Academic Partners
The Institution of Engineering and Technology

PHEE
A forum for Academic Leaders in Electrical Engineering and Allied Technologies

Professors & Heads of Mechanical & Manufacturing Engineering

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"Working Within Europe"

"Can Europe and its emerging energy markets contribute answers to new power system challenges in the GB low carbon economy?"

Helge Urdal
SMARTer System Performance Team Manager (acting) & Technical Leader – Generation and System Dynamics
National Grid

Key Note at Annual PHEE & PHM&ME Conference
IET, Savoy Place 11 January 2012.

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Content

- UK Future Energy Scenarios to 2050
  to meet Renewable + CO_2 targets
- Power System challenges arising from the new and changeable generation mix
- Preparation ahead of Europe opening up its energy markets in 2015
- Bridging the seas – GB becoming well connected
  What are the potential uses / benefits?
- The future human resources to match the challenges
  What do we do and what could you do?
- Conclusions

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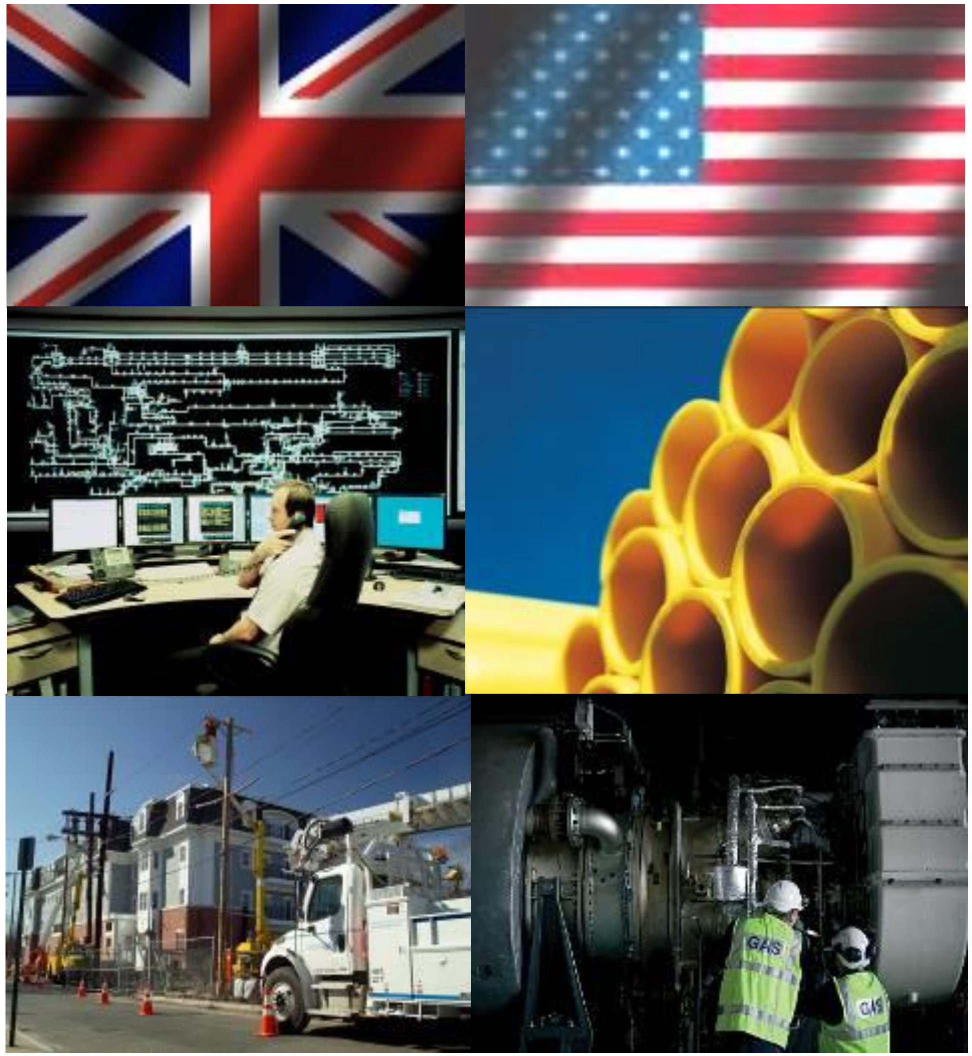
50:50



UK | US

Transmission | Distribution

Electricity | Gas

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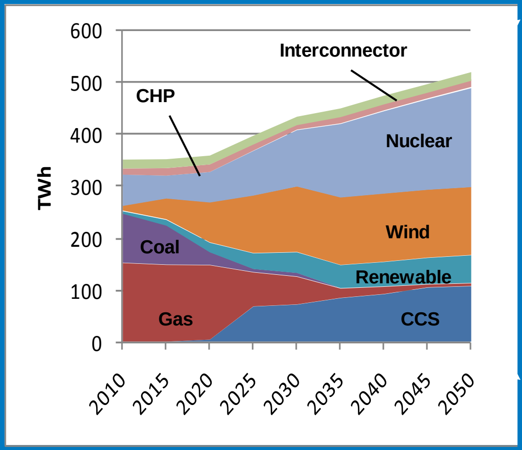
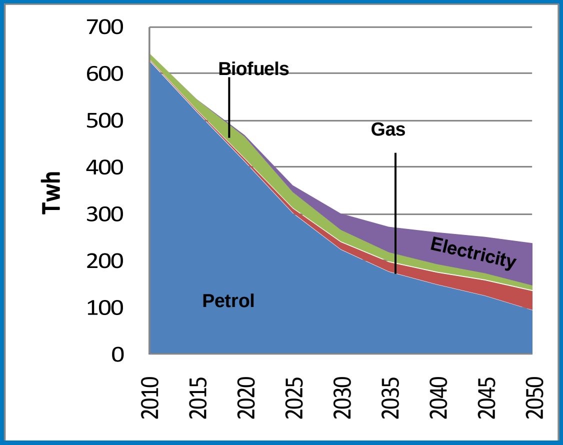
UK Future Energy Scenarios to 2050

to meet Renewable + CO2 targets

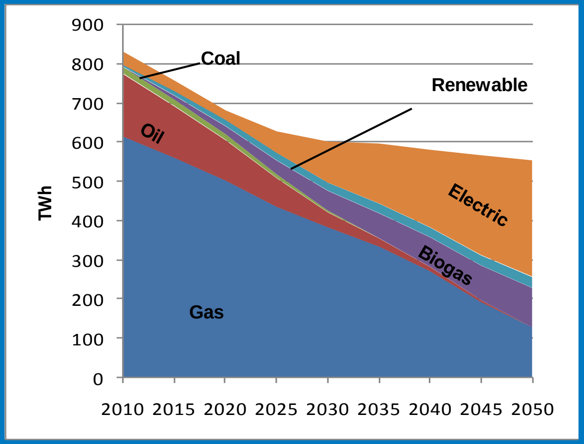
Electricity Generation



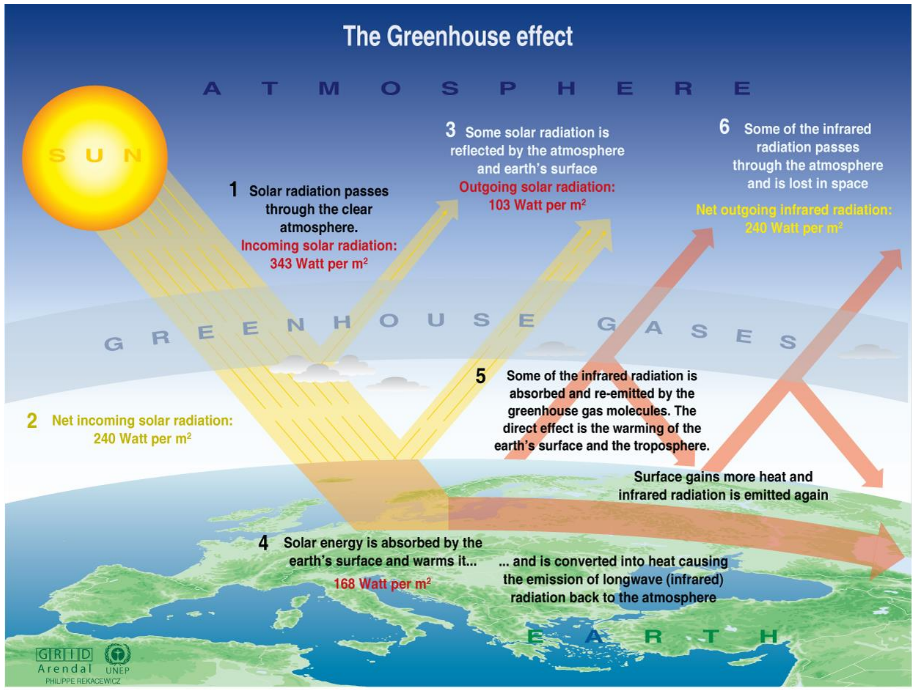
Road Transport



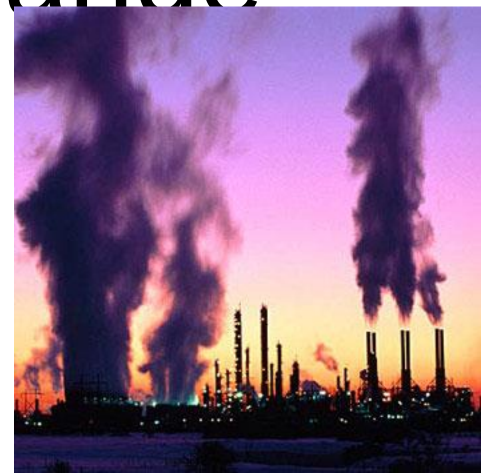
Heat



Drivers for Change



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.



UK energy landscape is changing

Sustainability

Affordability

Security of supply

Existing power station closures

~25%

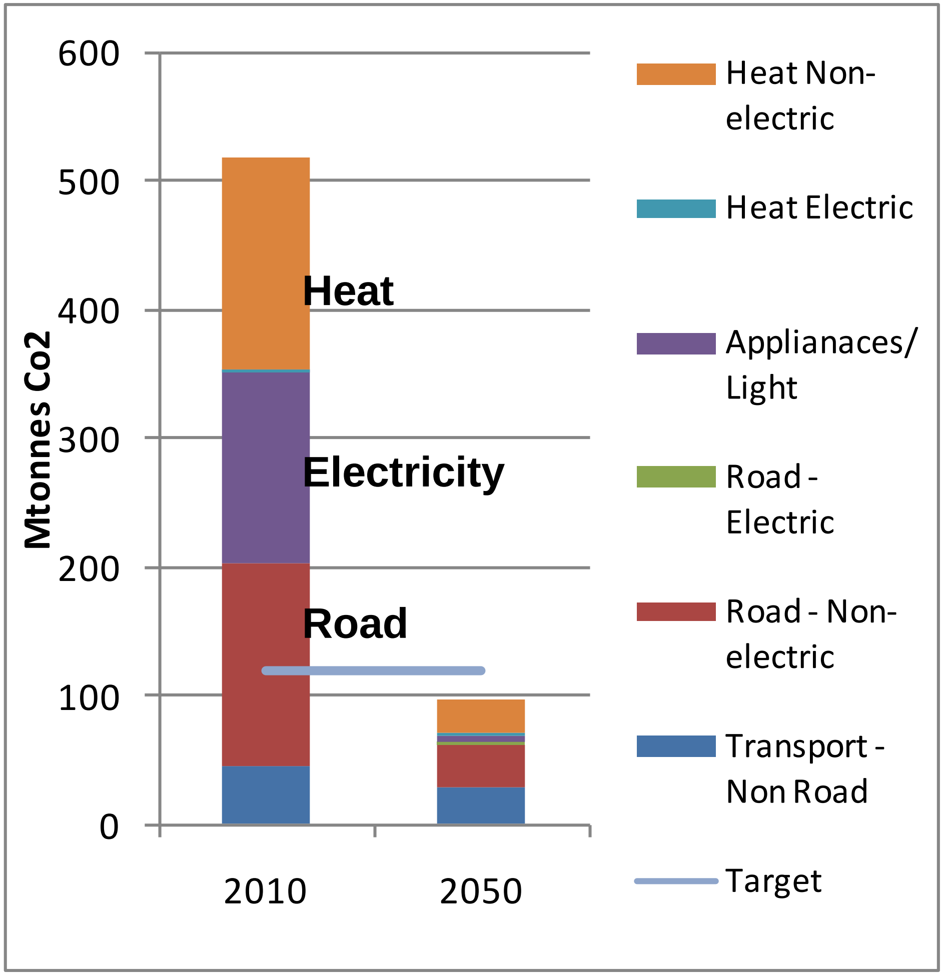
of total capacity by 2020

Gas from UK sources

~25%

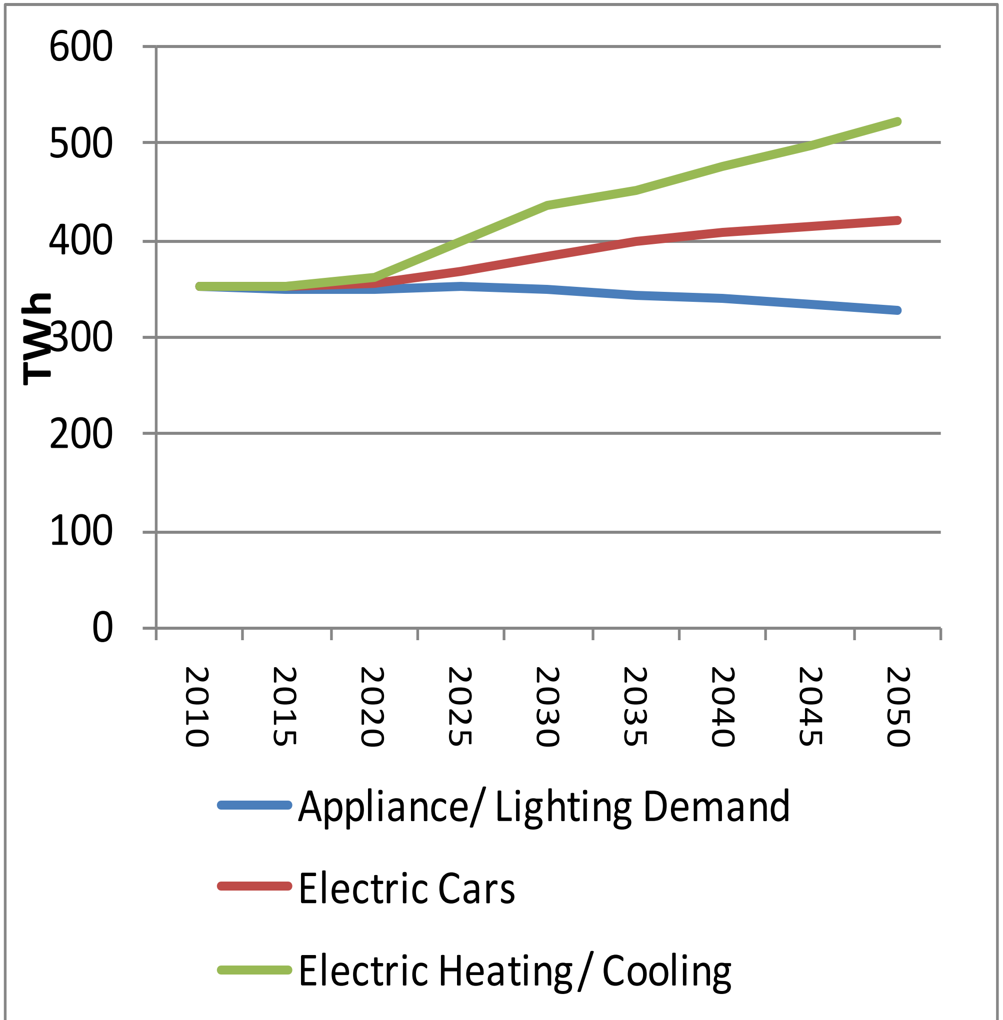
of total supplies by 2020

Emissions by sector



- Aim is to reduce emissions from 505M tonnes to 118M tonnes
- Emissions from all 3 main sectors greater than 118M tonnes – need to take action on all.
- Emissions reduce to 96Mtonnes in Gone Green scenario as agricultural emissions are not modelled
- Aviation emissions drop slightly as biofuel is diverted to air as electricity replaces petrol in cars and LGVs.

