REF 26 [CUP]

Cadwriaeth Ucheldir Powys Conservation of Upland Powys

The Mid Wales (Powys) Conjoined Public Inquiry into 5 Windfarm Proposals and a 132kV overhead Electric Line Connection

Re-determination of the applications by

RES (Llanbrynmair) and RWE (Carnedd Wen)

Additional information

August 2016

CADEIRYDD CHAIRMAN

1. Introduction

1. Conservation of Upland Powys was formed by people living within the county, our members range from families that have farmed the same land for generations to those who have more recently chosen the tranquillity, beauty and quality of mid-Wales life for their home. Our diverse membership, from all ages and all walks of life, shares the commitment to preserve the unspoilt uplands of Powys from inappropriate development for the benefit and enjoyment of everyone. All members apply in writing to join and their signed application is retained on file; CUP has a membership of 650 at present.

2. We have inherited the timeless beauty of these landscapes from our forebears and we recognise our duty to hand these pristine landscapes and environments on to future generations in the same, or better condition than we received them. The proliferation of wind turbines is a serious current and long-term threat to upland wildlife, landscapes and the ways of life that they support. We base our statements and conclusions on real world evidence. The small short-lived benefit from these proposals is wholly inadequate to justify the severe harm any one or more of them will cause.

2. Key members of the Alliance

1. CUP benefits through its membership not only from committed citizen scientists but also a good number of national and international experts in their fields of electrical and mechanical engineering, climate change and modelling, energy generation and distribution, tourism, economic and social research. Robust testing of all of the evidence provided through the Alliance has been undertaken. CUP has taken an active role throughout the Conjoined Public Inquiry (CPI) as members of the Alliance, and all evidence and comments provided by the Alliance are fully supported by CUP; the same applies for Alliance evidence provided in response to the Redetermination call for evidence.

2. CUP has reviewed the material provided by Dr John Constable (attached) and is in full support of its content. Dr Constable provides clear, irrefutable evidence that consent of these windfarms will add to the over capacity of installed electrical generation from wind by nearly 60%[1] and will also be at a budget overshoot over the lifetime (20 years) of £40 billion[2]. It should be noted that wind energy installed capacity is not generating capacity available at all times to meet the needs of the nation.

3. His evidence demonstrates that there is a modest contribution to overall targets for electrical output from these two windfarms, the benefit of which is outweighed by the acknowledged harms they bring.

4. CUP has gathered evidence over the past twenty years that demonstrates that increased reliance upon intermittent sources[3] of electricity generation increases the overall cost, and as described in Dr John Constable's material, the 'favouring' through subsidies of renewables has acted as a disincentive to development for the conventional (stable) energy generation sector[4]. It has also inordinately increased the cost of an essential utility requirement for every household and business. According to The National Energy Alliance[5] 4.5 million households are in fuel poverty today, almost double the fuel poverty figure in 2014.

3. Implementation of Planning Conditions

1. There are two windfarms currently under construction in Mid Wales; Tir Gwynt (developer Engie and Garreg Lwyd Hill (RES)). Planning conditions have been breached and not upheld by the Local Authority; CUP has now instructed lawyers in an attempt to force the Local Authority to carry out their duties, including

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[1] ALL-RED-05 § 9
[2] ALL-RED-05 § 8
[3] ALL-RED-Appendix § 4.1 p15
[4] ALL-RED-Appendix § 5 final paragraph
[5] http://www.nea.org.uk

meeting legislative requirements in Planning and those set out in the Countryside Act 2000. This measure has been taken after months of attempts to resolve the numerous issues through communication with Dyfed Powys Police, Powys County Council and the developers. But it is an expensive drain on local residents' and / or CUP's funds.

2. Examples of breaches of conditions or failure to enforce legislation include:
    a. A CUP member has photographs of an otter caught in a live mammal trap; it was dead and the trap remained unchecked for at least 7 days. The Police, Local Authority and developers have all been made aware but the only action was for the Police to finally remove the otter and confirm that it had died in the trap as seen from its damaged teeth and claws.
    b. Photographic records of habitat destruction
    c. Clear measurements of hedgerow removal far in excess of that in the application.

3. The Local Authority has a poor record of enforcing planning conditions on large developments, and members of CUP have seen illustrations time and again over the years. Illustrations include failure to detect and act upon extensive unauthorised hedgerow destruction and to respond to habitat destruction through mowing. It would appear therefore to be pointless to rely upon the Local Authority to monitor or police development activities, conditions and restrictions.

4. It has also accepted that it has failed on a number of occasions to engage with the procedural requirements affecting sensitive sites and habitats – including failure to engage with requirements for systematic analysis, publicity and notifications.

5. Over the past five years individual local residents have successfully taken legal action against the Authority's Planning department relying on these similar errors.

6. This is particularly worrying in view of the complex and unprecedented nature of the works proposed, particularly by RWE at Carnedd Wen, for timber removal and

for restoration of peat bogs, which are proposed to be controlled by conditions and a plethora of complex and unproven management plans.

4. AIL movements and other traffic

1. Abnormal Indivisible Loads (AILs) are now travelling from Goole in East Yorkshire to Tir Gwynt and soon from Liverpool to Garreg Lwyd Hill windfarm sites. Residents were informed that this would be one load of two or three AILs with Police outriders, six days each week. There are in fact two loads each day, requiring four Police on motorbikes and also a Police car from both Cheshire and Dyfed Powys forces involved in the operations. Clearly these vehicles are unavailable should an emergency occur; we are told that the Police are undertaking this work during their rest periods, but note that nurses and doctors who undertake contracting during their rest periods generate questions of patient safety. Once again, the real world shows that anticipated mitigation and management measures cannot be provided as originally forecast.

2. There are no dual carriageways in Montgomeryshire or Radnorshire and even when travelling from the motorway north of Chester, using dual carriageways the convoys take up the two lanes of the southbound route, causing huge tailbacks. Once they reach Powys matters are even worse, with all traffic following held up, and that travelling in the opposite direction pulled over to allow the loads through. Local people are unable to reach work, home etc without facing this daily ordeal. It should be noted that residents were informed that the convoy would travel through Welshpool between 12 noon and 2pm, once daily; the reality is that the two loads travel at whatever time suits them, so residents and businesses cannot time their own journeys to avoid the convoys and traffic jams. Delays to timetabled public transport, 'just in time' deliveries and emergency services may have far reaching impacts.

2. The local roads are unsuitable highways for vehicles of this quantity and magnitude. Windfarm developers and their contractors have already brought down telephone lines and damaged railway lines at crossings

5. Impact on the local economy

1. Contrary to the conclusion of the Inspector, that windfarm construction would provide local employment, both windfarms are being constructed by workers who do not live locally, nor do we benefit from them staying in the area whilst working here. The construction workers drive at excessive speed to leave the area and return to their homes in other parts of the country at the end of their working day. Apart from some of them purchasing snacks and occasional breakfasts at local pubs CUP members have found little evidence of workers spending money in the area.

2. Local business owners in Welshpool have begun to give unsolicited accounts of conversations with people from outlying areas who have stated that they will not be travelling into Welshpool until the AIL convoys have stopped, as the journey times and/or potential diversions are so unpredictable it is simpler to go elsewhere. Welshpool Town Council have been informed by holiday park site owners that regular visitors are cancelling bookings due to concerns over traffic congestion and building works on the uplands they come to enjoy. The developers have informed residents that once the AIL journeys for Tir Gwynt have been completed, those for Garreg Lwyd Hill will start; it appears that Welshpool and Newtown's small local businesses will suffer a reduction in trade for at least three months from the construction of just 29 turbines.

3. CUP is not aware that the timing of these current works has been considered by the Highways Agency and Local Authorities prior to them giving consent. These convoys of AILs commenced in July, just after the school holidays started and are being undertaken through the peak of the holiday season, affecting not only Mid Wales but also the Cambrian Coast. The original Capita Symonds report into windfarm transport in Mid Wales, commissioned by the WG and Powys County Council, was clear that transportation should not take place in peak holiday periods; a caveat with which the WG agreed.

4. Since the Inquiry ended further developments in the locality include:
    a. 12 turbines, 363 feet high under construction at Tir Gwynt (24.6mW);
    b. 17 turbines, 413 feet high under construction at Garreg Lwyd Hill (30.6mW);
    c. 13 turbines 413 feet high approved by Local Authority – Carno III (39 mW).

5. The National Grid Hub proposed in the Montgomeryshire Western Uplands, the associated lines into the hub and connection to the main Grid outwards towards and through England all contribute to make these applications unacceptable in terms of cost to the nation in implementation, and to the local economy which relies upon tourism and its scenery to maintain its social fabric as a resilient foundation upon which these rural communities depend.

6. Impact on wider Welsh economy

1. Of further importance, as stated in Banwy Community Council's evidence to the Inquiry[6], is the coastal route. It is now a salutary fact that the only A road route from England to anywhere on the west coast of Wales that is windfarm-free (not turbine-free) is the route through Welshpool, Llanfair Caereinion, Dolgellau to Barmouth, Fairbourne and other parts of the Gwynedd coast. The spectacular Cambrian coast is now blighted by the route to it, unless travelling from Ireland.

