Discussion Notes @ the 4th Annual Project Review Meeting of IMAGES (Integrated, Market-Fit and Affordable Grid-Scale Energy Storage)

Current Trends and Challenges in the Energy Sector

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Chief Technology Officer
Warwick UK, 21st November 2016

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AGENDA

- ❑ Brief Introduction to GAELECTRIC
- ❑ New Features of the Energy Sector
- ❑ New Trends Across Europe and the World

GAELECTRIC = GAEL + ELECTRIC

- Founded in 2004, proactive in the renewable energy and power sector with an investment of €500m.
- International operations across Ireland, the UK and USA, headquartered from Dublin.
- Business interests across six renewable energy and related sectors:
  1. Wind (Onshore & Offshore),
  2. Bioenergy,
  3. Solar Power,
  4. Energy Storage (both large scale & small scale),
  5. Energy Trading,
  6. Smart Integration, and Internet of Energy.

The Mission Statement

The empowerment of next generation energy users, through the development and deployment of sustainable energy solutions and services.

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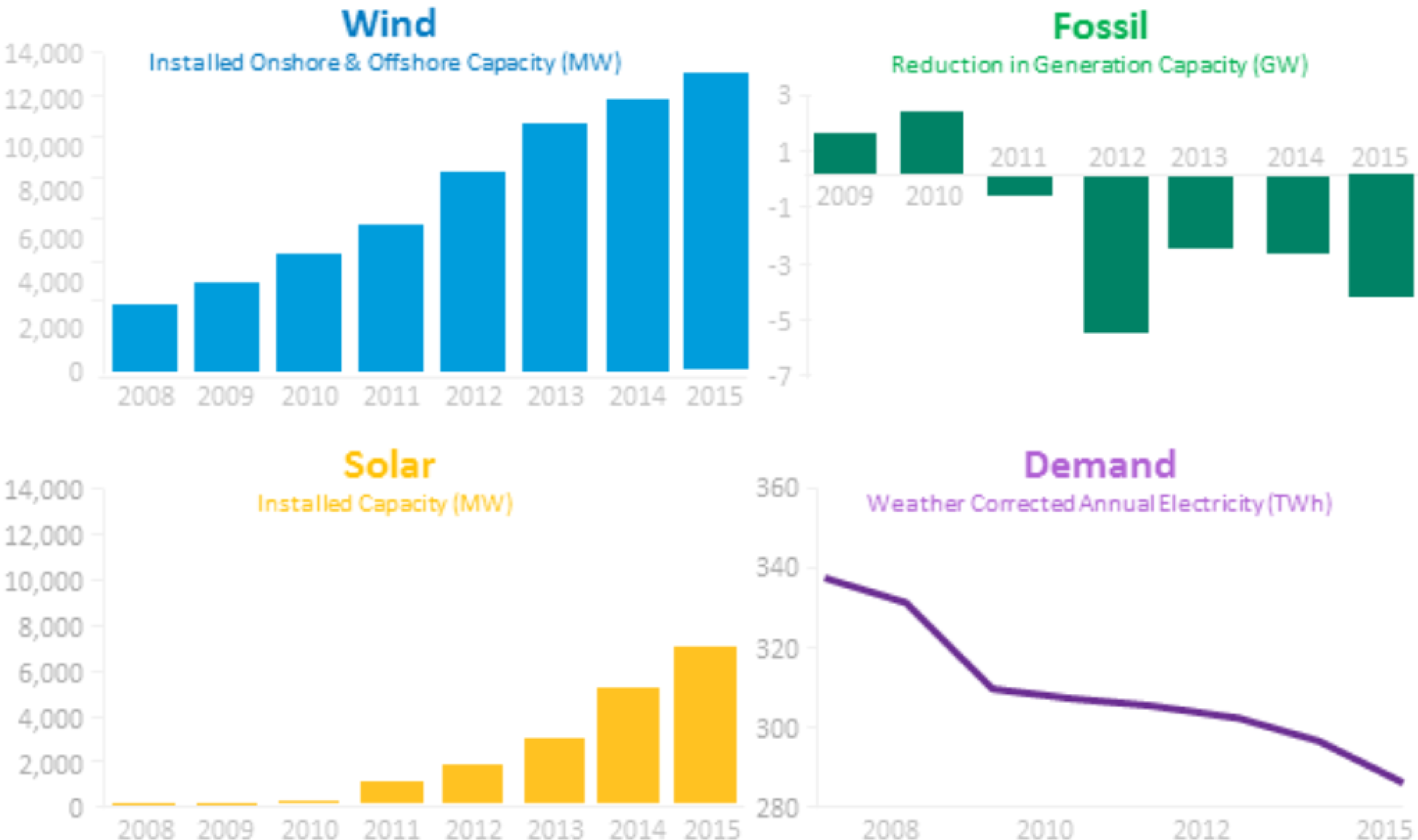
Key Features of the Energy Sector

- Decarbonisation
- Decentralisation
- Digitalisation

Decarbonisation, Decentralisation, Digitalisation

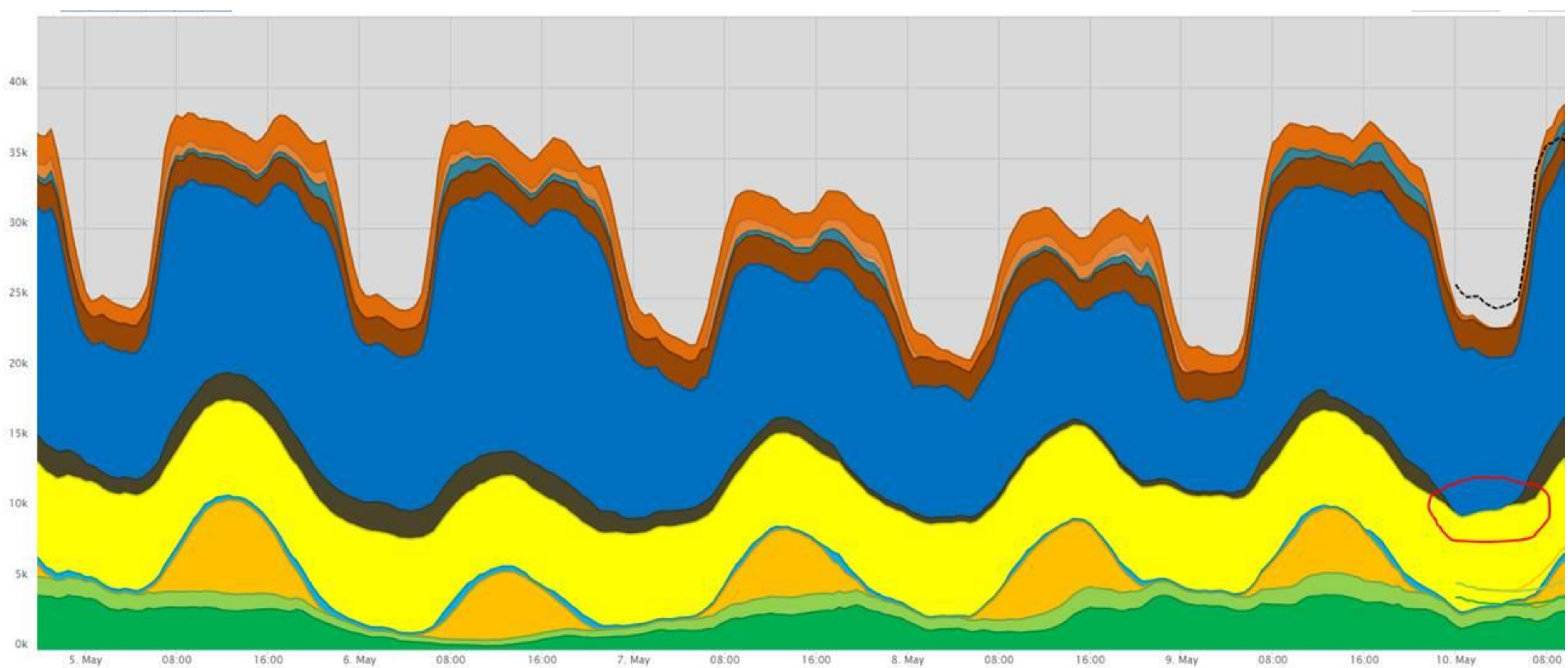
Changing Energy Landscape

Situation in GB, as an example



Coal Fired Power Starts to Disappear

(GB on Tues 10 May 2016)



Great Britain (GB) is scheduled to have all remaining coal-fired power stations closed off by 2025.