Energy Consumption - Electricity



- Decline in use for appliances & lighting despite increasing household numbers
  - From LED lighting and A+ rated smarter appliances
- Increased electrification of transport when battery issues are resolved
- Home heating shifts to heat pumps
  - Off gas grid properties retrofitted initially
  - Gas properties switch to heat pumps for base load heat later

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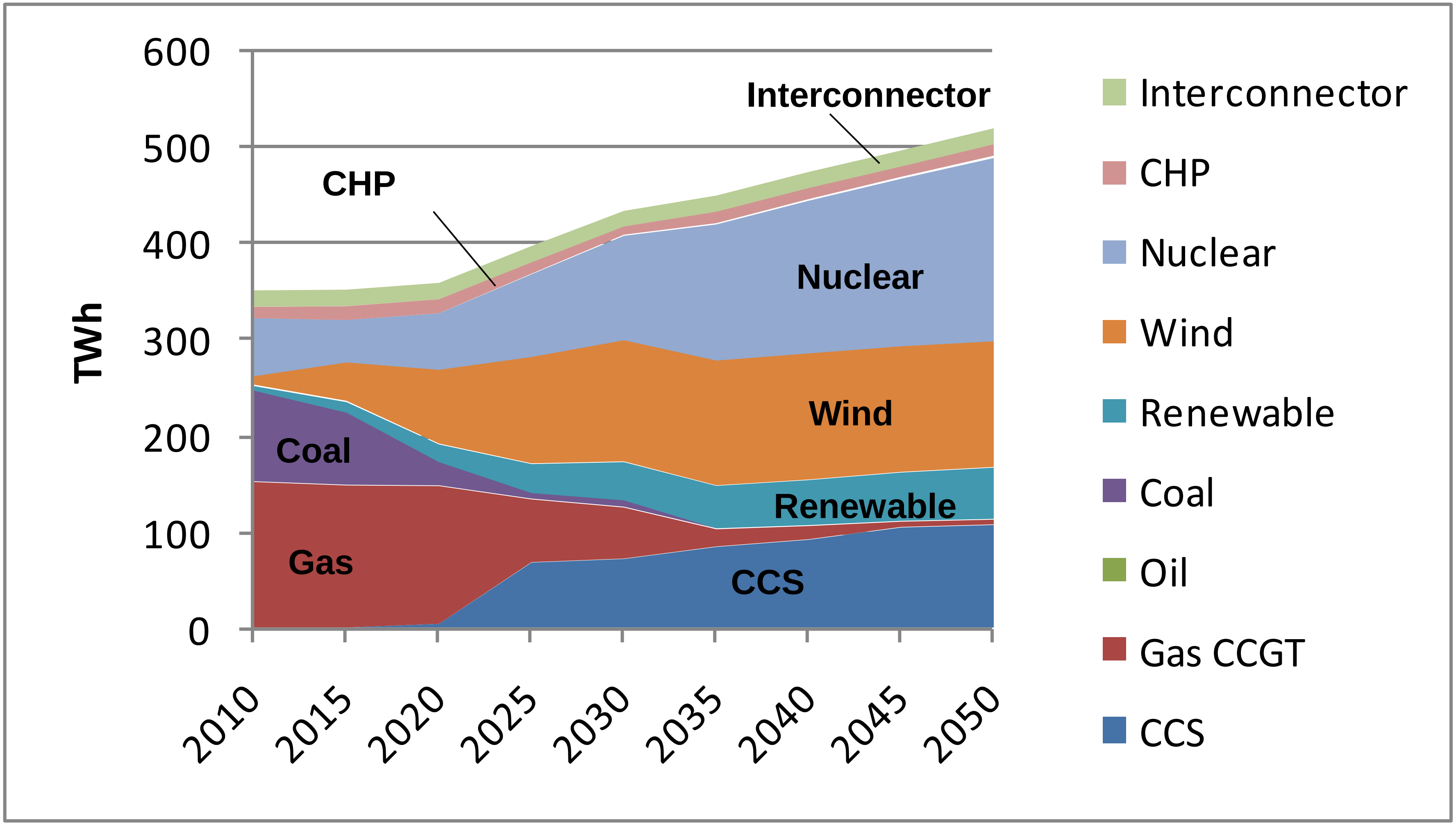
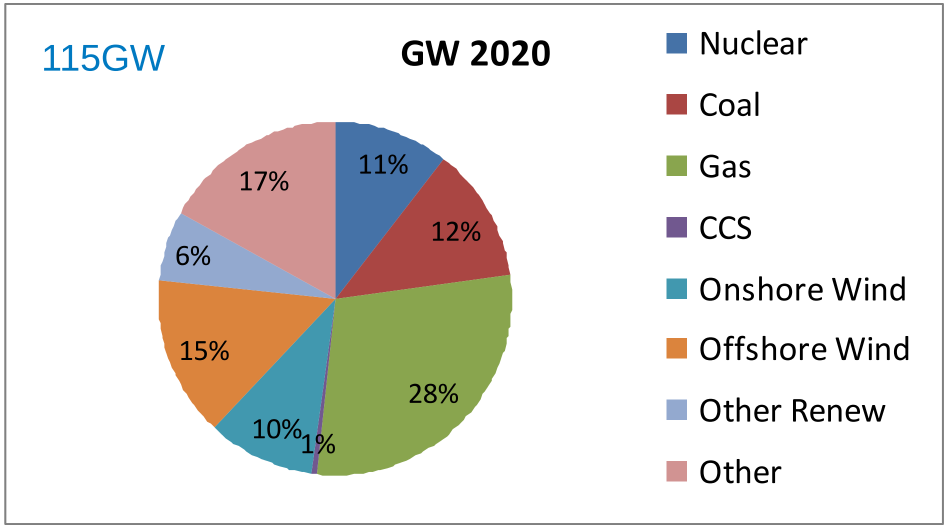
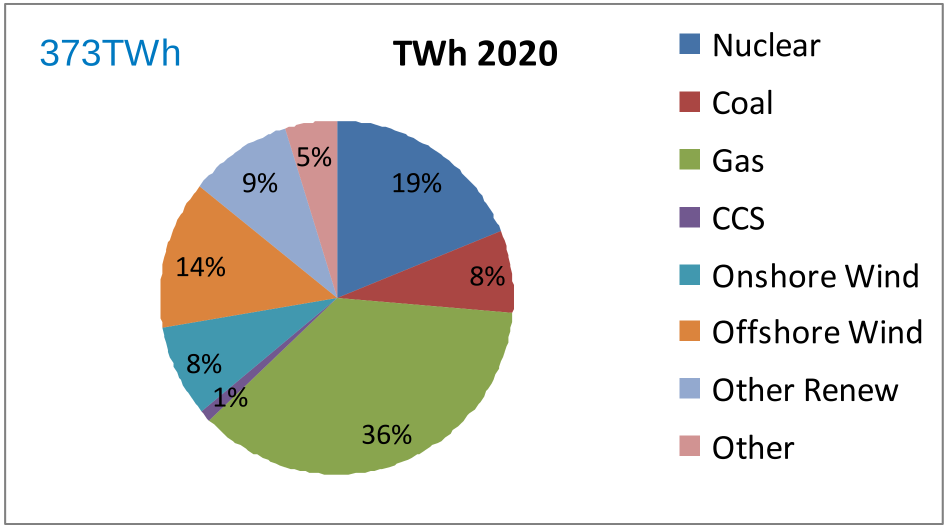
Electricity Profile 2010-2050



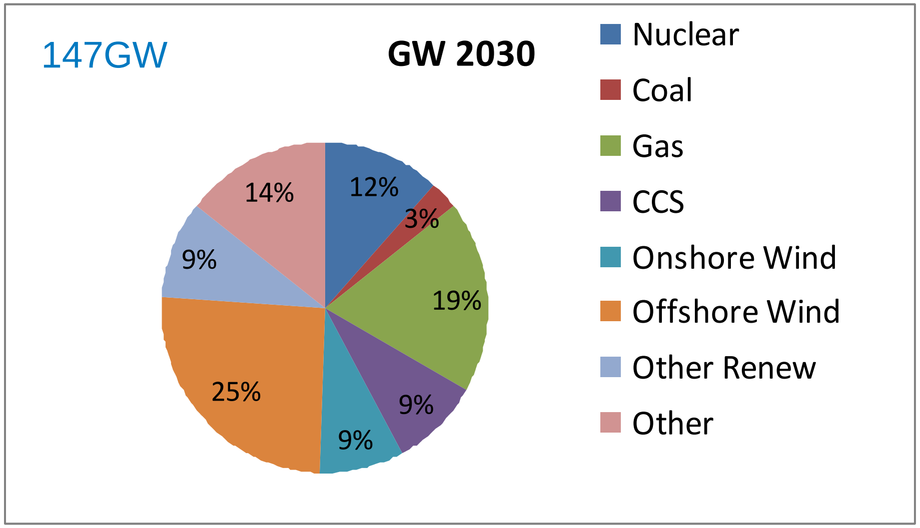
Electricity Supply – 2020
Generation mix overhaul
Transmission focus => less fossil fuel more wind…

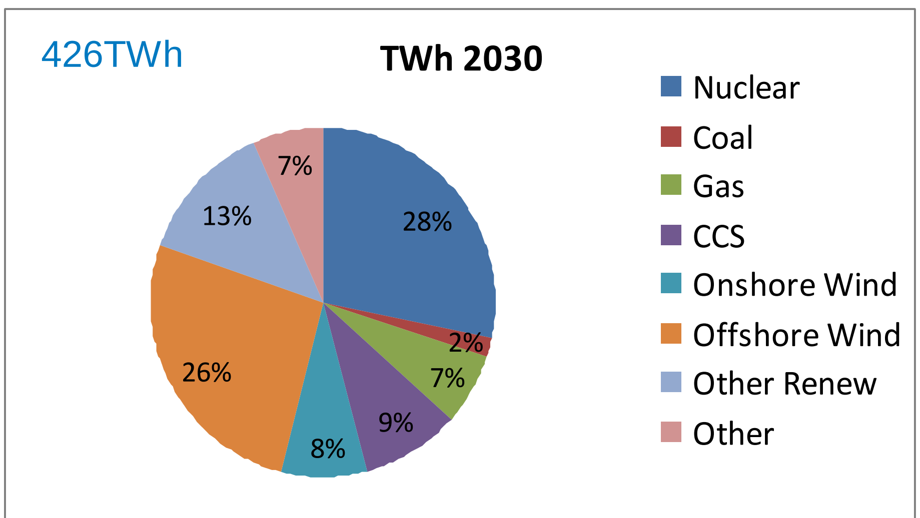




- Demonstration project for CCS supply small amount of load
- Some new nuclear online by 2020, existing plant has 10yr life extension
- 28GW of wind on the system (17GW offshore)
- Small (7GW) amounts of other renewables
- Significant CCGT build ensure plant capacity margin as oil and coal close. Start to operate as peaking plant managing wind intermittency

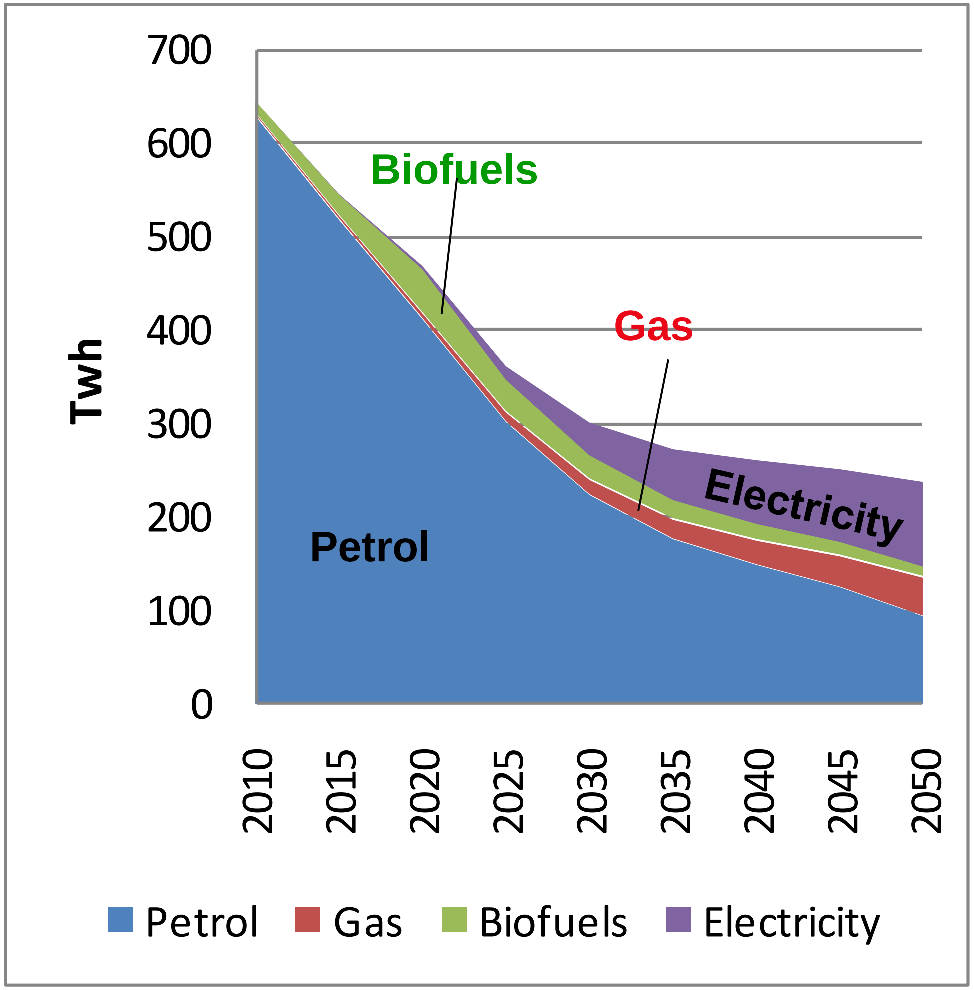
Electricity Supply – 2030
Nuclear replanting, CCS goes commercial & growth in demand





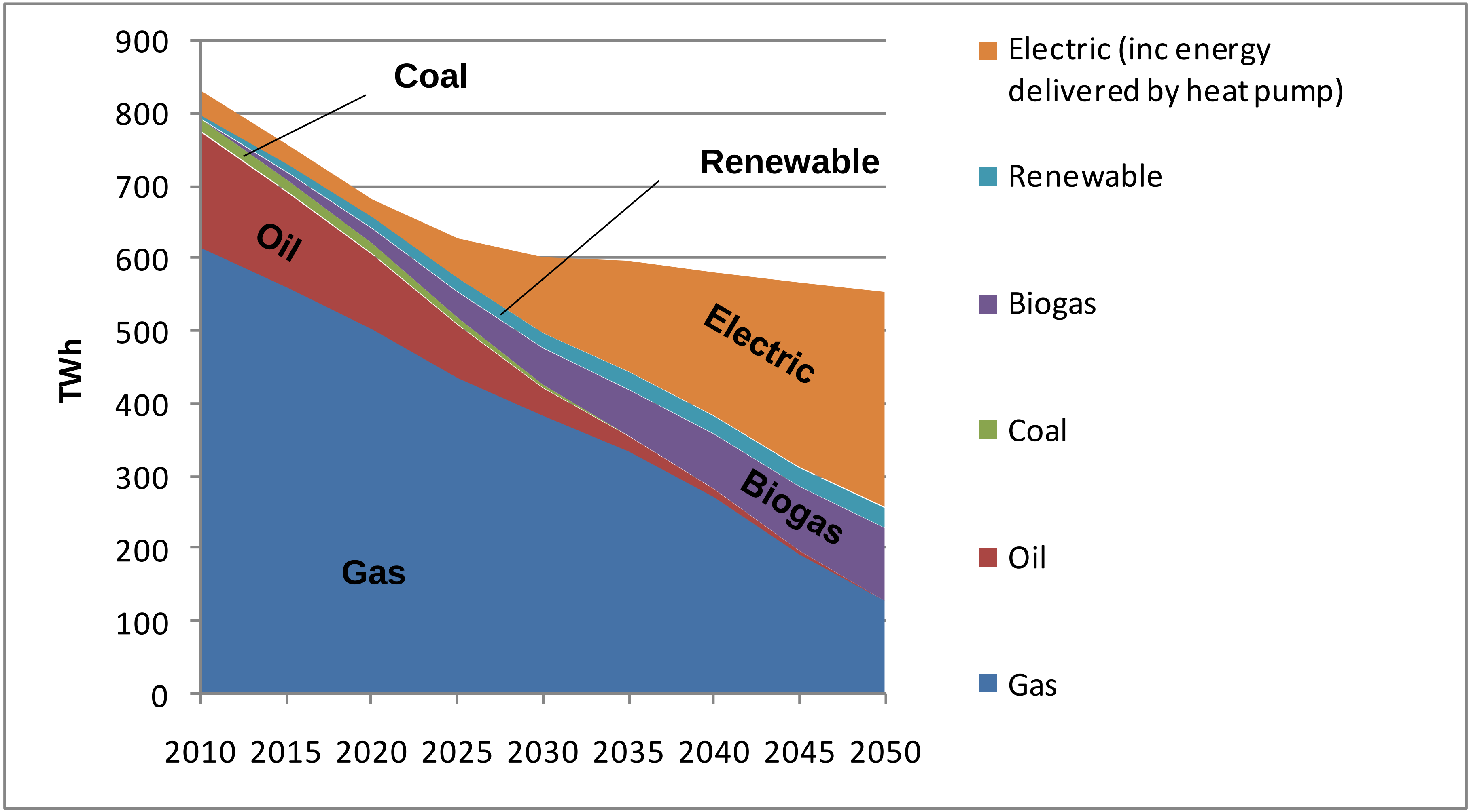
- Increase in Wind Generation to 49GW
- CCGTs marginal supply source for non-windy days.
- Most coal retired, CCS gas and coal increase to 13GW around clusters
- Nuclear new build well underway (13GW installed by 2030)
- Increased interconnection to balance system
- Electric car commercialisation

Road Transport – Fuel Supply



- Petrol use declines as engines go from 20% efficient to 40% using hybrids
- Biofuels make up 10% of Petrol from 2020
- CNG use for HGVs driven by large firms converting fuelling stations
- Electric vehicles make up 6% of cars by 2020 and 40% by 2030

Heat Supply - 2010 to 2050



Norway electricity totally decarbonised now

Heat pumps – Air to Air – My 90 year old aunt in Norway can!!

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Heat pumps are simple.

Air-conditioning reversed.

Works well at -10˚C.

Best in class claims: POC=5.3 @-15 ˚C Realistic?

