage hydroelectric power stations providing a further 2.8 GW of installed electrical generating capacity, and contributing up to 4.075 TWh of peak demand electricity annually

The potential for further practical and viable hydroelectricity power stations in the UK is estimated to be in the region of 146 to 248 MW for England and Wales, and up to 2.6 GW for Scotland.

Small run-of-river schemes may be owned cooperatively by community groups, providing sufficient energy for a small settlement. Such installations may be a useful addition in remote areas, and may have a role to play in limiting the burden on the grid during peak hours, but they comprise a fairly insignificant proportion of the total potential UK resource.

In 2019 there were 1,900 people employed in hydropower in the UK, and it is possible this could be doubled with a combination of small and larger-scale installations.

D A more detailed look at PV technologies and materials

Concerns have been raised about resource use, toxicity of materials, environmental degradation and health and safety of workers and communities due to the extraction of materials used in solar cells (eg here). These are important issues, especially given the important role we have given to solar PV in our suggested scenario. In what follows, we do not attempt a complete overview of solar technologies and their associated issues, but we do try to flag up some key points.

Issues with silicon cells

Currently most solar cells use silicon, as do most other electronic products. Silicon is obtained from silicon dioxide or silica (mined in the form of quartz). Silica is the most abundant material in the earth's crust, making up a large proportion of many stones, sand and clay. It is non-toxic if ingested, but inhaling fine silica particles can cause a range of serious lung diseases such as silicosis, bronchitis and lung cancer. Mining for silica can cause significant damage to the local environment, both due to removal of carbon sequestering vegetation and organic topsoil, and due to the fine dust which can kill plants by coating leaves and preventing photosynthesis.

Silica poses a health hazard not only to miners and nearby populations, but to workers in other fields, such as construction, sandblasting, and work that involves cutting on stone counter-tops. Silicon itself has many applications in electronics and other industrial processes (including fracking!) so these health and environmental issues are certainly not specific to the solar PV industry. The key to limiting damage is strict regulation of working conditions, provision of personal protective equipment and restrictions on choice of sites for extraction – and, as with all materials, minimising the need for extraction by avoiding waste in manufacturing processes, and by extensive re-use and recycling.

The production of pure silicon from silicon dioxide (silica) is normally accomplished by heating silica to extremely high temperatures with a carbon-based material (eg coke), and is extremely energy intensive. The CO2 from the fossil fuels burned to produce this heat are the main source of the lifecycle emissions of solar energy. As with other high temperature processes such as steel production, it is possible to power this process from renewables, but to minimise emissions and limit demands on renewable energy it is clearly desirable both to recycle as much silicon as possible, and also to develop solar cell technologies that require less energy input.

The metallurgical grade silicon produced from silica has to be further refined to produce polysilicon for electronics applications, including solar cells. This refining process produces three to four tonnes of highly toxic silicon tetrachloride for every tonne of polysilicon produced. This compound can serious inflammation, and if discarded into the environment will also react with water to produce hydrochloric acid, causing soil acidification and toxic fumes. This waste can be recycled to produce additional polysilicon – not only avoiding discharge of toxic waste, but also requiring far less energy than obtaining it from raw silica – but due to the expense of purchasing recycling plant, much of this dangerous by-product has been discarded into the environment.

Other toxic chemicals used in solar cell production include hydrofluoric acid, used to clean polysilicon after it has been processed into wafers. Hydrofluoric acid is a highly corrosive liquid that can destroy body tissue and decalcify human bone, and there have been incidents where spills have resulted in destruction of hundreds of fish and farm animals. However, other chemicals can be used instead, for example sodium hydroxide which, although also caustic, is less risky for workers as it is easier to treat and dispose of.

As is well known, toxic waste has been a particular issue in China, where the solar industry took off during a period of scant regulation and dramatic economic expansion, and which is still the biggest producer of both silicon and solar cells. Whilst technically all companies are now required to recycle at least 98.5% of silicon tetrachloride, oversight and enforcement may still be an issue, along with the equally well-known issues of poor labour rights and indeed forced labour in parts of the Chinese solar industry.

