UK Wind and Solar Power - variability and management

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Summary

The UK has set legally binding targets for a reduction in Greenhouse Gas (GHG) emissions of 78% by 2035 and of net zero emissions by 2050. A substantial element of achieving these goals is through large increases in wind and solar power. The supply of both of these power sources is highly variable, so measures will need to be taken both to balance supply and demand in order to avoid wasting power during periods of high variable power supply (known as curtailment) and also to reduce the amount of dispatchable (e.g. gas fired) generating capacity required from other power sources in periods of low variable power supply and/or peak demand.

Although published reports recognise that wind and solar are variable/intermittent sources of energy, this paper uses published data to quantify the considerable periods during which these renewables will be below and above anticipated demand.

In order to manage this variation in supply, the paper proposes the substantial use of:

- Battery electric vehicle (BEV) batteries to shift renewable power both:
    - to significantly reduce the peak capacity required of dispatchable power
    - to use variable renewable power, that would otherwise be wasted, to displace high carbon power and/or to store power for hydrogen generation.
- hydrogen generation by electrolysis, using renewable power which would otherwise be wasted. The hydrogen can be added to, or displace continuous hydrogen supply, whether by adding to the gas grid, storing, and/or using in industry or power generation.

Time distribution curves based on half hour electricity generation data are used to show both the variability of wind and solar power generation and the total power demand for 2020/21, 2025, 2030 and 2035. BEV battery storage is determined by stepping through each half hour period, moving electricity into and out of storage as required.

The results are summarised in the table below.

The table shows, for example, that by using BEV battery storage, the required generation capacity of dispatchable power in 2035 can be reduced by 40% from 51GW to 31GW.

In 2025 EV batteries can be used to recover an additional 4.1 TWh of variable power that would otherwise be wasted, to displace natural gas generated power.

In 2035 there is surplus wind and solar power generation of 58TWh, which is 17% of the total wind and solar power generation. BEV batteries can be used to store 13 TWh of this power until it can be used for hydrogen generation. A total of 50 TWh of surplus power can then be used for hydrogen generation by electrolysis. Thus, using BEV battery storage and hydrogen generation, nearly all the surplus power can be utilised, leaving power curtailment of just 4 TWh.

Summary of results					
		2020/21	2025	2030	2035
Variable renewable power					
Solar PV generation	TWh	12	24	41	60
Wind tubine generation	TWh	65	128	200	275
Surplus wind & solar power	TWh	0	7	41	58
Surplus power/total variable generation			5%	17%	17%
Power curtailment	TWh	0	3.2	2.6	4.0
EV Batteries					
Available grid balancing capacity	GWh		91	329	629
Surplus power recovery	TWh		4.1	8.4	13
Peak demand capacity reduction	GW		10.8	11.0	20.3
Hydrogen					
Hydrogen generation capacity	GW	0	0	12	16
Power for hydrogen generation	TWhe	0	0	36	50
Electrolysis load factor				34%	35%
Other Power					
Capacity required without EV storage	GW		37	35	51
Capacity required with EV storage	GW		26	24	31
Average load factor of other power			40%	33%	34%

The recent BEIS Energy and Hydrogen Strategies include demonstration projects for vehicle to grid (V2G) charging and for blending hydrogen into natural gas. These are both vital to being able to utilise surplus renewable power generation and reduce peak demand.

However, the strategies do not appear to recognise the extent of the combined variations of wind and solar power and power demand and how this will determine optimum investment decisions. Therefore further work is needed in the following areas:

- Use of V2G charging to reduce renewable power surpluses as well as for meeting peak demand
- Building intermittent hydrogen generation capacity, using curtailment power, rather than continuous hydrogen production using electrolysis or natural gas reforming.
- Reviewing the options for investment in low carbon dispatchable power generation, required during times of low wind and solar power output, given that the average load factor for these power units will only be about 34%

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1) Introduction

The UK has set legally binding targets for a reduction in GHG emissions of 78% by 2035 and of net zero emissions by 2050. A substantial element of achieving these goals is through large increases in wind and solar power. Targets are to increase solar power by a factor of 5 and wind power by a factor of 4 by 2035, compared to 2020/21. The supply of both of these power sources is highly variable, so measures will need to be taken both to balance supply and demand in order to avoid wasting power during periods of high variable power supply (known as curtailment) and also to reduce the amount of dispatchable (e.g. gas fired) generating capacity required from other power sources in periods of low variable power supply and/or peak demand.

This paper determines the variability of wind and solar power supply and power demand, using half hour data and evaluates the measures that can be taken to manage the variability.

2) Data sources

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To determine the variation in power supply, data for all types of power generation has been taken for every half hour period during an annual period from beginning October 2020 to end September 2021. Comparison of quarterly data from Energy Trends (ref. 1), over this period with previous years, shows that data after September 2020 is not significantly affected by COVID lockdowns. Half hour data for most sources of power supply is taken from the Balancing Mechanism Reporting Service (BMRS, ref 2). Half hour data of solar PV power supply has been taken from Sheffield Solar (ref 3). Since the half hour reported data do not cover all power sources, especially for wind, the half hour figures have been scaled up to match data from Energy Trends (ref. 1),Table 6.1.

Data for future generation of renewable power are taken from the Balanced Pathway Climate Change Committee 6th Carbon budget (CCC6B, ref. 4) Figure 3.4.c. These data for current and future power generation are shown in the appendix, table A1.

It has been proposed that the variation in wind power output will be lower in the future due to a wider spread of offshore wind turbines. However, a comparison between half hourly wind data in 2016 and 2020/21 showed no change in variability, despite a 64% increase in capacity. It is also expected that the load factors of offshore wind turbines will increase from 51% in 2025 to 63% in 2040 (ref 15, table 2.4). However it is not clear how this will affect the output variability, so the variability in output in wind and solar PV power in future has been taken as being similar to the period from Oct 2020 to Sep 2021. This can be updated as more data becomes available.

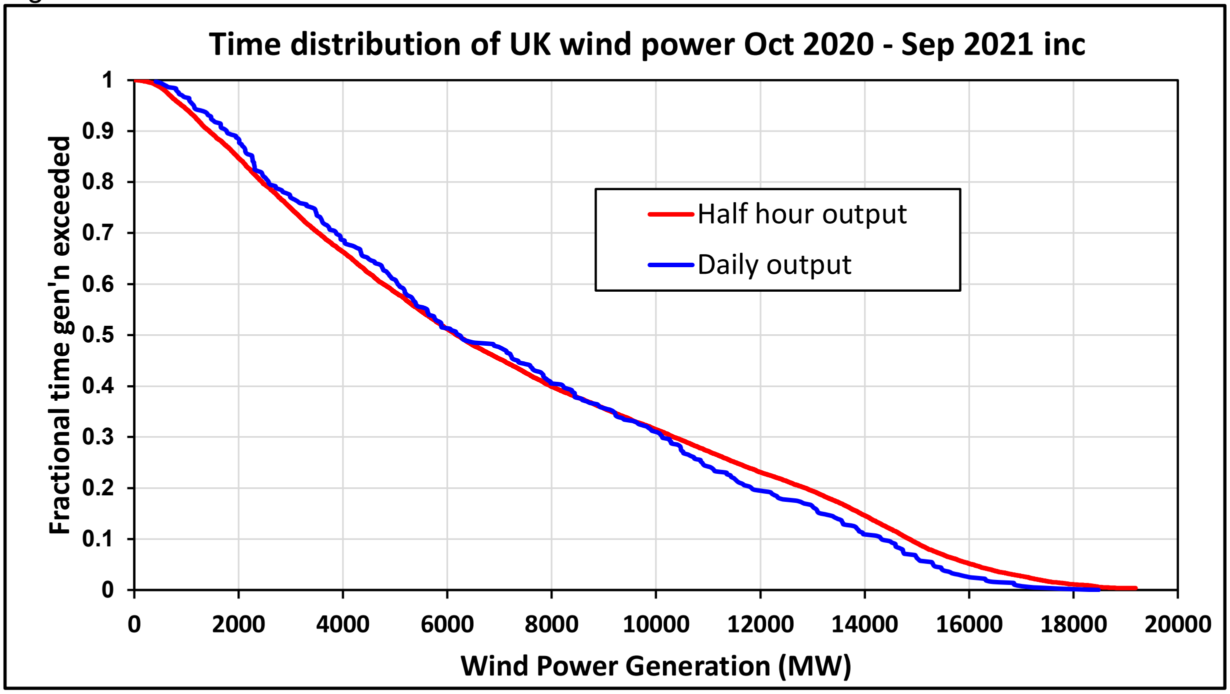
3) Wind and solar power variability

The variation in power supply and demand is shown in the form of time distribution curves. These curves, based on half hour power data, show the proportion of time that any power output or demand is exceeded.