7. Conclusion

1. The contributions from either, or both developments to UK energy targets is at best limited. There is a growing realisation (in the UK and Europe) that individually, and cumulatively now windfarm proposals are undermining confidence and investment in alternative, secure, base load generators. If approved, these developments will also add to the pressure for unsightly and damaging grid infrastructure.
The overall balance is clearly against granting consents.

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[6] OBJ-816-POE Banwy Community Council

2. **Conservation of Upland Powys requests that the Secretary of State refuses these applications not only on the grounds given in this representation and earlier CUP material, but also in that of the Alliance, which as stated, we support fully.**

ALL-RED-05

The Mid Wales (Powys) Conjoined Public Inquiry into 5 Windfarm Proposals and a 132kV overhead Electric Line Connection

Re-determination of the applications by RES (Llanbrynmair) and RWE (Carnedd Wen)

The Alliance

Supplementary Evidence of Dr John Constable

Supplementary Evidence relating to the Llanbrynmair and Carnedd Wen wind farm proposals

Introduction

1. I have been asked by The Alliance to provide updated evidence regarding the generation benefits of both the Llanbrynmair and Carnedd Wen wind farm proposals, on which I have commented in previous phases of the planning process. This document supplements evidence supplied to the Conjoined Public Inquiry (CPI) and should be read in conjunction with it.

2. For brevity I will not repeat many of the background points presented in my earlier evidence. Simply, as before, the intention of the material presented here is to enable the decision-maker to rationally balance the benefits of the proposals (including their electricity generation and contribution to targets) against the harm to interests of acknowledged importance.

3. I have reviewed earlier evidence, as summarised in the Alliance's Closing Submissions (ALL-030R) and see no reason to revise any of the statements and observations on the likely output, emissions savings, or contributions to security of supply. These contributions are, in spite of the physical scale of the proposals, modest at best.

4. Similarly, no substantial change needs to be made to the estimation of *scale* of contribution to the electricity component of the EU Renewables Directive (2009) target. The output of these wind farms is a small fraction of the overall requirement for electrical energy towards meeting the EU Renewable Energy Directive, individually being well under half of one per cent; and taken together only just over half of one percent, as given in the following tables drawn from the Alliance's Closing Submissions, but modified to make reference to the possible withdrawal of five turbines in the Carnedd Wen proposal, which I understand would reduce the capacity to 135 MW:

Llanbrynmair (RES)

Table 1: Llanbrynmair wind farm proposal: Capacity, output and scale of contribution to the electricity component (110 TWh) of the EU Renewables Directive (2009) target for 2020.[1]

Number of Turbines	*Nameplate capacity (MW)*	*Annual Output (@ approx. 30% load factor) MWh*	*EU Target Contribution*
30	90	236,520	0.2%

Carnedd Wen (RWE)

Table 2: Carnedd Wen wind farm proposal: Capacity, output and scale of contribution to the electricity component (110 TWh) of the EU Renewables Directive (2009) target for 2020.

Number of Turbines	*Nameplate Capacity (MW)*	*Annual Output (@ approx. 30% load factor) MWh*	*EU Target Contribution*
50 (with "CW 5")	150	392,100	0.36%
45 (without "CW 5")	135	354,780	0.32%

5. However, the *context* in which the contributions of these applications must now be placed, namely the contribution towards targets by other, already consented renewable electricity capacity, has changed significantly since earlier evidence, as discussed in the following section.

Significance of the Contribution to the EU Renewables Directive Target

6. In previous evidence to the CPI (ALL-CLO-POE-01) I noted that there was sufficient consented renewable electricity capacity to generate about 116 TWh (see para 9), which was 6 TWh over the 110 TWh required. Due to extremely rapid growth in the sector, this potential

1 During the course of the CPI timetable the expected target quantity was revised slightly downwards from about 120 TWh expected in the National Renewable Energy Action Plan of 2009 to 110 TWh in the updated NREAP of 2013, as discussed in my evidence to the CPI, ALL-CLO-POE-01, para 6.

overshoot from consented capacity has now (as of June 2016) risen to about 38 TWh, or 34% above the 110 TWh contribution expected from renewable electricity.

7. The potential overshoot is described in the table below, which is drawn from ongoing work by the charity Renewable Energy Foundation[2] to track progress towards the electricity component of the EU Renewables Directive (2009) for 2020. The fundamental data relating to the capacities of the various technologies is drawn from the UK Government's Renewable Energy Planning Database (REPD).[3] Output is estimated by reference to empirical load factors over an extended period of years, as recorded in the UK Government's *Digest of United Kingdom Energy Statistics*.

Table 3: Renewable electricity capacities Operational, Under or Awaiting Construction or submitted to the planning system; together with estimated outputs.
Source: Renewable Energy Foundation, Department of Energy & Climate Change (now Business, Energy and Industrial Strategy), calculations by REF.

	Bio-mass	*Hydro*	*Solar*	*Marine*	*Waste*	*Off-shore Wind*	*On-shore Wind*	*Total*
Operational (GW)	3.2	0.5	6.7	0.0	1.0	5.1	9.1	25.5
Under Construction (GW)	0.5	0.0	0.4	0.0	0.2	0.8	2.9	4.8
Awaiting Construction (GW)	3.3	0.0	3.2	0.5	0.7	13.6	3.2	24.5
Total Consented Capacity (GW)	6.9	0.5	10.3	0.5	1.9	19.5	15.2	54.8
Submitted to Planning (GW)	0.2	0.0	0.9	0.2	0.2	3.1	5.9	10.5
Probable Load Factor	62%	35%	9%	7%	38%	35%	26%	-
Est. output from consented capacity (TWh)	37.7	1.6	8.1	0.3	6.1	59.6	34.3	147.7
Est. output from in-planning capacity (TWh)	1.0	0.0	0.7	0.1	0.5	9.5	13.3	25.2

2 http://www.ref.org.uk/planning/index.php
3 https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract

8. As noted in earlier evidence (ALL-CLO-POE-01-RESPONSE) there is no governmental intention to reach a higher target, and there is no subsidy budget within the Treasury's 'Levy Control Framework' available to support excess generation. Indeed, the implied budget overshoot is very substantial, amounting to about £2bn a year. In a recent peer-journal article[4] (copy supplied with this submission as an appendix), my colleague Dr Moroney and I calculate that an overshoot on this scale could add some £40 billion to the lifetime cost of the programmes concerned. Exceedance on this scale is unlikely to be permitted.

9. It is important to note also that the planning system is in the process of considering a further 10,500 MW of capacity, amongst which the 240 MW of capacity proposed at Carnedd Wen and Llanbrynmair are a part. This capacity in planning would be capable, as the table shows, of generating an additional 25 TWh of electrical energy, increasing the target overshoot to some 63 TWh, or nearly 60%, above the 110 TWh required.

10. In other words, if all the consented capacity is built, the total generation would come to about 148 TWh, some 38 TWh or 34% above the required level of 110 TWh. If in addition to this all the capacity in planning is consented and built the total output would rise to some 173 TWh, or nearly 60% above the required level.

Conclusion

11. In the light of these circumstances I therefore conclude:

i) The electricity component of the EU Renewables Directive target for the UK in 2020 has been in principle more than met by already

4 John Constable, Lee Moroney, "Economic hazards of a forced energy transition: inferences from the UK's renewable energy and climate strategy", *Evolutionary and Institutional Economics Review* (2016). DOI 10.1007/s40844-016-0041-6.

consented capacity, and there is now a 38 TWh or 34% overshoot from this consented capacity, for which there is no subsidy budget.

ii) There is a considerable further oversupply of renewable electricity capacity being brought forward in the planning system, some 10,500 MW in fact. This capacity is sufficient to generate a further 25 TWh of electrical energy, enough to increase the overshoot to nearly 60%.

iii) Since the target has been in principle met by already consented capacity, and there is no renewable energy target subsequent to the EU RE Directive (2009) target, it is clear that decision makers should certainly give less and arguably no weight to the 2020 target contribution of any proposals currently under consideration.

