The value of flexible, firm capacity on a decarbonised grid

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Energy Research Partnershi

ERP Structure

Steering Group for this Project

ERP Energy Research Partnership

Co-Chairs

Department of Energy & Climate Change

Public
Prof John Loughhead
Chief Scientific Advisor, DECC

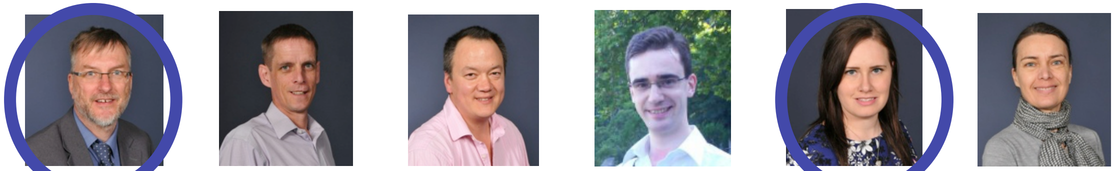
Private
Dr Keith MacLean
Independent Co-chair, formerly SSE

Members

Secretariat Support from DECC

bp, Shell, Turquoise International, Hitachi, drax, ABB, nationalgrid, ARUP, Atkins, ofgem, Scottish Enterprise, SSE, Innovate UK Technology Strategy Board, Ricardo, energy technologies institute, Carbon Trust, Research Councils UK, GE, Bosch, energy saving trust, UKERC UK Energy Research Centre, Department for Business Innovation & Skills, Department for Transport, origamienergy shaping energy with technology, University of Cambridge, Royal Academy of Engineering, Friends of the Earth, Llywodraeth Cymru Welsh Government

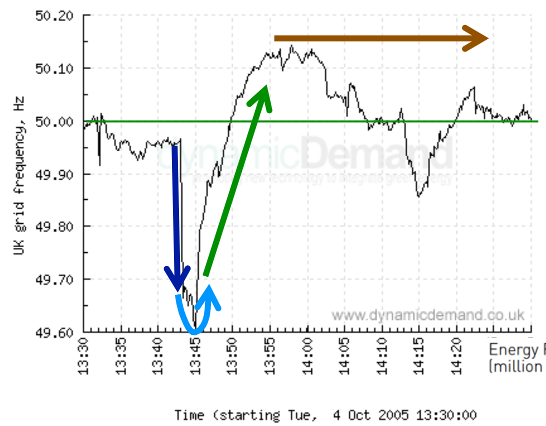
ERP Analysis Team



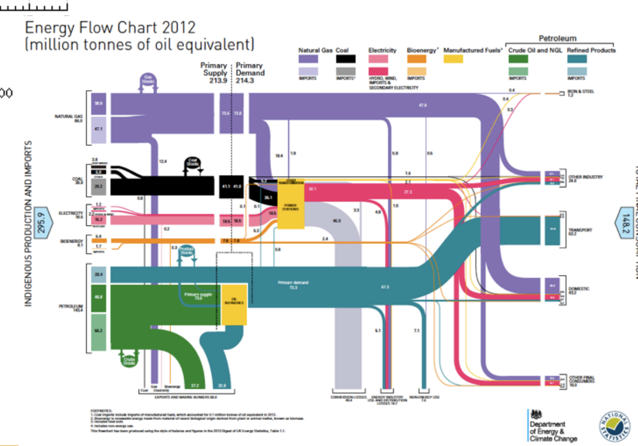
Hosted by Imperial College London

Key Messages

A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity



Policy makers and system operators need to value services that ensure grid stability so new providers feel a market



A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system

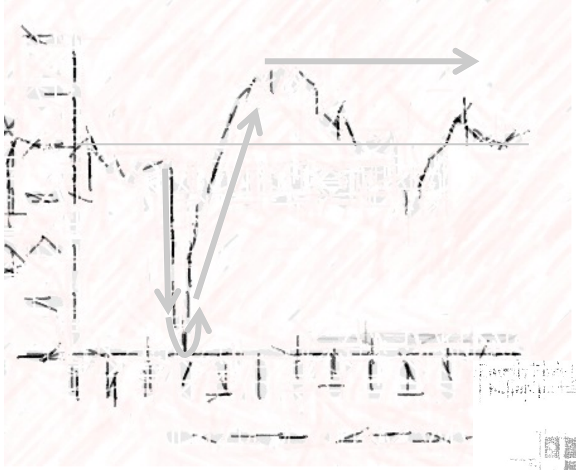
ERP Modelling

ERP modelling stacked generation to meet demand exploring different mixes of low carbon technologies on the system. It met the following criteria on an hourly basis:

- Energy balancing – nearly all modelling does this, at least on an annual basis
- Sufficient firm capacity – ensures peak demand can be met
- Sufficient flexibility – the model ensures there's sufficient reserve, response and inertia at all times.

