Scenarios for the future of the gas networks
Paul E. Dodds
Scenarios

1. Heat transition
2. Decarbonised gas
3. Business as usual
Method for comparing scenarios

• Economic focus
• Model of the whole UK energy economy – UK MARKAL

• Assume:
  1. Iron Mains Replacement Programme continues as planned
  2. No security of supply issues for importing natural gas
  3. Micro-CHP fuel cells and CCS technologies become available in future
  4. UK CO$_2$ emissions will be cut by 80% in 2050 relative to 1990, to 118 MtCO$_2$
  5. No atmospheric CO$_2$ sequestration (e.g. biomass CCS)
Why this model?

**Funding**
- **2000**
  - Rapid simple structured model development to inform EWP 03
- **2007**
  - CCS enhancement for CAT strategy
  - Major 2 year UKERC programme; enhanced UK model with MACRO extension
  - MED model development with major CCC and UKERC scenarios
- **2010**
  - Stochastic MED model

**Model type**
- **2000**
  - STND
- **2007**
  - MACRO
  - MED Stochastic

**Methodology**
- **EWP 03**
- **CAT Strategy**
- **Energy Review**
- **EWP 07**
- **CCC Bill**
- **CCC 1st report**
- **LCTP**
- **CCC & DECC analysis**

**UKERC, Research council projects, UK-Japan LCS, Ofgem, NGOs etc**

**UK Government, CCC**
Methodology

Assessing Energy, Economy, Engineering & Environment (E4) Interactions

UK MARKAL

AVAILABILITY/CHOICE OF TECHNOLOGIES

GDP & CAPITAL REQUIREMENTS

MINING LIMITS & TRADE

ENERGY SERVICE DEMANDS

ENVIRONMENTAL LIMITS

ENVIRONMENTAL EFFECTS

ENERGY AND ECONOMY

RESOURCES AND TRADE

ECONOMY AND SOCIETY

ENVIRONMENT
Methodology

Characterisation of the MARKAL model

- Bottom-up
- Perfect foresight
- Cost-optimisation
- Elastic demands

- Energy flows
- Environmental constraints, economic and policy focus
Revision of the UK MARKAL gas energy system
Scenario 1: Heat transition

- Key outcome of all UK decarbonisation studies
  - Electric heat pumps
  - Biomass boilers
  - District heating

- Low-carbon buildings are a important part of the Carbon Plan
Scenario 1: Heat transition

Residential heat demand

- District heating
- Water heaters
- Storage radiators
- Heat pumps
- Gas boilers

Pj/year

2010 2030 2050 2070
Infrastructure lock-in or stranded assets?
Impact of the Iron Mains Replacement Programme in 2050

Scenario 1: Heat transition

- Heat transition

Infrastructure lock-in or stranded assets?
Impact of the Iron Mains Replacement Programme in 2050

Annual gas consumption (PJ)

- No CO2 constraint
- With CO2 constraint

<table>
<thead>
<tr>
<th></th>
<th>No CO2 constraint</th>
<th>With CO2 constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programme</td>
<td></td>
<td></td>
</tr>
<tr>
<td>continues</td>
<td></td>
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<tr>
<td>Programme</td>
<td></td>
<td></td>
</tr>
<tr>
<td>abandoned</td>
<td></td>
<td></td>
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</tbody>
</table>
Scenario 2: Decarbonised gas

- Biomethane introduced in 2009
- Hydrogen injection and conversion have not been included in previous UK MARKAL studies

1. Which options are feasible?
2. Which options are cost-optimal?
### Scenario 2: Decarbonised gas

Cost-optimal biomethane in 2050 – only from sewage

<table>
<thead>
<tr>
<th></th>
<th>No CO₂ constraint</th>
<th>80% CO₂ constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total biomethane consumption (PJ)</td>
<td>0</td>
<td>105</td>
</tr>
<tr>
<td>Biomethane content of total gas consumption</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Biomethane use in the R&amp;S sectors</td>
<td>0%</td>
<td>0%*</td>
</tr>
</tbody>
</table>

Up to 250 PJ biomethane can be used for residential heat, but only if:
1. no heat transition occurs;
2. we require a 90% cut in CO₂ emissions.
Hydrogen injection

- Niche technology
- More important if no heat transition occurs
Hydrogen conversion

