



www.eti.co.uk

Energy system modelling in an uncertain world

A presentation to the East Midlands OR Society 13/11/2014

Chris Heaton

chris.heaton@eti.co.uk



What is 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



CATERPILLAR



e-on



Rolls-Royce



Department
for Business
Innovation & Skills



Department
of Energy &
Climate Change

EPSRC

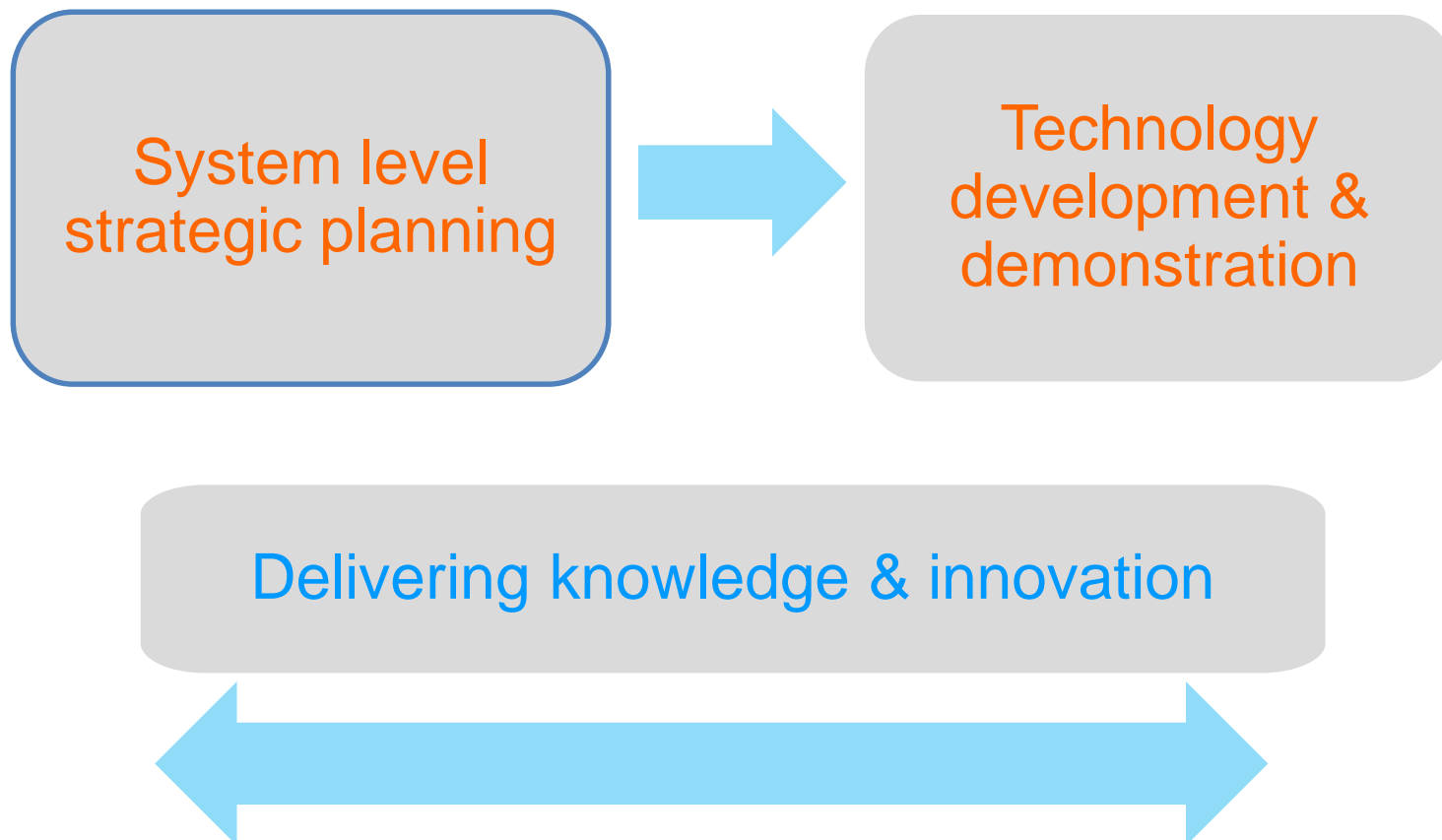
Pioneering research
and skills

Innovate UK

Technology Strategy Board

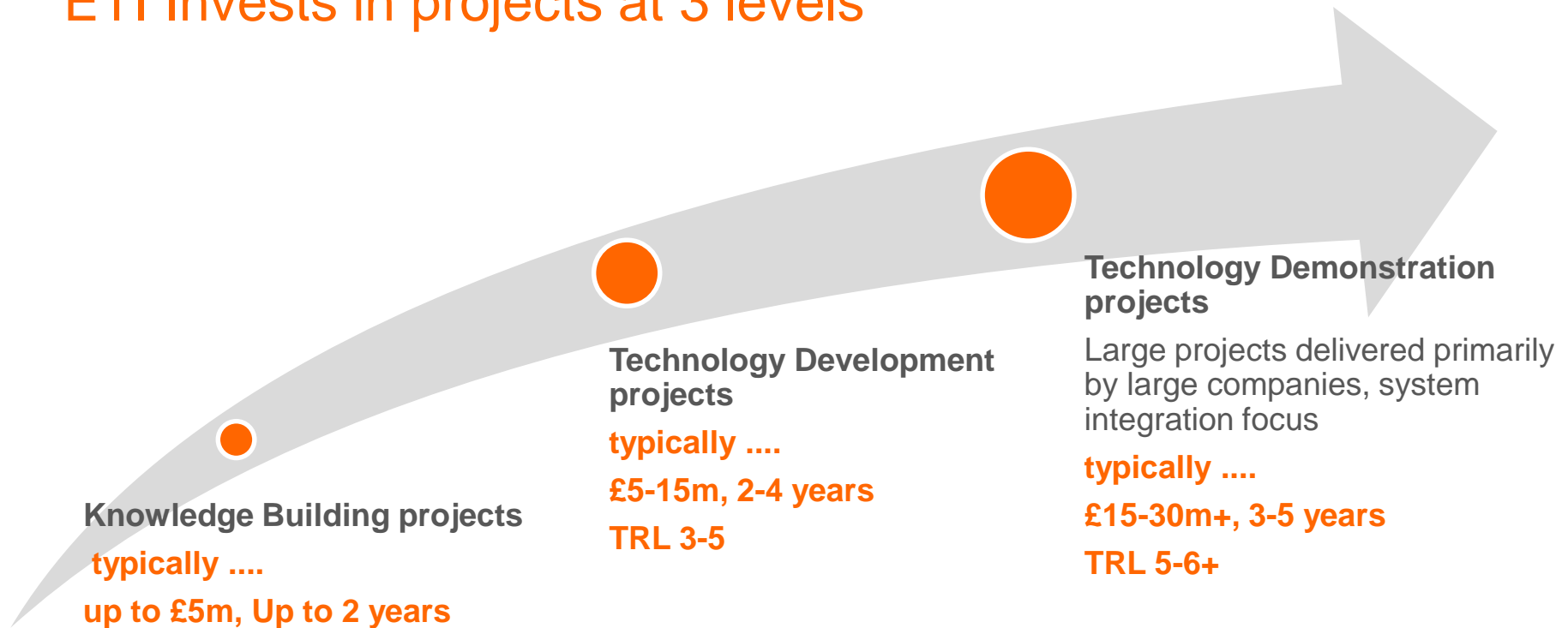


What is the ETI?





ETI Invests in projects at 3 levels





A national energy system design tool
Integrating power, heat, transport and infrastructure
searching for the lowest cost solution



Why do energy system modelling?