The distribution of UK wind power output for the period Oct 2020 to Sep 2021 is shown in Figure 3.1.

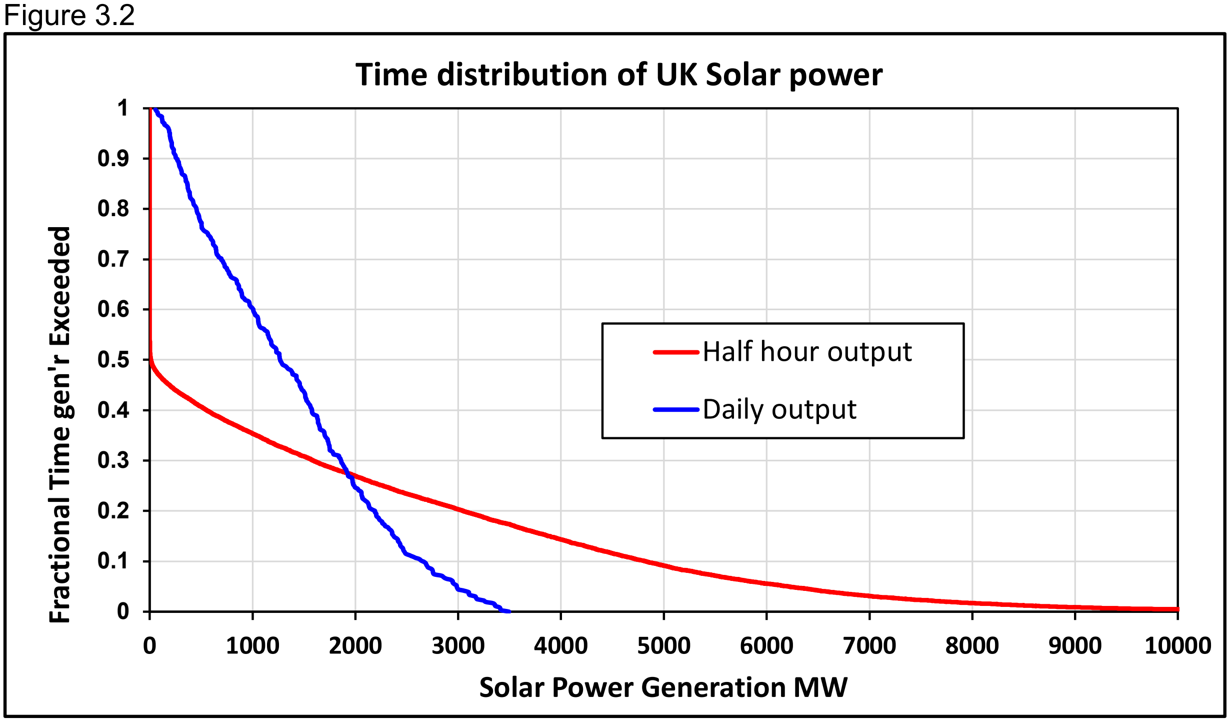
Figure 3.1 shows, for example, that a wind generation output of 8000MW is exceeded for 40% of the time. The total UK half hour wind power output varied from a low of 80 MW to a high of 19200 MW during the year. The daily power averages shows a slightly lower variation from 400MW to 18500 MW.

Figure 3.1



The distribution of solar PV power is shown in Figure 3.2.

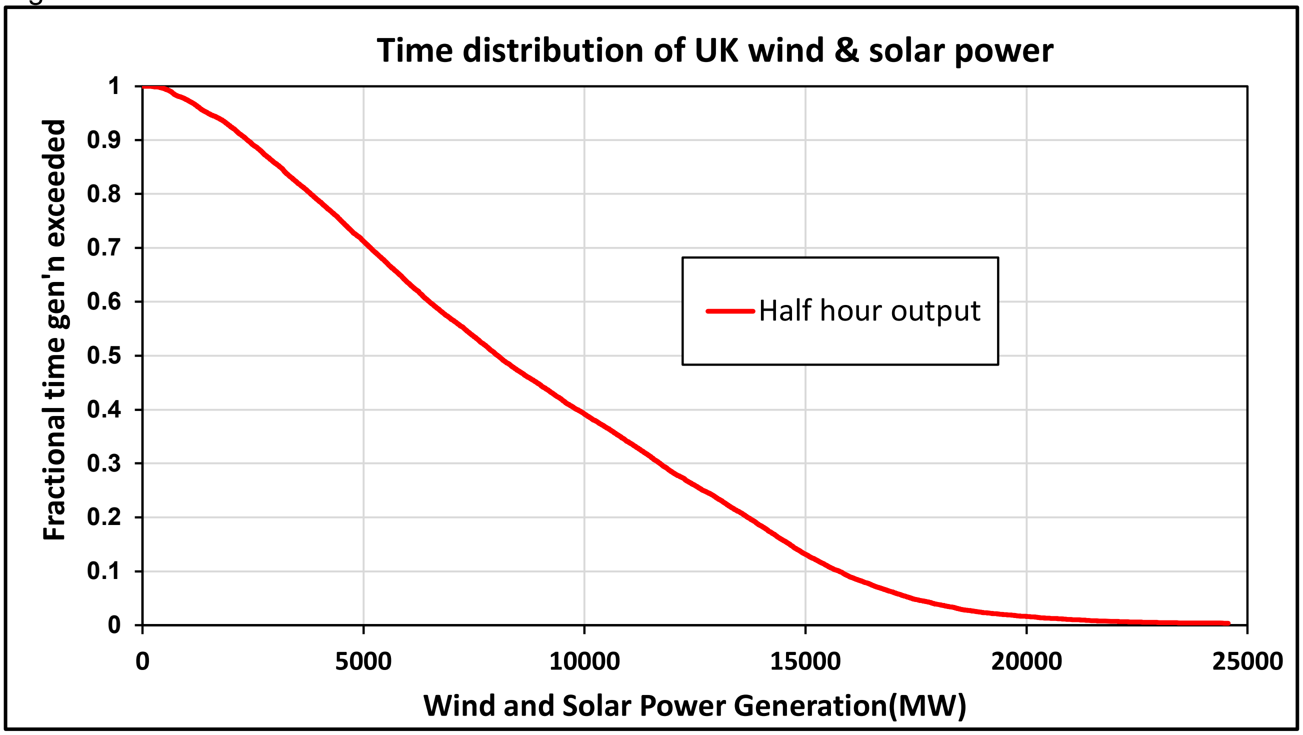
Figure 3.2



This shows a variation in half hour data from zero power for half the time up to a maximum of 10000 MW. The average daily output ranges from 50MW on some days to 3500MW on sunny days in summer.

There is a negative seasonal correlation between wind and solar power output, such that (in the winter) solar output tends to be lower when wind output is higher and vice versa in the summer. The distribution of total variable renewable power (wind + solar) output from Oct 2020 to Sep 2021 is shown in Figure 3.3.

Figure 3.3



This shows a variation in half hour output from a low of 130 MW to a high of 24500 MW.