Issues of this kind are not unique to renewable energy technologies, but have been a long-standing feature of energy production in the fossil era, not only for China but involving corporate and colonialist resource and labour exploitation globally, with frequently racialised and gendered labour abuses, child labour, dangerous and unhealthy work practices and theft and destruction of land used by local and indigenous populations for subsistence. Only a concerted internationalist approach by labour organisations, campaigners and policymakers can prevent such practices continuing to be an obstacle to a socially just and effective transition to sustainable and safe methods of production.

New development in solar PV technology

In addition to overcoming safety concerns, technological development has focused on improving the energy efficiency of solar cells, which in turn means less materials needed per unit of electricity produced. A far more energy efficient solar cell technology is that of thin-film cadmium telluride. This is produced from the highly toxic element cadmium, and the mildly toxic and rare tellurium. However, both these elements are produced independently of the solar cell industry, as by-products of other industrial processes, and in the form of cadmium telluride they are stable and harmless. Widespread use of this technology would depend on highly efficient use and recycling of the materials to prevent contamination of the environment, as well as improvements in production technologies to prevent workers being exposed to fine particles or fumes.

Materials known as perovskites are promising to achieve higher efficiencies, potentially reaching an energy conversion efficiency of around 33%, as compared with 26% for the best silicon cells and a more typical 22%. This is the efficiency with which light energy from the sun is converted into electrical current, but the lifecycle energy intensity of a perovskite cell is also far lower than for a silicon cell, because the perovskite can be produced at low temperatures, removing the need for a high energy input from either fossil fuels or from large amounts of renewably produced electricity.

The word “perovskite” first referred to the naturally occurring mineral calcium titanate, but a variety of perovskites can be produced using other readily available elements as substitutes for the calcium, titanium and oxygen whilst maintaining the same crystalline structure, which absorbs light more effectively than silicon. Different perovskites absorb different parts of the light spectrum, so layering them increases the amount of light that can be converted into electrical current.

Perovskite is used in a thin-film form, meaning that it can be applied to a variety of supporting surfaces, including flexible ones, making the technology more versatile. A UK company has recently adapted it to produce a solar film that it claims uses no scarce resources, uses widely available production processes and can be applied to any surface.. Another company is developing a cell created by layering perovskite on top of a silicon cell, to give greater efficiency than a silicon cell on its own.

No renewable energy technology is without its drawbacks; for example, it is not yet established that perovskite cells can be made as durable as silicon ones, which are generally expected to last at least 25 years. Along with energy demand in manufacture and energy conversion efficiency in use, the length of time which a solar panel or other installation lasts is a critical factor in its lifetime energy intensity, emissions intensity and use of finite resources. Whilst a range of improved technologies are in development, reducing our energy consumption will always be crucial, as will careful re-use and recycling of all materials.

Nevertheless, improved solar technologies must form a significant part of a decarbonised energy system. Large-scale solar farms – despite the fact that the land around and within them can be used for purposes such as growing crops and animal grazing – will often carry an emissions penalty due to the change of land use (degrading of land and vegetation that would have absorbed carbon, or preventing its being used for purposes such as reforestation). Despite improvements in cell efficiency, the amount of land needed to produce electricity on large scale solar farms is very significant. Technologies such as solar panels and films which enable a greater contribution for dispersed, local generation on rooftops and other surfaces, are probably necessary as part of an integrated energy system. This makes it all the more important that these should be not only supported but rolled out in a planned way for greatest efficiency, as part of a public energy service, rather than simply relying on incentives to individual homeowners, businesses or civic bodies.

E Is there really a role for Nuclear power in energy transition and climate jobs?

Nuclear power is cited as a low carbon fuel and some argue that it is essential to energy decarbonisation. Some who have previously opposed nuclear power[1], have switched position suggesting that it is "impossible" to achieve net, or zero, carbon without nuclear power as part of the mix. This argument remains unconvincing for a number of reasons which are explored below.