Firm Zero-C Capacity

A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity



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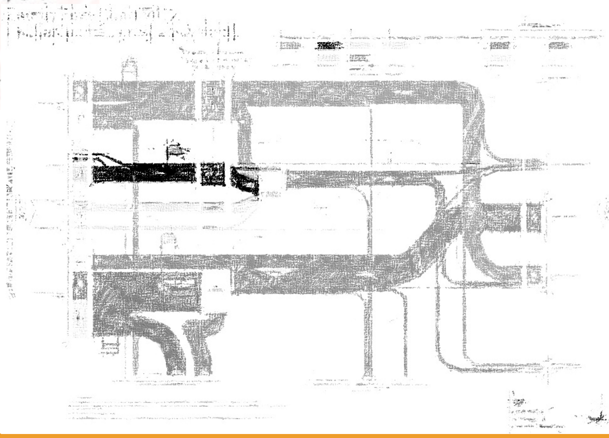
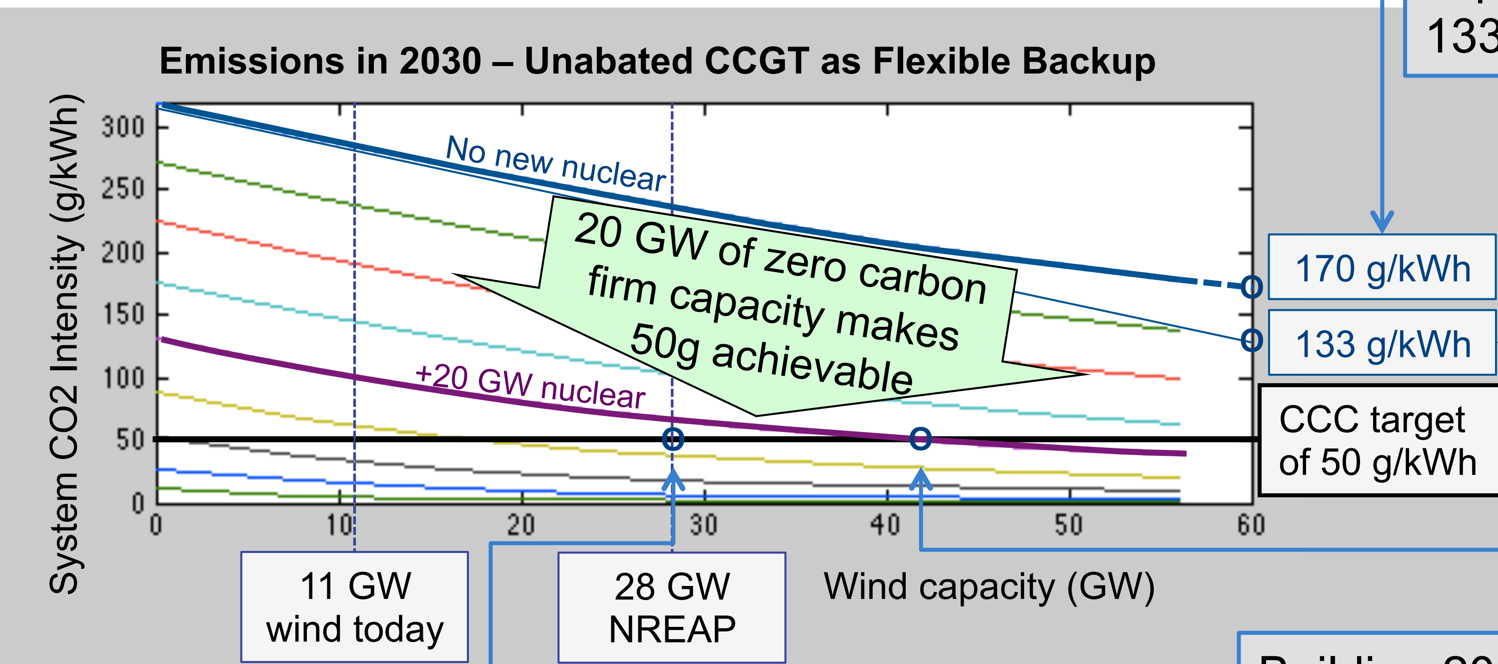


The need for firm capacity

With no new nuclear (or any other zero carbon firm capacity), the best that 60 GW of onshore wind can achieve is about 170 g/kWh

Infinite storage or demand side response could improve that to 133 g/kWh

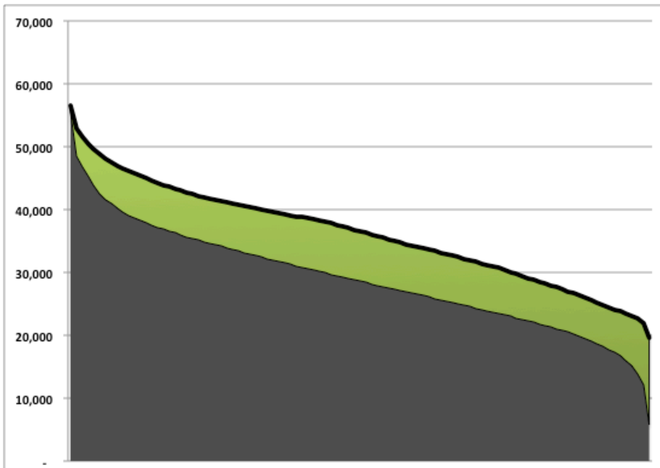


If wind build didn't exceed the National Renewable Energy Action Plant then 23 GW of nuclear would achieve 50 g/kWh

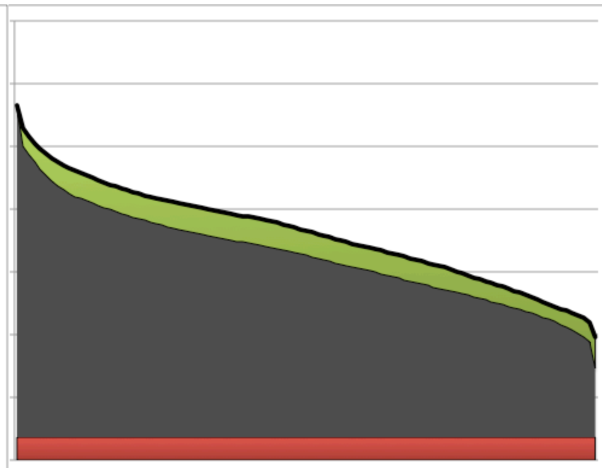
Building 20 GW of nuclear means 50 g/kWh can be achieved with 42 GW of onshore wind

