Electrical Energy Consumption and Markets

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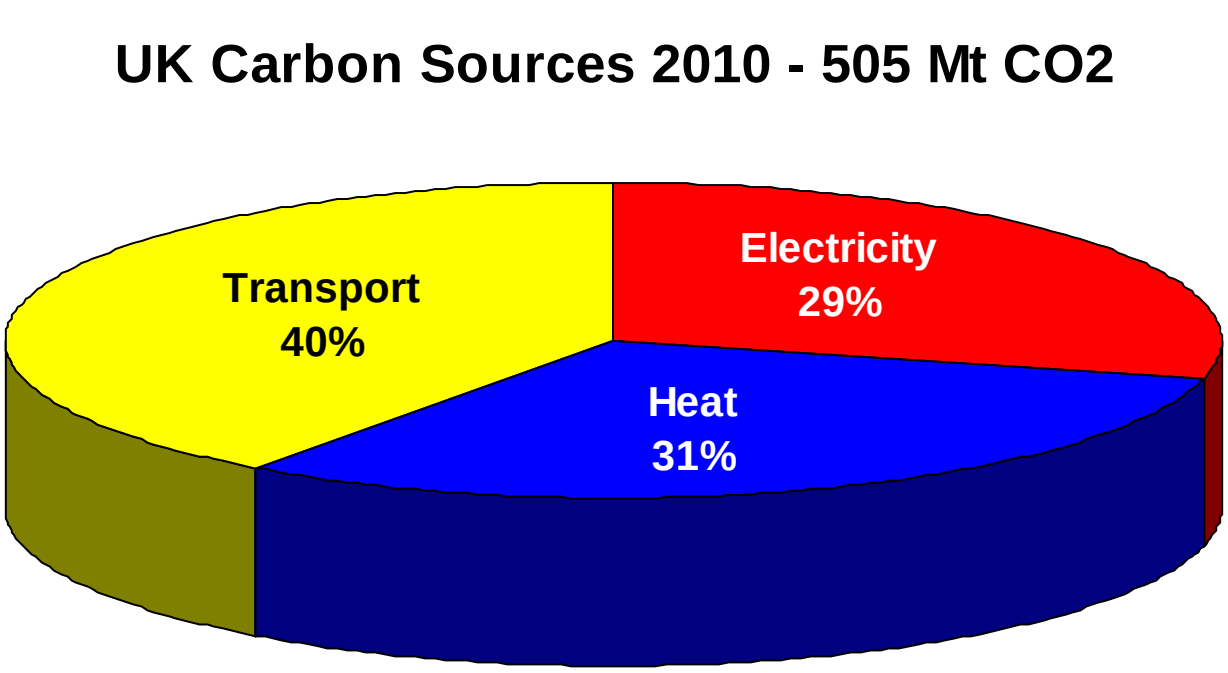
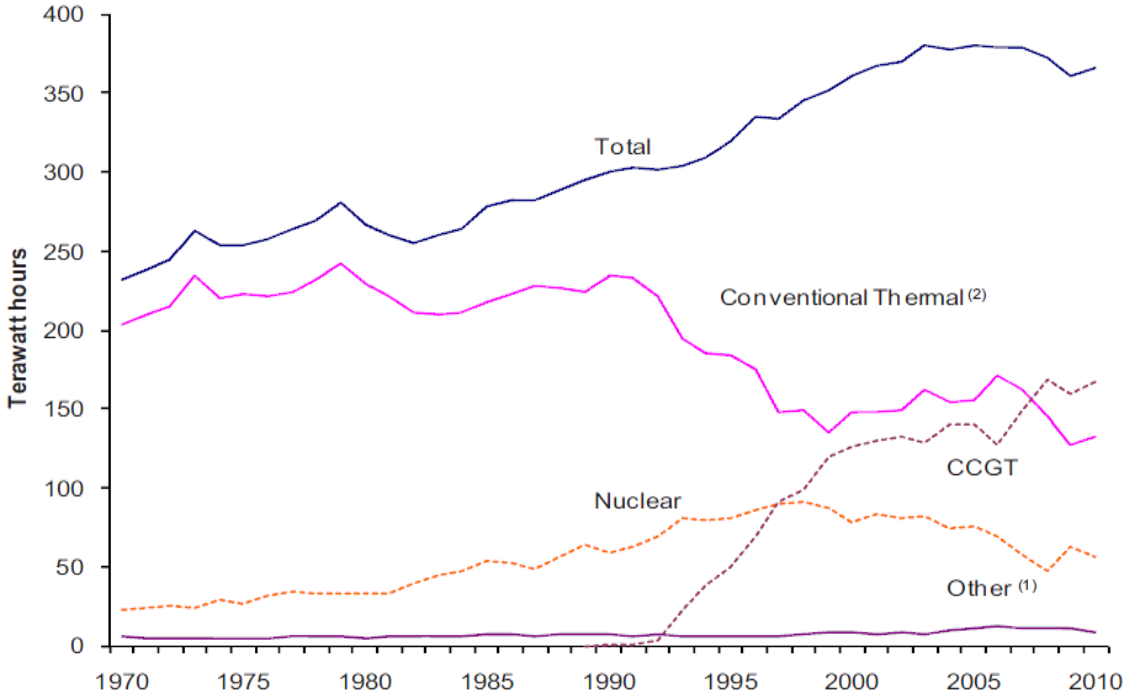
Electricity Supply



