Coping With Variability in *Renewables-Intensive* Electricity Systems

Catalan Society of Engineers, Barcelona

September 2010

Godfrey Boyle

Professor of Renewable Energy

Energy & Environment Research Unit

The Open University, UK

- ***Electricity Grid is an Integrated Supply-Demand <u>System</u>***
- ***Supply & Demand Vary Hourly, Daily & Seasonally***
- ***Multiple Supplies & Multiple Demands, all Inter-connected & Managed in Real Time***
- ***Need for <u>Systems Approach</u> in Considering Feasibility of Renewables-Intensive Futures***

Overview & Some Questions

- Is the Variability of (some) renewables a major problem?
- Terminology: *Intermittency* or *Variability*?
- How do Electricity Demand & Supply Vary *at Present*?
- How Much Extra 'Backup'/Storage Capacity is Required?
- How Much Will Extra Backup *Cost*?
- What Role is there for *Forecasting*?
- What is the Role of Demand Management?
- Can Spatial *Dispersal* Reduce Variability?
- Supergrids: European & Intercontinental?

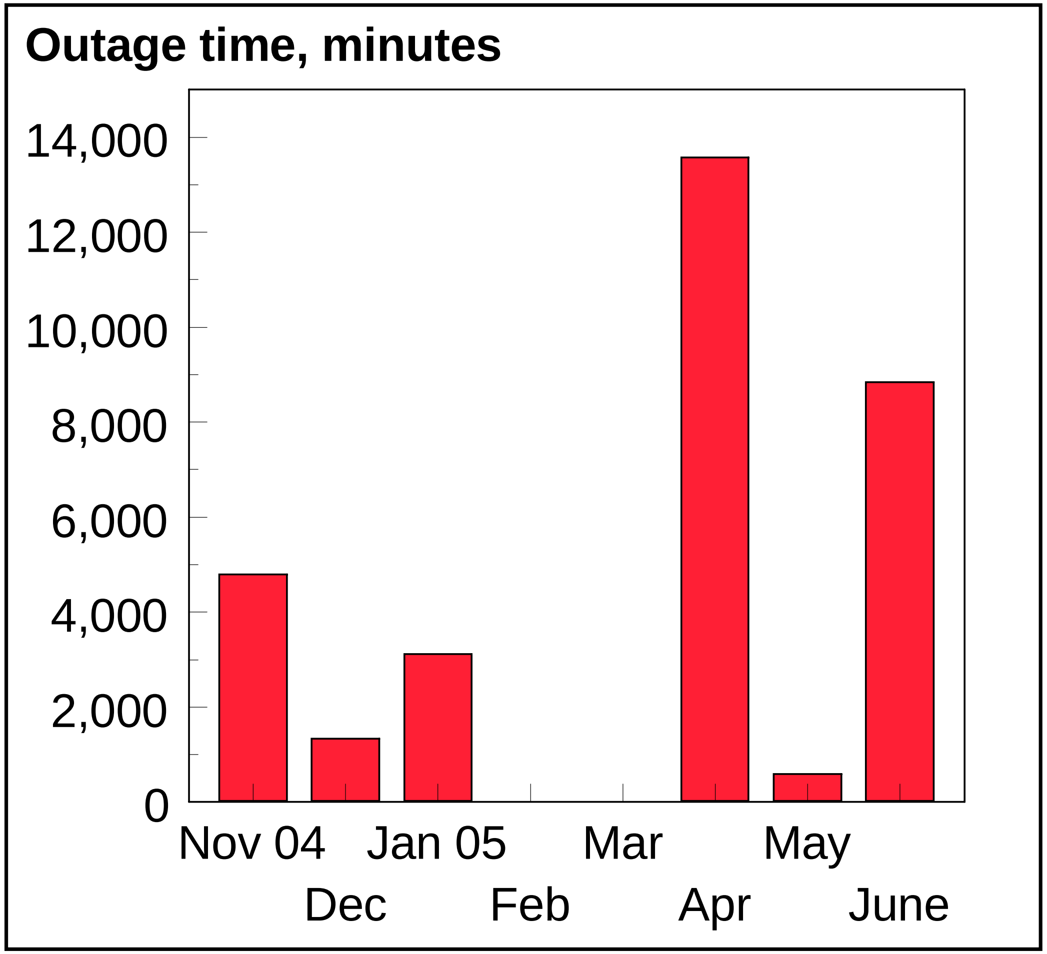
Intermittency or *Variability?*

- *Conventional* Power Plants all experience sudden unplanned 'outages'
- Utilities expect conventional large plant to be out of action unexpectedly for c. 170 h/yr (c.f. planned maintenance c. 600h/yr)

  e.g. UK-France Cross-Channel High Voltage DC Link, 2004-5 =>>

  (Source: D Millborrow/UTCE)

  This necessitates large backup plant to cover such 'outages'
- So changes in *conventional* plant output are best described as *intermittent*.
- Output of wind & many other renewables is best described as *variable* - variations are relatively slow & statistically predictable – at regional & national level.
- Some renewables e.g. biofuels, geothermal give *constant* output.