Load Duration for 20% low carbon

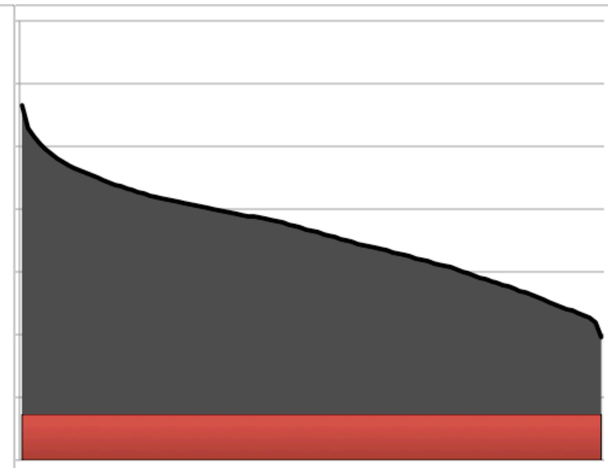
Renewable



Mix

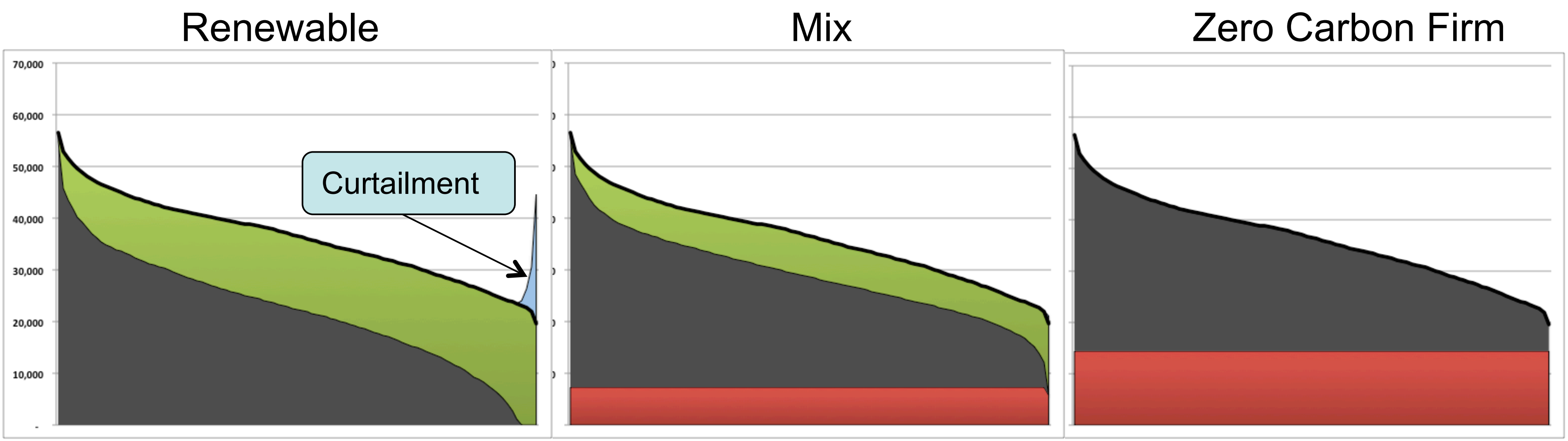


Zero Carbon Firm



Renewable	Mix	Zero Carbon Firm
17 GW PV	8 GW PV	No PV
17 GW Wind	8 GW Wind	No Wind
No ZCF	4 GW ZCF	8 GW ZCF
67 GW CCGT	63 GW CCGT	59 GW CCGT
330 g/kWh	330 g/kWh	330 g/kWh

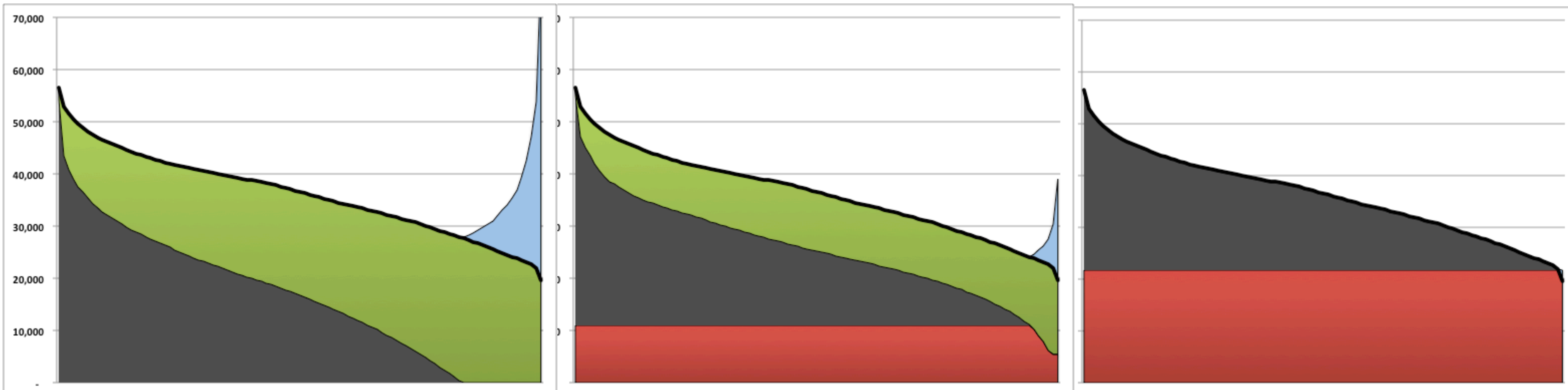
Load Duration for 40% low carbon



Renewable	Mix	Zero Carbon Firm
49 GW PV	24 GW PV	No PV
49 GW Wind	24 GW Wind	No Wind
No ZCF	8 GW ZCF	16 GW ZCF
67 GW CCGT	59 GW CCGT	51 GW CCGT
212 g/kWh	210 g/kWh	210 g/kWh