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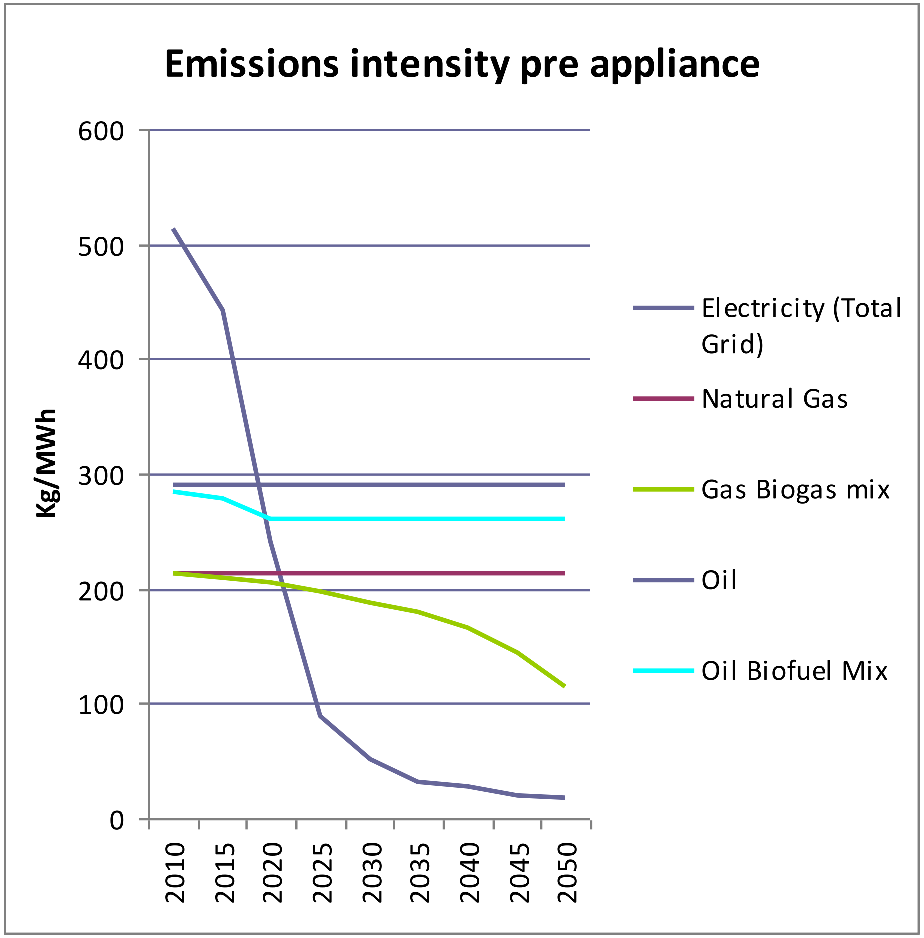
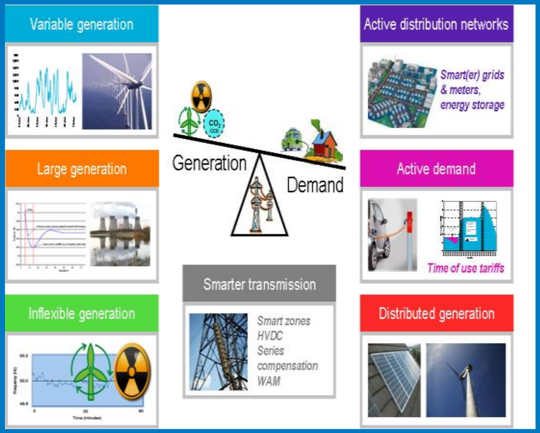
Carbon intensity of supply mix



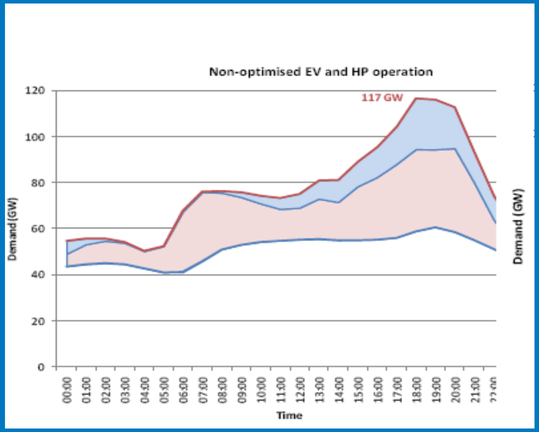
- Carbon intensity of average electricity generated will drop below that of gas and petrol in the next decade
- On this basis it seems straightforward that we should electrify everything but…
  - Additional electricity to heat and transport will be higher carbon than average. Marginal CO_2 intensity appropriate.

System challenges arising from the new and changeable generation mix

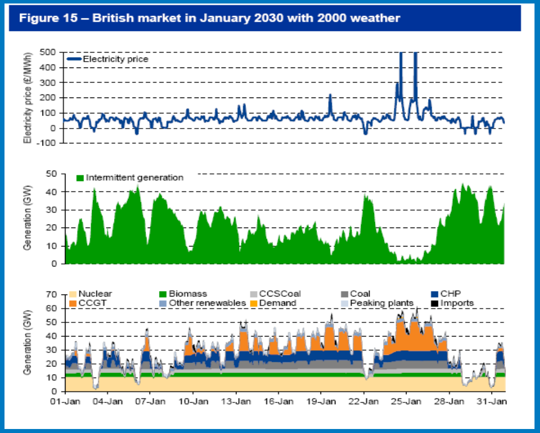
Balancing challenge



New demand – time of day?



No base load left



How will we balance supply and demand?

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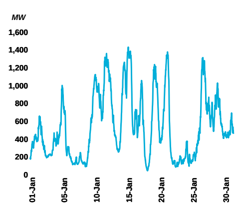
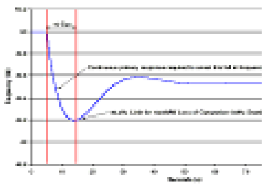
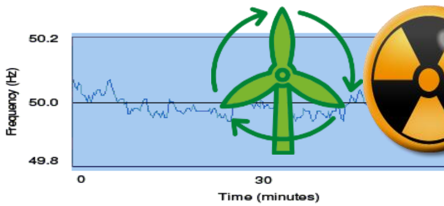
Variable generation

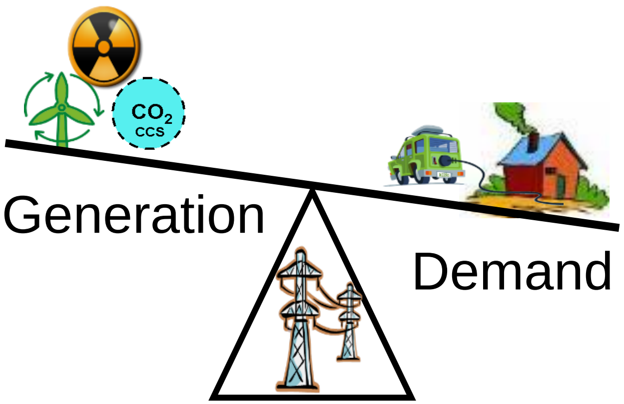


Large generation



Inflexible generation





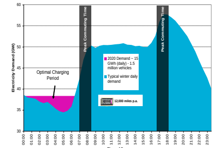
Smarter transmission

Smart zones
HVDC
Series compensation
WAM

Active distribution networks

Smart(er) grids & meters, energy storage

Active demand



Time of use tariffs

Distributed generation

New nuclear already in progress
AREVANP - French / German EPR – 1800MWe
New nuclear plans cover 12 GW - by 2025?

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AREVA

EPR Present Projects

EPR already under construction

TVO

Olkiluoto 3, Finland

EDF

Flamanville 3, France

- Specific set of local regulations (YVL) had to be taken into account
- Preliminary Safety Analysis Report reviewed by STUK (Safety Authority)
- Construction license issued by the Finnish government on February 17, 2005
- Commercial operation expected in 2011

- Design approval for EPR issued by the French government Sept. 28, 2004
- Authorization for construction granted on April 10, 2007
- Commercial operation expected in 2012

Large Frequency Incident on 27 May 2008
Led to Automatic Demand Disconnections

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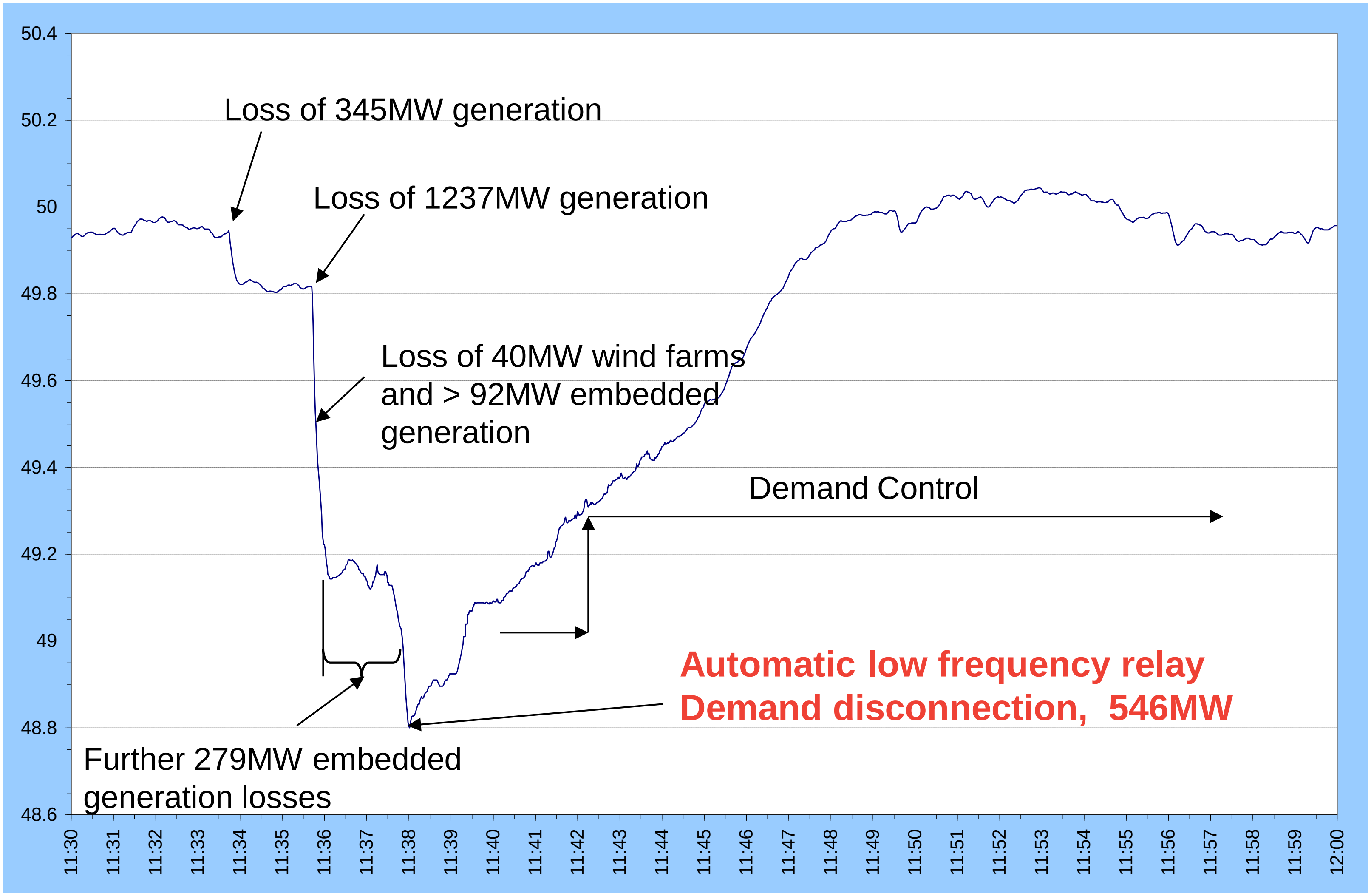
With 1800MW loss this becomes a routine challenge



Offshore Wind Scenarios
Four scenarios including Gone Green

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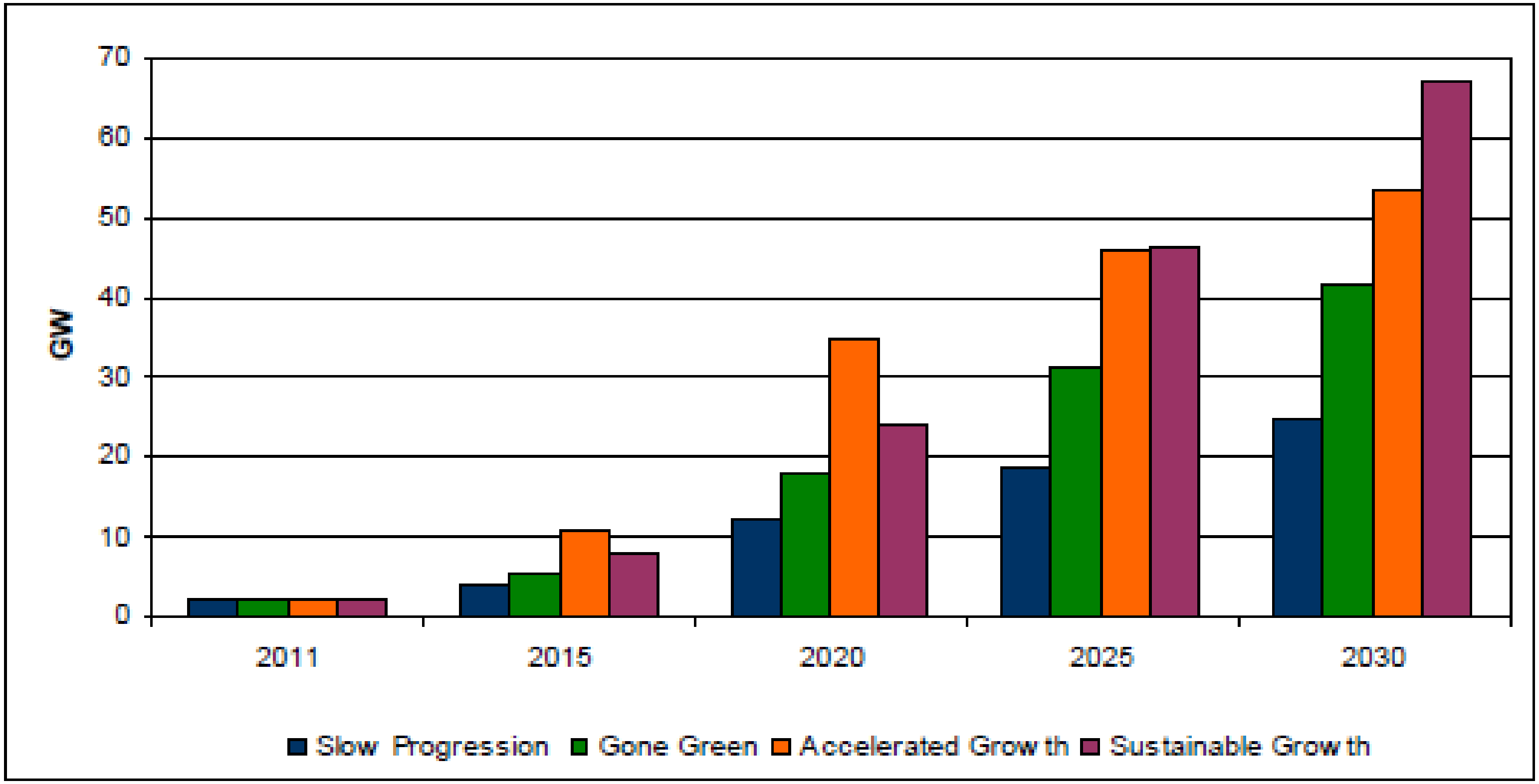
Up to 2020 transmission connection contracts roughly in line with Accelerated Growth

How large will the program slippage be? 18 critical months

Future Scenarios - Offshore Generation (Wind and Marine – Accumulative Installed Capacity)



Poyry Report – Jan 2000 (2030 generation) - No baseload left
CCGTs provides most flexibility when the wind varies

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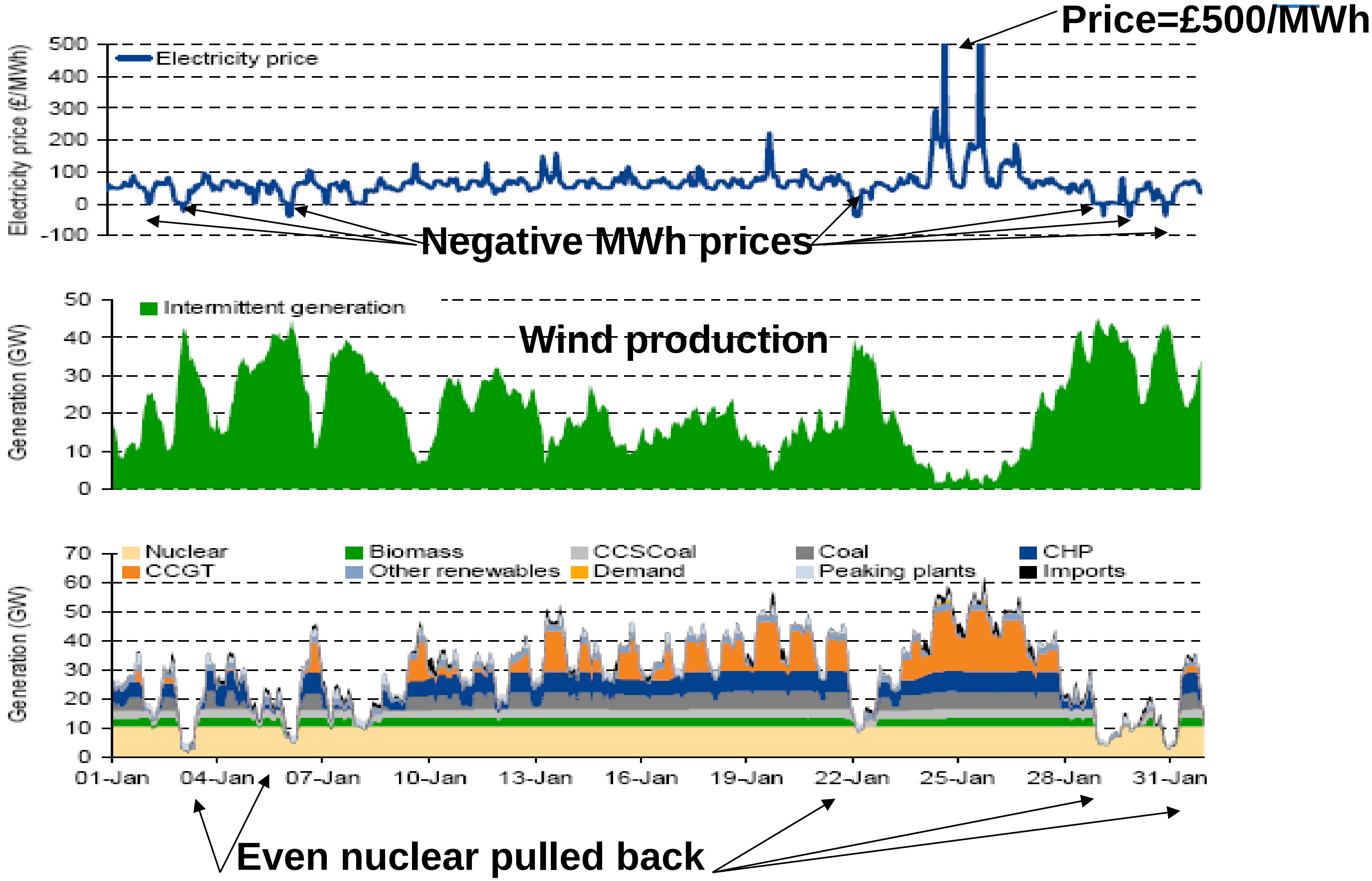
Figure 15 – British market in January 2030 with 2000 weather



When price goes negative

2005 data rerun with 40GW wind installation
Three Winter Months - Dec to Feb
Net demand = Demand – Wind Output . Negative 2% of year!