Dr John Constable

11 August 2016

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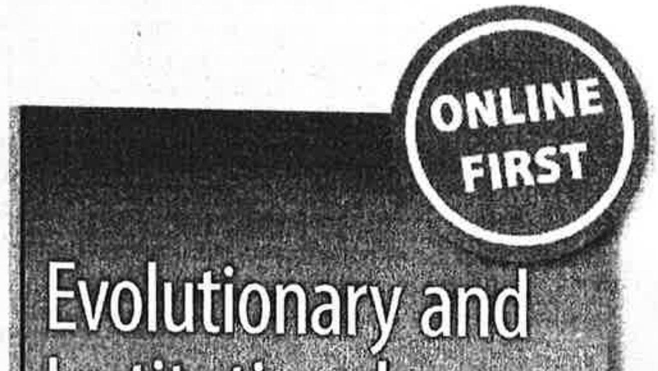

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ARTICLE

Economic hazards of a forced energy transition: inferences from the UK's renewable energy and climate strategy

John Constable[1] · **Lee Moroney**[1]

Abstract The UK government has recently announced a reorientation of its energy and climate policy, scaling back subsidies to renewables, suggesting that uncontrollable generators, such as wind may be required to meet their own system costs, and emphasizing the need for research and development towards an as yet undiscovered, fundamentally economic, low carbon transition. The government also aims to open the way for nuclear power, and the maximization of oil and gas recovery both from the North Sea, and, on-shore, from hydraulic fracking. The present authors argue that although this policy is self-characterised as a re-liberalisation of the markets, the revision is only in part political, and is better understood as a force majeure response to cost and technical problems with the previous renewables-centred policy. Specifically, subsidies have led to an overheated renewables sector with high costs that will exceed Treasury limits and place heavy burdens on consumers. Subsidies to renewables have also weakened investment signals to conventional generation, leading to low capacity margins that necessitate a costly Capacity Mechanism, in effect a subsidy, to guarantee security of supply. Taken together, these costs are significant, and are a matter for particular concern, since there are already signs of a trend towards a de-electrification of the UK economy, a trend which is undesirable for many reasons, including climate policy.

Keywords Renewables · Subsidy · Green economy · System costs

[redacted] A · E · N · O · Q

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1 Introduction: new energy and climate policy directions in the United Kingdom

On the 18th of November 2015, some 6 months after a general election at which the Conservative party was unexpectedly returned with an absolute majority, the Rt Hon Amber Rudd MP, Secretary of State for Energy and Climate Change, announced a major reset of the United Kingdom's policy. This speech confirmed that coal would have no part in electricity generation after 2025, but also admitted that previous ambitions for renewable energy were unrealistic, that gas and nuclear were central to the UK's energy future, and that the recovery of oil and gas from the North Sea must be maximised, as well as supported by gas from on-shore hydraulic fracking (DECC 2015b). Indeed, for the first time in some years, government seemed to be offering a focused energy policy, rather than a climate agenda, in which energy was compelled to play an ancillary part. Long-term income support subsidies to renewables were explicitly rejected—"Subsidy should be temporary, not part of a permanent business model", "No more blank cheques"—and uncontrollable generators, such as wind and solar, were even warned that the indirect subsidy resulting from the socialization of their system costs would not continue: "we also want intermittent generators to be responsible for the pressures they add to the system when the wind does not blow or the sun does not shine."

Overall, the speech goes well beyond the manifesto promise to end the development of on-shore wind, and clearly surprised many. However, revisions to the government's approach had been emerging piecemeal since the election, some giving fair warning of what was to come, including cuts in subsidy levels for new projects, the early closure of some support schemes for certain technology types, and, perhaps, the most significant of all, the removal of the Climate Change Levy (CCL) exemption for renewable energy, which was in effect a cut in subsidy income for all renewable generation, even those constructed and operational. Nevertheless, even if not entirely surprising, the speech may seem from the outside to be quite inconsistent with the government's position at COP21. However, the change of direction, while substantial, is not so much a rejection of the climate agenda, as an urgent attempt to remedy economic and technical problems arising from the subordination of energy policy to climate concerns, combined with the hope that climate goals can in fact better be achieved within the new framework. Indeed, it appears that far from being a purely political action, reflecting the only moderate concern with climate policy in the Conservative parliamentary party, membership, and vote-base, these are actions that any party in power would now have to take; in other words, there is an element of force majeure underlying the government's announcements. The difficulties all resolve themselves ultimately in terms of cost, though the fundamental causes vary in character. Total annual subsidies to renewable energy, particularly electricity, are growing so fast that they are certain to breach consumer spending limits set by the government unless firm action is taken. Furthermore, the electricity system costs of integrating uncontrollable renewables are being confirmed as highly significant, not least, because the market distortions of renewables subsidies have weakened investment signals for conventional generation leading to tight capacity margins that have necessitated the introduction of expensive subsidies to conventional generation via the new capacity mechanism.

The total annual scale of the additional costs of the climate policy for renewable electricity is not only significant, but would result in emissions abatement costs greatly in excess of even high estimates of the Social Cost of Carbon.

There is also a clear trend towards a reduction in energy consumption that cannot be satisfactorily explained by energy efficiency improvements, and suggests fundamental economic weakness. Of these, the most remarkable of all is the sharp decline in the consumption of electricity, a decline that reverses the historical trend since the 1880s. This downward trend is not entirely the result of policies (the economic turbulence of 2008 appears likely to be relevant), but it does seem reasonable to infer that the policy costs are inhibiting recovery.

In this context, it is hardly surprising that the government of the United Kingdom has had to act, if only, because attempts to reduce the state deficit are posited on future economic growth. The UK case is of general interest in that other governments may well find themselves in similar positions; even where the geographical and economic character of the country concerned is very different. This can be brought out by considering each of the major pressures on the UK government in turn, beginning with the trends in energy consumption, and then examining the costs of meeting the EU Renewables Directive (2009), before turning to the capacity margin question, and finally, the issue of emissions abatement costs.

2 Energy in the United Kingdom: recent history

2.1 Final energy consumption in the United Kingdom

There are two principal features in the trend in the Final Energy Consumption (FEC). The first is the surprising decline in this quantity since the turn of the millennium. After a long period of steady increase, FEC peaked in about the year 2000, stalling at about 160 mtoe per year, and in 2005, began a steep decline that appears to be continuing, with consumption in 2014 of about 135 mtoe per year, a level not observed since the 1960s. While this might appear to be an indication of improvements in efficiency, or a shift towards a 'knowledge' economy, and, therefore, to be welcomed, the abrupt nature of the change, and the approximate coincidence with the economic downturn of 2008, all give cause for concern. Moreover, there are reasons, grounded in the Jevons paradox (Jevons 1865), for thinking that larger quantities of energy will be consumed in spite, and, indeed, because of improvements in efficiency.

The second major story regarding FEC is the displacement of coal by petroleum, electricity, and natural gas. In 1948, coal accounted for 1180 TWh or nearly 80 % of FEC, yet by 2008, this proportion had fallen to 30 TWh, less than 2 % of FEC, as can be seen in Fig. 1.

It is worth noting at this point that at the primary consumption level, the reduction in coal's share is less marked, declining from 90 % (1489 TWh) to 16 %

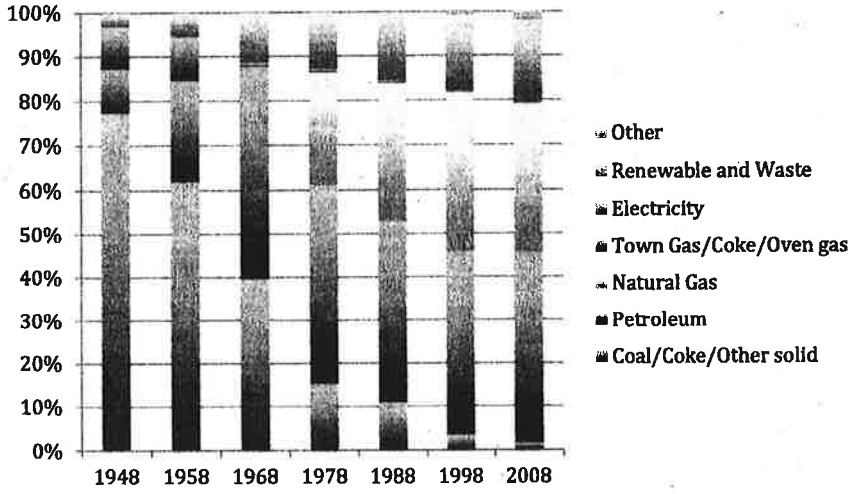

Fig. 1 Final energy consumption in the United Kingdom, 1948–2008, by fuel type Source: DECC (2008), 8. Chart by the authors

(441 TWh), a level largely accounted for by the continuing importance of coal in the electricity generation sector.

Of the displacing fuels, the transition towards electricity is, perhaps, the most important in the longer term, as well as being the most unproblematically positive in character. As a very high grade *carrier* of energy, electricity offers cheap and rapid transmission over long distances, and ready transformation into a wide range of forms of energy at the point of consumption. Historically, it is recognized as facilitating the more intensive use of available resources, a feature that continues today (Byatt 1979, 4), and is part of the reason that electrification is widely considered to be central to any viable long-term decarbonisation of global energy supplies, and therefore, a key component in policies intended to address climate change (IPCC 2014). Further electrification of final energy consumption, then, seems straightforwardly desirable, and likely to occur spontaneously, since it improves human wellbeing with few downsides.

However, the trend towards electrification appears to be faltering. Instantaneous load on the transmission network of Great Britain peaked at roughly 60 GW (gigawatts) in about 2002, and is now falling, with the peak currently at about 54 GW, a level last seen in the mid 1990s. Such a fact could be accounted for, by general, efficiency improvements in conversion devices, such as the use of low wattage Compact Fluorescent Lights (CFLs) and Light Emitting Diodes (LEDs), and also a substantial rise in embedded generation, so is not necessarily troubling in itself, though, as with the fall in Final Energy Consumption discussed above, the timing, the scale, and the abrupt nature of the change, and various other theoretical considerations, suggest that this explanation is not entirely satisfactory.