4) Power demand and net supply variability

The power demand (including losses) is assumed to be equal to the power supply for each half hour period and is determined from the half hour power generation data. The half hour variation in UK power demand is shown in Figure 4.1

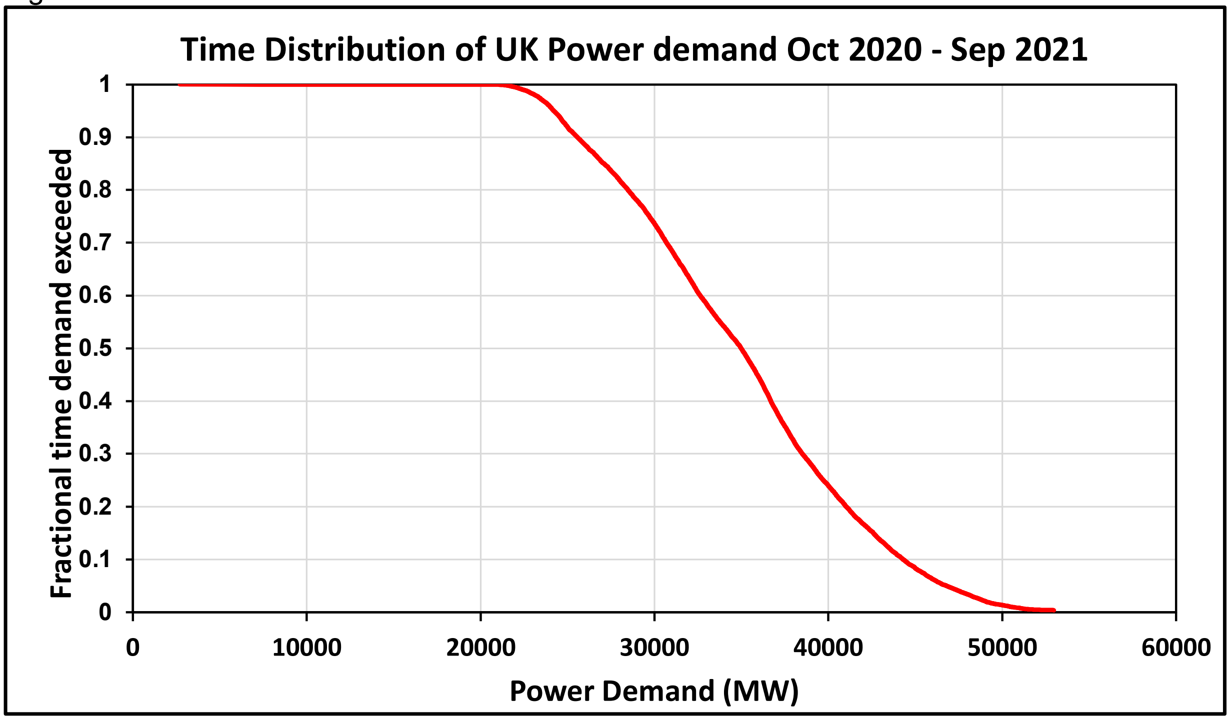
Figure 4.1 shows that the half hour power demand varies from 20GW to 53GW.

Wind and solar power generation can be in surplus or deficit, compared to demand and this is a function of both the variation in demand and variation in supply. The total distribution of variations in demand and variable renewable power (net low carbon power supply) is equal to:

Variable renewable power supply + firm power supply – demand

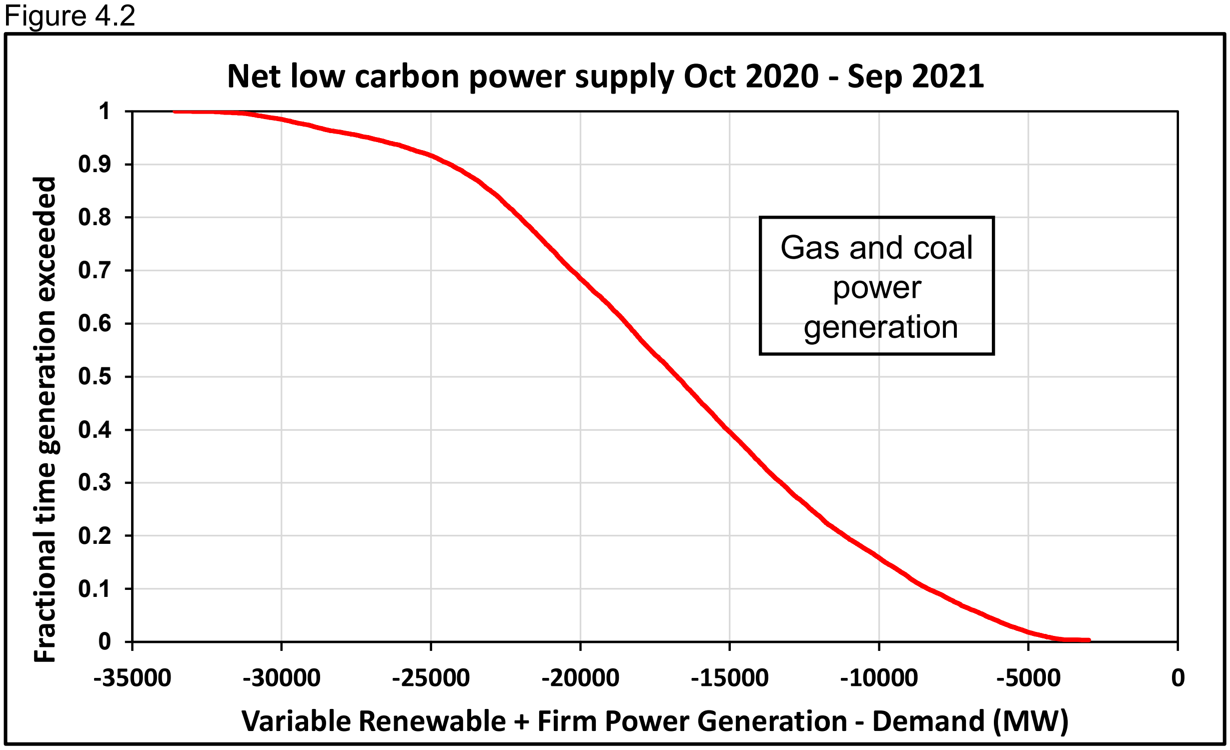
Firm power is low carbon power that is produced continuously and for this exercise has been taken as nuclear plus hydro plus biomass power.

Figure 4.1



The variation of the “net low carbon power supply” for 2020/21 is shown in Figure 4.2.

Figure 4.2



In 2021/22 the variable power plus firm power was always less than demand and the gap was made up from high carbon power generation from gas, coal and import via interconnectors.

5) Managing surplus power

As the capacity of wind and solar power generation are proposed to increase rapidly over the next few years, it is expected that from about 2023 there will be times when there is surplus wind and solar power.

There are various options for avoiding or managing this surplus power:

- Extend dynamic pricing of power
- Export power using interconnectors.
- Reduce output from Drax and other biomass power producers.
- Utilise battery electric vehicle (BEV) battery capacity
- Install static battery electric storage systems (BESS)
- Generate hydrogen for storage or to feed into the gas grid

Extended dynamic pricing will help to even out intraday variations, but the effect over longer periods will be small.

Power export using interconnectors will provide some benefit, but since many countries are increasing use of wind and solar and weather patterns in neighbouring counties tend to be similar to the UK they will have a surplus or deficit at the same time as the UK.

The GHG emissions from biomass power are still about half that of power from natural gas in combined cycle gas turbine (CCGT) units. It is therefore better from a GHG emissions viewpoint, to temporarily reduce the output from these units, rather than curtail the output of wind and solar PV units. However, these units are designed for continuous operation. Also for Drax, which is by far the largest biomass power unit, the GHG emissions from deforestation and pelleting are not incurred in the UK and are not included in the UK GHG figures. CCC6B data (ref 4 figure 3.4.c) shows no significant reduction in the output of biomass power generation between 2021 and 2025, so it has been assumed that biomass power will continue to run to capacity. This can be updated if more data is available.

6) Utilising BEV battery capacity

Battery electric vehicle (BEV) batteries can be used both to supply power to the grid in peak demand periods and also to store surplus power. Several assumptions have had to be made for this analysis, so the results are illustrative.

Assumptions are:

- EV vehicles growth and power usage is as per CCC6B (ref 4)
- EV battery cycle efficiency is 87% (ref 8)
- Storage is utilised for both storing surplus power and for peak shaving
- 25% of cars will not be parked on drives or in garages and a significant proportion of drivers will need a fully charged battery every day, so it is assumed 40% of usable EV battery capacity is enabled for grid balancing (V2G).

BEV capacity data used for this analysis is shown in the Appendix Figure A2

It is also assumed that weather forecasting is used to determine when to reduce the average battery charge prior to a period of surplus power, or to increase the average charge prior to a period of peak shaving.