Source: National Grid

Electricity Supply

Increase in total electricity supplied and type of plant 1970-2010

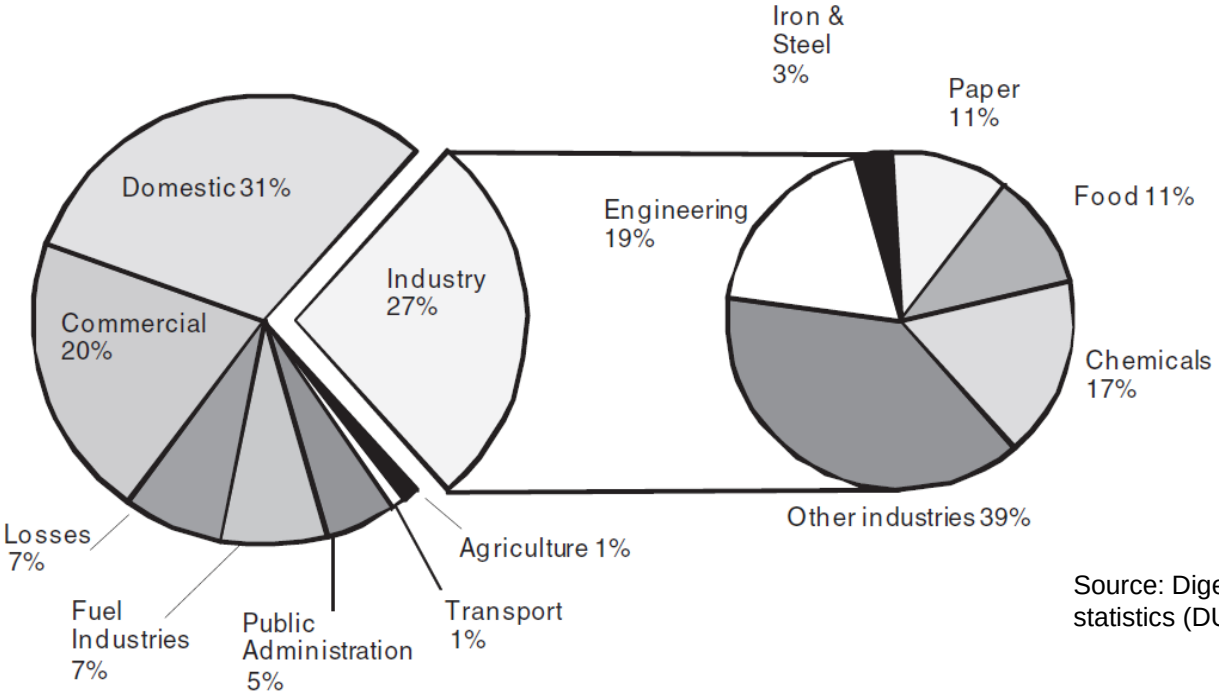


Source: Digest of UK energy statistics (DUKES) 2011

Total of ~ 400000 GWh produced in the UK per annum

Electricity Demand

Electricity demand by sector in 2010



Source: Digest of UK energy statistics (DUKES) 2011

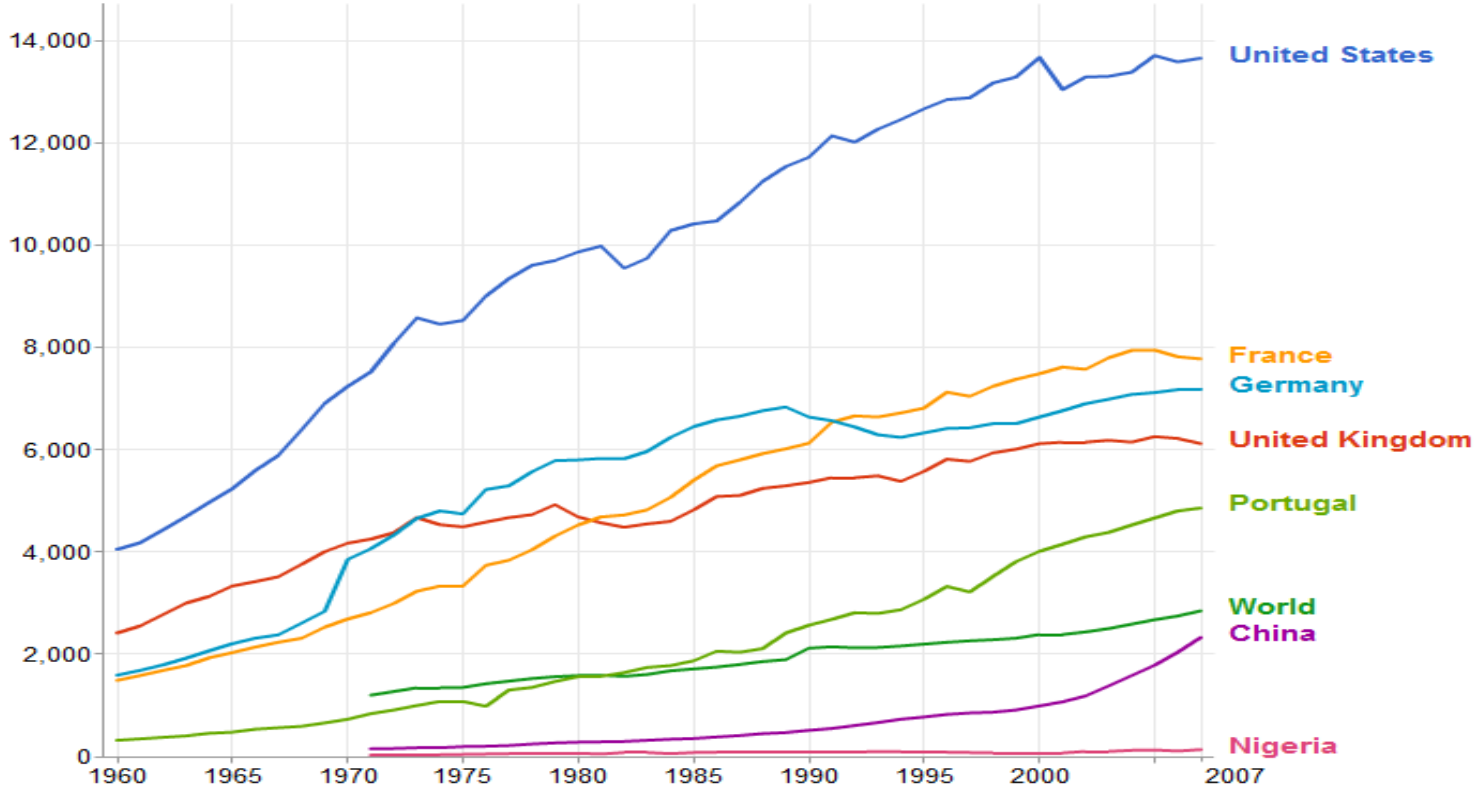
Total demand 384003 GWh

Industry demand 104499 GWh

Electricity Demand

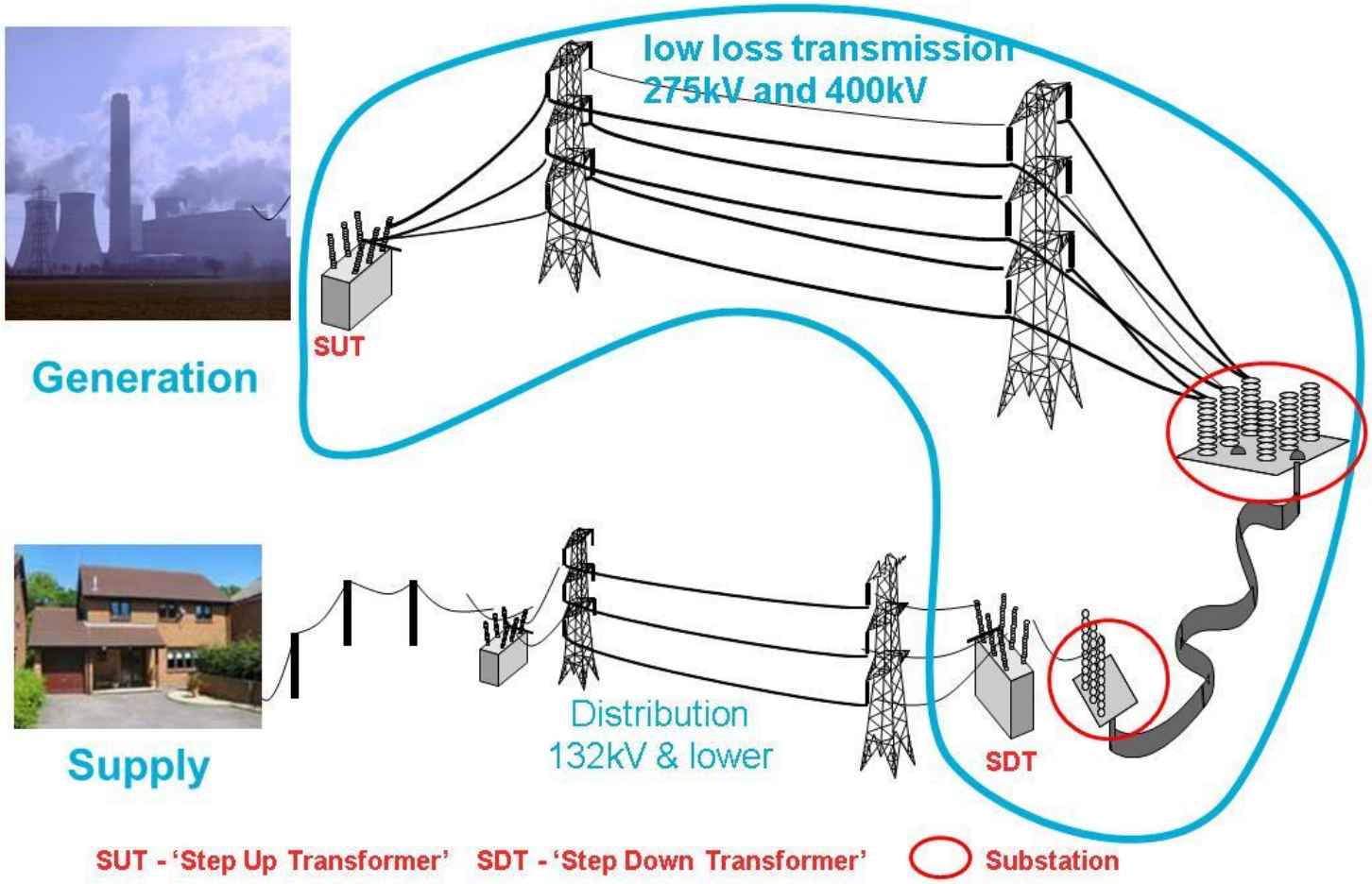
Electric Power Consumption (kWh per capita)

(Electric power consumption measures the production of power plants less transmission, distribution, and transformation losses and own use by power plants)