- Energy systems are subject to key decision points and path dependency; choices are long lived
- Energy systems are complex and inter-dependent, made more so by emissions reduction objectives
- Efforts to cut emissions are substitutable across power, heat, transport, industry and infrastructure
- ... but governed by well-understood physical laws, so quantitative modelling is capable of representing system interactions and capturing dynamics that would otherwise not be understood



ESME

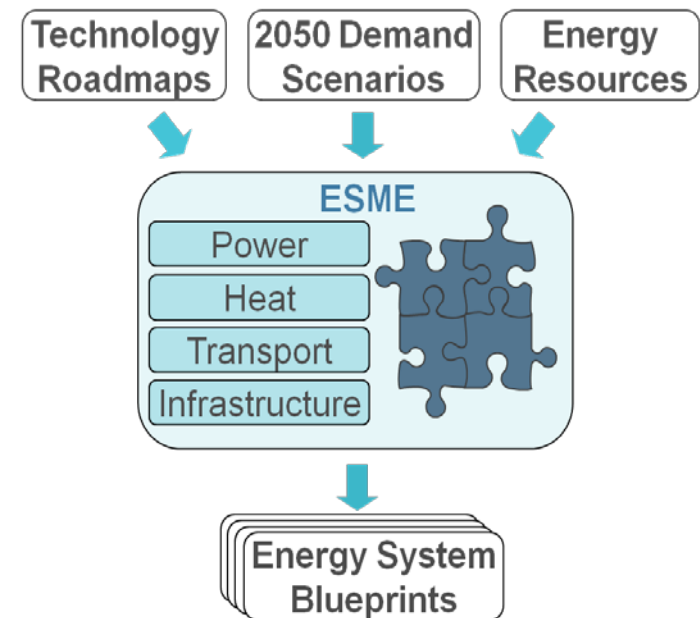
A peer-reviewed national energy system design tool

Energy system design based on policy-neutral least cost optimisation

ESME is a central part of ETI's energy system analysis

Insights from modelling are combined with evidence from technical experts

A view is taken on ETI "additionality" for all investments





Types of Debate that ESME is used to inform

- What might be 'no regret' technology choices and pathways to 2050?
- What is the total system cost of meeting the energy targets?
- What are the opportunity costs of individual technologies?
- What are the key constraints e.g. resources, supply constraints?
- How might accelerating the development of a technology impact the solution?
- How might uncertainty in resource prices and availability influence system design choices?
- Where should new generating capacity optimally be located?
- How might policies and consumer choices influence technology development?



ESME in use by ETI, its members and partners

- ESME developed to inform technology development choices and targets for ETI & members
- ESME used to inform policy work by DECC* and CCC⁺
- ETI Members are developing own versions for specific countries of interest
- ESME software licence available to academics for research projects.