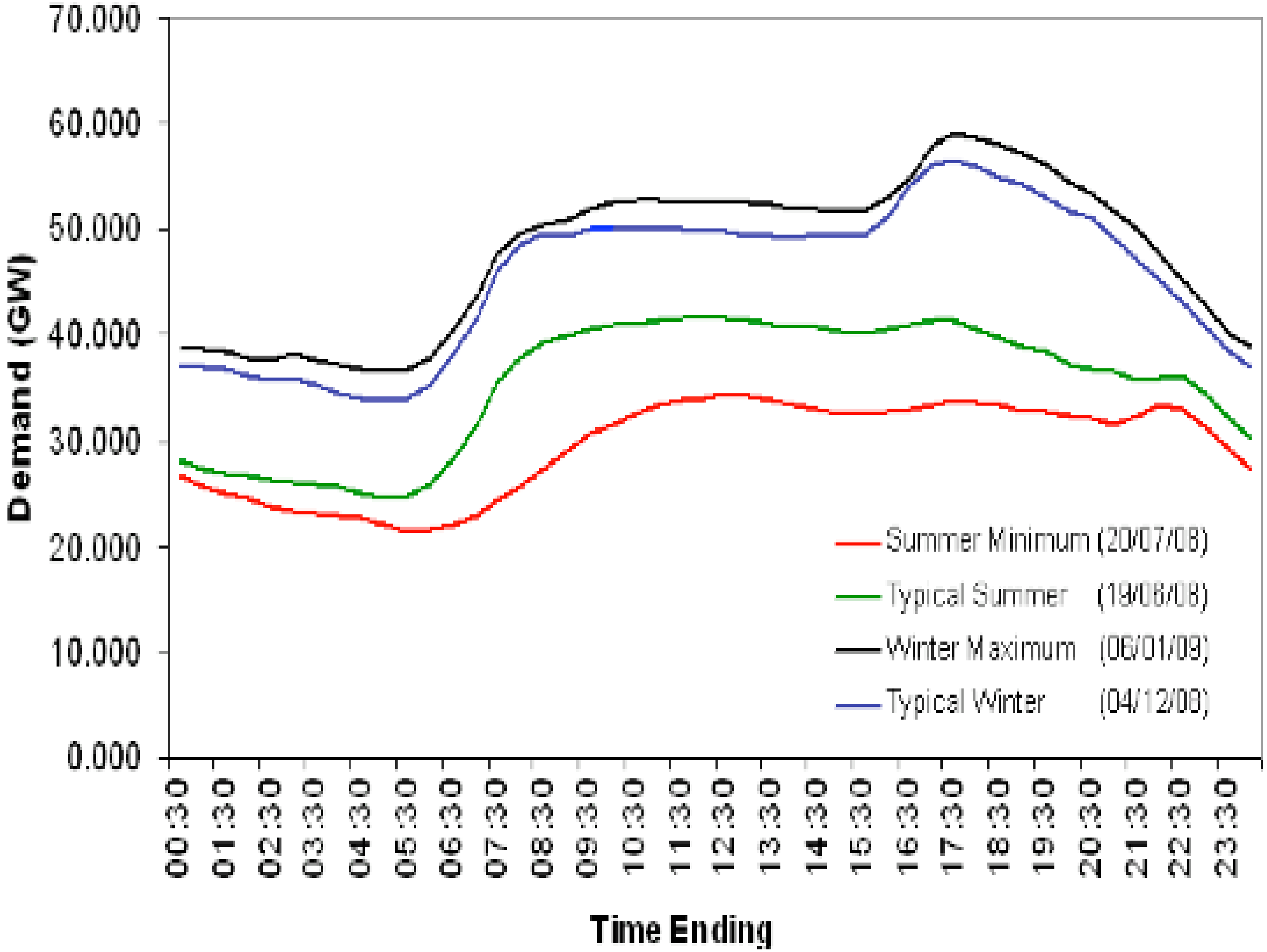


Electricity *Demand* in UK: Magnitude & Variability

- UK Daily and Seasonal Demand Variations:
- Coldest Winter day:
  maximum c.59 GW
  minimum c. 33 GW
- Warmest Summer day:
  maximum c. 33 GW
  minimum c. 21 GW.

(Data: National Grid Transco 2008-9)

Figure 2.2 - GB Summer and Winter Daily Demand Profiles in 2008/09

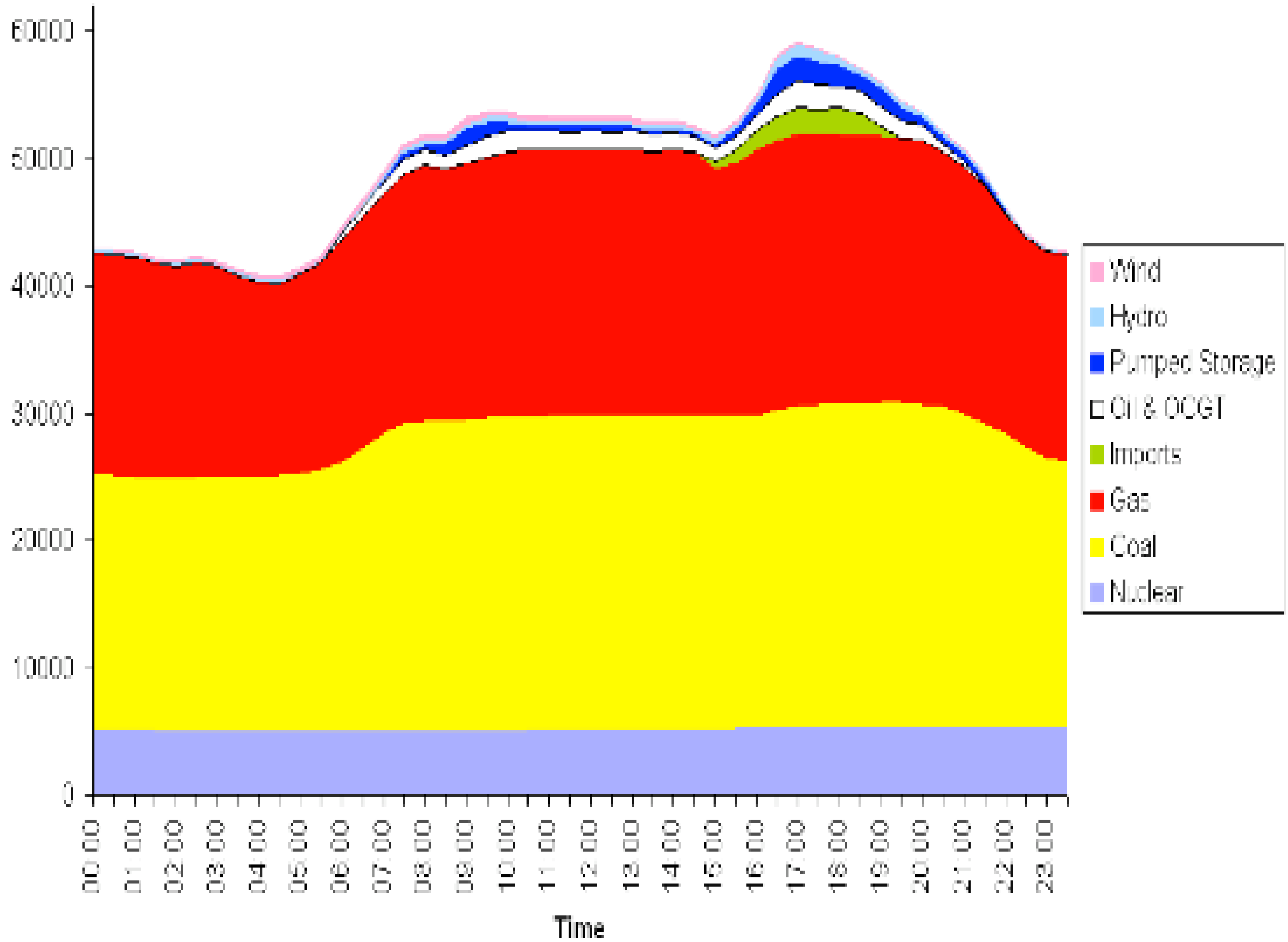


How Power *Supplies* Follow Daily Variations in *Demand* (UK Winter)

- In UK “Base Load” supplied by Nuclear, Combined Cycle Gas Turbines & Large Coal Plant
- Other power plant contributions vary in response to demand:
  - Imports
  - Pumped storage
  - Hydro
  - Wind

(Data: NGT Transco 2008-9)

Figure 7.1 (a) - Maximum Winter Demand: Tuesday 06 Jan 2009



How Much *Backup/Storage* in a Renewables-Intensive Future?

