2024-07-12 **The Road to Net Zero Can Save Government Funds** **Gordon Taylor**

Summary

Net-Zero may be achieved while freeing substantial sums for other government expenditures.

For guidance, the UK needs a Net-Zero study similar to those undertaken for the US and Australia, using a methodology from Princeton. This should include energy saving and efficiency options, for which the technical potential is huge.

For the electricity, heat, transport and agricultural sectors, the government should set emission trajectories, with waypoints at 2030 and net-zero by 2050. Existing and new suppliers could offer a combination of energy saving and efficiency and transition from fossil to renewable sources, taking account of the changing wider economy, both measures and costs.

Net-Zero could be achieved very largely with private funding from multiple suppliers, provided that the measures are well-chosen. To ensure local democratic engagement and control, local governments should be funded to invite private companies to tender for specific contracts. Options that are monolithic and lack multiple suppliers would be too slow and too costly.

A UK Net-Zero study should show that energy savings, renewable energies and storage can meet the 2030 and 2050 targets. This is because these options are proven, easy to deploy at scale, and affordable. Moreover, they increase energy security and employment, while displacing imports of nuclear, fossil and biomass fuels. ‘A new report concludes that a 100% renewable energy mix for the UK would save well over £100bn in achieving net zero by 2050, compared to the UK Government’s current strategy. It would also mean more than 20% lower cumulative carbon emissions in the process’.
This would also enable major government savings by removing funding of nuclear fission and fusion, oil and gas, carbon capture and storage (CCS) and imported biomass, as in Table 1.

Table 1

Action	Government Saving
Remove government funding of Sizewell C, SMR, ANF and FNEF	£ 1155 million
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Remove government funding of imported biomass for Drax etc	£ 606.8 million in 2022
Total of above	About £ 8.6 billion a year

References are included as endnotes in the full text.

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1 Setting the Scene

The world agreed to limit global warming to well below 2 C by 2050 [1]. 'The budget for staying below the 2°C threshold, for its part, of 1,150 Gt, would be exhausted in about 23 years'. With CO2 emissions of 1,337 tonnes per second, the World Carbon Budget has already fallen to 963 gigatonnes [2]. As they must total to the World Carbon Budget, national Carbon Budgets must not be on a territorial basis, as declared at present, but on a consumption basis, including imports less exports and international transport [3].

Professor John Barrett and others from Leeds University have recently suggested four additional climate targets for the UK:

1. Emit no more than 50 million tonnes annually by 2050
2. Remove 50 million tonnes of carbon each year
3. Reduce energy demand by a minimum of 40%
4. Less than 10% of primary energy from fossil fuels by 2050 [4] [5].

2 What can be done at national government level

The Institution of Mechanical Engineers (IMechE) has proposed an 'energy hierarchy' for sustainability. Tier 1 is Energy Demand Reduction, Tier 2 is Energy Efficiency, Tier 3 is Utilization of Renewable, Sustainable Resources, Tier 4 is Utilization of Other, Low-GHG-Emitting Resources, Tier 5 is Utilization of Conventional Resources as we do now [6].

2.1 Energy Savings

The scope for energy saving (Tier 1) and increased energy efficiency (Tier 2) is huge at about 80%. [7] This refers to:
2010, Theoretical efficiency limits for energy conversion devices, Jonathan M. Cullen, Julian M. Allwood, [8] and:
2011, Reducing Energy Demand: What Are the Practical Limits?, Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein, [9]
When checking the links for the above, I found a later paper:
2019-08-22 Technical limits for energy conversion efficiency, Leonardo Paoli, Jonathan Cullen, [10] .
I combined the effects of the two later papers in my unpublished note: 2022-06-14 Energy Transition Technologies, [11] .
Many measures for saving electricity and increasing electricity efficiency may be cheaper per kW and kWh than supply so – if neglected – much of the supply side investment could be wasted, raising the cost of electrically-powered energy services. Moreover, much of the demand side end use equipment is shorter-lived at e.g. 10 years, enabling early replacement, where much of the supply side, electricity generation, transmission and distribution equipment is longer-lived at e.g. 30 years.