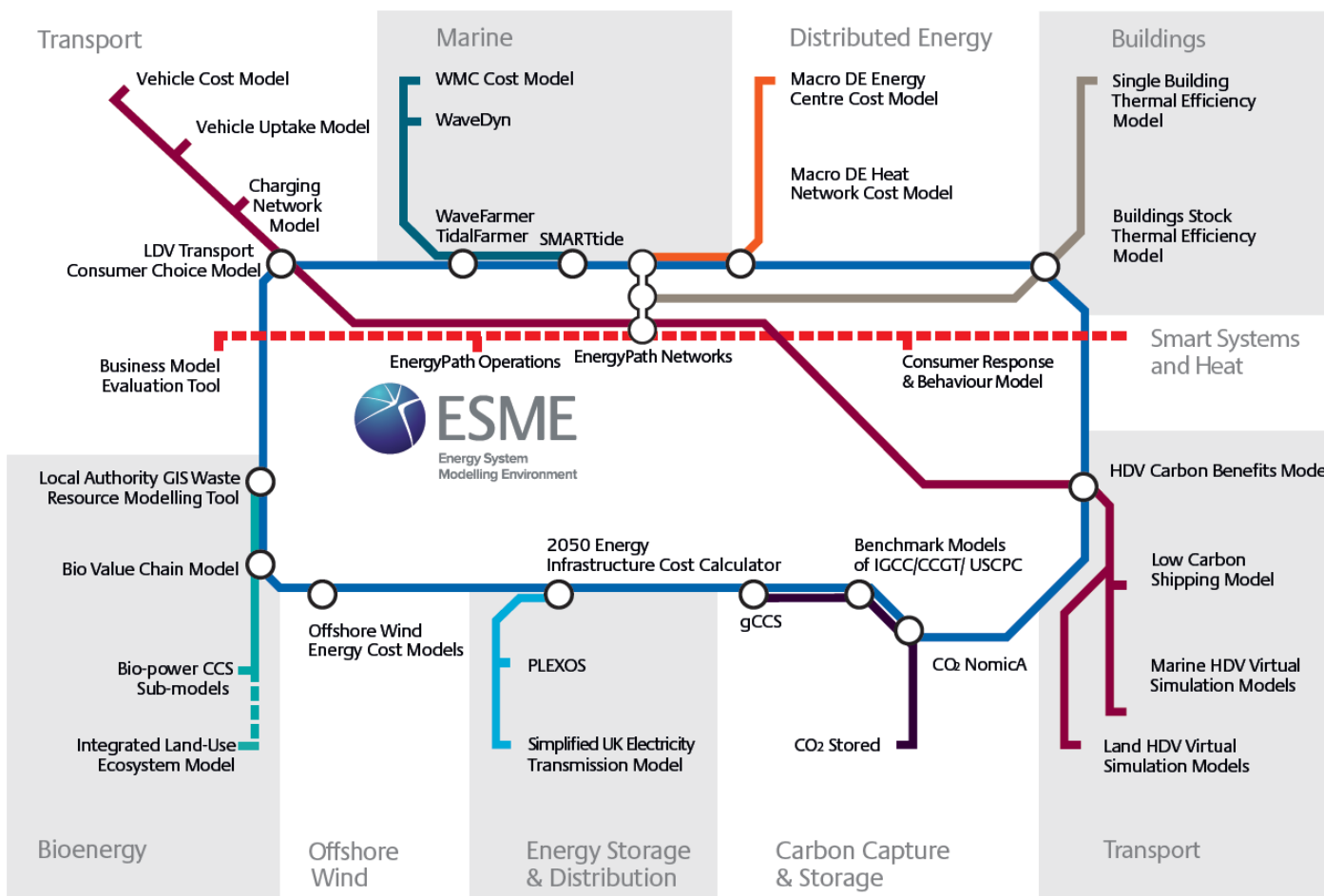


* UK Government Department of Energy & Climate Change

⁺ Committee on Climate Change, a statutory UK body



Knowledge from across ETI programme areas is integrated in ESME



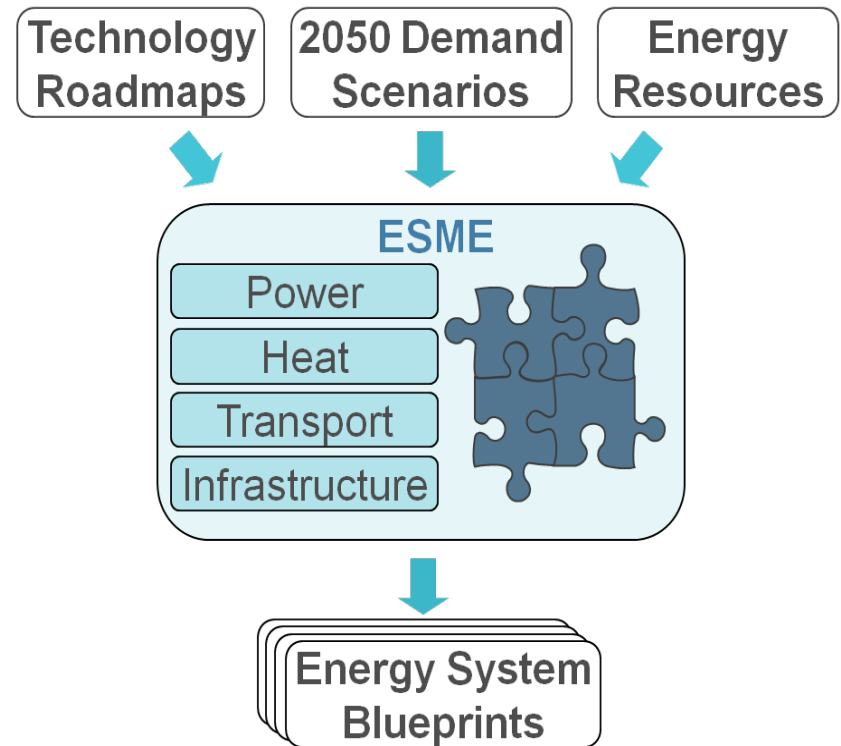


