The BOW GROUP

Target Paper

Rescuing Renewables

How Energy Storage Can Save Green Power

by Tony Lodge

with a foreword by Kit Malthouse MLA

WWW.BOWGROUP.ORG

The Bow Group was founded in February 1951 as an association of Conservative graduates, set up by a number of students who wanted to carry on discussing policy and ideas after they had left university. They were also concerned by the monopoly which socialist ideas had in intellectual university circles. It originally met at Bow, East London, from which it takes its name.

Geoffrey Howe, William Rees-Mogg and Norman St John Stevas were among those attending the first meeting. From the start, the Group attracted top-flight graduates and quickly drew the attention of a number of government ministers, notably Harold Macmillan. In the intervening time, Michael Howard, Norman Lamont and Peter Lilley have all held the Bow Group chairmanship. Christopher Bland, the current Chairman of BT, was Bow Group chairman in 1969. In the May 2010 General Election five recent members of the Bow Group Council were elected to Parliament.

Since its foundation the Bow Group has been a great source of policy ideas, and many of its papers have had a direct influence on government policy and the life of the nation. Although it has no corporate view, it has at times been associated with views both of left and right - always within the broad beliefs of the Conservative Party.

The Bow Group (BG) has four clear objectives:
To contribute to the formation of Conservative Party policy
To publish members' work and policy committee research
To arrange meetings, debates and conferences
To stimulate and promote fresh thinking in the Conservative Party

Recent publications include:

Equity and Excellence: Liberating the NHS – Opportunities and Challenges
(Bow Group Health Committee) **August 2010**

The Case for Energy Crops – How developing countries can help themselves and boost UK Energy Security (BG Energy Committee) **July 2010**

The Enterprise Nation? Developing Northern Ireland into an Enterprise Zone
Ross Carroll with a foreword by Lord Trimble (BG Economics Committee) **April 2010**

The Quality and Outcomes Framework – What Type of Quality and Which Outcomes
Gary Jones, Stuart Carroll and Jennifer White (BG Health Committee) **February 2010**

The Right Track – Delivering the Conservatives' Vision for High Speed Rail
Tony Lodge with a foreword by Lord Heseltine (BG Transport Committee) **January 2010**

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CONTENTS

A Report by the Energy and Transport Committee of the Bow Group

November 2010

Technical Acronyms

CCC	Committee on Climate Change
CCS	Carbon Capture and Storage
CEGB	Central Electricity Generating Board
CHP	Combined Heat and Power
DECC	Department for Energy and Climate Change
FIT	Feed in Tariff
GW	Gigawatt
H_2	Hydrogen
kWh	Kilowatt hour
LCPD	Large Combustion Plant Directive
MW	Megawatt
NO_x	Nitrogen Oxide
OEM	Original Equipment Manufacturer
PV	Photovoltaic
RO	Renewables Obligation
ROC	Renewables Obligation Certificate
ROO	Renewables Obligation Order
RTFO	Renewable Transport Fuels Obligation
SO_2	Sulphur Dioxide
TSO	Transmission Storage Operators
UPS	Uninterrupted Power Supply

Bow Group Energy and Transport Committee

The Bow Group Energy and Transport Committee is committed to researching and analysing the implications and challenges facing both sectors as a result of, or lack of, Government policies. The Committee regularly meets to discuss new research projects and how it can support viable, sustainable and effective policies in both of these vital areas.

Chairman – Tony Lodge
email: energyandtransport.policy@thebowgroup.org

Executive Summary

- Britain's target of reducing carbon emissions by 32% by 2020 (on 1990 levels) cannot be met unless policies are changed to make the contribution of intermittent renewable sources of energy more effective

- Britain's target of producing up to 34% of electricity and 15% of all energy from renewables by 2020 cannot be met unless the energy from these renewables is harnessed, stored and used more effectively as a carbon free fuel by industry, transport and households

- Britain's renewable policy must be changed to encourage the storage of clean and free energy which intermittent renewables, such as wind and solar, produce so that it can be used later in a targeted way. This will help stabilise the grid and reduce unpredictable shocks to the electricity supply industry.

- Harnessing and storing energy from renewables using energy storage technologies such as hydrogen produced through electrolysis of water, allows this zero-carbon fuel to reduce carbon emissions and justify the vast sums already spent on intermittent renewable energy

- The development of new efficient electrolyser technology is geared specifically to convert intermittent renewable energy into hydrogen far more efficiently than before

- Individual homes, industrial premises and communities can become independent from the grid and not dependent on the energy companies by supporting their own energy storage systems from local renewables, whether solar panels on their roof or wind systems. This energy independence reduces stresses on the grid and prevents future blackouts due to local generation.

- Using hydrogen in transport, a modified combustion engine, a fuel cell, boiler or power plant releases no CO_2, just the very water from which it was created, so there is no carbon penalty. It also improves air quality.

- Government should introduce a Renewable Energy Storage Incentive (RESI) to initially co-exist alongside the feed in tariff.

- Hydrogen should also be generated from off-peak nuclear plants thus retaining a near zero-carbon footprint, albeit from conventional power

- As Britain's renewable sector endures increasing criticism over its ability to deliver reliable energy, green energy storage has evolved as one of the best options to rescue renewable policies at a time of financial restraint and Government cutbacks.

- The tiny, windswept island of Utsira (right), situated off Norway's south western coast, is home to the world's first full-scale system for cleanly transforming wind power into hydrogen. The island is completely self sufficient in green energy because it has addressed wind energy's intermittency and stores excess wind energy as hydrogen.

- When the wind turbines on Utsira slow or stop, electricity is either provided by the hydrogen powered engine or the fuel cell using stored renewable energy.

- National Grid has started to pay wind farm companies to turn off their turbines because their erratic surges unbalance the system. Scottish Power received £13,000 for closing down two wind farms for over an hour on May 30th. A lack of energy storage will increase such events.

- Energy storage technologies such as hydrogen can enable the UK to utilise its vast, but intermittent renewable energy resources with greater ambition, broader scope and increased reliance. The process of 'green in – green out' represents genuine energy carbon neutrality.

FOREWORD

by Kit Malthouse, MLA
Deputy Mayor of London and Chairman of the London Hydrogen Partnership

I have always been a hydrogen "believer" but well aware that most people would scoff at the idea of a hydrogen economy until it solved real problems in their daily lives. In a country addicted to carbon fuels, trying to persuade people that there is a viable alternative for propulsion and power generation, without them being able to "kick the tyres" would always be met with hostility and scepticism. Hitherto, investment in the hydrogen economy required faith, a faith we have sadly lacked in the UK. As a result we lag far behind our competitors in planning and preparing for the fuel of the future.

And yet as Tony Lodge argues in this compelling paper, hydrogen could well be the key to our alternative energy ambitions. As a country we have made all the right noises about alternatives; solar; wind; wave and biofuel. We have certainly invested a lot of money. But there has always been a nagging doubt, a feeling that something is missing, something holding the industry back from taking its place alongside carbon burning and nuclear fission. Our national policy has, as Tony accurately puts it, seemed "one dimensional".

That missing dimension is the ability to store power generated from these green but inherently intermittent sources. At the moment they provide stuttering coughs of power, when we need full throated, prolonged roars. And once you stop looking at hydrogen as a kind of substitute for petrol, and see it as that extra dimension, a store of energy, the solution becomes obvious.

In London, we are putting hydrogen on the ground, building a network of refuelling stations so that Londoners can "kick the tyres" and will hopefully then buy the cars. It is a modest contribution to what we hope will be the slow end of the carbon economy. Tony Lodge however offers us an even greater prize: an alternative power generation industry that can at last provide smooth, predictable, green energy for the grid. Faith is no longer required. The reality is here. Let's hope the Government is listening.

Kit Malthouse MLA
November 1st 2010

Chapter 1 – Why Should We Store Green Energy?

The most common forms of renewable energy are characterised by their intermittent nature[1]. Put simply, the energy harvested from, for example a wind turbine or solar panel, is only available when the wind is blowing or the sun is shining which will not always match demand.

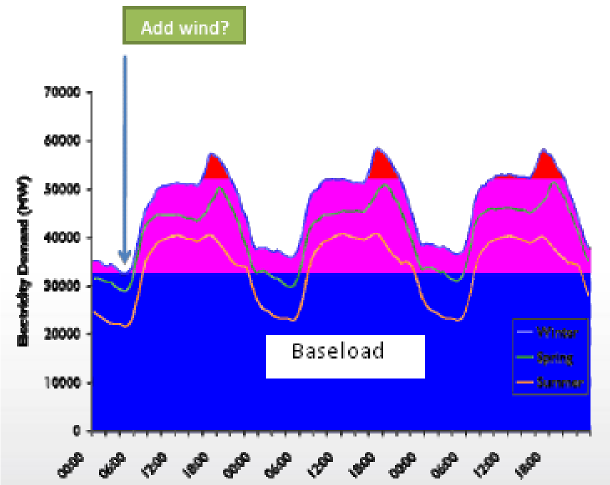
In the quest to achieve lower carbon energy use, this fundamental characteristic of renewable power should be considered with respect to creating a low carbon future based on our ability to harness, store and use renewable energy at all times.

A failing renewables policy

Renewable power is the only genuinely green energy form, all other forms either release CO_2 to the atmosphere and/or consume finite fossil fuel reserves. So the only option is to build an energy system that is built mainly on renewable power. Green electricity is arguably the most sustainable form of energy but it cannot always be matched to time varying demands for heat, power and mobility without energy storage. Britain's present one dimensional renewables policy will falter as the intermittent renewable power penetration increases, so a shift is needed to a two dimensional renewables with storage policy. Renewables only makes sense if Government adopts a 'renewables+storage' policy.

The need for storage

As the penetration of renewables into the grid increases, intermittent wind power will need to be increasingly curtailed to maintain power system stability. At any one time the grid has a block of baseload power in operation, reducing this to accommodate intermittent power risks destabilising power supply. Alternatively, wind energy's admission to the grid could exceed consumer demand. Excess wind electricity is then wasted. It should be stored, instead, as a clean fuel.



[1] Tidal and biomass are the two main predictable non-weather dependent renewables

Undermining investment

This waste of power and resource undermines the investment case for deploying new renewables; if no storage solution is applied the penetration of renewables will self-limit in all regions due to the diminishing investment case and will fail to exploit the full potential of our proven renewable power generation technologies. Curtailment is already occurring in Spain and Germany (i.e. renewable electricity is being prevented from entering the power system at times of high availability and low demand) and spot prices are often low and occasionally negative.[2] In the UK the first case of wind operators being paid to turn off turbines occurred earlier in the summer.[3]

It is therefore important to address this fundamental issue before it happens more widely in the UK. Policies which support increasing the percentage of electricity generated from renewable sources will fail unless there is a commitment to support energy storage. This presents both a challenge and technological opportunity for the UK.

The admission of renewable power inputs to the grid provides genuinely green energy at the points of entry, but it creates a huge operational problem in managing the 100 or so large central generators to cover any transient variations in wind power input and consumer demand. The need to cover or "shadow" wind has led to increased operation of large fossil (coal and gas) plant at part load, keeping plant idling just in case the wind input dies away sooner than forecast. This is known as 'spinning reserve' and is expensive and carbon intensive.

Full benefits lost

In these modes of operation fossil plants are operating at lower efficiency and generating relatively high CO_2 outputs per kWh generated. So the full benefit of a green kWh entering the grid cannot be realised because 1kWh of green energy cannot displace 1kWh of fossil generated electricity.

