Assessing the energy and emission reduction potentials in the UK industry sector in the scope of an energy systems analysis

Birgit Fais, Nagore Sabio, Neil Strachan
UCL Energy Institute, University College London

37th IAEE International Conference
New York, June 16, 2014
Agenda

1. Introduction and objective
2. Model and methodological approach
3. Comparative scenario analysis on the UK energy system
4. Conclusion
1. Introduction and objective

**UK climate policy**

- **Climate Change Act (2008):** legally binding framework for the abatement of greenhouse gas emissions committing the country to an emission reduction of 80% until 2050 compared to the level in 1990
- In line with the **EU Energy Efficiency Directive:** indicative national energy efficiency target of an 18% reduction in final energy consumption for 2020 compared to the UK’s 2007 BAU projection for 2020

**UK industry sector**

- Accounts for slightly more than a quarter of total greenhouse gas emissions and almost a fifth of final energy consumption
- Dual challenge of implementing low energy and low carbon technologies while at the same time maintaining international competitiveness
Motivation and objective for this analysis

Low-carbon systems analysis often focuses on the evaluation of the mitigation potentials on the energy supply side, but substantial contribution is required from the different energy end-use sectors if the ambitious long-term targets are to be fulfilled.

Bottom-up energy system models constitute powerful tools to analyse long-term emission reduction pathways in a systematic manner with the advantages of including a high level of technological detail and accounting for all interactions within the energy system.

**BUT:** due to the complexity of the industry sector, its representation in energy system models is often strongly simplified without including the actual production processes and accounting for the substantial differences between subsectors.

**OBJECTIVE:** develop a new, process-oriented modelling approach for the industry sector in energy system models based on process level data from a bottom-up industrial energy database and apply it in a scenario analysis for the UK energy system.
2. Model and methodological approach

UKTM – The UK TIMES energy system model

- **Bottom-up integrated energy system model** → technology-rich, dynamic, linear programming optimisation, partial equilibrium model
- Representation of the entire **UK energy system** with detailed description of the demand sectors (industry, residential, tertiary, agriculture and transport), public & industrial electricity and heat production, refineries and other fuel conversion
- Successor to **UK MARKAL**
- **New features**: flexible modelling of storage and other energy infrastructures, representation of non-CO2 greenhouse gases, Non-energy mitigation options, new time slices (4 intra-day x 4 seasonal)
- **Open source modelling**: Transparency at the forefront of development (data, assumptions, structure is clear and traceable, full replicability of results, comprehensive QA processes)
Traditional approach: aggregated service demand module
Relatively simple model structure based on the different types of industrial energy service demands (e.g. high temp. heat, motor drive, drying, etc.)

Shortcomings
The actual process technologies in the various industry subsectors are usually not explicitly modelled
→ important technological constraints can often not be accounted for
→ radical technological changes in the production processes (e.g. CCS technologies) cannot be included
→ difficult to consider process emissions and mitigation options for these emissions.
New approach: disaggregated hybrid module

Based on the **Usable Energy Database (UED)** (Griffin et al., 2013): baseline energy use and emissions by technology in 2010 and a wide range of possible future technologies for a number of energy-intensive industry sectors in the UK.

<table>
<thead>
<tr>
<th>Structure of the new industry sector in UKTM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IIS</strong></td>
</tr>
<tr>
<td><strong>ICM</strong></td>
</tr>
<tr>
<td><strong>IPP</strong></td>
</tr>
<tr>
<td><strong>ICH</strong></td>
</tr>
<tr>
<td><strong>IFD</strong></td>
</tr>
<tr>
<td><strong>INF</strong></td>
</tr>
<tr>
<td><strong>INM</strong></td>
</tr>
<tr>
<td><strong>IOI</strong></td>
</tr>
</tbody>
</table>

**Technology choices in the process-oriented sectors**

(1) exploitation of already commercial technology options with higher energy efficiency or less carbon-intensive energy inputs;
(2) improvement potentials for already installed process technologies;
(3) more radical process changes.
Example: Cement industry