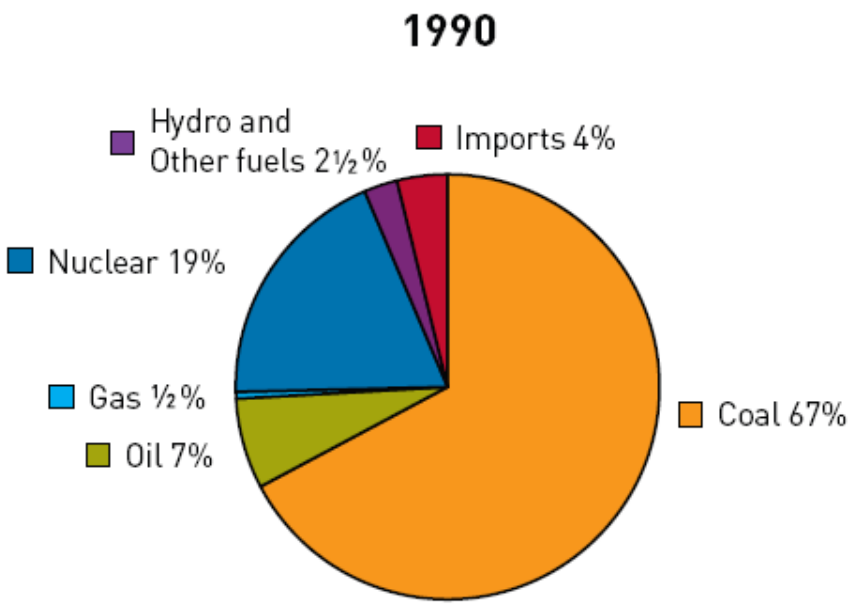
Source: International Energy Agency, World Bank – World Development Indicators

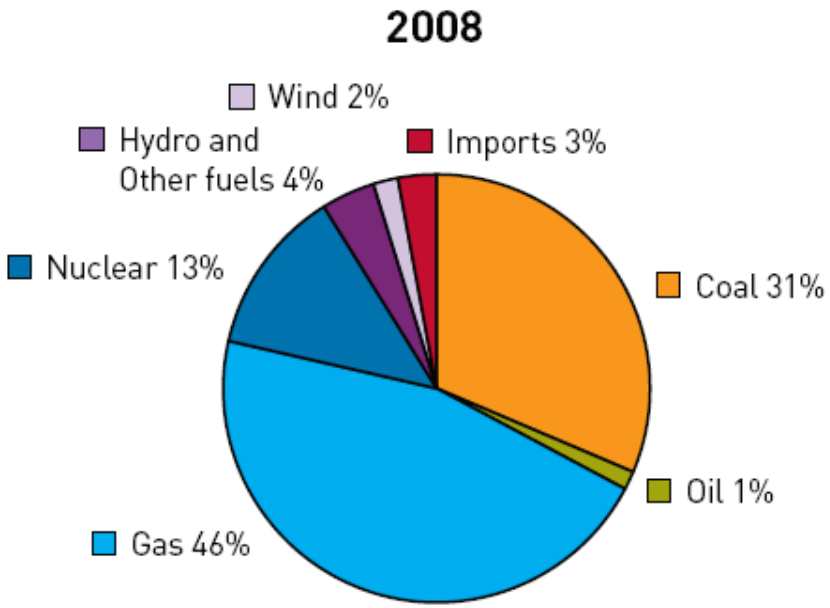
UK electrical network



Electricity Supply

Fuel used in electricity generation in 1990 and 2008





Hydro includes both natural flow and pumped storage

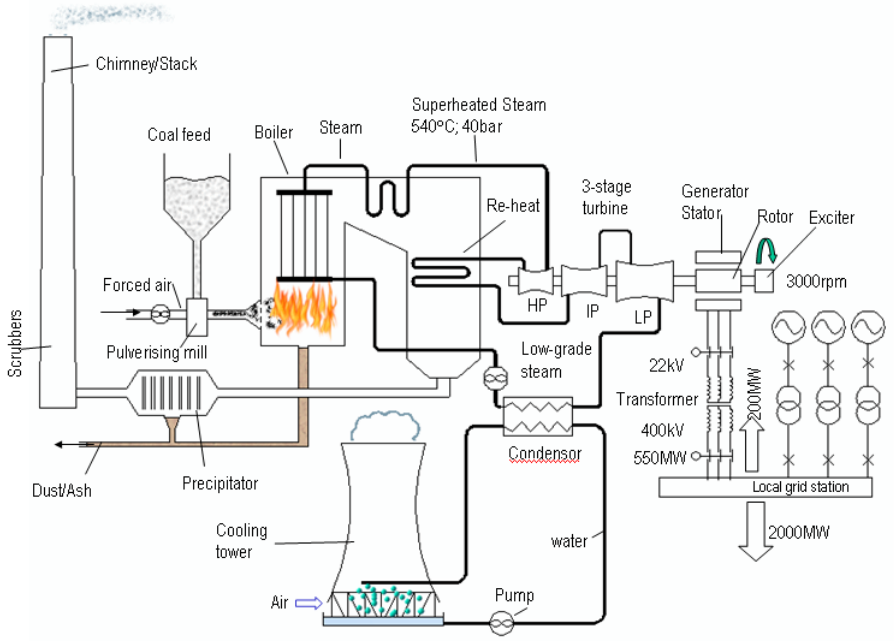
Source: Digest of UK energy statistics (DUKES) 2009

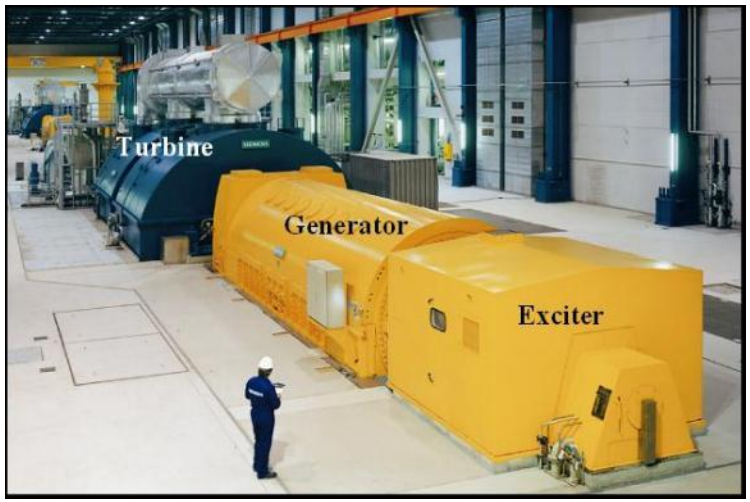
- **Diversity required to protect the supply of electricity from fuel availability difficulties and cost fluctuations**
- **Diversity required to cover the different operational conditions as no energy storage in the system (e.g. fast response for rapid load changes)**

Electricity Generation

Thermoelectric Power Station

- Burns fossil fuel (coal,oil etc.) to generate steam which drives steam turbine connected to the electrical generator
- Usually sited near source of fuel (e.g. coalfield) and plentiful supply of cooling water (e.g. river or coast)





Electricity Generation

COAL & OIL

- Relatively cheap
- Slow response to load fluctuation (4 – 8 hours to start–up)
- Practical thermal efficiency ≈ 35-37%
- 500MW per machine is typical (but up to 1000MW are possible)
- Run 24hours/day BASE LOAD stations

NUCLEAR

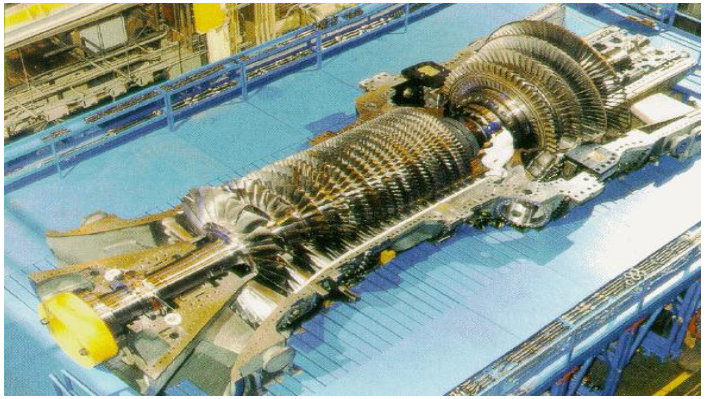
- Low fuel costs
- High construction and decommissioning costs
- Handling/storage of nuclear waste
- Practical thermal efficiency ≈ 40%
- 500MW per machine
- Run 24hours/day i.e. BASE LOAD stations