One example of this is in Denmark which has the most intense concentration of wind generation in Europe. At peak output the Danish wind farms can account for nearly 70% of Danish peak power demand, but this rarely occurs when it is needed. In recent years Danish carbon emissions have risen as the Danish grid has fallen back on older fossil fuel generation to plug the gap left by

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[2] *Energinet* Journal, May 2010

[3] 'Firms paid to shut down wind farms when the wind is blowing', *Daily Telegraph* 22 June 2010

underperforming wind farms.[4] For this reason there is a strong argument for fostering a distributed renewables system which generates, stores and utilises green energy at the point of use; the approach offers huge potential benefits to the operational effectiveness of the grid unlike the current "must take" policy for renewables.

The real state-of-play and its hidden costs

Denmark generates the equivalent of about 19% of its electricity demand with wind turbines, but wind power contributes far less than 19% of the nation's electricity demand. The claim that Denmark derives about 20% of its electricity from wind overstates matters. Being highly intermittent, wind power has recently (2006) met as little as 5% of Denmark's annual electricity consumption with an average over the last five years of 9.7%.

In the absence of large-scale electricity storage, any modern electricity system must continuously balance electricity supply and demand, because even small variations in system voltage and frequency can cause damage to modern electronic equipment and other electrical equipment. Wind power is random, especially in the very short term (e.g., over any given hour, 30 minute, or 15 minute period). This has created a completely new challenge that transmission system operators (TSOs) all over the world are only now learning how to handle. Some draw from Denmark's experience. But Denmark's special circumstances make its experience of limited transferability elsewhere.

Denmark manages to keep the electricity systems balanced due to having the benefit of its particular neighbours and their electricity mix. Norway and Sweden provide Denmark, Germany and Netherlands access to significant amounts of fast, short term balancing reserve, via interconnectors. They effectively act as Denmark's "electricity storage batteries". Norwegian and Swedish hydropower can be rapidly turned up and down, and Norway's lakes effectively "store" some portion of Danish wind power.[5]

The need for storage in homes and communities

Direct action at local level to make large reductions in fossil fuel dependency and CO_2 emissions are feasible with solar power technology, micro hydro and wind power, but storage is needed to match these supply technologies with user demand.

[4] *Energinet*, February 2009
[5] 'Wind Energy – The Case of Denmark', Center for Politiske Studier, September 2009

An effective storage mechanism would enable the outputs from intermittent renewable sources that exceed the immediate requirement to be captured and utilised at a later time. Storage is the central component to any distributed energy system, which aims to supply green power, heat and transport fuel to end users whenever required.

Storage technologies and in particular hydrogen would allow remote communities to use their intermittent renewable energy for a greater range of applications, including transport and heating.

Incentives

In most respects applying storage on a large scale is problematic because of the large amounts of energy that needs to be generated and stored each day, not to mention the large capital expenditure. This is, however, feasible with hydrogen stored locally at multi MW wind farm sites. Applying this strategy at the distribution level (districts, streets, farms) and the highly distributed level (homes, hamlets) is a very attractive proposition as it encourages mass storage solution deployment and a reduction in capital costs.

Incentivisation of storage solutions is required at two levels:

- wind-hydrogen solutions located at or near small/medium size wind farms of 10-50MW, and
- at the kW and sub-MW level where the solutions will be applied at or close to the points of demand.

This equates to a subsidy for renewable generation and storage systems at these sites in the same way wind farm operators and developers are already assisted. Correct action at these levels would in the long term result in the national energy demand profile morphing to a flat line compatible with the utilisation of base-load nuclear and high efficiency coal and gas plant. In short, the grid would not be constantly ramping up and down to meet peaks and troughs due to renewables' intermittency.

The need for a 'renewable+storage' policy

The task is to change the renewables policy to a renewables plus storage policy, or let that be a subset of the total mission. As with other immature renewable technologies, initial financial incentives will be required to help cover the cost of renewable+storage systems to gain traction, especially given that the investor will have to pay for the renewable power source such as the photovoltaic solar panels and also for the storage technology (e.g. electrolyser and hydrogen storage tank) and the reconverter technology such as the fuel cell or H_2 car. Importantly, once this payment is made for the necessary technology the process of harnessing and using renewable energy is then free.

Policymakers need to work with the commercial grain of implementing zero carbon solutions and incentives via hydrogen. It is not a panacea. The key is to encourage ambitious early adopters and incentivise them to live in zero-carbon homes with large solar roofs or small wind systems.[6]

As of August 2010, solar PV panels had been fitted to 2,257 homes, up from 1,700 in July and 1,400 in June. These homes will not be able to harness the full energy potential of intermittent solar energy unless they also adopt energy storage facilities.

[6]Department of Energy and Climate Change

Chapter 2 - How can Storage Boost the Grid?

There is a growing need for energy storage as more intermittent renewable energy technologies are employed in the drive to decarbonise electricity generation and supply. As already highlighted, renewable technologies, like wind and solar energy, are unpredictable and need storage technologies to be fully and effectively utilised.

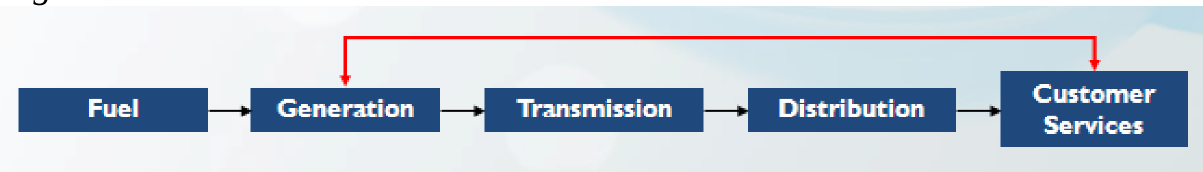
The unique advantage of hydrogen as a form of energy storage is that it can deliver a fuel for making power or heat or for fuelling a car, while absorbing intermittent power inputs from renewable sources. This inherent flexibility is the overarching reason to integrate hydrogen generation by electrolysis within the UK energy system.

Fundamental principles

Balance is key to the electricity industry. Production and consumption are dynamically coupled; supply must match demand in a sub-second timescale. The addition of new components, particularly if these are unpredictable (like weather dependent renewables), can undermine the balance. Thus, energy storage is one of the 'holy grails' of the power industry.

As shown below, the only part of the electricity system where energy storage currently takes place is in the fuel itself; as soon as this is burned for generation, dynamic coupling with the customer is established. Electricity cannot be packaged, unlike the products of other utilities, such as gas and water.

Figure 1

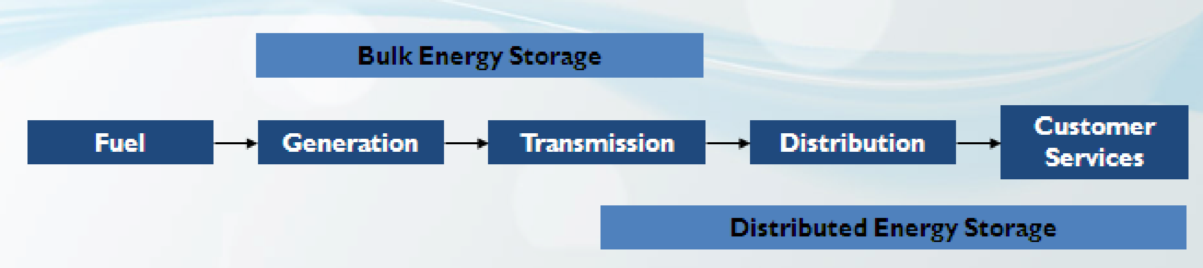


Electricity is a pure commodity, undifferentiated at the point of supply. Although there is contractual differentiation, the consumer remains unaware of which supplier is providing electricity to their home or business at any particular point in time from the electricity pool.

The electricity supply chain involves no warehouse and no packaging. When the product is made, and when it is required, it must be delivered, owing to the dynamic coupling of supply and demand. A 'warehouse', or electricity storage system, would therefore be of great value to the electricity industry.

As indicated in figure 2, bulk energy storage could be added at the generation and transmission stages, and distributed energy storage at the distribution and customer services stages. Adding energy storage would lead to new business models, new service strategies and new pricing structures to the ultimate benefit of the consumer.

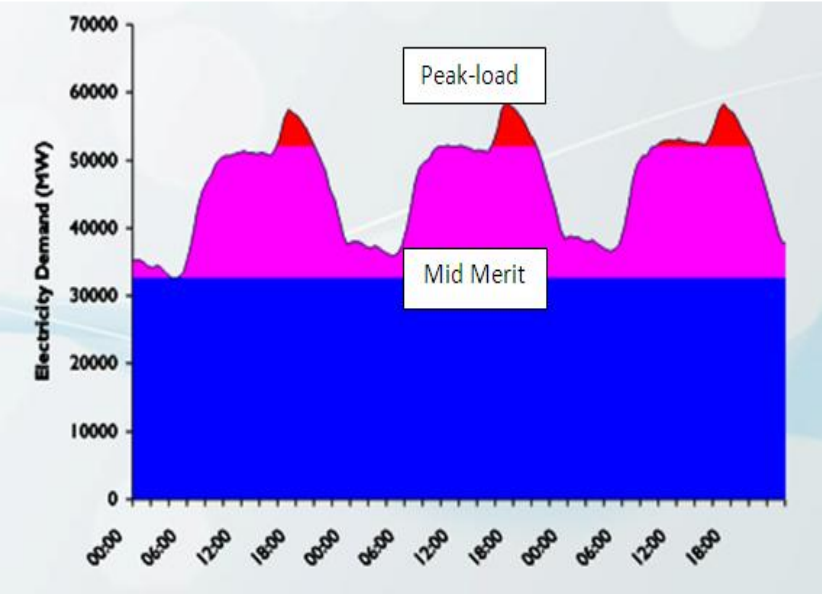
Figure 2



Industry snapshot

Figure 3 shows the UK's typical electricity demand across three days in winter. The blue is base-load, which is always on, the purple is mid-merit and the red is peaking plant[7]. Base-load has the potential to have a very low carbon footprint; for example, through the use of nuclear power, which tends to be inflexible and responds poorly to being turned off and on.

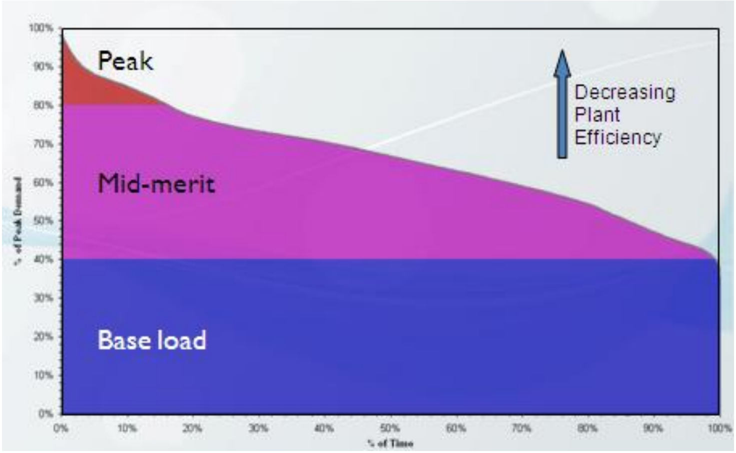
Figure 3



In the UK, mid-merit plant tends to be gas-fired and peaking plant to be open-cycle gas turbine (OCGT) driven and oil. Ideally, under a centralised and planned electricity grid, the use of mid-merit plant would be minimised and the use of oil peaking plant avoided altogether, as its use is inefficient, expensive and carbon intensive as it is ramped up and down in order to track demand.