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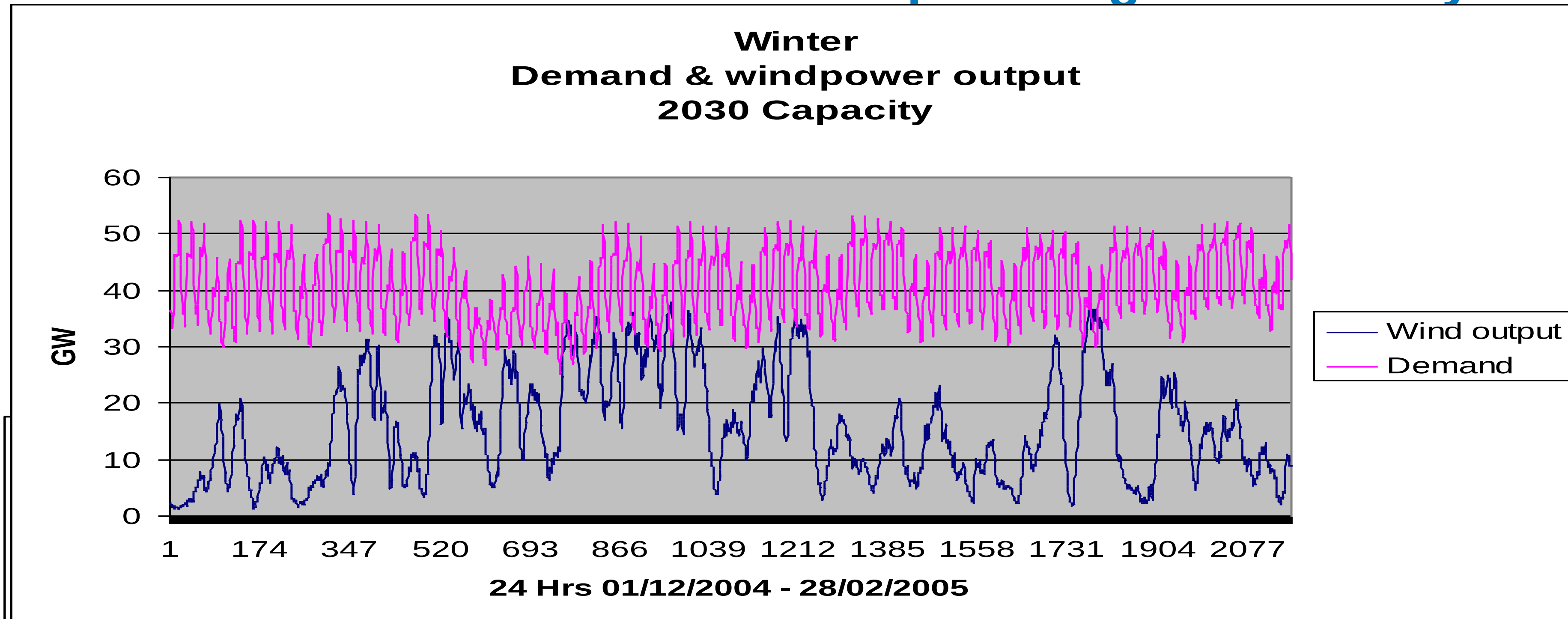

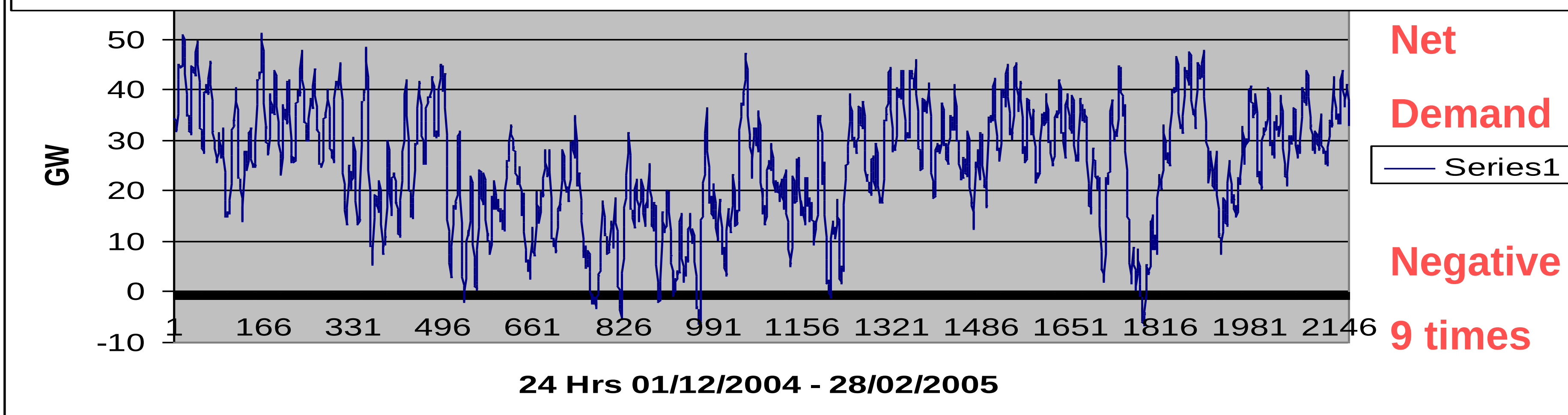

The GB Transmission challenge: £2B/year and additional investments offshore.

SMARTer network to minimise costs & risks

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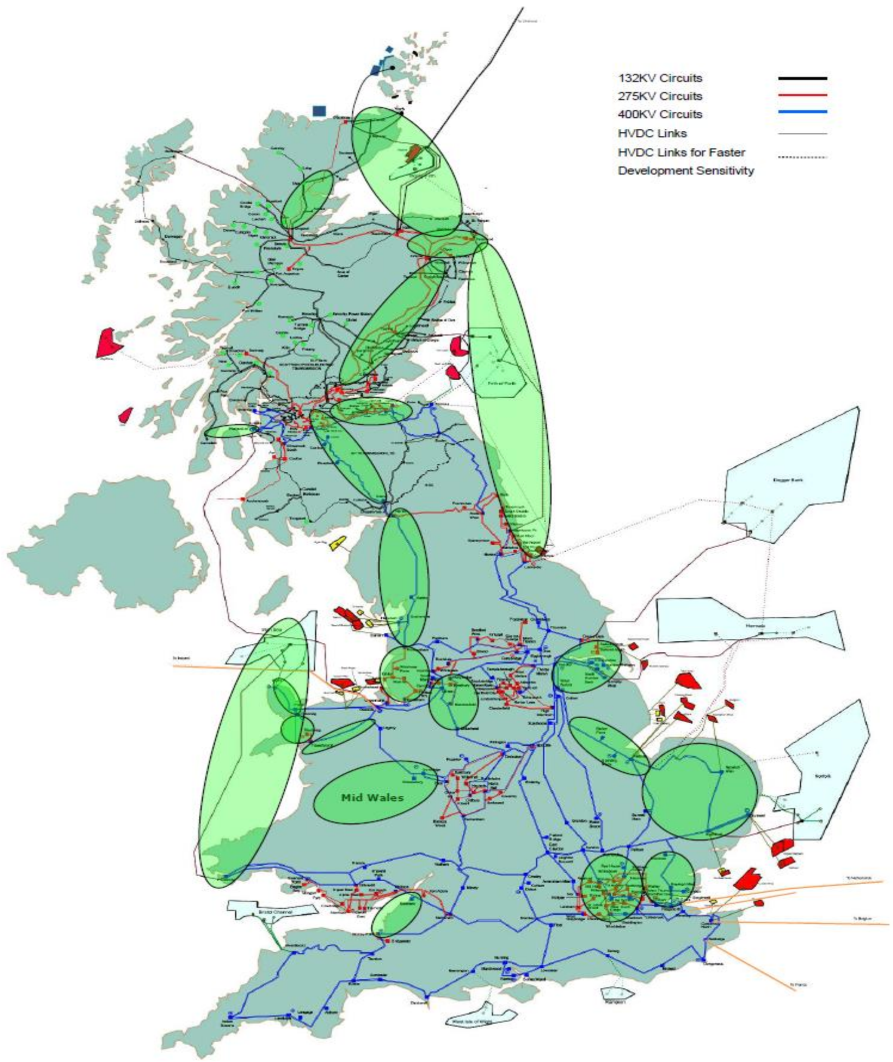

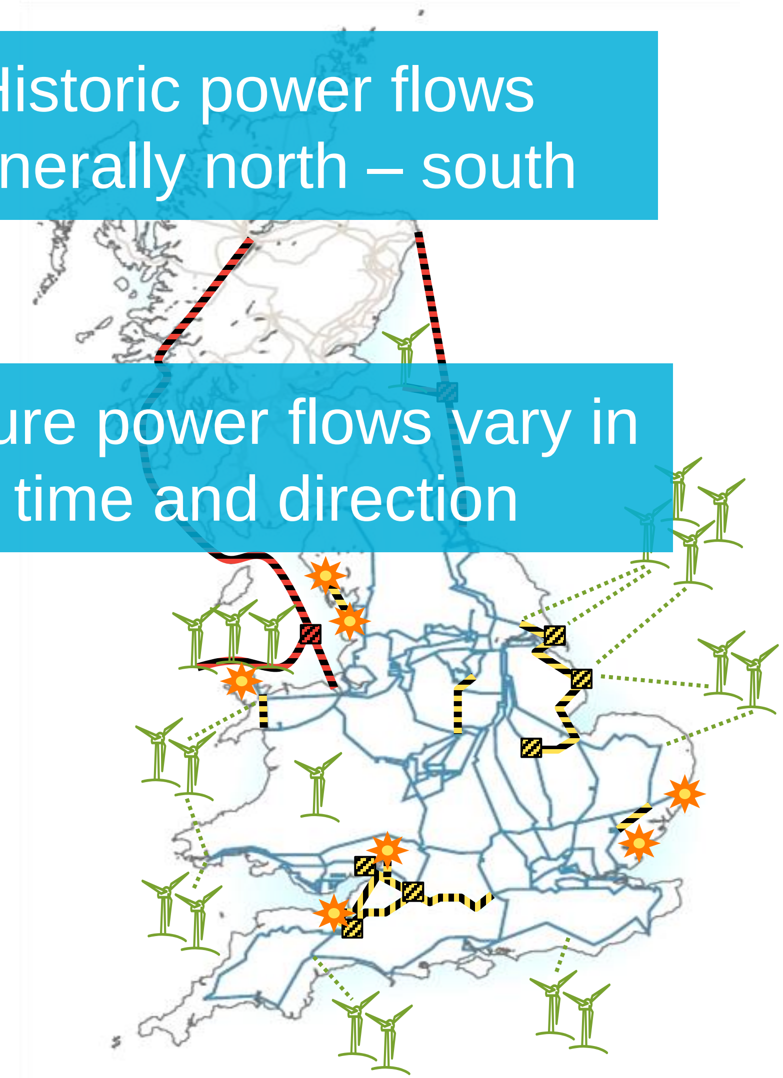

Historic power flows generally north – south

Future power flows vary in time and direction

Electrification of Transport and Heat Need Time of day SMARTer Demand

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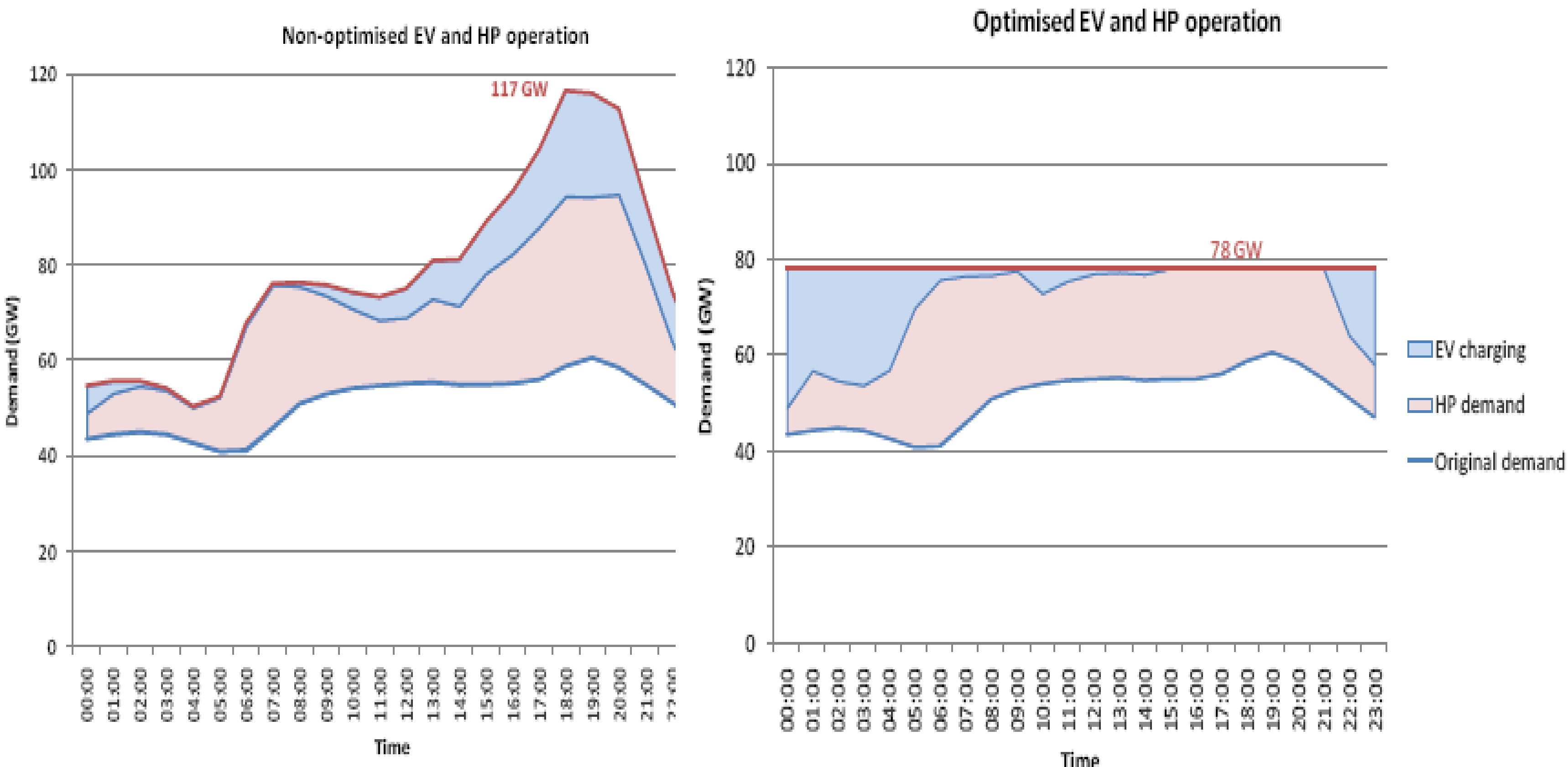

Potential value of Smarter Demand – equivalent to a saving of almost 40GW of installed generation capacity

2030 high wind system technical challenges & progress in pipeline

- Frequency response – all generation flexible
  - Wind – achieved already Technically :yes- economically: yes/no
  - New nuclear – by 2020 Technically :yes- economically: no
  - Carbon Capture & Storage – by 2020? Technically :probable-economically :no
  - Demand – technically easy – incentives complex or make standard?
  - Interconnectors – ENTSO-E new Network Codes – 2016?
- Inertia in high wind – in progress – some solutions implemented post 2015?
  - AC link to Europe could deliver inertia and frequency response
- Short Term Operating Reserve – big shortfall for 2020 – DSR from EVs & White goods + new Pump Storage overseas (Norway 20GW?)
- Variable & extremely low fault levels – Protection updates / HVDC (LCC)
  - Quality of Supply – Harmonics, Vsteps, Resonances
- Need further analysis work for large ac cable systems

High wind – little synchronous plant
Low system inertia – frequency stability?
Introduce synthetic inertia or fast response

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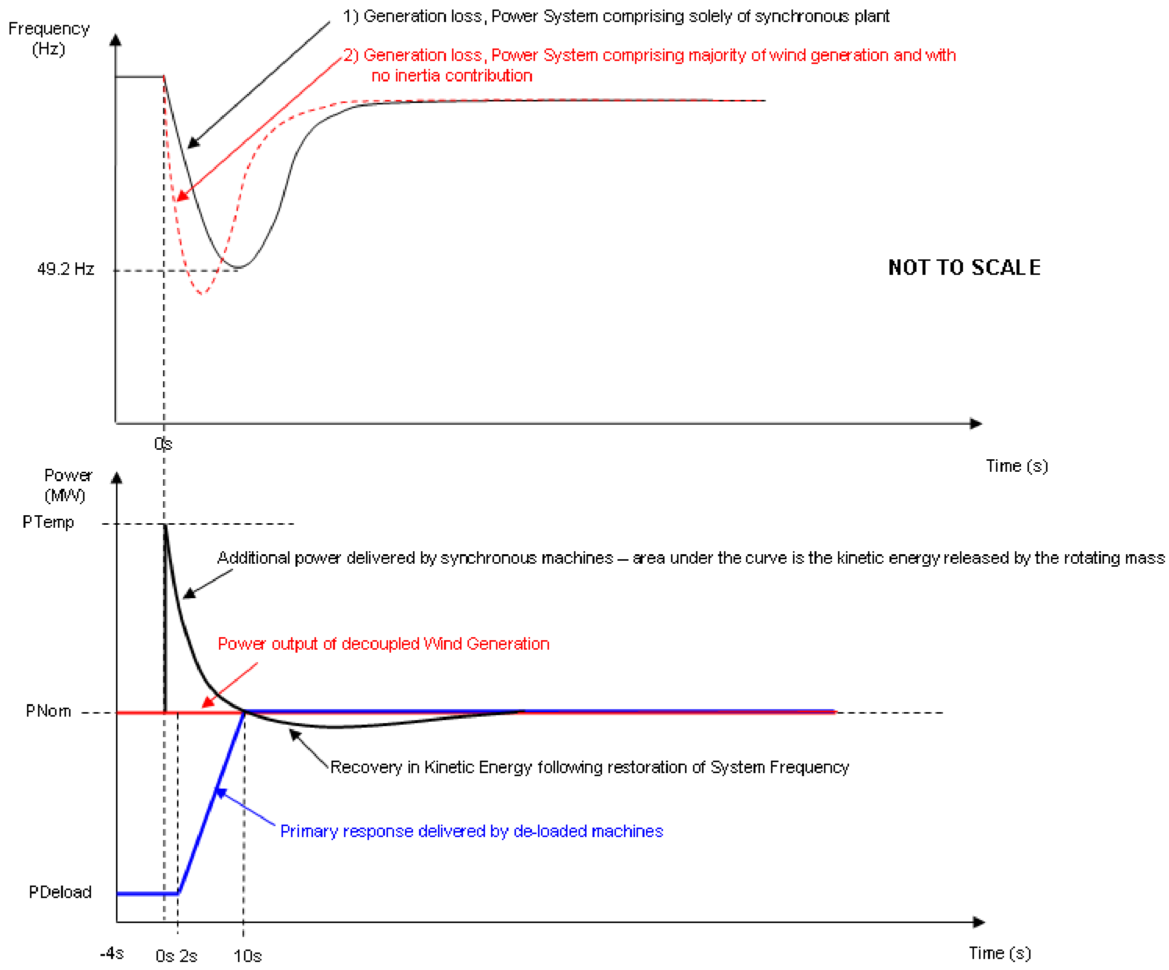