There are many aspects to the nuclear debate ranging from mining of uranium and its wider environmental impacts, to issues of waste management and health issues. This article, however, mainly covers the role of nuclear energy in relation to the twin aims of decarbonisation technology pathways and climate jobs. It concludes that, even putting aside the politics and climate justice issues of nuclear, the numbers do not add up.

There is a powerful political and corporate lobby behind nuclear, and there is also some support within sections of the trade union movement. The trade union lobby argues that the sector is one which provides "highly skilled", well paid and unionised jobs. The political and corporate lobby is linked to a 'revolving door' between politicians and the nuclear industry[2] – on all sides of the political divide . And no discussion about nuclear power can take place in a vacuum, separated from its links to nuclear defence capabilities and the need to develop civilian programmes to cross-subsidise the defence programme.[3]

Nuclear and climate targets

In a report by the Rosa Luxemburg Foundation, a strong case was made about why nuclear is not a viable "tool in the climate solutions toolbox".[4] Critically the report noted that nuclear should not be viewed only through a lens of emissions and energy resource modelling, but from an understanding of the "real-world trends and conditions of this technology in particular." Crucially the report argues that nuclear is a mature technology about which there is a lot of existing knowledge making visible the key issues..

Before coming to some of those aspects, it's worth taking time to look at nuclear within the UK Government's net zero 2050 plans.

The first point of note is that the UK Government has agreed to accept the Climate Change Committee's (CCC) 6th carbon budget of a 78% reduction of greenhouse gas emissions by 2035. This means taking clear policy decisions in the current decade, for which the CCC has set out a number of potential pathways. Whilst the CCC does not prescribe government pol-

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[1] Power Failure – George Monbiot

[2] Warnings over 'revolving door' between EDF Energy and UK government ahead of Hinkley decision - Unearthed (greenpeace.org)

[3] Electricity consumers 'to fund nuclear weapons through Hinkley Point C' | Hinkley Point C | The Guardian

[4] Judson_ENG_endnotes.indd (maryland.gov)

icy, it is nevertheless clear that wind energy will form the “backbone” of UK power generation, and that hydrogen, carbon capture and storage, and nuclear will also have a key role (among other technologies).

Under what the CCC call their “Balanced Pathway”, 485 TWh of low carbon generation will be required in 2035.[5] It goes on to say that around 130 TWh of current generation is low carbon but a large part of that comes from nuclear power. Nuclear currently equates to around 20% or 65 TWh of the current total energy mix (not just low carbon sources).

Around 50% of current nuclear capacity is to be retired by 2025 and all existing nuclear power plants are to end generation by 2030,[6] with Hinkley Point C being the only new plant due to come on stream in this time.

Yet conflictingly, the CCC forecasts nuclear to be restored to 2020’s levels with 10GW by 2035 including 8GW of new build capacity. It also provides a balanced energy mix forecast of 10GW, but in other modelled scenarios – with renewables accounting for 90% including 175 GW wind and 90 GW solar, and dispatchable generation capacity 8% of total - nuclear is cited as a contributing a contracted capacity of 5GW.

We have already seen a rapid advancement – and cost reduction – in renewable energy technology, therefore keeping a role for nuclear in the final analysis appears a ‘bolt-on’ rather than offering any real justification for why nuclear is indeed needed. The key argument is the need for baseload or ‘firm’ power generation when the wind isn’t blowing or the sun isn’t shining to balance the grid. In this case, nuclear is seen as a consistent energy source that can fill that gap[7]. Yet research refutes the need for nuclear to provide base load power[8]. This research argues that aiming to provide base load power simply ensures that expensive energy runs at all times rather than addressing the need for dispatchable energy which can be used flexibly, in response to demand. The inflexibility of nuclear power creates the perverse situation that nuclear has to be prioritised over renewables supply when there is excess capacity on the grid.[9]

