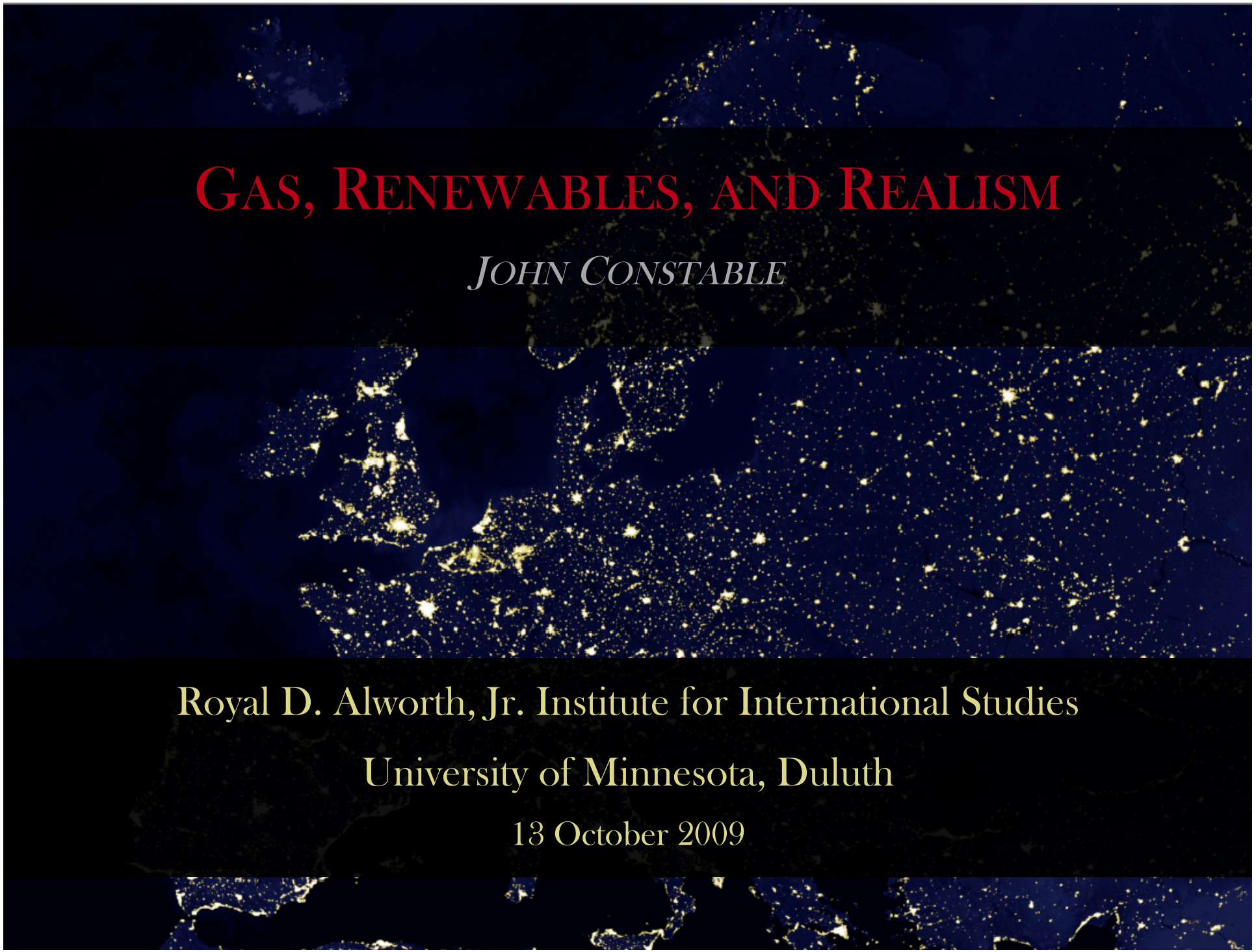


Gas, Renewables, and Realism

John Constable

Royal D. Alworth, Jr. Institute for International Studies

University of Minnesota, Duluth

13 October 2009

REF

RENEWABLE ENERGY FOUNDATION

- Energy think tank
- Independent UK charity
- Supported by private donation
- No corporate members
- No political affiliation
- Publish data and analysis
- www.ref.org.uk

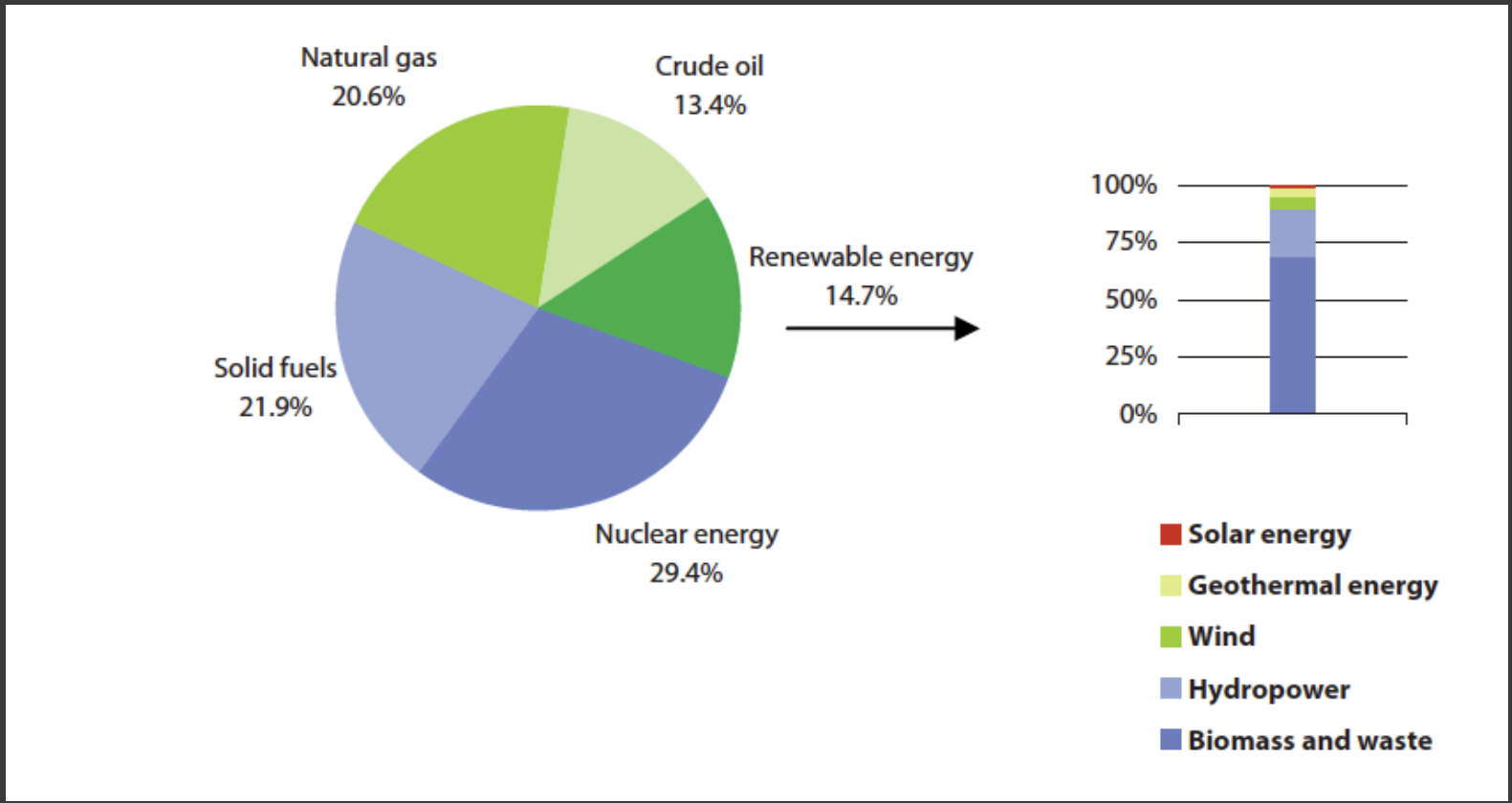
European Union 27:
Population, Economy, Energy

- Population: 500 million
  - US: 305 million
- GDP: €12 trillion ($18 trillion)
  - US: $14 trillion
- Energy consumption: 1.8 billion tonnes of oil equivalent (toe)
  - US: 2.3 billion toe