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Prevailing Trends in the Energy Sector

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Reduction in Subsidy without Reducing RE

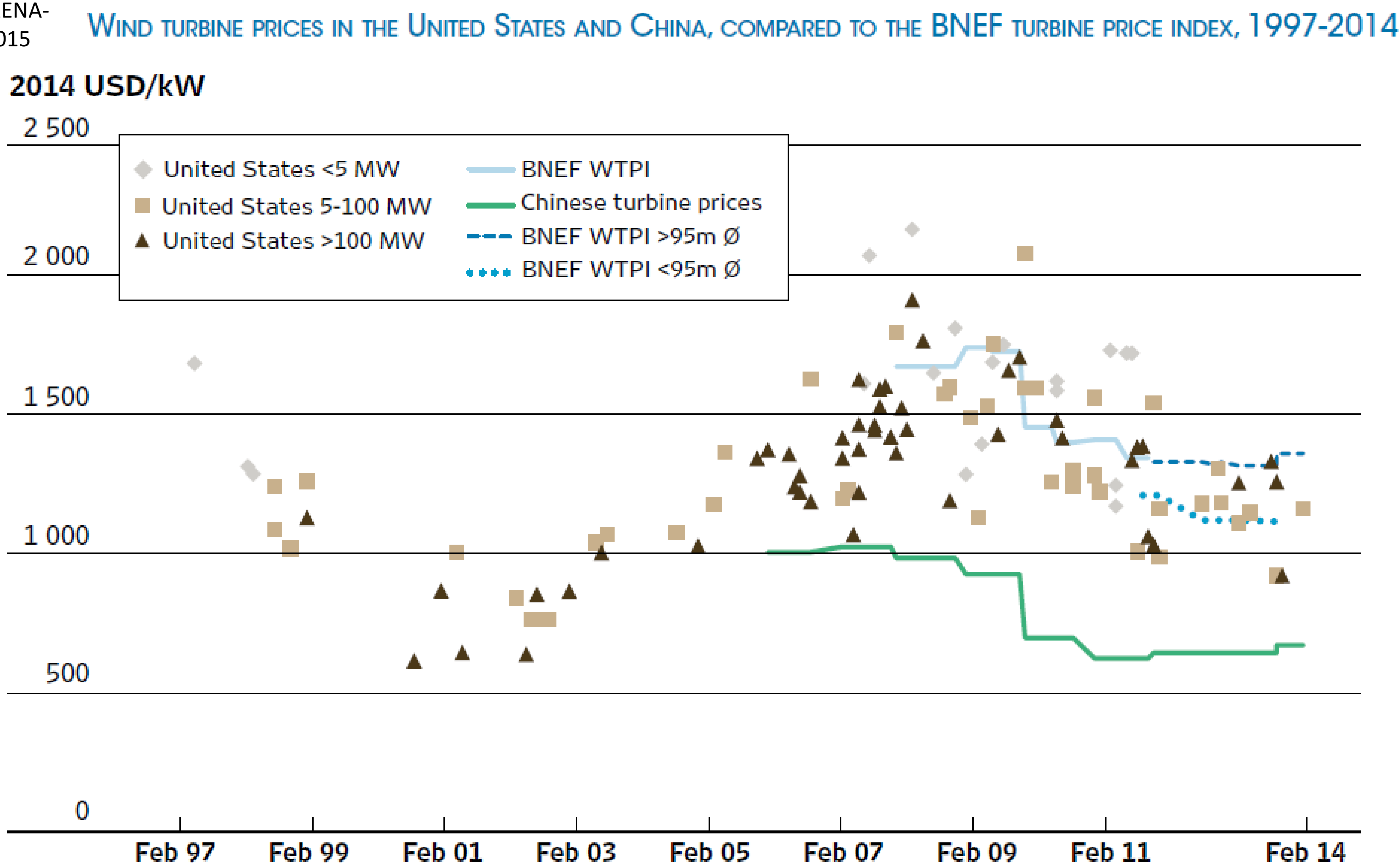
Government subsidy has been the most important lifeline to the continuing development of the renewable energy sector over the last 25 years.

But this situation has started to change and the subsidy is being scaled back to much lower or even to zero.

- Is this reasonable?
- What impact on the renewable energy sector and the wider energy sector will be?
- How will the renewable energy sector be able to continue?
- ....

Journey of Wind Turbine Costs (Prices)