Whilst the issue of managing supply and demand isn’t by any means settled, there are options around improved storage capacity and interconnections for import/export of renewable energy as we look to balance the grid and improve demand forecasts. As we electrify more in sectors such as transport and heating/cooling, this will create more demand. But equally, this also requires that we assess what that demand is for within a wider organisation of society and the economy - for example, moving to mass public transport rather than reliance on individual cars. Increased efficiency of electric appliances and ending inbuilt obsolescence will also play a part.[10]

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[5] Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf (theccc.org.uk)

[6] Energy White Paper (publishing.service.gov.uk)

[7] Plugging the energy gap: keeping our reactors running, to keep the lights on (manchester.ac.uk)

[8] Dispelling the nuclear 'baseload' myth: nothing renewables can't do better! (theecologist.org)

[9] UK Electricity: Renewables and the problem with inflexible nuclear - Dr Ian Fairlie

[10] UK Electricity: Renewables and the problem with inflexible nuclear - Dr Ian Fairlie

A final point on emissions and targets is the CO2 equivalent impacts of nuclear compared to other technologies. Nuclear is zero carbon at the point of generation, though unlike wind and solar it has a small but significant greenhouse gas impact from the water vapour emitted in operation. There are also of course embodied carbons in uranium extraction, fuel cycle and construction stages particularly. Whilst no technology is entirely emissions free, if we take into account – as we should - the overall impact of the years-long lead-in times for new nuclear installations to be planned, constructed and come on stream compared with the far shorter timescales for installing wind and solar, and if we compare the efficiency with which a transition to renewable electricity could be accomplished by investing in wind, solar and marine rather than nuclear technologies, we see that nuclear energy is a costly option in terms of GHG emissions as well as financially.[11]

The clock is running down but we do have time to resolve the gap in energy. A priority that is historically long overdue is to front load demand-side reduction work such as retrofit and insulation programmes. Essential right now is to have a plan to put in place across the whole system that will enable us to reach our carbon targets. The numbers for nuclear don't fit with that time frame, especially in view of the long lead-in time for construction and financing models.

Nuclear ownership and financing

Nuclear Power started out under public ownership evolving from nuclear weapons technology in the 1940s. It lagged behind the privatisation of the other parts of the electricity industry due to the lack of commercial viability of the sector. Indeed "whether any new nuclear station could be built with private sector finance" was a key criterion for privatisation going ahead.[12] The establishment of the privatised British Nuclear Energy company in 1996 lasted a mere six years, collapsing in 2002,[13] and its assets being sold off to EDF.

In reality, although privatised, it has been impossible to finance nuclear energy without government subsidy[14] as the International Institute for Sustainable Development pointed out.[15]

The new plant at Hinkley Point C in Somerset is no exception to this. In 2017, the National Audit Office concluded that the Department for Business, Energy and Industrial Strategy:

> **"…has committed electricity consumers and taxpayers to a high cost and risky deal in a changing energy marketplace. Time will tell whether the deal represents value for money, but we cannot say the Department has maximised the chances that it will be."[16]**

The subsidy for Hinkley takes three forms:

i) Strike price which guarantees EDF, a French state owned energy and plant operator, a power price of GBP 92.50 per MWh, linked to Consumer Price Inflation (CPI) inflation for a duration of 35 years. The current wholesale electricity price is

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[11] See eg Jacobson (2021) https://web.stanford.edu/group/efmh/jacobson/Articles/I/NuclearVsWWS.pdf

[12] See House of Commons Nuclear Privatisation Research Paper 96/3 15 January 1996 (accessed 4 June 2021)

[13] BBC NEWS | Business | British Energy: Generating a crisis

[14] Nuclear_power_subsidies_MPsbrief.pdf (no2nuclearpower.org.uk)

[15] The United Kingdom is to Subsidize Nuclear Power—But at what cost? (iisd.org)

[16] Hinkley Point C - National Audit Office (NAO) Report

£45 per megawatt-hour (MWh) so in this scenario, EDF will be paid the shortfall between £45 and £92.50 by the tax payer and this will be added onto energy bills - an arrangement which has been much criticised across the political spectrum

ii) Loan guarantees is a further subsidy which ensures that government acts as a backstop to pay and safeguard lenders against project risks, such as cost overruns or delays.