- For up to c.10-20% *wind* penetration on UK Grid, little/no additional backup required – it already exists on system

  (UK Energy Research Centre Report 2006)
- For higher % penetrations, BACKUP options include:
  - Open Cycle Gas Turbines (OCGT) (fossil or *biofuelled*)
  - Standby diesels (fossil or *biofuelled*)
  - Cogeneration (CHP) plant (fossil or *biofuelled*) with *heat* storage

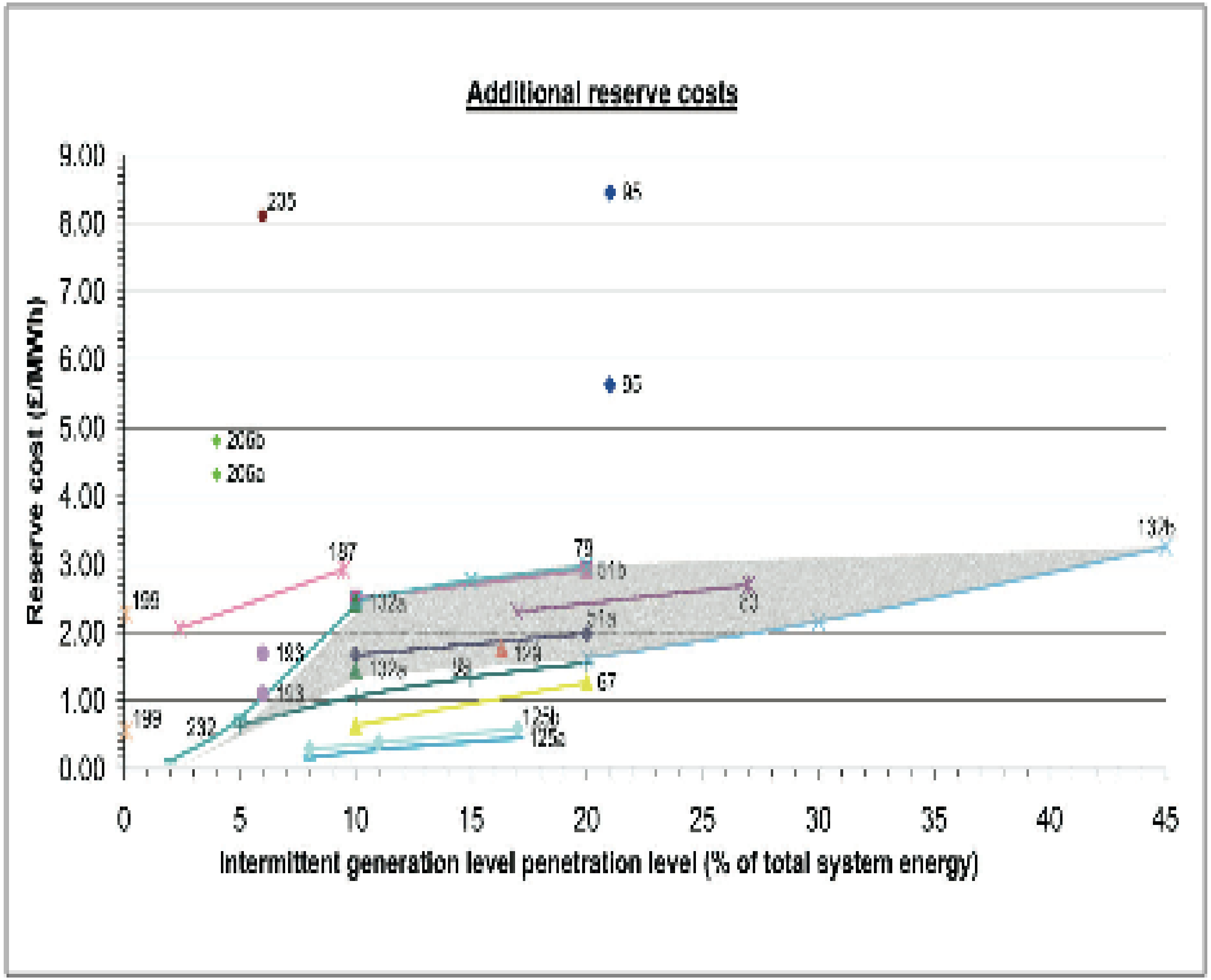
  STORAGE OPTIONS:
  - Pumped hydro storage
  - Compressed air storage
  - Flow Batteries
  - Batteries of Electric Vehicles

Cost of Extra Backup?

- For c.10-20% UK wind electricity, backup costs c.£2.5-3.0/MWh
- For 20-45% of UK wind electricity, backup costs c.£3-3.5/MWh

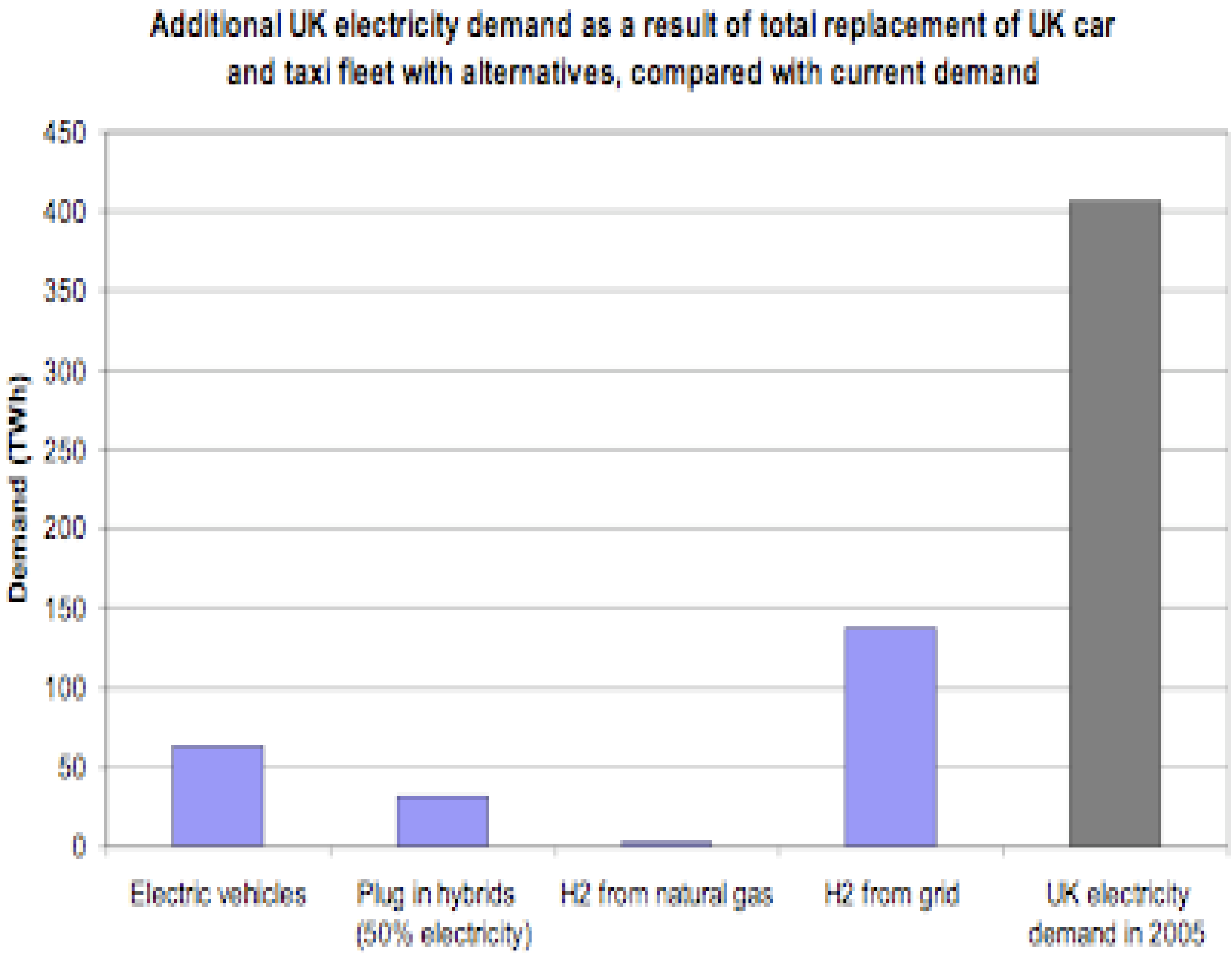
  c. 5% of UK Elec.costs

(UKERC Report 2006)