The significance of these concerns can be confirmed by reference to final consumption of electrical energy (MWh), which includes energy from embedded generation, represented in Fig. 2 between 1965 and 2014.

Other data related to major power producers and in the same set (DECC 2015e) shows a more or less smooth increasing trend from 1920 to the early 1960s, where this chart begins, after which clear perturbations appear, and from the late 1960s and the early 1970s, the pace of electrification appears to slacken, before going into decline, having peaked in 2005, at 349 TWh. The increasingly widespread use of gas for domestic heating and cooking is doubtless a key factor in the trends of the early 1970s. In later years, efficiency improvements should doubtless also be considered. However, the downturn must remain a matter for concern, because a fall of this scale, a little over 45 TWh in under a decade, is clearly inconsistent with the UK's rising population, up from 59 m in 2000 to 64 m in 2013, a 9 % increase (Office of National Statistics 2014). Remarkably, the United Kingdom is now using less electricity than it was in the mid 1990s.

The decline in overall electricity consumption can be further analysed by sector, as shown in Fig. 3.

The fall in consumption appears to be a general phenomenon, and not confined to industry alone. The domestic and industrial sectors peak in about 2005, while the commercial sector flatlines from that date, and may now be in decline. As would be expected, public administration is more resilient, with only a slight decline over the period. While improvements in energy efficiency may account for part of the general trend, it seems very unlikely to account for all of it. Certainly, in industry, where demand is more elastic, it seems reasonable to infer that if efficiency measures were actually working, then, consumption would rise as the output of these businesses became more attractive both within the UK and in the international markets.

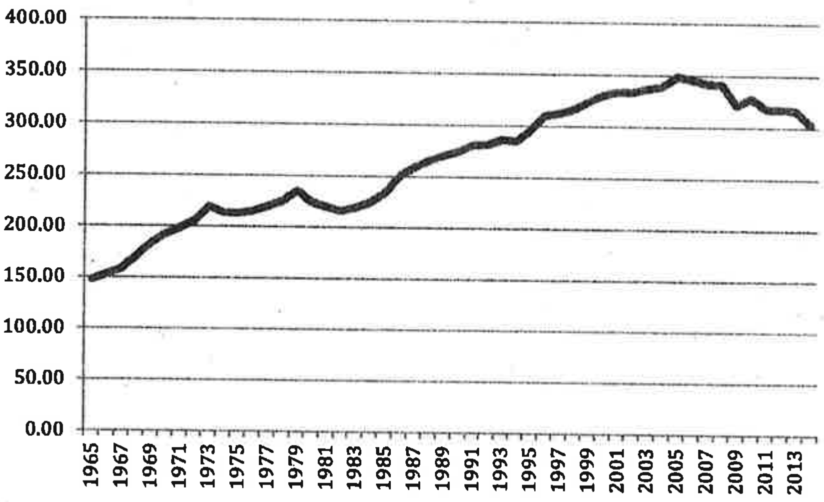

Fig. 2 Final electricity consumption (TWh), 1965–2014 Source: DECC (2015e). Chart by the authors

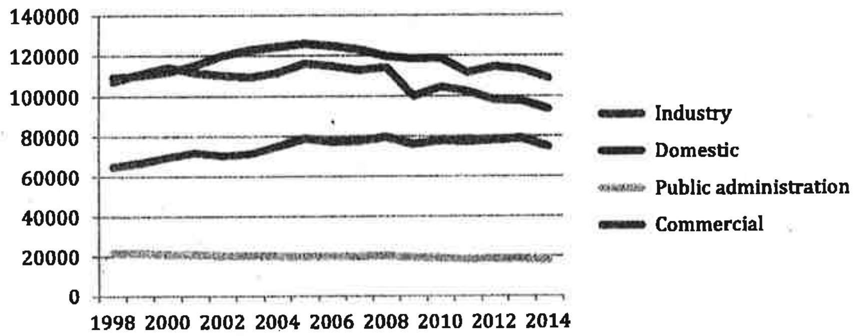

Fig. 3 Final consumption of electricity 1998–2014 (GWh) for the industrial, domestic, public administration, and commercial sectors Source: DECC (2015a) Table 5.1. Available at https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes)

If the pace of electrification is slackening off, and it is still an open question, this would be particularly regrettable since, as with Primary Energy consumption, the main shift in electricity, since the Second War has been from coal to gas and nuclear, with a dramatic increase in thermal efficiencies (rising from just under 10 % in 1926 to approximately 40 % in 2014 (DECC 2013), with a consequent reduction in specific emissions (currently about 0.4 to 0.5 tonnes per MWh). In 1948, coal fuelled almost all electricity generation in the UK, but by 2008, it had fallen to about 35 %, with gas at nearly 50 %, and nuclear contributing just over 10 % (though now declining, since closing power stations are not being replaced). Admittedly, the combined impact of two separate regulations, the Large Combustion Plant Directive (LCPD), which required the fitting of Flue-gas Desulphurisation, and Selective Catalytic Reduction to remove oxides of nitrogen, and the Carbon Price Floor, created a perverse incentive for owners of coal stations that were not opted into the LCPD program to run intensively and use up their remaining allotted hours of operation before the rising Carbon Price Floor eroded profit margins. In 2012, this created the remarkable and embarrassing spectacle of a sharp increase in the output of coal-fired generation combined with a collapse in gas-fired output. Although the peak of this effect has passed, gas has yet to fully recover, partly because of low load factors, discussed further below, due to growth in renewables (14 % of demand on the transmission system), and partly due to falling demand.

Thus, it appears that while government was ostensibly in favour of new gas-fired generation, policies were and are discouraging such development. Similarly, and though no one would suggest that the fall in electricity demand is entirely the result of policy, government may be theoretically in favour of electrification, but at the same time inhibiting demand recovery through policy costs, such as renewable electricity subsidies. In this context, and given the importance of the sector, both to policy and to the future of the UK economy, it is useful to consider the character of the electricity industry and its relation with policy.

2.2 UK electricity market history and character

In her speech, Amber Rudd divided the recent history of the UK electricity sector into two phases, that inaugurated by Nigel Lawson's liberalisations, and that begun by Tony Blair's 2007 undertaking to commit the UK to the EU Renewables Directive of 2009. This is not wrong, both are certainly major landmarks, but a more detailed consideration brings out other facts, particularly the role of the state in the sector, and the extent to which the current moves represent a reversal of a non-interventionist approach.

It is conventional and correct to see Lawson's reforms as an unravelling of the nationalized industry created in 1948 by the Attlee government as part of its institution of a socialist planned economy. However, the deeper history shows Lawson's project as still more original in that it ran against tendencies evident over the entire history of electricity in the UK. Indeed, even in the Electric Lighting Act of 1882, the state not only put a ceiling on prices but also mandated the public purchase of private electricity companies at a written down value after a period of 21 years (Hannah 1979, 9). By 1903, local government authorities were supplying over two-thirds of the electricity load (Byatt 1979, 7). Furthermore, as early as the 1920s, the sector was gradually being moved towards centralization, largely as the result of the recognition that an interconnected system of transmission cables would be desirable, a conclusion reached by the Weir Report of 1925 to the Department of Transport. The study's title is suggestive: *Report of the Committee appointed to review the National Problem of the Supply of Electrical Energy* (Weir 1925). Bearing this mind, the formal nationalization of the six hundred or so private and municipal companies in 1947 was, in essence, less of a departure from the past than Lawson's privatisations of the 1990s, a point that prepares us for the equally surprising fact that as early as 2001, when privatisation culminated in the introduction of the New Electricity Trading Arrangements (NETA) and bilateral trading in electrical energy, the drift back towards state management had already begun. Indeed, it seems reasonable to identify the Royal Commission on Environmental Pollution report of 2000, The Changing Climate (RCEP 2000), not only as the herald of climate policy, but also of a return to the view that electricity constituted a 'national problem' best handled by the state. This tendency rapidly gathered pace, though obscured by repeated governmental claims to be only guiding a liberal market, and by 2014, a significant and growing part of the total charge to the electricity consumer was not the result of the wholesale market, but of climate and other state policies, including the Climate Change Levy (2001), the Renewables Obligation (RO) (2002), the EU Emissions Trading Scheme (2005), the Feed-in Tariff (2010), and numerous cross subsidies from one set of consumers to another to fund energy efficiency and related social measures. Indeed, government itself estimated that in 2014, 17 % of the retail price to domestic households, for example, resulted from policies rather than the wholesale market (£164/MWh as compared to £140/MWh without policies) (DECC 2014). By 2020, the Department estimated that this would have risen to 27 % of the price of electricity in the central fossil fuel price scenario, and still higher fractions in the low fossil fuel price scenario. These fractions, it should be remembered, are based on the direct subsidy or cost impacts only, and do not include system and other management costs imposed by the renewables policies.