Load Duration for 60% low carbon

Renewable | Mix | Zero Carbon Firm



Renewable

73 GW PV
73 GW Wind
No ZCF
67 GW CCGT

158 g/kWh

Mix

37 GW PV
37 GW Wind
12 GW ZCF
55 GW CCGT

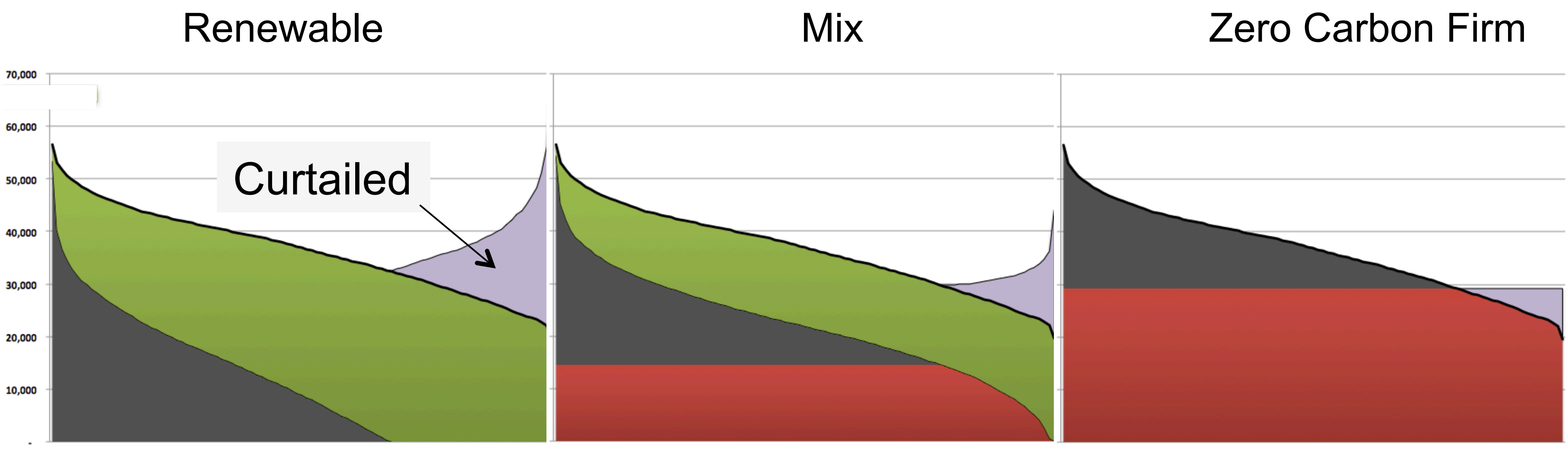
143 g/kWh

Zero Carbon Firm

No PV
No Wind
24 GW ZCF
43 GW CCGT

139 g/kWh

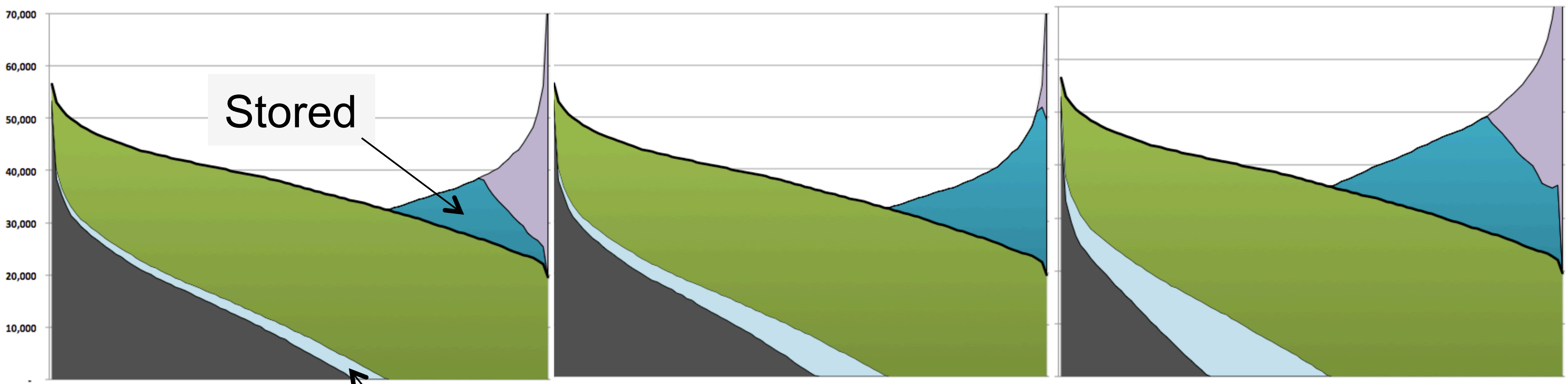
Load Duration for 80% low carbon



Renewable	Mix	Zero Carbon Firm
68 GW PV	34 GW PV	No PV
68 GW Wind	34 GW Wind	No Wind
No ZCF	16 GW ZCF	32 GW ZCF
67 GW gas	51 GW gas	35 GW CCGT
128 g/kWh	98 g/kWh	91 g/kWh

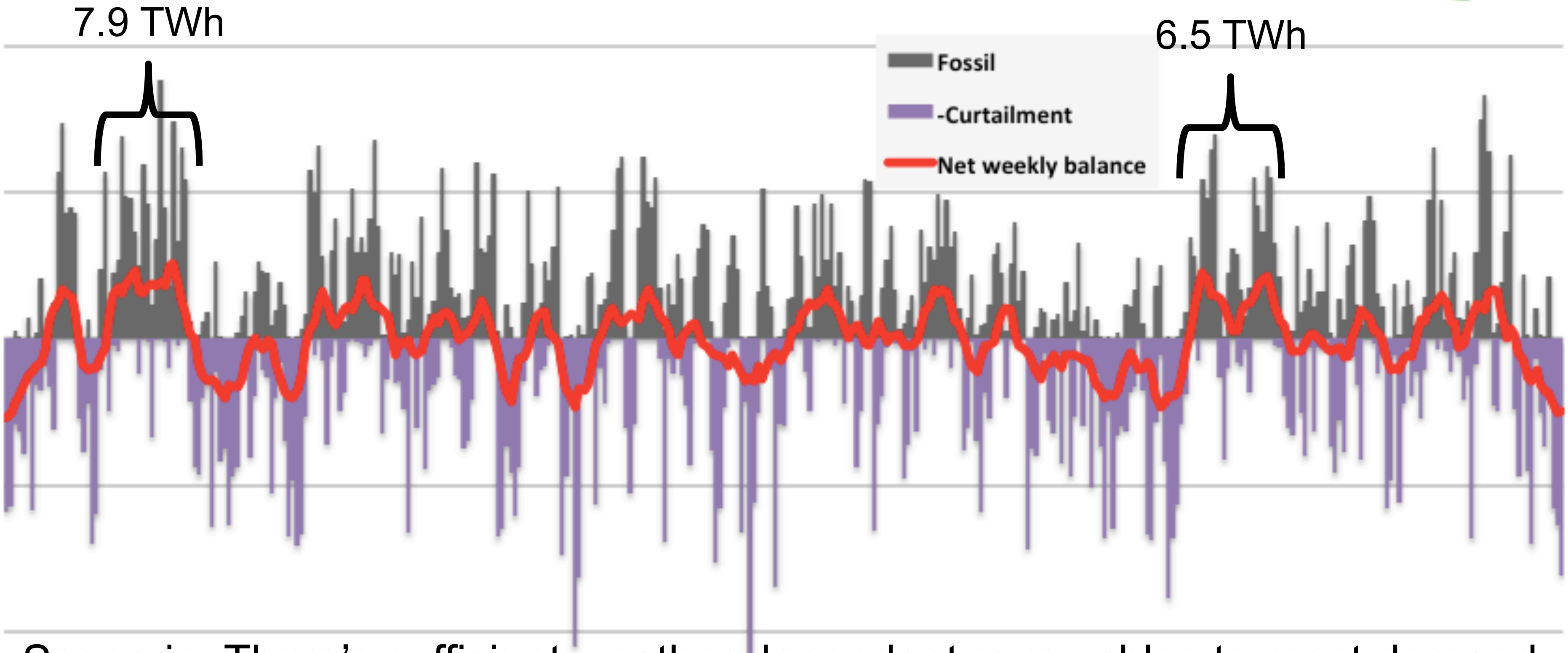
Load Duration for 80-100% Renewable

6h storage, 80% renew | 48h storage, 80% renew | 48h storage, 100% renew



6h storage, 80% renew	48h storage, 80% renew	48h storage, 100% renew
68 GW PV	68 GW PV	86 GW PV
68 GW Wind	68 GW Wind	86 GW Wind
No ZCF	No ZCF	No ZCF
67 GW CCGT	67 GW gas	67 GW gas
30 GW 6h store	30GW 48h store	30GW 48h store
112 g/kWh	98 g/kWh	50 g/kWh
6% curtailment	1% curtailment	8% curtailment