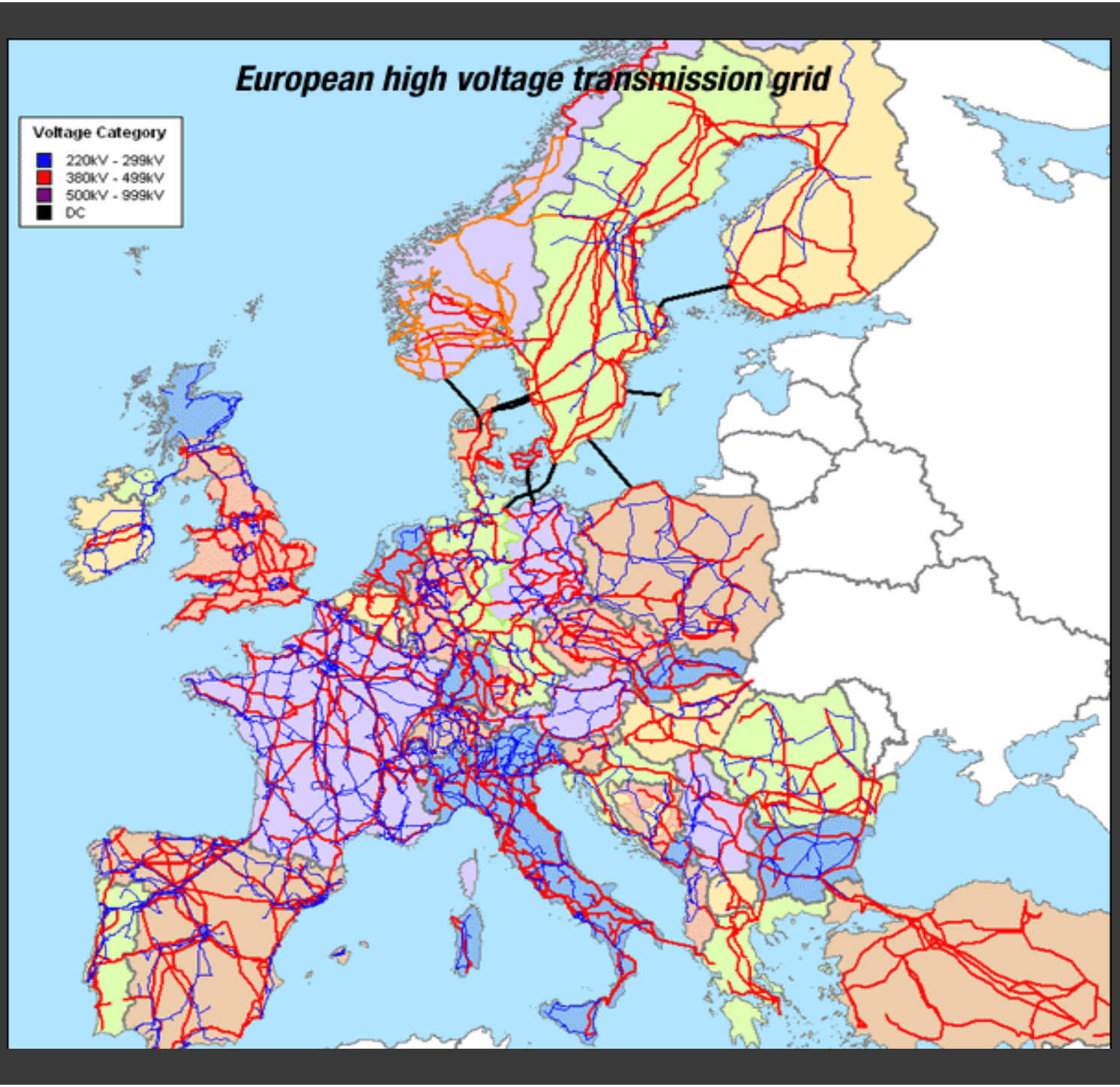
EU 27 Energy 2008: Import Dependency

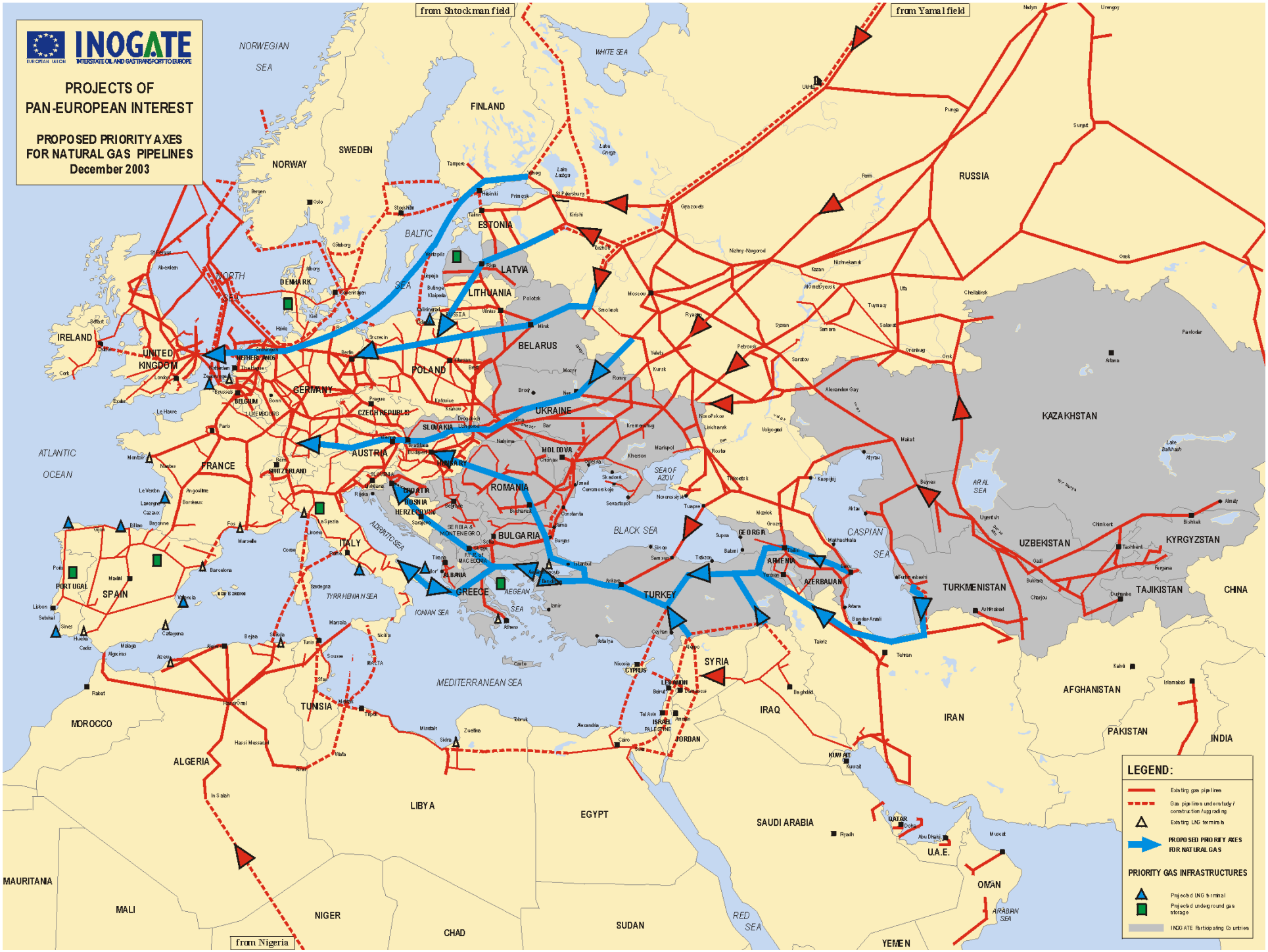
- Energy consumption: 1.8 billion toe
- Energy Production: 871 million toe
  - UK is largest producer: 21% of EU production
- Net imports: 1 billion toe
- Import dependency: > 50%

EU 27 Energy Production: 2006



Source: *Eurostat*

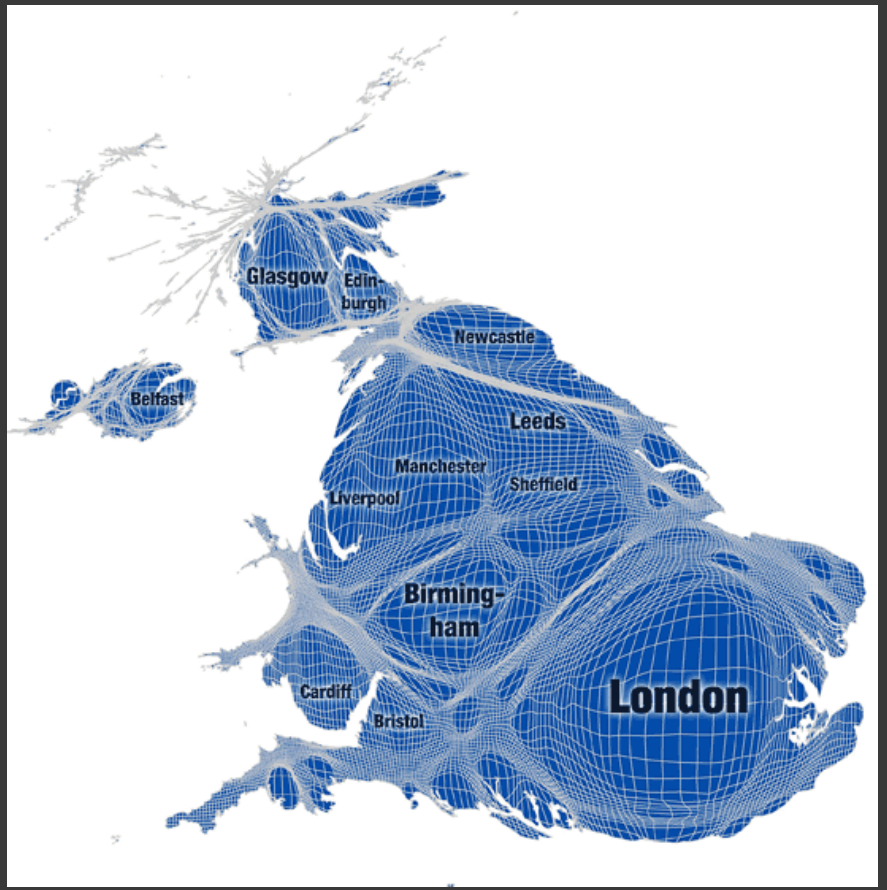

European high voltage transmission grid
Voltage Category
220kV - 299kV
380kV - 499kV
500kV - 999kV
DC


INOGATE
EUROPEAN UNION
INTERSTATE OIL AND GAS TRANSPORT TO EUROPE
PROJECTS OF
PAN-EUROPEAN INTEREST
PROPOSED PRIORITY AXES
FOR NATURAL GAS PIPELINES
December 2003
from Shtockman field
from Yamal field
from Nigeria
NORWEGIAN SEA
WHITE SEA
BARENTS SEA
NORTH SEA
BALTIC SEA
FINLAND
SWEDEN
NORWAY
ESTONIA
LATVIA
LITHUANIA
RUSSIA
BELARUS
IRELAND
UNITED KINGDOM
NETHERLANDS
DENMARK
POLAND
GERMANY
BELGIUM
LUXEMBOURG
CZECH REPUBLIC
SLOVAKIA
UKRAINE
MOLDOVA
AUSTRIA
HUNGARY
SWITZERLAND
FRANCE
ROMANIA
CROATIA
BOSNIA HERZEGOVINA
SERBIA & MONTENEGRO
BULGARIA
ATLANTIC OCEAN
BLACK SEA
SEA OF AZOV
CASPIAN SEA
ARAL SEA
KAZAKHSTAN
UZBEKISTAN
KYRGYZSTAN
TURKMENISTAN
TAJIKISTAN
CHINA
GEORGIA
ARMENIA
AZERBAIJAN
ITALY
ADRIATIC SEA
TYRRHENIAN SEA
IONIAN SEA
AEGEAN SEA
ALBANIA
GREECE
TURKEY
PORTUGAL
SPAIN
MEDITERRANEAN SEA
SYRIA
IRAQ
IRAN
AFGHANISTAN
PAKISTAN
INDIA
LEBANON
ISRAEL
PALESTINE
JORDAN
CYPRUS
KUWAIT
SAUDI ARABIA
QATAR
U.A.E.
OMAN
ARABIAN SEA
RED SEA
YEMEN
SUDAN
EGYPT
LIBYA
CHAD
NIGER
MALI
MAURITANIA
ALGERIA
TUNISIA
MOROCCO
MALTA
LEGEND:
Existing gas pipelines
Gas pipelines under study / construction /upgrading
Existing LNG terminals
PROPOSED PRIORITY AXES FOR NATURAL GAS
PRIORITY GAS INFRASTRUCTURES
Projected LNG terminal
Projected underground gas storage
INOGATE Participating Countries

UK Population

- Population: 61.5m
  - England: 51.5m
  - Scotland: 5.2m
  - Wales: 3m
  - N. Ireland: 1.8m
- London: 18m