7) Hydrogen Generation

Surplus power is used to generate hydrogen by intermittent electrolysis (CCC6B Ref 4, p151). The hydrogen could be utilised directly by addition to natural gas in the UK gas grid. Other uses for the hydrogen are for example: manufacturing, construction and transport CCC6B (ref 4), figure 3.5.b. These demands will require hydrogen storage and additional infrastructure cost, but the hydrogen cost will still be significantly cheaper than other supply routes such as fossil gas + CCS or continuous electrolysis (ref 14).

The optimum level of hydrogen capacity will depend on:

- Electrolysis capital costs in 2030
- Electrolysis load factor
- Forecast natural gas prices
- Carbon price

8) Variation in net low carbon power supply 2025

The demand/supply balance for 2025 has been determined for each half hour period through the year by scaling from 2020/21 half hour data. Changes included are: increase in wind and solar PV capacity, reduction in nuclear capacity, increase in EV charging and increases in demand. Data used for changes in power demand and supply are shown in the Appendix Table A1.

Regarding EV charging, RAC research shows that 75% of vehicles in the UK are parked in garages or on driveways (ref. 7) and will therefore be able to use smart home chargers. It is assumed that of these 80% will use smart meters that will charge off-peak. Thus it is assumed that 60% of BEVs will be charged off-peak and the other 40% will be charged during the rest of the day.

The distribution of net low carbon power supply in 2025 is shown in Figure 8.1.

In Figure 8.1, the areas between the curve and the zero line on the x axis show the amount of surplus wind and solar power (when $x > 0$) and the power deficit (when $x < 0$), that must be supplied from other power sources. In 2025 coal power generation will be shut down and power with CCS or from hydrogen will not have been built, so the deficit will be met by natural gas power generation. There will be surplus power for 17% of the time, with a maximum surplus of 17500 MW. The surplus power is equal to 5% of the power generated by wind and solar PV. If another use cannot be found for this power, there will be curtailment of generation of this power.

The power generated from fossil fuel generation will fall from 147 TWh in 2021/22 to 95 TWh in 2025

The use of EV battery capacity to manage the surplus power has been evaluated. This has been done using the data used for Figure 8.1, by stepping through each half hour period and using algorithms to decide when to move electricity into and out of BEV storage. The results are shown in Figure 8.2.

Figure 8.1

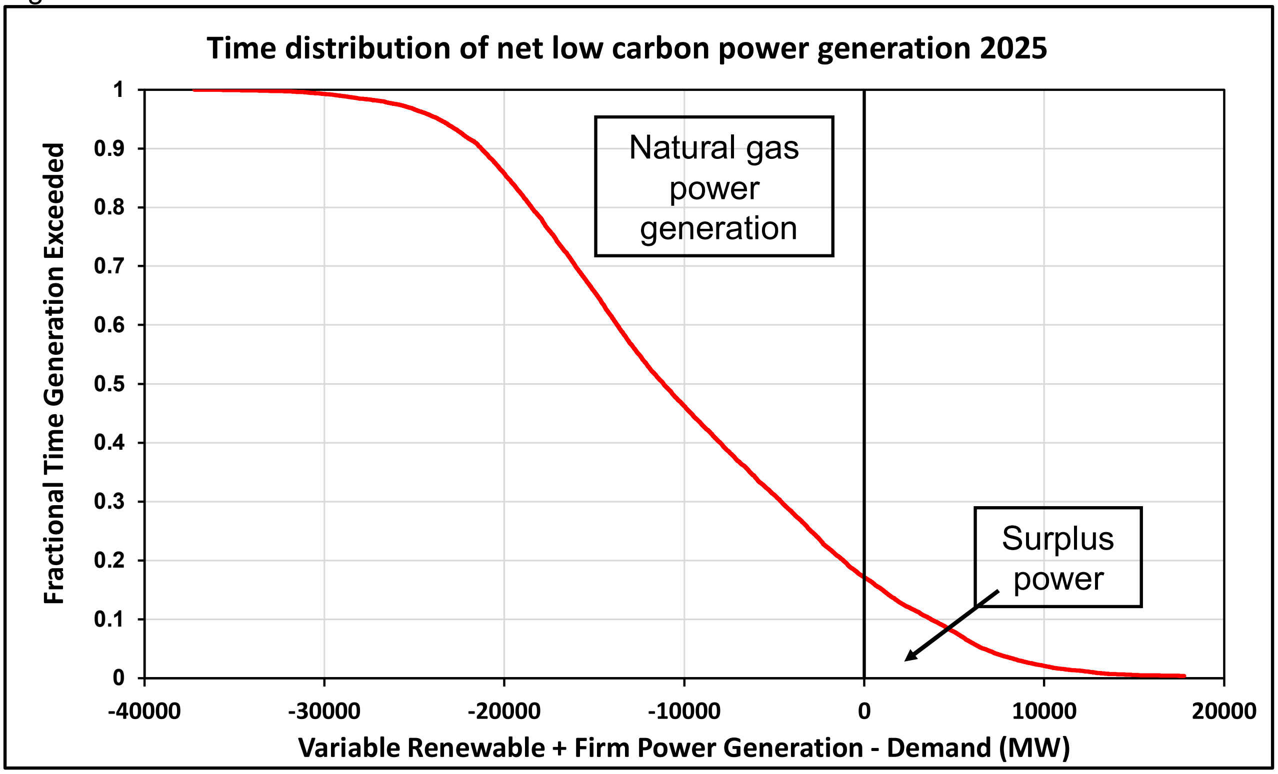
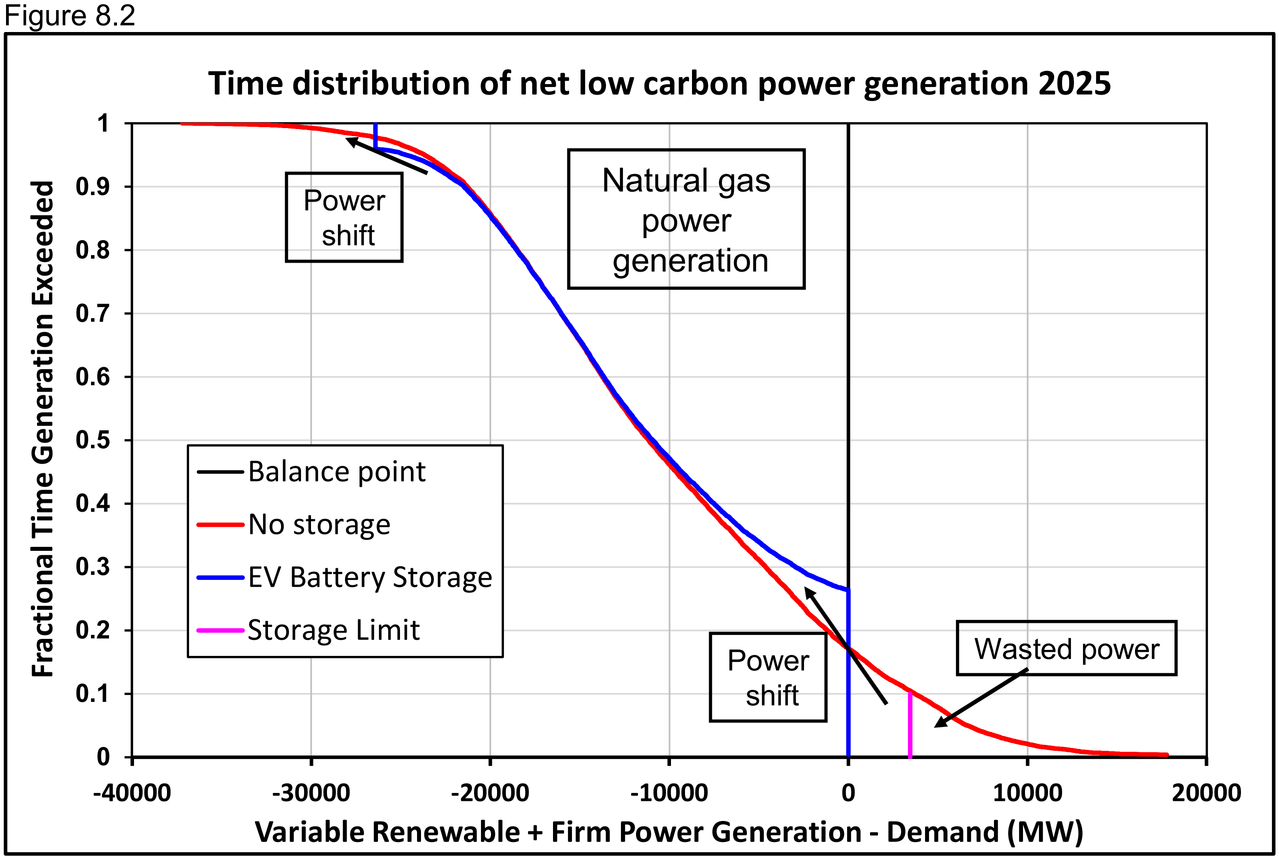


