Role of electricity and hydrogen storage in low carbon energy system – Modelling in Temporal MARKAL model

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International Energy Workshop
3 July 2008

Outline

- UK MARKAL models
- DfT Hydrogen infrastructure project
- Flexible time slice in MARKAL
- Strengths and challenges
- Insights from temporal model
- Concluding remarks

The UK MARKAL model

- The first UK MARKAL model was developed for the 2003 Energy White Paper
- Extensively updated during 2006-08 through the UK Energy Research Centre (UKERC)
- Development and application of the model is maintained by a consortium of UK research organizations
  - King's College London
  - AEA Energy and Environment
  - Policy Studies Institute
  - Imperial College
  - University of Oxford
- Objectives of the consortium
  - To maintain the model's transparency, peer review and open access
  - To ensure that in iterative updates there is only one core model structure and data-base of the UK MARKAL model family, thus avoiding competing models

Application of the UK MARKAL model

- DTI: Energy White Paper 2007
- DfT: State-of-art modelling of hydrogen infrastructure (with flexible time slice and GIS link)
- SuperGen: UKSHEC1 Hydrogen visions
- WWF 2050 Vision (80% CO2 reduction including international aviation)
- UK-Japan Low Carbon Scenarios
- UKERC Energy 2050 scenarios
- OFGEM: Electricity networks scearnio
- SuperGen: UKSHEC2 Plus
- SuperGen: Bioenergy
- TSEC (Towards sustainable energy economy) - Biosys
- EON

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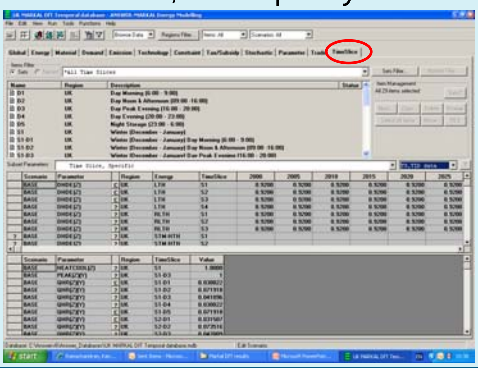
DfT Horizon project

- Five projects explored different aspects of the practicality & timing of the introduction of the infrastructure required to support hydrogen-fuelled vehicles funded by the *Department for Transport*
- **A state-of-the-art modelling of hydrogen infrastructure development for the UK: Geographical, temporal and technological optimisation modelling**
  - Methodology/tool: MARKAL energy system model
    - A soft link to GIS database
    - An improved temporal representation
- Full reports are available from http://www.dft.gov.uk/pgr/scienceresearch/futures/horizons/june08

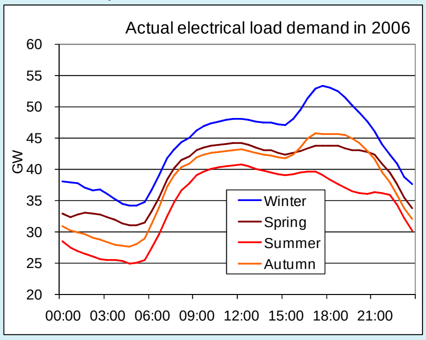
Temporal-MARKAL: Flexible time slice

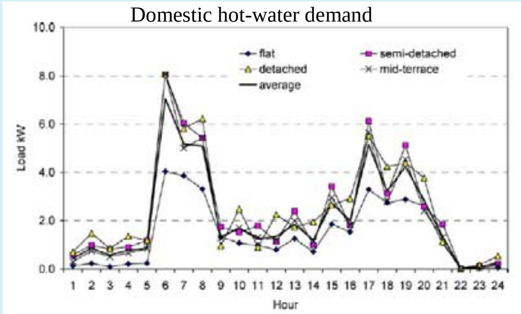
- Electricity & heat are tracked seasonally and diurnally.
- By default six time slices in the standard MARKAL
  - Electricity load by six day/night and seasonal splits
  - Heat by three seasonal splits
- In flexible time-slice, user specify the number of time-slices



How many time slice can to be chosen?