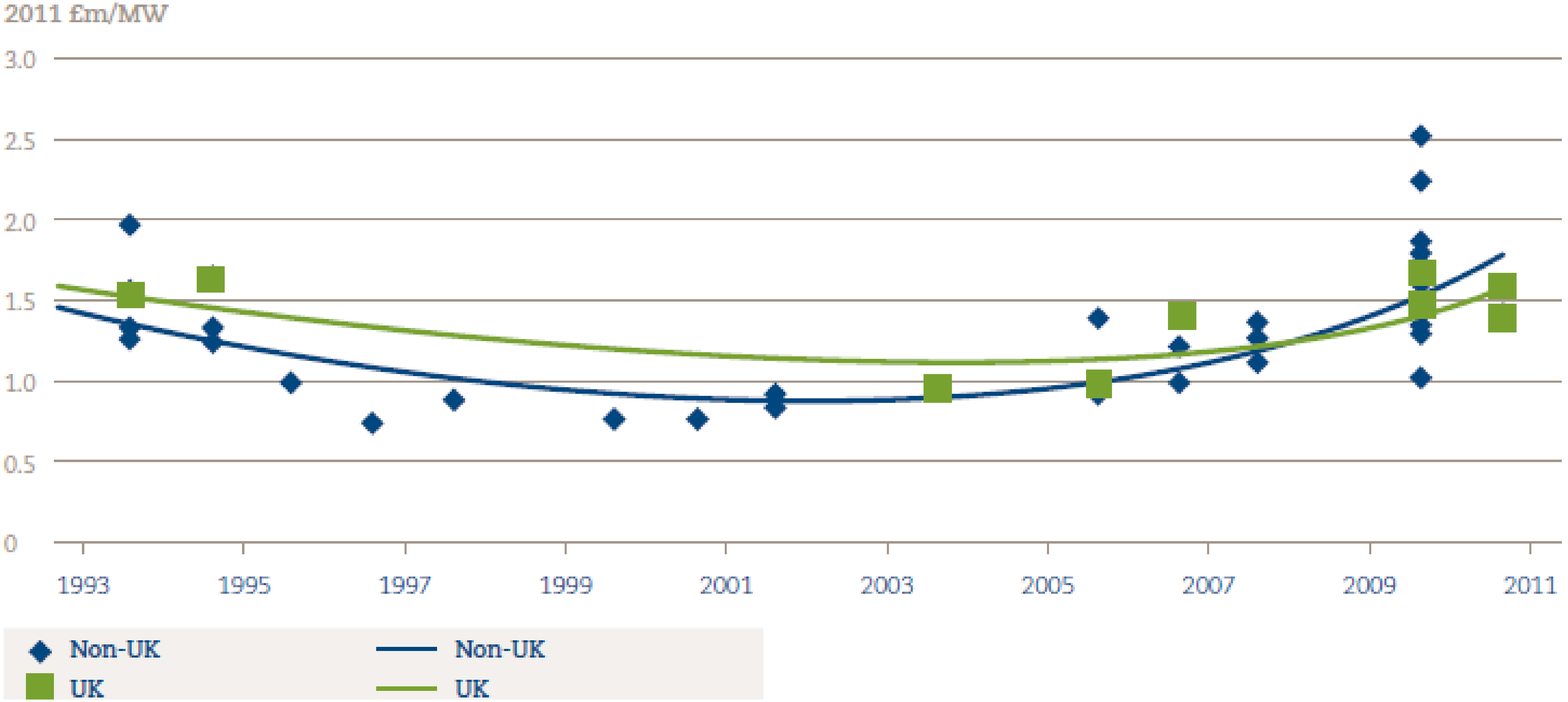
IRENA-2015



Journey of Wind Power Capex (£m/MW)

UKERC 2013 Nov

Range of capital costs of onshore wind 1994 – 2011



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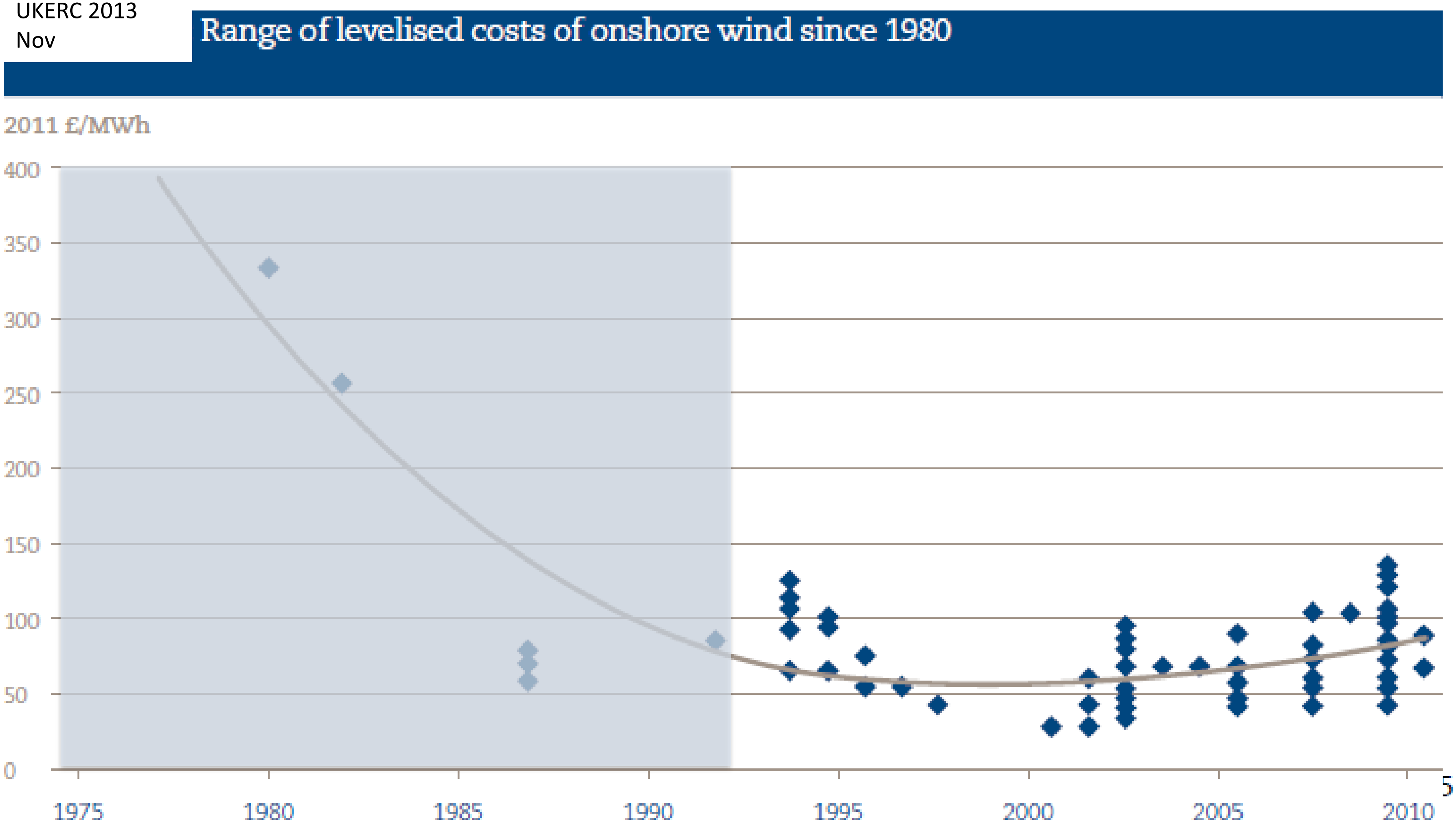
Journey of Wind Power Cost (£/MWh)

UKERC 2013 Nov



Solutions Are Available

The sector seems to accept the emerging reality of low subsidy or even no-subsidy and starts to explore solutions to cope with the life post subsidy.

Technical Approach:

- There are technical ways to reduce Capex and Opex, such as, using T-in grid connection, etc.

Commercial Approach:

- Introducing cheaper wind turbines.
- Rectify the poor/nil interchangeability issue between products from different OEMs which hinders competition to some extent.

Regulatory Approach:

- Exploring ways (such as subsidy-free CfD) to improve project **certainty** and make onshore wind and solar a sector of low risk and low return sector, now that the return without subsidies is no longer high. A reduction of 1 percentile in borrowing rate is worth €6/MWh.
- Reducing cost by overplanting/over-installation, by shortenng development duration, etc.
- Allowing higher tip heights.

A Solution Example

Wind Turbine OEMs have stated that if the limit on wind turbine tip height (of 125m) can be relaxed, wind projects can be made viable without subsidies.

Let us look at two 2MW wind turbines:

Turbine Ta:

- ✓ 80m hub height, 90m blade diameter, Tip height =125m

Turbine Tb:

- ✓ 80m hub height, 110m blade diameter, Tip height =135m

The energy yield difference:

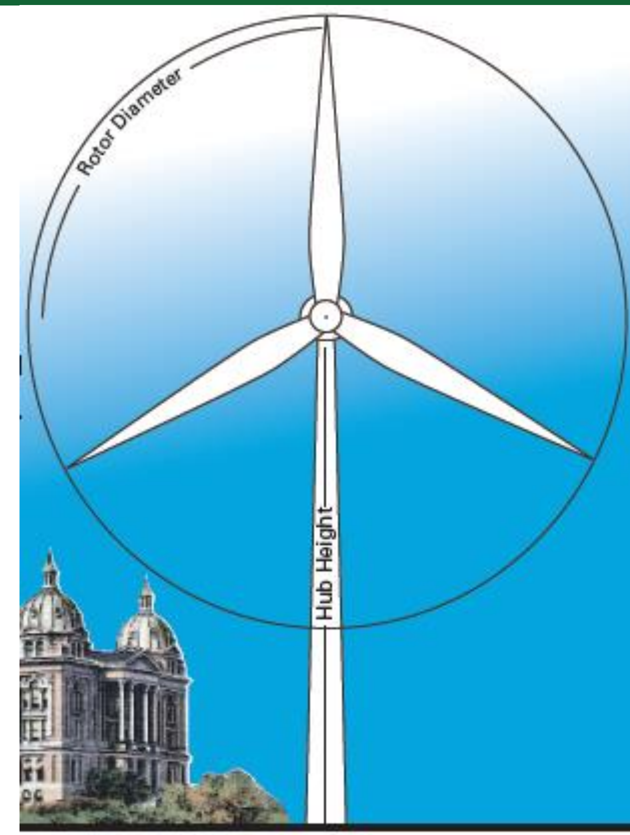
- ✓ Tb - Ta = 1.4 GWh p.a = 24% above Ta