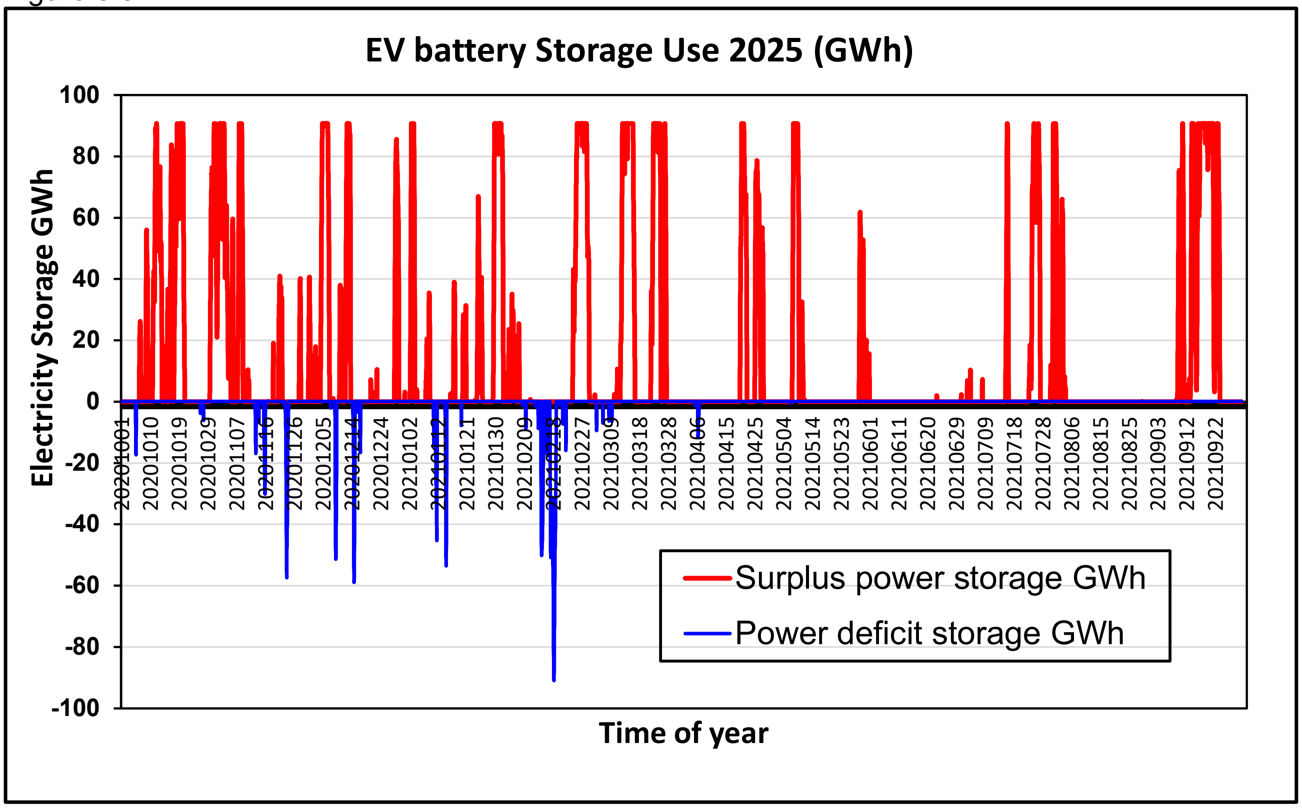
Figure 8.2



Utilisation of EV battery capacity enables 4.1 TWh of surplus power to be shifted to reduce the amount of natural gas power generation. It also stores 0.6 TWh of power for peak demand periods to reduce the maximum capacity for natural gas power generation from 37GW to 26GW.

The utilisation of BEV storage simulation is shown in Figure 8.3

Figure 8.3



BEV storage easily balances intraday power variability, but will not cope with all the longer term variability. The longest period during which surplus power would be stored was using updated half hour data for Sep 2021 and would lasted 11 days. The EV battery capacity would be cycled 87 times during the year, to cover both surplus power storage and peak shaving. Any additional battery storage (BESS) would only cycle about 25 times in the year. While BESS systems are economic for intraday storage, it can be shown that, at these low cycle rates, they would not be economic in addition to BEV battery storage for grid storage.

The data for utilizing BEV battery capacity in 2025 is summarised in table 1.

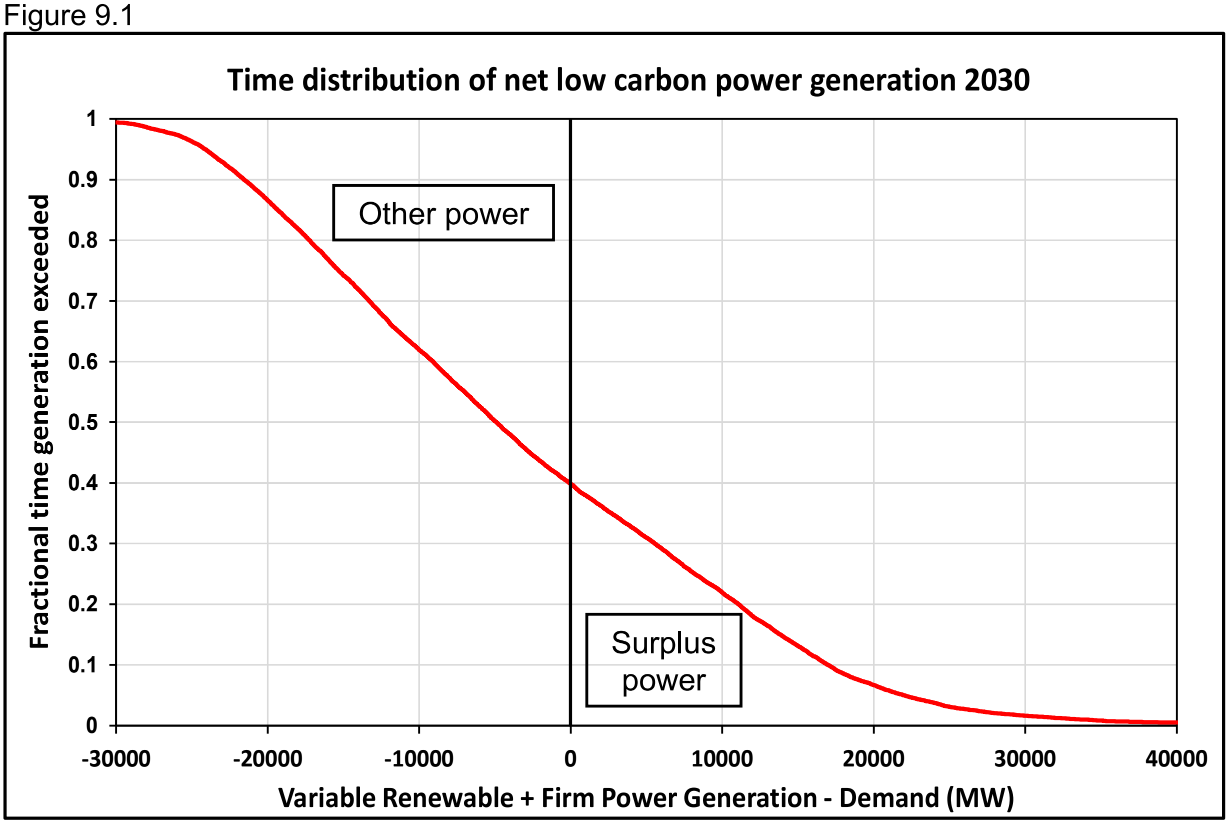
Table 1

Data for use of EV storage 2025		No EV storage	Including EV Storage
Variable power			
Power curtailment	TWh	7.3	3.2
Curtailment/Variable power generation		4.8%	2.1%
Natural gas power generation			
Max power demand	GW	37.2	26.4
Natural gas power gen	TWh	95.1	91.6
EV Battery Utilisation			
Cycle efficiency			87%
V2G enabled capacity	GWh		91
Battery capacity turnover	cycles p.a		87
Battery power loss	TWh		0.62

9) Variation in net low carbon power supply 2030

Changes included for 2030 (table A1) are: increases in wind and solar PV capacity, increase in nuclear capacity and increases in demand.
The distribution of net low carbon power supply in 2030 is shown in Figure 9.1

Figure 9.1



This shows that in 2030 there will be surplus power for 40% of the time, with a maximum surplus of 45000 MW. The surplus power is equal to 17% of the power generated by wind and solar PV.