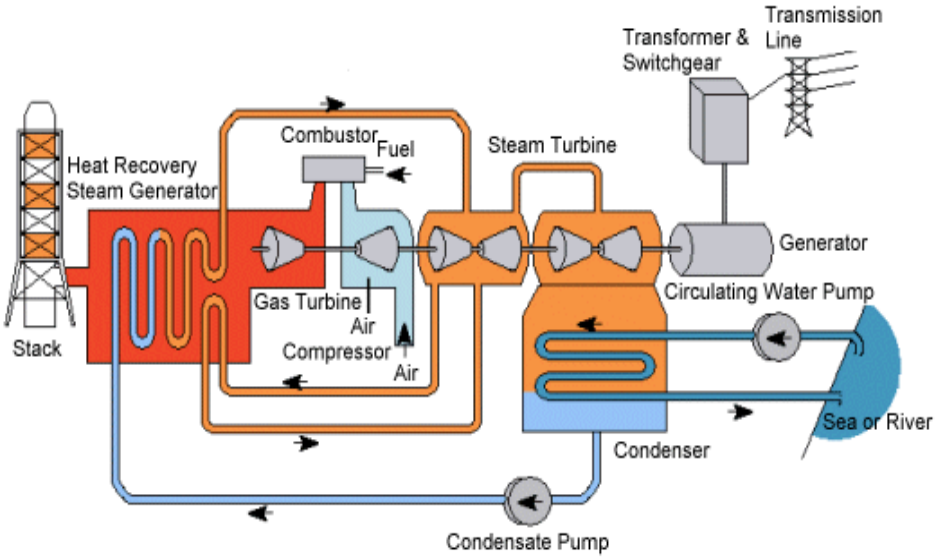
Electricity Generation

COMBINED CYCLE GAS TURBINES (CCGT)

- A gas turbine generator generates electricity and the waste heat is used to raise steam to generate additional electricity via a steam turbine
- Very fast response (Start-up 2 – 3 minutes)
- Currently cheap (availability of natural gas and turbine technology)
- Usually relatively low power (often sited near to load centres)
- 10-300MW per machine
- Practical thermal efficiency ≈ 60%

- More efficient so use less fuel





Electricity Generation

COMBINED HEAT AND POWER

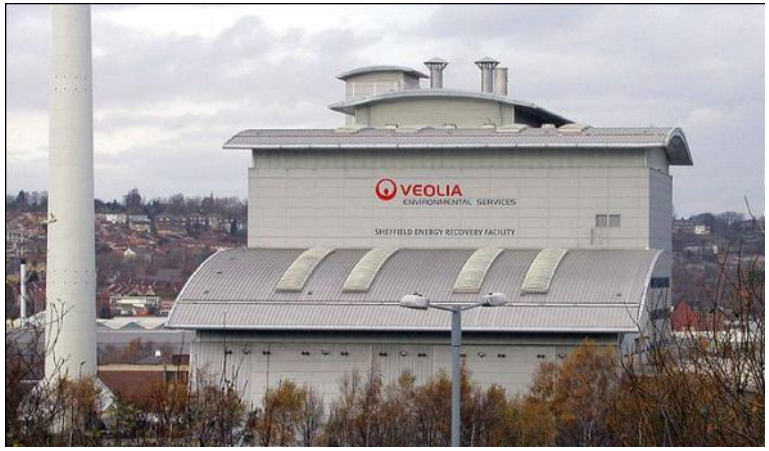
- **Either waste heat from gas turbines used to provide heating OR, heat from combustion of fuel for heating also used to raise steam and drive turbine for electricity**
- **Sheffield Heat and Power – incineration of refuse, used for district heating and provides electricity**

Utilises 225000 tonnes of household waste per annum

Produces 60MW of heat to 140 buildings (including the University) through 44km pipes (≈ 120000MWh/annum)

19MW of electrical power (≈ 22600 homes)

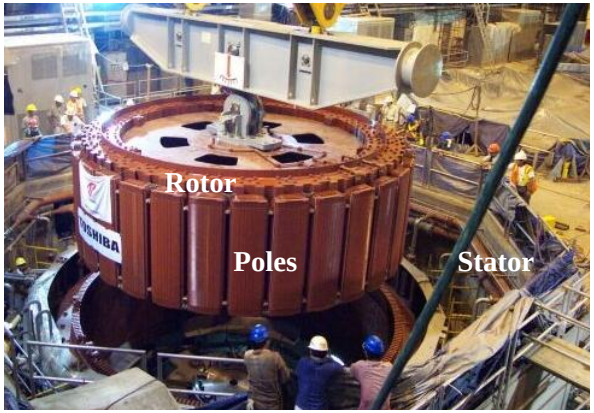
Over 12000 tonnes CO_2 prevented/annum



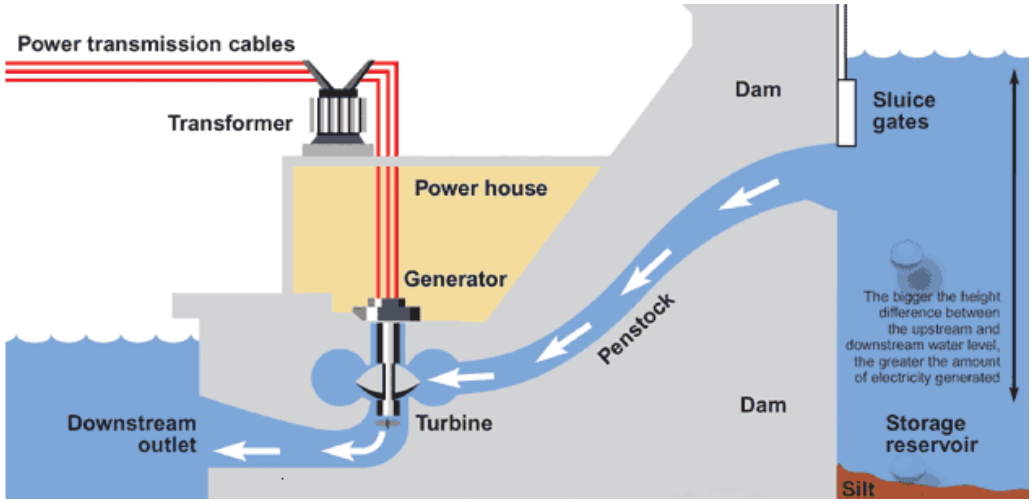
Electricity Generation

HYDRO-ELECRTIC – NATURAL FLOW

- **Geography (not prevalent in UK, most in Scotland)**
- **In other countries Hyrdo can be significant (Norway 99% is Hydro)**



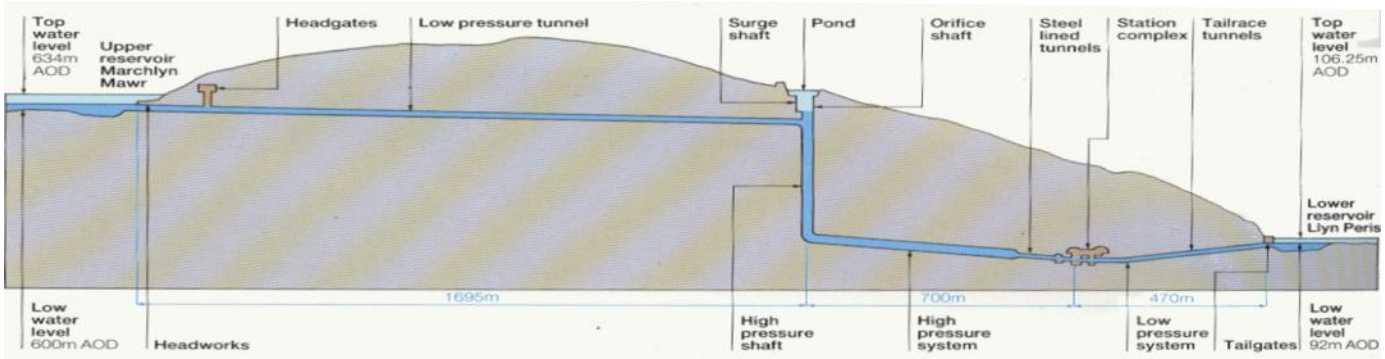
500MVA, 15kV, 200 rpm generator
Diameter 9.2m; 2.3m long, 378 Slots



Electricity Generation

HYDRO-ELECRTIC – PUMPED STORAGE

- **Used to meet peak demands (peak lopping)**
- **Head of water pumped back electrically when demand is low and electricity is cheap**
- **Fast response**
- **E.g. 1740MW Station, Dinorwig, Wales**
  6 pump/generator sets
  1740MW generation (typically 5 hours/day)
  1650MW pumping (typically 7 hours/day)
  Zero to full output in under 16s



