A perspective on (whole systems) energy modelling

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16th June 2016
Overview

• About the ETI

• Our Modelling and Analysis
  – Energy System Modelling Environment (ESME)
  – Wider suite of modelling tools
  – Low carbon scenarios
  – Key insights

• Modelling and policymaking
  – Direct and indirect uses of ESME
  – UK MARKAL/TIMES
About the ETI

• The Energy Technologies Institute (ETI) is a public-private partnership between global industries and UK Government

Delivering...

• Targeted development, demonstration and de-risking of new technologies for affordable and secure energy

• Shared risk

ETI members

BP

CATERPILLAR

EDF ENERGY

Rolls-Royce

Shell

EPSRC

Department of Energy & Climate Change

Department for Business Innovation & Skills

Innovate UK

Technology Strategy Board

ETI programme associate

HITACHI

Inspire the Next
Delivering innovation from strategic planning to technology demonstration

Knowledge building to:

» Inform industry decision making through robust, shared evidence and commercially available projects
» Build a better understanding of decarbonisation potential in developing industries
» Inform policy debate

Demonstrating technology to:

» De-risk new systems
» Focus and accelerate low carbon innovation
» Build investor confidence

Strategic analysis and planning to:

» Develop an internationally peer-reviewed national energy system design and planning capability

» Identify the lowest-cost decarbonisation pathways for the UK energy system

» Produce technology and industry sector insights and develop whole system modelling capability

Developing technology to:

» Build supply chain capability
» Create economic opportunities
» Exploit UK technology knowledge and skills

Supported by Market, Policy & Regulatory Analysis & Consumer Behaviour Research
Objectives:

- Inform the ETI project portfolio
- Strategic insights to ETI & members
- Enable dialogue on modelling & strategy with HMG

* Academic projects on: Demand Response, Equity issues, Modelling under Uncertainty (UKERC), WholeSEM (EPSRC), Realising Transition Pathways (RCUK) and Energy Infrastructure Modelling (CASE)
The ESME model

- Whole-system approach:
  - power, heat, transport, industry and energy infrastructure

- Least cost optimisation, policy neutral

- Deployment & utilisation of 300+ technologies

- Probabilistic treatment of key uncertainties

- Pathway and supply chain constraints to 2050

- Spatial and temporal resolution sufficient for system engineering
Probabilistic analysis

**Deterministic mode**
- All parameters have a deterministic profile 2010-2050.
- ESME can conduct a single deterministic run using these values.

**Monte Carlo mode**
- Some parameters have a 2050 distribution (mostly technology costs, but can include resource availability, build rate limits etc).
- In Monte Carlo mode, multiple simulations are conducted.
- In each simulation, these parameters are assigned a 2050 value from distribution.
- Allows a statistical analysis of the energy system design space.
Model resolution

- Perils of aggregation!
Spatial resolution

- Co-location of supply and demand
- Transmission distances and costs
- Siting requirements for e.g. Nuclear / CCS plant (safety/water abstraction)
- Density of built environment for District Heating uptake: ESME, we

Tranches of Housing density vary by region
Temporal resolution

• A Day in the Life of ‘Levelised Cost of Energy’:

• A Year:

...and in the Real World:

Daily peaks, troughs, swings

Seasonal variation
Temporal resolution

- **ESME**
  - Two seasons
  - Five diurnal time slices

- ESME solution then tested in a more finely grained dispatch model (PLEXOS)
UK Solar PV 2015

~9GW Annual Summary

- **Demand:** 300 TWh
- **PV Output:** 8 TWh

GB Electricity Demand for **Avg July Day** showing PV share (from 9GW capacity)

GB Electricity Demand **Avg December Day** showing PV share (from 9GW Capacity)
PV scenarios – 50GW

GB Electricity Demand for *Avg July Day*
showing PV share (from 50GW capacity)

GB Electricity Demand *Avg December Day*
showing PV share (from 50GW capacity)

50GW Annual Summary

- **Demand**: 300 TWh
- **PV Output**: 49 TWh
  (<1% spill)
300GW where total PV output = total demand

An inconvenient tooth?

~300GW Annual Summary

Demand 300 TWh

PV Output 300 TWh

(57% spill)
ESME and the wider ETI modelling suite

- Transport
  - Vehicle Cost Model
  - Vehicle Uptake Model
  - Charging Network Model
  - LDV Transport
  - Consumer Choice Model
  - Business Model Evaluation Tool

- Marine
  - WMC Cost Model
  - WaveDyn
  - WaveFarmer
  - TidalFarmer
  - SMARTtide

- Distributed Energy
  - Macro DE Energy Centre Cost Model
  - Macro DE Heat Network Cost Model
  - Consumer Response & Behaviour Model

- Buildings
  - Single Building
  - Thermal Efficiency Model
  - Buildings Stock
  - Thermal Efficiency Model

- Smart Systems and Heat
  - HDV Carbon Benefits Model
  - Low Carbon Shipping Model
  - Marine HDV Virtual Simulation Models
  - Land HDV Virtual Simulation Models

- Bioenergy
  - Local Authority GIS Waste Resource Modelling Tool
  - Bio Value Chain Model
  - Bio-power CCS Sub-models
  - Integrated Land-Use Ecosystem Model