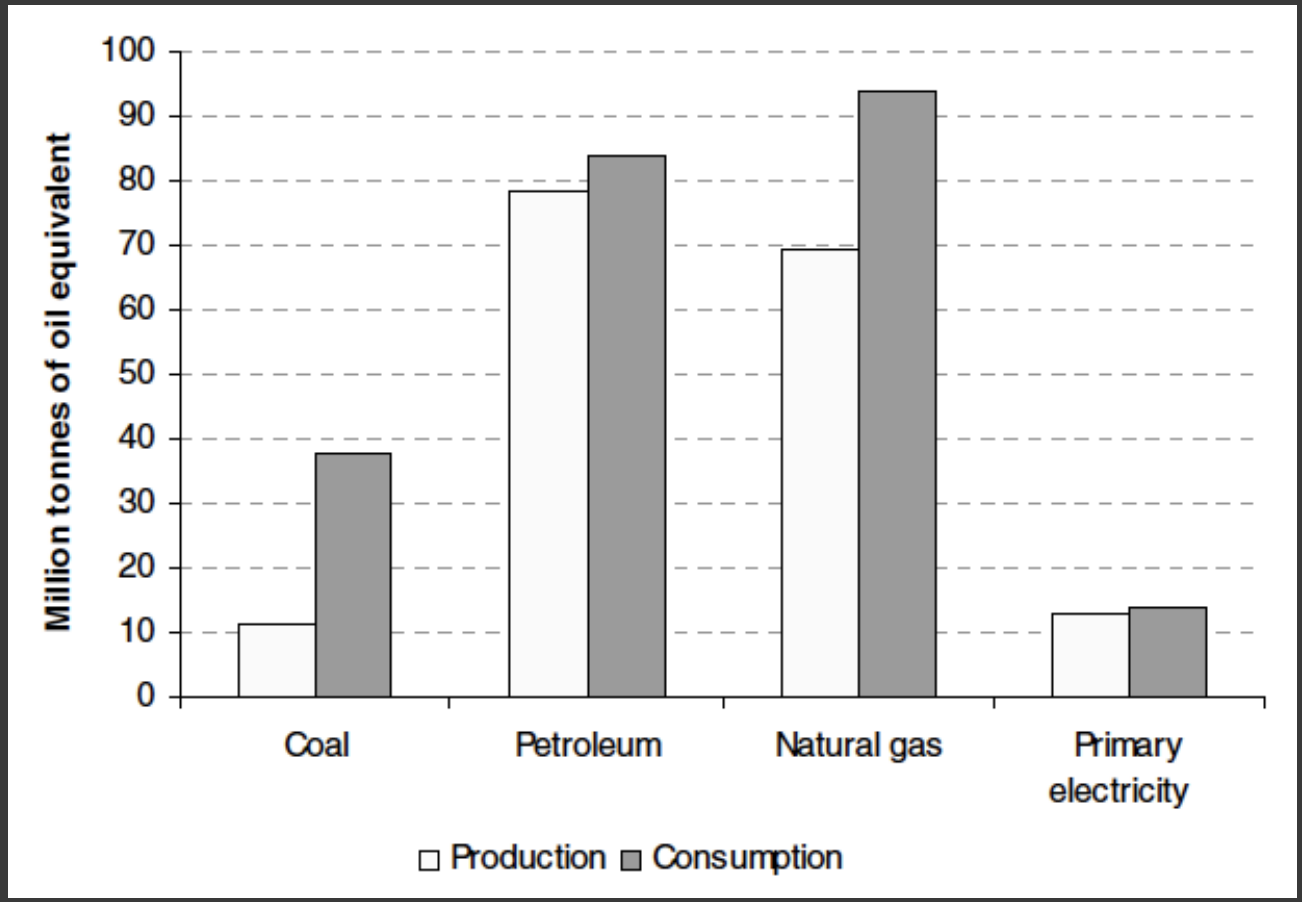
Source: ONS, Worldmapper



UK Energy and Economy

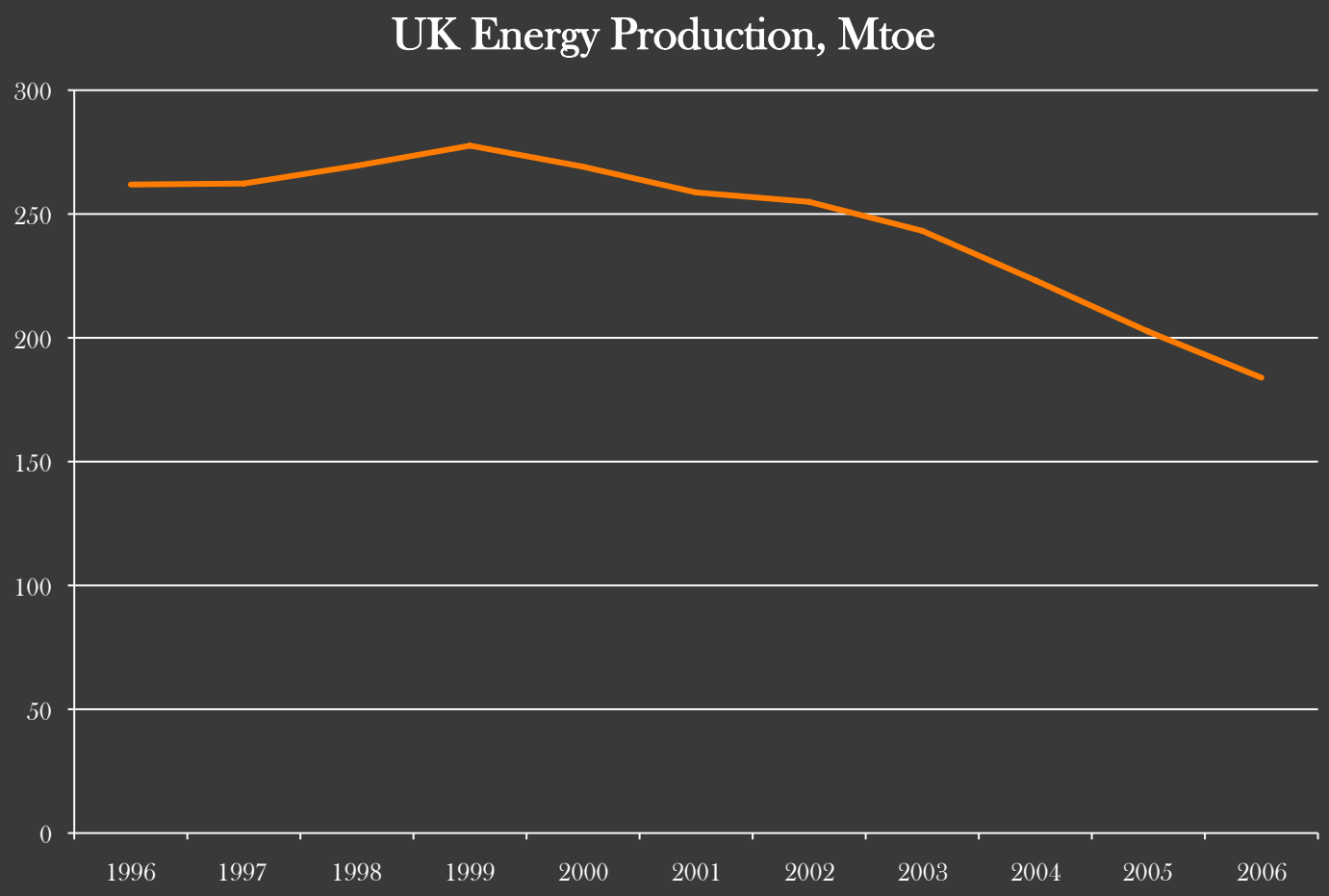
- GDP = £1.44 trillion ($2.3 trillion)
- Total energy demand: 234 mtoe
- Indigenous production: ca. 175 mtoe
- Net import dependent since 2004
- UK consumers spend £120 bn a year on energy ($192 bn), 8.3% of GDP.

UK Energy 2008: Production and Consumption



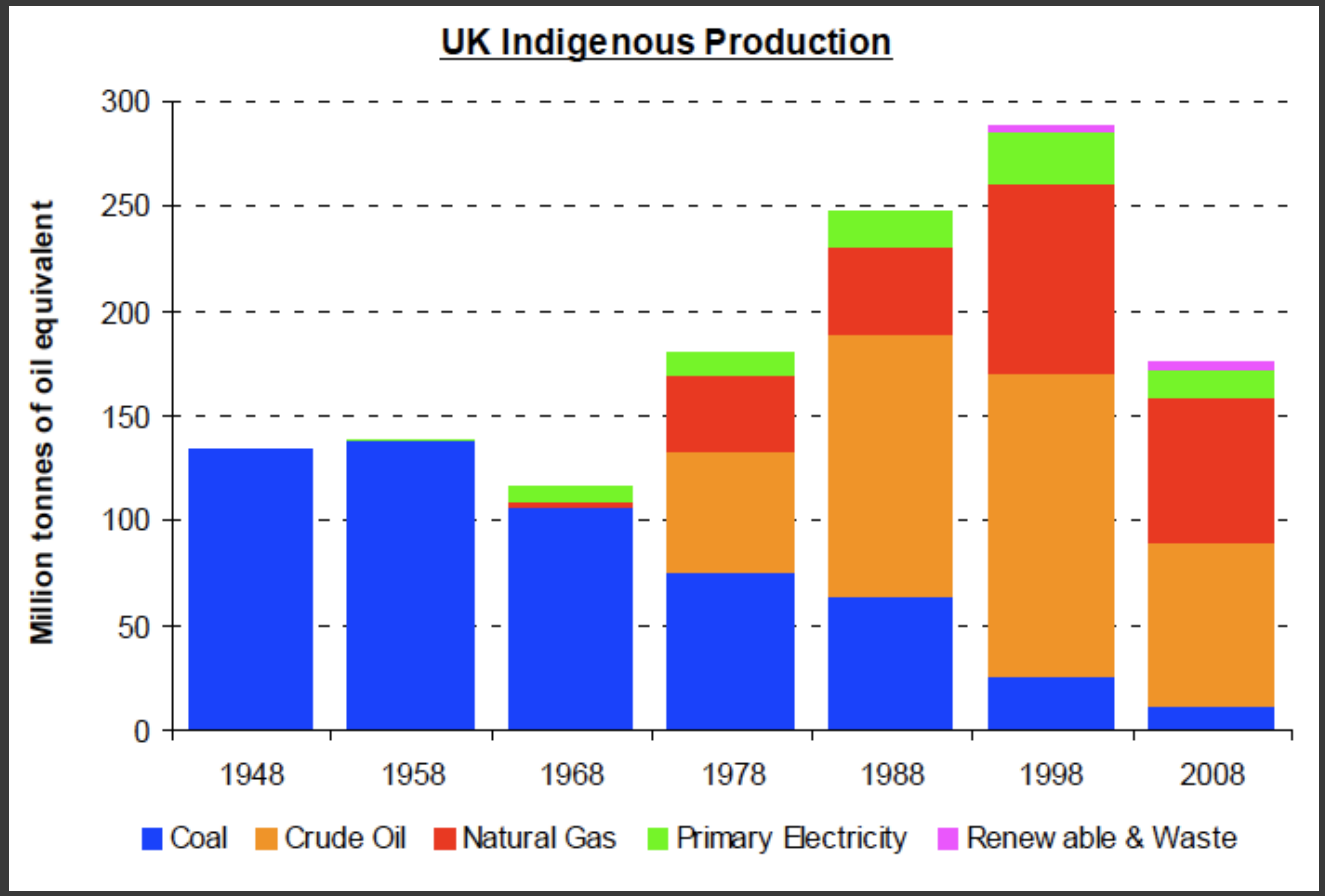
Source: *Dept. of Energy and Climate Change*