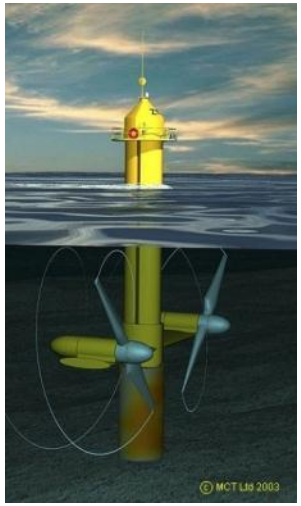
Electricity Generation

WIND POWER

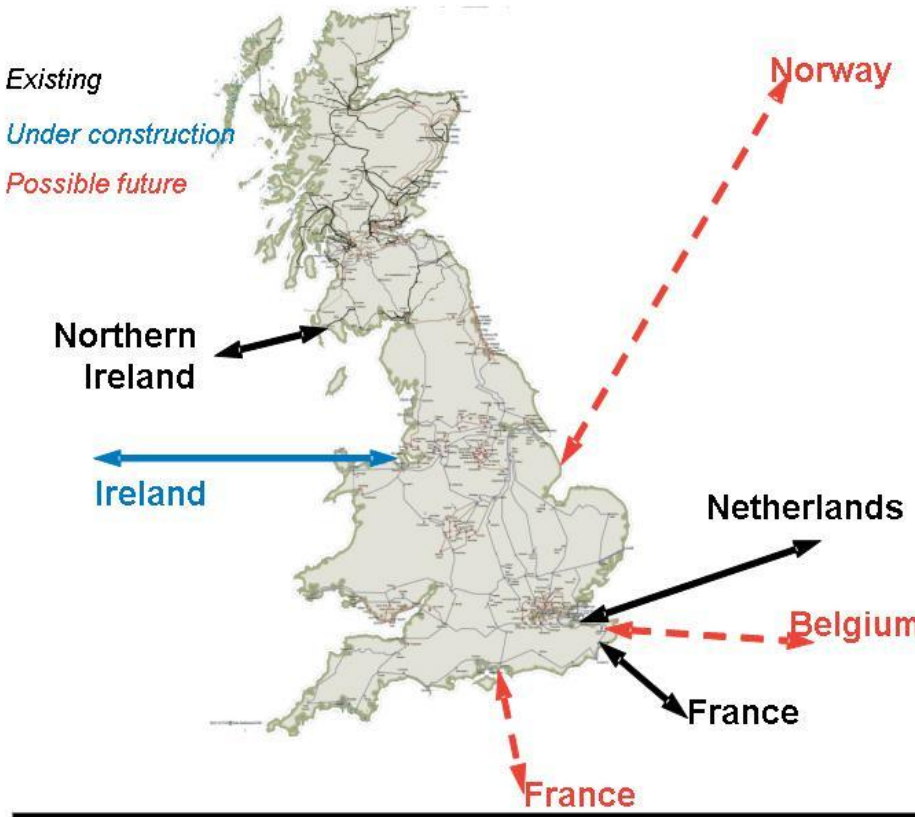
SOLAR POWER

WAVE POWER

TIDAL POWER



Interconnects



GB-Netherlands (BritNed)

- Subsea cable laid (~260km)
- Converter stations at Massvlakte and Grain constructed
- Operational beginning 2011