The ESME model and approach



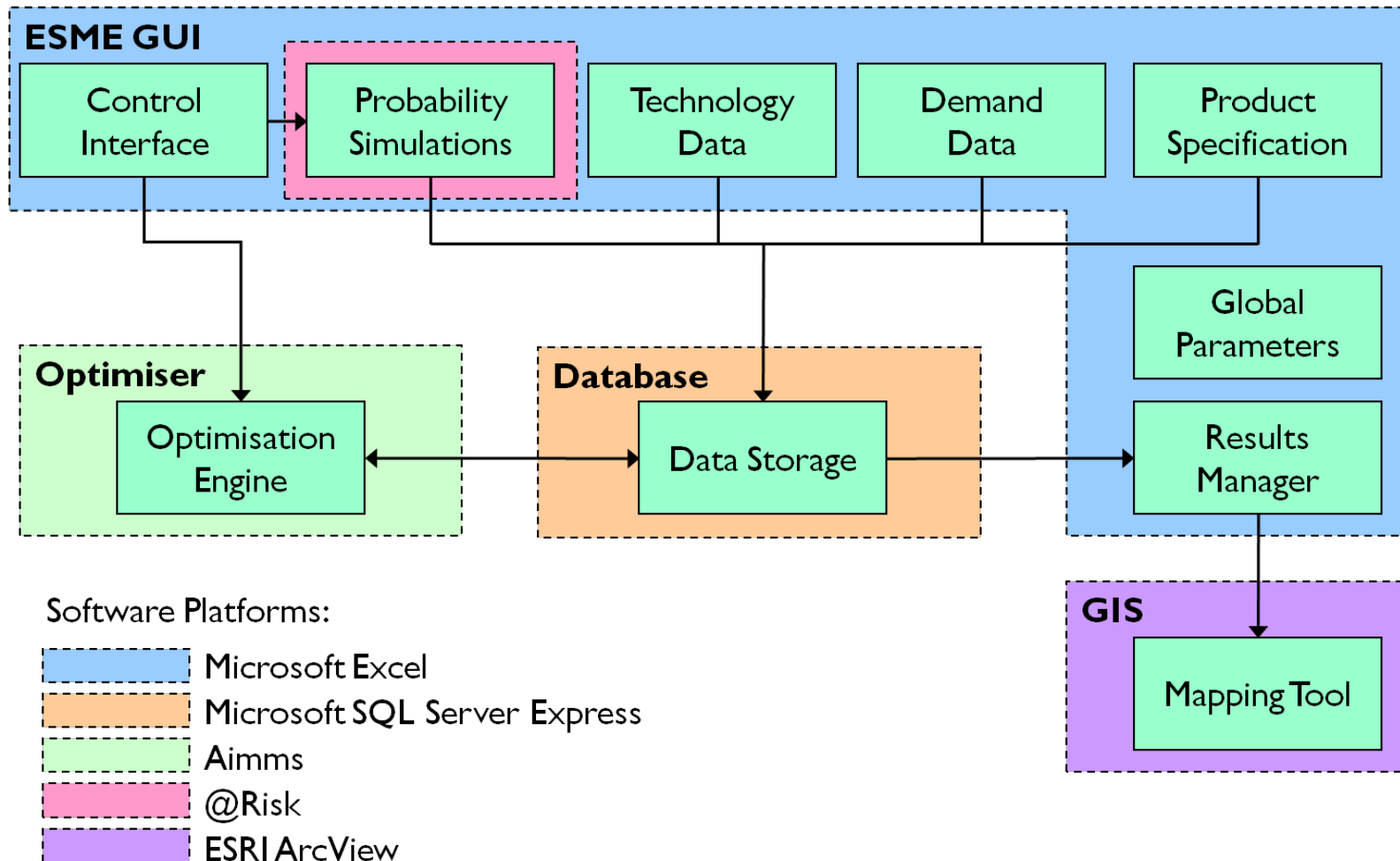
The ESME modelling approach

- Least cost optimisation, policy neutral
- Deployment & utilisation of >250 technologies
- Probabilistic treatment of key uncertainties