The Capex difference:

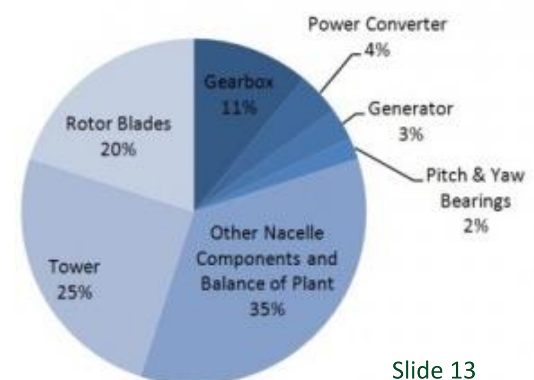
- ✓ Tb - Ta = 10% x 20% x €2m = €40k

(1 year extra energy can pay it off)

(For a slightly windier site: only 18% above Ta energy)



CAPEX cost breakdown for a wind turbine



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Wind/Solar/Battery Colocation

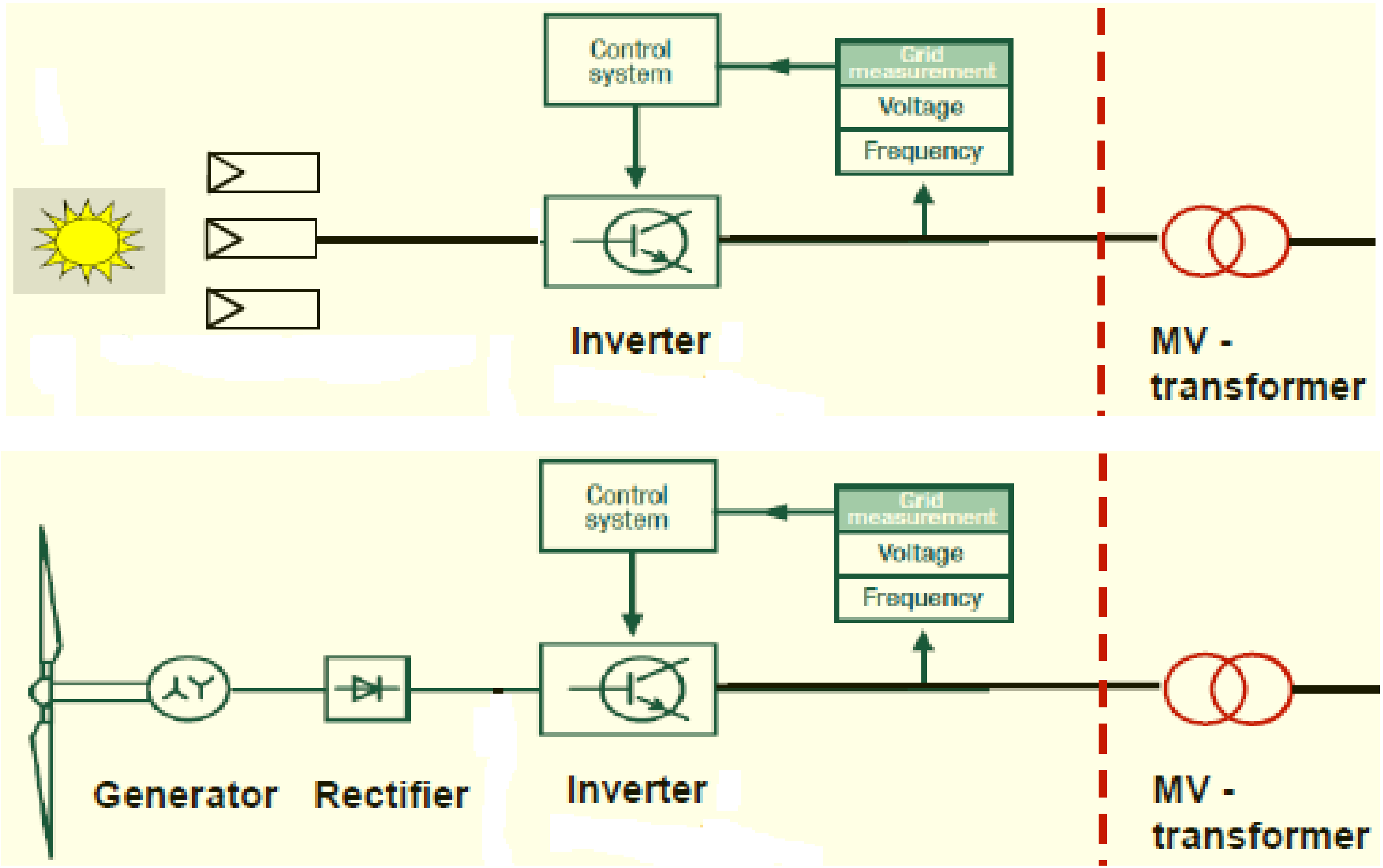
New Approaches:

- Colocation of Mixed Technologies - Future development should have wind/solar/distributed energy storage included at the outset, although not all development will eventually consist of all 3 elements. This would require a change in mindset. Barriers to enable hybrid plants should be removed.

New Challenges and Issues:

- Colocation is fairly new and network companies seem a little nervous.
- In spite of the fact that developers are committed to limiting any instantaneous export to 100% MEC, DNOs may still want to cap over-installation to 120% MEC.
- It would be practicable and more efficient to allow an over-installation to: 150% of MEC for solar technology; and 120% of MEC for wind technology, as the two cases would have the same annual yield and the same impact on capacity factors.
- Other regulatory barriers:
  - will each of the collocated wind/solar/ES be a dispatchable unit?
  - do the market operation codes allow solar/wind to charge battery unit if they are regarded separate units?
  - If not separate units, how can one unit be used for energy but ES for services?