GB-Belgium (Nemo) ~ currently 2019

- 1000 MW, 150km sub sea cable
- Connection secured in GB and Belgium

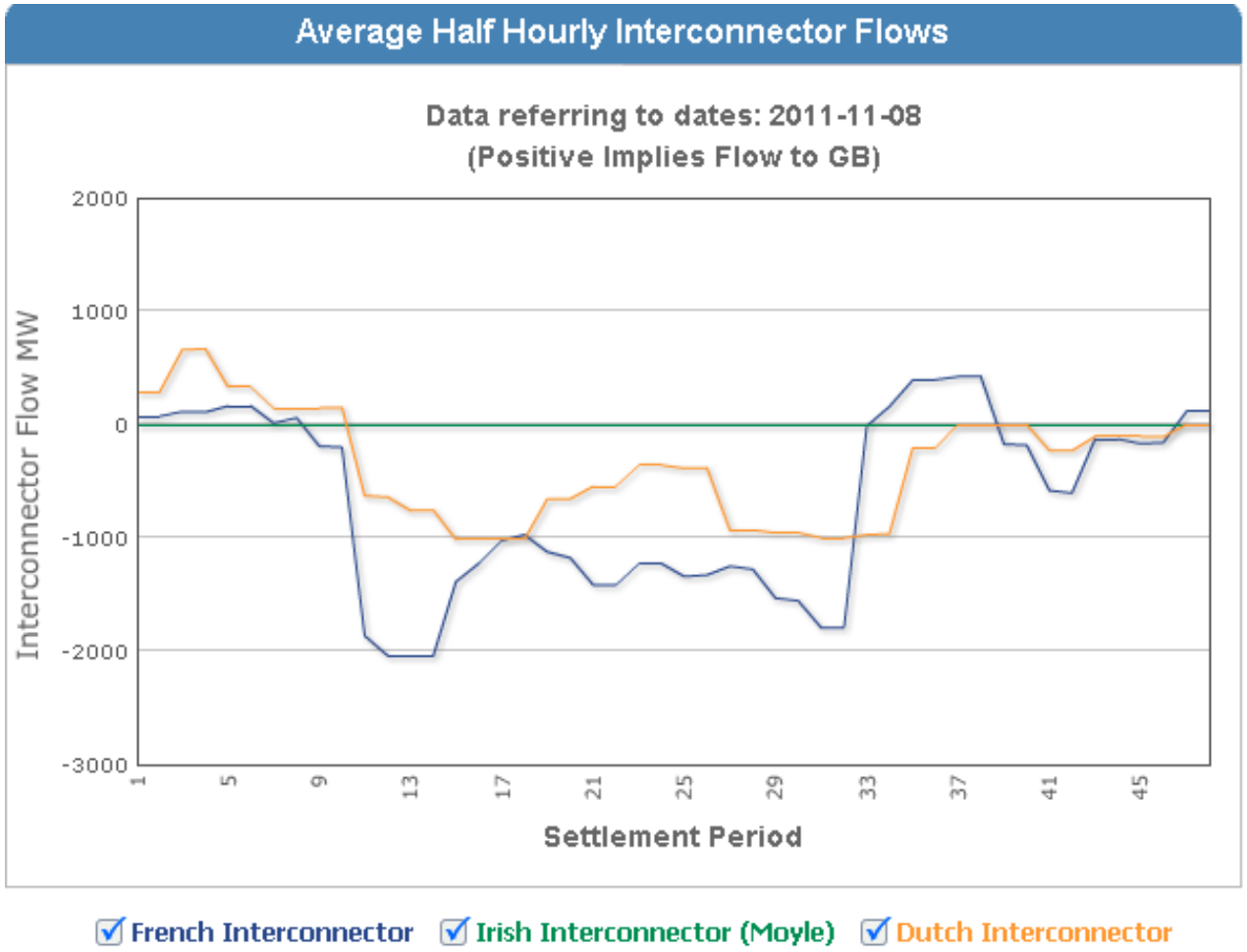
GB-France (IFA2) ~ currently 2018

- 1,000MW, 170km sub sea cable
- Feasibility stage

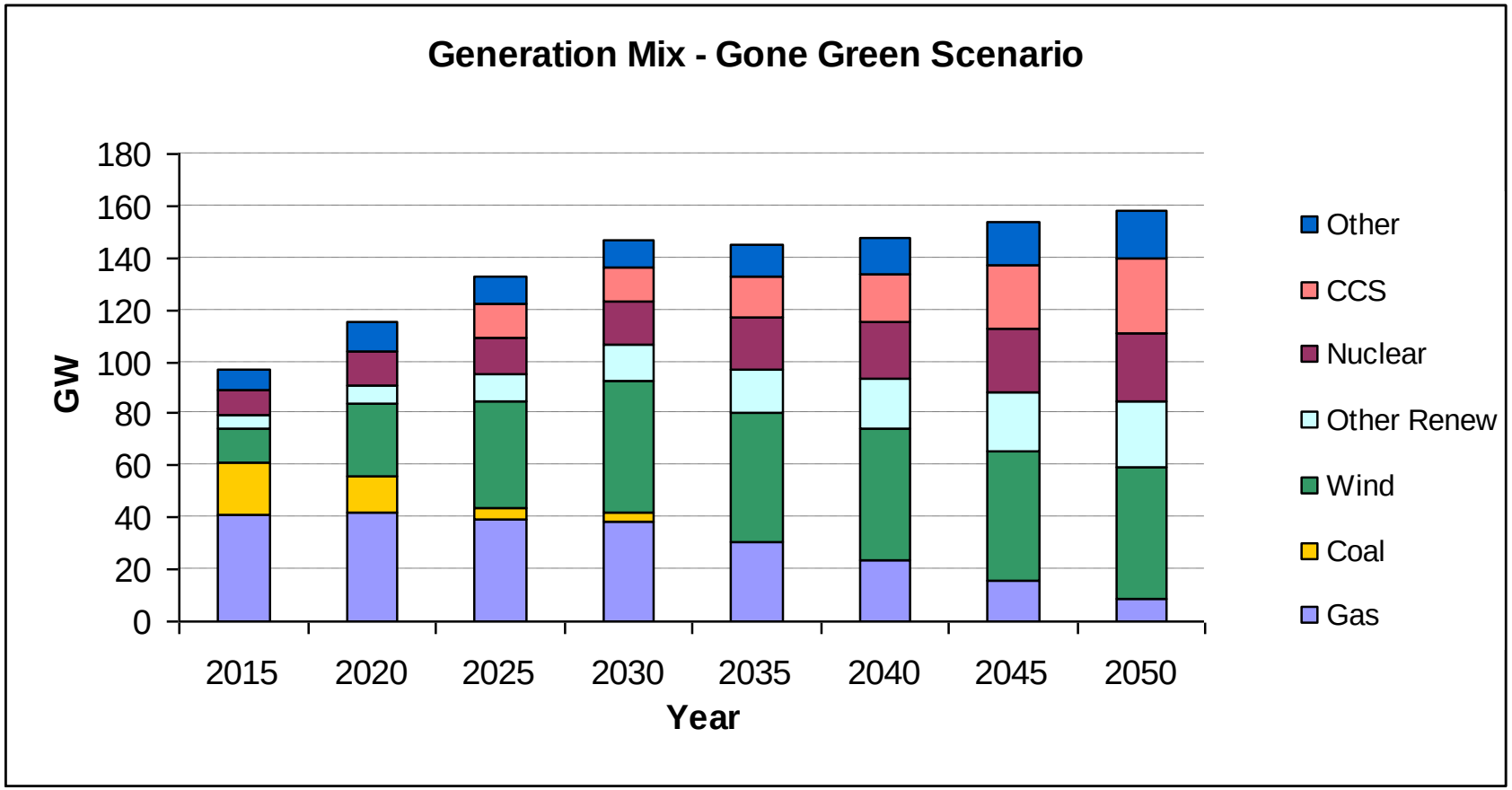
GB-Norway (NSN) ~ currently 2018/2020

- 1,000MW, 850km sub sea cable
- Connection secured in Norway

Interconnects



Electricity Generation - Projections



Source: National Grid

Frequency variation

- National Grid has statutory obligation to keep frequency within ±1% of 50Hz
- Affects the efficiency and performance of electrical equipment
- Mechanical power = Electrical Power (frequency =50 Hz)
- Mechanical power > Electrical Power (frequency >50 Hz)
- Mechanical power < Electrical Power (frequency <50 Hz)

Frequency

Generation

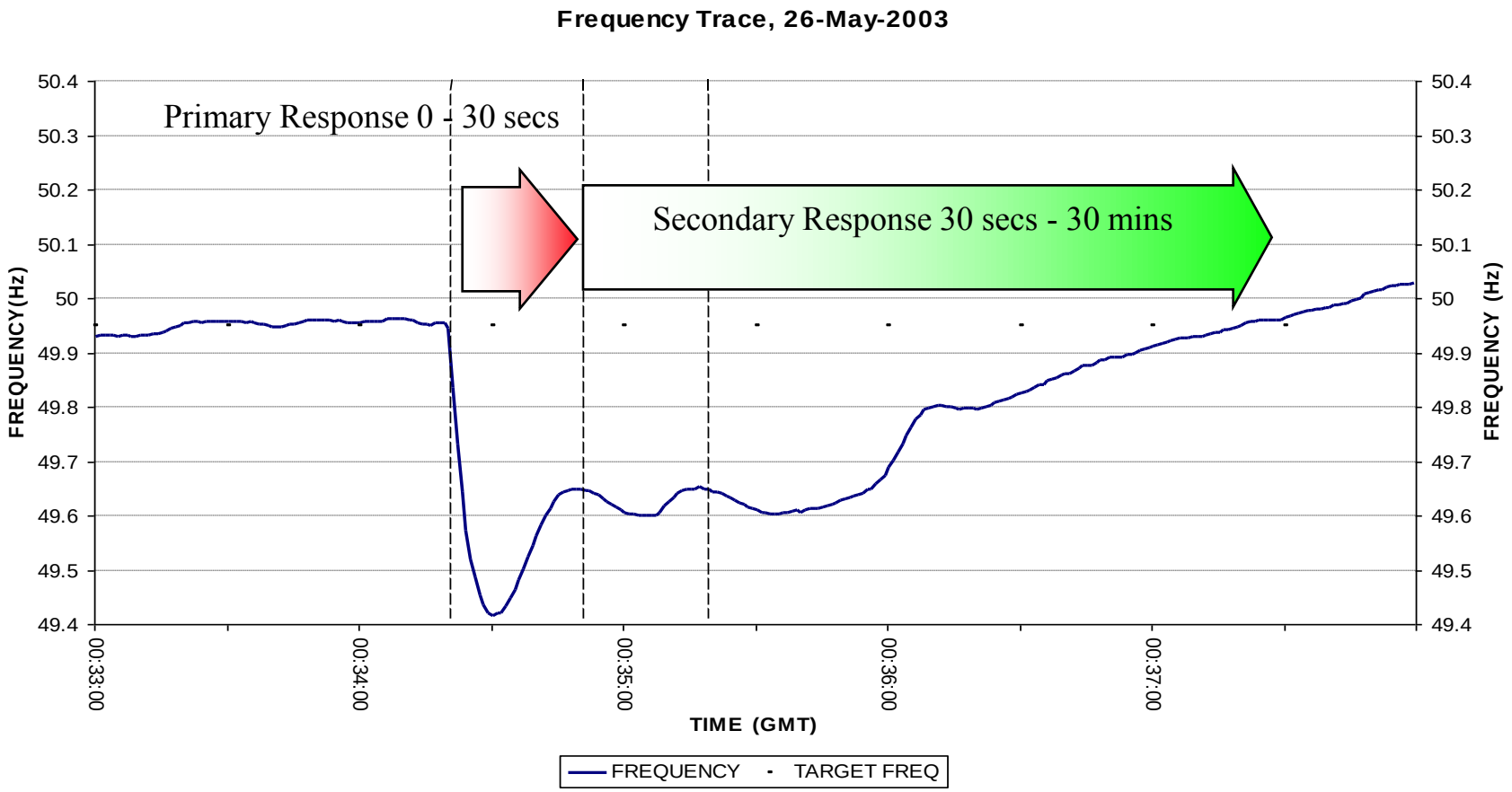
Demand

50.0 Hz

50.0	Normal operating frequency
50.5	Upper statutory limit
52.0	Generators tripping
49.5	Lower statutory limit
48.8	Demand disconnection starts
47.0	Demand disconnection complete