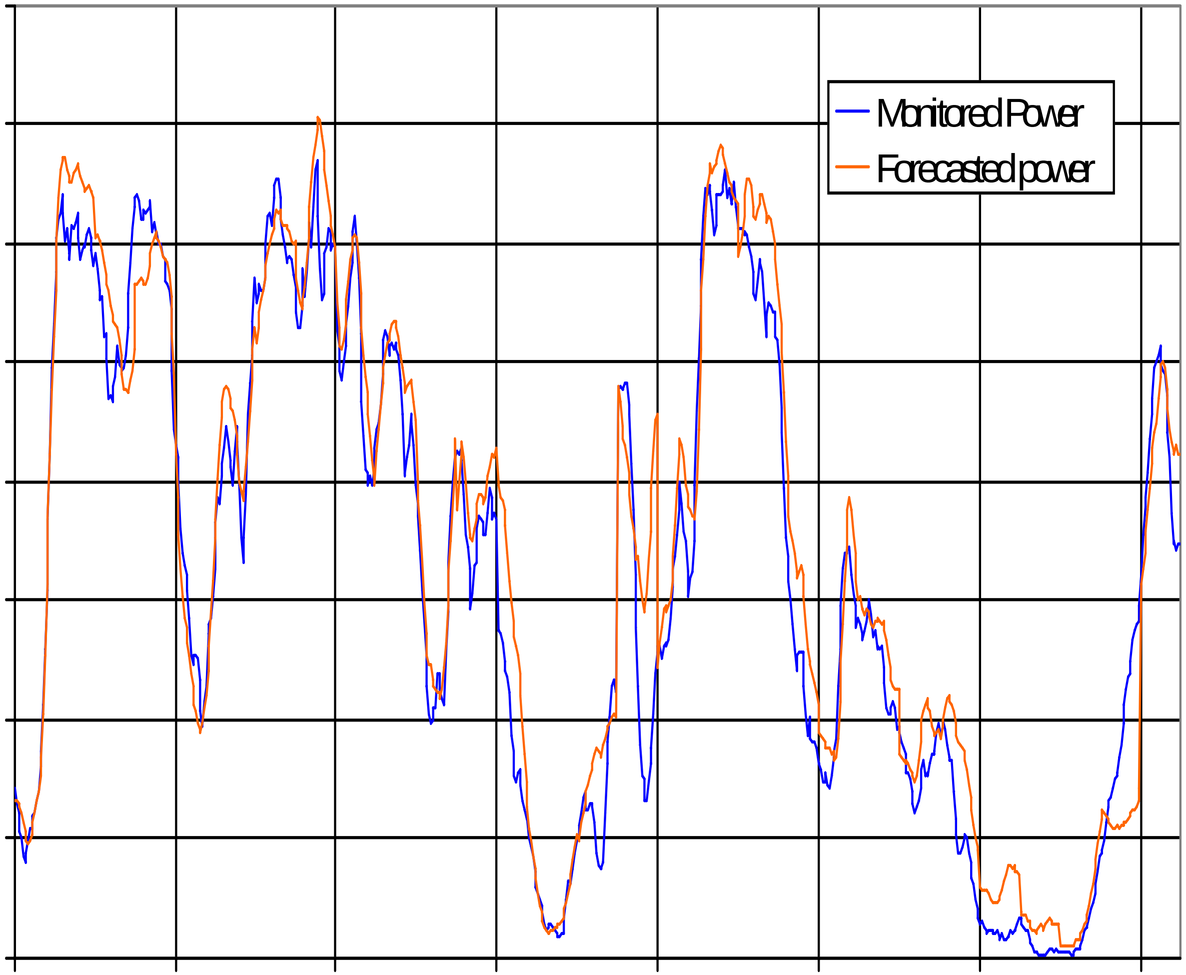
Storage in Electric Vehicles & Plug-in Hybrids – Additional Demand

UK Business Dept Renewables Consultation 2008
"..widespread adoption of electric vehicles could significantly increase demand for electricity.. estimated at around a **16% increase** (approx 64 TWh) if all 26 million of the UK's passenger cars were electrically powered, around 8% (32 TWh) if plug-in hybrids were adopted and around 34% (138 TWh) if the car fleet was converted to vehicles using hydrogen produced from grid electricity."
Figure Ref: E4 Tech 2007



Wind Power *Forecasting* Facilitates Backup & Integration

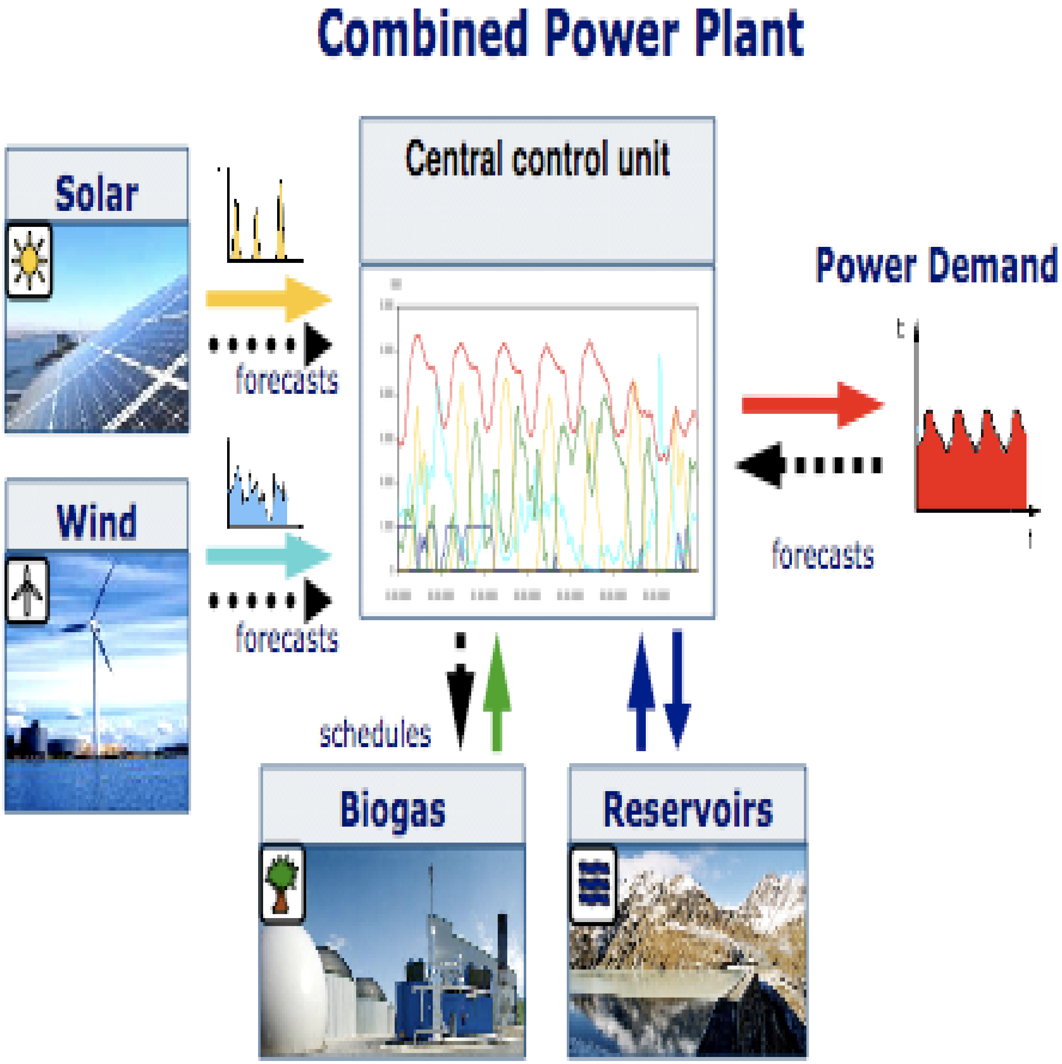
- **Main Approaches:**
- *Start with numerical weather prediction (NWP) model, then:*
- Physical approach, based on physical processes
- Statistical approach: analysis of past time series
- Learning approach: using artificial neural networks
- Use a combination of these 3 approaches:
- Day ahead forecast for Germany =>>