Role for Storage



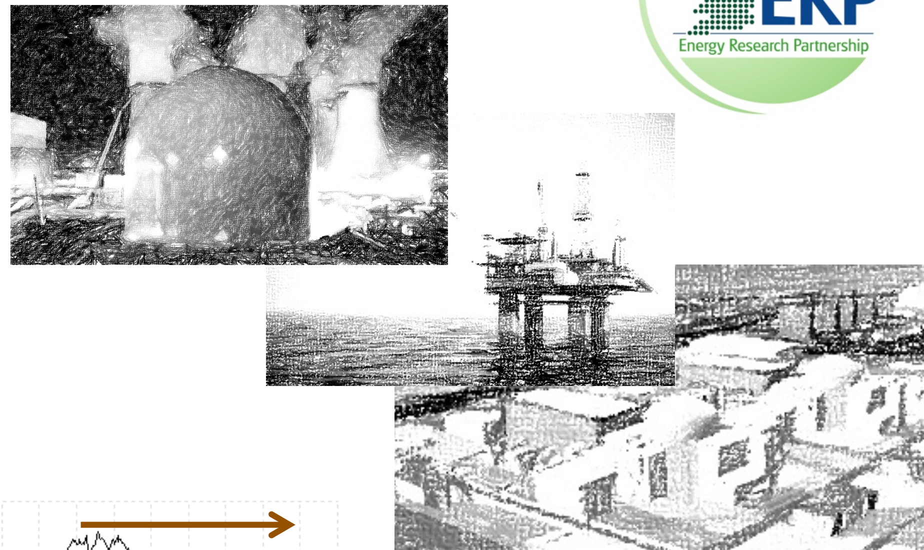
Scenario: There's sufficient weather dependent renewables to meet demand, PV and Wind balanced to eliminate summer/winter imbalance

For storage to eliminate fossil (or other firm capacity) would require ~15GW to hold ~8 TWh ready for lulls in output with 1-2 cycles p.a.

Hence providing security is probably not best role for storage

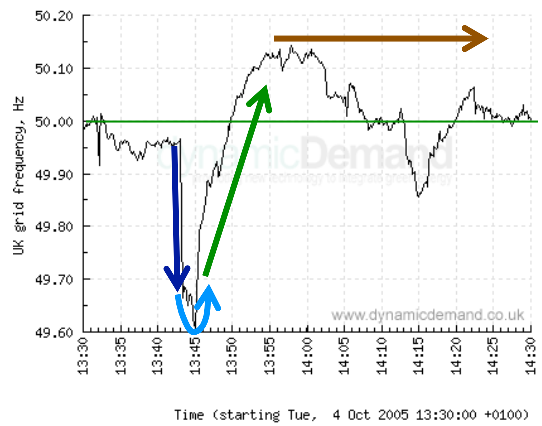
But 25 cycles above, or diurnal cycles or reserve, response or inertia may be.

Valuing Flexibility

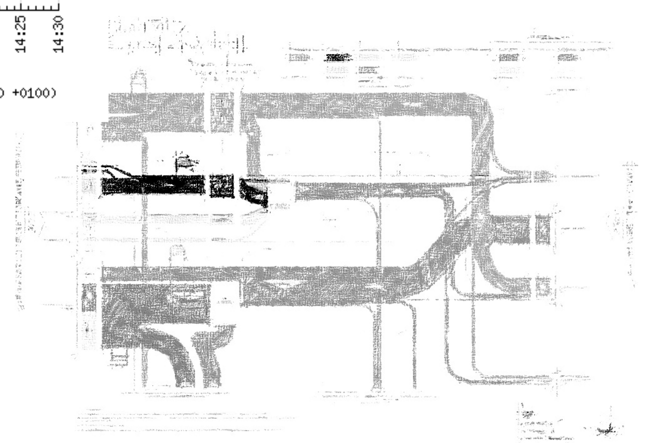


A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity

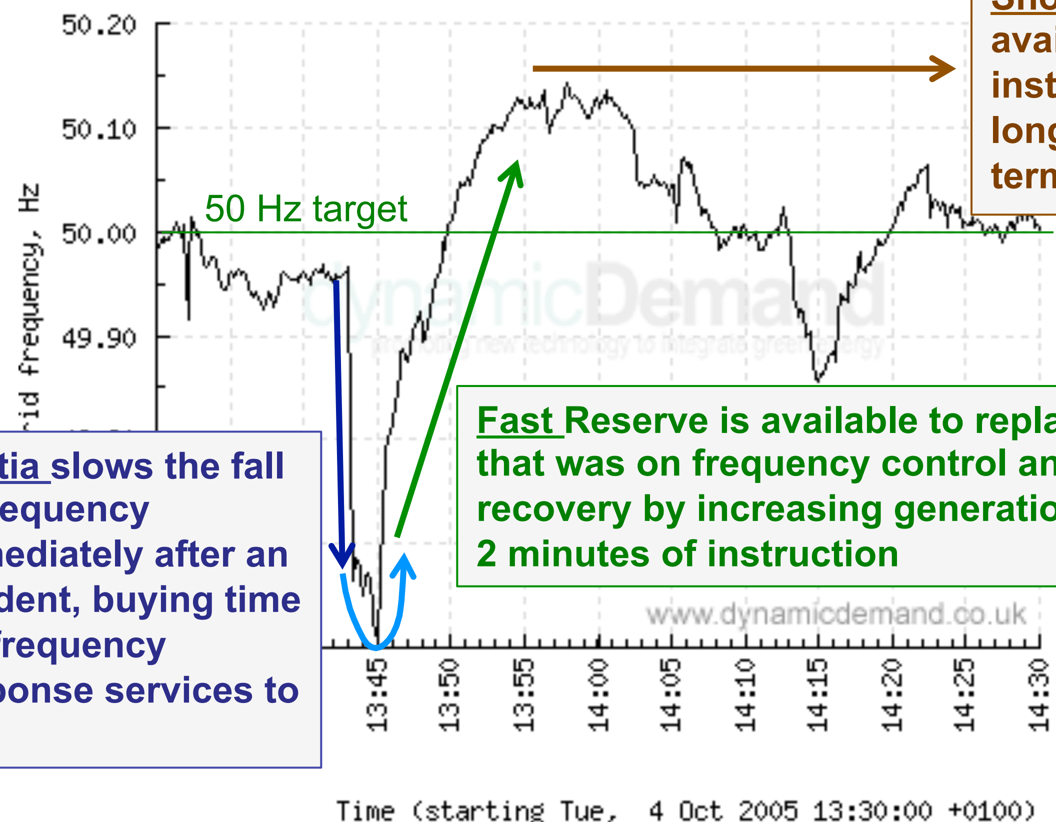
Policy makers and system operators need to value services that ensure grid stability so new providers feel a market



A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system



Essential Grid Services



Short Term Operating Reserve (STOR) is available within 5-20 minutes of instruction, although some can be as long as 4 hours. This provides a longer term replacement for the lost generation

Generator loss incident
1000MW is lost at 13:43. Frequency drops to 49.6 Hz before recovery begins. Statutory limit is 49.5 Hz.

Fast Reserve is available to replace plant that was on frequency control and aid recovery by increasing generation within 2 minutes of instruction

Inertia slows the fall in frequency immediately after an incident, buying time for frequency response services to act

There are 22 ancillary services NG buy, but these four are key for energy balancing + the need for firm capacity > peak demand*

Frequency response automatically increases generation or decreases demand to begin recovery. Acts in 10-30s window (primary) or 30s-30m window (secondary)

* Others include: voltage control; MaxGen, warming and fast start contracts for fossil; intertrips; transmission constraint agreements; SO to SO (interconnector) services; black start.