Legend
- Existing technologies
- New, Energy efficiency options
- New, fuel switching options
- New, CCS options
- Grinding & mixing, clinker substitution option
- Cement substitution option

UK industry sector modelling
Birgit Fais

- Semi-wet kiln, exist.
- Semi-dry kiln, exist.
- Dry kiln with precalciner, exist.
- Dry kiln w/o precalciner, exist.
- Dry kiln, BAT
- Fluidised bed kiln
- BAT kiln with increased waste utilisation
- Fluidised bed kiln with increased waste utilisation
- BAT kiln with MEA Post-combustion CCS
- BAT kiln with KS-1 Post-combustion CCS
- BAT kiln with Partial Oxy-combustion CCS
- MEA Post-combustion CCS retrofit
- KS-1 Post-combustion CCS retrofit
- Partial Oxy-combustion CCS retrofit
- Grinding and mixing, exist.
- Grinding and mixing, new
- Grinding and mixing with increased clinker substitution
- Low CO₂ cements
3. Comparative scenario analysis

Objective: assess the contribution of the UK industry sector to emission and energy demand reduction targets

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>REF</td>
<td>Business as usual reflecting the current policy framework</td>
</tr>
<tr>
<td>GHG80</td>
<td>REF + emission reduction target of 80% until 2050 compared to 1990</td>
</tr>
<tr>
<td>GHG80_FEC</td>
<td>GHG80 + reduction in final energy consumption of 1.5% per year until 2020, of 1% per year until 2040 and 0.5% per year until 2050</td>
</tr>
</tbody>
</table>

Basic scenario assumptions (2010-2050):
• GDP growth rate of 2.4% p.a.
• Population growth of 0.5% p.a.
• Rise in the world market price for crude oil of 73% (in real terms)
Results (1): Industrial energy consumption

- Reduction in energy consumption already in REF due to decline in production, the shift to high value, less energy-intensive subsectors, use of profitable energy efficiency options (rising fossil fuel prices!)
- No additional reduction in GHG80: stronger emphasis on energy efficiency measures but balancing effect due to use of CCS, industry CHP and biomass options
- Strong additional emphasis on energy efficiency in GHG80_FEC and less use of CCS, biomass and CHP options
Results (2): Fuel consumption in industry CHP plants

- Contribution of CHP drops significantly in REF due to the availability of cheap electricity from the public generation sector.
- In low-carbon scenario GHG80, use of biomass in CHP plants is a viable emission abatement option.
- Specification of energy efficiency target (on final energy consumption) leads to considerable decline in industry CHP generation in GHG80_FEC.
Results (3): Contribution to energy efficiency

- Increase of final energy consumption of 8% between 2010 and 2050 in REF, reductions only realized in the industry sector
- Reduction of 8% in GHG80, electrification and uptake of conservation measures in residential and tertiary sector; strongest reductions still in industry
- Additional efforts to improve energy efficiency needed in GHG80_FEC, industry leads reduction of final energy consumption with -38% between 2010 and 2050
Results (4): Greenhouse gas emissions

- Highest contribution to emission reduction until 2050 from electricity generation (-100%), followed by service sector (-73%) and industry (-68%)
- CCS technologies (used in blast furnaces, cement kilns and steam reforming) particularly important for the reduction of process related emissions
- Contribution of the industry sector to emission reduction is reduced considerably with the implementation of the energy efficiency target
- Additional energy efficiency target has dampening effect on GHG emission price
Results (5): Energy system costs

<table>
<thead>
<tr>
<th>Difference in annual undiscounted energy system cost</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
<th>Cumulated 2010-2050 [Bn £2010]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG80 vs. REF</td>
<td>0.2%</td>
<td>1.5%</td>
<td>7.5%</td>
<td>489.4</td>
</tr>
<tr>
<td>GHG80_FEC vs. REF</td>
<td>1.8%</td>
<td>3.3%</td>
<td>13.5%</td>
<td>906.0</td>
</tr>
<tr>
<td>GHG80_FEC vs. GHG80</td>
<td>1.5%</td>
<td>1.8%</td>
<td>5.6%</td>
<td>416.6</td>
</tr>
</tbody>
</table>