Slide courtesy of National Grid

Frequency

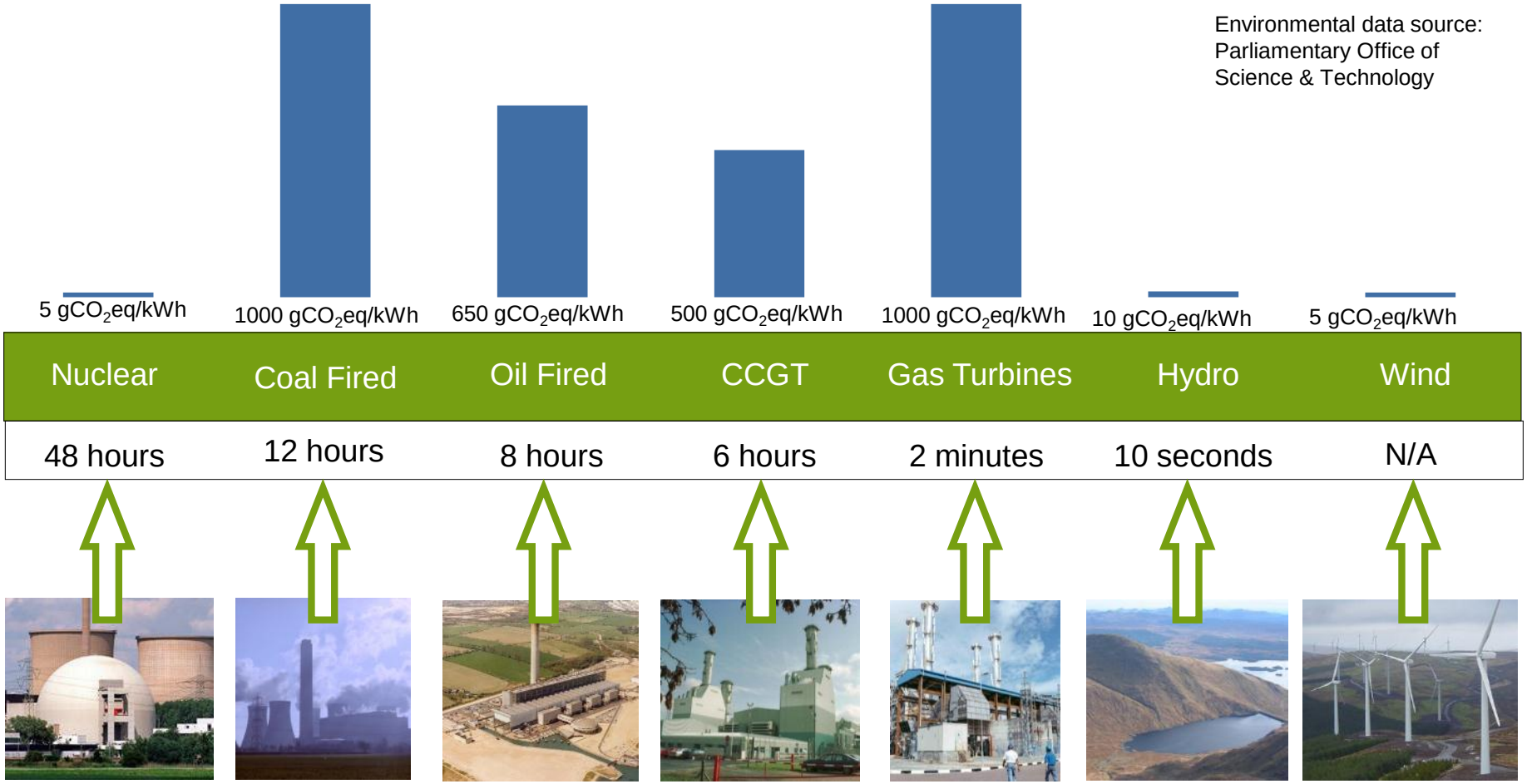


Source: National Grid

Effects of weather

Weather Effect	Demand Response	Generating Units (500MW)
Temperature (1° C fall in freezing conditions)	+ 1%	
Wind (10 mph rise in freezing conditions)	+2%	
Cloud cover (clear sky to thick cloud)	+3%	
Precipitation (no rain to heavy rain)	+2%	
Temperature (1° C rise in hot conditions)	+1%	

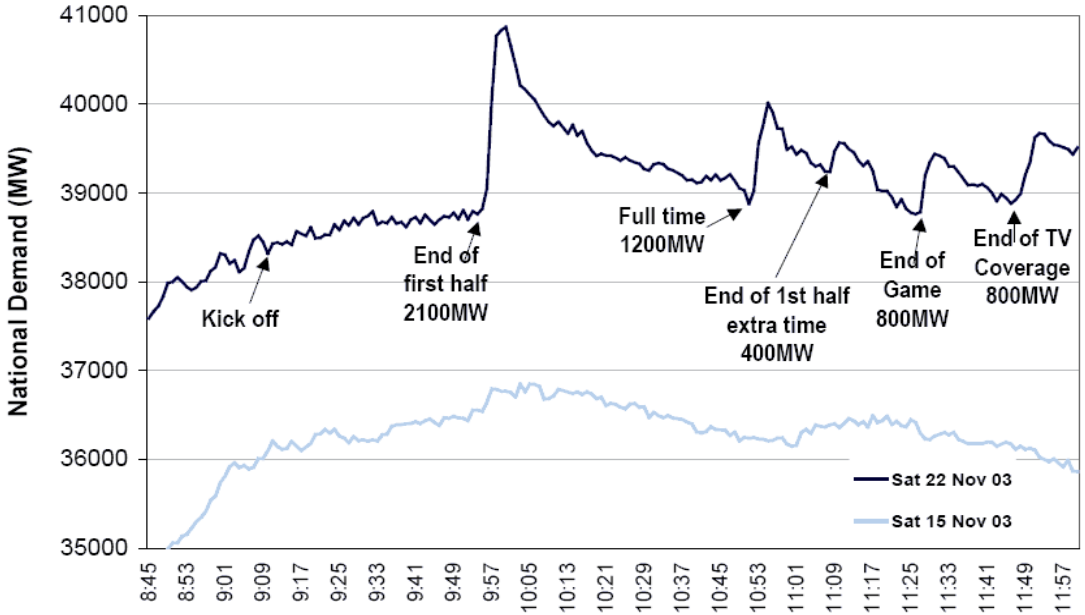
Forward planning



Electricity Demand

TV PICKUPS

- Peaks caused by kettles, toilet flushing (water pumps) in intervals and end of programmes
- National Grid spend significant effort in monitoring TV schedules and weather to try and predict future demand.



England vs Australia Rugby World Cup Final (22/11/2003)

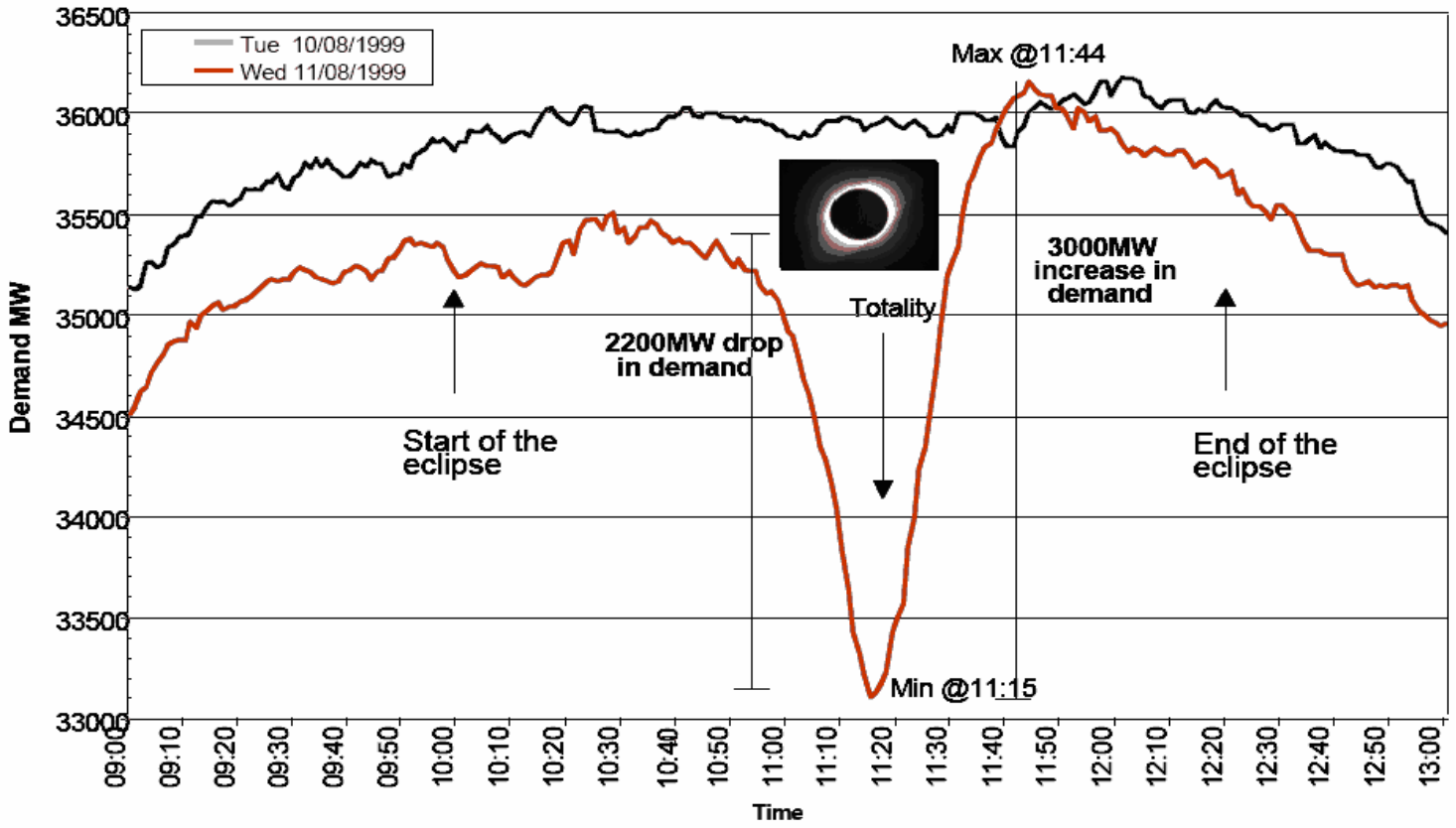
4/7/1990,	World Cup Semi-final (West Germany v England)	2,800MW
22/1/1984,	The Thornbirds,	2,600MW
21/6/2002	World Cup (England v Brazil),	2,570MW
29/4/2011	Wedding of Prince William and Kate Middleton	2,400MW
12/6/2002,	World Cup (Nigeria v England)	2,340MW
5/6/2001	Eastenders (Who shot Phil Mitchell?)	2,290MW
8/5/1985	Dallas (Who shot JR?)	2,290MW
20/4/1991	Darling Buds of May	2,200MW
22/11/2003	Rugby World Cup Final	2,110MW
18/4/1994	Coronation Street	2,100MW