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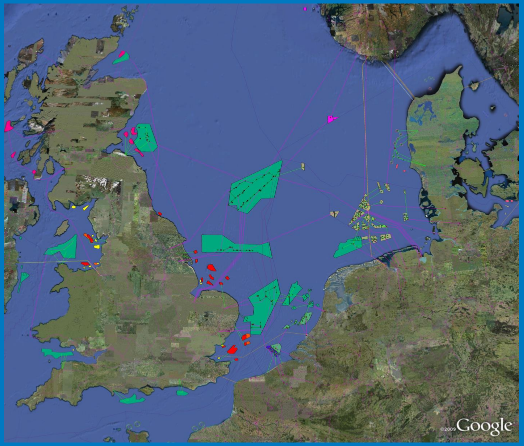
Preparation ahead of Europe opening up its energy markets in 2015



ENTSO-E has significant role in delivering European energy and climate change objectives

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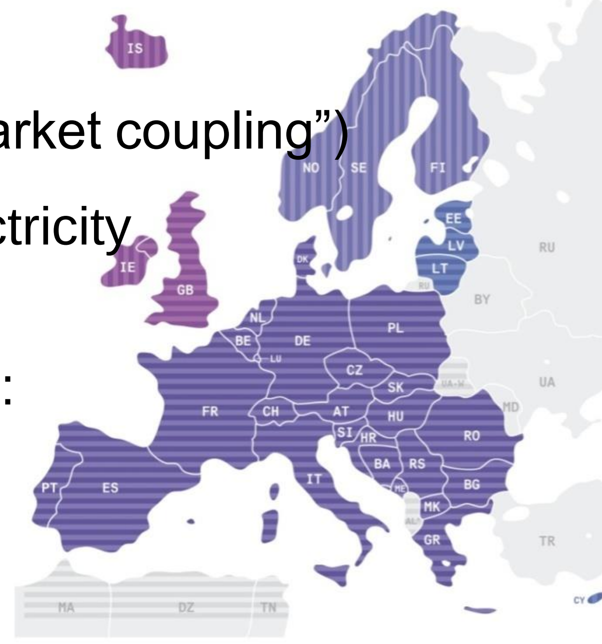
Represents 41 member Transmission System Operators from 34 countries

- **Key activities set out in Regulation 714/2009 (on cross-border electricity trade, part of the 3rd Internal Energy Market Package)**
- Deliver **network codes**
- Deliver **network plans** European / regional view of system needs ("TYNDP")
- Deliver crucial aspects of **market integration** ("market coupling")
- **R&D Plan** (fully included in EEGI – European Electricity Grid Initiative, part of the SET Plan)
- Through its members deliver the **infrastructure** to:
  - enable markets to function,
  - secure energy supply,
  - meet climate change objectives through connecting RES



General Framework - Regulation 714/2009
The process to create Network Codes

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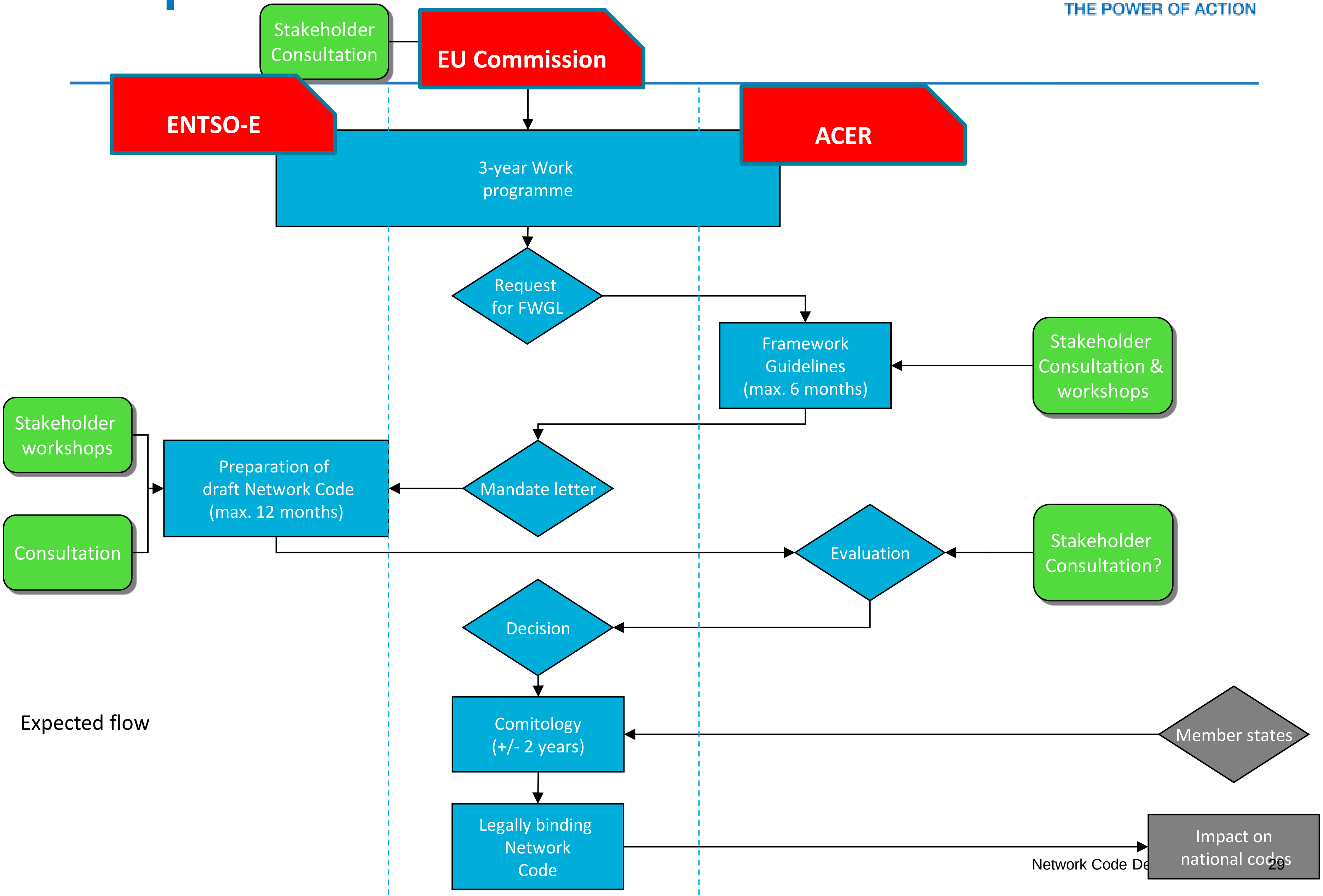

Preparation of laws ahead of the European Energy Market Opening 1.1.2015

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- Development of Network Codes – drafting the rule books – the new EU laws
- Connection Codes
  - Requirements for Generators – advanced – June 2012 to ACER
    - From small domestic 400W to largest nuclear 1800MW
  - Demand Connection Code – End 2012 to ACER
    - Expected to define Demand Side Response service needs by Transmission
  - HVDC Connection Code – End 2014 to ACER
    - Performance needs for interconnectors etc
- System Operation Codes – in progress
- Market Codes – in progress
- Ten Year Network Development Plan (TYNDP) – TYNDP12 in progress
  - Reduce physical bottle necks for trading – energy & balancing

Indicative Potential Demand Side Response (DSR) services in GB by 2020 - Domestic & Industrial

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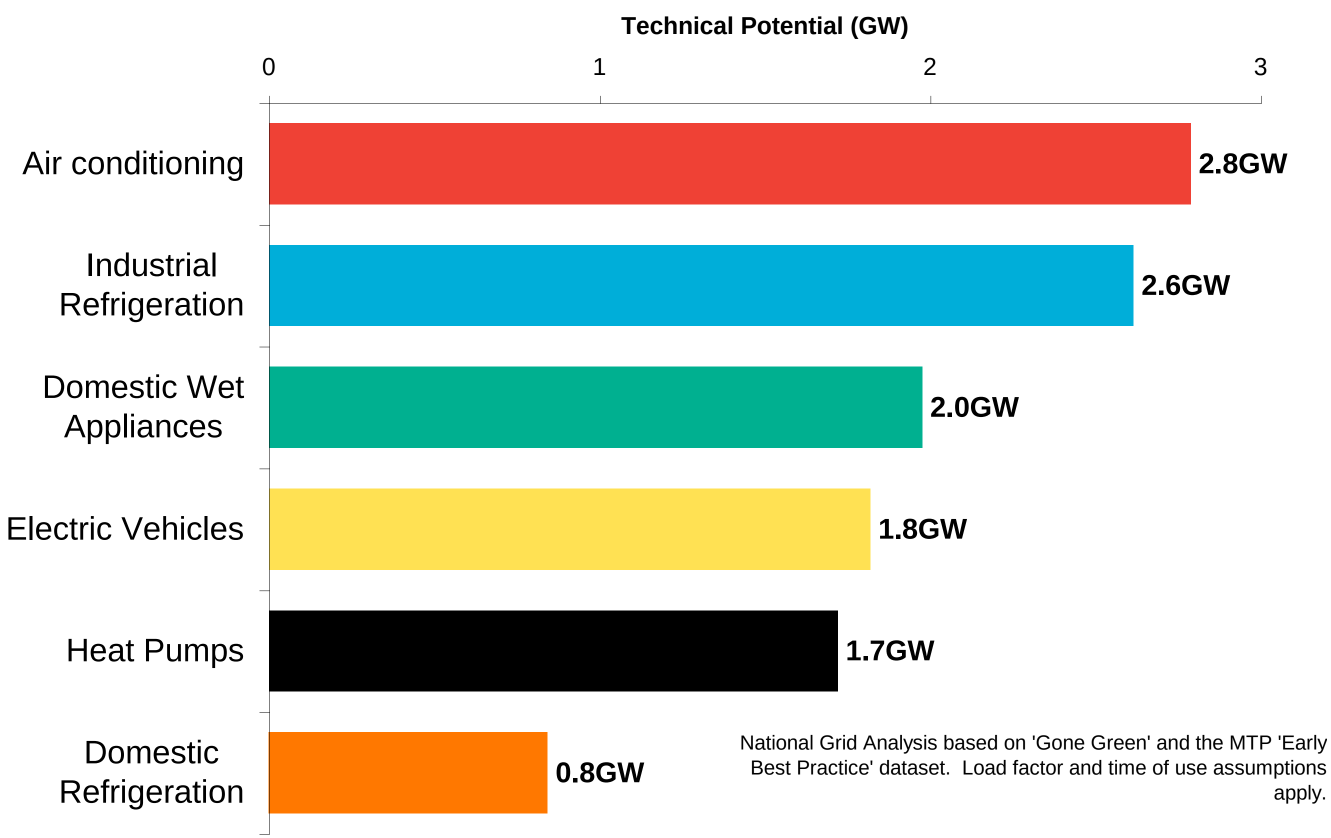
EU Network Code to define TSO service needs in progress



Best suited type of DSR to use it for?

Frequency Response

Frequency Response

Reserve Services

Reserve (+ FR ??)

FR (+ Reserve with storage ?)

Frequency Response

Bridging the seas
GB becoming well connected

What are the potential uses / benefits?

September 2011

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ODIS

Offshore Development Information

Statement

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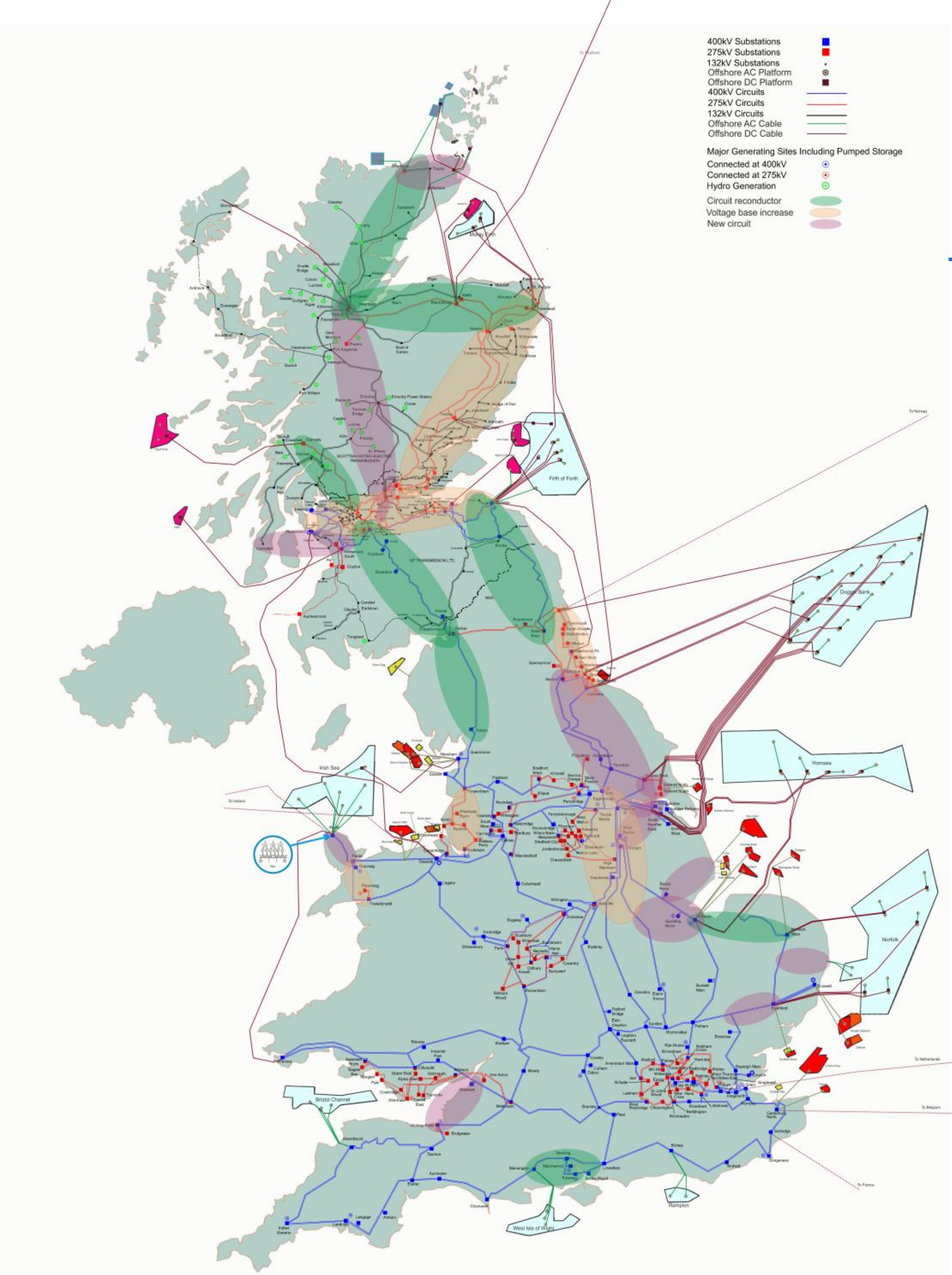
GB Radial Design Accelerated Growth 2030



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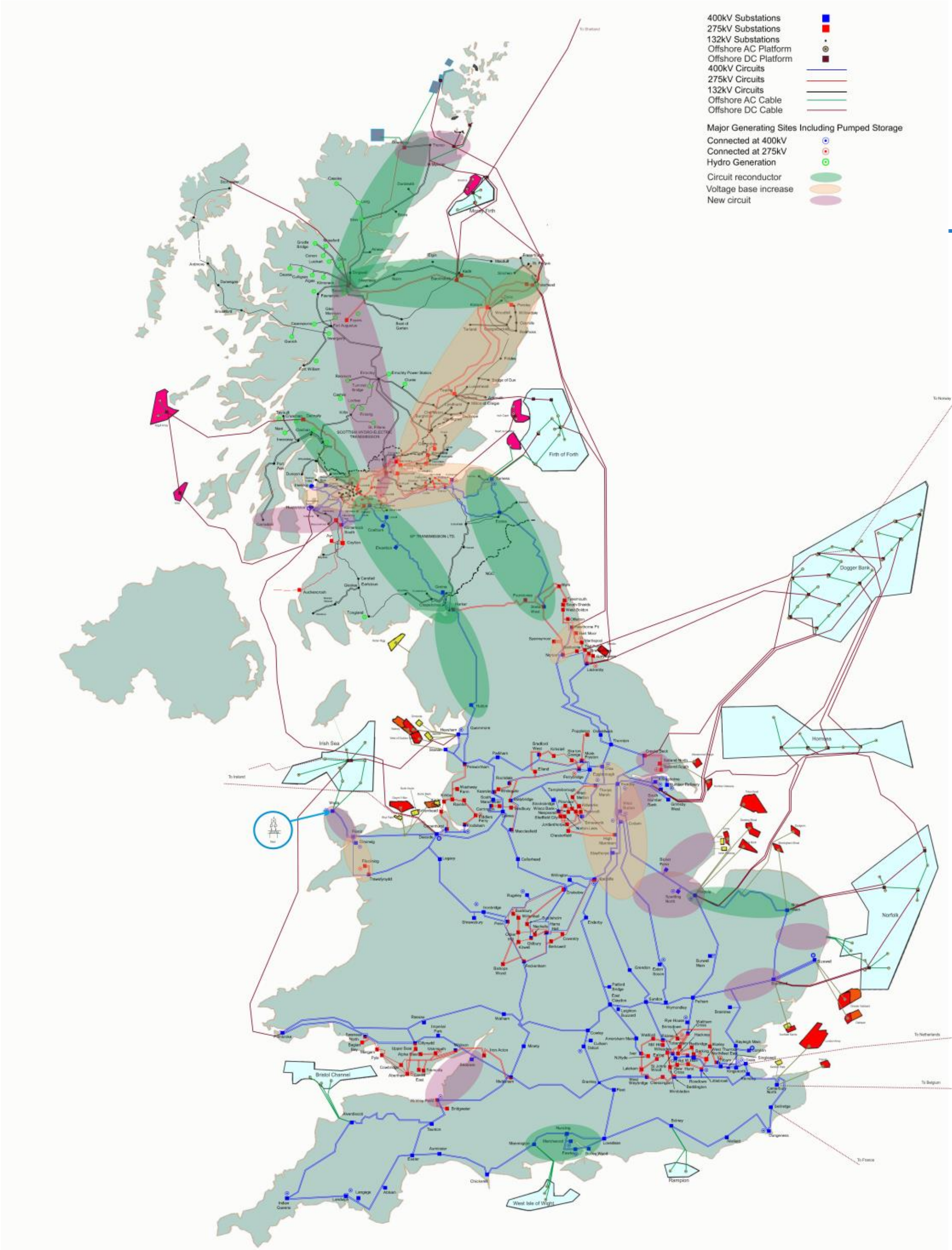
GB Integrated Design Accelerated Growth 2030