iii) Waste disposal is the final area where the plant operator will avoid the real costs of nuclear power generation. The UK Government contract to provide a waste disposal service for spent fuel and intermediate-level waste is set according to the government's waste transfer pricing methodology and is capped at GBP 5 billion. Any costs above this are then passed on to the government (tax payer). Nuclear waste storage facilities are likely to be another burgeoning cost and involve significant construction challenges and issues around finding sites for waste disposal. These sites need to meet specific geological conditions, including consideration of future climate risk, eg rising sea levels, and must be able to store nuclear waste for 100,000 years. Understandably, communities are resistant to having this on their doorstep however deep under the ground, and this is a major factor when compared with other power technologies.[17]

New Nuclear would add additional pressure from waste when we are still faced with dealing with the legacy of a nuclear civil and defence industry that dates back to the 1940's.

The difficulties of financing have been one reason for the delay in decisions in relation to new nuclear. Indeed, with the collapse of financing arrangements for the proposed plant at Wylfa in Wales for example, the government is now scrabbling around for alternative financing mechanisms. With this comes the proposed Regulated Asset Based (RAB) model which is already used in large infrastructure projects, but again is another glorified form of subsidy where the tax payer shoulders the risk of upfront capital costs. Sadly this is a position supported by the TUC.

Considering different types of power generation for climate jobs

The UK Government energy white paper says a further large scale nuclear power plant could support a peak of around 10,000 jobs during construction but jobs in the nuclear industry cover a range of functions. According to the website Nuclear Power Jobs[18] these include:

Power generation
Operation engineering
Safety consultancy
Waste management
Decommissioning

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[17] UK returns to grappling with toxic nuclear waste dilemma | Financial Times (ft.com)

[18] Nuclear Power Jobs UK, Nuclear Engineering Jobs, Nuclear Jobs & Industry Recruitment - nuclearsectorjobs.co.uk

Nuclear liabilities management
All aspects of the nuclear fuel cycle

The Government's Nuclear Sector Deal states that:

"By 2021 the UK is expected to need more than 100,000 workers in the civil and defence sectors" increasing from 87,000 today, and covering generic skills ('skills for nuclear'), nuclear skills and Subject Matter Expert skills. With a high attrition rate, where vacancies aren't filled, it says there is a requirement for around 7,000 entrants each year to join the sector. [19]

The category of "Subject Matter Experts" covers more specific nuclear scientists and engineers, which are generally an ageing demographic, near retirement age, so there is an anticipated shortfall in this area. There is a crossover, and deliberate strategy, to develop skills for both civil and defence nuclear, and recognition that workers have transferable skills from other sectors; and they are "focused initially on oil and gas, the armed forces and manufacturing and aligned to regional skills priorities".

Hinckley point C, the only new plant currently under construction, was anticipated to create 25,000 jobs in construction and operation, with up to 1,000 apprenticeships. The developer expects 64 per cent of the construction contracts, by value, will go to UK-based companies, with potential in the domestic supply chain beyond Hinkley Point C, across the nuclear lifecycle; from enrichment and fuel fabrication, through new-build construction, plant operation, world leading R&D and future nuclear technologies to waste management, decommissioning and final disposal.

Nuclear construction costs however are an area most focused on to cut the capital costs of nuclear build along with financing models such as the RAB.[20] This is an area that a lot of prospective trade union jobs come from as some of this will be through off-site construction with development of small modular reactors (SMRs).

According to the UK SMR consortium led by Rolls Royce, 6,000 regional UK jobs can be created in the next five years as part of the government's levelling up agenda *if*" the UK Government makes a clear commitment that enables a fleet of 16 small modular reactor (SMR) power stations to be built over the next 20 years"[21] This is contingent on 80% (by value) of the power station components being made in English factories (Midlands and North of England) for onsite assembly inside "weatherproof canopies".