(Lange et al, ISET, Kassel)

Germany's 1:10,000 Scale Renewable Electricity System

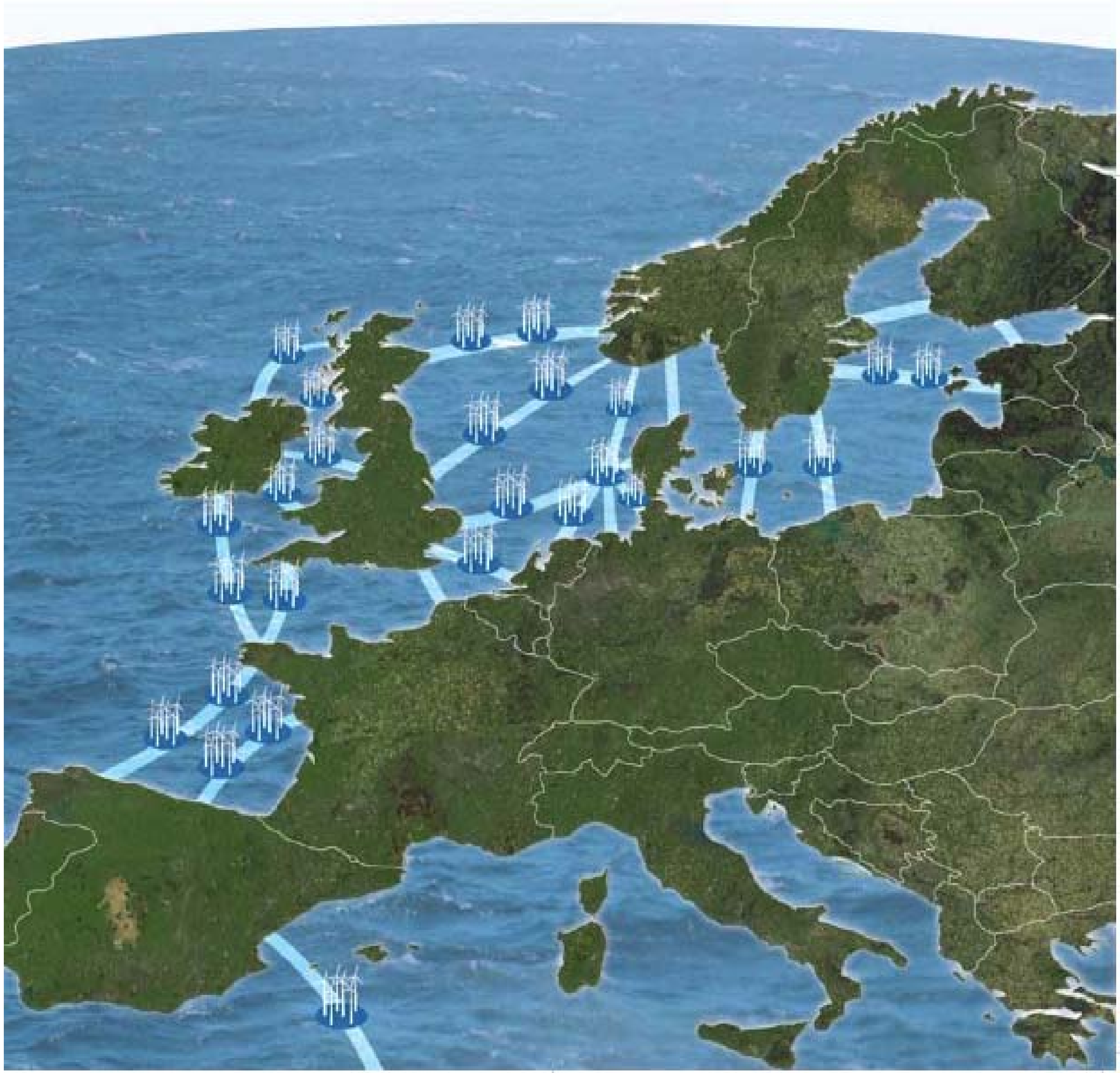
Demonstrates Successful Integration of Wind, Solar PV, Hydro & Biogas