- Requires all appliances to be changed – more complex than the switch from town gas to natural gas because:
  - the gas networks are now more complex and integrated;
  - the gas industry is more fragmented.
- House conversion cost? First estimate between £5bn and £11bn
- Mains conversion costs? New pipeline construction costs?
- Safety issues?
- Operational issues?
Hydrogen conversion: residential heat demand

Scenario 2: Decarbonised gas

Table 5: Potential impact of gas decarbonisation options in the period 2050–2100

- District heating
- Fuel cell micro-CHP
- Water heaters
- Storage radiators
- Heat pumps
- Electric boilers
- Gas boilers
Scenario 2: Decarbonised gas

Hydrogen conversion: residential consumption

[Bar chart showing delivered hydrogen (PJ/year) for different conversion costs (None, 0%, 25%, 50%, 75%, 100%) with and without CO2 constraint.]
Scenario 2: Decarbonised gas

Hydrogen conversion: technology price uncertainty

Delivered hydrogen (PJ/year)

Conversion costs

None  0%  25%  50%  75%  100%

Base conversion case
High micro-CHP costs
High heat pump costs
Scenario 2: Decarbonised gas

Hydrogen conversion: residential consumption

![Graph showing marginal electricity price (p/kWh) with varying conversion costs. The graph compares different scenarios: Base conversion case, High micro-CHP costs, and High heat pump costs. The x-axis represents conversion costs ranging from 0% to 100%, while the y-axis shows the marginal electricity price. The graph indicates that as conversion costs increase, the marginal electricity price also increases, with different levels depending on the cost scenario.]
Scenario 3: Business as usual – gas boiler types

Source: English Housing Survey
### CO₂ emissions in 2050

<table>
<thead>
<tr>
<th>Scenario</th>
<th>R&amp;S</th>
<th>Transport</th>
<th>Industry</th>
<th>Hydrogen</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat transition</td>
<td>13</td>
<td>3</td>
<td>47</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Decarbonised gas</td>
<td>0</td>
<td>3</td>
<td>48</td>
<td>29</td>
<td>39</td>
</tr>
<tr>
<td>Business as usual: natural gas</td>
<td>44*</td>
<td>3</td>
<td>34</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>Business as usual: 50% biomethane</td>
<td>36</td>
<td>4</td>
<td>23</td>
<td>10</td>
<td>45</td>
</tr>
</tbody>
</table>

* Doesn’t include methane leakages from the gas network

R&S emissions reduce from 71 MtCO₂ to 44 MtCO₂ through demand reduction and complete decarbonisation of the service sector (in all three scenarios)
## Cost savings and demand reduction

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CO₂ marginal in 2050-2070</th>
<th>Change in discounted system cost (£bn)</th>
<th>Elastic reduction in residential heat demand in 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat transition</td>
<td>284</td>
<td>-50</td>
<td>-11%</td>
</tr>
<tr>
<td>Decarbonised gas</td>
<td>250</td>
<td>+8</td>
<td>-9%</td>
</tr>
<tr>
<td>Business as usual: natural gas</td>
<td>372</td>
<td>0</td>
<td>-18%</td>
</tr>
<tr>
<td>Business as usual: 50% biomethane</td>
<td>212</td>
<td>+109</td>
<td>-19%</td>
</tr>
</tbody>
</table>
Is fuel poverty an issue?

Comparison of cases

1. Heat transition
2. Gas decarbonisation - hydrogen conversion
3. Business as usual: gas
4. Business as usual: 50% biomethane
Issues

- What do you do with the houses that cannot use heat pumps, if the network is shut down?
- Iron mains replacement programme
  - Is it good value for money?
  - Cut back if we are going to shut the network anyway?
  - Alter the programme to enable a switch to hydrogen in a few decades?
- Fuel poverty
- Biomass CCS
Overall conclusions

- Transmission network still used in all scenarios
- Low-pressure network future uncertain – gas becomes a high-carbon fuel by 2050
  - The least-cost method is to shut down most of the network, but this raises lots of issues
  - Networks are stranded assets – no infrastructure lock-in
  - Biomethane is a niche fuel, best used in industry
  - Hydrogen injection is a niche technology
  - Hydrogen conversion is an interesting but uncertain option
  - Continue using natural gas and decarbonise other sectors?
Thank you for listening

Questions?