However, these are manufacturing jobs which could and should be created for the wind power sector and for other decarbonisation work, for example mass transit, which are not contingent on being tied to SMRs. It would also suggest that current onsite construction jobs would be displaced for modular manufacturing work. A further 34,000 long-terms jobs envisaged "by the mid-2030's" in high value manufacturing, do not need to be uniquely tied

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[19] Nuclear Sector Deal - GOV.UK (www.gov.uk)
[20] Nuclear Sector Deal - GOV.UK (www.gov.uk)
[21] Nfairuclear Power Stations Will Create 6,000 UK 'levelling Up' J (globalenergyworld.com)

to the nuclear sector. These could be climate jobs as part of publicly owned manufacturing for renewable energy or mass transit programmes.

Technologies

“Small Modular Reactors and Advanced Modular Reactors are being touted by the nuclear industry as a core alternative to large nuclear reactors with an important role to play in the critical challenge to tackle the climate emergency.” [22] In 2020, the UK Government announced £40 million for “next generation” nuclear technology.[23] This includes 3 Advanced Modular Reactor projects (£30m) and £10 million into smaller research, design and manufacturing projects with a view to creating *up to* 200 jobs, and includes £5 million put into “strengthening the UK’s nuclear regulatory regime”.

The other ‘big ’investment is in building a commercially viable fusion power plant by 2040:[24]

“The aims are to develop a concept design for the Spherical Tokamak for Energy Production (STEP) – expected to be the world’s first compact fusion power plant, to be built in the UK by 2040 – and to invest in facilities and infrastructure to make the UK a global fusion industry hub. In December 2020, the STEP programme published an open call for communities across the UK to apply to be the host site for STEP. “

There is enormous scepticism about the Tokamak programme, which has been under discussion for a long time. There is currently no existing ability to make such a proposal a reality. It is an unproven technology, whilst many proven technologies are being sidelined. Investment must be prioritised in realising the capacity of proven technology now – including energy efficiency[25] - not technologies that may or may not come on stream down the line, when carbon budgets have already been spent and climate tipping points passed.

A further point about SMR technology to be understood and concerned about is the push towards nuclear as a cogeneration technology that is beyond electric power generation. In the words of a 2020 Royal Society Briefing:

“Nuclear cogeneration is where the heat generated by a nuclear power station is used not only to generate electricity, but to address some of the ‘difficult to decarbonise ’energy demands such as domestic heating and hydrogen production. It also enables a nuclear plant to be used more flexibly, by switching between electricity generation and cogeneration applications.”[26]

This mean siting reactors nearer to urban populations, increasing risks. These developments need to be well understood within the wider energy decarbonisation process, along with

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[22] Microsoft Word - NFLA New Nuclear Monitor No65 SMR in the UK overview.docx (nuclearpolicy.info)

[23] £40 million to kick start next-gen nuclear technology - GOV.UK (www.gov.uk)

[24] Energy White Paper (publishing.service.gov.uk)

[25] Boris Johnson faces calls for nationwide home retrofit scheme to make houses more energy efficient (inews.co.uk)

[26] Nuclear Cogeneration: civil nuclear in a low-carbon future | Royal Society

the players involved in pushing them such as Rolls Royce who are closely linked to the UKs defence sector.

Nuclear risks and threats

There are multiple risks and threats to consider with nuclear power: operational, occupational health and safety, environmental, and climate change impacts. Most recognise what Jonathan Porritt refers to in his paper '*Net Zero without Nuclear*,' that "the nuclear industry is peculiarly vulnerable to 'high-impact, low-probability 'events". [27] The most notable in people's minds are no doubt Three Mile Island in the US in 1979, Chernobyl in 1986, and the Fukushima disaster in 2011. All these were devastating events, but they still only tell part of the story.