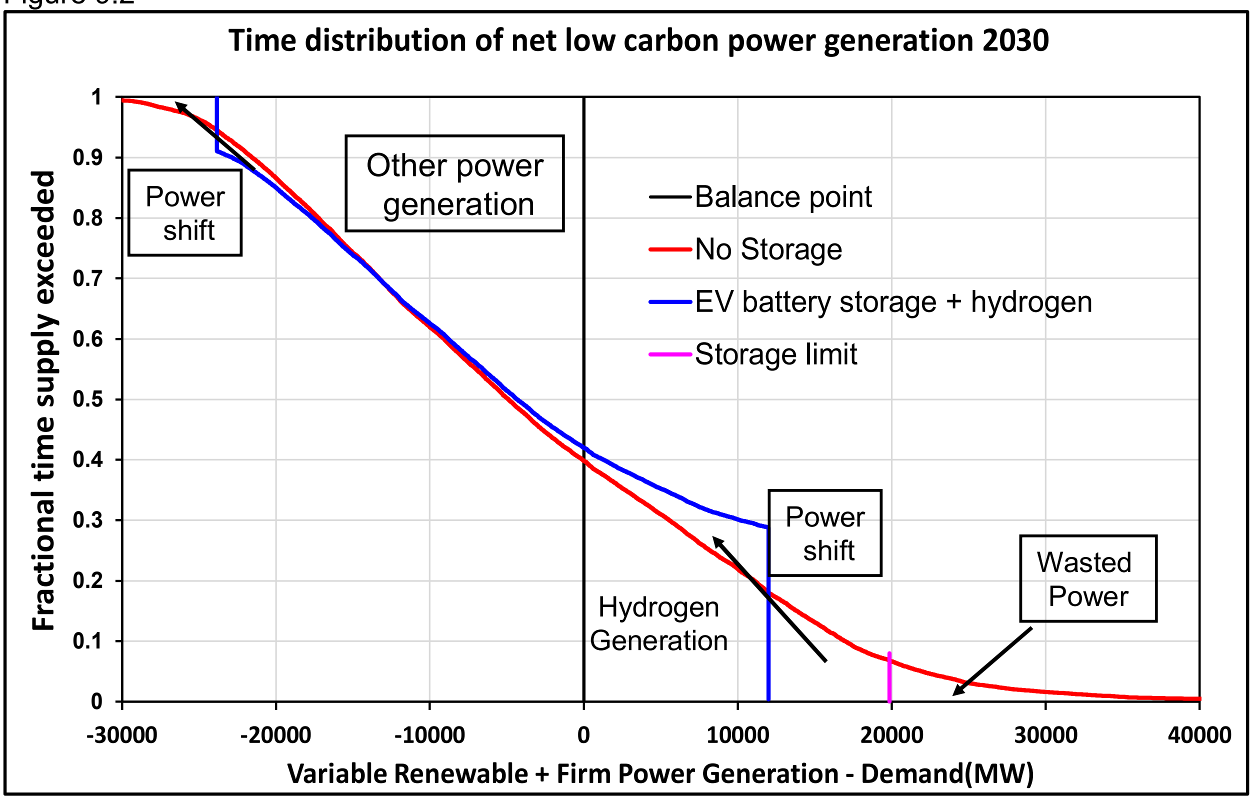
When wind and solar power are in deficit, other power will be generated from CCGT, gas with carbon capture and storage (CCS), bioenergy CCS (BECCS) and hydrogen. This power deficit will fall from 95TWh in 2025 to 71TWh in 2030.

BEV battery storage reduces the maximum capacity for other power generation from 35GW to 24GW. However, just using EV battery storage capacity to reduce the variable renewable power surplus, still gives curtailment of 27 TWh or 11% of wind and solar power generation.

In order use this power, the power is used for hydrogen generation. An illustration of use of hydrogen generation by electrolysis, with a reasonably optimum electricity capacity of 12000 MW is shown in Figure 9.2.

BEV storage shifts surplus power, mainly to hydrogen generation. This raises the average load factor for hydrogen generation to 34%, and significantly reduces the electrolysis capital and operating charges per MWh of hydrogen.

Figure 9.2



Wasted power is reduced to 2.6 TWh, equal to 1.1% of total wind and solar power generation.

Data associated with this option are shown in table 2.

Table 2

Data for use of EV storage and hydrogen generation 2030				
		No EV storage	EV battery storage	EV battery Storage + 12 GW H2 Gen
Variable renewable power				
Power curtailment	TWh	41.2	27.3	2.6
Curtailment/Variable power generation		17.1%	11.4%	1.1%
Other power				
Max other power demand	GW	34.9	23.8	23.8
Other power gen	TWh	70.9	58.8	69.6
EV Battery				
Cycle efficiency			87%	87%
V2G enabled capacity	GWh		329	329
Battery capacity turnover	cycles p.a		130	37
Battery power loss	TWh		2.0	1.3
Hydrogen				
Generation capacity	GWe			12
Power usage	TWh			35.7
Average load factor				34.0%

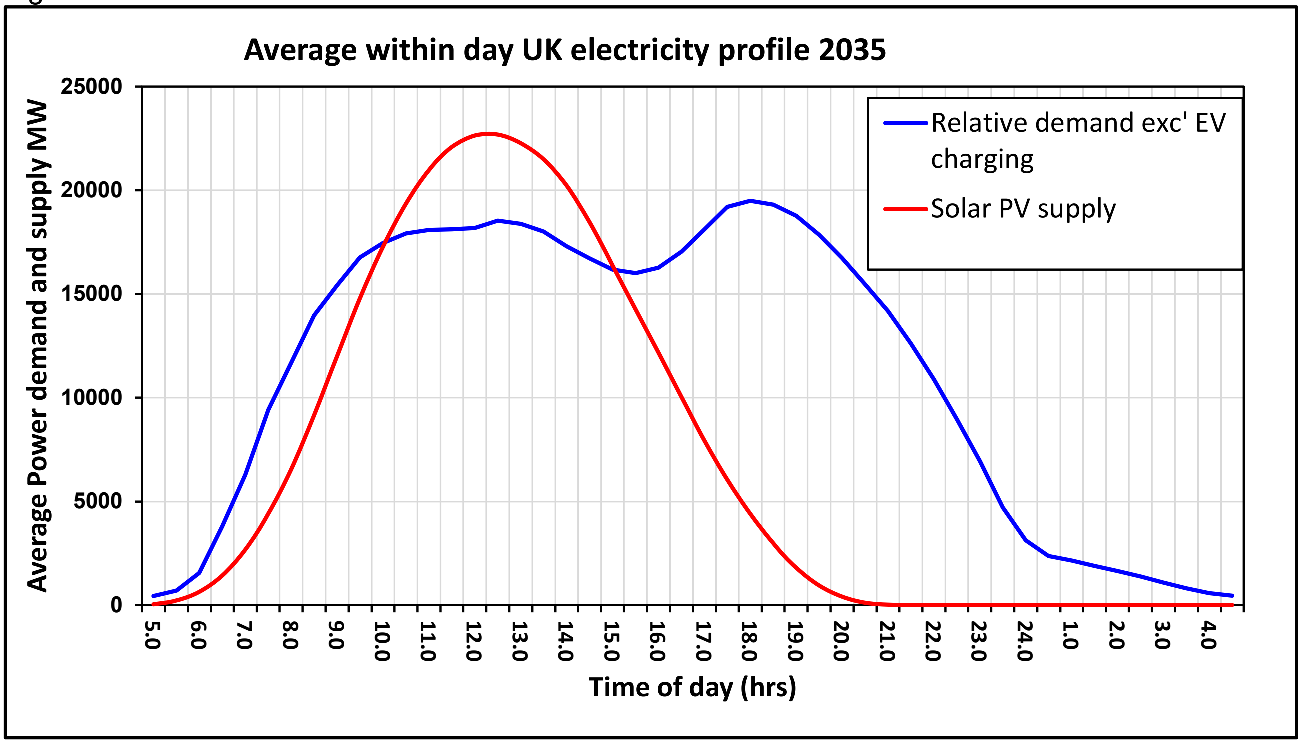
10) Variation in net low carbon power supply 2035

Changes included for 2035 are: increased wind and solar PV capacity, scale up of nuclear capacity and a substantial increase in demand.