Our integrated network solution has multiple benefits

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72%
less new onshore circuits

34%
less landing points

21%
less HVDC cabling

51%
more AC cabling

16%
capital cost reduction

- Significant environmental and consenting benefits
- Improved management and utilisation of valuable resources including land take, corridor routes and manufacturing capability
- Reduced cost for UK consumer
  - Capital cost, operational costs such as maintenance costs and congestion management costs
- A flexible offshore transmission network that is better able to respond to future challenges

£6.9 billion cost saving

- **£5.6 billion capital cost**
- **£1.2 billion congestion management cost**
- **£0.1 billion maintenance**

Note: Under Accelerated Growth scenario

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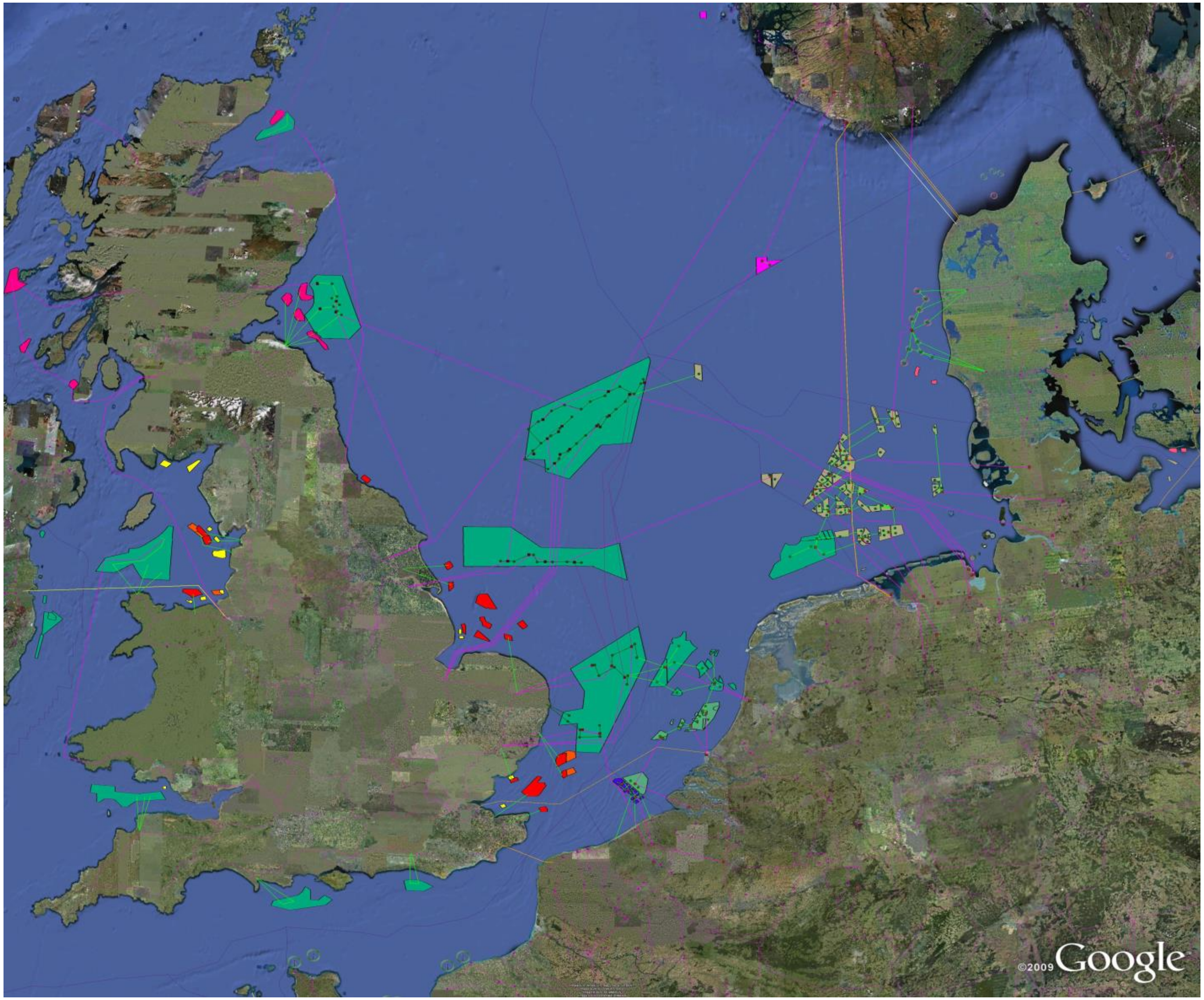
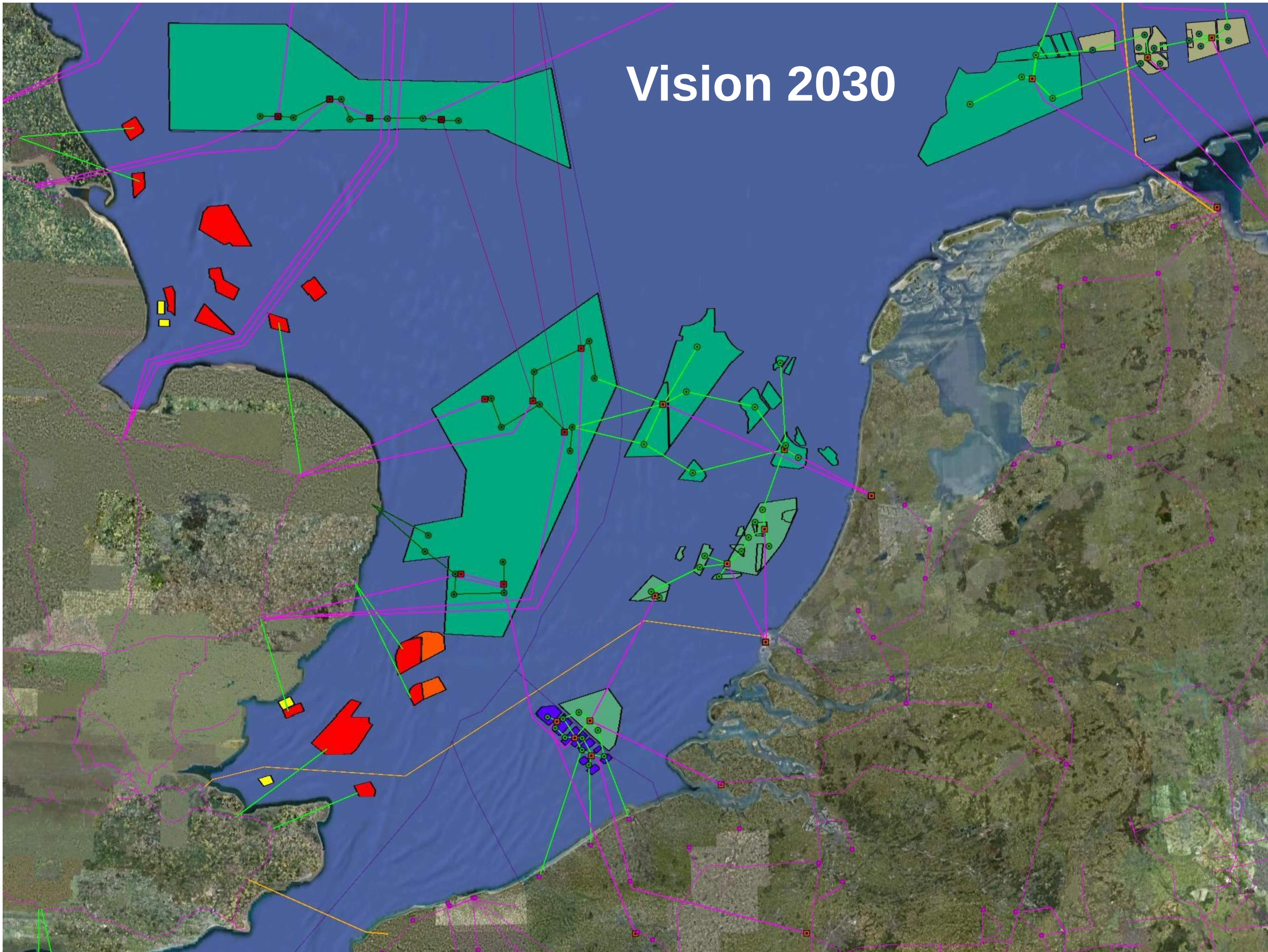
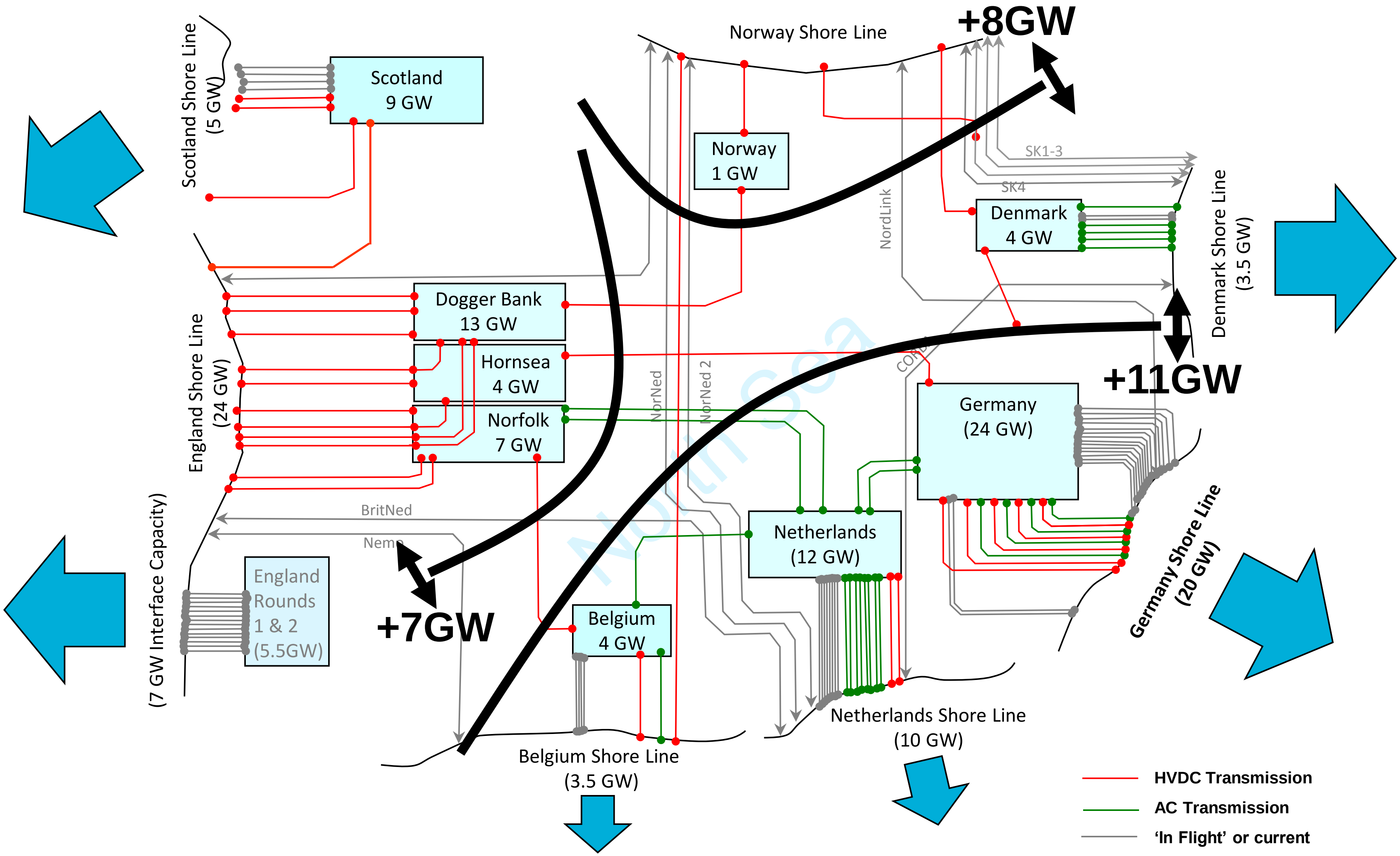
Vision 2030 - North Sea European Integrated Grid




Vision 2030

Conceptual design for 2030



Smart Demand meets Smart Grid Objectives

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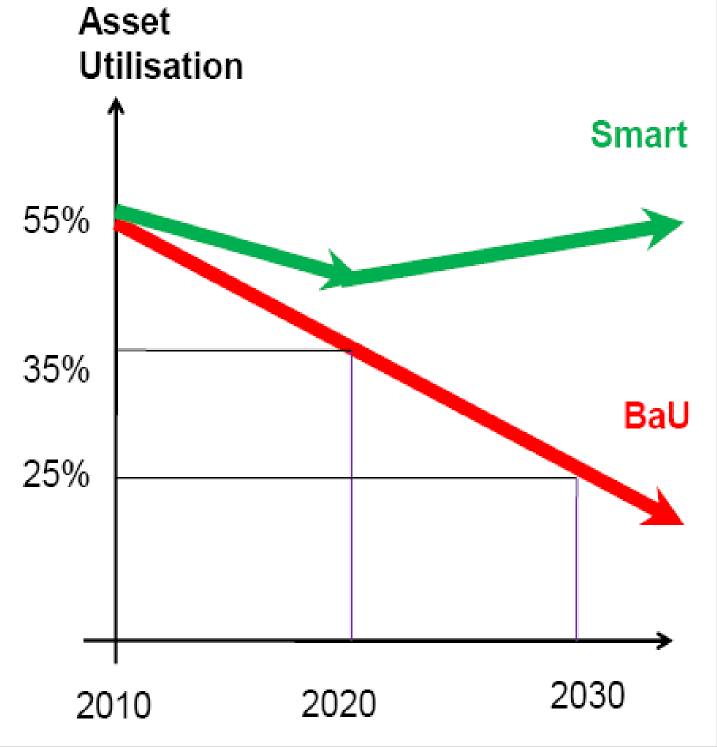
Smart Grid = Paradigm shift in providing flexibility

From redundancy in assets to more intelligent operation through incorporation of demand side and advanced network technologies in support of real time grid management



Dynamic Demand and Active Demand Side Management

HVAC offshore transmission initially: Three core sub-sea cables

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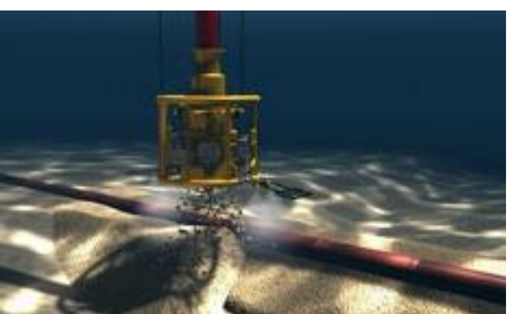
Power cable plough
IHC Engineering Business

Cable carousel on Nexans Skagerrak Image courtesy Nexans



Rock Placement courtesy of Tideway

Image courtesy of Prysmian

HVDC challenge: Scale up to 2000MW with multi-terminal operation – selective fault clearance

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Done in Germany: 400MW BorWin Alpha offshore VSC converter

Power	400 MW
DC voltage	±150 kV
Topside weight	3300 t
Size	50 x 33.5 x 22 m (approx)
Jacket weight	1500 t
Height	62 m
Sea level to topside	20 m

1. AC power area
2. Converter reactors
3. HVDC valves
4. DC power area
5. Cooling system

From ABB website www.abb.com

European TSOs sharing experience to develop Network Code for HVDC connections.

GB in Europe – Could we go even further?
What are the potential uses / benefits?

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The new GB Electricity Market Reform calls for

- A market in capacity
- To cover peak demand during low wind

- Demand Side Response identified as possible capacity service
- Could foreign generation capacity be relied upon as a GB capacity service?
  - Norway considering 20GW of additional Pump Storage – existing lakes
  - Provide firm capacity for GB?

Could we connect by ac to Europe?

- Similar length cable to Sicily – mainland Italy – 2 X 1GVA in progress
- GB may need 4-6GW links to be dynamically stable
- Potentially good tool for response & inertia – 90% from overseas
- Deliver some undesirable affects

Would “ac like” performance from HVDC be better / more economical?

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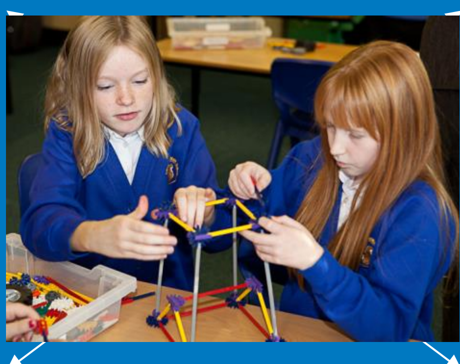
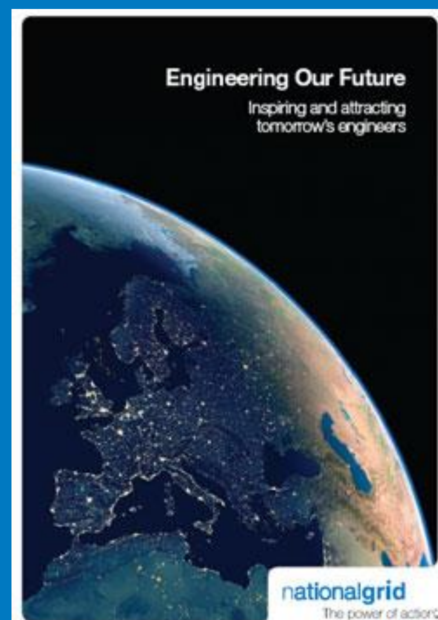
The Future Human Resources to Match the Challenges

What do we do and what could you do?





Inspire Engineers of the Future!