Continent-Wide Dispersion: The European Supergrid

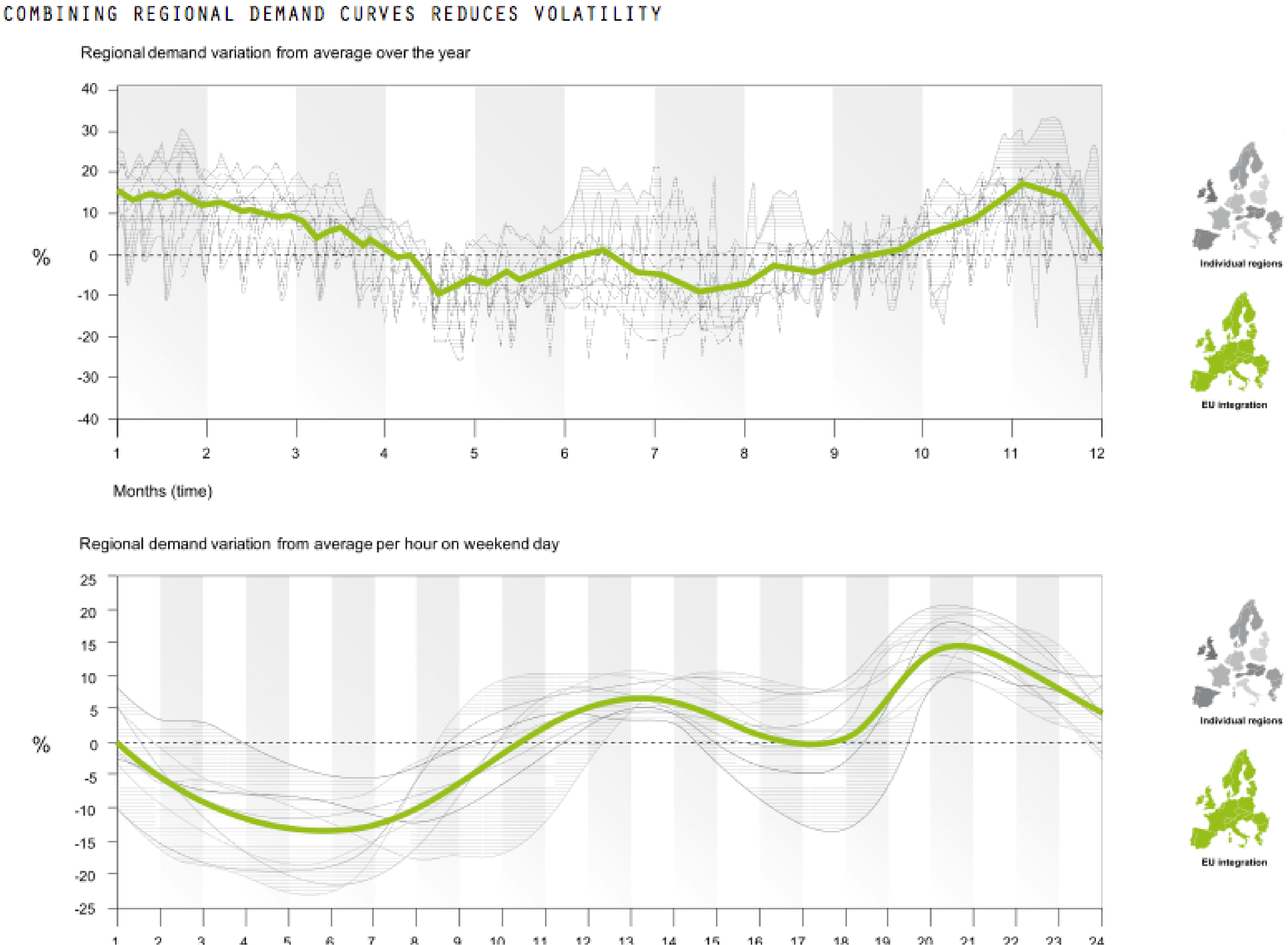
Proposal to link Offshore Wind Farms across Europe

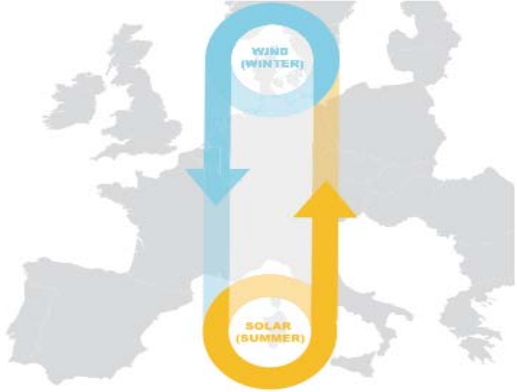
- Endorsed by EU
- First projects starting in North Sea now



ECF *Roadmap 2050*: Combining Regional Demands Reduces Volatility

European Climate Foundation Report 2010: ***Roadmap 2050: A Practical Guide to a Prosperous Low Carbon Europe.***