[7] Base-load generation is that used to meet continuous demand even at its lowest level. Non base-load generation is brought in progressively as demand increases. Peak-load generation is used to satisfy short periods of maximum demand. Mid merit generation is that which falls between base-load and peak-load

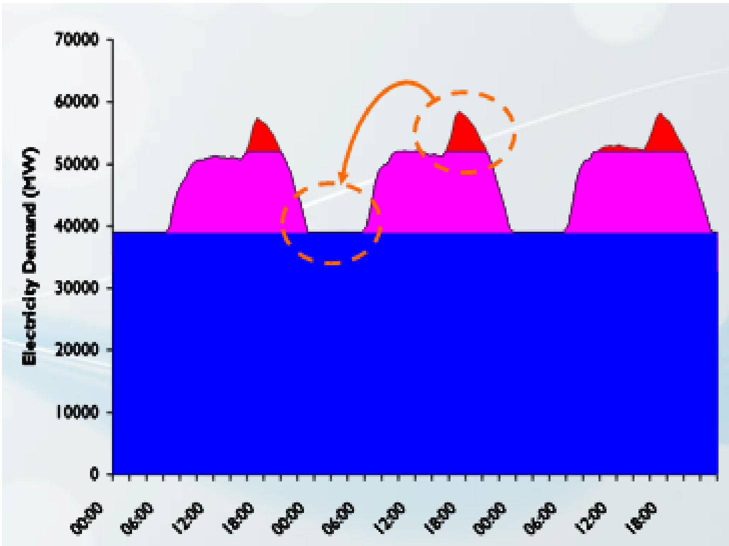
Figure 4



Reducing inefficient plant

The power load duration curve for the UK is shown in figure 4. Some 40% of UK power plant runs constantly (the base-load); there is significant utilisation of the more inefficient mid-merit and peaking plant. Up to 10% of peaking plant is run around 3% of the time[8] – this is a waste of capital and very inefficient. As suggested in figure 5, bulk energy storage has the potential to reduce the need for peaking plant by 'shifting the peaks to fill the troughs'. Mid-merit and peaking plant have high carbon footprints; they are required intermittently and the running down and running up of a plant is inefficient as already explained.

Figure 5



Replace peaking plant

It is possible to have spinning reserve, where the machinery is spinning but output is not locked in[9]; however, the best solution would be to leave the plant running and to store the energy.

The stored energy would then be available to replace the use of peaking plant. This solution also turns mid-merit plant into base-load, eliminates inefficient peaking plant and allows base-load to be predominantly nuclear powered and therefore decarbonised.

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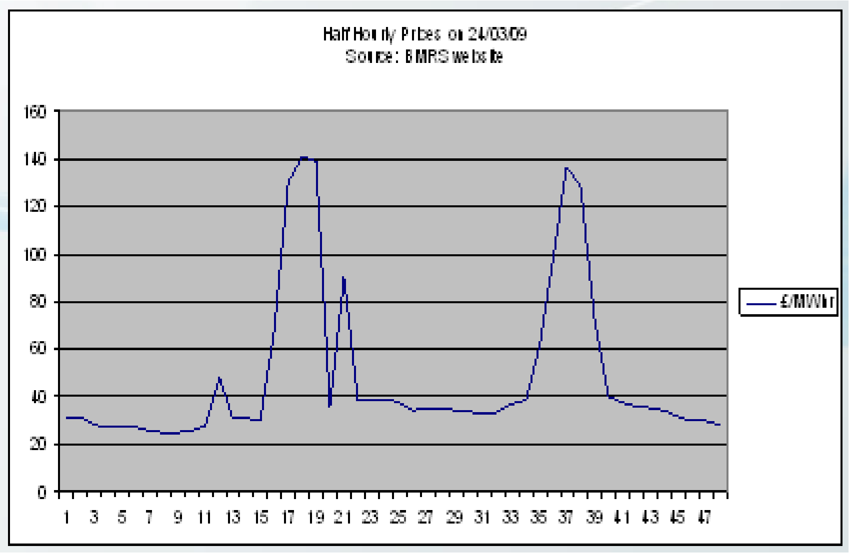
[8] National Grid

[9] The spinning reserve is the unused capacity which can be activated on decision of the system operator and which is provided by devices which are synchronized to the network and able to affect the active power. Source:http://www.eee.manchester.ac.uk/research/groups/eeps/publications/reportstheses/aoe/rebours%20et%20al_tech%20rep_2005A.pdf

Figure 6



The graph in figure 6 is from the Balancing Mechanism Reporting System (BMRS) website[10] and shows half hourly prices for electricity on 24/03/09. It can be seen that over the first fifteen half hours, electricity was priced at roughly £35 per MWh. Just half an hour later, the price jumped to £140 per MWh, owing to the day – night differential. This indicates how valuable energy storage would be from a commercial point of view as those with storage can utilize this energy to avoid paying peak prices.

Benefits of energy storage on peak prices

There are a range of other benefits associated with energy storage, including improvement of operational efficiency and the integration of weather dependent renewable energy technologies such as wind and solar. For example, if conditions are good for significant production of wind energy, this energy must (at the moment) be taken by the grid connected to the wind farm. This surge of energy is unscheduled and cuts into base-load, turning it into mid-merit plant as this plant needs to be ramped up and down to handle wind's penetration. It also prevents the most effective use of nuclear powered base-load plant, as this is inflexible. Thus, renewable energy storage would better support the use of nuclear power for base-load.

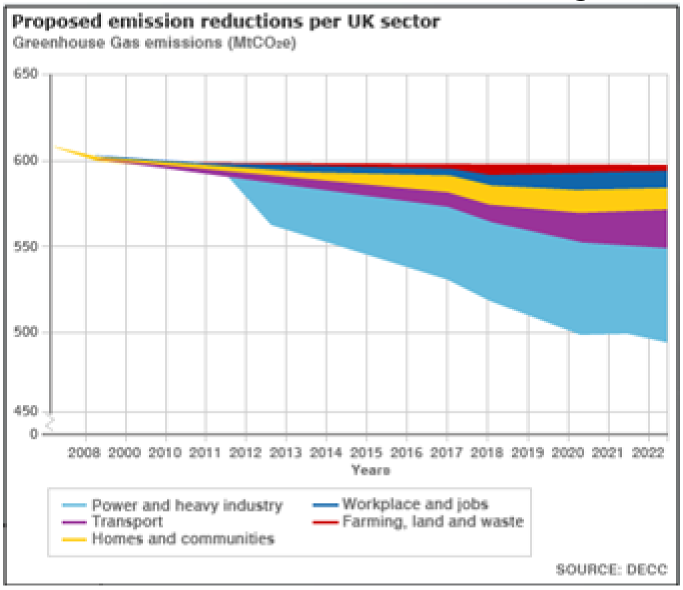
Energy storage applications

There are two types of energy storage on the electricity system at the moment. Firstly, pumped hydro[11]is used for frequency control and black start[12].

[10] http://www.bmreports.com
[11] Conventional pumped hydro uses two water reservoirs, separated vertically. During off peak hours, water is pumped from the lower reservoir to the upper reservoir. When required, the water flow is reversed to generate electricity.
[12] A black start is the process of restoring a power station to operation without relying on external energy sources.

Secondly, and more importantly, the inertia in rotating machines (large steam turbines) is also a form of energy storage; without it, the system would not work. If the system receives a shock, the big steam turbines of coal plants slow down and speed up again as the shock fades, trading power and frequency. Gas and wind powered plant cannot react in the same way. Coal plants are ideal to cope with these shocks but many will close by 2016.[13] The UK Low Carbon Transition Plan[14] requires five sectors to meet significant CO_2 reduction targets by 2020, as detailed in figure 7.

Figure 7



It is evident from the graph on the right that a great proportion of these reductions will be borne by power and heavy industry. The Department for Energy and Climate Change (DECC) also proposes that 32% of UK electricity generation will come from renewables by 2020, alongside 29% coal and 22% gas. Without energy storage, this seems an unfeasible mix.

Such a level of renewables would require the inertia of steam turbines for stability; gas cannot provide this and many coal plants, as already explained will have closed. If energy storage is deployed, however, the inertia of steam machines is not required for frequency compensation.

Energy storage is key to manage intermittent renewables

Thus, energy storage is key to renewable energy management. Many renewable energy technologies, such as wind, have low load or capacity factors (the load factor being the percentage of the theoretical maximum output that is actually generated). Importantly, new research by Professor Michael Jefferson of the University of Buckingham has, using Ofgem statistics, uncovered the capacity performances of the onshore wind developments around the UK for 2009. They show England was just 21%, Scotland at 28.5%, Wales at 25% and Northern Ireland at 25%.[15]

[13] The EU Large Combustion Plant Directive (LCPD) will force the closure of many coal and oil fired plants by 2016 on pollution grounds

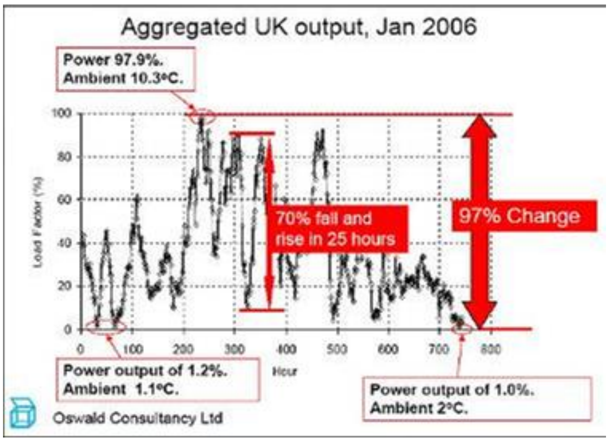
14http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx

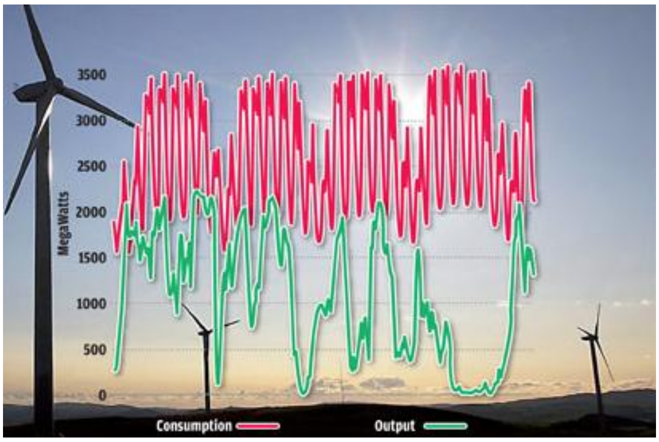
15 Data supplied to the author by Professor Michael Jefferson, University of Buckingham

Chapter 3 - Energy Storage and Intermittent Renewable Energy

The intermittency of renewable energy results in supply and demand mismatch, as illustrated in figure 8. In the left hand graph, it can be seen that there was a 97% change in wind output over the month of January 2006. Moreover, as shown in the right hand graph from Denmark in 2008, renewable supply (green line) does not fit with the demand curve (red line). Denmark is Europe's most wind energy intensive state.