- Depends on variations in electricity-driven energy service demands & energy resources
- UK experience:



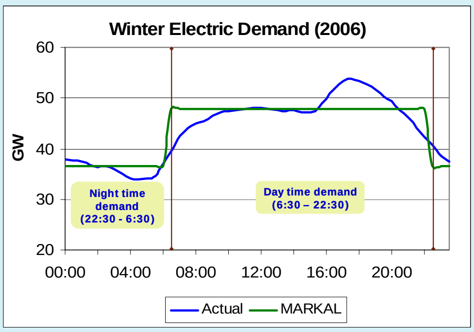


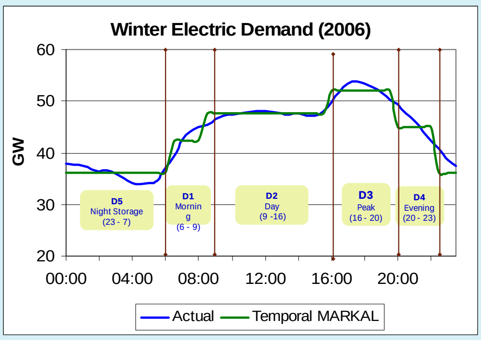
- Number of time slices - 20 Annual time periods from the original six

Diurnal	**Seasonal**
1. Morning: 6:00 – 9:00 (D1)	1. Winter: December – February (S1)
2. Daytime: 9:00 – 16:00 (D2)	2. Spring: March – May (S2)
3. Evening peak: 16:00 – 20:00 (D3)	3. Summer: June – August (S3)
4. Late evening: 20:00 – 23:00 (D4)	4. Autumn: September – November (S4)
5. Night storage: 23:00 – 6:00 (D5)	

Strengths – Power sector

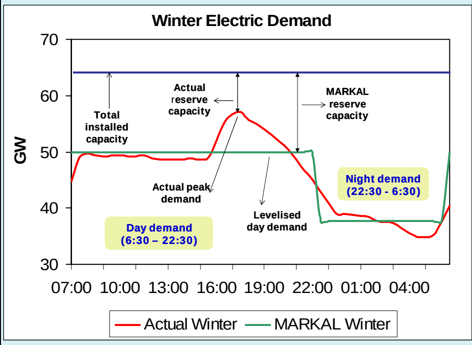
- Flexibility to model electricity demand profile thereby get a better fit on electricity demand

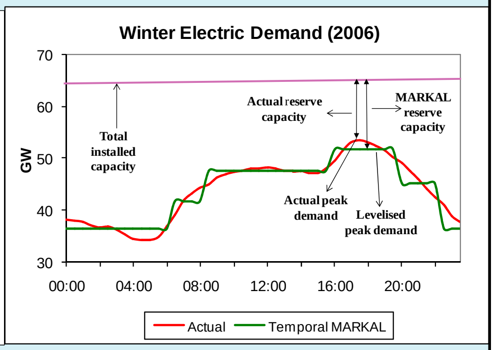




Strengths – Power sector

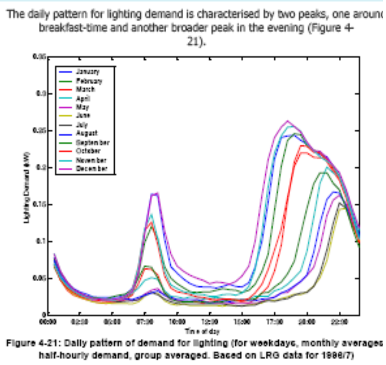
- Better convergence of actual versus MARKAL electric demand margins, i.e. levelised electric peak and actual peak demand.
- More justifiable electric reserve margin



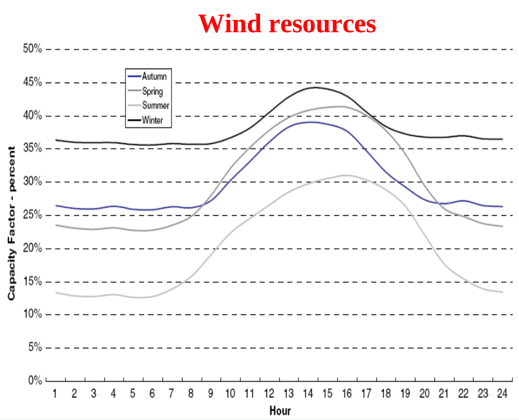


Strengths – Demand & Resources

- Detailed modelling of fluctuating energy service demands
- Seasonal representation of intermittence renewable energy sources