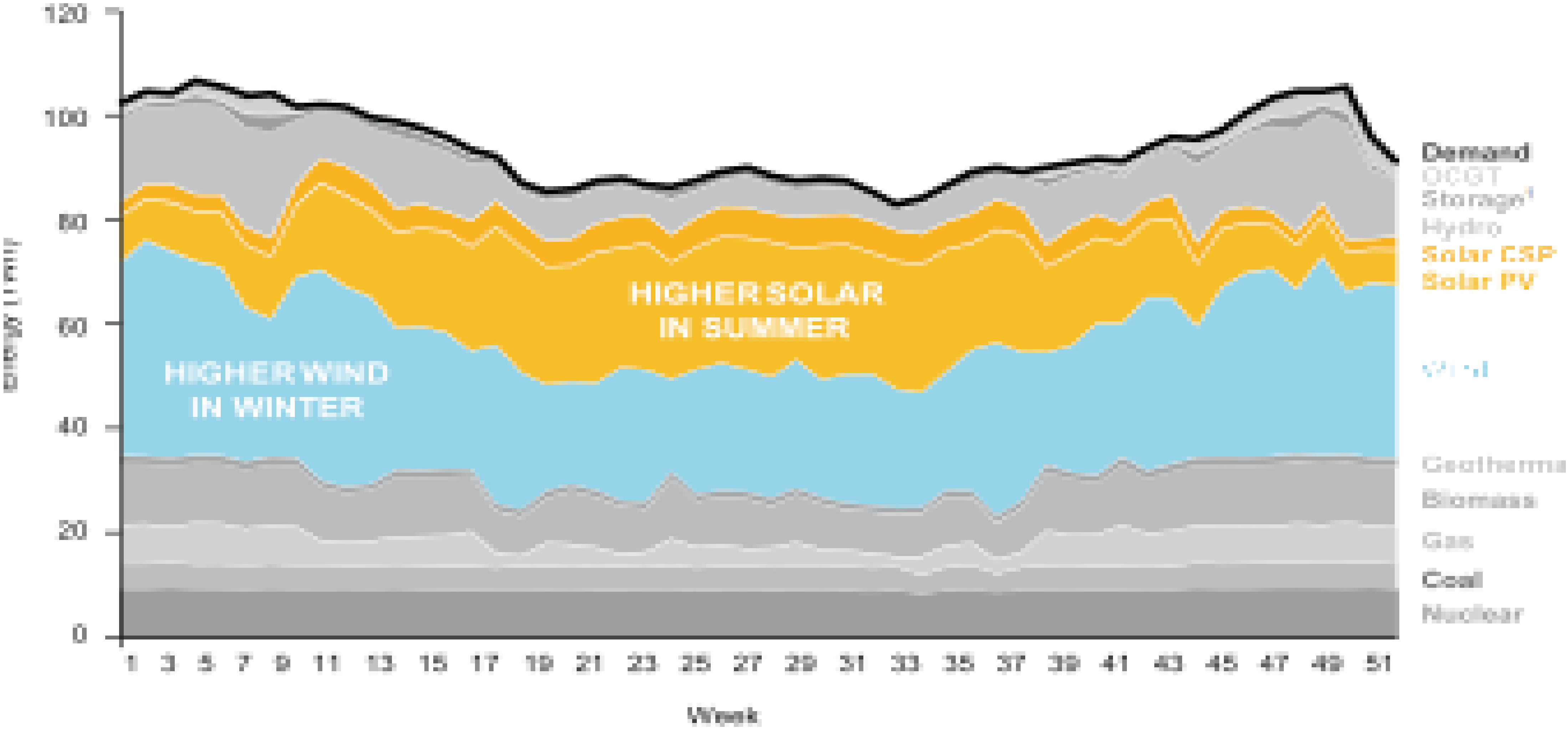




ECF *Roadmap 2050*

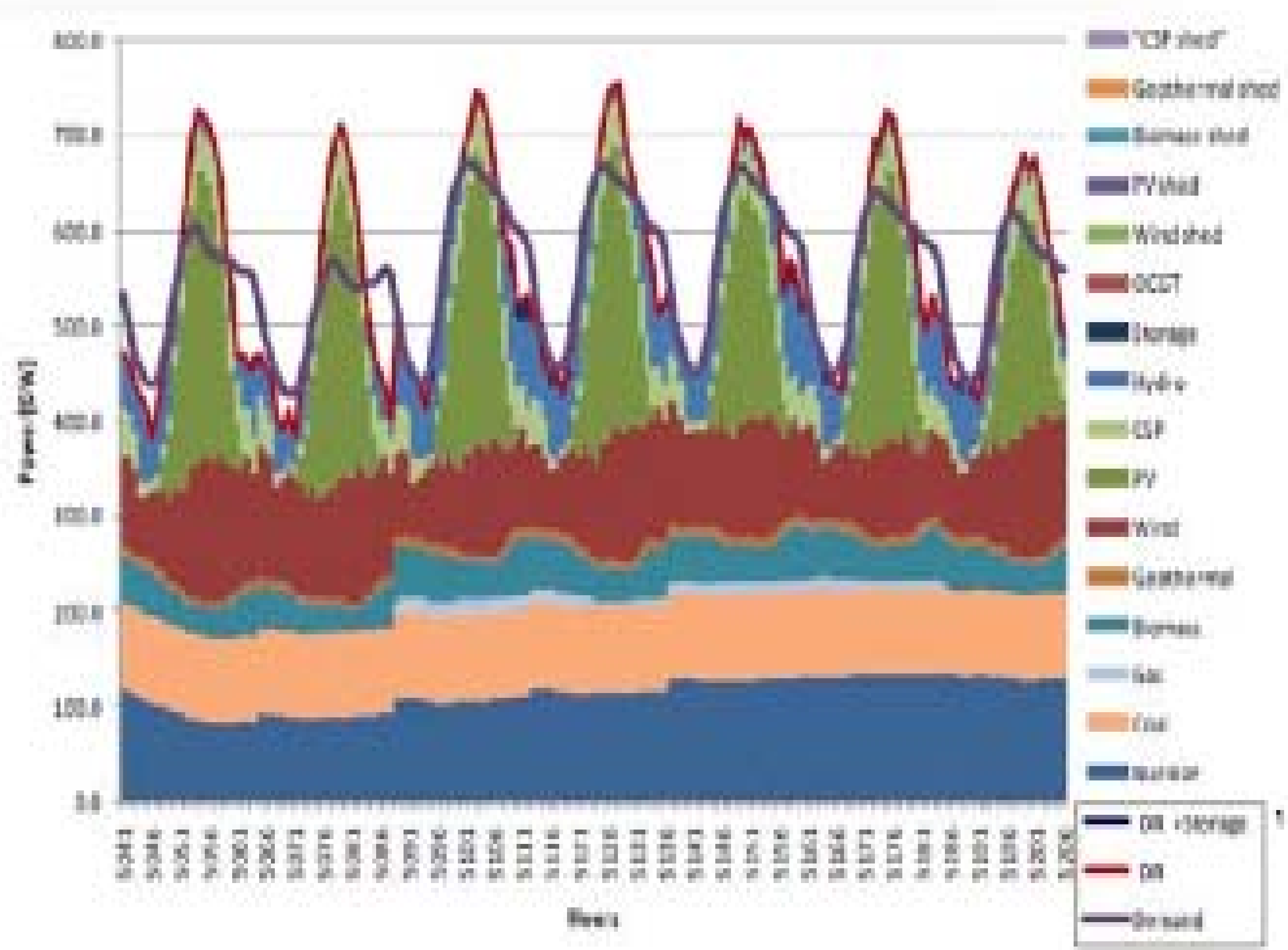
- Wind in Winter Complements Solar in Summer

Overview of yearly energy balance, 80% RES pathway (TWh per week)



ECF Report: Role of Demand Management in Future Smart Grids

- Demand Management Helps Demand to Follow Supply, Maximising Utilization of Renewables



1 The graph shows how the original demand line (purple) is shifted to a higher level (red line) by DR to capture the higher PV production

DESERTEC - Renewable Electricity for Europe, Middle-East & North Africa

DESERTEC Foundation & Industrial Initiative: ABB, E-On,Siemens, RWE *et al*

Links:
Concentrating Solar
Photovoltaics
Hydro
Wind
Biofuels
Geo-thermal

A Near-Constant Supply from Wind in Europe & Beyond?