Grid Connected Solar versus Wind



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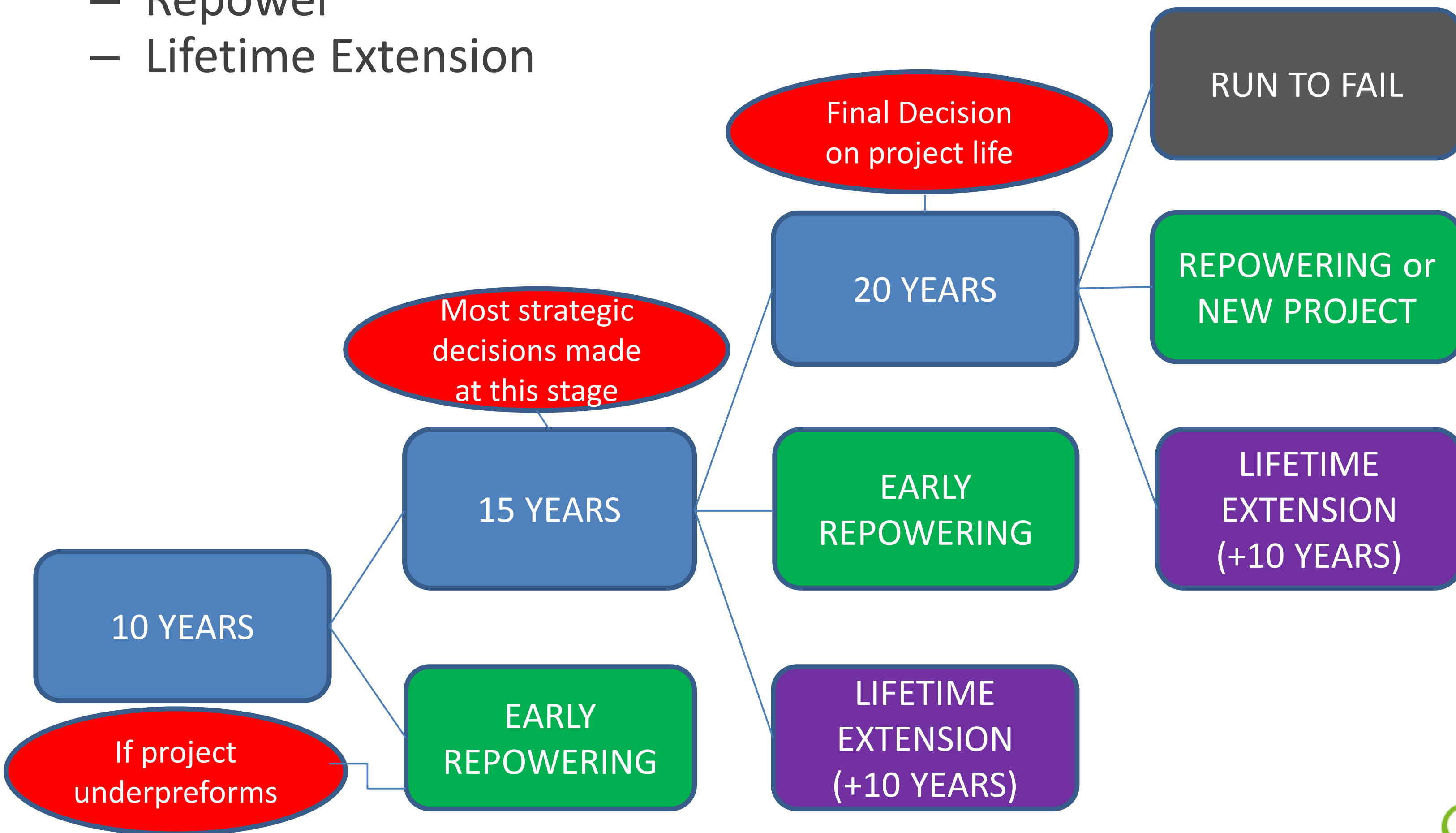
Wind RePowering - a Second Spring for Wind

- **Lack of new sites available for greenfield development**
  - Most good sites have already been used up
  - Reusing original sites is a most sensible option as turbines are part of that landscape
- **Lifetime of onsite wind data collected**
  - Greater energy yield certainty for investment case
- **Decrease in productivity and increase in O&M costs on older projects**
  - Rule of thumb that wind turbines last 20 years however evidence has shown that deployment of machines in early 90s was done without degree of siting expertise available today
- **Significant gain in yield**
  - Taller turbines are exposed to wind speeds that are increasing exponentially. Power available increases eight fold for every doubling in wind speed.
  - New wind turbines have increased efficiency and are technically more advanced.

RePowering and Timing Decisions

- Choices facing older projects
  - Run to fail
  - Repower
  - Lifetime Extension



Size of the RePowering Opportunities

Commercial Fleet Age in ROI

- 228 wind farms are operating
- At the end of 2015 there were a total installed capacity of 3,377MW
- 20 wind farms (143.3MW) are 15 years or older in 2016

- 227 operating wind farms (3,377MW) at start of 2017
- 51 wind farms (665.5MW) will be 15 years or older in 2020

Commercial Fleet Age in Europe

- 7GW (6.8%) of onshore wind capacity is older than 15 years.
- By 2020 this number will rise to 38GW (22%)

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Demand Side Response and Participation

- Demand side response (DSR) is a power system management tool which has been used passively for a century. Since 1990 DSR has become slightly more active but mainly involving major power users such as steel plants.

- Since 2010, in particular since 2015, DSR has attracted unprecedented attention and interest, mainly for two reasons:
  a) More and more electricity generation from renewable energy comes on line while more and more conventional thermal power generation is retiring.
  b) The wide spread of internet has made remote control of mini load (say 1kW) practically and economically achievable.

- The relevance of DSR to the industry is twofold:
  a) DSR could bring or become a new business within the industry; and
  b) DSR can have tangible impact on the viability of other energy business streams, such as energy storage.

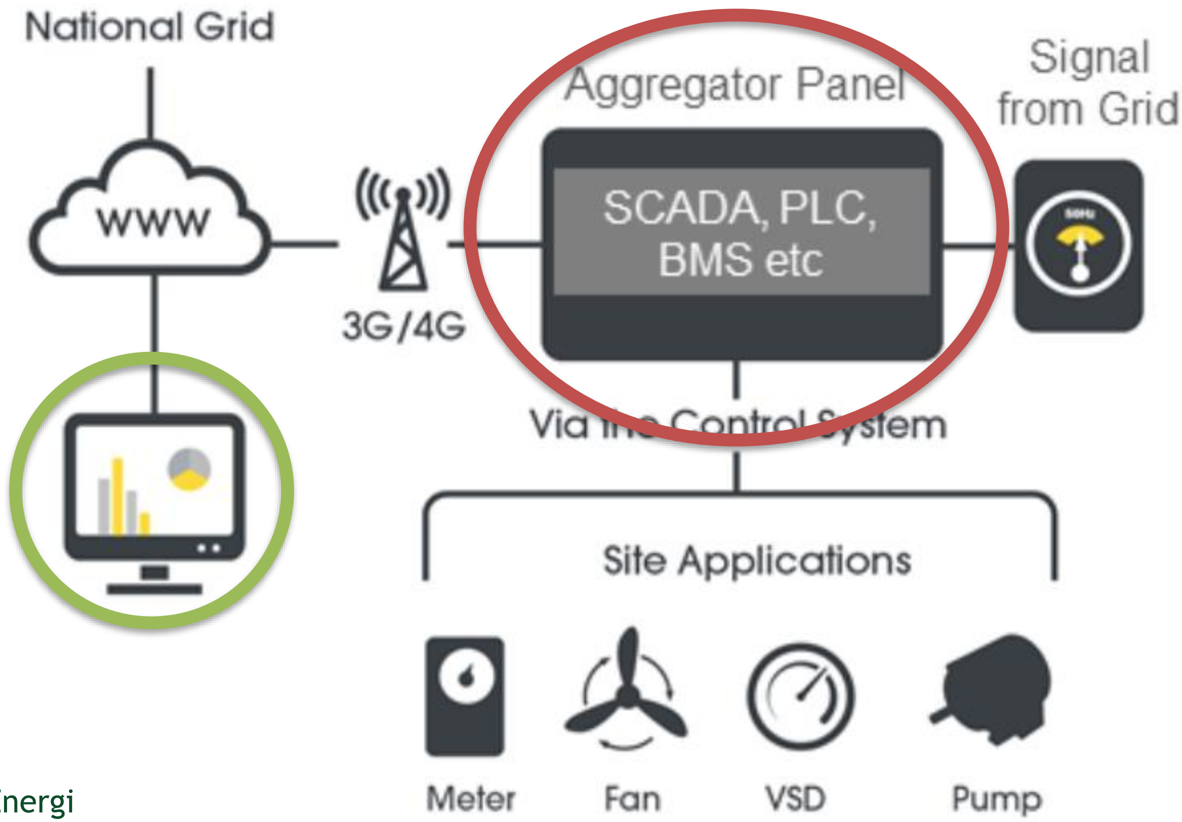
- A good example of DSR is for fridges or air conditioning equipment (and alike) to switch on/off based on grid frequency deviation signal, whose interruption for a few minutes does not cause any issues but can give a much needed support to the grid operation.