The Need for Market Pull

There are technical services essential for grid stability

Balance of grid services

SUPPLY
is disappearing

Traditional suppliers are going:
- Closure of coal & …
- closure of auxiliary gas turbines
- Closure of Oil
- AGR end of life
- Poor economics & low load factors of gas

DEMAND
is increasing

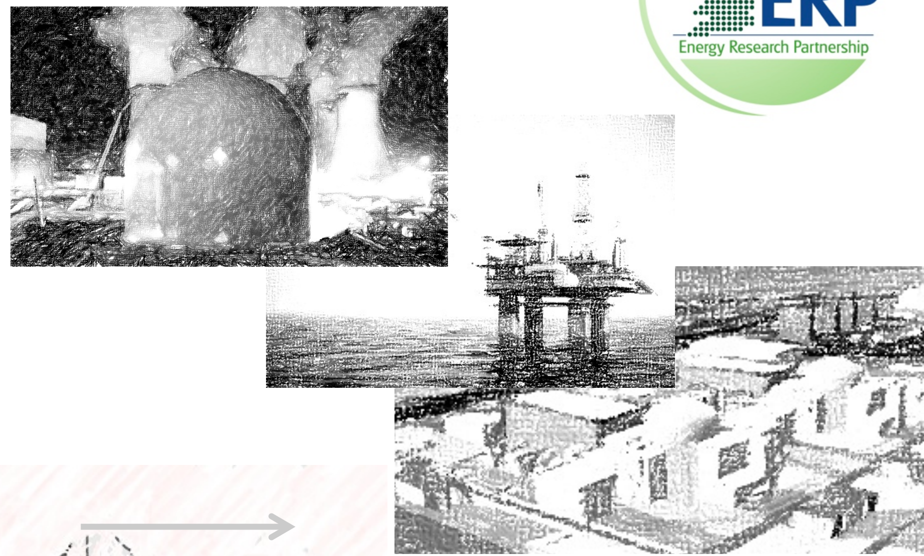
More intermittent renewables + larger unit size (new nuc.):
- Greater need for reserve
- Less inertia (stability)
- Greater demand for response
- Response has to be faster

NEW SUPPLY?
but little incentive

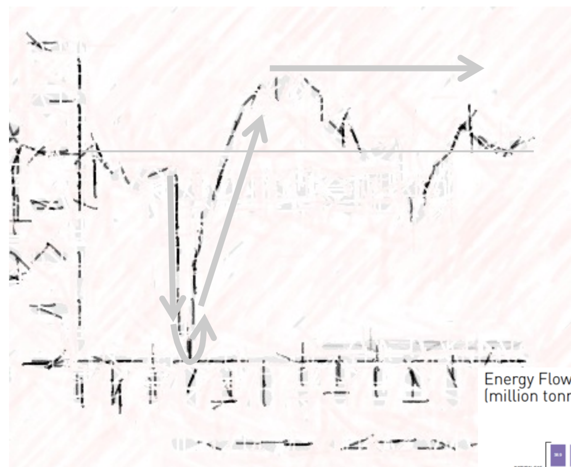
- Dynamic use of interconnectors
- Storage
- Existing demand => responsive
- New active demand (EV, HP)
- New gas plant
- New CCS
- Flexible biomass
- Existing embedded generation

Little or no value is attributed to some essential grid services.
New providers cannot develop if there is no long term market signal

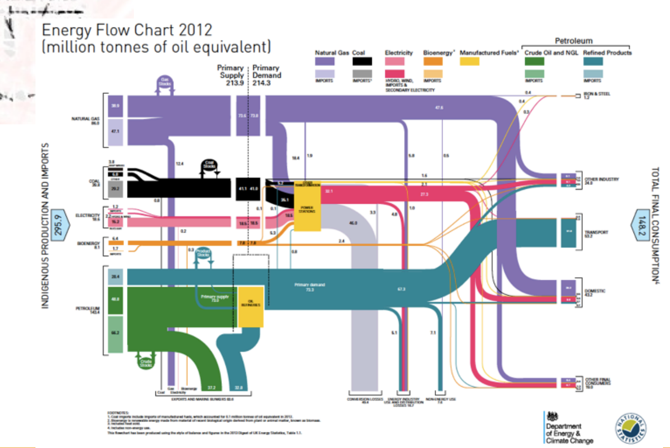
Holistic Evaluation



A zero- or very low- carbon system with weather dependent renewables needs low carbon technologies to provide firm capacity



Policy makers and system operators need to value services that ensure grid stability so new providers feel a market



A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system

The Need for a Holistic Approach

Traditional approach – all that matters is delivery of energy so calculate the levelised cost of energy.

$$\text{LCOE} = \frac{\text{all costs annualised*}}{\text{annual energy production*}}$$

* These can be reduced with an annual discount factor

Example using DECC costs

LCOE		£/MWh
1st	Wind	81
2nd	Nuclear	87
3rd	Gas-CCS	91

This is simple and **works well for conventional thermal & hydro** comparisons – When energy is delivered they can all offer other services:

- flexibility (load following, reserve, response)
- inertia
- firm capacity

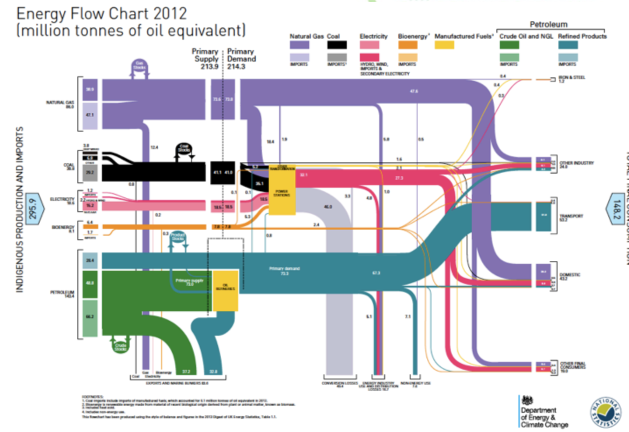
However this doesn't work for technologies

- that only deliver some of these services
- deliver no energy
- increase the need for some grid services

- Wind
- PV
- Nuclear
- Storage
- Demand Resp.
- Interconnectors

Key Messages

A <u>holistic approach</u> to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system



	Additional services provided / increased need			Traditional	Holistic: Reduction in system cost	
Tech.	**Provides Flexibility**	**Inertia**	**Firm Cap.**	**LCOE (£/MWh)**	**Net Value to pure gas sys. (£/MWh)**	**Net Value to Sys with 30 GW wind (£/MWh)**
Nuclear	doubtful	yes	yes	87	11	8
Wind	demands	very little	very little	81	-3	-17
Gas-CCS	yes	yes	yes	91	6	4