G. Czisch, University of Kassel

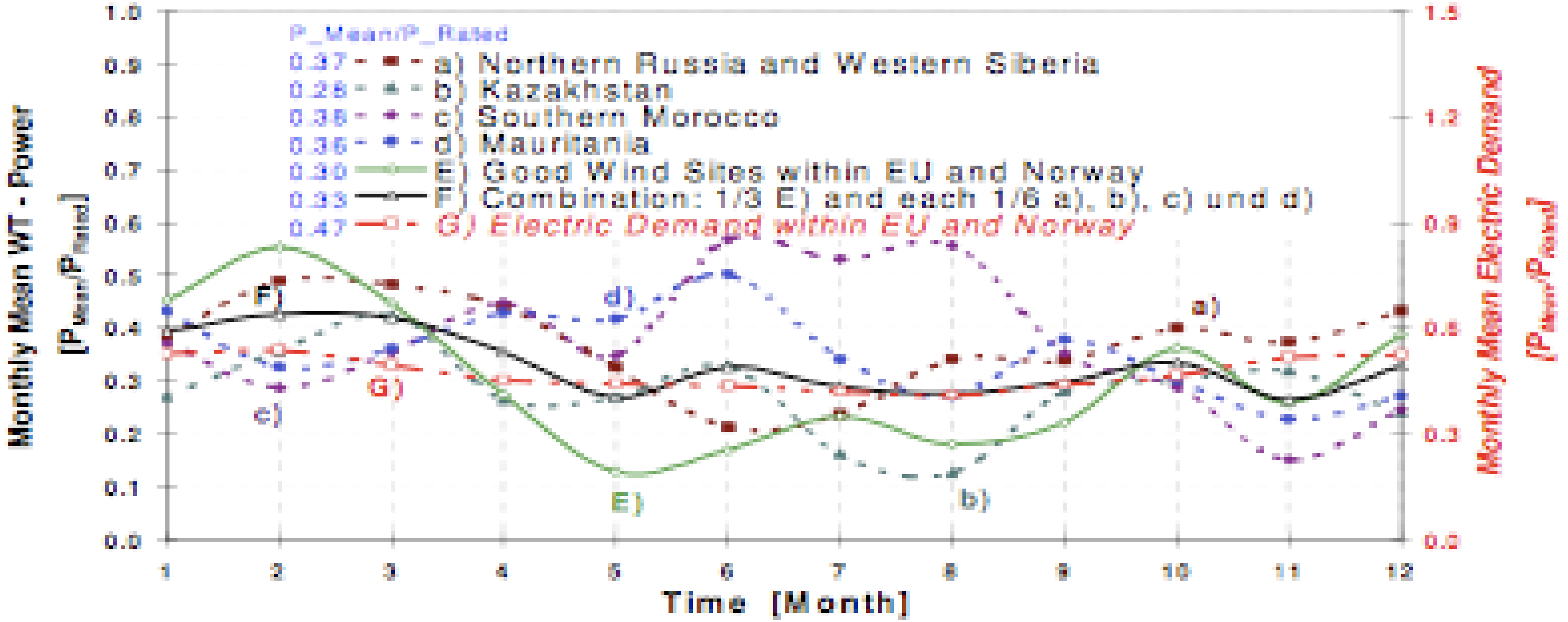
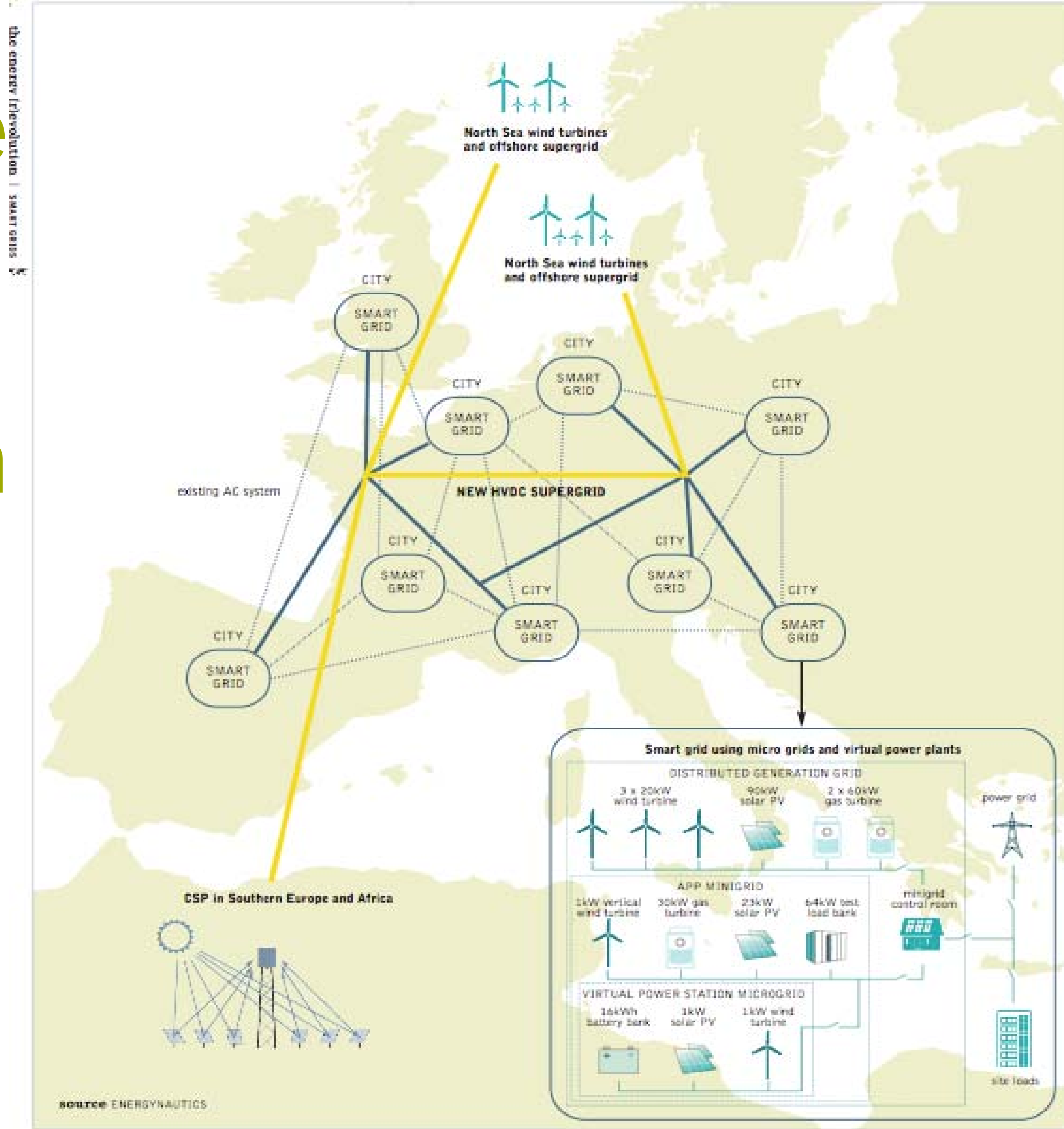


Figure 5 Relative monthly average: electricity production from wind turbines (WT) in selected good wind are and electricity consumption of EU and Norway. a.) to d.) represent Extraeuropean production E.) represents European production and F.) is the combined production of wind power at all regions whereas G.) represent: the average consumption in the EU & Norway weighted with the today's rated power of all power plants installed.

Greenpeace *Energy Revolution 2010:* Vision

- Supergrid Linking EU & N Africa
- Smart Grids in Cities
- Local Mini-
  & Micro Grids



Conclusions - and Questions

- Renewable supplies are *variable*, not intermittent - & some *constant*
- Electricity *demand* shows very large variations, daily & seasonally
- Existing electricity supply systems cope with these variations through *backup & standby* supplies: very little storage needed
- *Costs* of additional backup in a renewables-intensive system are *low*: c.5% of electricity costs for up to 45% renewable elec. <u>in UK</u>
- *Batteries of electric vehicles* could provide substantial storage in a renewables-intensive future
- Wind power can be *forecast* with high accuracy c.1 day ahead: enables scheduling of lower-cost backup supplies
- *Wide spatial dispersion* can smooth variations in wind & solar
- Renewables can provide a very high % of future electricity
- *European Supergrid*: construction already started
- *Other Supergrids* could follow – EU- North Africa
- ***Question:*** *What's the optimum balance between large, centralized and small, decentralized renewable electricity systems??*

For Further Information:

- ***Renewable Electricity and the Grid: The Challenge of Variability***, **edited by Godfrey Boyle, Earthscan, h/b 2007; p/b 2009**
- ***'Renewable Energy Technologies'*** **by Godfrey Boyle, in *Harnessing Renewable Energy in Electric Power Systems: Theory, Practice, Policy*, Earthscan/Resources for the Future Press, 2010, edited By Boaz Moselle, Jorge Padilla and Richard Schmalensee.**

  'A comprehensive and timely review of the international experience in fostering the use of renewable energy sources in the electricity industry.' Blas Pérez Henríquez, University of California, Berkeley.

  Launch of book in Madrid October 2010