The role of Nuclear in meeting the 2050 climate target

The Nuclear Institute - 24th June 2010

Duncan Rimmer – National Grid
Agenda – Roadmap to 2050

- Energy policy & climate challenge
- Primary energy & emissions
  - Electricity (incl. issues around new nuclear)
  - Transport
  - Heat
- Base Case & sensitivities
- Conclusions
Climate change key challenges

**Targets**
- 15% of all energy to come from renewable sources by 2020
- 80% reduction in CO2 emissions by 2050

**Energy policy objectives**
- Sustainability
- Secure energy supplies
- Affordability

The challenge is to meet all the targets and the policy objectives simultaneously, in a timely way.
Aim is to reduce emissions from 505M tonnes to 118M tonnes.

Aviation emissions remain the same (40M tonnes) due to difficulty in replacing jet fuel with low carbon sources.

All sectors emissions greater than 118M tonnes – need to take action on all.

Emissions for all other sources reduced from 465M tonnes to 78M tonnes.

Some consumption reduction is assumed but can hit target if don’t reduced consumption – but at additional cost.
Energy consumption by sector

- Consumption is reduced using the following measures
  - Heat
    - Insulation
    - Increased boiler efficiency
    - Use of Heat Pumps
  - Electric
    - Low energy lighting
    - A-rated appliances
  - Transport
    - Hybrids delivering greater efficiency
    - Batteries delivering further efficiencies
We need decarbonisation across all sectors...

- **Electricity**
  - Simple efficiency measures across all sectors
  - Decarbonised electricity fuels zero emission vehicles

- **Heat**
  - Insulate homes
  - Decarbonised electricity...
  - Heat pump
    - Mainly for new homes

- **Transport**
  - Efficient engines and integrated transport
  - and decarbonise transport
  - CNG
  - Biomethane
2050 – Overview of approach

- Model works on Carbon optimisation with highest CO2 sources being displaced first
  - Coal and CCGT replaced by Renewable, CCS and Nuclear
  - Coal and Oil heating being replaced by Gas, Biogas and Electricity where suitable
  - Petrol Transport being replaced by Plug in Hybrids and EVs for most transport and Hybrids where electrification not suitable.

- Supply chain constraint limits
  - i.e Nuclear at 30GW

- Cost optimisation also carried out to provide best economic solution for meeting CO₂ targets
  - Prevents power station being run at low load factors (i.e for peak heat demand during winter)
  - Least cost-effective method of Carbon mitigation used as last resort
Carbon intensity matrix

Decreasing Carbon intensity

Kg CO₂/MWh

Coal Electric

Petrol

CCS Coal

H2 Fuel Cell

CCS Gas

Solar CHP

Oil Heat

Coal Heat

PHEV

Gas Heat

Gas CHP

EV

Wind

Solar PV

Biogas

Nuclear

Solar Thermal

Wave/Tidal

Heat

Electric

Transport
Energy Consumption - Electricity

- Decline (25%) in uses for traditional electric appliances from
  - Use of low energy/LED lighting
  - Improve appliance efficiency
- Full roll-out of electric transport from late 2020s as
  - Spare low-carbon electricity is available
  - Electric car battery issues/costs are resolved
- Spare Low–Carbon electricity used for both heat and electric purposes for future planning despite electrification of transport giving larger emissions reductions
# Electricity Generation Mix 2010-2050

<table>
<thead>
<tr>
<th>Year</th>
<th>TWh</th>
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<td>2046</td>
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<td>2050</td>
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- **Interconnector**
- **Oil**
- **Coal**
- **CCS**
- **CCGT**
- **Wind**
- **Renewable**
- **Nuclear**
- **CHP**
Electricity Supply - 2020

- Stations are run in order of Carbon intensity
- 28GW of wind on system
- Small amounts of other renewable (hydro, tidal, biomass)
- New nuclear build after retirements allow for 11GW of nuclear generation (2.5GW retired, 2.8GW new build by 2020)
- Demonstration CCS Coal plants supplying 2.4GW in total
- Large amount of unabated coal still available but run at low load factors for low wind, high demand conditions
- Interconnector refers to assumed import levels, floating interconnectors are excluded.
Electricity Supply - 2050

- Increase in CCS generation – operates at load factor of 50%
- Large increase in nuclear generation to 30GW – replanting all existing sites to maximum capacity and a small number of new sites
- Some wind is not replanted due to economic viability without subsidy
- Increases in electric generation used for heating homes and in transport (roll out of electric cars largely complete by mid 2040s)
- Approx 15GW of interconnection capacity is available to allow for different amounts of renewable generation
Electricity generation mix rationale

- High Carbon generation replaced with low Carbon Sources
- Nuclear first as cheaper and near zero emissions
- CCS next most economic but limited by 2050 Carbon limit
- Wind used substantially in early years as CCS not commercial and long timescales for nuclear – hits 2020 renewable target
- Only replanted where economic to do so.
- Sensitivities to Base case exist for low/high nuclear cases and when CCS isn’t viable.
The network challenge: electricity transmission

- Future potential investment to connect Scottish renewables
- Potential wind farm sites
- Potential nuclear sites
- Future potential onshore load related investment
- Existing network
Issues around new nuclear