Electricity and Transport Sectors
Household electricity consumption can be measured by smart meters, but attribution to particular appliances – known as 'disaggregation' - is not easy. Disaggregation hardware and services are available. [12] Nowadays they often benefit from AI techniques [13]. However, a simple plug-in power meter may be used to estimate the electricity consumptions of most appliances in the home [14]. For lighting, LEDs offer such large savings – up to 90% from filament lamps and around 50% from fluorescent lamps - that they should be replaced as soon as possible [15]. It is not usually sensible to replace major appliances solely for energy saving. However, in case they should fail suddenly beyond economic repair, it is worth researching possible replacements. One reliable and independent database is at: [16]. Most appliances sold in the EU have energy labels, and these were updated in 2021 [17] Heating and cooling appliances are now included at: [18].
The scope for electricity savings can be large when account is taken of the number of units in operation. 2021-10-26 Millions of Smart Central Heating Pumps Add Up To Big Savings, [19]. Inefficiency (not just emissions) is driving out fossil fuels [20].

Buildings – Largely Heat Sector
Cambridge Architectural Research (CAR) carried out a study of the costs of building energy-saving measures: 2017-04 WHAT DOES IT COST TO RETROFIT HOMES?, Updating the Cost Assumptions for BEIS's Energy Efficiency Modelling, [21].
University College London carried out a study on fabric energy efficiency assumptions. 2020-12-09 Analysis work to refine fabric energy efficiency assumptions for use in developing the Sixth Carbon Budget (University College London), [22].

2.2 Energy Supply Options

Four low carbon energy supply options were highlighted in the studies Net-Zero America [23] and Net-Zero Australia. [24]. These are Renewables, Storage and Transmission, Biomass and Biofuels, Fossil Fuels with CCS, and Nuclear Power, Heat and Hydrogen. The first two correspond to the IMechE Tier 3, and Fossil Fuels with CCS to Tier 4. Fossil Fuels without CCS and Nuclear Power, Heat and Hydrogen correspond to Tier 5.

2.2.1 Renewable Energies and Storage

Renewable energies such as Solar PV and Wind are diffuse, but land requirements can be reduced by mounting on rooftops and on farmed land with AgriVoltaics and Onshore Wind Turbines, on water bodies as Floating PV, and at sea as Offshore Wind Turbines, both fixed and floating.

Systems with high proportions of PV can be 'firmed' by batteries, which require to be 'cycled' frequently to be economic. Short-term Storage can be provided by Pumped Hydro systems that do not depend on precipitation (rain- and snow-fall), and by Hydro Power, which does. Suitable sites for the former are available in almost all countries [25]. Longer-term storage of electricity may be via natural gas or electrolytically produced green hydrogen, which is stored in underground caverns, and later burnt in Gas Turbine Power plants, either Combined Cycle or Open Cycle. [26] [27]

Others have addressed the challenge of long periods of low wind and solar power. They include: [28], [29], and the 2023 Royal Society report on Large Scale Electricity Storage. This foresees the use of green hydrogen stored in caverns [30].

Systems with large proportions of weather-dependent energy – mainly Solar PV and Wind – require significantly more high voltage transmission lines than of old. These require a 'social licence' with fair sharing of impacts and benefits. However, the latter can include significant increases in jobs.

Another source of renewable energy for both heat and power is Geothermal. Although this comes from the molten core of the finite Earth, this will not be exhausted before the Sun dies some five billion years hence [31]. It also has intrinsic storage and may be located close to the load, so minimising the transmission of heat and power [32].

I created a simple model for electricity generation in GB using wind power with annual storage. This shows that a given carbon reduction may be achieved by different combinations of wind power and power-to-gas power, and that 75% carbon reduction may be achieved with zero power-to-gas power [33].

Several studies propose 100% renewable energy supplies: [34], [35].
Other studies propose low-carbon and energy-efficient technologies:
'Apart from flying and shipping, all of our current uses of energy could be electrified. With tremendous commitment the UK could generate enough non-emitting electricity to deliver about 60% of our current final energy-demand, but we could make better use of that through incremental changes in the technologies that convert energy into transport, heating and products' [36].
'To achieve net-zero emissions by mid-century, global energy systems must undergo a wholesale switch to low-carbon and energy-efficient technologies' [37].