How Does the DSR Work?

- An aggregator (basically an IT company) does all the work.
- TSO pays all the money (to Aggregator). The Aggregator pays the DSR owner.
- What does the Aggregator do? They install and run the following:

a) a control unit (mini computer), see the red circle below

b) an application software on clients' PC for clients to view if they want, see the green clr



Source: Open Energi

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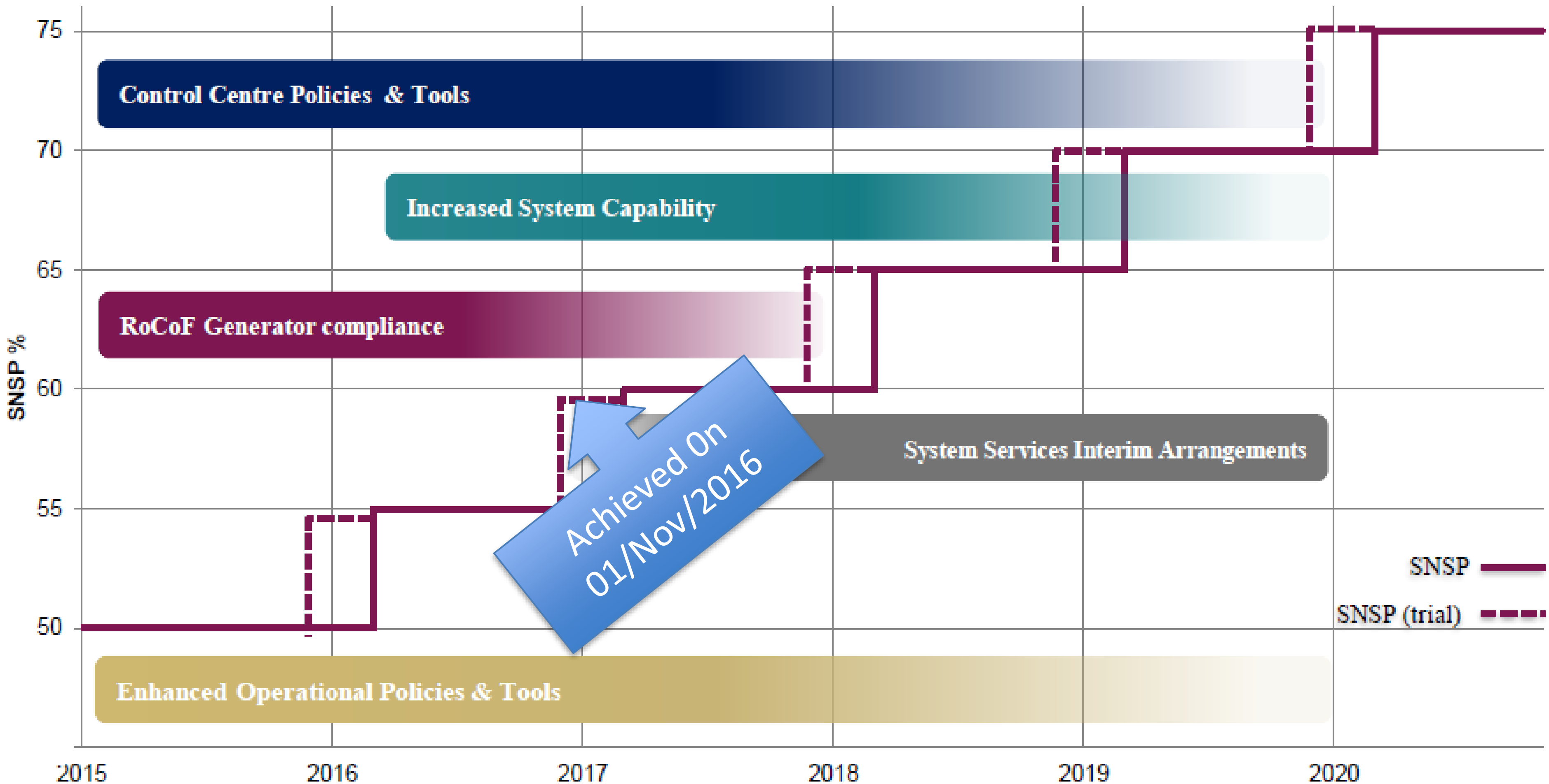
System Services & High Level RE Penetration

- Eirgrid/SONI has set a great example in exploring system services
- GB National Grid seems to follow Eirgrid/SONI to pay more attention to the other 'use' of RoCoF.
- Within the Irish new set of system services (DS3), inertia has become an ancillary services, for the first time.
- There would be a need to further develop the usefulness of the synthetic inertia if a non-synchronous generator can be made to be able to feel any system disturbance and react spontaneously rather than to be instructed by an external instruction signal as a result of translation of a system disturbance.
  - *A research topic: can all frequency disturbances be reflected as a voltage deviation? Any proofs?*

SNSP Can Be Substantially Increased



Source: Eirgrid

SNSP = System Non-Synchronous Penetration

One observation: In the chart above, most measures have been considered but energy storage does not seem to be listed explicitly.

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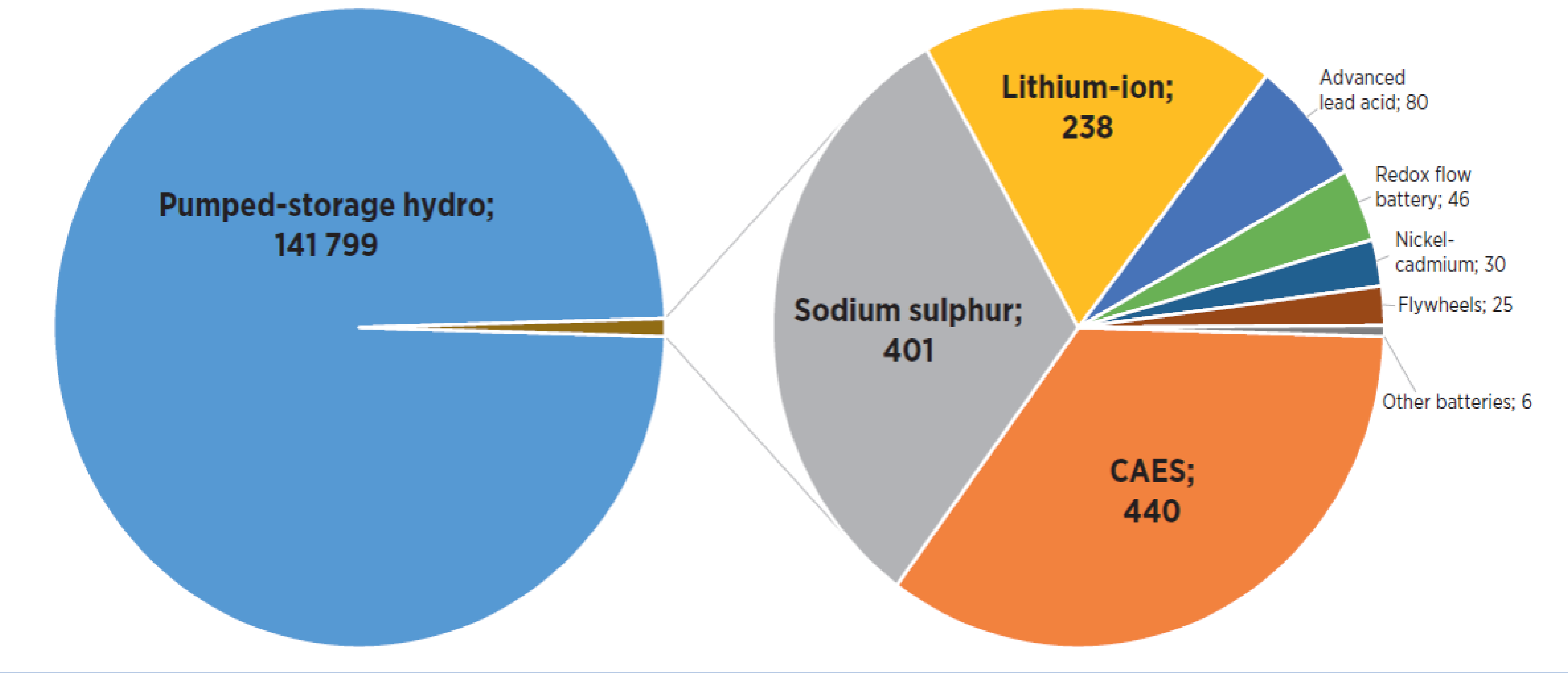
Energy Storage – Practical & Effective