It is now clear that this phase is coming to an end, and that a return to liberalisation is the intention of the current government, though this is recognized as being a medium-term goal. As Amber Rudd puts it in her speech:

> We want to see a competitive electricity market, with government out of the way as much as possible, by 2025. Getting there will not be easy. The process of privatisation itself spanned five Parliaments. (DECC 2015b).

Indeed, judging from the policy measures currently being proposed by the government 'Getting there', will involve a great deal of further state involvement as part of transitional arrangements intended to correct previous errors. The government's freedom of movement is further constrained by the UK's commitments under the European Union's Renewables Directive of 2009, and the strength of the UK's commitment to this Directive is questionable in the light of these difficulties.

3 The UK and the European Union renewables directive (2009)

The EU renewables directive (2009) requires that 20 % of EU Final Energy Consumption, across all sectors, heating, transport, and electricity, should be renewable by 2020, with transport having a mandatory level of 10 %. The United Kingdom's burden share entails that 15 % of its FEC should be renewable by the target date, one of the larger proportionate increases amongst the major economies, up from 1.5 % in 2009, and with the implication of disproportionately high costs. Indeed, the UK government analysis during the negotiations in 2007 preceding the Directive calculated that upwards of 25 % of the EU wide costs of the policy would fall on the UK alone.[1]

FEC in 2020 is, of course, uncertain, but we can estimate that the UK would need to generate approximately 230–270 TWh of renewable energy along the following lines:

Transport fuel: 45 TWh (10 % of UK transport fuel).
Electricity: 120 TWh ($\sim$30 % of UK electricity).
Heating and cooling: 70 TWh ($\sim$12 % of UK heating and cooling).

It has already been noted that both Final Energy Consumption and electricity consumption are falling in the United Kingdom. This is mixed blessing: on the one hand, it reduces the quantum of renewable energy required; on the other, because

[1] The 25 % figure is a government estimate contained in a document leaked from within the department of Business Enterprise and Regulatory Reform in 2007 (BERR 2007). The text is published on the Guardian website: (http://image.guardian.co.uk/sys-files/Guardian/documents/2007/08/13/RenewablesTargetDocument.pdf) Note that the European Commission estimated the total cost to the EU of the renewable energy target at 24 billion euros in 2020 (See Table 4???). BERR thought that this was an underestimate, but also estimated the costs to the UK at some £6–10 bn (see Table 3, but note that the table unfortunately transposes the figures for a 14 and a 15 % target).

the UK has been planning to rely very heavily on renewable electricity, with a large pipeline of construction that can only be restricted with difficulty, it implies that a very much larger share of electricity consumption will be taken by renewable generators, with significant technical implications and a detrimental impact on the economics of those generators meeting the residual load and guaranteeing security of supply.

Nevertheless, electricity is the core of the UK's attempts to comply with the Directive, and efforts have not been half-hearted. Government has employed a series of policies that coerce the economy into purchasing renewably generated electricity at an above market price, starting with the Renewables Obligation (RO) in 2002, a scheme that will close to new entrants in 2017 and be replaced with a scheme of Feed-in Tariffs with Contracts for Difference (so-called CfDs). A separate system of feed-in tariffs aimed at smaller developments, though open to projects with an installed capacity as large as 5 MW, was initiated in 2010. The annual additional cost of these schemes to the consumer is charted in Fig. 4.

The total, cumulative, cost from April 2002 to March 2014 is approximately £19.6 billion. Her Majesty's Treasury introduced a limit to this spending, the Levy Control Framework (LCF), starting in 2011, with a Framework cap to spending in 2020 of £7.6 bn a year (equivalent to about 0.5 % of the current UK GDP).

Such subsidy expenditures have ensured that there has been a very rapid progress towards the renewable electricity target, as can be seen from Fig. 5.

In 2010, the United Kingdom was not on track to meet the 2020 target, but the sector expanded rapidly in the period 2010–2014, probably in response to increased subsidies for off-shore wind, and continued support from the Liberal Democrat-led Department of Energy and Climate Change during the Coalition Government, which was widely perceived as sheltering the sector from the Treasury's attempts to limit spending.

On the basis of the present trends, it seems reasonable to conclude that the UK will meet the electricity share of the target. Indeed, reference to project pipeline data suggests that the scale of development exceeds that required by a large margin. Table 1 uses data from DECC's Renewable Energy Planning Database (REPD) to calculate the likely output from all capacity that is either operational or under or awaiting construction. In other words, it estimates output from all projects that have already received land-use planning consent from the relevant governmental authority. Table 1 also gives data for the capacities still seeking such planning consent.

There is 54.6 GW of capacity with planning consent, of which 23.2 GW is operational and 31.4 either under or awaiting construction. A further 11.6 GW is awaiting a planning consent decision from the relevant governmental authority.

The output from the consented capacity would be approximately 149 TWh, some 35 % in excess of the 110-TWh target for electricity. If all these capacities were constructed and subsidized at current levels, the cost would overshoot the Levy Control Framework (LCF) by about £2 billion (30 %). The principal causes of this overshoot are growth in solar photovoltaic, which at 9.6 GW consented, is now over 6 GW in excess of that anticipated in the National Renewable Energy Action Plan (NREAP); and off-shore wind, which at 20 GW consented, is now 7 GW in excess

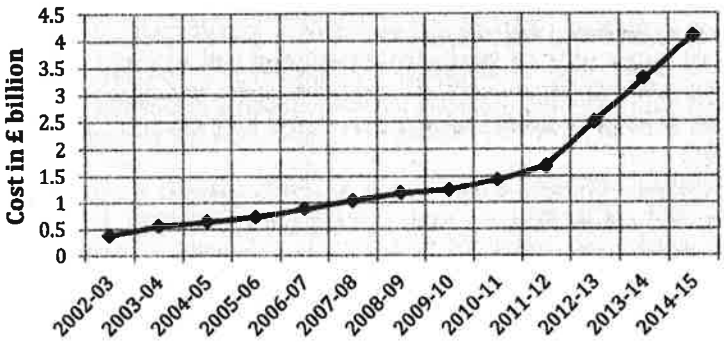

Fig. 4 Renewable electricity subsidy cost 2002/3–2014/15 Source: DECC, Ofgem. Calculations and chart by authors

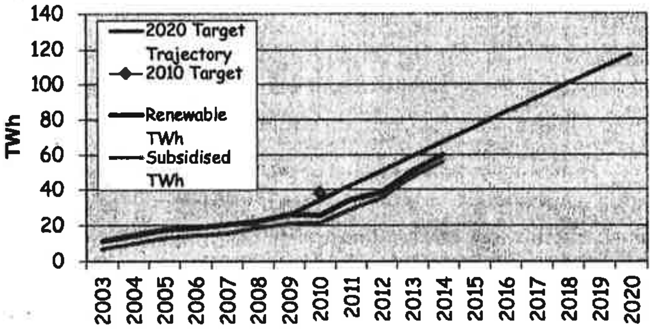

Fig. 5 Renewable electricity generation (TWh) in the United Kingdom Source: DECC, Ofgem. Calculations and chart by the authors. The *blue line* represents total renewable electricity; the *green line* shows the subsidized component. The *orange diamond point* represents the 2010 renewable electricity target, which was missed, and the *red line* the trajectory needed to meet the electricity contribution to meeting the EU Renewables Directive (2009) in 2020

of that anticipated in the NREAP. On-shore wind is already at the upper level anticipated for 2020, 15 GW, and there is, as can be seen, a further 6 GW seeking planning consent.

In earlier work for the Renewable Energy Foundation, we estimated the cumulative subsidy cost (i.e., over and above the cost of the conventional energy) of meeting the electricity component of the UK's commitment under the EU Renewables Directive at about £160 billion from 2002 to 2040, even conservatively assuming that while no new subsidies were available after 2020, existing contracts would be honoured (Renewable Energy Foundation 2011). An overshoot of £2 bn in 2020 would add, very approximately, a further £40 bn to the cumulative cost.