2.2.2 Biomass and Biofuels
Biomass and biofuels are limited by competition between food and fuel in countries with high population densities. Also, because they have low energy densities (kJ/kg), they are costly to transport long distances, especially with empty return running of the ships, trains and trucks.

2.2.3 Fossil Fuels
Energy carbon emissions come from burning coal, oil and gas. Coal has been eliminated from electricity generation in the UK, though some is still used for iron ore reduction. However, oil is very widely used in transport and natural gas in heating. So the emissions trajectories depend on the transitions in these sectors. The energy scenario being pursued would affect the nature and amounts of fossil fuels required for the energy transition. These could be translated into the national needs for coal, oil and gas fields, whether indigenous or from overseas.
Authors from University College London found: 'Our research confirms an earlier finding of policy experts at the International Energy Agency (IEA): that no new [oil] fields are needed to meet energy demand as the world attempts to achieve net zero emissions. However, our analysis goes further by demonstrating that no new fossil-fuelled power stations are needed either.
If governments stop new projects, the production and consumption of fossil fuel will gradually decline over coming decades as existing assets reach the end of their lifespans. This gradual transition will give time to plan the process, to protect and create jobs and to build solar and wind farms that meet energy demand as fossil fuels are phased out' [38].

To prevent adding further GHG emissions, fossil fuels would require Carbon Capture and Storage (or Sequestration) (CCS). This is proven but so far used mainly for Enhanced Oil Recovery (EOR). So this increases, rather than decreases, GHG emissions. As all options must meet interim and final carbon intensity targets, those proposing fossil fuels should be required to price them to include the cost of CCS. This may include Direct Air Capture of CO2, CO2 pipelines to areas with suitable geology, and the actual sequestration. Also, they should be required to carry the cost of insurance against the risk of CO2 leakage. All forms of CCS have significant leakage risks [39].

Emissions from other than energy are largely from agriculture, notably NOx from fertilisers, which are very hard to reduce. National carbon emissions could be reduced by 'negative emissions', but planting trees has small potential in the UK due to limited land area and competition with food and forage crops. Carbon Capture and Storage (CCS) from industrial processes is limited by the required capital plant and the finite storage capacity. Biomass Energy with CCS (BECCS) is limited by the required capital plant, the finite indigenous biomass available as fuel, and the finite storage capacity. Direct Air CCS (DACCS) is limited by the required capital plant, the energy consumption and the finite storage capacity.

However, dependence on new technologies has been questioned:
'This article reviews the characteristics of fifteen different UK Net Zero pathways (three government pathways and 12 additional pathways) and shows how the expectation of technology innovation and low-carbon energy abundance closes down the space potential pathways can occupy. In particular, we find that while conceptually different, the three government pathways display a high degree of similarity and that the majority of pathways rely on significant amounts of new clean energy and retain large residual emissions in 2050 which requires the deployment of significant new carbon dioxide removal technologies' [40].

‘Our report reveals that CO2 emissions from Blue Hydrogen and Gas-CCS projects could be two to three times higher than reported when considering upstream emissions from gas extraction, processing and transport. Proponents of Carbon Capture, Utilisation and Storage (CCUS) technologies promise that CCUS-based hydrogen (i.e., blue hydrogen) and gas power plants with CCS (i.e., gas-CCS) can offer a low-carbon solution to decarbonise industrial and power sector. This report evaluates the impact of upstream emissions to determine whether or not gas-based CCUS technologies could have a positive climate impact, assuming the technology would work as claimed by the CCUS industry. This problem is particularly important for the UK and EU which following the 2022-23 energy crisis are increasingly reliant on imported LNG, particularly from the USA’. [41].

2.2.4 Nuclear Power
The UK National Nuclear Laboratory has proposed the inclusion of nuclear power, including future fuel cycles, for Net-Zero scenarios [42] [43] [44]. However, nuclear power has eight disadvantages, such as fuel depletion, uninsurability and potential lethality. Here are links to my presentation ‘Nuclear Power Has No Future’ and a supporting document with 117 references: [45].
A recent paper with eight authors finds nuclear power to be unsuitable for climate change mitigation on seven criteria including technical risks, economic implications and incompatibility with renewable energy systems. This too has many references [46].