* *The data has been verified and augmented with data from the DOE global database for capacity installed to date (lithium-ion, vanadium redox flow, zinc bromine redox flow and nickel-cadmium) for operational projects.*

Source: Navigant Research (Dehamna, Eller & Embury, 2014) for installed battery capacity by type, and GlobalData (2015) for the pumped-storage hydroelectricity capacity.

Issues and Challenges to Energy Storage

Regulatory:

- what an ES is? Not a gen, not a demand, but a mixture of both!
- will an ES be regulated or non regulated asset or both?
- what licence will an ES project require?
- how an ES should be remunerated? For its power, energy, services, or more?
- what an ES should pay for using the networks?
- How will an ES project be permitted through the planning system?

Technical:

- CAES – Adiabatic without sacrificing Round Trip Efficiency
- CAES – Alternative configuration which there are two trains
- Battery – number of cycles, life span, localisation and H.S.E
- Large scale centrally dispatched energy storage vs distributed energy storage

Commercial:

- Cost reduction
- Market trading conditions

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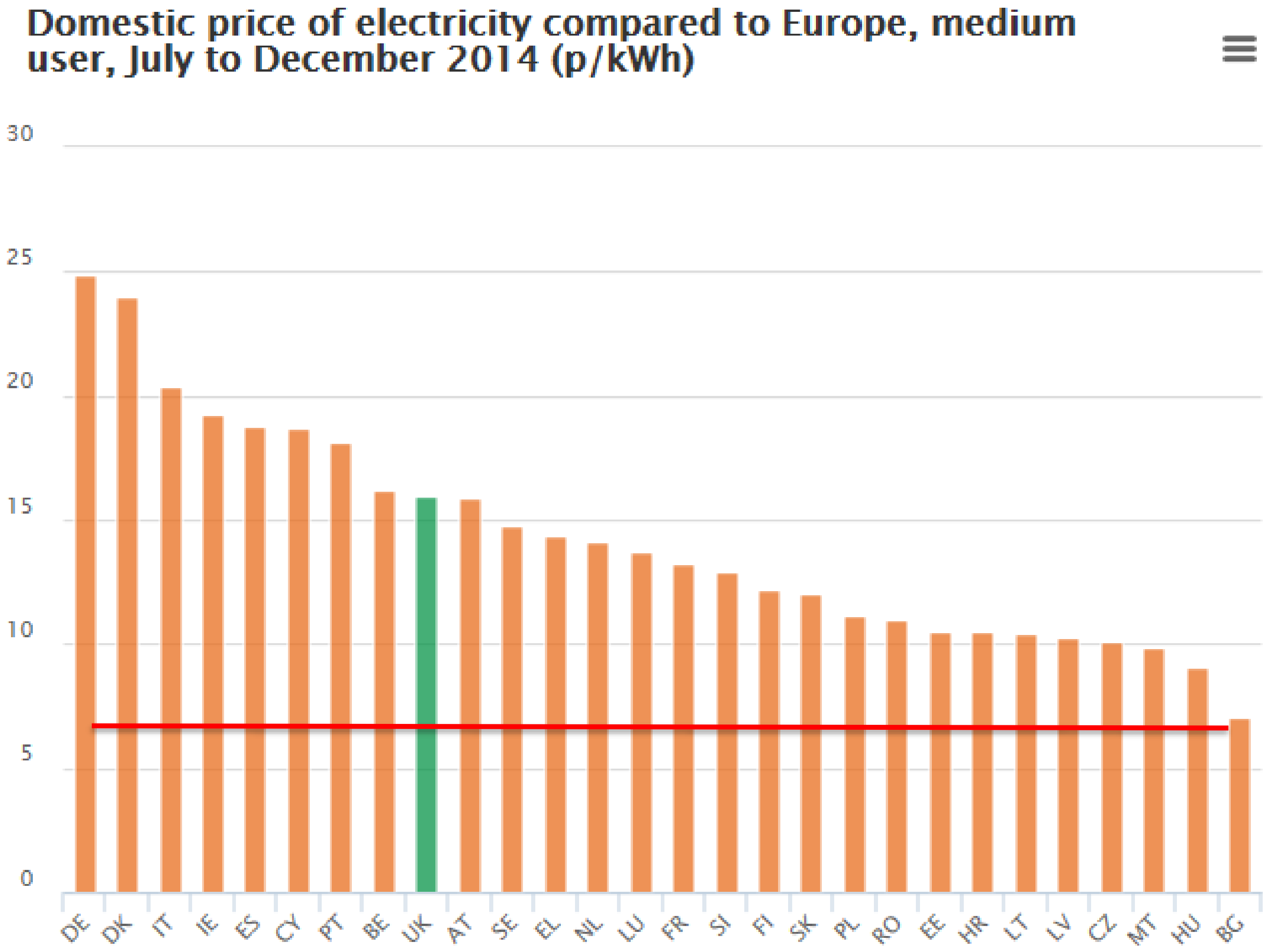
Behind the Meter Trading & Energy Uber