- Offshore Wind
  - Energy Systems Modelling Environment
  - Offshore Wind Energy Cost Models
  - PLEXOS
  - Simplified UK Electricity Transmission Model

- Energy Storage & Distribution
  - 2050 Energy Infrastructure Cost Calculator
  - gCCS
  - CO2 NomicA

- Carbon Capture & Storage
  - Benchmark Models of IGCC/CCGT/ USCPC
  - CO2 Stored
SCENARIOS AND INSIGHTS
ETI Scenarios

- UK energy system – power, heating, transport, industry & infrastructure
- Bound by Climate Change Act – 80% emissions reduction by 2050
- Building on several years of modelling, analysis and scenario development using ESME
- Devised in consultation with ETI members and stakeholders
- Launched on 4th March 2015
INTRODUCING THE
SCENARIOS

CLOCKWORK

PATCHWORK
One route to meeting - 80% CO₂ for the UK

Power now, heat next, transport gradual – cost optimal
Abatement Cost

Additional cost of delivering 2050 -80% CO2 energy system
NPV £ bn 2010-2050

- No Targets
- No CCS
- No Bio
- No building packages
- No nuclear
- No offshore wind

1% of 2050 GDP
Key Messages

1. The UK can achieve an affordable transition to a low carbon energy system over the next 35 years. Our modelling shows abatement costs ranging from 1-2% of GDP by 2050, with potential to achieve the lower end of this range through effective planning.

2. The UK must focus on developing and proving a basket of the most promising supply and demand technology options. Developing a basket of options (rather than a single system blueprint) will help to limit inevitable implementation risks.

3. Key technology priorities for the UK energy system include: bioenergy, carbon capture and storage, new nuclear, offshore wind, gaseous systems, efficiency of vehicles and efficiency/heat provision for buildings.
Key Messages

4. It is critical to focus resources in the next decade on preparing these options for wide-scale deployment. By the mid-2020s crucial decisions must be made regarding infrastructure design for the long-term.

5. CCS and bioenergy are especially valuable. The most cost-effective system designs require zero or even "negative" emissions in sectors where decarbonisation is easiest, alleviating pressure in more difficult sectors.

6. High levels of intermittent renewables in the power sector and large swings in energy demand can be accommodated at a cost, but this requires a systems level approach to storage technologies, including heat, hydrogen and natural gas in addition to electricity.
ENERGY MODELLING AND POLICY
Beyond ETI

- UCL Energy Institute – ESME one of many models including UK MARKAL, UK TIMES and global models used to inform low carbon policy by demonstrating:
  - value of an energy systems approach, need for all sectors to play a role
  - The enabling role of early decarbonisation of the electricity sector
  - Range of potential system costs and implications for carbon pricing
  - Value of energy service demand reductions, hedging against high costs of decarbonisation as well as security of supply issues

- See UCL REF2014 submission ‘Energy-economic modelling of long term decarbonisation pathways: The policy impacts of the MARKAL-TIMES model family’
  - http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=36988
Energy modelling and policy

Selected citations of ESME

The Renewable Energy Review (CCC, May 2011)

The Carbon Plan (HMG, Dec 2011)

UK Bioenergy Strategy (DfT, DECC, DEFRA, April 2012)

The Future of Heating (DECC, Mar 2013)


Advanced fuels: call for evidence (Department for Transport, Dec 2013)
Wider impact of ETI

• Role on advisory boards (for CCC, EU H2020, EPSRC WholeSEM)
  – ETI’s whole systems strategy helping inform the low carbon agenda

• Support for DECC Technology Strategy (Summer 2015)

• Craig Lucas, Acting Director of Science and Innovation, DECC:
  – “Analysis work undertaken by the ETI has played a key role in helping to inform our innovation strategy, technology priorities and options across a broad range of energy policy areas. The ETI’s approach combines analytical rigour with a very practical approach based on their broad industrial experience and strong links to industry. This provides a robust evidence base for DECC’s analysts to use to support policy makers”

• Amber Rudd, Secretary of State:
  – “The environmental and economic arguments [for CCS] have been made so well by so many people in so many ways. For example the Energy Technologies Institute said, ‘no other technology has such a dramatic impact in lowering the cost of the low carbon economy as CCS. Deploying CCS would keep electricity bills as low as possible, 15 percent lower than without CCS’”
Evidence of action?

UK cancels pioneering £1bn carbon capture and storage competition

- ETI assessment of impact: additional £1bn per year throughout 2020s as a result of reconfiguring the system to adopt second-best solutions

- Policy reset - focus on affordability and security.
  - Affordability through (limited) innovation funding

- False economy?
  - Often no substitute for learning by doing (de-risking)
Summary

- Energy System Modelling Environment ESME
  - One part of the strategy toolkit
  - Employed in context of wider engineering, economic and policy expertise
  - From probabilistic analysis through to specific scenarios

- (Whole system) Modelling and Policy
  - Provides systematic basis for articulating assumptions, and testing their interaction under uncertainty
  - Identification of no regrets technologies, option values, ‘world without x’ etc
  - Starting point for detailed analysis of suitable policy mechanisms

  - ‘Whole system’ mind set not necessarily shared by all decision makers