The new Conservative government appears to take the Levy Control Framework seriously, and some degree of negligence in previous administration is implicit in Amber Rudd's remark that she had "inherited a department in which policy costs on

Table 1 Renewable energy capacities, operational, under, or awaiting construction, and in the planning system Source: Department of Energy and Climate Change (DECC) online Renewable Energy Planning Database (REPD), for December 2015, accessed 16 January 2016; and DECC's latest renewable sources data (Table 6.7 in DUKES 2015 Chapter 6: Renewable Sources of Energy) and the UK National Renewable Action Plan (NREAP)

	Biomass	Hydro	Solar	Marine	Waste	Off-shore wind	On-shore wind	Total
Operational (GW)	2.9	0.5	5.2	0	0.9	5.1	8.6	23.2
Under construction (GW)	0.5	0	0.5	0	0.2	0	2.1	3.4
Awaiting construction (GW)	3.7	0.1	3.9	0.5	0.7	14.9	4.2	28
Total consented capacity (GW)	7	0.6	9.6	0.5	1.9	20	15	54.6
Submitted to planning (GW)	0.2	0	1.9	0	0.1	3	6.4	11.6
Load factor	62 %	35 %	9 %	7 %	38 %	35 %	26 %	NA
Est. output from consented capacity (TWh)	38.1	1.7	7.5	0.3	6.1	61.2	33.9	148.9
Est. output from in-planning capacity (TWh)	1.2	0	1.5	0	0.2	9.2	14.4	26.6

Assumed load factors are then used to calculate probable outputs from the consented capacity, i.e., all that with formal planning permission from the relevant state authority

bills had spiralled". Indeed, the principal proximal goal of her renewable policy changes is to bring costs back within the Treasury limits, but it remains to be seen whether the reductions in subsidies and early closure of schemes will be sufficient to discourage the surplus generation capacity already consented from proceeding to construction before the RO closes in 2017. After that time government has more control over subsidy costs, since the granting of CfD contracts is at their discretion. Assuming that these measures are successful, some grounds for concern remain. First, according to the Department's own modelling, the impact of renewables subsidies will have a very significant impact on electricity prices and consumer bills even in the High Fossil Fuel Price scenario, where policies were expected to increase electricity prices to domestic households by 30 % in 2020 (£217/MWh as compared to £168/MWh), and prices to medium-sized businesses by 45 % (£152/MWh as compared to £105/MWh) (DECC 2014). In the Low Fossil Fuel Price scenario, which now seems more probable than not, the household impact would be to increase prices by 42 % (£186/MWh as compared to £131/MWh), and the impact on medium-sized businesses an increase of some 77 % (£122/MWh as compared to a pre-policy price of £69/MWh). Indeed, it was a commonplace of analysis before 2015 that the UK renewables policy was in effect a wager on the future price of fossil fuels, and one interpretation of the present redirection of policy is as a discrete admission that this bet has been lost.

4 UK electricity generation capacity

The activity visible in the renewables sector contrast sharply with that in the conventional generation, where there is a very little development at all, and in which, capacity margins over peak load on the GB network are now at low levels. Indeed, one clear intention of Amber Rudd's speech is to add rhetorical support to other government measures aimed at drawing private investment into the construction of new gas generation in the short and medium terms, and nuclear, thereafter, to ensure secure electricity supplies.

4.1 The capacity crisis?

All casual discussions of the 'electricity crisis' begin with the question of 'keeping the lights' on; in other words, a doubt as to whether there is sufficient generation capacity to meet instantaneous load, a question that is all the more exciting and novel, since system reliability in the UK over the last 40 years has been, industrial action aside, generally excellent. However, this has not always been the case, and as Hannah observed in his standard history, in the years immediately post-war "[...] demand sometimes exceeded the capacity available to meet it, with very slender margins of capacity over potential load. As a consequence, both power cuts and voltage reductions were essential". It was against this background, and in the knowledge that other systems in the world operated with larger margins, that a more generous provision was planned from about 1968 onwards (Hannah 1982). Consequently, margins during the Central Electricity Generating Board (CEGB) period were uniformly large, around 30 % and sometimes much higher. This

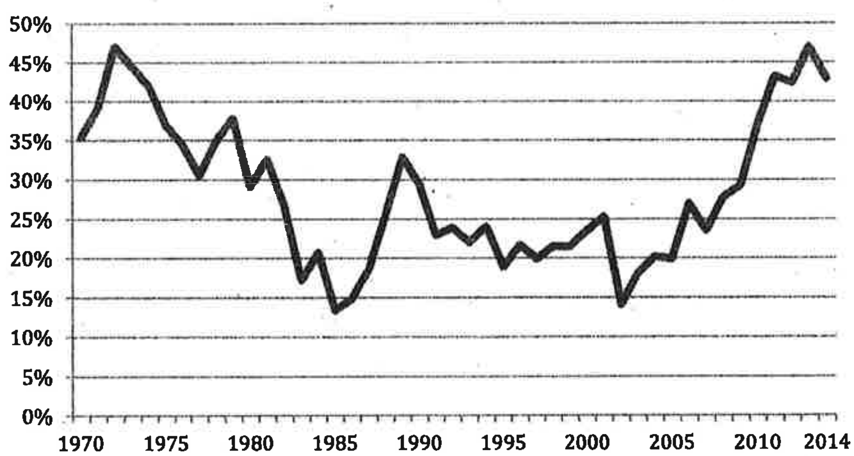

Fig. 6 Capacity margin (%) in the United Kingdom, 1970–2014. Calculated as the margin Total Declared Net Capacity (DNC) over the simultaneous maximum load met on the system in that year Source: DECC (2013). Chart by the authors

arguably too conservative level was gradually reduced, as can be seen in Fig. 6, with the process beginning well before the privatisation often identified as the cause. Indeed, if anything, the Dash for Gas of the 1980s seems to have bolstered the capacity margin.

A glance at this chart might suggest that there is no particular problem at the present, since the capacity margin seems to have been growing steadily since 2002, with current levels comparable to early 1970s, partly as a result of falling peak load and partly as a result of new power plant construction. To be specific, in 2014, there were power stations with a Declared Net Capacity (DNC) of some 77 GW, against a peak load of about 55 GW (down from 60 GW in 2005). Current concerns arise from the fact that much of the new capacity is non-firm wind and solar generation and so variable and uncontrollable and, consequently, has a low probability of generating at a specified output at any specified time, peak load on a dark cold windless, and winter's afternoon for example.

At the time of writing (January 2016), the UK has a total operational renewable electricity fleet of about 23 GW, of which 80 % is not firm (5 GW of solar; 13 GW of wind, on-, and off-shore). A further 31.4 GW of capacity is under or awaiting construction, of which 80 % is not firm (4 GW of solar; and 21 GW of wind, on-, and off-shore).[2] In other words, of the over 54 GW of renewable electricity capacity consented since 2002, over 80 % (44 GW) contributes little or nothing towards the capacity margin. Thus, in spite of quite remarkable rates of construction, and major capital investment (ca. £40bn), the renewables explosion has done little to address the need for new firm capacity required to replace the conventional oil, coal, and nuclear power stations as they retire.

This problem has been well understood for some time, and analysts have been remarking on the matter, since the rapid development of renewables first began in response to the introduction of subsidies under the Renewables Obligation in 2002. EdF, one of the Big Six vertically integrated electricity companies, was amongst the first in the field, providing crucial data in evidence submitted to the government's "Energy Review" of 2006, data that predicted a rapid decline in the conventional generation:

> The UK is facing an electricity generation capacity shortage during the next decade as coal- and oil-fired power stations close, largely in response to new environmental controls imposed by the Large Combustion Plants Directive (LCPD), and as gas cooled nuclear power stations reach the end of their useful lives. [...] Between now and 2016, 13 GW of coal and oil plant that have "opted out" of the LCPD will close. "Opted in" coal plant may also be closed by 2016 depending on the economics of fitting further equipment to reduce emissions of nitrogen oxides—for which new limits are to be introduced after 2015. 7.5 GW of nuclear closures is scheduled by 2015. [...] The UK will have a generation gap of 32 GW in 2016, assuming moderate demand growth and expected growth in renewables in line with the Renewables Obligation

[2] Calculated from data collected by DECC for the Renewable Energy Planning Database, and reprocessed by the Renewable Energy Foundation at www.ref.org.uk: http://www.ref.org.uk/planning/index.php.

(RO). Even under very optimistic scenarios regarding grid electricity demand reduction, the generation gap will still be 25 GW in 2016 (EdF 2006, 12).[3]

These concerns quickly became mainstream, and in 2009, the regulator Ofgem initiated 'Project Discovery', a "year-long study of whether the current arrangements in GB are adequate for delivering secure and sustainable electricity and gas supplies over the next 10–15 years" (Ofgem 2010). Ofgem reported on this work in February 2010, and "identified a number of concerns with the current arrangements and have concluded that a significant action will be called for given the unprecedented challenges facing the electricity and gas industries" (Ofgem 2010, 1), one of the principal concerns identified being lack of capacity:

> Short-term price signals at times of system stress do not fully reflect the value that customers place on supply security which may mean that the incentives to make additional peak energy supplies available and to invest in peaking capacity are not strong enough (Ofgem 2010, 5).

In its latest report on the subject, Ofgem expects there to be some 71.6–75.3 GW of capacity, depending on scenario, in 2017/18, of which only 58–61 GW will be firm capacity. Consequently, the capacity margin will range from −1.9 to 5.1 % depending on scenario, which is low by most standards (Ofgem 2015a, 14).

Given the clear need, it is reasonable to wonder why so little conventional capacity reached Final Investment Decision. The explanation lies partly in the opportunity cost of broad-scale renewables development, which has absorbed a large part of the capital available for power sector investment, but the principal cause is that the presence of so much subsidized renewable generation has weakened investment signals for, otherwise, fundamentally economic technologies. Ofgem itself notes:

> Capacity in the market has continued to drop, since last year's assessment. National Grid now expects a net reduction of around 4 GW of installed capacity between winter 2014/15 and 2015/16. This is a 2-GW net reduction compared to the expectations in Future Energy Scenarios 2014. National Grid projects this reduction is mainly caused by gas-fired plants leaving the market either permanently or through mothballing, due to poor plant economics (Ofgem 2015a, 14).