Top 10 TV Pickups

Electricity Demand

UNUSUAL EVENTS

- **Solar Eclipse 11th AUGUST 1999 – 3000MW Pickup following eclipse**

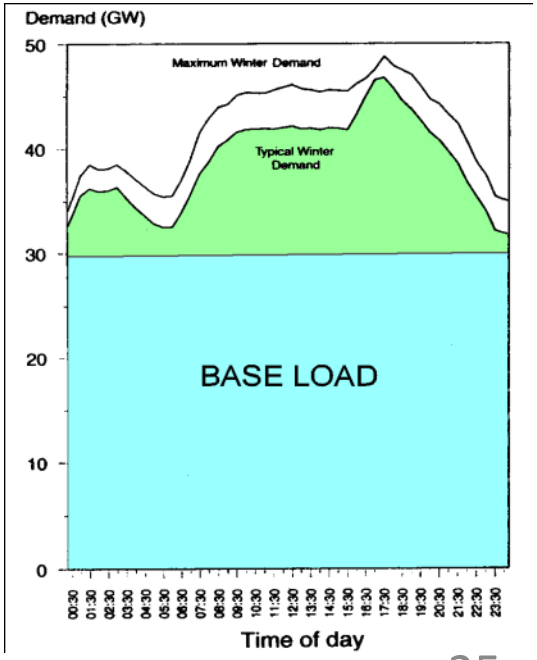


Electricity Demand

BASE LOAD

- **To cope with demand changes, a base load is defined - provided by high efficiency power stations**
- **Minimum amount of power that a distribution company must make available for its customers, or amount of power required to meet minimum demands based on reasonable expectations of customer requirements**

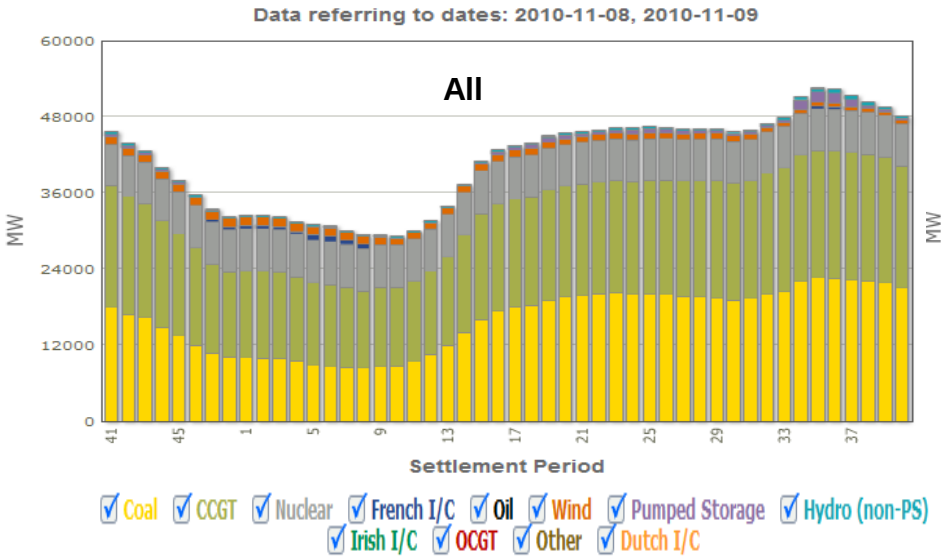
  - Fast response generators kept in reserve to deal with peak loads
  - Peak power is expensive as generators are idle for most of the time
  - Proportion of Generators are operated ≈ 75% load to allow overhead for peak demands and/or compensate for faulted generators
  - Pumped storage hydro also used for peak demands

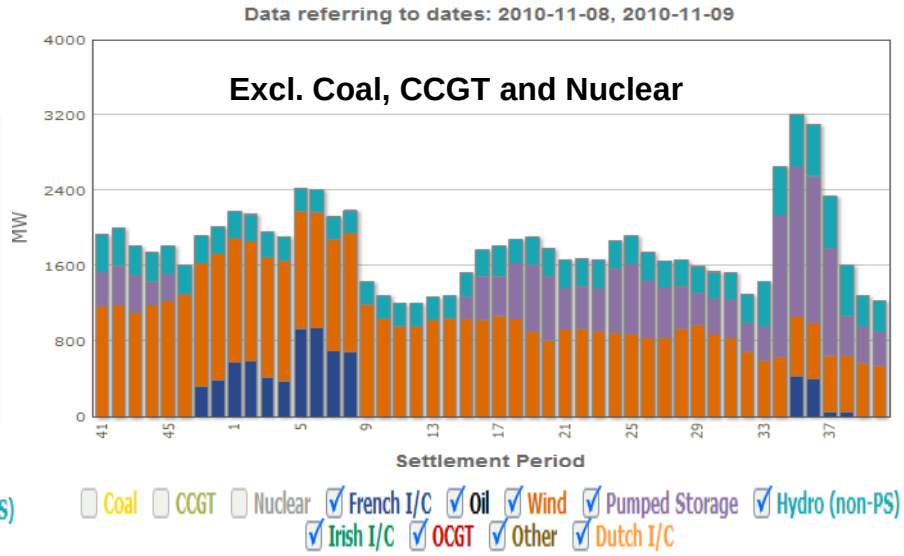


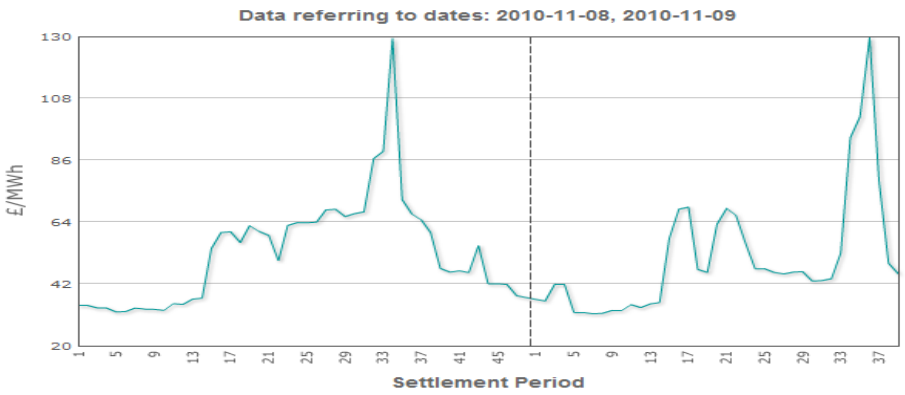
In addition to meeting demand it is crucial that voltage and frequency maintained
Domestic Voltage: 230V ±10% 50Hz ±1%

Electricity Generation

Electrical generation by type of plant







Wholesale cost of electricity

http://www.bmreports.com/bsp/bsp_home.htm

Source: National grid / NETA