- Planning
  - Station design & consents
  - OHL consents
- Capital cost
  - Current overruns
  - Learning rates
- Operational cost
  - Maintenance
  - Uranium cost
  - Waste
- Supply chain
  - Significant new build around the world
Road Transport: Consumption in Base case

- Total miles driven remains flat
- Reduction in energy due to efficiency gains (tank to wheel)
  - Average current petrol engine (25%)
  - CNG/Petrol Hybrid (40%)
  - Electric powered (70%)
- Some vehicles are unsuited for electrifying
  - HGVs (20% of road transport energy), Hybrids can be used instead
Fossil fuel consumption declines with energy consumption

Greater use of biofuels provides 10% of energy requirements for Petrol vehicles

From late 2020’s electric vehicles price/capacity developed enough to make commercially viable

Petrol/CNG Hybrids provide fuel for HGV’s

CNG vehicles marginally more expensive than Petrol but deliver carbon savings
Heat: Consumption – Base Case

- Energy usage in existing buildings drops by a third due to improvements in insulation and turning down of thermostats.
- 10 million well insulated new homes require additional 60 TWh of energy by 2050.
- Overall reduction in heat output (existing and new stock) of 25%.
- Boiler improvements and use of heat pumps reduce the amount of input energy required, hence an overall decrease in input energy of around 34%.
Heat: Supply – Base Case

- Oil and Coal use eliminated
  - Replaced mainly by electric although gas network can expand
- Increased use of electric heating as carbon intensity of electric drops below gas
- Increased use of Biogas
  - 100 TWh in base case
- Increased use of Solar Thermal and wood/biomass.
- Majority of fossil gas is used in high temperature industrial processes
Future heating options and costs

- Gas is cheapest fuel but also has highest Carbon intensity (235kg/MWh)
- Heat Pumps require investment in networks and power stations – Carbon emissions depend upon source of electricity
- Solar Thermals deliver little heat on coldest days
- Biogas and gas can be stored to deliver heat at high demand times.
- Direct low-carbon electricity can also be used – cost and emissions are dependant on power plant.
Heat curve flattens with improved insulation but still peaky compared with electric
Combined electric and heat daily load duration curves

- Heat 2050
- Electric 2050 (with Transport)
- 100% LF line

Current network capacity 80GW (2000GWh/day)

Day

GWh

0 500 1000 1500 2000 2500 3000 3500 4000 4500

1 37 73 109 145 181 217 253 289 325 361

105 GW

45 GW

55% Load factor

100% LF line

national grid
The power of action:
Economics of heating using Biogas/CCS or Gas

Impact of decreasing load factor

- **Fuel cost**
- **Capital Cost**

<table>
<thead>
<tr>
<th>Load factor</th>
<th>£/MWh</th>
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<tr>
<td>85%</td>
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<td>75%</td>
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<tr>
<td>25%</td>
<td>Biogas Cost</td>
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<tr>
<td>15%</td>
<td>Gas cost</td>
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Coal Cost

CCS Cost

The power of action:
Energy demand and carbon emissions in 2050

The graph shows the energy demand and carbon emissions across various sectors and technologies in 2050. The upper graph illustrates energy demand in GWh across different days, with categories including Gas (Heating), Biogas, Solar Thermal, CCGT, CCS, Wind/Renewables, Nuclear, Gas (CNG), Petrol, and Aviation.

The lower graph displays carbon emissions in Mtonnes CO2, with categories such as Nuclear, Wind, CCS, Coal, CCGT, Solar Thermal, Zero Carbon Gas, Fossil Gas, Oil for Road, CNG For Road, Aviation, and a Target line.

The data suggests significant shifts towards renewable and zero-emission technologies, with a reduction in fossil fuel reliance.
2050 – Average Day

Low Carbon Energy Sources
(Maximise Use)

- Nuclear
- Renewable
- Carbon Capture
- Biomass
- Biogas

High Carbon Sources
(Minimise Use)

- Fossil Gas
- Petrol/Diesel

Electricity Network
(Sized for Typical Day)

Road

Gas Network

Household

Smart Grid manages interaction between electric and gas demand along with wind intermittency

Lighting/Appliances

Heating/Storage

Boilers

Plug In Hybrid Electric Vehicles

Heat Pump/Boilers

Plug In Appliances

Road Network

(Sized for Typical Day)
2050 – Low Wind/High Demand Day

Low Carbon Energy Sources
(Maximise Use)

Nuclear
Renewable
Carbon Capture
Biomass
Biogas

High Carbon Sources
(Minimise Use)

Fossil Gas
Petrol/Diesel

Electricity Network
(Sized for Typical Day)

Road
Gas Network

Lighting/Heat Pump/Boilers Plug In Appliances Storage Hybrid Heating

Household

Smart Grid manages interaction between electric and gas demand along with wind intermittency
<table>
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Conclusions

- Key priorities from modelling
  - Energy efficiency
  - Nuclear & CCS
  - Battery technology & cost & smart technology
  - Economic wind & heat pumps
  - Use of gas/biogas for peak heating

- Other key priorities
  - Energy policy (market, SoS, communication)
  - Planning
  - Investment