In other words, gas plant has become uneconomic, because the electricity market has been coerced into accepting so large a share, some 20 % in fact, of subsidized renewables that gas-fuelled generators are no longer able to recover their costs of operation. In fact, Combined Cycle Gas Turbines (CCGT), which are technically capable of a 90 % load factor, have in the last few years been compelled to run at a level that DECC itself concedes is about 30 % (DECC 2015a, 122). Load factors this low inevitably make investment in and even the operation of existing CCGTs unattractive. Furthermore, with renewables poised to take still larger shares of the market, investment in the conventional plant becomes extremely unlikely.

[3] EdF's work, and that of others is reported and analysed in Sharman and Constable (2009), 1–4. See also Sharman and Constable (2008).

The present Secretary of State for Energy and Climate Change, the Rt Hon Amber Rudd MP, recognizes this in the reset speech with which this discussion began:

> We now have an electricity system where no form of power generation, not even gas-fired power stations, can be built without the government intervention (DECC 2015b).

In effect, by distorting the markets so extensively with subsidies to renewables, the government has driven conventional, firm generation from the market, and so reduced the capacity margin to uncomfortable levels. Government has, thus, been obliged to introduce expensive system management tools to guarantee security of supply. In effect, having damaged the market with subsidies to one sector, it is now compelled to introduce a Capacity Mechanism, to subsidise the conventional generation that in an undistorted market would be fundamentally economic and spontaneously attractive.

4.2 Future electricity demand

Of course, the question of where there is sufficient plant in the system to meet load relies crucially on projections of future demand. Obviously, if electrification had continued to grow there would have had to be a major expansion of generating capacity, probably not dissimilar to that predicted by Bending and Eden, whose 1984 study, UK Energy, foresaw consumption of about 452–666 TWh per year in 2020 and a fleet of between 113 and 166 GW (Bending and Eden 1984). Even in 2006, as noted earlier, EdF expected moderate demand growth. However, load and demand have not grown, leaving analysts with the uncomfortable necessity of hedging. As Ofgem wrote in its recent Security of Supply Report of the approaching winter of 2016/17, "our assessment is that there is potential for the risks to be managed by either a strong market response or a continued reduction in demand" (Ofgem 2015a, 4). In other words, if load and demand return to growth, there would have to be a strong market response if the government's security of supply standard, a Loss of Load Expectation (LOLE) 3 h per year (i.e., 0.03 %), is to be satisfied, but if the trend is towards further reductions in demand, then no additional market response will be called for.

However, electricity demand forecasting is notoriously difficult over anything longer than a few years, and reference to earlier projections, such as those of Bending and Eden, which are impeccably reasoned, should be fair warning. With this sort of background, no current public decision maker can afford to gamble on future demand staying low. Since 2013, three mechanisms have been introduced to allow National Grid to address the increasing risks to security of electricity supply:

1. Supplemental Balancing Reserve (SBR), which is a scheme in which power stations that would, otherwise, close or be mothballed contract to be available at a specified time (at present described as weekdays in winter between 18.00 and 20.00) (National Grid 2014a).

2. Demand Side Balancing Reserve (DSBR) is a scheme, in which large energy users can contract to reduce their energy demand in return for payments from the consumer, via National Grid (National Grid 2014a).
3. The Capacity Mechanism (CM) is a scheme under which a power station, new or old, receives a guaranteed income, in effect, a retainer, irrespective of the energy (MWh), it generates, and in return undertakes an obligation to supply capacity (MW) on request (National Grid 2014b).

SBR and DSBR are already active, and have been employed in winters 14/15 and 15/16, while the CM will become active in 2018/19. In passing, it is worth noting that while all three are implemented in such a way that they retain elements of competition, via auctions, they have the general consequence of reducing competition in the electricity markets, and accelerating the trend towards administrative pricing noted above. While arguably necessary in the short term, it is doubtful whether this is in the longer term interests of the consumer.

However, these mechanisms are powerful and can address the difficulties insofar, as they can be foreseen. One of Ofgem's principal findings in its most recent review is that without the SBR and DSBR, LOLE fails to meet the government's Reliability Standard in 2015/16, potentially reaching levels of as many as 20 h of interrupted supply, with a capacity margin of around 4 % or less, and with the possibility of it running into negative numbers. However, with the special measures now available, the LOLE falls to around 4 h, or less, and the margin to around 6 %, and no less than 3 % (Ofgem 2015a, 12).

Nevertheless, it is worth noting that the measures are not resulting in comfortably high margins, and, indeed, the situation in 2016/17 deteriorates, and margins are predicted to vary between 0 and 4 % in spite of the available measures, though in 2017/18, the outlook improves as the Capacity Mechanism brings mothballed firm generation plant back into service. Even so, margins are still hardly impressive, with Ofgem only feeling able to predict a margin of about 3–7 %, and LOLE "broadly [...] within the government's reliability standard". This qualified result is disappointing given the costs of the mechanisms, to which we will now turn, putting them into the context of current and earlier Balancing Services Use of System Costs (BSUoS).

4.3 Balancing services use of system costs

The UK System Operator, National Grid, must correct for errors in the demand and generation forecast, and also for congestion in the transmission network. These include purchasing additional generation at short notice, as well several other ancillary services (National Grid 2015b). The cost of these services, which are known as Balancing Services Use of System (BSUoS), and National Grid's own administration costs and profit, are initially charged to generators and to electricity suppliers, though, obviously, ultimately recovered from electricity consumers (National Grid 2015a).

Fig. 7 tracks Balancing Services Use of System (BSUoS) charges since 2001/2.

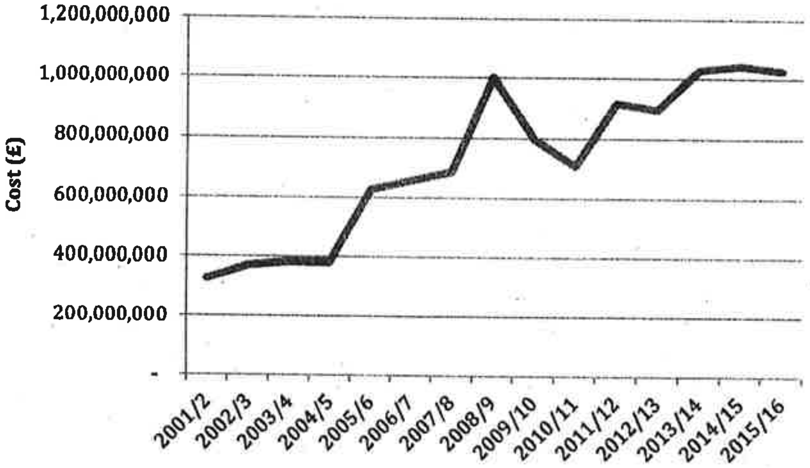

Fig. 7 Balancing services use of system (BSUoS) costs (£) 2001/2 to 2014/15 Data source, 2001/2–2014/15, current and historic datasets available at: http://www2.nationalgrid.com/bsuos/. Data for 2015/16, from National Grid (2015c), 39. Chart by the authors

BSUoS costs have increased by a factor of three in the decade 2001–2012, a point that is all the more remarkable against the backdrop of falling demand, meaning that the BSUoS cost per unit of electricity carried through the system-to-consumers has increased by a factor well in excess of three, and has now reached levels of about £3.5/MWh.

Constraint, i.e., congestion, costs account for a large part of the increase of BSUoS costs, and the rapid rise in constraint costs is largely caused by the rapid expansion of the on-shore wind power fleet located north of the Anglo-Scottish border, which is a major grid bottleneck separating these generators from the centres of load in England. The problem is simply that wind power generation often exceeds demand in Scotland, but cannot be exported to England, in spite of being contracted into the market. Consequently, National Grid must curtail wind output to protect the system. Wind loses its subsidy income, about £45/MWh, when it is curtailed, though it retains its wholesale payment. Consequently, National Grid must compensate wind generation for this lost income. However, and arguably, because wind generators are aware of their market power, this payment usually exceeds the subsidy lost. Indeed, when these payments began in 2011, some wind farms asked for and received very high prices, some as high as £999/MWh, twenty times the lost income, and though these fell sharply as the result of adverse publicity in the national press, current prices still exceed lost income, with the publicly controversial result that wind farms make more money when discarding their energy than when they sell it to consumers. Furthermore, volumes continue to grow sharply. 2015 was a record year, both in total payments to wind power and in volumes of energy, as can be seen in Table 2.

Table 2 Constrained off volumes of wind energy and payments to wind generators in the United Kingdom, 2011–2015 Source: Fundamental data from BM Reports: reprocessed and analysed by the authors. For latest data, see also www.ref.org.uk

Year	Cost (millions)	GWh	Average price £/MWh
2011	£12.8	59	£218
2012	£5.9	45	£130
2013	£32.7	380	£86
2014	£53.2	659	£81
2015	£90.5	1,274	£71

The total volume constrained off in 2015, 1.27 TWh is approximately 7 % of total on-shore wind energy generated in the UK (roughly 19 TWh per year at present), and the payments to wind alone are nearly 10 % of current BSUoS costs.