Some believe that other decarbonisation options will emerge in time to be deployed at sufficient scale by 2050.
One such is Small Modular Reactors. However, these would have LCOEs even higher than current large nuclear reactors [47].
Another such is Nuclear Fusion. There is insufficient tritium fuel, which wastes away with a half-life of 12.5 years [48].

2.3 Hard to mitigate items
‘Feasible supply of steel and cement within a carbon budget is likely to fall short of expected global demand’ [49]. However, steel and concrete are required in large volumes during a country’s development phase, for housing and factories, but then at much lower volumes for replacement and for population increase. [50] Professor Julian Allwood of Cambridge University has recently summarised the scope for Zero-emissions production of steel. [51], for Zero-emissions production of cement [52], and for Innovation for living well with less material [53].

A target for steel, both indigenous production and imports, could be set as carbon intensities and dates. E.g. XX by 2030, YY (near-zero) by 2050. (Targets should be set as performance, rather than be prescriptive, which would inhibit innovation). However, the first target should be set at what is achievable by proven technology. Iron ore can be reduced by green hydrogen to produce iron metal. Then from iron metal (including scrap) of steel in various alloys (such as stainless and magnetic), and in steel mills of various steel forms such as rolled sections, plates, and sheets, in all cases heated in electric arc furnaces. Even so, the carbon intensity also depends upon the ore grade, the shipping, and that of local hydrogen and electricity.

Many countries import significant embedded carbon. [54] There are moves to identify and deter these [55]. There is already monitoring from land, air and earth satellites of gaseous emissions, such as ‘global warming’ refrigerants (e.g. CFCs) [56], methane [57] and CO2 [58]. This should deter manufacturers from using undeclared gases in their production processes. However, emissions of methane (natural gas) requires independent verification. [59] [60].

Housing, offices and factories should not stand empty, but should be re-purposed at far lower carbon cost [61]. When built new, all these should be of Passive House design [62]. Such buildings have very long thermal time constants and so remain comfortable during long hot and cold spells [63]. While the space heating cost is reduced over current building codes by 80-90%, the added initial cost is about 8% or less [64]. This may be offset by savings in heat and/or power networks.

2.4 Delivery to Time and Cost with Intended Benefits
Professor Bent Flyvbjerg of Oxford University has collected data on over 16,000 capital projects, and ranked 25 categories for how ‘fat-tailed’ they are in terms of cost – i.e. how much they are in danger of extreme cost overruns. ‘..wind, solar, and electrical transmission projects are all very likely to get delivered on time, on budget, and deliver the promised benefits once the first shovel hits the ground. Meanwhile, nuclear power plants and big hydroelectric dams are about as bad as they come for failing to deliver, down there with the ongoing and very visible failures of the Olympics’ [65] [66].

3 What can be done at local government level
Delivery of Net-Zero building heating and cooling, and of transport, both public and private, are major challenges. Piecemeal delivery of low carbon building heating and cooling makes no sense and is needlessly expensive, as has already been learned for water, sewage, electricity and gas supply. The design and deployment of heat networks and heat pumps, with necessary upgrades to insulation and heating systems, is best done zone-by-zone by energy professionals and installers under contract. They can buy in bulk and be subject to quality control. However, it should be delivered via local governments, who require far lower than commercial rates of return [67]. After all, buildings are national assets, regardless of who is their temporary owner.

Local governments could deliver low carbon public transport, again publicly funded. This can be via electric trains, trams, trolleybuses and battery electric buses, which have much lower operating and maintenance costs than those using diesel engines. For equity and the reduction of car traffic, travel on public transport could be free for all, rather than only students and senior citizens.

4 Conclusions

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For guidance, the UK needs a Net-Zero study similar to those undertaken for the US and Australia, using a methodology from Princeton. This should include energy saving and efficiency options, for which the technical potential is huge.

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