Grid@75 Build and Test Your Own Power System

…We have a skills gap to manage…

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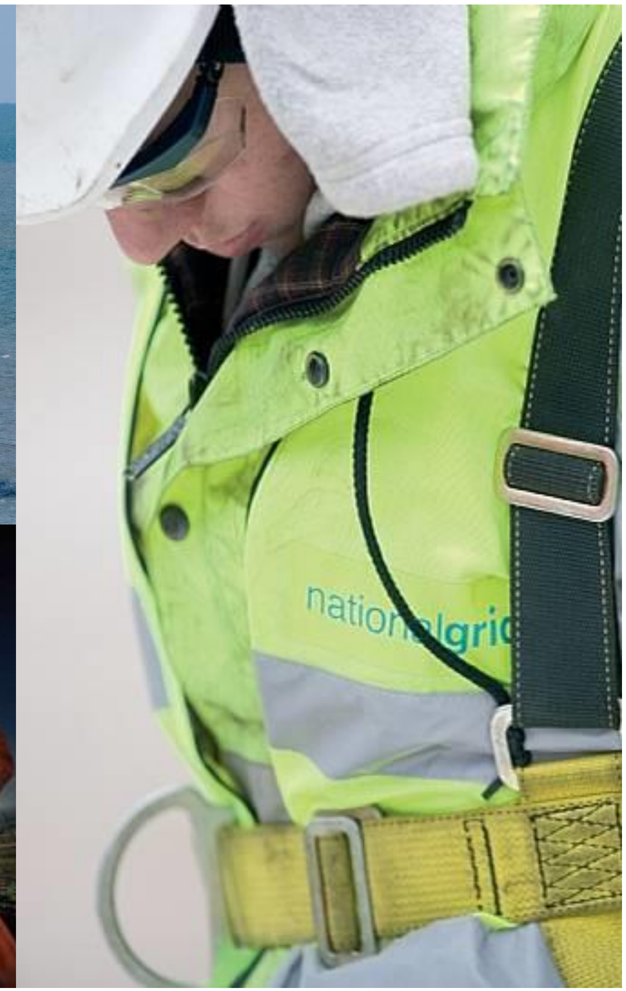

Energy industry needs engineers. Can you deliver?

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- June 2007 Parliament Committee challenge to Univ Vice Chancellors
  - DTI worried – not enough engineers to prepare 20/20/20 policies
  - HU: We need 4-5 orders of magnitude more “Doers” to deliver these
- Electricity Network Investment in National Grid
  - Our capital investments will have increased by ~10 times in 10 years
  - It has been very hard to recruit just to double staff 150 to 300
  - Selected on communication skills, team work & project skills
  - Extensive training of numerate graduates after appointment
- Soon the DNOs will have to become DSOs – massive up skilling
- Supply chain for energy installations – domestic to industrial – massive
- Are you able to deliver the engineers?

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'Just do it' (Our portfolio of engagements, UK, 2010/11)

Imagineering

SCHOOL power

Teachers' CPD

Open House

Ambassadors

Work Experience Week

Project Ladder

Interest & 'enthuse' 4 - 11	Choose STEM! 11 -13	Nurture talent 14 - 19	Secure talent	Develop

Greenpower
INSPIRING ENGINEERS

STEM AMBASSADORS
ILLUMINATING FUTURES

National Grid Environmental Education Centre Network

*

smallpeice

POWER ACADEMY
ENGINEERING POWER AT YOUR FINGERTIPS

Engineering Education Scheme
England & Scotland
EDT

The Year in Industry
EDT

Headstart
EDT

* Programmes actively being developed

Students gaining skills & enthusing the next generation of engineers. Can these two be combined?

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- Broadening trial for engineering students at Coventry University
  - Hands on fun Imagineering clubs
  - Students as Tutors - using proven formula and readily available logistics.
  - Enthuse as early as 10 year olds – future Univ. customers!!
- Ideal training for Under Graduates:
  - Maths through Imagineering
  - Communicating in simple language
  - Managing tutoring team and projects
- Your students better prepared for world of work

For more info:

http://www.imagineering.org.uk/

Your Country Needs You to deliver the engineers to create the future!!!

Contact

Helge Urdal

Email: Helge.Urdal@uk.ngrid.com

http://www.nationalgridcareers.com/

National Grid is also willing to help you

– e.g. guest lectures

Conclusions "Big challenges require big solutions"– **we must:**

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- Inform and partner with customers and communities
- Work and lead with our regulators and policy makers
- Co-ordinate across national boundaries
- Seize the opportunity to meet these challenging targets
- Keep options open for technology developments
- Balanced solution with no silver bullets!

Climate change key challenges
Targets & Policy

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Targets	*Energy policy objectives*
15% of all energy to come from renewable sources by 2020	Sustainability
80% reduction in CO_2 emissions by 2050	Secure energy supplies
	Affordability

The challenge is to meet all the targets and the policy objectives simultaneously, in a timely way

Working Within Europe

Significant prospect for Europe to facilitate us to be SMARTer

Thank you
for your attention.

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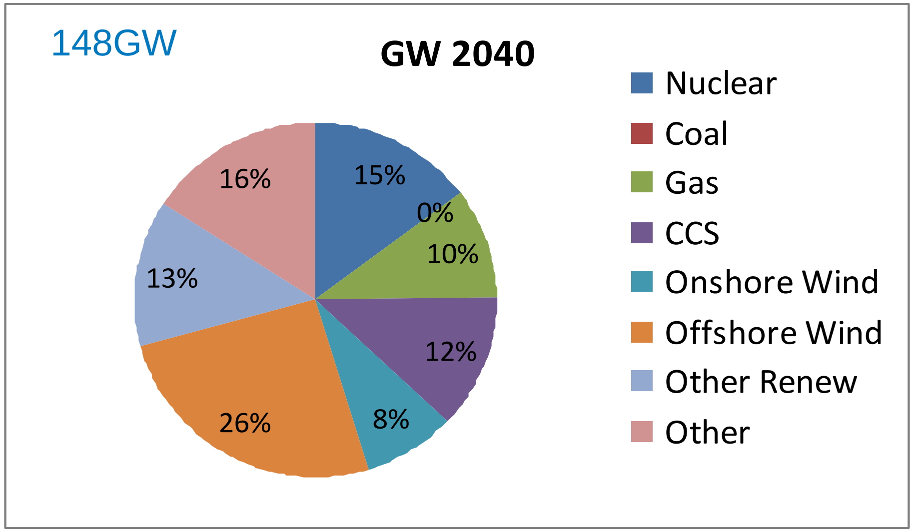
http://www.nationalgridcareers.com/

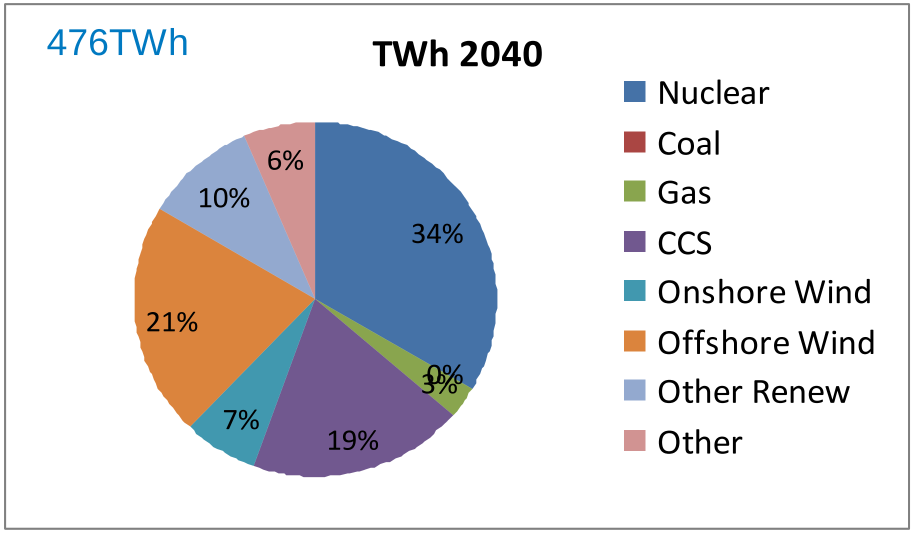
Electricity Supply – 2040

Supplying heat and transport with CCS & nuclear

148GW



476TWh



- Large increase in generation output as heat and transport undergo significant electrification
- More nuclear and CCS on system providing baseload power
- No growth in wind as it goes into maintenance mode with economic sites replanted with larger turbines but less economic sites abandoned

Electricity supply – 2050
Smart interconnected systems

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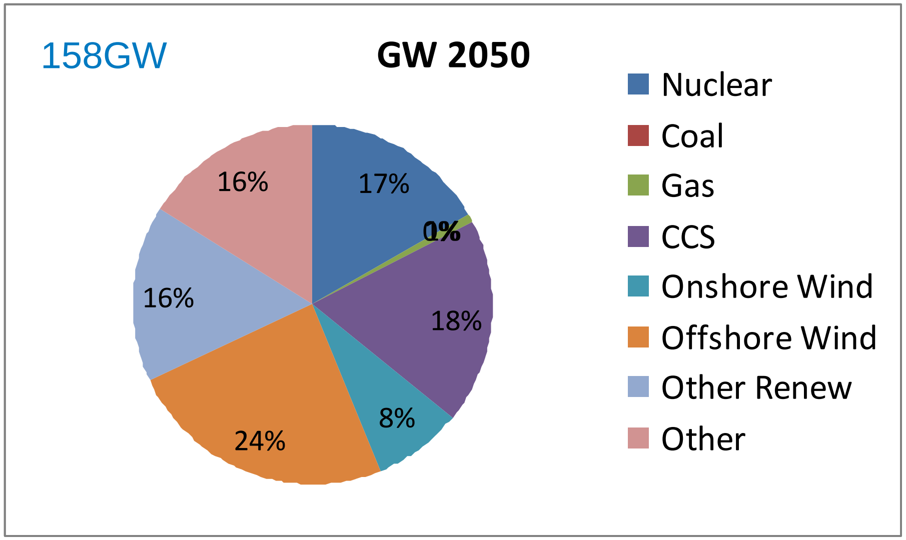
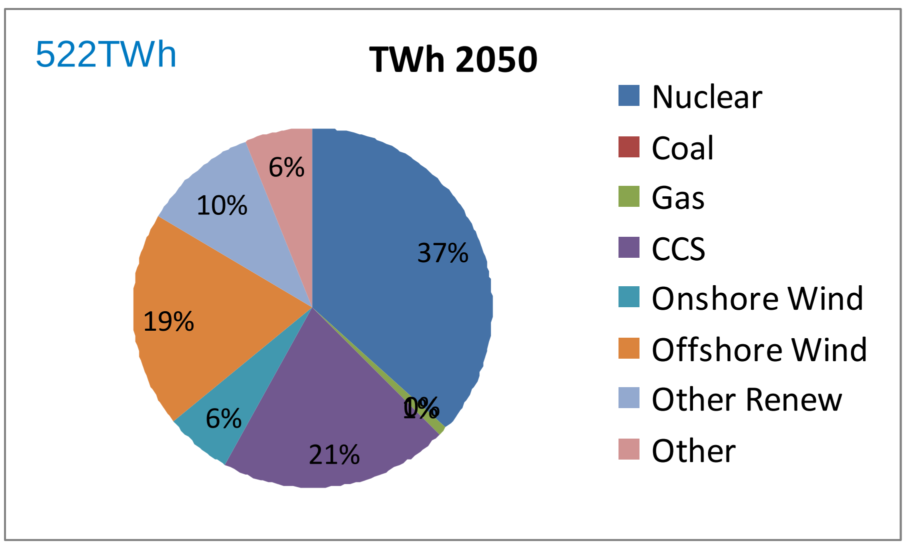
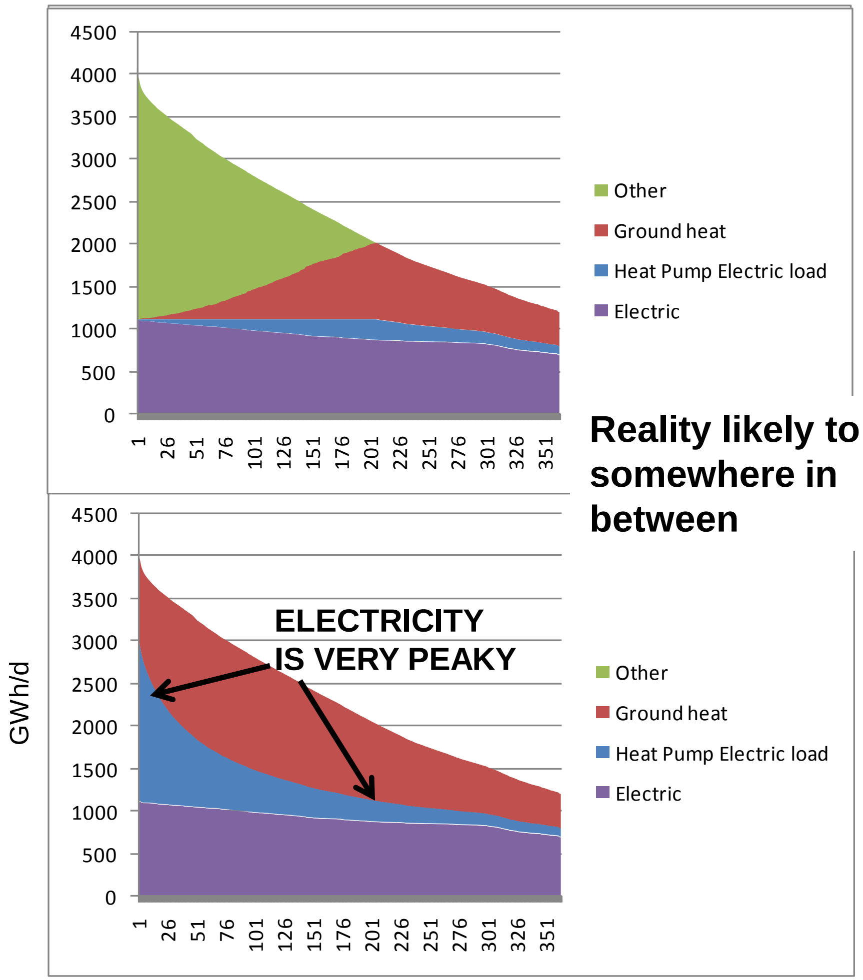




- Further increases in heat and transport electrification, large penetration of hybrid heating systems and vehicles
- All existing nuclear sites replanted with 26GW of capacity
- 28GW of CCS on system
- 15GW of interconnection with Northern Europe as part of a European supergrid which together with flexible heating help balance the system

Some food for thought – 100% electric heat pump



Reality likely to be somewhere in between

- If every building had a electric heat pump/gas hybrid we could electrify nearly half of heat without building additional generation capacity
- 20GW additional capacity would raise this level to 80% but we would need to build a further 80GW to electrify fully!

Contribution to Control of System Frequency Wind Farms can Contribute Solutions, not just Balancing Problems

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Frequency Response

- Required for all WF installations >50MW
- Capability required and paid for as for other types of generation.
- 10% in 10 seconds
- Fast (start within 2 seconds) and proportional

Greatest Benefit

For low to medium wind penetration

- Economic for high frequency response, see top RHS
- Low loss wind production, useful at low demand

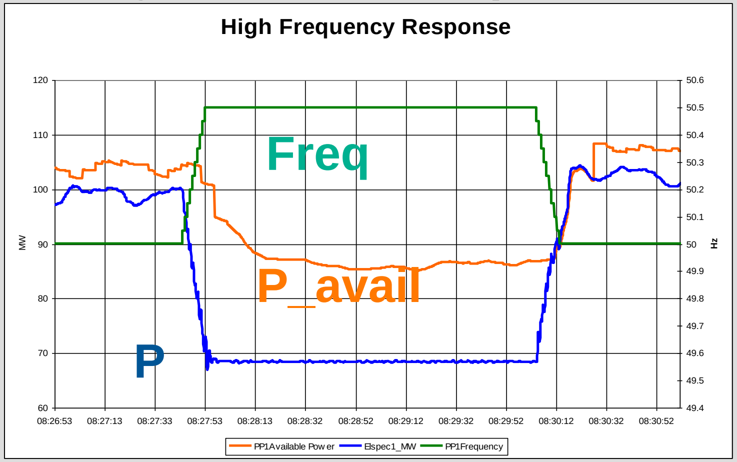
Future use during high or extremely high wind penetration:

- Low frequency response with headroom, see bottom

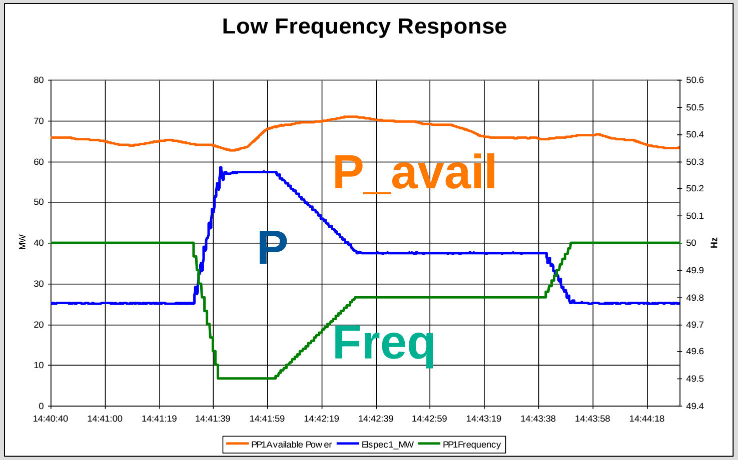
Delivery

- Proven successfully by several manufacturers
- Most flexible & best controlled plant on system!!!!
- Valuable for low system demand with high wind
- Securing full BS for future extreme cases when demand cover by wind close to 100% of total

Inject +0.5Hz ramp over 10s



Inject -0.5Hz ramp, recover to 49.8Hz



Reactive Power with Fast Acting Voltage Control is now routine.
Completing Studies and Testing is the basis for Verified Models

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Reactive capability

- 0.95 lead & lag power factor at PCC
- Freedom to define means – varied solns
- Full converter WTG – tend to deliver Q themselves
- Most DFIG WTG types tend to use central Q compensation (including STATCOM + switched reactor + capacitor)

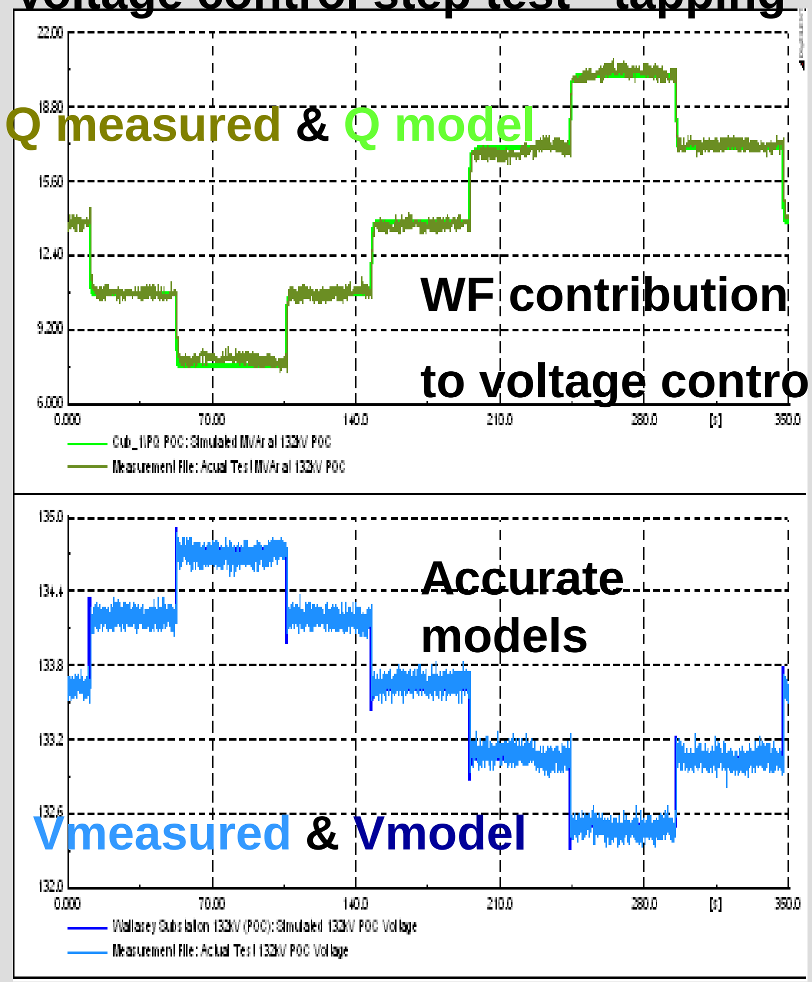
Same dynamic performance

- Deliver 90% of Q in 1 second
- Settle to correct Q within 5 secs
- Selectable Vtarget and V-Q slope
- Stability – "first swing" & small signal

Verified capabilities

- Pre-connection models and studies by owner supported by manufacturers
- Witnessed on site tests
- Comparing tests and studies, see RHS
- Verified models for security assessments

Voltage control step test - tapping



Cleaner coal (IGCC version) with front end CCS, e.g. Hatfield – Powerfuel – At TM Doncaster

PS Picture not exact fit: Fuel is coal – not petcoke – CO2 offshore & not for enhanced recovery.