Falling UK Energy Production



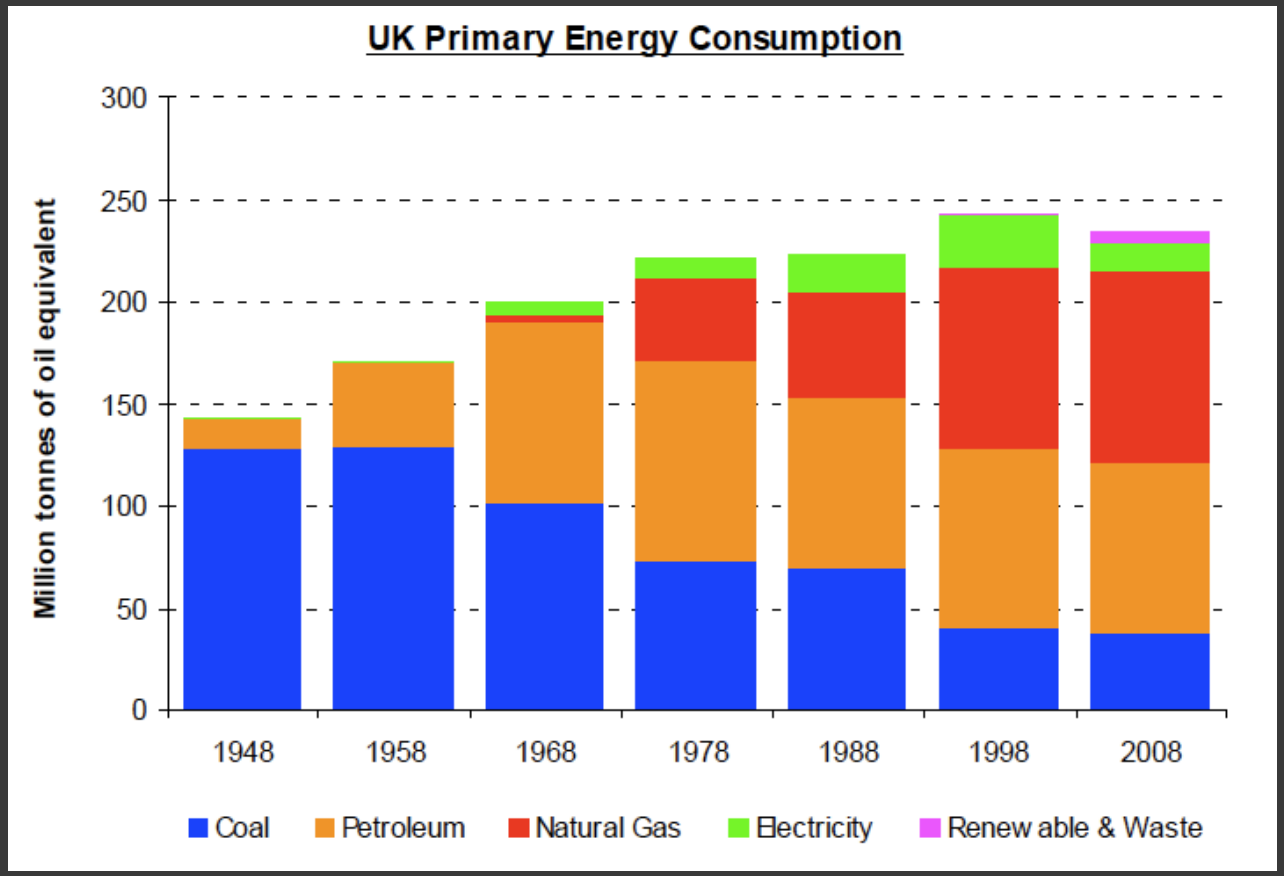
Source: *Eurostat*

History of UK Energy: Production



Source: *Department of Eneergy & Climate Change*

History of UK Energy: Consumption

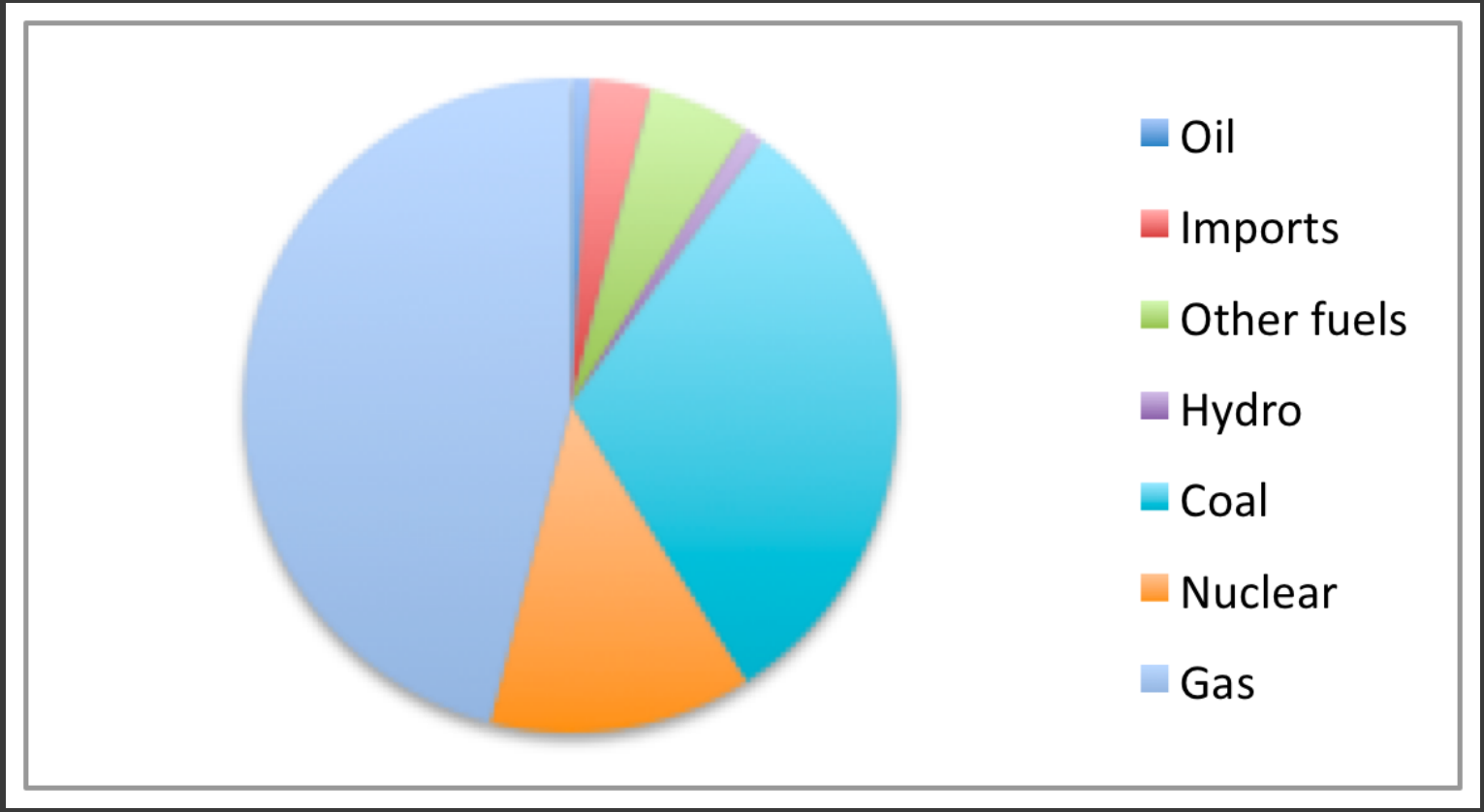


Source: *Department of Eneergy & Climate Change*

Where Natural Gas is Used in the UK

- 50% of gas is consumed in homes
- 66% of home energy use is gas
  - 22% is secondary electricity
- UK electricity is 46% gas fired
- In substance, UK homes are gas fuelled

UK Net Electricity by Fuel 2008



Source: *DECC*

Gas Dependency & Climate Change

- EU and UK want energy security and a low-carbon economy, but
- Indecision over coal with CCS
- Hesitation over nuclear
- Practical response limited to
  - Market liberalisation
  - Pipeline diplomacy
  - Renewables

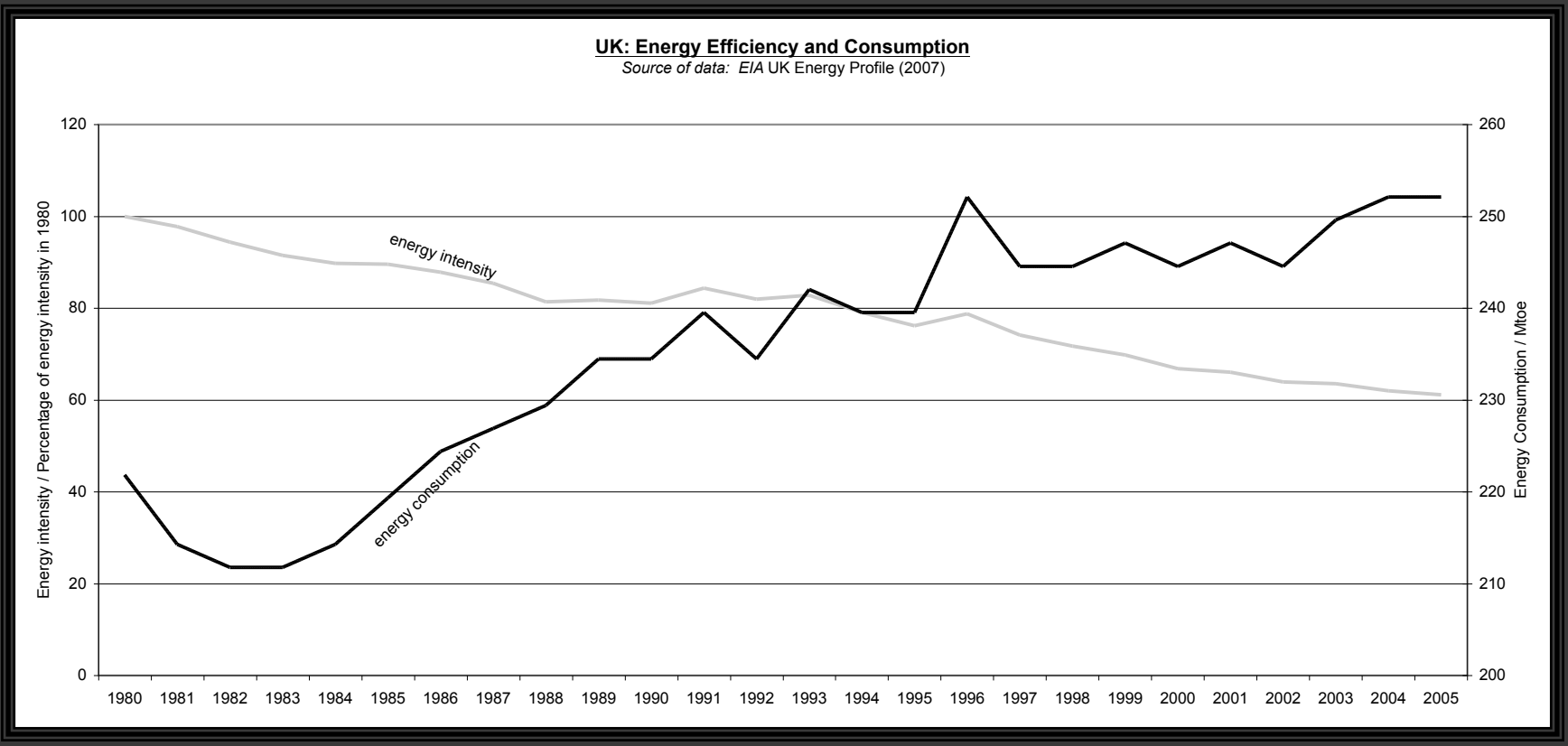
2009 EU Renewable Energy Directive

- 20% of EU Final Energy Consumption (FEC) from renewable sources by 2020
- 10% of EU transport fuels to be renewable
- UK burden share: 15% of FEC
- UK currently at 1.3% of FEC
  - Only Malta and Luxembourg face a larger increase

UK Target Magnitude

- HMG estimates that in 2020 FEC will be unchanged from today's value:
  - 150 mtoe
- In spite of:
  - Rising population: ca. 65 million
  - Return to economic growth
- **HMG assumes *efficiency* reduces consumption**

UK Efficiency Gains and Total Consumption



W. S. Jevons, 1865

- *"[...] it is wholly a confusion of ideas to suppose that the economical use of fuels is equivalent to a diminished consumption. The very contrary is the truth."*

Target Magnitude for the UK: Implications

- UK FEC in 2020 = ca. 170 to 180 mtoe
- Target: 26.25 mtoe (305 TWhs)
  - UK electricity generation = 400 TWhs
- At least ½ to ⅔ of target must come from electricity
  - UK has a small landmass limiting biomass heat
- 40–50% of UK electricity must be renewable.
  - Govt. admits to 35%.
- Current level: 5.4%

UK Renewable Energy Policies

- Renewables Obligation subsidy
  - Doubles a renewable generator's income
  - Costs consumer ca. $1.6bn a year at present
- RO cost in 2020:
  - $8bn – $16bn a year
  - Other costs, grid expansion, system balancing, large but unknown.

Will the Renewables Policies Deliver?

- Are UK renewables policies feasible?
  - No
- Will the policies mitigate gas dependency?
  - Even if successful, no
- **Current renewable electricity policy will deepen and sharpen UK gas dependency**

35%–50% Renewable Electricity: 150 to 200 TWhs

- Biomass: 28 TWh
  - Imported timber from Canada
- Hydro: 4.6 TWh
- Tidal: Severn Barrage: 17 TWh
  - Costs $40 billion
- But mostly wind
  - Onshore: 10 GW, Offshore: 30 GW
  - Generating 120 TWh

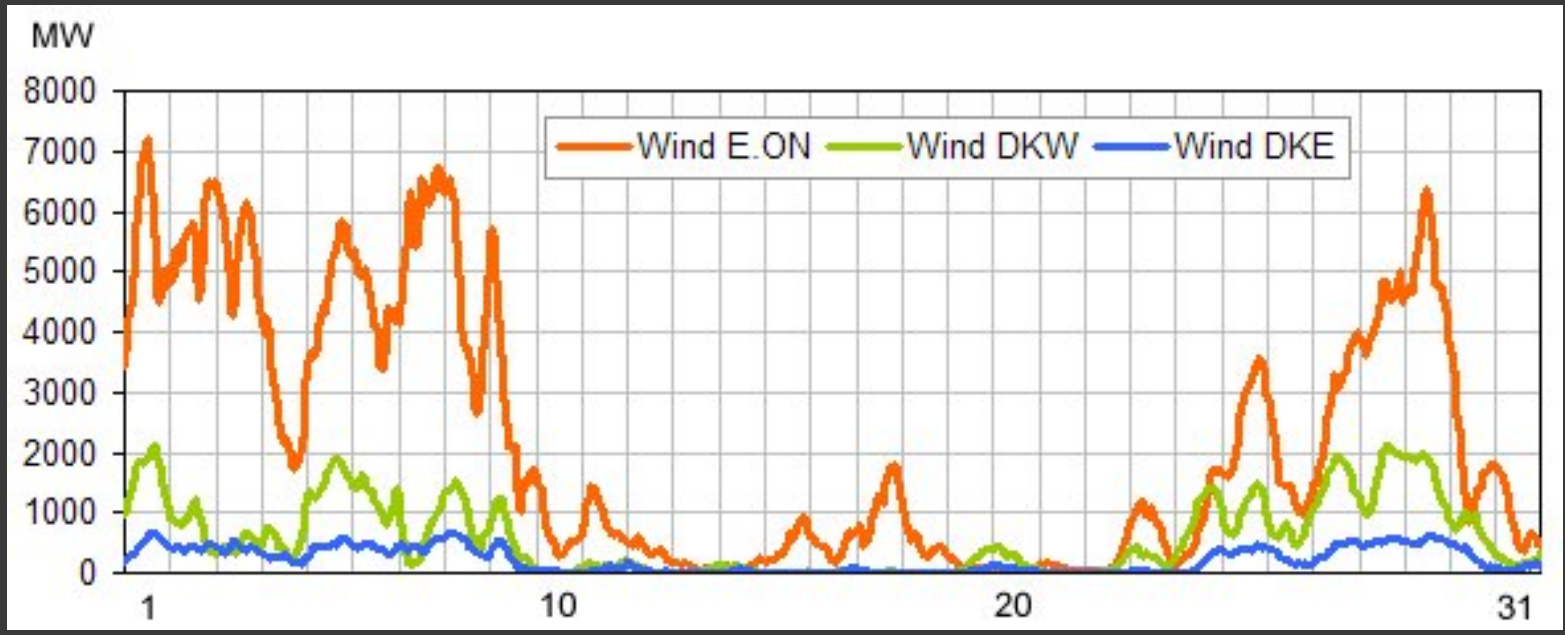
Offshore Wind: Horns Rev (Denmark)