Figure 8





Energy storage would also improve power quality and reliability through:

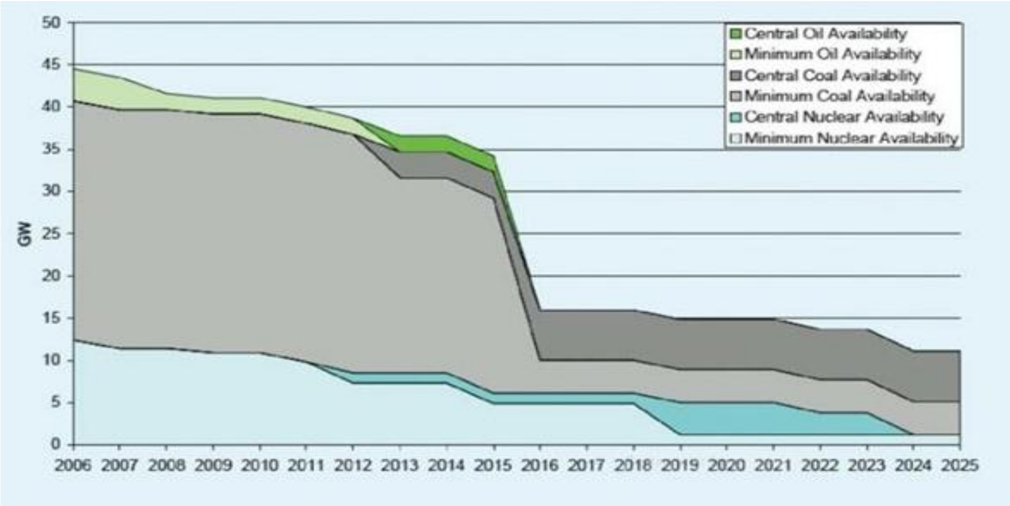
- allowing off-grid energy independence
- providing back-up power
- eliminating power cuts
- supporting weak grids

Uninterruptible power supplies are vital for many industries; sensitive equipment such as those found in the semiconductor and glass industries may be severely affected by a power cut, to the extent that the whole capital investment may be lost. These industries currently employ uninterruptible power supply (UPS) systems or a dual supply to avoid such an event. Power quality is also a political issue; in the UK, the system is good, and power cuts are memorable events. However, in some other countries, the power system is so inefficient that cuts are daily or weekly events.

The Low Carbon Transition Plan indicates that a shortfall in energy supply will begin around 2016, as shown in figure 9 (over). A significant proportion of the UK's traditional oil and coal fired power stations will close under the EU's Large Combustion Plant Directive, along with some elderly power plants[16].

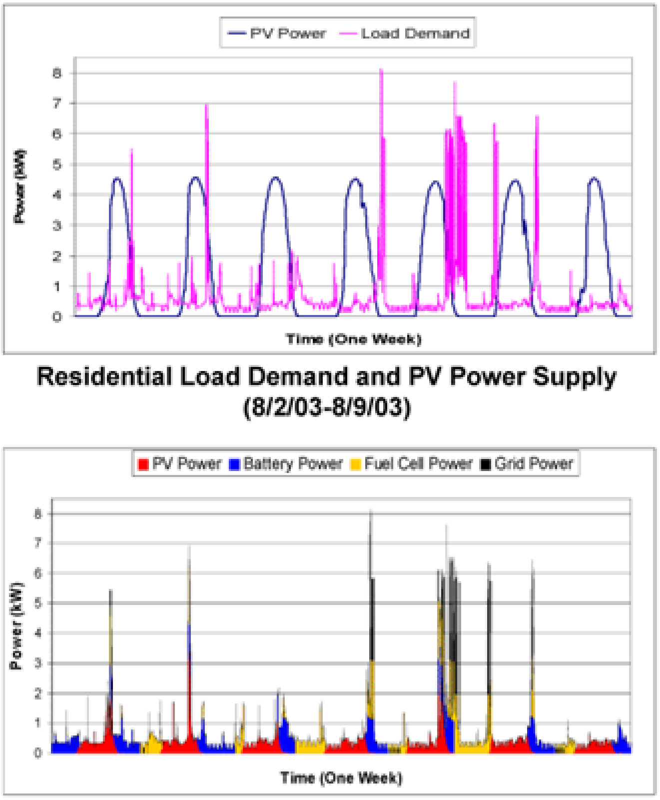
[16] http://www.defra.gov.uk/environment/quality/air/airquality/eu-int/eu-directives/lcpd/

Figure 9



It is suggested that the Transition Plan predictions are based on optimistic economic and timescale projections; the actual situation could be far graver.[17]

Figure 10



Residential Load Demand and PV Power Supply (8/2/03-8/9/03)

Grid-Parallel Power Balance by Source (1kW Fuel Cell, 1.9kW Electrolyzer, 500A-hr Battery)

As illustrated in figure 10, the first graph shows the most extreme peaks in the electricity system are at the customer end. This graph is from a study undertaken in California and illustrates the use of power in a house over one week with solar PV panels. Note the intensity of weekend demand. The peaks are made up of a collection of very 'peaky' events which occur at a similar time, such as putting the kettle, the washer/dryer and the cooker on after returning from work. PV supply (blue line) and consumer demand (pink line) do not match.

The most effective way of managing a supply and demand

[17] http://www.telegraph.co.uk/finance/comment/damianreece/5837550/Green-energy-is-great-but-we-need-investment-to-keep-the-lights-on.html

mismatch such as this is to deal with it locally. This is achieved through the use of energy storage. The second graph is from a study of a house with a fuel cell[18] and electrolyser[19], a battery, and grid connection.

Demand side management

Another way of managing energy is through demand side management, or moving the peaks around. One way of achieving this is allowing the householder more access to information on peaks and pricing. An example is Google's PowerMeter[20]. This is a free software tool that allows the householder to view a home's energy consumption, using data from utility smart meters and in-home energy management devices.

[18] A fuel cell is an electrochemical energy conversation device. It converts hydrogen and oxygen into water, producing electricity and heat in the process

[19] An electrolyser is a device used to separate Hydrogen and Oxygen from water via electrolysis

[20] http://www.google.org/powermeter/

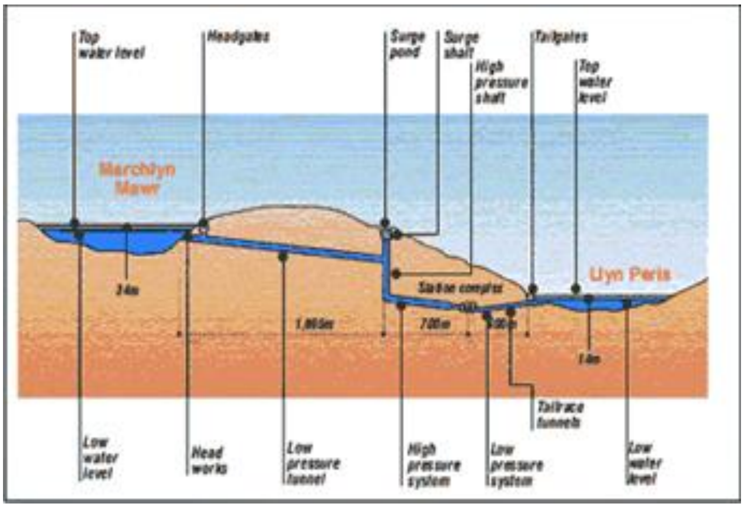
Chapter 4 – What are the Energy Storage Technologies?

There are many energy storage technologies and some have more advantages and efficiencies than others. All these technologies play a part in different areas; not one of them is a complete solution. Some are for bulk storage, some for the distribution end of the chain, and some are more versatile.

Pumped storage

Dinorwig Power Station[21] is one of two carbon neutral hydro-pumped storage power plants in Wales. Pumped storage is a straightforward mechanical cycle; water is pumped up and then flows down again.

Figure 11



Dinorwig’s turnaround efficiency is 74% and five hours of energy storage is possible. Power is genuinely separated from energy in the pumped storage process. If it is necessary to store this power for a longer period of time, the solution is to make the lakes bigger. Thus, the water runs down for longer and power is delivered for longer.

Dinorwig cost £200 million to construct and was sold during energy privatisation to Mission Energy for £354 million. Today, Dinorwig is the only black start capability on the whole system – the only bulk energy storage where no machines are rotating.

Batteries

Batteries must be charged and discharged within a time limit. Batteries are highly responsive to electrical demand and they are thus capable of delivering a wide range of power outputs. However, they cannot be charged quickly and if they are discharged deeply or subjected to high summer or freezing winter

21 The Dinorwig Power Station is a 1,800 MW pumped-storage hydroelectric scheme, near Dinorwig, Llanberis in Snowdonia national park in Gwynedd, north Wales. It comprises 16 km of tunnels, 1 million tons of concrete, 200,000 tons of cement and 4,500 tons of steel.

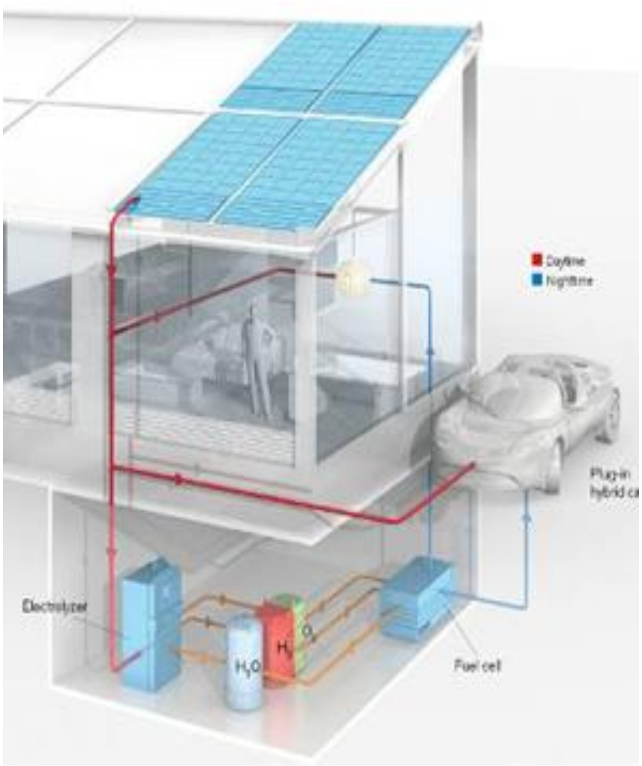
temperatures, their subsequent performance deteriorates and makes their energy storage capability uncertain.

For every hour of time that a battery is used to store energy, the physical battery capacity needs to be proportionally increased, so batteries are good for energy storage over short timescales. For longer timescales avoiding excessive quantity of battery capacity, using an electrolyser to produce hydrogen provides the opportunity to separate energy and power, so the electrolyser can produce hydrogen, indefinitely and the hydrogen can be stored in a separate storage vessel

Hydrogen stores however can be charged and discharged at widely varying rates across a very wide range of ambient temperatures without any deterioration in energy storage performance.

Green hydrogen

Figure 12



An alternative method of separating power and energy is through an electrolyser and a fuel cell. Electrolysers produce hydrogen and oxygen from water and fuel cells produce power from hydrogen and oxygen. As seen in figure 12 this is useful for small scale energy storage applications such as the domestic home. To increase storage time, the hydrogen and oxygen storage capacity can be increased.

Importantly, the Government has pledged to make all homes zero-carbon by 2016. This can only be genuinely achieved if this model is supported. A genuine zero-carbon home will require a zero-carbon fuel to allow for zero-carbon living.[22]

This self-contained clean energy system involves solar panels and an electrolyser linked to a hydrogen system that provides back-up power, heat and

[22] http://www.businessgreen.com/business-green/news/2264768/property-sector-fears

gas for cooking. The hydrogen system also provides fuel for the zero carbon hydrogen vehicle.