- Consistent manner of assessing the additional energy system-wide cost burden caused by the introduction of ambitious emission and energy reduction targets
- The transition to a low-carbon energy system in the UK causes additional costs to the energy system of almost £500 billion cumulated over the period from 2010 and 2050.
- Implementing an additional target on energy efficiency can distort the cost efficient pathway of reaching the desired emission reductions.
Results (6): Sector-wise assessment

- **Iron & steel**
- **Cement**
- **Paper**
- **Chemicals**

UK industry sector modelling
Birgit Fais
4. Conclusions

• A more detailed, process-oriented representation of the industry sector in a bottom-up energy system model can help to evaluate the contribution of this sector to long-term energy and emission reduction targets.

• The main emission reduction options in the UK industry sector comprise energy efficiency measures, the use of biomass for heating, CCS technologies in the iron and steel, cement and chemical industry as well as applying some radical changes in the production processes of these sectors.

• Interactions between the emission reduction target and additional targets for energy efficiency (or renewables) need to be taken into account as they might result in a distortion of the cost efficient emission reduction pathway.

• Further methodological work is needed to (1) improve the representation of the less energy-intensive and highly heterogeneous industrial subsectors, (2) address the uncertainty in the technological parameters and (3) assess the effects of the transition to a low-carbon energy system on industrial production levels in the UK.
Thank you for your attention!

Birgit Fais
Research Associate

UCL Energy Institute
University College London
Central House, 14 Upper Woburn Place
London WC1H 0NN, United Kingdom
Phone: +44 20 3108 5940
Email: b.fais@ucl.ac.uk

This analysis was part of the UKERC project “Industrial Energy Use from a Bottom-up Perspective” (http://www.ukerc.ac.uk/support/RF2IndustrialEnergyUse)
BACK UP
### Demand projections for the industry sector in UKTM

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron and steel (hot rolled steel)</td>
<td>8415</td>
<td>1</td>
<td>0.92</td>
<td>0.90</td>
<td>0.87</td>
<td>0.83</td>
<td>0.80</td>
</tr>
<tr>
<td>Cement</td>
<td>9440</td>
<td>1</td>
<td>1.01</td>
<td>1.01</td>
<td>1.00</td>
<td>0.97</td>
<td>0.89</td>
</tr>
<tr>
<td>Paper and paper products</td>
<td>4564</td>
<td>1</td>
<td>0.90</td>
<td>0.87</td>
<td>0.81</td>
<td>0.75</td>
<td>0.70</td>
</tr>
<tr>
<td>Chemicals</td>
<td>3840</td>
<td>1</td>
<td>1.05</td>
<td>1.16</td>
<td>1.41</td>
<td>1.72</td>
<td>2.10</td>
</tr>
<tr>
<td>Other non-metallic minerals</td>
<td>-</td>
<td>1</td>
<td>0.94</td>
<td>0.92</td>
<td>0.89</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>-</td>
<td>1</td>
<td>0.92</td>
<td>0.90</td>
<td>0.87</td>
<td>0.83</td>
<td>0.80</td>
</tr>
<tr>
<td>Other non-metallic minerals</td>
<td>-</td>
<td>1</td>
<td>1.01</td>
<td>1.01</td>
<td>1.00</td>
<td>0.97</td>
<td>0.89</td>
</tr>
<tr>
<td>Food, drink and tobacco</td>
<td>-</td>
<td>1</td>
<td>0.92</td>
<td>0.96</td>
<td>1.03</td>
<td>1.11</td>
<td>1.20</td>
</tr>
<tr>
<td>Other industries</td>
<td>-</td>
<td>1</td>
<td>0.84</td>
<td>0.83</td>
<td>0.80</td>
<td>0.78</td>
<td>0.75</td>
</tr>
</tbody>
</table>