- 80 x 2 MW turbines
- 361 ft overall height
- Length: 20km
- Cost: $400m
- Output: 0.6 TWh
  - = 0.15% of UK electricity
- 520 ft turbines in construction

Wind is Stochastically Variable

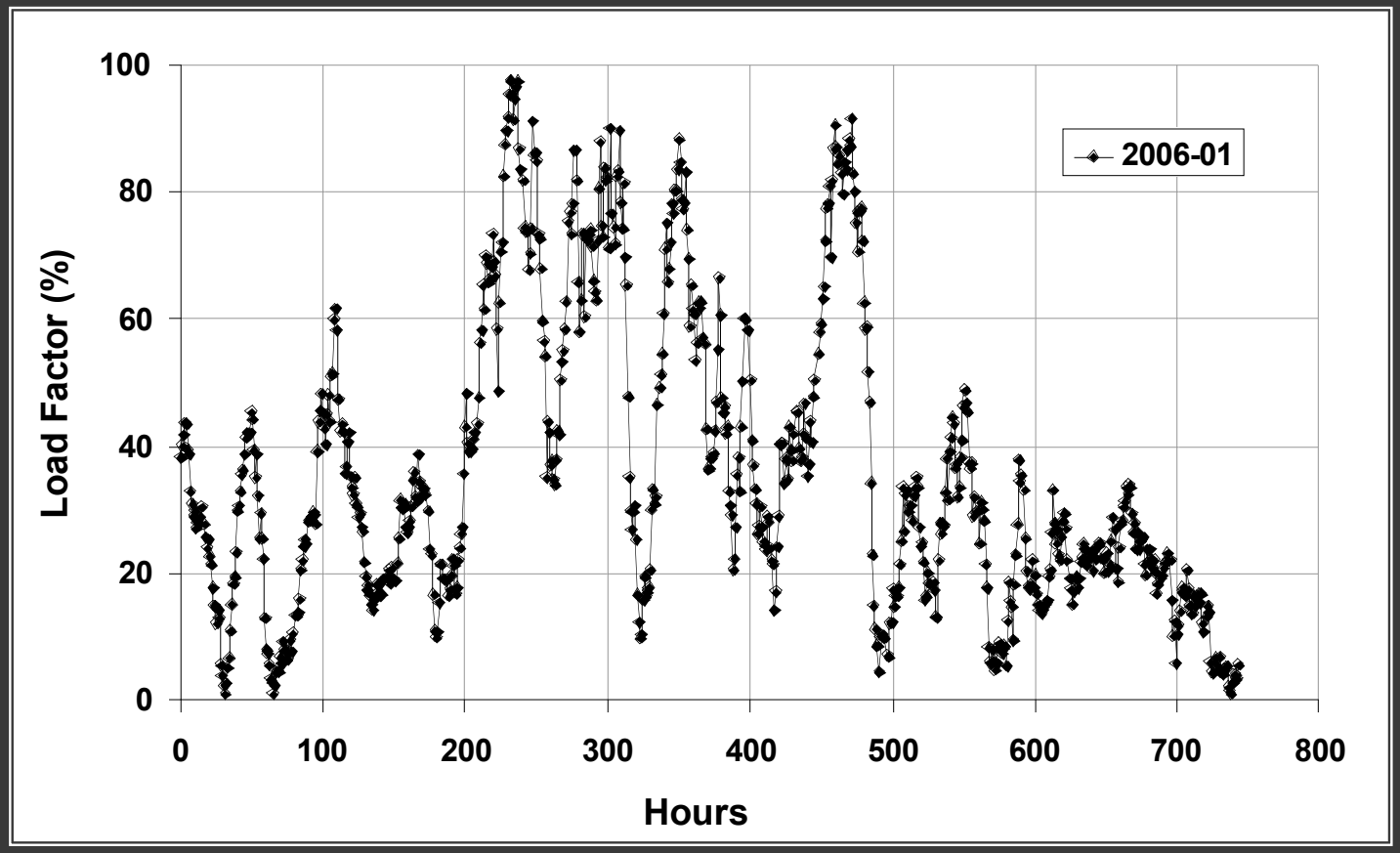
- Wind generation provides supplementary energy (MWh), not reliable capacity (MW)
- Electrical energy cannot be stored economically on the industrial scale
- Wind power output varies widely and is poorly synchronised with patterns of human demand

German and Danish Wind, December 2007



Source: Paul-Frederik Bach, for REF:
Wind Power and Spot Prices: German and Danish Experience 2006-2008 (2009)

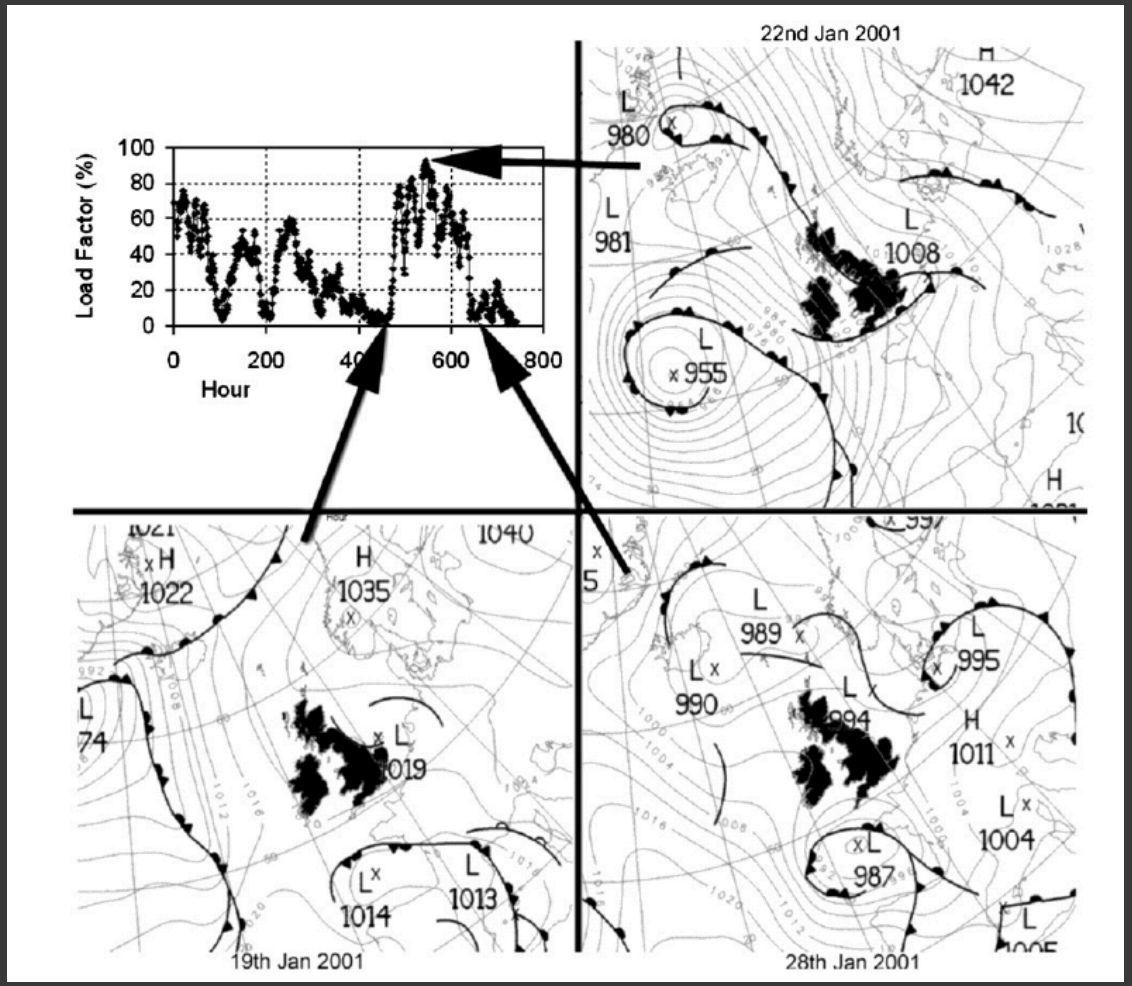
REF's UK Wind Model



Modelled power flow from 25 GW of wind spread over the UK

Source: Jim Oswald, et al., "Will British Weather Provide Reliable Electricity", *Energy Policy* 36 (August, 2008)

Wind: Little or No *Firm* Capacity



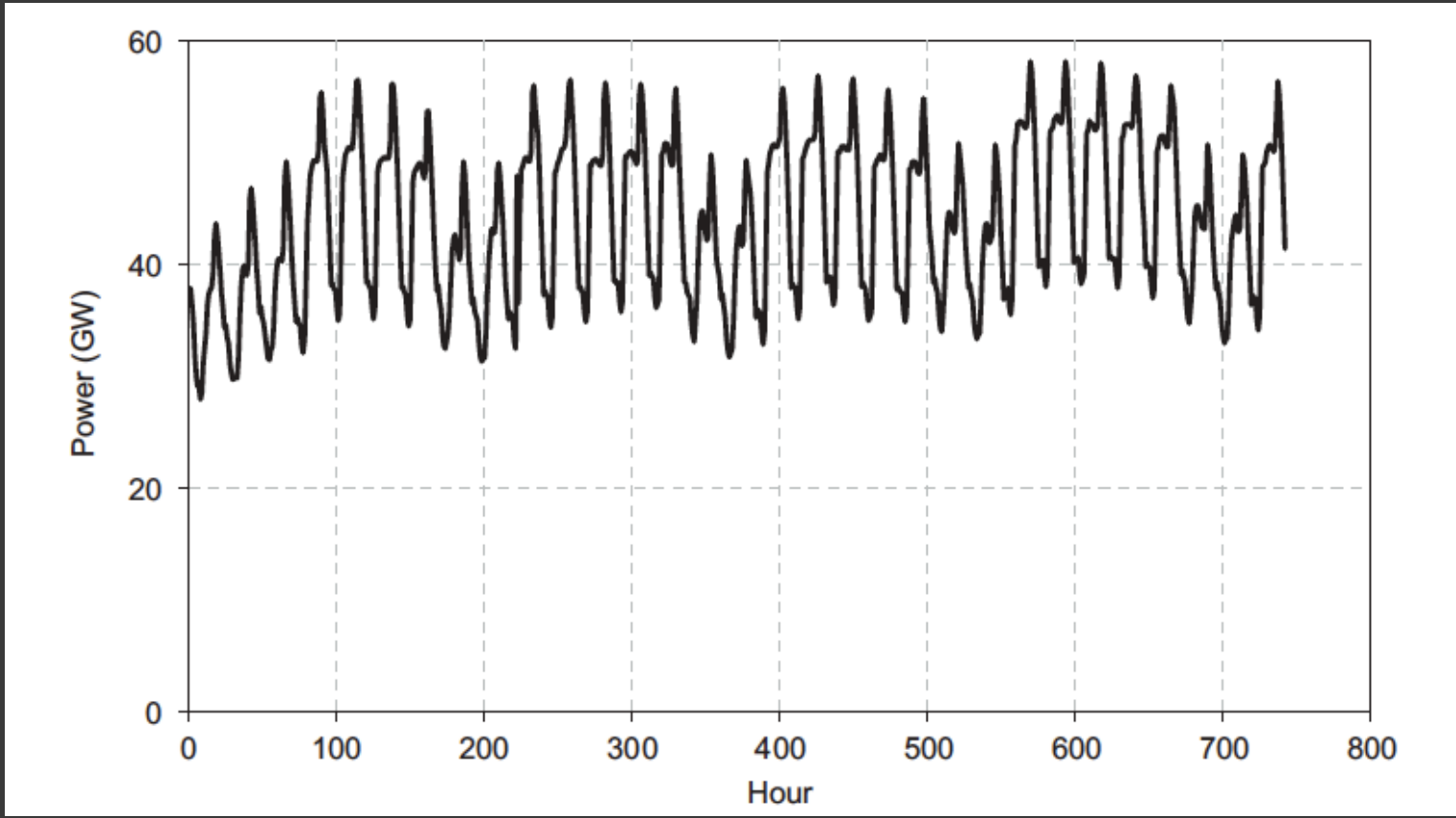
Wind Capacity Credit

"Irrespective of the amount of wind capacity installed in the system, the conventional capacity required will never be less than the peak load. [...] the 20% conventional plant margin [...] will never be reduced [...] to less than 9 or 10%"