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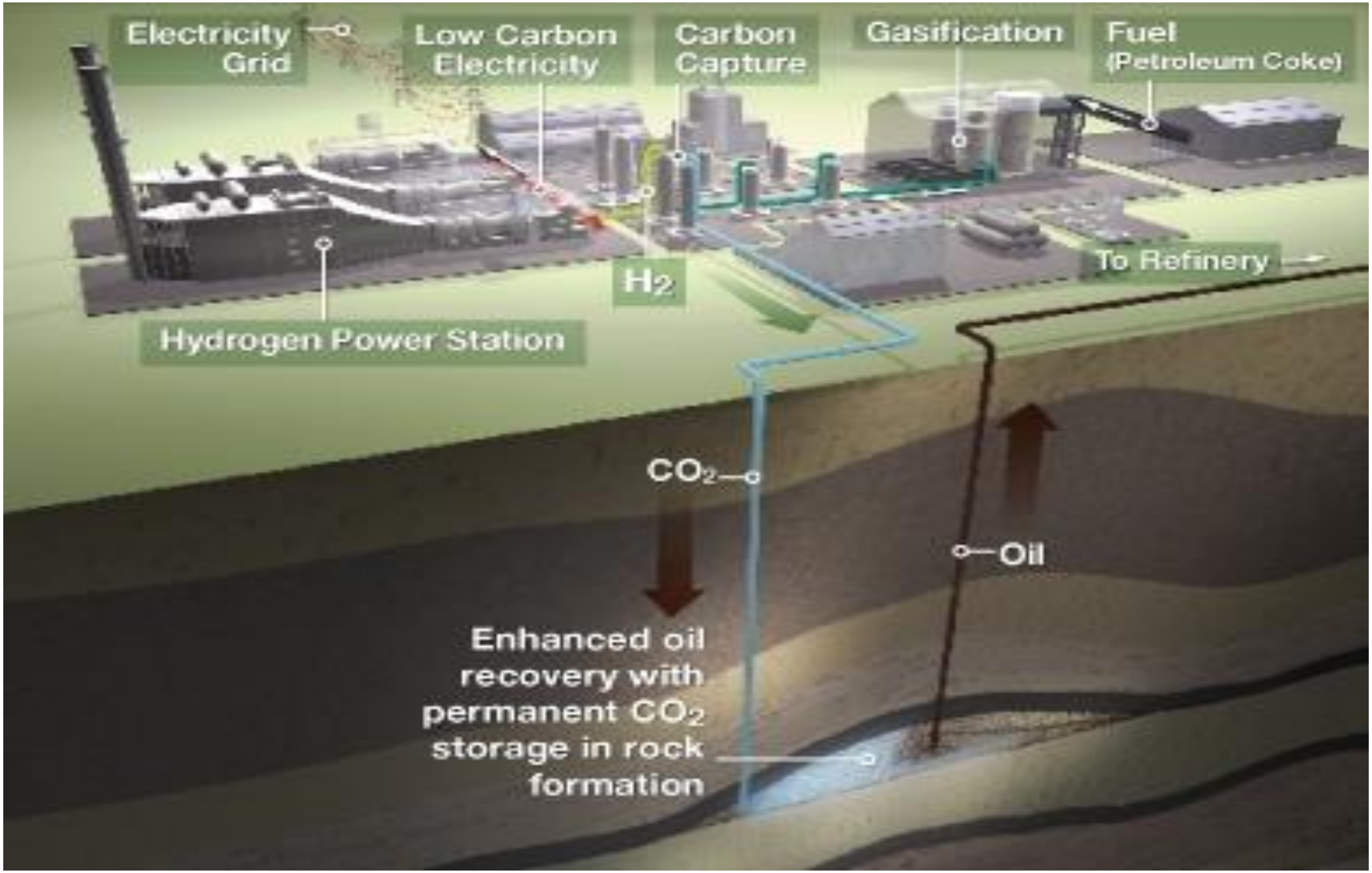

Today's European grid challenges

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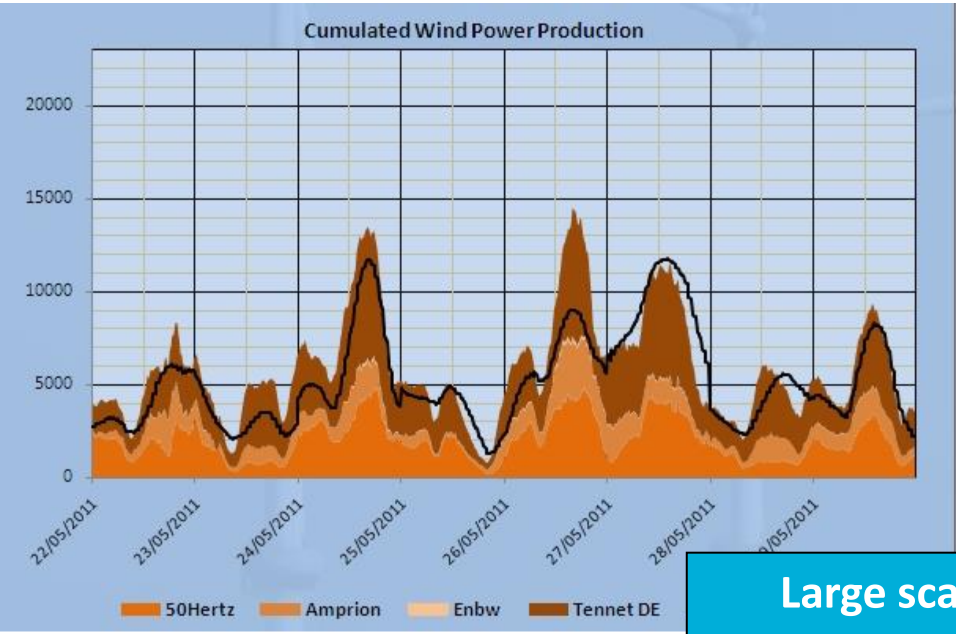
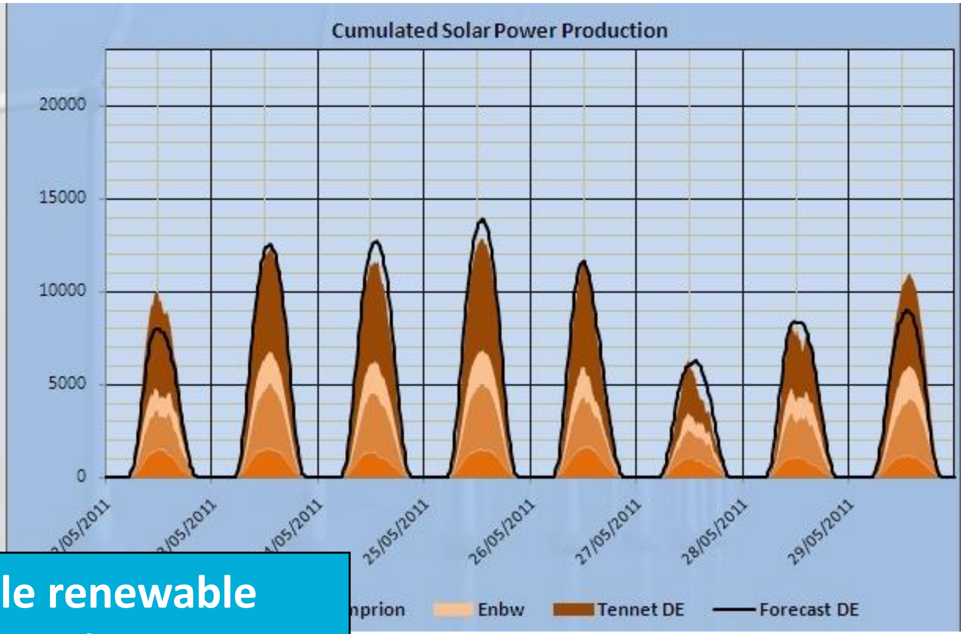
A week in May - wind & solar power in Germany – 2 X 13GW!!

The Renewable Energy Sources are one of the major variable source in the grid.





Large scale renewable generation

High variability – geographical concentration

GB Stakeholders' Opportunities for Engagement in Europe

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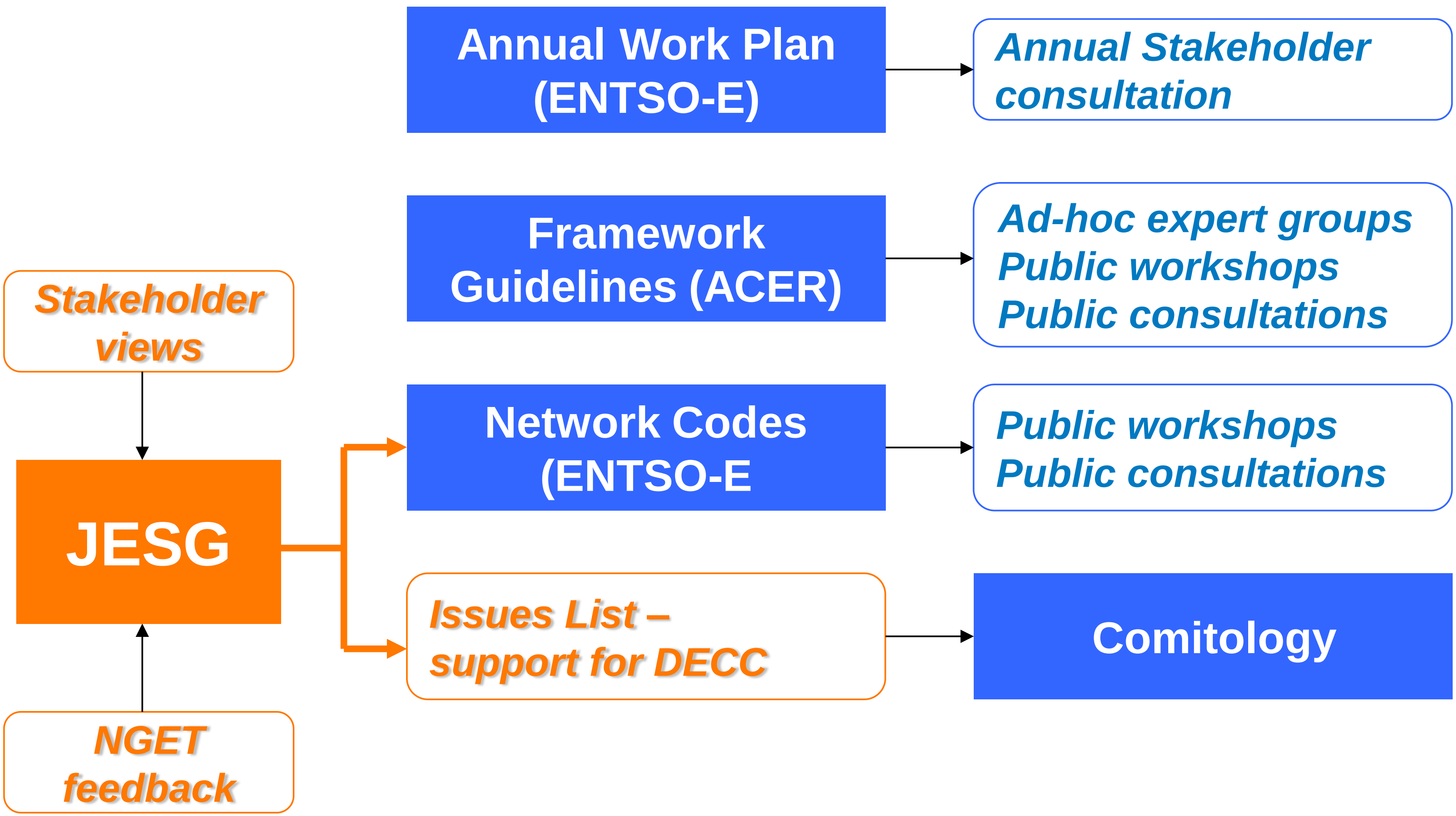

The future – efficiency, decarbonisation and electrification

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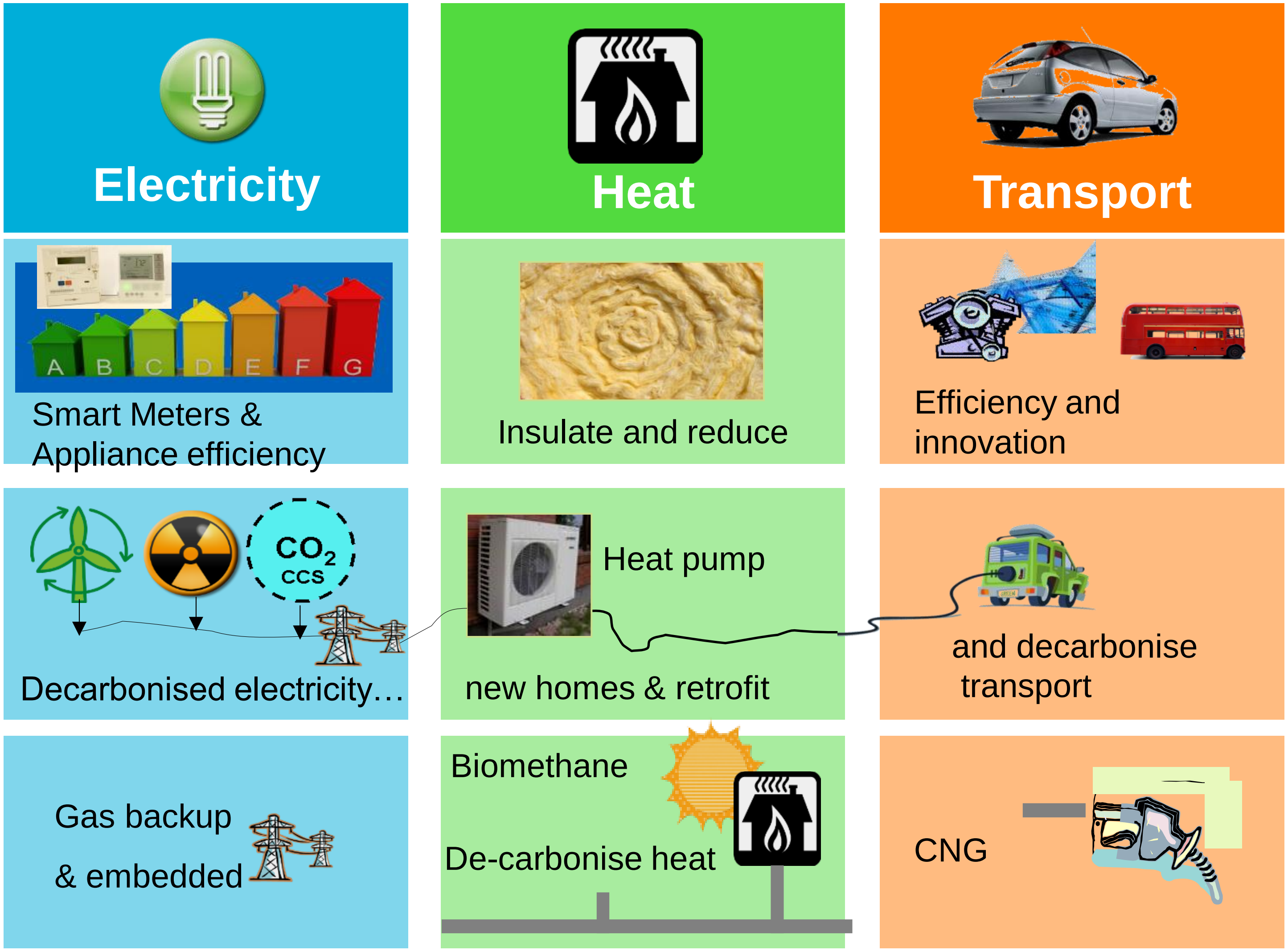

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Open House – Visits to National Grid Sites.

- 22 Events last year, 400 students.
- Content around four themes:
  - Engineers & their jobs
  - National Grid ‘kit’
  - The future of energy
  - Career pathways.

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National Grid Work Experience Week

Residential courses designed to give a taster. 100 Students.

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Ambassadors

imagineering

smallpeice