It should be noted, of course, that when wind is constrained off in Scotland, the market is, consequently, out of balance, and the conventional generation must be constrained on south of the constraint to rectify this error. This cost is not included in Table 2, and is extremely difficult for those outside National Grid to estimate, but since these conventional generators are being asked to respond at short notice, the cost can not be low, and will constitute a significant fraction of the now £1bn a year total BSUoS cost.

An obvious means of reducing such constraint payments is to add new grid and reinforcements to alleviate the bottlenecks, and this is currently occurring. However, while BSUoS may now fall, as constraint payments are eased by the construction of these grid reinforcements, including subsea High Voltage Direct Current (HVDC) cables on the eastern and western sides of Scotland (Ofgem 2015c), overall costs to consumers will probably not fall, since the capital cost of these new lines and reinforcements must also be recovered from consumers at a rate of between 5 and 10 % of the capital cost for the life of the assets, say 30 years, and this annual cost is unlikely to be less than hundreds of millions of pounds a year. Indeed, it is conceivable, perhaps, likely, that overall cost to consumer may exceed that of constraint payments, since under-utilised grid is almost certainly a less efficient way of dealing with the overbuild of Scottish wind power than constraint payments.

Furthermore, the special instruments introduced by National Grid are themselves expensive. SBR and DSBR, which are holding the fort, while the Capacity Mechanism is implemented, cost £31.3 m in 2014/15, £34.7 m in 2015/16, and National Grid has successfully requested that both schemes be extended to 2017/18 (Ofgem 2015b). While this cost will presumably lapse when the CM starts, the overall cost to consumers will not fall. The Office for Budget Responsibility has estimated that in its first year, 2018/19, the CM will cost some £600 m. In 2019/20, this expected this to rise to £1.1bn and then to £1.3bn in 2020 (OBR 2015). These estimates would appear to be approximately correct. The first auction, for the year 2018/19, secured 49,300 MW at a cost of £19,400/MW, giving a total cost of £956 m (DECC 2015d). The second auction, for the period 2019/20 secured

46,534 MW at a price of £18,000/MW, giving a total cost of £834 m (DECC 2015c). Thus, the total cost is approximately £1.79bn for just one element of BSUoS for these 2 years, 2018/19 and 2019/20, almost exactly the OBR's estimate.

These costs are all the more striking when it is recalled that before the current energy and climate policies began to bite, i.e., before 2002, BSUoS was in total costing £300 m a year, and that the need for the services covered by that charge, for instance, Frequency Response and Black Start have not disappeared. The CM costs are additional to the earlier BSUoS costs and do not replace them.

None of this is really surprising, and many analysts foresaw the problems. In 2011, work by the present authors for the Renewable Energy Foundation used work written for the Institute of Engineers and Shipbuilders in Scotland (IESIS) by Mr Colin Gibson, former Power Networks Director (PND) at National Grid, to estimate that the systems costs of the renewables target alone would put an additional £5bn a year, on the national electricity bill, including additional rapid response plant to cover errors in the wind forecast, additional grid, and grid reinforcements, and the additional cost of running at low load factor a conventional generation fleet equivalent to peak load (plus a margin) to guarantee security of supply (Renewable Energy Foundation 2011).

Additional costs of this kind add to concerns about the cost of reducing emissions from the current policies, and it is to this subject that we will now turn.

5 Emissions abatement costs in the UK

Table 3 calculates the subsidy cost per tonne of carbon dioxide saved by the various renewable technologies in the United Kingdom, assuming that each MWh of renewable electricity displaces grid average emissions of approximately 0.5 tonnes of carbon dioxide, a generous assumption, since renewables tend to displace gas in

Table 3 Estimated abatement costs per tonne of carbon dioxide in the United Kingdom Source: Calculations by the authors from subsidy and grid average abatement figures from the United Kingdom's Department of Energy and Climate Change and the Department of Environment Food, and Rural Affairs (DEFRA); where multiple costs per tonne of CO_2 appear, this reflects the increasing level of subsidy as the size of the generator decreases

Technology type and band	Subsidy cost per tonne CO_2
Roof mounted solar PV	\$380–\$1450
Free-standing solar PV	\$228
Small on-shore wind (<500 kW)	\$608
Large on-shore wind (>1 MW)	\$137
Off-shore wind	\$274
Dedicated biomass	\$198
Hydro	\$0–\$137–\$684
Anaerobic digestion	\$274–\$380
Incinerated municipal biomass	\$0

the UK, with much lower savings. Conversion to dollars has been made assuming an exchange rate of $1.5 to the pound.

If we add system costs to these subsidy costs; then, the cost per tonne on-shore wind, for example, rises to about $350/tonne, and that for off-shore to about $470/tonne. The system costs of solar in the UK are not sufficiently well understood to permit analysis, but we can be reasonably certain that they will add significantly to the total abatement cost.

Such costs can be compared with the estimates of the Social Cost of Carbon (SCC), for example, in Marten (2011), which suggests a range of \$0–\$206/tCO_2. In work by the Environmental Protection Agency of the United States government, which finds SCC ranging from $12 per tonne to $120 per tonne in 2015, depending on discount rate, and $29–$240 per tonne in 2050 (United States Environmental Protection Agency 2015).

Even at the upper ends of the SCC estimates, the costs of abatement from the major renewable energy technologies do not appear spontaneously compelling. Indeed, it would appear to be rational to prefer climate change and its harms to the economic harm resulting from the costs of adopting renewables.

In other words, efforts to drive low carbon energy into the sector with subsidies that simultaneously increase the costs of the conventional generation or otherwise disadvantages conventional generation and discourages investment in that sector are, from the perspective offered in this paper, simply mistaken, and will all, however, inevitably put the low carbon agenda on a collision course with the human desire to seek greater wellbeing for themselves and their offspring. This is the clear microcosm in the UK case, where the additional costs implied by renewable electricity will be about £14 billion a year (i.e., £7.6bn plus £5bn system costs plus VAT), equivalent to just under 1 % of the current GDP. Such costs will be damaging in themselves, but will also drive the UK further towards de-electrification, a phenomenon that is already observable in the data and which raises grave doubts about the fundamental health of the UK economy.

6 Conclusion: high cost explains new directions

This paper began by remarking on the Secretary of State for Energy's announcement of a new direction in energy and climate policy. We can now see that this is in essence a response to economic problems arising from the current policies, problems that have been neglected under previous governments, and are now pressing. The UK government has very little room for manoeuvre or further delay. However, as noted above, this does not imply a rejection of climate change concerns, for as the Secretary of State remarked in her speech,

> Our most important task is providing a compelling example to the rest of the world of how to cut carbon while controlling costs. [...], it is not clear we have done that so far (DECC, 2015b).

While it is rational to have an insurance policy against climate change, that policy can only offer real cover against the hazard if it is compelling to others, and consequently, the policy must pass two fundamental tests: The premium must be intrinsically affordable and proportional to the risk (i.e., the scale of the hazard multiplied by its estimated probability). The UK's policies do not appear obviously satisfactory by such standards, and should, therefore, be redesigned. In this light, perhaps, the most encouraging remarks of all in Rudd's speech were those which admitted in clear terms what many others; for example, the authors of a series of papers issued under the aegis of the Hartwell Group (Prins et al. 2013) have been urging for some time, namely, that current low carbon technologies are neither adequate nor affordable and that an aggressive invention and innovation policy is required. As Amber Rudd put it:

> Let's be honest with ourselves, we don't have all the answers to decarbonisation today. We must develop technologies that are both cheap and green.[4]

What the UK will do to transform this recognition into practical policy is far from clear. A revenue neutral carbon tax might well be best from a theoretical perspective, but increased R&D funding, with all the risks of waste and ineffective targeting that this brings, is likely to be more politically probable in the short term. However, it is, perhaps, significant that the Secretary of State went out of her way to comment on the EU Emissions Trading Scheme (ETS), and to say that in spite of its flaws, it represented the best chance for co-ordinated action at the European level, and that her government was committed to restoring the ETS to "full health". This may be taken as an indication of a growing preference within government for carbon taxation to provide a signal for invention and innovation, rather than an attempt to deliver set volumes of emissions savings through the subsidized deployment of existing technologies.

The largest question hanging over this policy reset is whether the realisation of the ambitions will be adequate to the task, particularly in the light of low fossil fuel prices. It is conceivable that retrospective cuts in subsidies to renewables will be required, and though the removal of the Climate Change Levy exemption is a precedent, such moves would be legally very complex and may not be possible so long as there is a commitment to renewable targets as part of climate policy at the European level. Assuming that the UK does not vote to leave the EU in the 2016 referendum, it seems certain that energy and climate will be a focus for a restoration of national self-determination in any negotiations between Westminster and Brussels.

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