Michael Laughton
Emeritus Professor of
Electrical Engineering
University of London

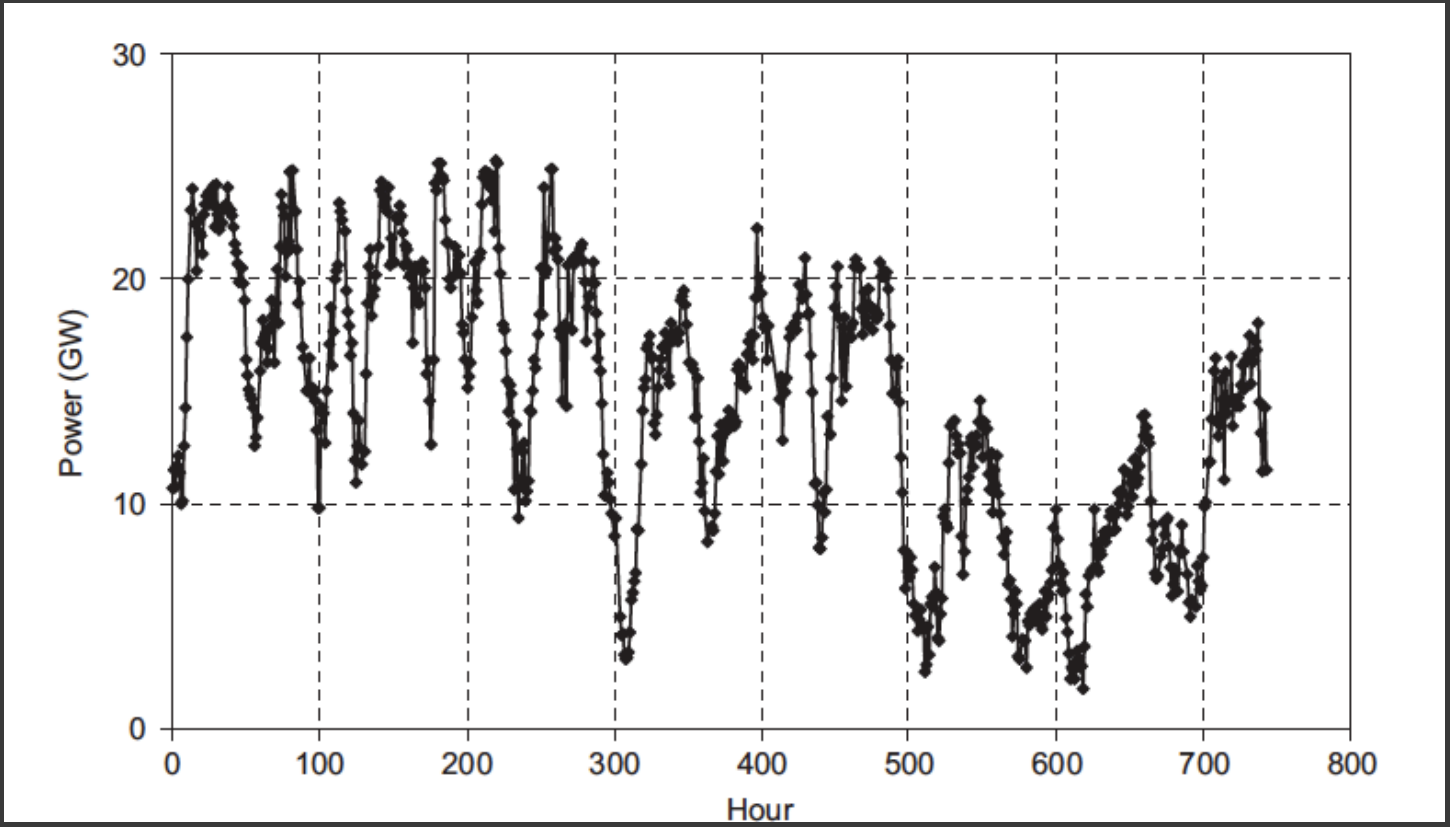
"Power Supply Security with Intermittent Sources: Conventional Plant Capacity Requirements", *Power in Europe*, 460 (10 Oct. 2005).

UK Electricity Demand: January 2005



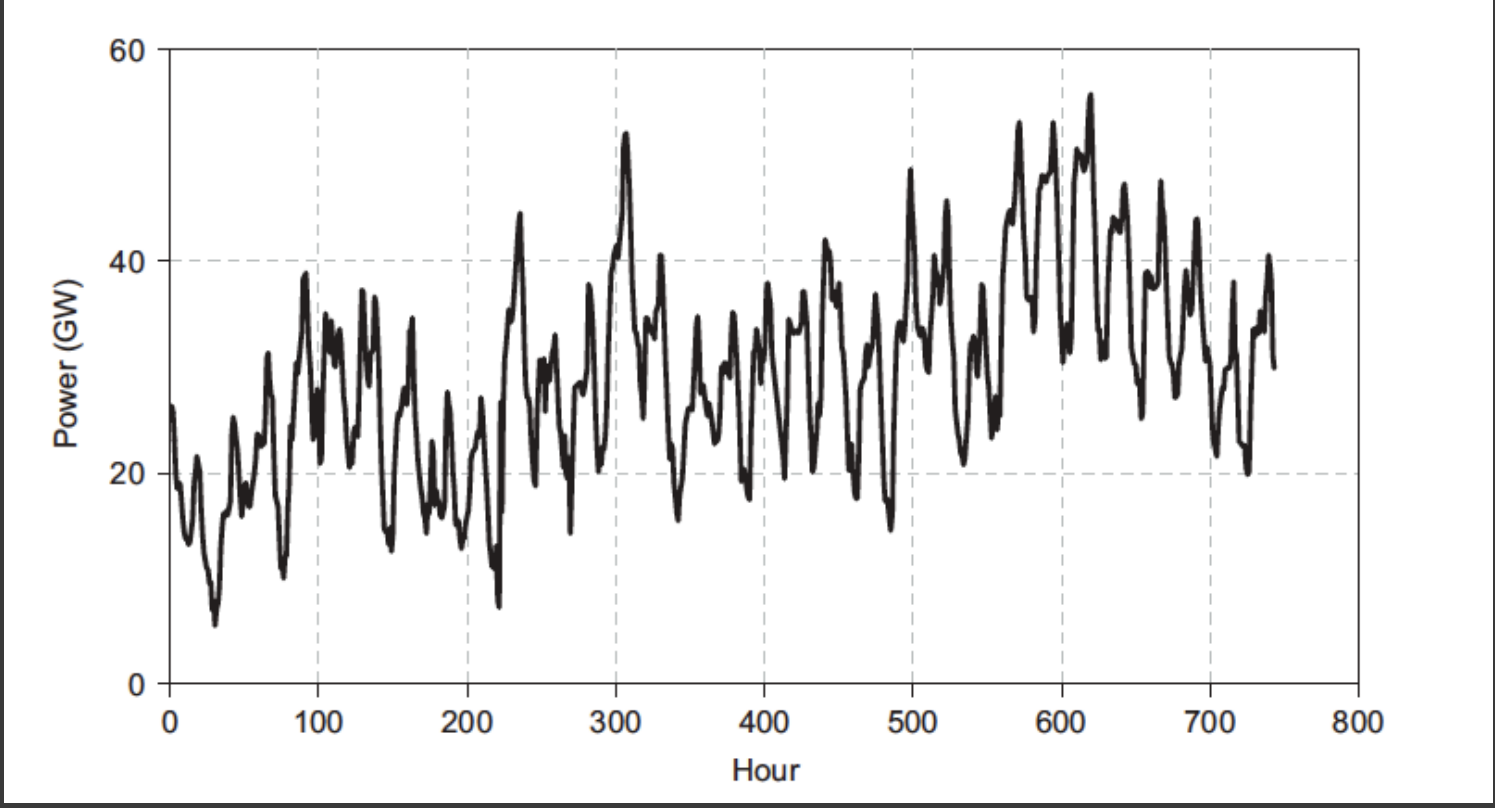
Source: Jim Oswald, et al., "Will British Weather Provide Reliable Electricity", *Energy Policy* 36 (August, 2008)

Modeled Output of 25 GW of UK Wind



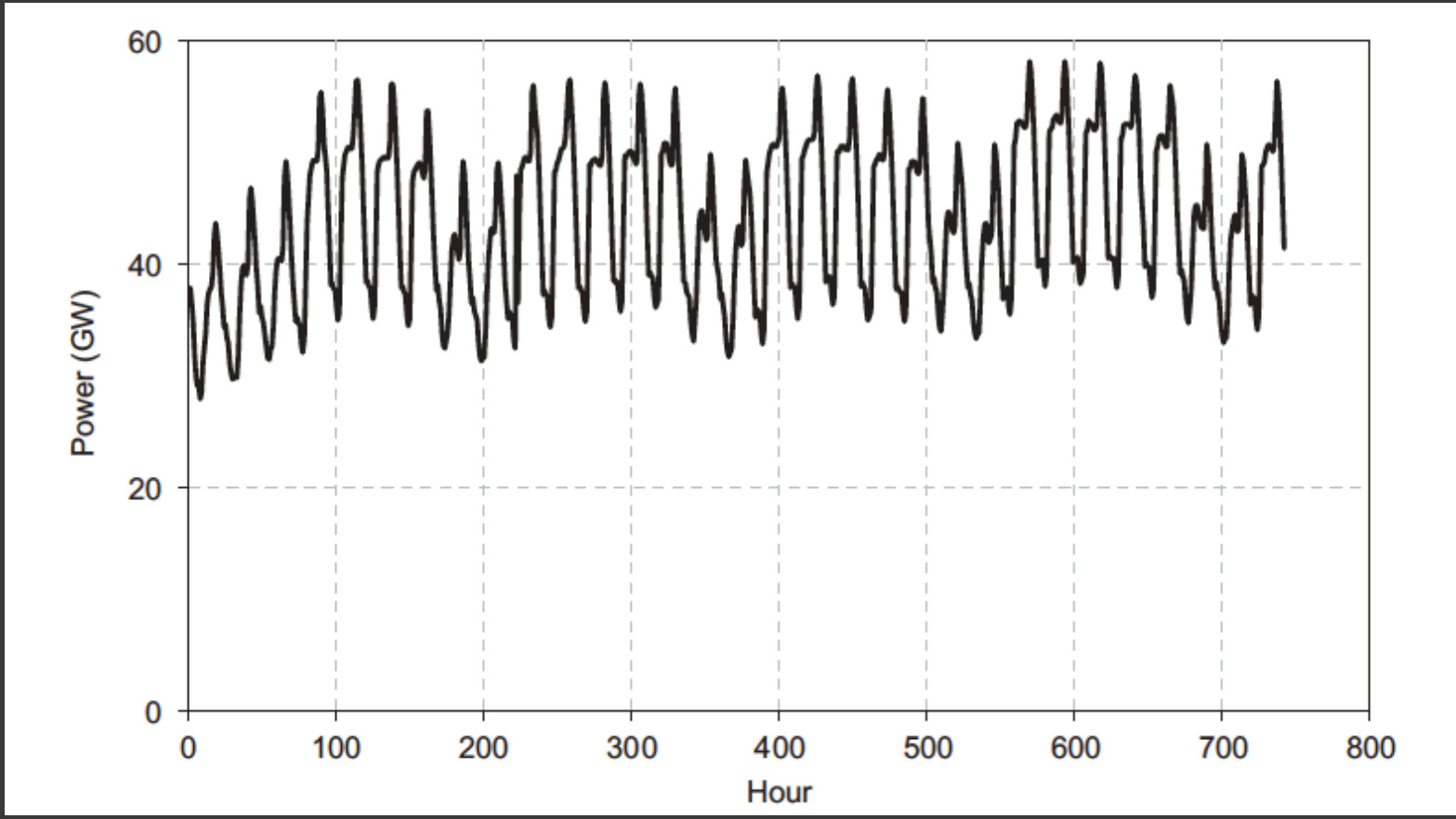
Source: Jim Oswald, et al., "Will British Weather Provide Reliable Electricity", *Energy Policy* 36 (August, 2008)