Off-grid zero-carbon power

For example, in an off-grid area with weak fuel supply logistics, such as an island or remote centre a renewable energy and fuel-making technology is an inviting proposition. Energy storage would give many advantages to such communities; the Isle of Man is a good example. The island is powered by three or four 1MW – 1.5MW diesel engines, the fuel efficiency and maintenance of which is costly and the grid is weak. Energy storage would allow interconnection and the 'trading off' of peaks.

The Norwegian Model - Utsira

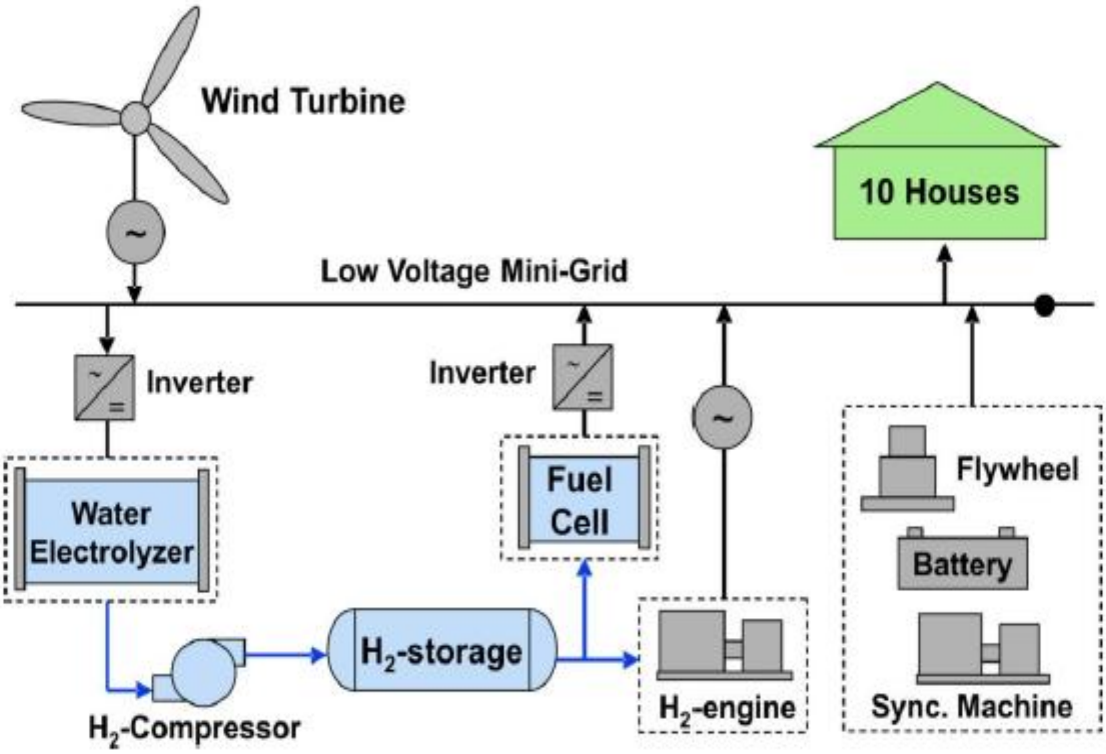
The island of Utsira, 15 miles off the south west coast of Norway, is totally self-sufficient in renewable energy. In 2004 it installed a ground-breaking renewable energy storage system ideally suited to its wind conditions. The wind/hydrogen power system was designed to meet the entire energy demand for ten households using intermittent wind energy either directly or indirectly via hydrogen storage.

Importantly, the renewable energy storage systems on Utsira allows for the provision of three days of stored zero carbon power, if a wind-free period occurs. This length of storage time can be increased by simply expanding the hydrogen storage capability.[23]

Two wind turbines have been installed on Utsira (left), but only one of these is used to provide direct power to the local grid. The other feeds directly into the hydrogen storage system, thus providing the hydrogen storage as shown in figure 13 (over).

[23] The Utsira Wind/Hydrogen Demonstration system in Norway, EWEC - 2009

Figure 13



For the past six years the Utsira system has demonstrated that intermittent wind connected to hydrogen systems can be used to supply green power to remote area communities and transport networks at all times. However, further technical improvements and cost reductions are necessary to make wind/hydrogen systems more viable and competitive against diesel powered systems.

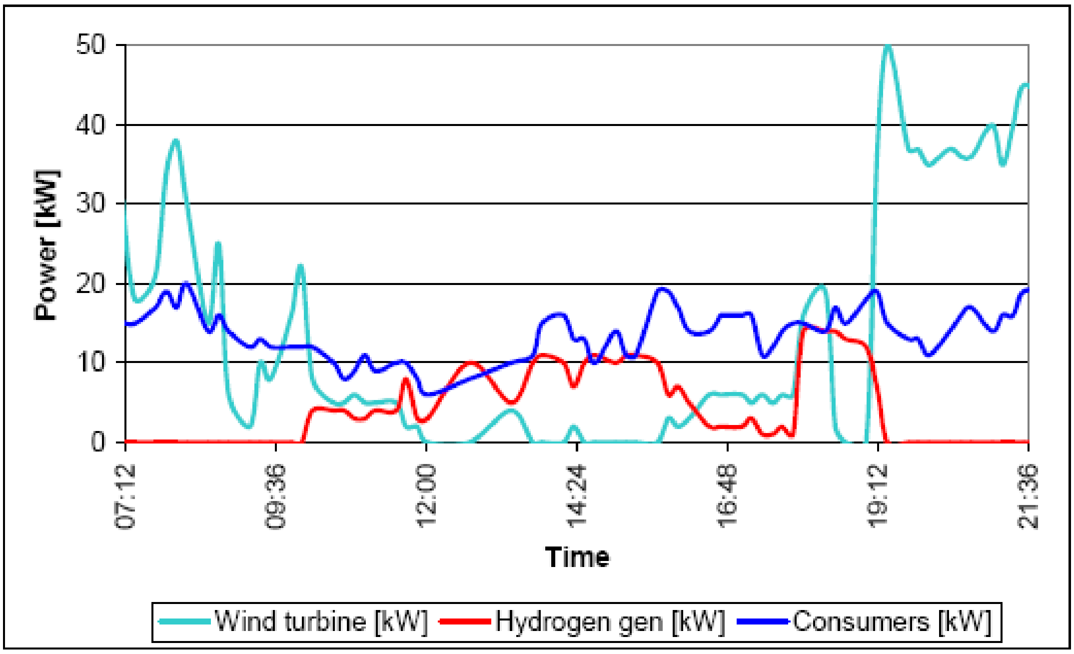
Utsira is, at the moment, relying solely on intermittent wind energy with hydrogen storage. If it were to boost its renewable portfolio with the installation of solar PV, wave and tidal capability, it would add to the island's ability to generate and store green energy for use when needed.[24]

How does Utsira work?

Figure 14 illustrates how the Utsira energy system works. In low wind mode when direct wind input does not match demand the hydrogen (H_2) engine starts to compensate for insufficient wind; while in high wind mode the electrolyser is busy producing and storing hydrogen for future use.

[24] 'Stand-Alone Power Systems for the Future' – Norwegian University of Science and Technology, 2006

Figure 14



Between 7am and 9.30pm on a random day in 2008 wind power decreases and cannot supply the island. In this time period the H_2 engine (red line) meets demand to fill the troughs left by the absence of wind.

Figure 15

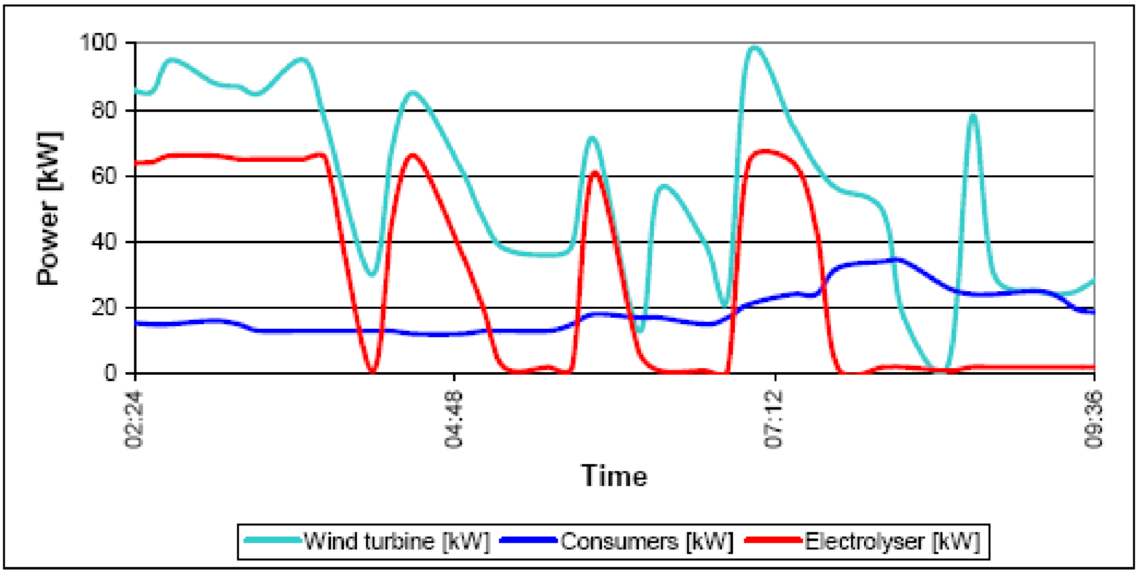


Figure 15 shows what happens in high wind mode on Utsira. Demand is met and the electrolyser is busy generating green hydrogen for later back-up use.

Figure 16

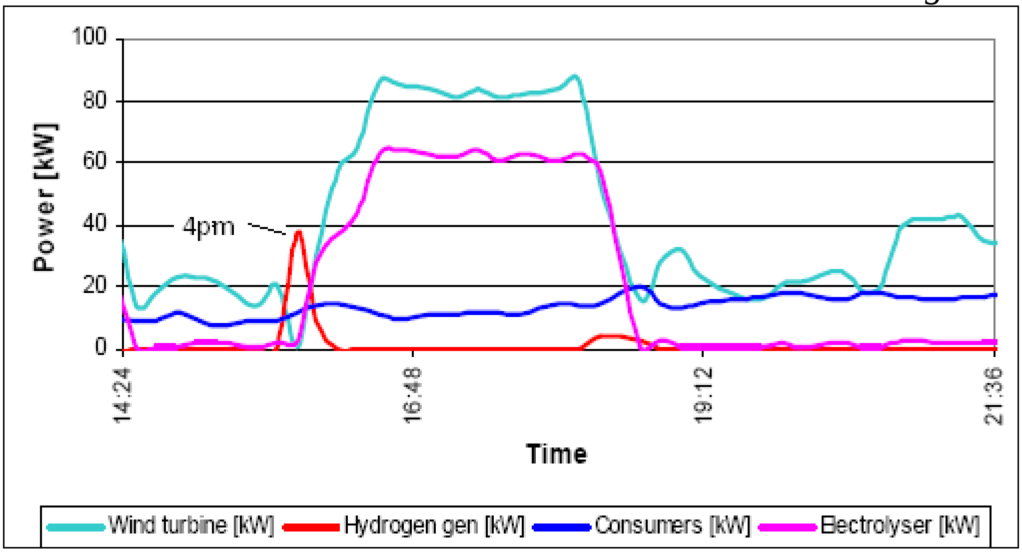


Figure 16 best illustrates the Utsira green energy solution. During this time period between 2pm and 9.30pm we can see the high wind mode and H_2 production in the electrolyzer and the low wind mode with the H_2 engine quickly ramping up (see the H_2 load – red line - at around 4pm) to cover the complete lack of wind power.