The 'international nuclear and radiological event scale '(INRES)[28] - a global tool for publicly communicating the scale of safety threat from nuclear and radiological events - makes clear that we need to understand the safety of the industry in a much wider context. For example, its scope covers storage, transport and use of radioactive materials, including those used for medical purposes. This paper is only concerned with nuclear power plant and related activities, and notes that the INRES, in itself narrow, is again only one yardstick to use in considering nuclear power safety.

The health effect of low-level ionising radiation from nuclear activities (within and around operational and decommissioned nuclear facilities, transportation, and mining) is a contested space.[29] There is an established regime for setting, monitoring and regulating 'safe ' dosage levels in the UK and internationally[30], but this ignores gendered impacts of radiation on women and girls health.[31]

Another concerning aspect of safety is the push to extend the operation of nuclear plants well beyond their planned lifespan[32] which means reduced operational efficiency, and risk of safety lapses,[33] as has happened at the Hunterston plant in Scotland.[34]

The final and no less critical risk is climate change itself. As stated by the UK Environment Agency:

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[27] Net Zero Without Nuclear: the Case Against Nuclear Power - Jonathon Porritt

[28] International Nuclear and Radiological Event Scale (iaea.org)

[29] Low level radiation – a game changer for the nuclear power and weapons industries? – Yorkshire Bylines

[30] For example, the International Commission on Radiological Protection (ICRP), the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the UK

[31] Radiation and women's health: CND webinar report - (cnduk.org)

[32] Research aims to extend operational life of nuclear plants | The Engineer The Engineer

[33] Fate of UK's nuclear plants in doubt over ageing infrastructure | Nuclear power | The Guardian

[34] Concerns over nuclear safety 'lapse' at Hunterston (theferret.scot)

"UK nuclear stations built before today, and a large number of fossil fuelled stations, discard their heat to water via direct cooling, the key reason favouring construction on the coast or estuaries."[35]

This document sets out a range of water related issues in terms of consumption, impacts on local environment and contamination. Concerns have been raised for both Hinkley Point C in Somerset and the proposed Sizewell C in Suffolk about the staggering impact on fish which are regularly swallowed up as part of the cooling processes.[36] And according to a report in the Guardian in 2012[37], a Defra survey concluded that 12 of Britain's 19 civil nuclear sites, including the Sizewell site, were at risk from flooding and coastal erosion. That was nearly a decade ago, and now we are at a stage of even more intense climate change impacts, with far worse inevitably to come.

The final irony in the climate change impacts story for nuclear is that water used for cooling is becoming unusable or insufficient in times of record high temperatures and drought. Both scenarios have become prevalent in recent years in France, for example, where either water that is too hot or water levels too low have forced plants to close.[38] This brings an interesting twist to the refrain that nuclear is needed for when the wind doesn't blow or the sun doesn't shine.

Climate Justice – uranium extraction and waste

Critical to any decarbonisation proposal is to assess whether it meets the imperatives of climate justice. This should encompass economic, social, environmental and political justice aims including reparation for historical harm, particularly, but not exclusively, for the global South. As we move from fossil fuel extraction, concerns about mining practices for renewable or low carbon energy cannot be ignored. This has implications for both resource constraints and for the development of new extraction colonialism.[39]

For nuclear, uranium mining is already an environmental racism concern due to working conditions, and the location of mining resources[40]. In 2019, over 50% of uranium production came from four countries: Australia, Canada, Kazakhstan and Namibia.[41] Australia is said to have the world's biggest reserves, putting indigenous ("aboriginal") communities at direct risk. This is already lived experience and an even worse future will occur if the current push for nuclear energy (and co-generation) is successful.