The increase in solar power compared to 2020/21 will significantly change the shape of the intraday net demand/supply. The average relative demand (demand minus minimum demand) and solar PV supply over the day are shown in Figure 10.1. Other power sources are reasonably constant through the day.

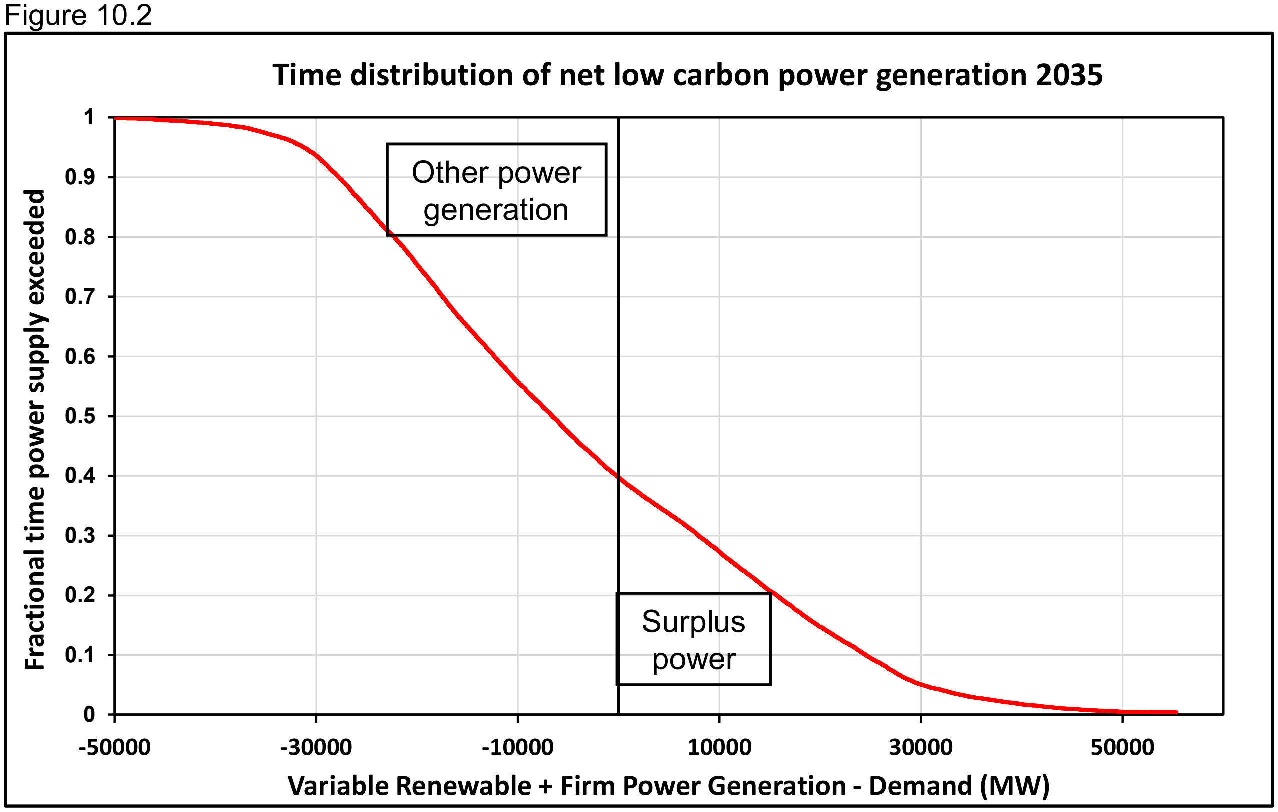
Figure 10.1 shows that on average, the peak demand in daylight hours is satisfied by solar PV power, leaving a relative excess demand over supply only between the hours of 5 pm and 11 pm. This gives more flexibility to the timing of off-peak demands such as EV vehicle charging and electric storage heaters.

Figure 10.1



The distribution of the net variable renewable power supply, including EV vehicle charging is shown in Figure 10.2

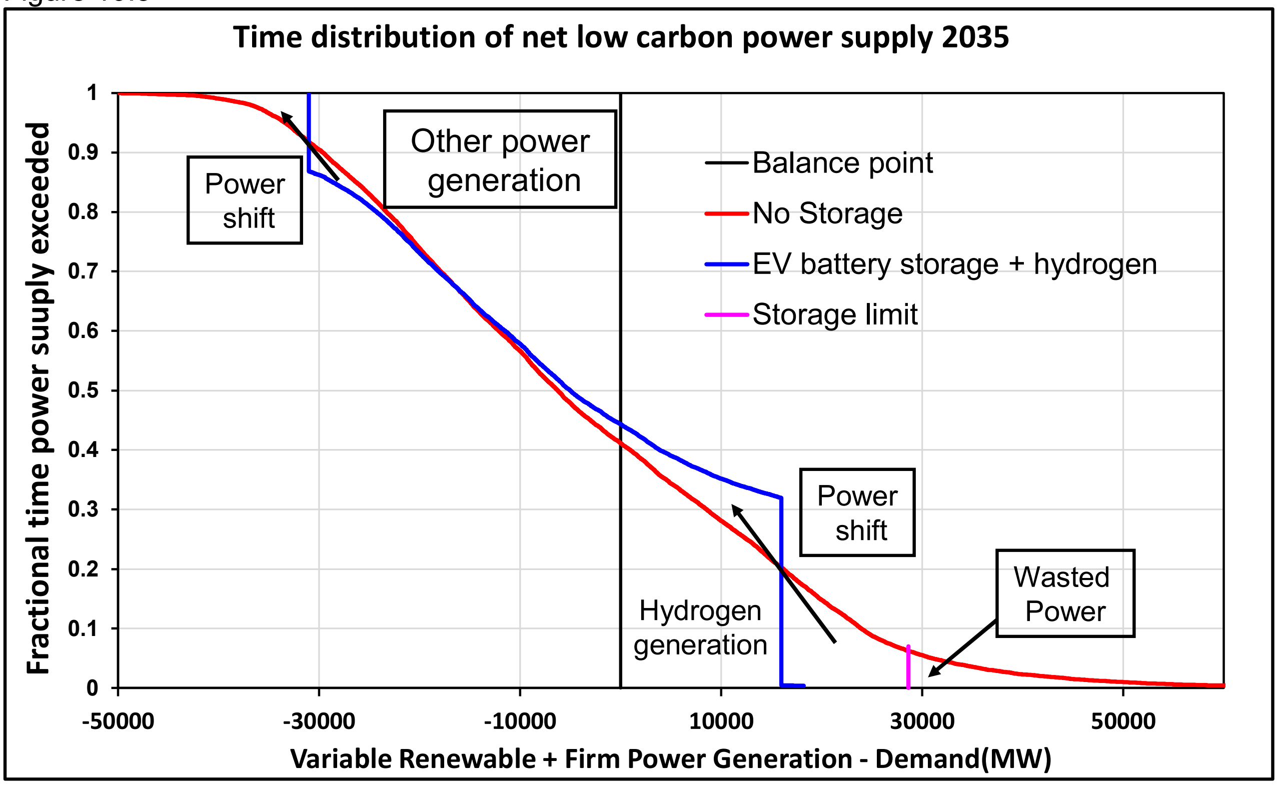
Figure 10.2



This shows that in 2035 there will be surplus power for 40% of the time, with a maximum surplus of 55000 MW. The surplus power is equal to 17% of the power generated by wind and solar PV. It is targeted that unabated fossil fuel power generation will be phased out by 2035, so dispatchable power will be generated from natural gas CCS, BECCS and hydrogen.