Chapter 5 – Providing a British Policy Lead

In the UK Yorkshire based ITM Power[25] has built a hydrogen refueling station for vehicles outside its Sheffield offices. It has also built a mock hydrogen powered zero-carbon home at its factory. ITM's hydrogen is generated directly from solar PV panels at the factory. Three further refueling stations are based at the Universities of Glamorgan, Birmingham and Loughborough with another two to be opened in Camden and Sheffield. ITM's converted zero carbon Ford Focus can achieve an average of 130 miles on a single tank of hydrogen before it is forced to switch to petrol.

Green hydrogen

The true eco status of hydrogen is governed by the carbon footprint of the process so if hydrogen is generated from renewables and nuclear it can claim to be zero or near zero carbon. Hydrogen created from coal and natural gas is known as 'brown hydrogen' and the process carries a significant carbon footprint. Significantly, in October, ITM announced plans to team up with global wind turbine manufacturer, Vestas, with the aim, in the words of Rob Sauven of Vestas, "of generating the most sustainable return on wind for our customers."[26]Vestas is the world leader in wind technology with a 12.5% market share in 2009.

However, it is important to note that many energy storage technologies are unproven and the cost targets are difficult to define. Engineering scale also poses a technology risk; every stage of scaling up, e.g. from 100kW to 500kW to 1MW and beyond, introduces new risks to a new section of the market.

The electricity industry is extremely conservative and reluctant to take on this risk. It will be down to Government to encourage the energy storage sector, as it has done with wider renewable through Renewable Obligation Certificates (ROCS).

[25] www.itm-power.co.uk

[26] 'Wind Turbine company joins ITM Power trials' *The Business Desk.com*, October 4 2010

The Eigg problem

In May and June the remote Scottish island of Eigg[27], which relies on wind, hydro and solar energy to provide all electricity and heat, endured an unusual but prolonged period of high pressure. Consequently, the absence of wind and rainfall meant the island had to rely on its solar PV panels. However, these were unable to provide enough energy to meet demand. Eigg's small battery storage system was also unable to store enough energy to cover the prolonged energy drought as it could only cope with interruptions of up to 24 hours.

Unlike the Norweigan island of Utsira, the lack of large scale green energy storage exposed Eigg and its 87 residents to electricity rationing. Large-scale hydrogen energy storage could have seen the island through the gap and maintained a zero-carbon footprint. Instead, the island had to switch to emergency diesel generators. Eigg is now looking at an Utsira style hydrogen storage system.

The potential for transport fleets

The ideal initial scenario for decarbonising the transport sector with green fuel generated by renewables would be to target commercial fleets such as taxis, buses, delivery vans and coaches as such vehicles return to base. Zero-carbon fork lift trucks operating indoors are an obvious opportunity.

London Mayor, Boris Johnson has called for a huge increase in the number of electric cars on the streets of London, whilst also supporting a hydrogen dimension too as Deputy Mayor Kit Malthouse sets out in his Foreword. Electric vehicles endure many limitations and there are emerging questions over their green credentials.

ITM's hydrogen on site trials (HOST) of its transportable refuelling station begins in 2011 with logistics partners across different sectors, and aims to demonstrate the production of a clean fuel at the point of use, thus eliminating the carbon footprint of the production and transportation of a fuel, as the fuel can be produced anywhere it is required (left), by plugging into electricity and water.

[27] http://islandsgoinggreen.org

Such containerisation would be a competitive solution for remote and difficult areas such as offshore oil rigs, islands, remote rural communities, drilling stations etc. All such areas have high fuel prices; to be able to make fuel on-site for vehicles with a renewable energy supply would be an attractive proposition as energy prices rise. The potential is also clear for fuel provision for military operations in difficult and remote theatres.

Investing in low carbon technologies

The UK needs new and emerging low carbon technologies to meet its climate change targets as existing technologies - energy efficiency, onshore wind and nuclear - will only take us part of the way towards it[28]. With demand set to grow, there is also an economic imperative to developing a thriving low carbon industry in the UK. NESTA[29] research estimates that by 2013 the global low carbon market could potentially be worth £46 billion. In 2025 the world energy demand will have increased by 50% compared to 2005 levels and will reach the equivalent of 15 billion tons of oil equivalent. In 2030, the EU will import almost 70% of its energy needs.

However, the UK currently has less than a 5% share of the global market for green technology – less than Japan, France, Germany, Spain or the US. International companies are also beginning to invest in low carbon technologies, as demonstrated by Google's announcement of a Proof of Concept fund to address the lack of funding between the research and development (R&D) and commercialisation stage.

The UK needs to utilise its strengths by seeking to exploit early science and technology research and development, as well as the financing of low carbon technologies. In developing proposals for a 'Green Investment Bank', the Government should consider how it could play a key coordinating role in bringing together financiers of low carbon technologies with early stage developers in the UK such as the pioneers of energy storage technology.

In his 2010 report, *Ingenious Britain*, Sir James Dyson highlights that while overall levels of R&D have increased, the level of investment as a percentage of GDP is still only 1.7%. More importantly, analysis of R&D investment by companies indicates that UK companies invest less in R&D regardless of their size as compared to their G8 competitors.[30]

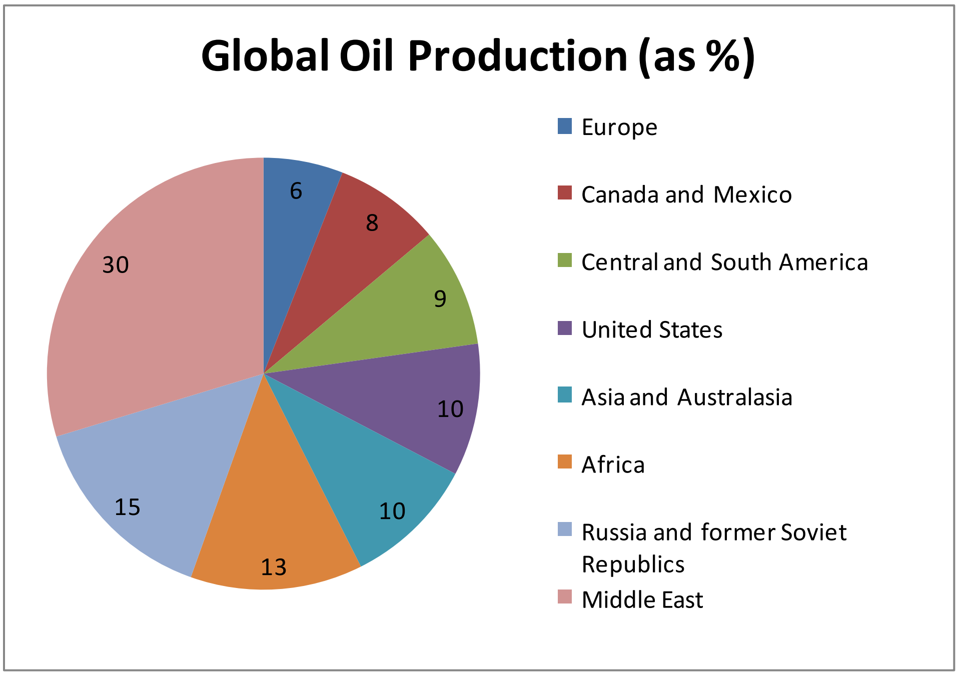
[28] Carbon Trust submission to the Low Carbon Task Force
[29] NESTA: National Endowment for Science, Technology and the Arts
[30] DBERR, Innovation and Skills, R&D Scoreboard (2009)

Why we must shake off our dependence on oil

The UK is now a net importer of oil and gas, highlighting the grip the Middle East has again on the UK and the global economy as shown in figure19.

The following graphs shows who buys oil and, more importantly, who sells it, showing an almost upside down scenario where the countries that consume the most oil no longer produce even a fraction of what they require. Importantly, Middle East dominance is set to increase still further this century.

The Global Reserves chart at figure 19 shows that oil reserves in the Middle East dwarf those discovered in other parts of the world. The grip that this region holds on the oil markets is particularly concerning given the volatile political situation and huge dependence on oil in the West. Not only does the UK consume vast quantities of oil, estimated at 1.7 million barrels per day, but this oil dependence purveys all major sectors including transport, industry, domestic use and electricity generation as shown in figure 20. [31] *Figure 17*

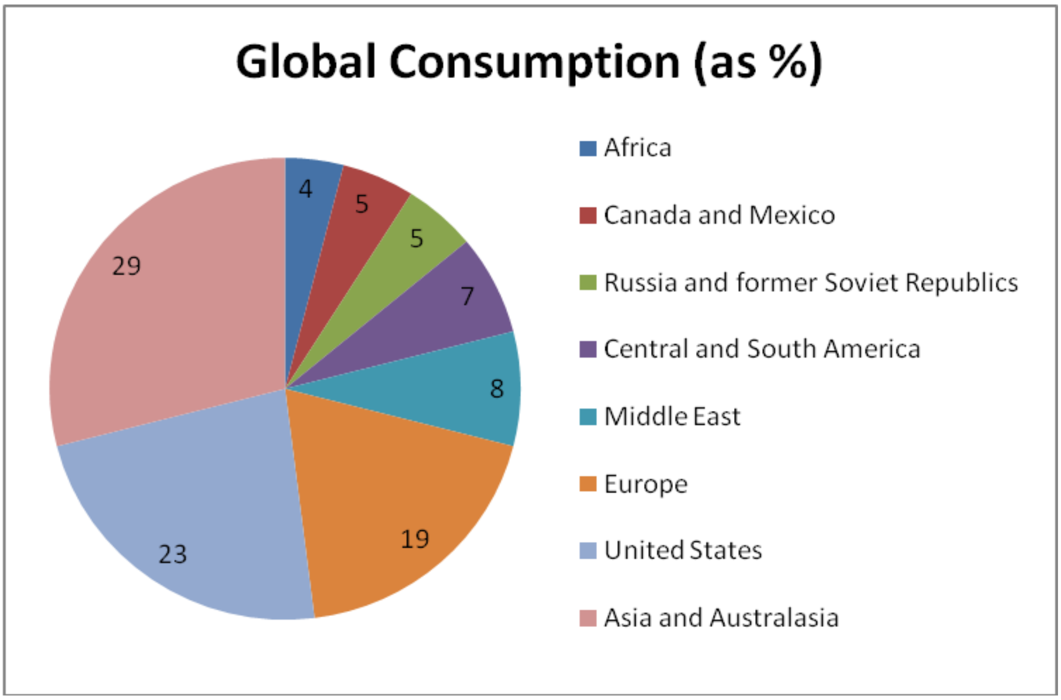


Production: 85.4 million barrels per day[32]

[31] The source for all charts and associated statistics is the US Energy Information Administration. All Figures are 2009. Some charts do not add up to 100% due to rounding.