Waste from the industry poses similar challenges and problems. As mentioned above, the UK still faces a challenge in dealing with legacy waste from the 1940's, and has struggled for

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[35] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291077/scho0610bsot-e-e.pdf

[36] Sizewell C nuclear plant could kill 500m fish, campaigners say | Nuclear power | The Guardian

[37] UK nuclear sites at risk of flooding, report shows | Nuclear power | The Guardian

[38] Drought provokes shutdown of nuclear reactors in northeast France (rfi.fr)

[39] Resisting Green Colonialism: Lithium, Bolivia, and the Green New Deal // New Socialist

[40] 141115_U-mining.pdf (ejolt.org)

[41] Uranium Mining Overview - World Nuclear Association (world-nuclear.org)

decades to find a solution for waste disposal. This remains the case, and it seems there is plenty of waste to keep workers in nuclear roles dealing with current issues without creating new ones for future generations to have to contend with. With current ambitions to bribe communities in what former energy advisor Lord Howell referred to as the "desolate north"[42] to accept nuclear waste, it should be understood that once again it will be poorer, working class communities that will have to live with the threat on their doorsteps rather than the elites deciding this policy.

Nuclear and the military

It is no longer any secret that the push to nuclear in the UK is directly linked to the nuclear weapons system. Detailed and groundbreaking work has been done by academics Andy Stirling and Phil Johnstone of the Science Policy Research Unit (SPRU) at the university of Brighton on the links between UK civil and defence nuclear policy.[43] From a jobs perspective this is significant as the defence programme is driving the civil programme as noted earlier. This from the MoD updated report (2020) provides a good summary:

"We are working with all stakeholders in the defence and civil nuclear sectors to optimise nuclear skills for the future and as a group lead on the 'people' strand of the Nuclear Sector Deal. This activity will develop the environment for collective coordination and integration across the wider nuclear sector, and by combining a larger cadre of nuclear-skilled people providing a more robust and efficient supply chain to help meet the skills challenges."[44]

The billions that will be wasted on a nuclear deterrent has been called the most expensive job creation programme in history. This is even worse when you consider that the money is being used to produce some of the most expensive electricity in the world when Hinkley Point C comes on stream is cross-subsidising the nuclear defence programme. This is money which could be better invested into public services, delivering decarbonisation across all sectors of the economy,

While not so apparent in UK, in the US the push for mobile nuclear power is being made to secure energy for the battlefield. Used in the US navy, this is postulated as a way to wean themselves off the high fossil fuel demand of their military operations. This is not driven by concern for the climate but to limit casualties of war that result from targeting of energy transport convoys.[45] Of course the safest strategy, for both civilians and the environment, would be to seek a peace agenda rather than war.

Conclusions

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[42] Fracking can take place in 'desolate' north-east England, Tory peer says | Conservatives | The Guardian

[43] Shining a light on the UK's nuclear deterrent : Business and Economics research : ... : Research at Sussex : University of Sussex

[44] The United Kingdom's future nuclear deterrent: the 2020 update to Parliament - GOV.UK (www.gov.uk)

[45] U.S. military marches forward on green energy, despite Trump | Reuters

There are challenges to energy decarbonisation which should not be underestimated. All technologies, including renewables, have wider implications when the ‘life cycle’ of their production and generation, including infrastructure, is taken into account. With climate change having clearly arrived and the urgent task of trying to stabilise global temperatures is making little headway in terms of real action at governmental level, it’s understandable that previously anti-nuclear heads could be turned by the current debates.

Yet while we must use every tool in the box to meet the challenge of decarbonisation, that does not mean losing sight of climate justice which should be at the heart of policy and the creation of climate jobs. Claims that new, and untested, nuclear technology are the answer are ‘fools gold’. Nuclear is a mature technology closely tied to the defence sector and the maintenance of weapons of mass destruction that would be the ultimate in climate catastrophe. It is also being shaped to fit new agendas such as industrial processes and district heating which should raise alarm. Along with this are the issues of ownership and public financing of the nuclear sector; finance which should be put into democratically planned development of a safe and genuinely sustainable energy system under public ownership.

Nuclear jobs will not contribute to the urgently needed decarbonisation of energy to meet our climate targets and avoid further destabilisation of the climate. Workers in the nuclear industry deserve recognition for their skills and, as with fossil fuel workers, for the contribution they have made to ‘keeping the lights on’. As part of this, they need to be transitioned into the clean-up operation to wind down the nuclear industry, which will last well into the future, and to new safer technologies rooted in climate justice.