Load minus Wind output = Residual Load

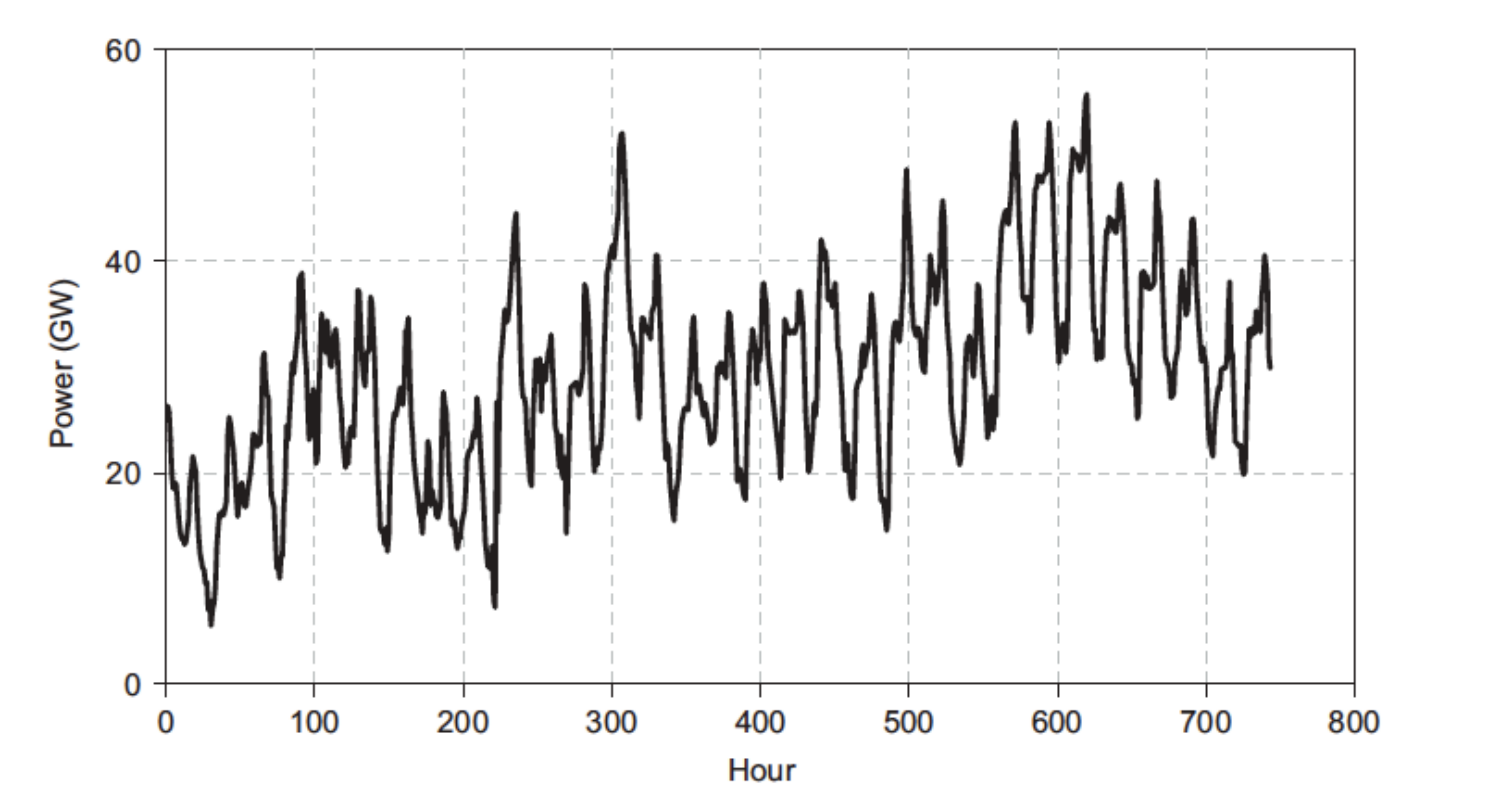


Source: Jim Oswald, et al., "Will British Weather Provide Reliable Electricity", *Energy Policy* 36 (August, 2008)

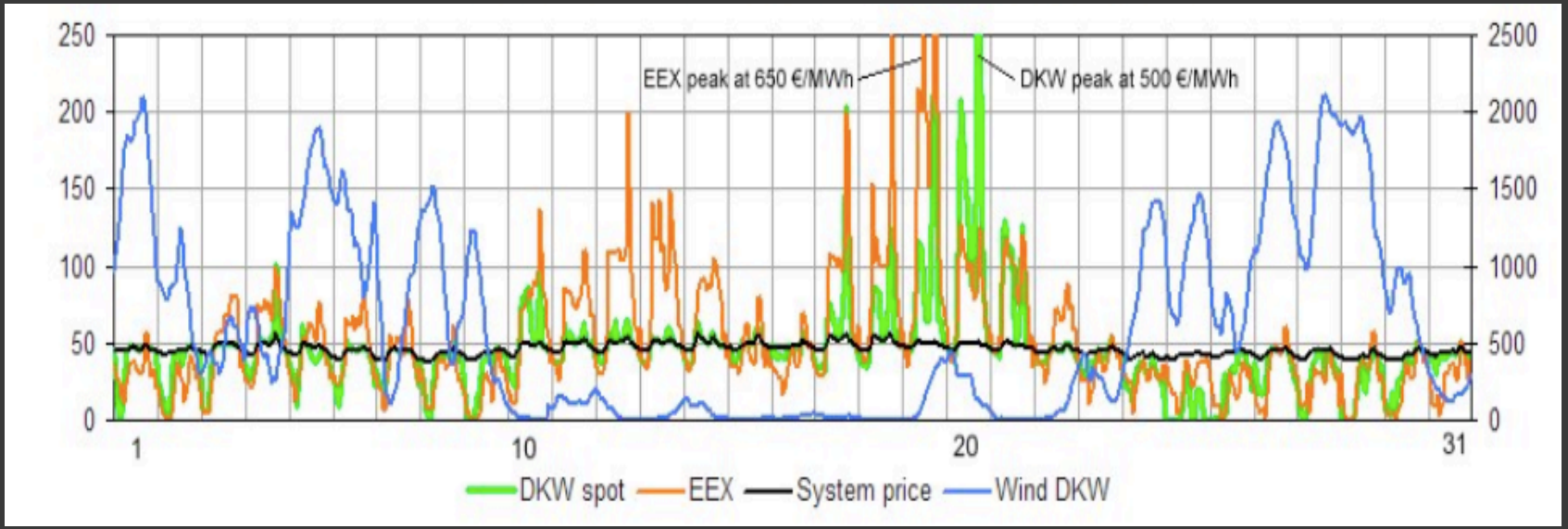
UK Electricity Demand: January 2005



Load minus Wind output = *Residual Load*

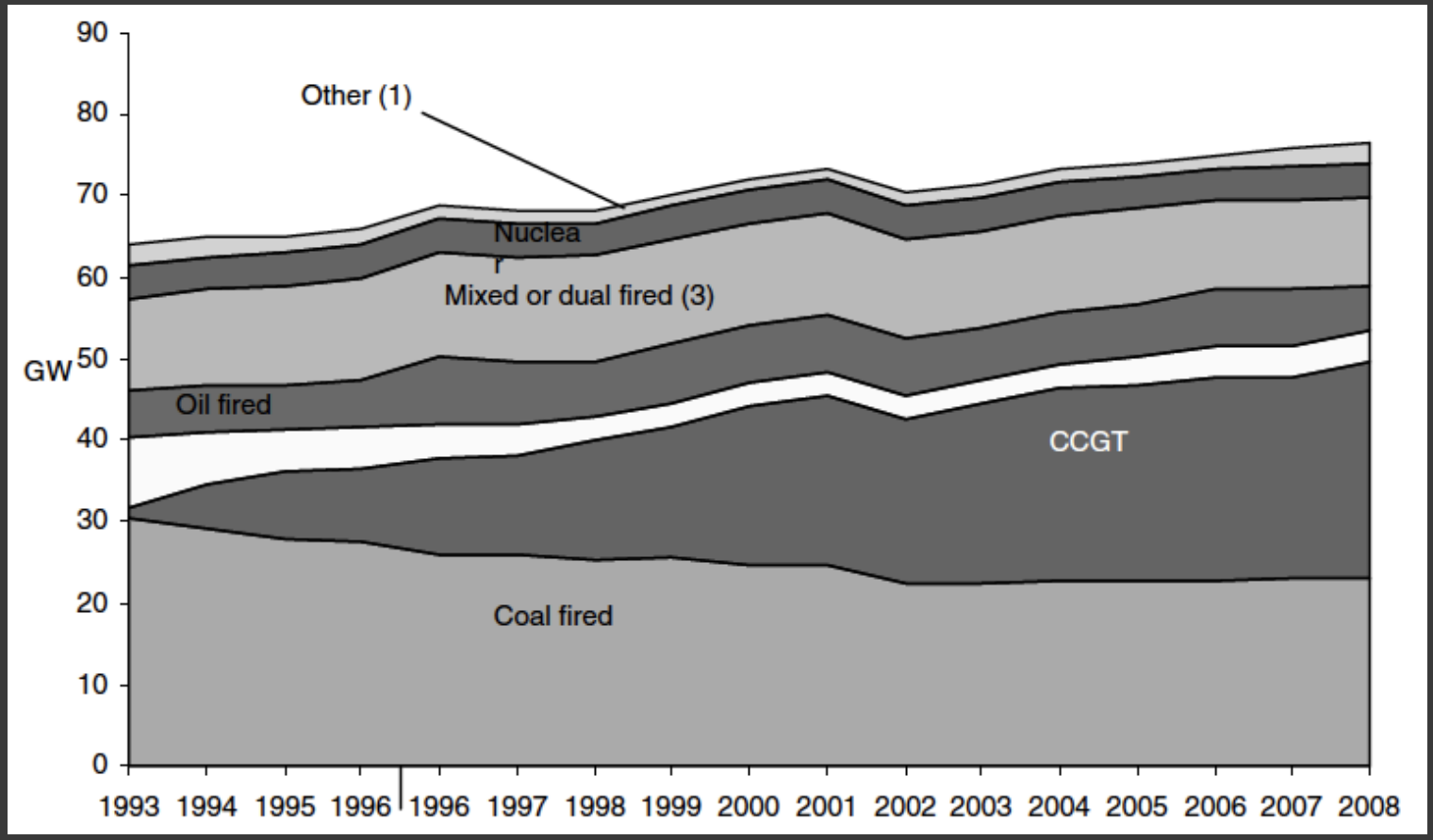


Spot Prices in Denmark and Germany, Dec. 2007



Source: Paul-Frederik Bach, for REF:
Wind Power and Spot Prices: German and Danish Experience 2006-2008 (2009)