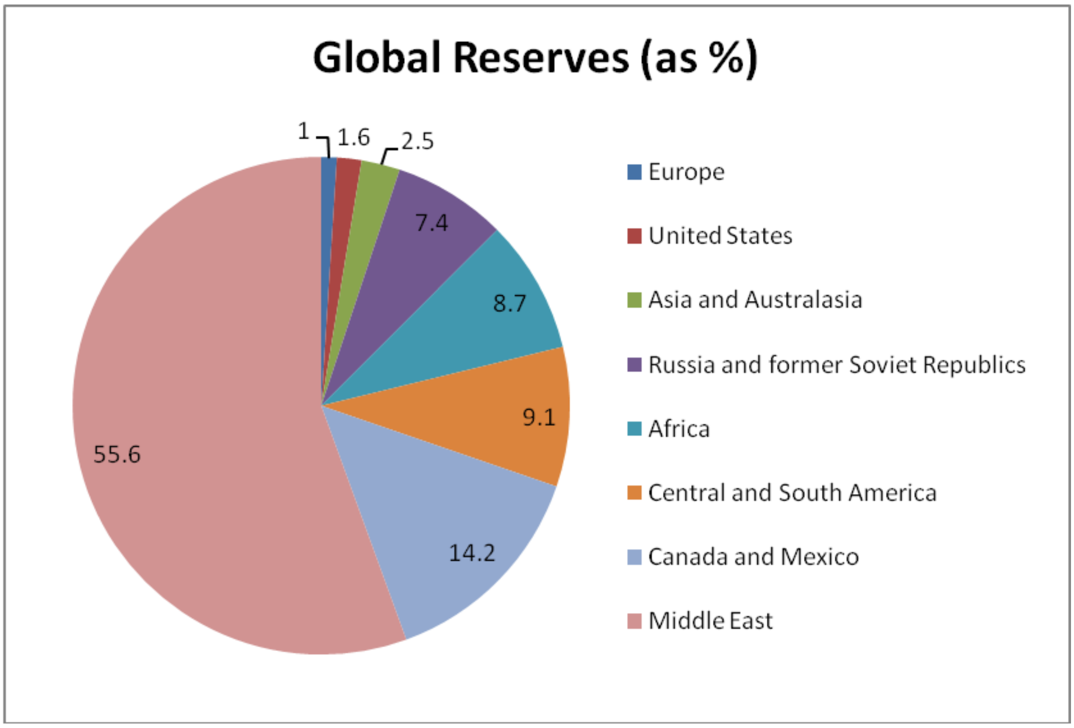
[32] 1 barrel of oil represents 42 US gallons or 158.984 litres

Figure 18



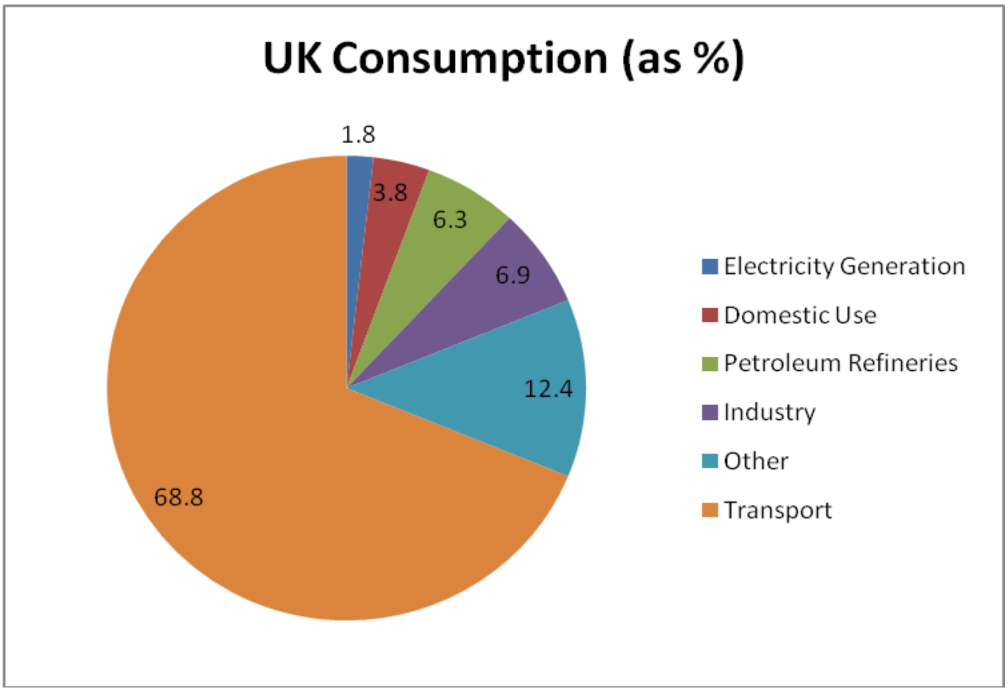
Total Global Consumption: 85.8 million barrels per day

Figure 19



Global reserves: 1.3 trillion barrels

Figure 20



Total UK Consumption: 1.7 million barrels per day

Total UK Production: 1.5 million barrels per day

Accounting for nearly 69% of UK oil demand, the transport and automotive sector's ongoing and increasing thirst for oil represents the biggest challenge in the task of decarbonising this vast and growing sector and reducing the UK's hydrocarbon dependence.

Chapter 6 - Realising the Potential and Cutting Energy Bills

As explained, green energy storage can provide many householders with protection against expected electricity blackouts, providing a level of emergency back up to the national grid as well as allowing households to manage their own energy consumption. Importantly, it will also deliver significant improvements in air quality by reducing the release of pollutants into the atmosphere, particularly from transport. This could have a major impact on reducing health costs over time.

Localism in energy

Green energy storage provides a localist bottom-up solution for the Coalition towards energy and environment policies without Ministers having to cherry-pick technologies or pick winners.

Houses with green hydrogen fuel systems can reduce their domestic fuel bills by up to a quarter – reducing the incidence of fuel poverty that looks set to soar as the UK's electricity prices are increasingly driven by anticipated higher gas prices. By 2015, 60% of UK electricity will be generated by gas, up from 20% in 2004.

A green localist energy strategy should not:

- Produce perverse effects by driving up rather than reducing carbon emissions.
- Impose massive burdens on the UK economy by costing more than the value of the carbon it saves.
- Prompt rises in fuel bills that exacerbate poverty and hamper economic competitiveness
- Delay policies which can improve air quality and health

An assessment from a recent government report[33] puts the annual cost of renewable energy policies at £4.3bn, delivering an annual average benefit of £0.3bn. Over a 20 year period the net benefit of the policy is MINUS £56bn. The total value of carbon saved over the same period is put at just £5bn on current prices. This clearly does not make economic sense, particularly at a time of recession and when taxpayers are facing a rise in taxation and cuts in public services.

[33] Impact Assessment of UK Renewables Strategy – published July 13 2009 (DECC)

Impact of meeting renewable targets

Using the Government's Committee on Climate Change (CCC) modelling of the 'business as usual' model; the number of households in fuel poverty in the UK falls from 3.5 million in 2006 to 2.1 million in 2022. However, the possible increases in gas and electricity prices over this period needed to meet the carbon targets would increase the number of fuel poor households in 2022 to nearly four million households.

The cost of offsetting these price increases for all fuel poor households has been estimated at £500 million. Further energy efficiency improvements through the Supplier Obligation[34] would increase prices further and raise the total number of fuel poor households in 2022 to over 4 million. The CCC argues that income transfers and social tariffs would be needed to offset these impacts.[35]

If the Government continues its predecessor's policy of forcing "very substantial" taxes on oil, gas and electricity then the renewable heat incentive and renewable obligation systems will necessarily increase fuel poverty. The UK Renewable Energy Strategy and the UK Fuel Poverty Strategy are therefore incompatible. A more effective use of Britain's growing but fledgling renewable sector is key to combating this unwelcome effect.

DECC Incentives must support storage

In order to reach its carbon output targets, previous governments placed an over-emphasis on renewables funded by taxes on fossil fuels. The UK's strict carbon reduction targets can only be reached if a more market-oriented solution is supported but which recognizes the need to incentivize renewable energy storage and clean fuel policies.

[34] This replaces the Carbon Emission Reduction Target form 2011

[35] *Building a low carbon economy* – the UK's contribution to tackling climate change, Committee on Climate Change, Chapter 12

Chapter 7 - The Challenge for Policymakers

The Government presently provides financial support for the renewables sector through Renewable Obligation Certificates (ROCs). It does not provide any incentive for the storing of renewable energy as a clean fuel by households who choose to fit micro-generation systems. In some cases, households may fit systems which generate well in excess of their own electricity requirements but are not rewarded for doing so.

This contribution to greening the typical household low-voltage network should be encouraged, but especially in the case of solar panel PV systems there will be substantial exports occurring at times of the day when domestic electricity demand is low, leading after a few days to significant reverse flows in some parts of the network.

Renewable Electricity Storage Incentive (RESI) for green storage

A Renewable Electricity Storage (RESI) should now be made available for the micro-generation of green hydrogen by electrolysis. Various studies have shown that this route of absorbing electricity at times of high or excess renewable availability for later use at times of high demand offers flexibility (e.g. car refueling, emergency backup power, as well as peak time supply).

It is likely that a significant proportion of consumers will discover that they have a new role as micro-generators of green energy as well as users. They will then appreciate the balance between generation and use leading to more energy efficient practices. In this context energy storage technology should be encouraged within a micro-generation strategy. This would help those who wish to achieve more autonomous energy solutions and a low carbon footprint with the installation of suitable equipment such as a home refueller.[36]

Feed-in tariffs just reward exporters of energy

Present policies support a future feed-in tariff system which rewards homes for ‘exporting’ or giving back green energy. Exporting provides no incentive to smooth out intermittent loads on the local distribution network. Energy storage technology would address this issue by mopping up intermittency in the form of a clean fuel consumed at household level.

[36] A home refueller includes an electrolyser, control system, compression unit, storage and hydrogen dispensing technology

Deployment of decentralised energy storage technology would promote effective utilisation of renewable energy generated at times when it is surplus to requirements (for example, when the wind blows at 3am in the morning, or when the sun shines at midday when energy demand is comparatively low). The stored energy could be used to supplement peak demand or used as a fuel for hydrogen vehicles.

A feed-in tariff for energy storage – the RESI - and micro-generation of hydrogen would be invaluable for remote off–grid communities like Eigg, allowing energy from renewable sources (wind and solar PV), to be used for cooking, heating and electricity generation, whenever required. This tariff should instead include micro-generation of a clean fuel and should incentivise its storage for later use.

What price the storage incentive?

Presently, households are rewarded 36p per kWh for generating and using renewable electricity and receive a 3p per kWh feed in tariff for exporting green energy back to the grid. The Renewable Energy Storage Incentive (RESI) should co-exist alongside the existing feed in tariff but better incentivise the user to store and use green energy. Retention of the 36p per kWh rate for generation with a 10p tariff for storing green electricity will sufficiently provide this incentive as the concept is commenced.

Government should look, as it has to incentivise the purchase of low carbon cars, to provide a grant towards to purchase of a hydrogen refuelling unit.

Storage can resolve the renewables dilemma

The renewables debate is reaching a climax. In order to appreciate this, the underlying incentive for a household or developer to install the relevant equipment requires more attention.

This raises the question of why a homeowner would want to install solar PV or wind turbine equipment if they cannot feel the full benefit. Afterall, most homeowners at work when the sun shines or the wind blows are not going to profit from any energy generated.

Government's record

Government does not have a good record of picking winning technologies, especially when their guesses and gambles are based on inadequate science.

There is now general acceptance that Labour's emphasis on "first generation" biofuels was misguided – misspent subsidies encouraged the cultivation of non-sustainable biofuels, drove deforestation, and caused rises in food prices and fatal shortages in food supplies. The recent Bow Group pamphlet, *The Case for Energy Crops*, addressed this very question and argued for sustainable and traceable energy crops.[37]

A further report from Fells Associates[38], *"A Pragmatic Energy Policy for the UK"*[39] says that the UK Renewables Strategy will, "require a monumental shift in investment and build rate for renewables across all energy sectors." The report points out another problem with wind, "Renewable energy can play a part, but it is not base-load. Wind farms require 90% back-up to deal with windless days, so a large increase in wind-generated capacity actually exacerbates the problem."