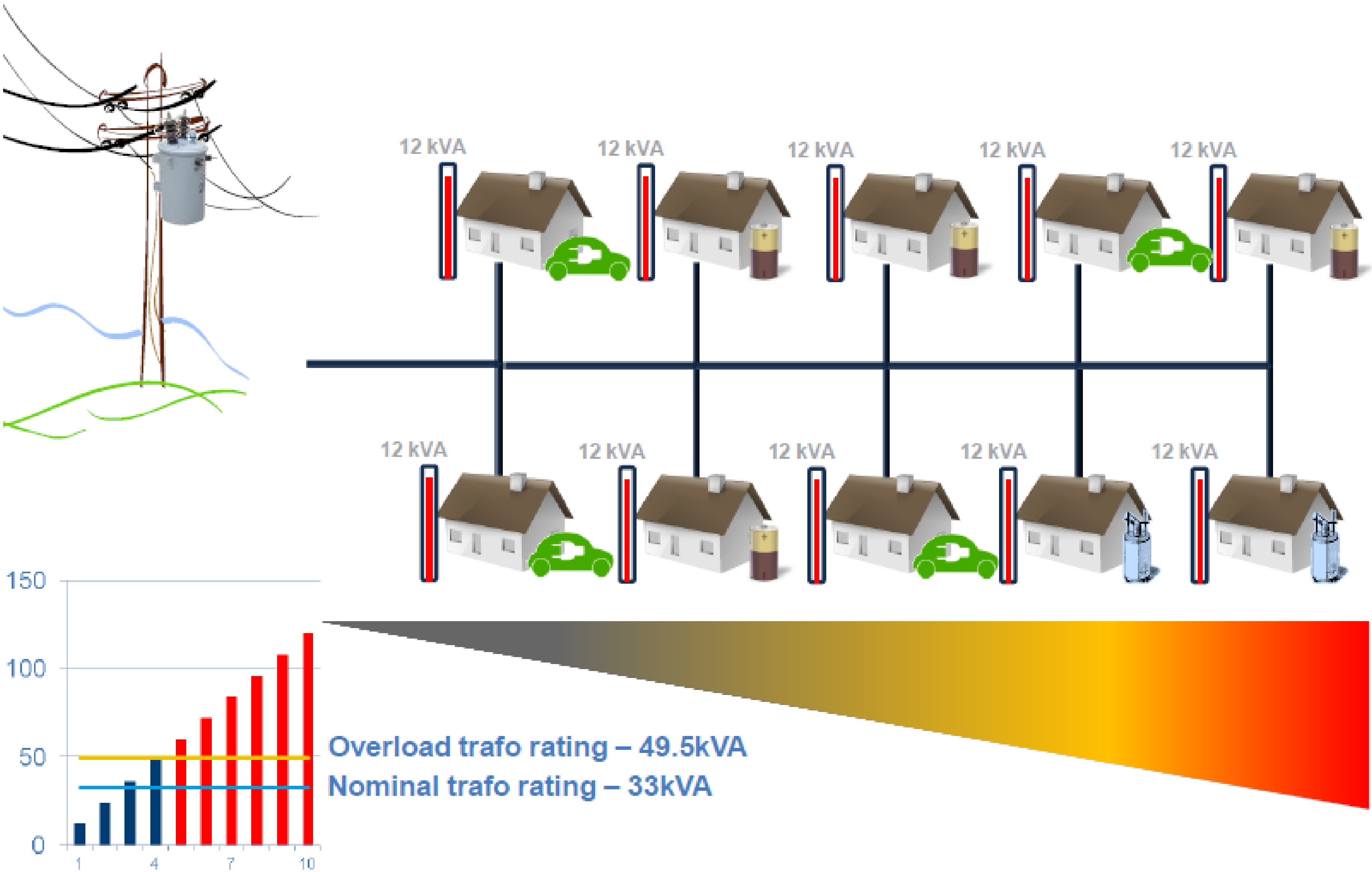


The wholesale power price is only 5 p/kWh (the red line).

The margin available for local generators to supply locally is attractive. In addition, the distributed generation is more advanced than ever before.

Source: Ofgem, UK

A Physical Barrier Requiring Attention



Source: ESB

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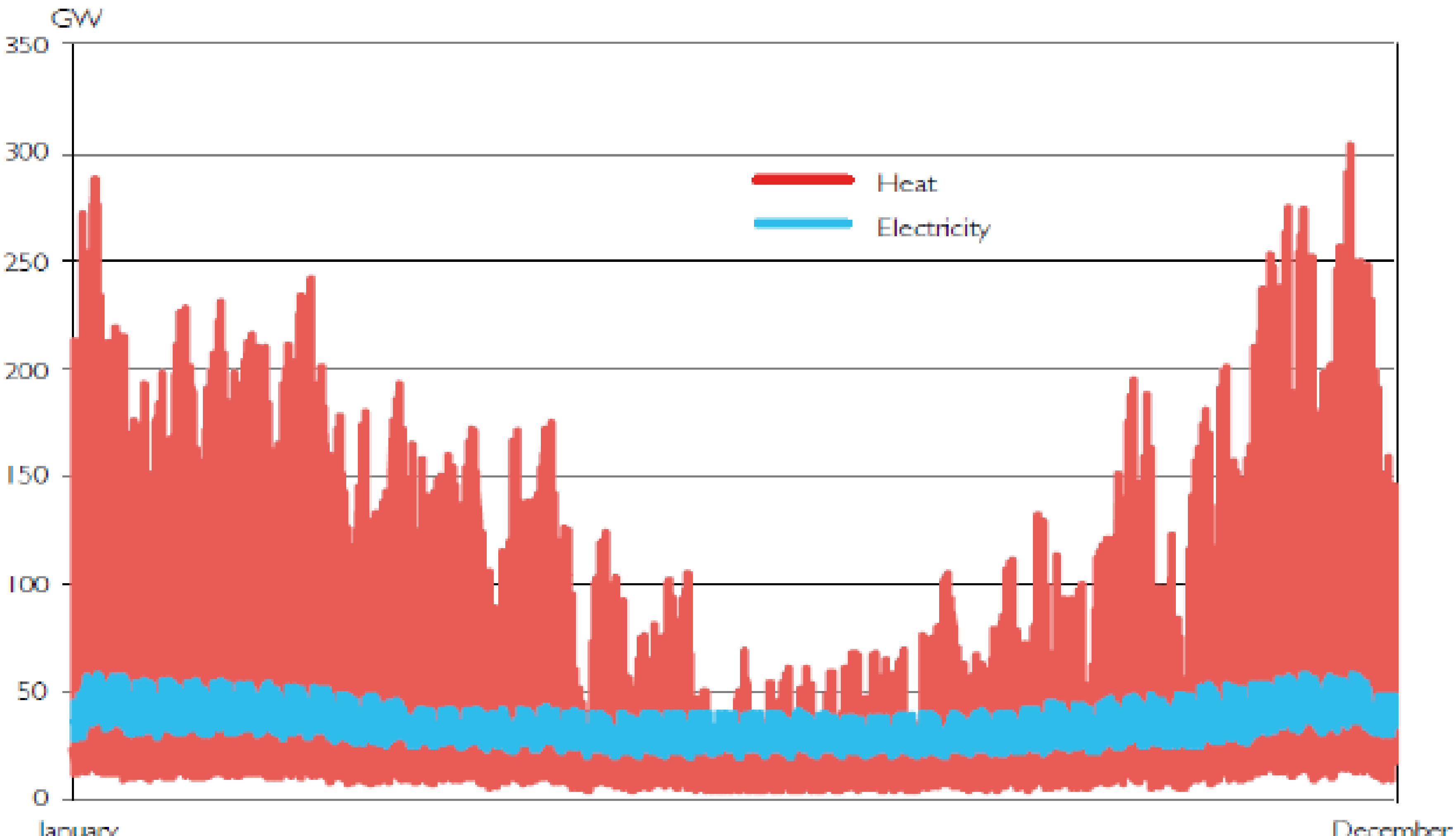
Beyond Electricity - Heat Is important

Comparison of Heat and Electricity Demand Across a Full Year (2010) Source (UK Government)



Beyond Electricity - Heat Is important

Use GB as an example

- Almost half (46%) of the final energy consumed in GB is used to provide heat, around 700 TWh/year (4/5 of that is currently met with natural gas)
- Heat is responsible for around a third of GB's greenhouse gas emissions.

On this basis, the current heat resurgence would not be surprising - Correct recognition of the impact of heat element on the energy sector including energy storage, renewable energy penetration and overall cost of energy would be essential.

In particular, **heat can be an important means of electricity storage (storing electricity as heat and used as heat)**

Concluding Remarks

The energy systems across the world) are changing fast, reflected in

- Reduction in subsidy and emergence of merchant energy & community energy
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The essence of these changes may be summed up in three words:

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