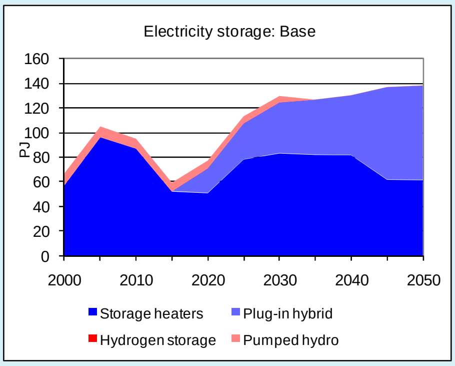
Residential lights

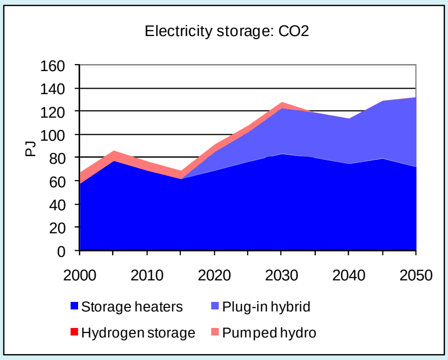


Challenges

- Storage is still limited to ONE period (YNITE). Therefore a period to period storage is not possible to deal with intermittence renewable energy sources
- Data Issues
  - Diurnal/seasonal break-up of energy service demands is not commonly available though their electricity demand profile can be found
  - Similar issues on availability of data for energy resources

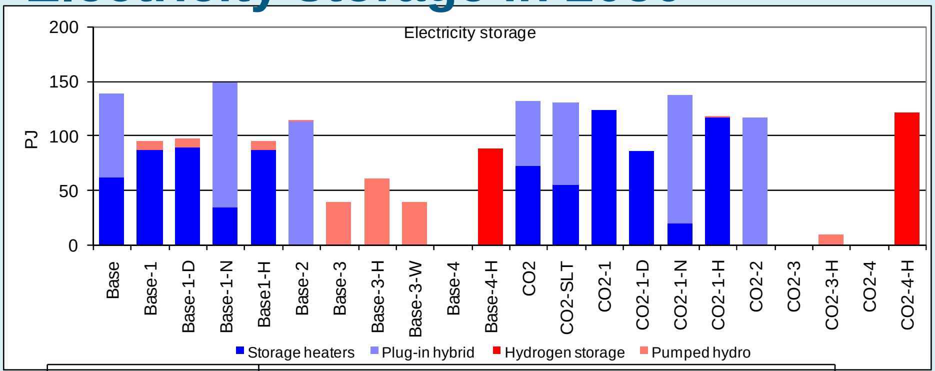
Electricity storage





- On average, the system chooses about 7 - 10% of electricity demand as storage
- Demand side storage is preferred, partly due to their lower costs