New Government support

Encouragingly, in recent weeks two senior Coalition Ministers, including the Minister for Energy, Charles Hendry, has spoken in support of renewable energy storage. On October 13th Mr Hendry told the Commons in a debate on offshore wind, "wind is intermittent...back up is required, including from coal, gas or biomass. It could also be done through storage; pump storage and hydrogen or battery technologies."[40]

Similarly, just 24 hours before this statement the Minister for Science, David Willetts, told the Innovate 2010 Conference, "we have good prospects in wind and marine, in fuel cells and energy storage."[41]

DECC's Low Carbon Transition Plan[42] recognizes the back-up problem in the Executive Summary but does not solve it. "In 2020, a larger proportion of renewable generation, particularly wind generation, will create challenges from increased intermittency.

Analysis suggests that these risks to electricity security of supply are manageable before 2020, but that after 2020 they could potentially become a problem due to the closure of old gas and coal plants and additional renewable

[37] *The Case for Energy Crops*, Bow Group Energy Committee, July 2010
[38] http://fellsassociates.awardspace.com/
[39] 'A Pragmatic Energy Policy for the UK', Fells Associates, 17 September 2008
[40] *Hansard*, 13 October 2010, Column 139 Westminster Hall
[41] www.bis.gov.uk/news/speeches/david-willetts-innovate-2010
[42] Low Carbon Transition Plan, DECC, 15 July 2009

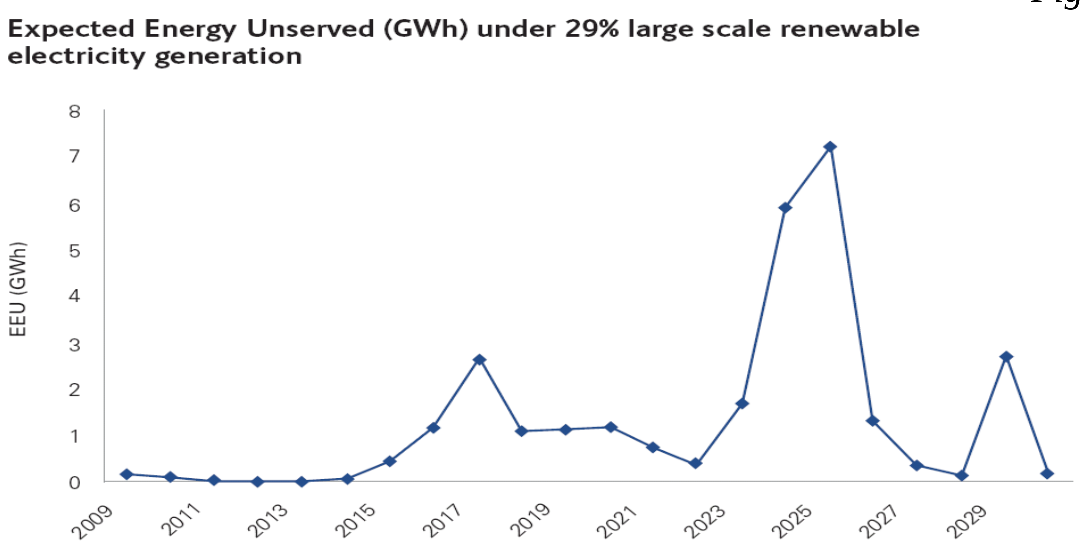
deployment". The ongoing delay in bringing new nuclear plant on-line will only exacerbate this problem.

Minding the gap

The year 2017 will be the beginning of a likely energy crunch with shortfalls of 3GWh rising to 7GWh as power station closures take effect (figure 21). The figures become all the more concerning when it is borne in mind that they depend on the delivery of the wind capacity being on target to the total capacity of 26.4GW by 2020.

Under Labour's plans Britain was heading for significant electricity blackouts which could now be exacerbated by failure to make adequate progress to the targeted wind capacity. The Coalition now has the opportunity to address this looming problem and support increased energy storage of renewable energy. This will lessen the pressure on the grid and provide householders with a large measure of protection against forthcoming blackouts and price spikes.

Figure 21



The health and environmental benefits of green energy storage

Government renewable heat targets are expected to be met "mainly through encouraging switching by industrial, commercial and residential customers located off the gas grid from oil, coal or electrical heating, to biomass or other renewable technologies" [43]

[43] para.4.1.6, The UK Renewable Energy Strategy 2008

Biomass power plants without stringent controls would cause significant pollution in urban areas and would require Government direction on their location to minimise the effect of particulate and NO_X emission on the general population. Bioliquid plant for electricity generation is more beneficial on particulate and NO_x grounds, but Government still hesitates to provide proper support for bioliquids to generate electricity.

The emission of particulates is estimated to advance 8,100 deaths a year in Great Britain and to cause an additional 10,500 respiratory admissions to hospital[44]. The last Government's Biomass Strategy, announced in May 2007 stated, "Substitution of natural gas with biomass, on the other hand, generally leads to increases in emissions of all major pollutants". [45]

The last Government's Consultation on Draft Local Air Quality Management Guidance (July 2008) states, "In the light of current Government policy, it is particularly important that climate change and air quality policies are joined up".[46] The danger is that Labour's renewables and transport strategy, if not changed by the new Coalition Government to support renewable energy storage and zero carbon transport, will subvert the Air Quality Strategy and worsen air quality in urban and rural areas.

[44] Quantification of the Effects of Air Pollution on Health in the United Kingdom, DoH, 1998
[45] Para 5.17 DEBRR Biomass Strategy (May 2007)
[46] Draft Local Air Quality Management Guidance

Chapter 8 - The Solution: HYDROGEN

Local renewable energy storage is the only viable way both to slash UK carbon emissions in the short term and to meet strict renewable targets.

Renewable storage will reduce rather than increase fuel bills. Once a household has paid for the necessary equipment the resulting fuel is free with all of the additional benefits of reducing fuel prices.

The technology is practical and commercially viable as has been demonstrated on Utsira and in various test facilities, including the mock zero carbon home at ITM Power in Sheffield.[47] Local storage is based on clean technology – cleaner than oil, coal, biomass and natural gas thereby improving air quality. In addition it will provide greater stability to the power supply providing protection against power cuts and can replacing existing electricity and gas supplies at peak times.

It can decarbonise the transport sector and slash air pollution in urban centres.

Energy at the point of use – the advantages

Generating electricity at the point of use avoids the wasted energy associated with power stations and transmission systems. Most analysts now agree that the UK is becoming over-dependent on gas for the generation of electricity. In 2010 the generation of electricity was responsible for 40% of all UK gas use[48].

Gas usage is further confused when consideration is taken of its efficiency in domestic cooking and heating compared with its use in the generation of electricity.

This is because when gas is used for either heating or cooking its efficiency approaches 100%. Only half the amount of gas would need to be burnt to bring a pan to the boil on a gas cooker than would need to be burnt to generate the necessary electricity on an electric cooker. This is because of the energy loss which results from the transmission of electricity over long distances. Locally produced green hydrogen enjoys the near same thermal efficiency as natural gas and minor conversions to typical kitchen cookers are straightforward.

Combined with solar technology and insulation measures a hydrogen generation and storage system should be able to achieve the Government's 80% emission

[47] www.itm-power.com The author visited ITM's demonstration hydrogen powered zero-carbon home in June
[48] Energy Security – A National Challenge in a challenging World, DECC, August 2009, p64

target by 2050. These systems can be serviced by engineers with existing skills. Over time, following initial installation and payment for the equipment, the outlay will be recouped as reductions in total household energy bills of up to 25% are achieved.

Conclusion – What the Coalition Needs To Do

The Coalition needs to revise the UK Renewables Energy Strategy without losing sight of the carbon emissions targets. Renewables may be part of the answer but the subsidy required to deliver Labour's heroic targets will be economically unsustainable unless incentives to store green energy are introduced.

A new policy to rescue renewables

A policy which rests on a net cost eleven times the quantified benefit it delivers is highly likely to fail at a time of public spending restraint and scrutiny. The pain is almost completely avoidable. Common-sense solutions to climate change are politically far more palatable.

In Scotland, Alex Salmond has set a target for Scotland to become 80% self sufficient in renewable energy by 2025. Such vision is to be applauded given the opportunity presented by Scotland's exposure to wind and tidal conditions but it cannot work without renewable energy storage.

If however, one considers the experience of Denmark, that according to a report in 2009 has installed wind turbines equivalent to 20% of its power generation, yet finds that only 5% of its energy demand can be served by the wind due to intermittency, it is clear to see that such aspirations may exceed reality, unless that is, that the wind's power can be harnessed to be used later, when it is required to meet demand, through the deployment of energy storage. With this approach, the potential for Scotland and the rest of the UK is huge.

The Danish lesson

In fact, Denmark's predicament is that 50% of the wind generated electricity it produces has to be exported anyway, as it cannot be used, and is sold at a discount to the cost of generation to neighbouring Norway and Sweden.

Wind generation has not displaced any of Denmark's fossil fuel power stations because of intermittency and unpredictability, and there are occasions, usually in the coldest months of January and February, when Western Europe experiences weather systems which can result with weeks of windless days. It is therefore all the more important that when the wind does blow it can be fully utilised through green energy storage.

There are a number of ways to store electricity ranging from small scale, such as batteries for short periods of time to large scale pump storage reservoirs for storing vast amounts for long periods of time. Unfortunately the UK doesn't have many available sites to flood in order to create such reservoirs.

There is however another option; as this paper has detailed and as Kit Malthouse, Deputy Mayor of London and Chair of the London Hydrogen Partnership is aware. Renewable energy can be stored as hydrogen, a clean fuel, that can be obtained from renewable generated electricity, resources that the UK enjoys in abundance. The process is electrolysis, and the technology is British.

Not only does energy storage using hydrogen enable efficient capture of increasing amounts of variable renewable energy it also has a beneficial impact on how power is generated from existing power stations, allowing those stations that have to turn on and off, as we wake up or return from work, to be run at a steady load and hence high efficiency and less carbon intensive.

The hydrogen so generated by electrolysis at small, medium and large scales may be reconverted to power at a later time, it can displace the dirty hydrogen derived from fossil fuels that are used in industry such as glass, and fertilizer, and importantly it can be used as a clean transport fuel, that burns with zero carbon emissions in modified petrol engine vehicles and is used to power fuel cell vehicles. The zero carbon home of the future will rely on green hydrogen.

Britain can gain the technological and engineering edge

Most vehicle OEMs[49] have well developed H_2 cars such as Honda, Nissan, General Motors and Daimler. They will shortly need H_2 refuelling arrangements in countries to attract their early deployment. Those countries that are early adopters will benefit most in the development of hydrogen and fuel cell industries. The UK has the opportunity to hoist itself up the pecking order and facilitate H_2 cars entering here early instead of it all happening in California, Japan and Germany first with us seen to follow subsequently.

In other words the flexibility of hydrogen energy storage is that it can do more than just clean up the power system, it can also clean up the transport system, dramatically reducing carbon emissions, providing the UK with a global manufacturing and engineering edge whilst improving air quality in cities at a stroke. Unlike batteries, hydrogen is a fuel, it can be stored for long periods of

[49] OEM – original equipment manufacturer

time. It therefore provides the security that society seeks, and independence from diminishing oil and gas reserves.

The UK will only be able to realise its ambitious renewable growth and carbon reduction targets if green energy storage is deployed through hydrogen. The UK has the opportunity to boost its energy security with a clean fuel which guarantees clean air, decarbonises the power and transport sectors, improves the health and quality of life in cities and towns and rescues the ailing renewable sector. This opportunity cannot be missed.

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