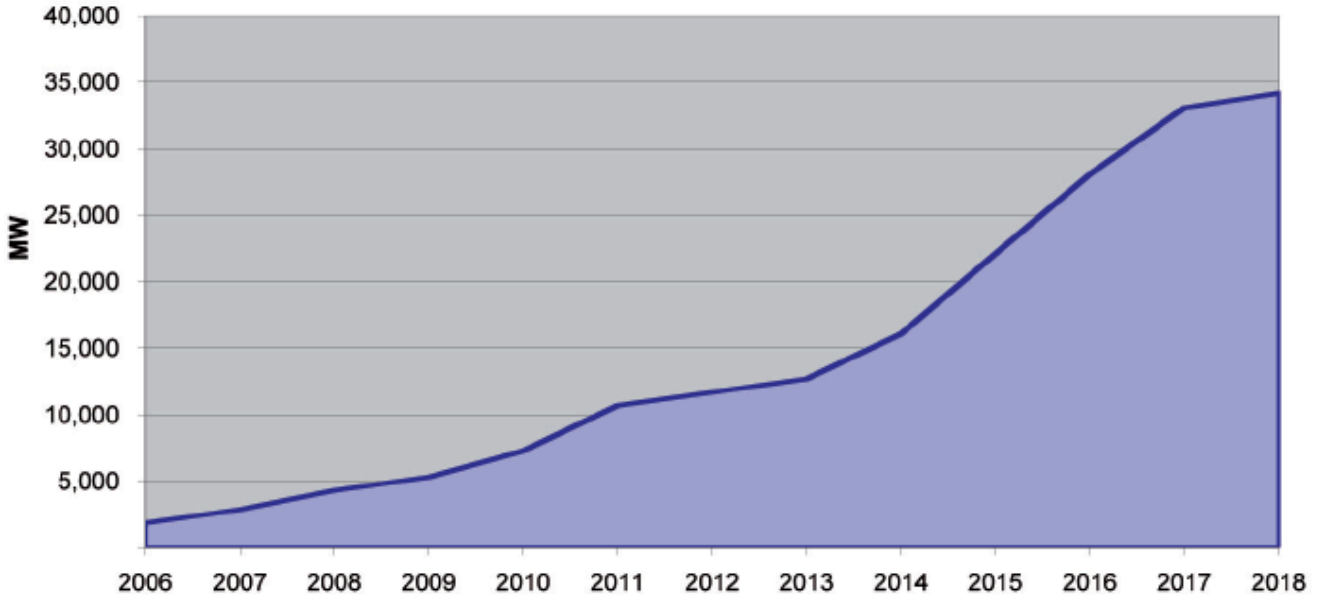
UK Generating Portfolio: Major Power Producers



Source: DECC

Digest of United Kingdom Energy Statistics 2008

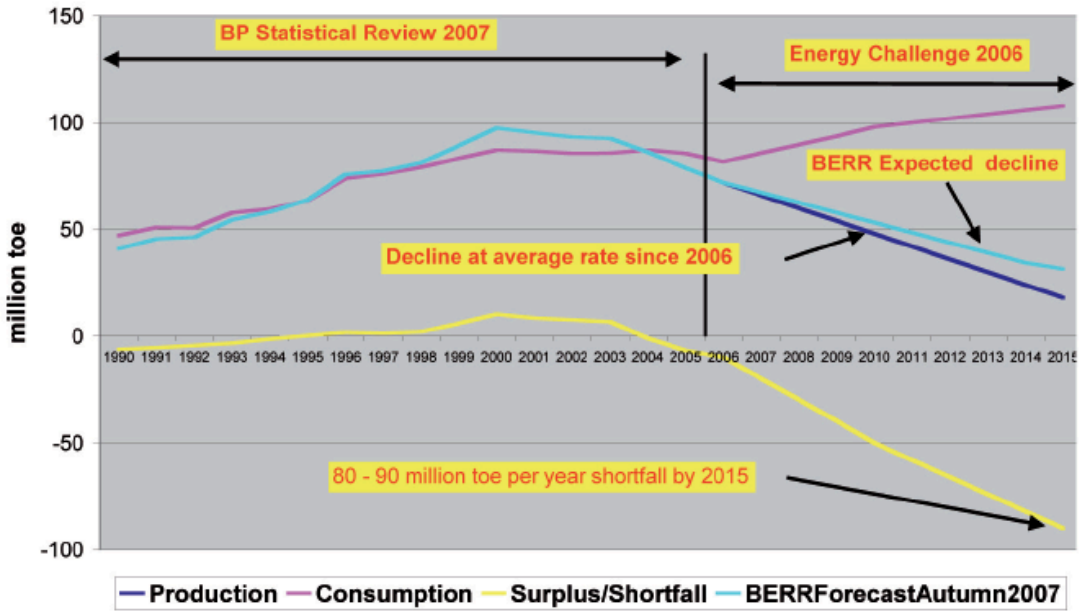
Required New Capacity Build Rate



6. Cumulative Capacity Commissioning in each year to 2018 required to maintain a 25% margin (MW).

Source: John Constable, Hugh Sharman,
Electricity Prices in the United Kingdom: Fundamental Drivers and Probable Trends (2008)

UK Natural Gas Production



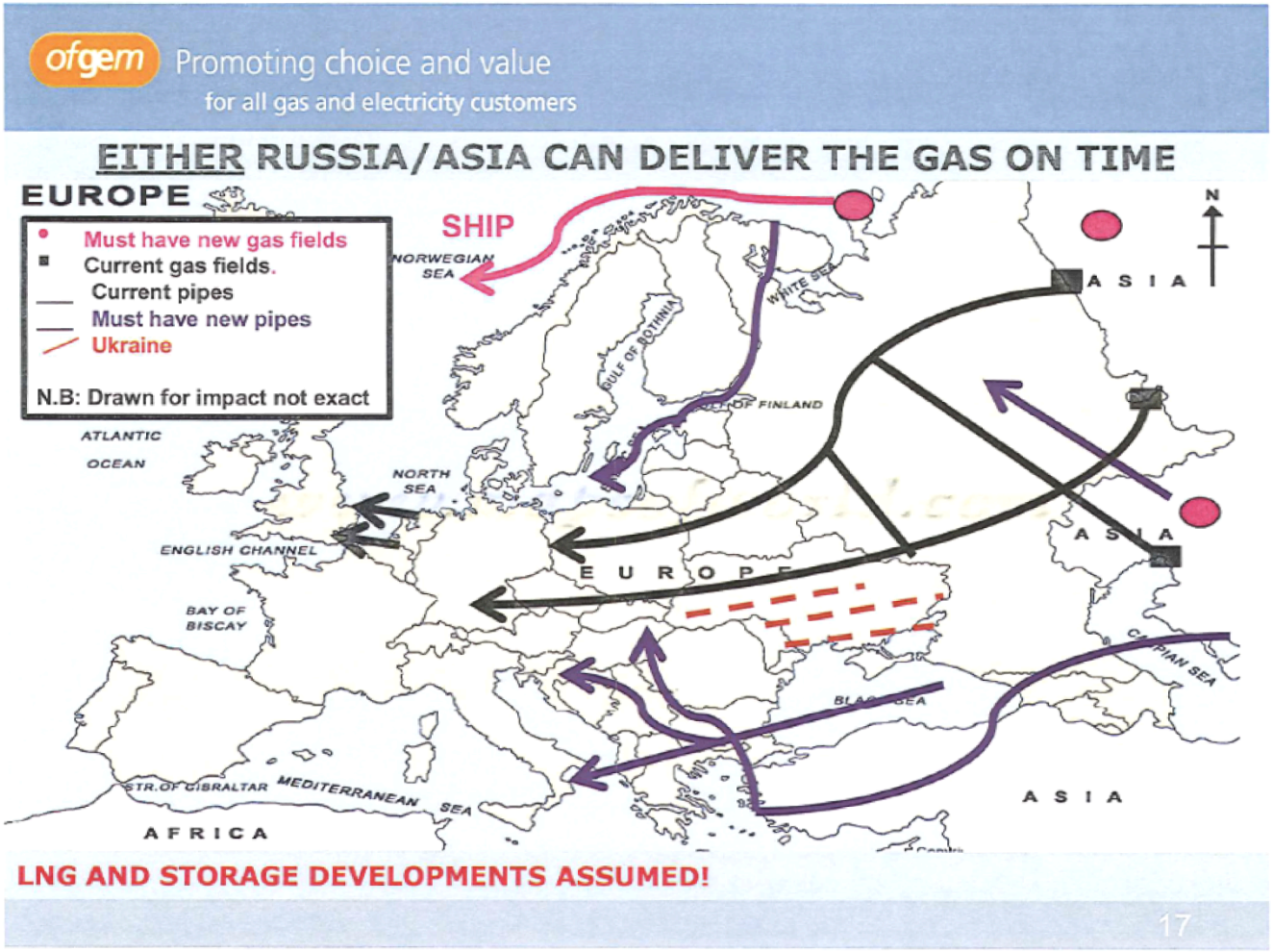
17. UK Natural Gas Production & Consumption to 2015. Sources: BP, *Statistical Review of World Energy*, DTI, *The Energy Challenge*, 2006.

Source: John Constable, Hugh Sharman,
Electricity Prices in the United Kingdom: Fundamental Drivers and Probable Trends (2008)

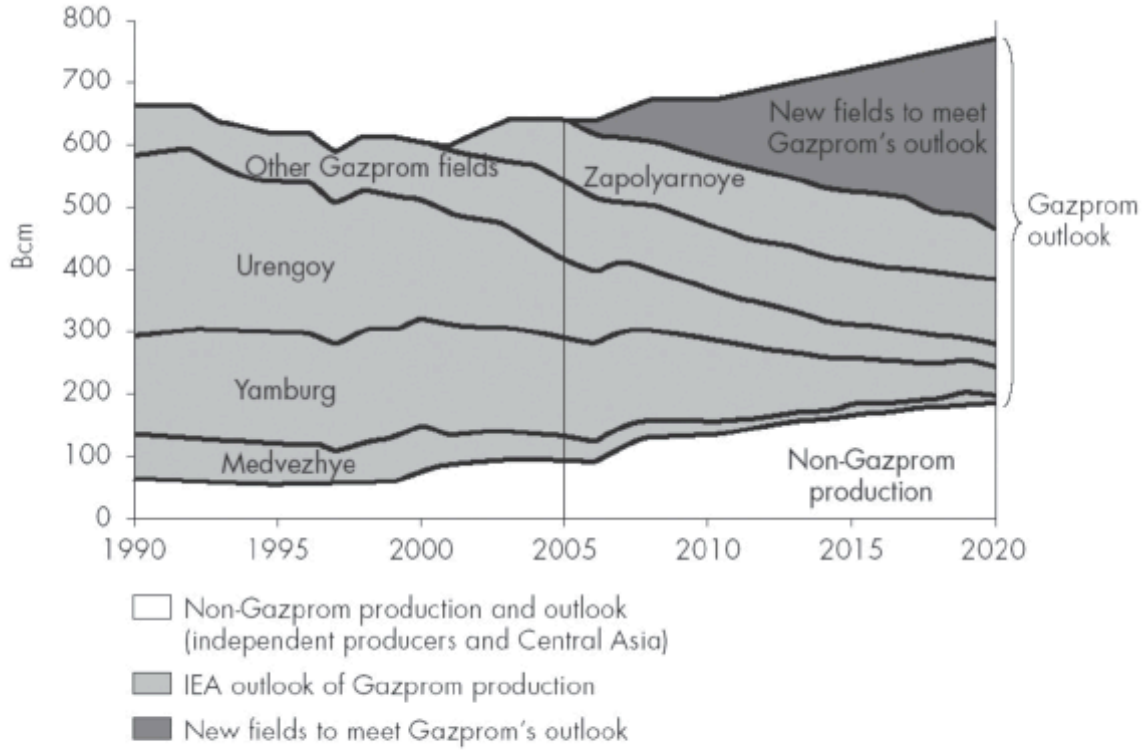
EU and UK Gas Demand and Supply

- EU demand in 2020: 700bcm
  - UK demand 100 bcm
- Gazprom: 220bcm
  - Assuming Shtokman
- LNG: 156bcm
- Other (Norway): 324bcm
  - Assumes Nabucco
- If all goes well, demand is supplied

$135bn of Gas Infrastructure Needed



Russian Gas Production



23. Russian Gas Supply Outlook. Source: IEA Estimates. © OECD/IEA.[33]

Conclusions

- EU renewables policies misconceived
- UK (and EU) overly gas-dependent, and at risk of price shock and interruption of supply
- *Force majeure* use of older coal stations likely
- New coal and nuclear are essential
- Renewables have potential as fuel savers, but economic and physical integration is a daunting engineering challenge