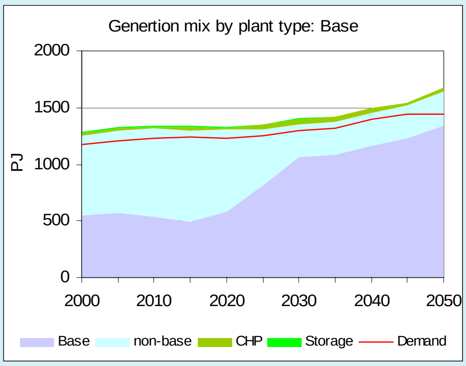
Electricity storage in 2050

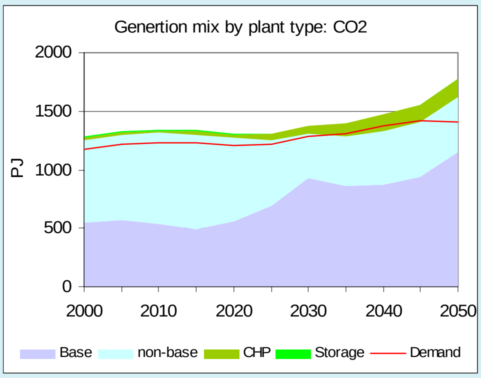


Base	A business as usual case
CO_2	60% CO_2 reduction from 2000 level by 2050
Base-** / CO_2-**	1: No plug-in hybrid vehicles 2: No night storage heaters 3: No plug-in or night storage heaters 4: No storage H: night storage hydrogen production enabled W: alternate wind profile enabled

Generation by plant type

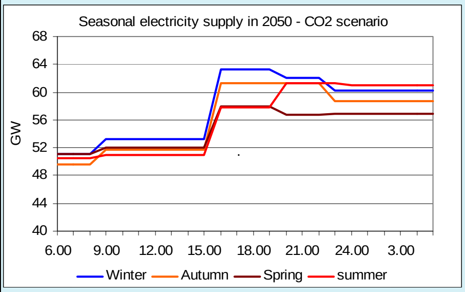
- **Better utilization of base load plants**

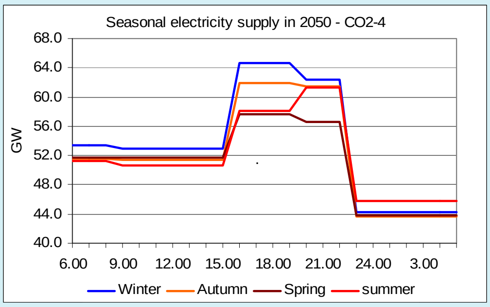




Power system balancing

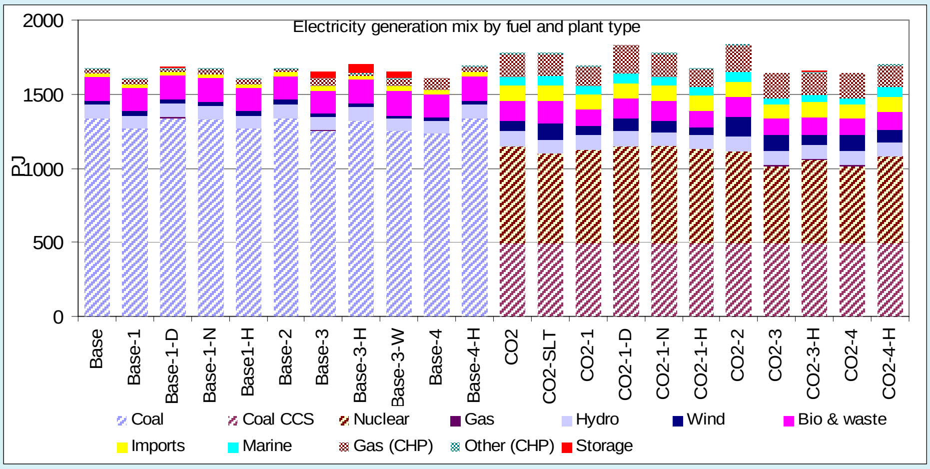
- Electricity storage is important as a power system balancing mechanism (even though a 20 time period model still represent aggregation).





With electricity storage **Without electricity storage**

Power generation mix in 2050



Concluding remarks

- **Flexible time slice is successfully implemented in the UK MARKAL model**
- **Temporal MARKAL enhances the depiction of electricity demand profile and representation of renewable energy resources**
- **Electricity storage is inevitable for system balancing. However, with ONE time period storage option in MARKAL, a detailed modelling of intermittence renewable is inadequate**
- **Other models (e.g. electricity dispatch model) could be used for intermittency analysis**

Thanks!

For further information

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  - Ramachandran Kannan - r.kannan@kcl.ac.uk
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- UK MARKAL documentation
  http://ukerc.ac.uk/ResearchProgrammes/EnergySystemsandModelling/ESMMARKALDocs08.aspx
- DfT hydrogen infrastructure reports
  http://www.dft.gov.uk/pgr/scienceresearch/futures/horizons/june08