- Previous 1st choice is different
- Value changes with the system
- Diminishing returns effect

The values here are not important, but it illustrates fact that the holistic approach values CCS firmness and flexibility

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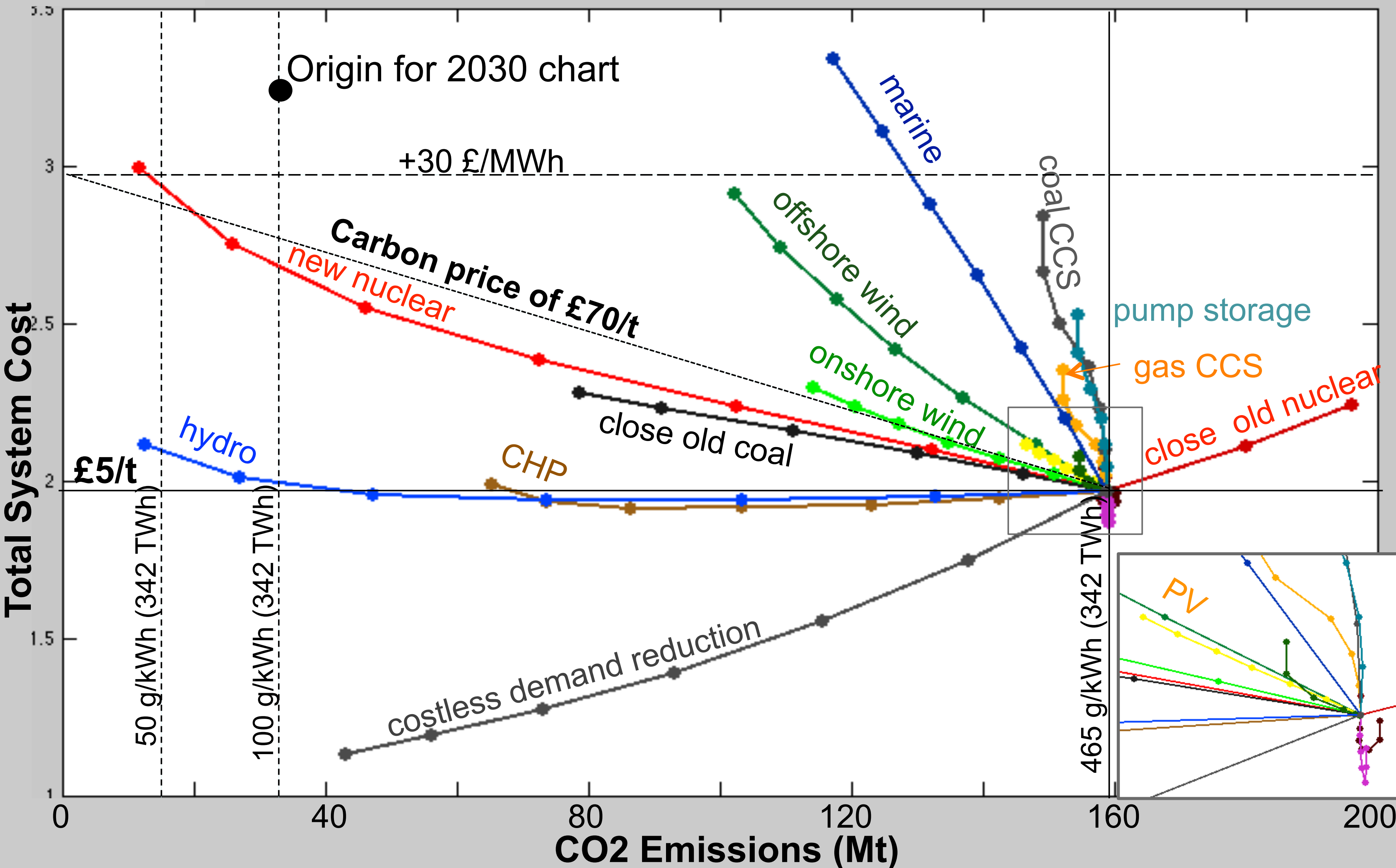
Value of Additional Capacity 2015



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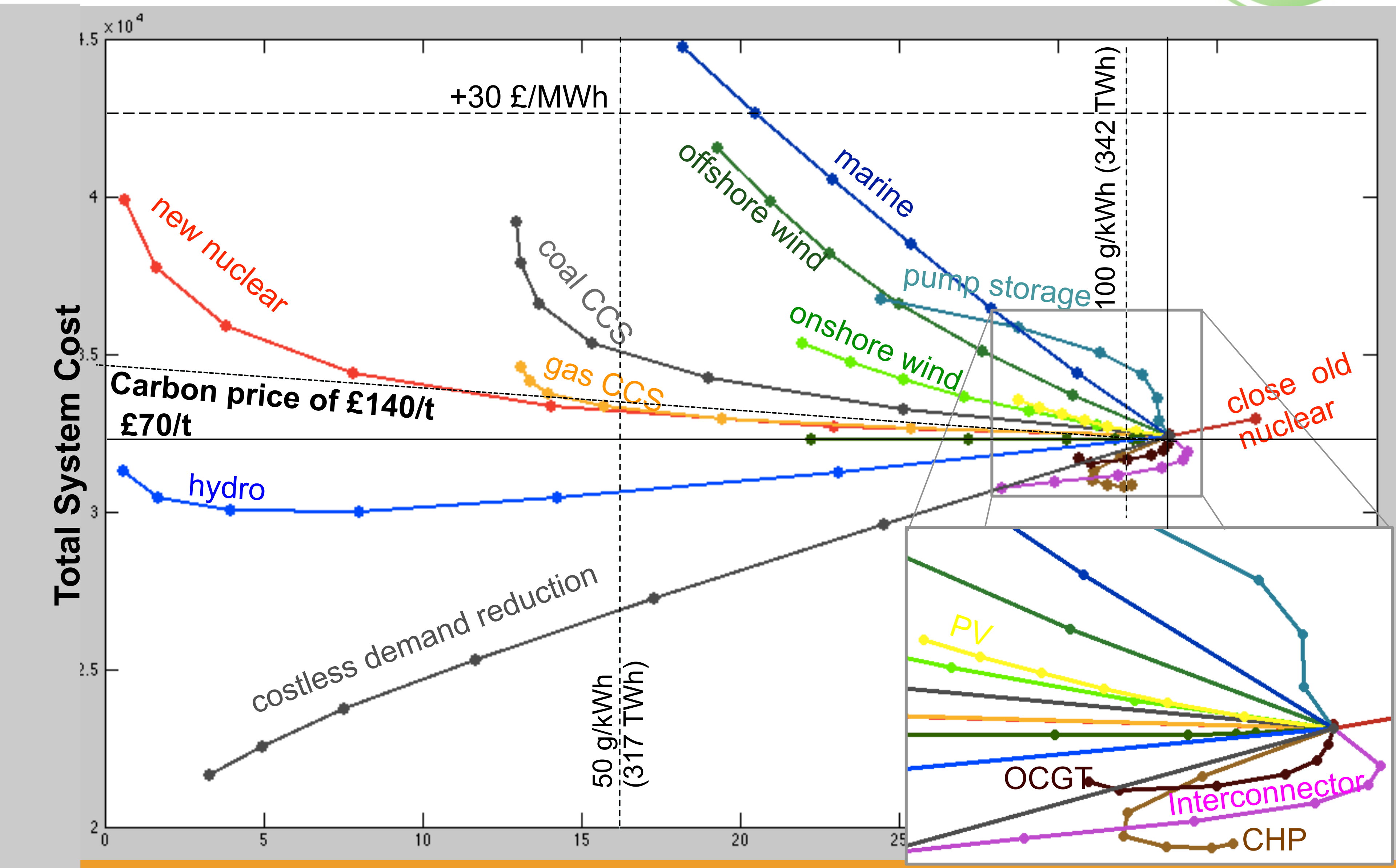
Value of Additional Capacity 2030