An illustration of the benefit from EV battery storage and hydrogen generation with a reasonably optimum electricity capacity of 16000 MW is shown in Figure 10.3.

Figure 10.3



EV batteries are used to store 13 TWh of this power until it is released for hydrogen generation. 50 TWh of surplus power can then be used for hydrogen generation by electrolysis. Thus, using EV battery storage and hydrogen generation, nearly all the surplus power can be utilised, leaving power curtailment of just 4 TWh.

EV batteries are also used to store power to be released in peak demand periods. This enables the generation capacity of other power to be reduced by 40% from 51GW to 31GW.

Data associated with this option are shown in table 3.

Table 3

Data for use of EV storage and hydrogen generation 2035		No storage	EV battery storage	EV battery Storage + 16 GW H2 Gen
Variable renewable power				
Power curtailment	TWh	58.3	37.0	4.0
Curtailment/Variable power generation		17.4%	11.0%	1.2%
Other power				
Max other power demand	Gwe	51.3	31.0	30.6
Other power gen	TWh	93.0	75.3	90.4
EV Battery				
Cycle efficiency			87%	87%
V2G enabled capacity	GWh		629	629
Battery capacity turnover	cycles p.a		102	31
Battery power loss	TWh		3.5	2.1
Hydrogen				
Generation capacity	Gwe			16
Power usage	TWh			49.7
Average load factor				35%

11) Summary of results

The summary of the results from modeling the changes and their balancing and storage of variable renewable power are shown in table 4.

The large amounts of surplus renewable power (up to 17% of generation) can be utilised by EV battery storage and intermittent hydrogen generation, so that the reduction of power generation by curtailment is minimal.

The targeted power generation from wind and solar will increase from 2030 to 2035 in line with the total increase in power demand. Also due to the increase in EV battery storage, the peak demand capacity reduction from EV storage is substantially higher. However, because of the high variability of wind and solar output, the capacity of other power from gas CCS, BECSS and hydrogen must be still be substantially increased from 24 to 31 GW. The load factor for this power generation in 2035 will be between 12% and 57% (Figure 13), with an average of 34%.

Table 4

Summary of results					
		2020/21	2025	2030	2035
Variable renewable power					
Solar PV generation	TWh	12	24	41	60
Wind tubine generation	TWh	65	128	200	275
Surplus wind & solar power	TWh	0	7	41	58
Surplus power/total variable generation			5%	17%	17%
Power curtailment	TWh	0	3.2	2.6	4.0
EV Batteries					
Available grid balancing capacity	GWh		91	329	629
Surplus power recovery	TWh		4.1	8.4	13
Peak demand capacity reduction	GW		10.8	11.0	20.3
Hydrogen					
Hydrogen generation capacity	GW	0	0	12	16
Power for hydrogen generation	TWhe	0	0	36	50
Electrolysis load factor				34%	35%
Other Power					
Capacity required without EV storage	GW		37	35	51
Capacity required with EV storage	GW		26	24	31
Average load factor of other power			40%	33%	34%

12) Discussion

12.1) Finance

The use of BEV capacity to help balance the grid, using smart V2G chargers should be self financing and is being led by electricity providers such Ovo energy using Kaluza grid balancing technology and by Volkswagen. Volkswagen has said it will add bidirectional charging to all its electric cars with a 77kwh battery in the next 6 months (ref. 11).

Using surplus renewable power for generation of hydrogen by electrolysis to be fed into the gas grid, or to replace continuous hydrogen generation, should be self financing for UK Ltd. However, work is needed by BEIS to determine who should lead it, who will pay for it and operate it and how will they recover their costs?

12.2) UK energy and hydrogen strategies

There are four areas where this analysis interacts with UK energy and hydrogen strategies:

- Demonstrations
- Use of V2G to recover surplus wind and solar power
- Use of hydrogen generation to utilise surplus wind and solar power
- Economics of other power generation.

Demonstrations

The UK Energy Strategy Dec 2020 (ref 12) and UK Hydrogen Strategy Aug 2021 (ref 13) outline work on:

- Demonstration of V2G charging
- Evaluation and development of blending hydrogen into the natural gas

These are both very important for being able to utilise surplus renewable power generation.

Recovery of surplus power

There is no apparent recognition of the extent of wind and solar power variability, or the extent to which the UK will need to use V2G charging. The only reference for V2G charging in the Energy Strategy (ref 12 p. 24) is for managing peak demand, whereas a major, perhaps main benefit from using V2G is being able to use BEV storage to recover surplus variable renewable power.

Hydrogen generation

Data in table 4 shows that in 2030, 36 TWh of surplus renewable power, which would otherwise be curtailed, can be recovered for hydrogen generation using intermittent electrolysis with a capacity of 12GW. At an electrolysis efficiency of 81%, used in the CCC6B (ref 4), these data are equivalent to a capacity of 10 GW of hydrogen (HHV) and production of 29 TWh of hydrogen.

The target in the BEIS strategies (ref 12 p.127 and ref 13) is for total hydrogen generation capacity of 5GW or 42 TWh by 2030. These data imply continuous operation hydrogen production, rather than intermittent production using surplus renewable power. CCC6B (ref 4). Fig 3.5.c shows production of 30 TWh of hydrogen by 2030, but indicates that only 14 TWh of this will come will come from electrolysis. BEIS hydrogen production cost data (Ref. 14), summarised in the Appendix Table A3, shows that the cost of hydrogen using free curtailment power is only 56% of the cost of hydrogen from natural gas and only 29% of the cost of hydrogen from continuous electrolysis using grid power. Again there is no recognition in either the CCC6B work (ref 4) or the Hydrogen Strategy (ref 13) of the extent of wind and solar power variations and that therefore in 2030 hydrogen demand can be met entirely from curtailment power.

Dispatchable power generation

The UK electricity generation strategy is that natural gas CCGT generation in 2025 will steadily be converted to hydrogen or replaced by units using gas CCS or BECCS. The economics of converting or building these new units are shown in a BEIS Electricity costs paper (ref 15). It can be seen from Figure 10.3 that in 2035, power from other sources than firm power, wind and solar is only required for between 12% and 55% of the time. While open cycle gas turbine (OCGT) generation and conversion to hydrogen may be used for plants running at the lower end of the load factor range, new units with CCS will need to be economic at load factors from say 30% to 55%. The cost data for new gas CCS and BECCS plants are calculated and presented using load factors of about 90% (ref 15 tables 2.5 and 2.6), but it is acknowledged that these units will run at less than maximum load factors. The comparison of new dispatchable power options for future low carbon energy investment should be presented and made, using costs calculated at the much lower load factors estimated for 2035.

Appendix

Table A1 Power Generation and Demand data

Power generation and use data TWh/yr				
	2020/21	2025	2030	2035
	Energy Trends	Data from CCC6B		
Nuclear	45.2	45	59	75
Variable Renewable	76.5	152	240	335
Solar PV	11.7	24	41	60
Wind	64.8	128	200	275
Total power demand	305	309	363	478
Demand for BEV charging	7.0	19	47	79

CCC6B references: Fig. 3.4.c and pages 134-135

Table A2 EV Battery Capacity

Average usable battery capacity		
	kWh	Reference
BEVs UK	62.5	Ref 5
PHEVs WW	11	Ref 6

EV cars in UK (m)			EV Battery	EV Battery
	BEVs	PHEVs	usable capacity GWh	Grid balancing capacity GWh
2015	0.025	0.025		
2020	0.14	0.20	11	
2025	3.2	2.4	227	91
2030	12.6	3.3	822	329
2035	24.6	3.0	1573	629
Reference	CCC6B (Ref 4) Figure 3.1.b			

Table A3 Hydrogen Generation costs

Hydrogen Levelised costs	£/MWh H2 (HHV)		
	2030	2035	Ref 14
Natural gas based			
SMR or ATRwith CCUS 300MW	65	65	
Electrolysis based			
Alkaline Grid baseload power	130	130	Chart 6.1
PEM - Grid baseload power	125	125	Chart 6.1
Average grid baseload lower	127.5	127.5	
Intermittent operation using curtailed power			
Alkaline curtailed power 25% Load Factor	53	52	Chart 6.2
PEM curtailed power 25% Load Factor	48	46	Chart 6.2
Average curtailed power 25 % Load Factor	50.5	49	
Average curtailed power 34 % Load Factor	37	36	

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