Could UK Have it's Own EnergieWende?

In essence – **yes** – UK needs a strategic narrative:

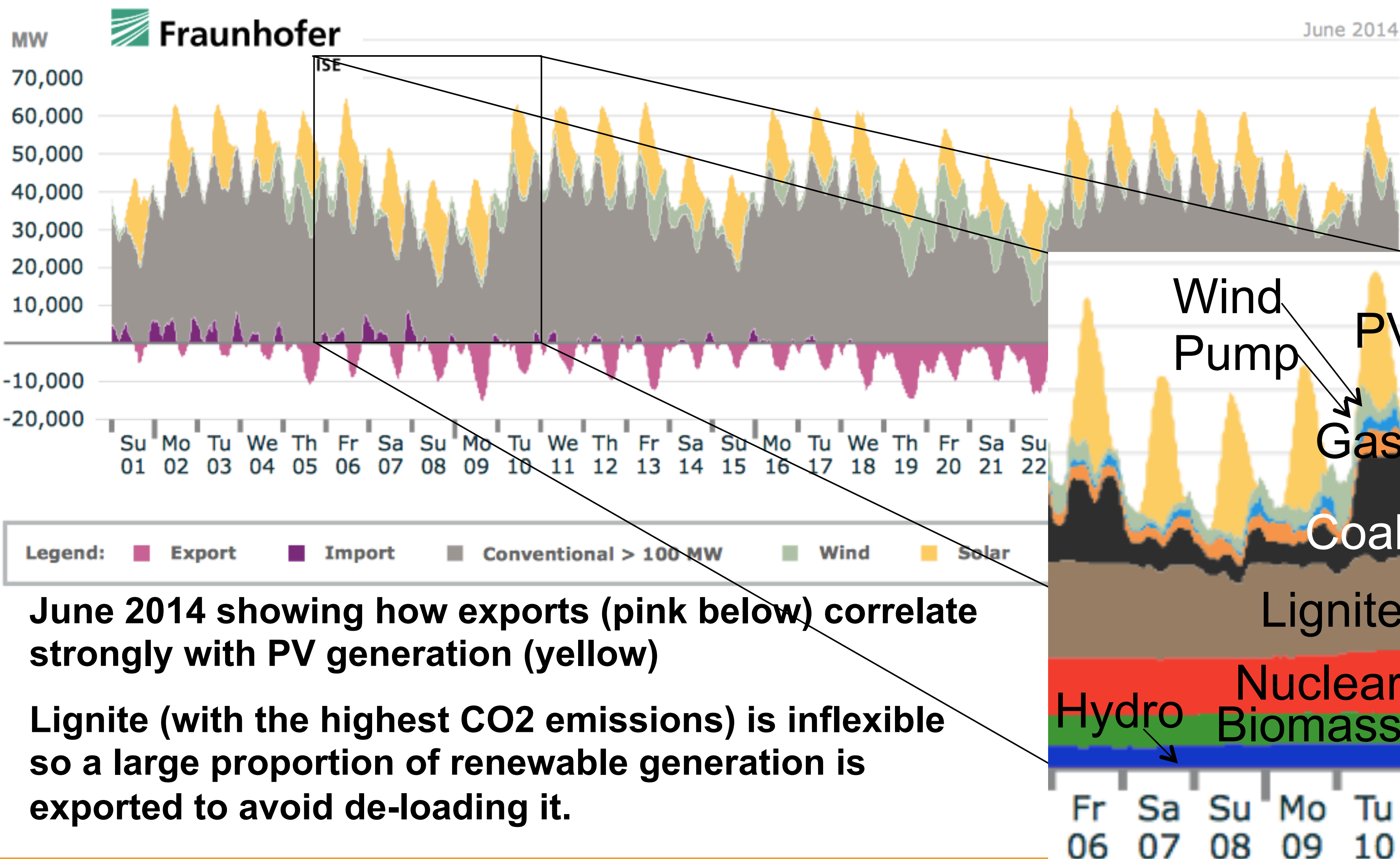
- Public engagement
- Policy Stability
- Investor Confidence

http://erpuk.org/project/public-engagement/

The same as Germany's– **no** – GB & German systems and objectives are chalk & cheese

Drive for low price	Acceptance of high subsidies
Build gas stations	Mothball new gas
Close all coal stations	Building coal stations
Close coal mines	Subsidise coal mines
Life extend old nuclear	Close old nuclear early
Island - Weak interconnection	Small part of large System

Germany



June 2014 showing how exports (pink below) correlate strongly with PV generation (yellow)

Lignite (with the highest CO2 emissions) is inflexible so a large proportion of renewable generation is exported to avoid de-loading it.

Key Messages

A zero- or very low- carbon system with weather dependent renewables needs companion low carbon technologies to provide firm capacity

- Cannot decarbonise to 50 g/kWh by weather dependent renewables alone
- Storage, demand side & interconnection help
- 15-20GW of new nuclear, biomass or fossil CCS is essential
- Provides clean supply for dark, windless weeks

Policy makers and system operators need to value services that ensure grid stability so new providers feel a market

- Some necessary services (e.g. inertia/ frequency response) are free or mandated
- Demand for them is growing
- Traditional providers (fossil) are disappearing
- Weather dependent renewables are not consistent suppliers
- New providers can't develop with no market

A holistic approach to system cost would better recognise the importance of firm low carbon technologies and the cost of balancing the system

- The value of a technology is dependent on
  - the existing generation mix
  - the grid services it provides
- So it cannot be valued by a single number such as levelised cost of energy (LCOE)