- Pathway and supply chain constraints to 2050
- Spatial and temporal resolution sufficient for system engineering



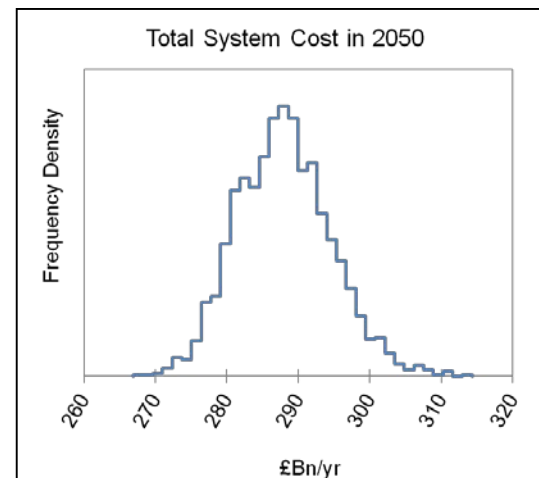
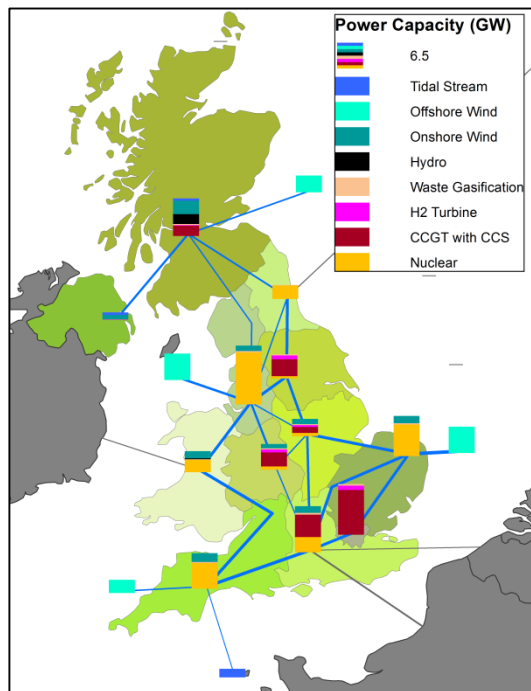
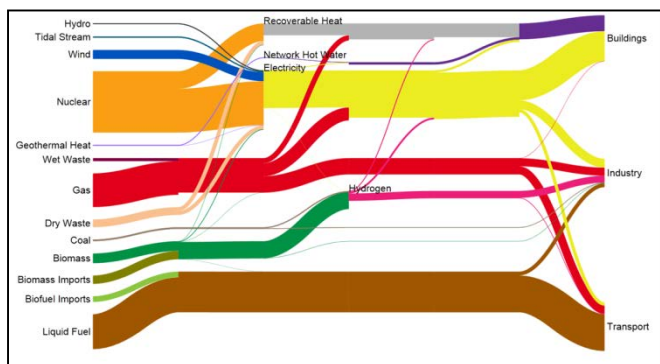
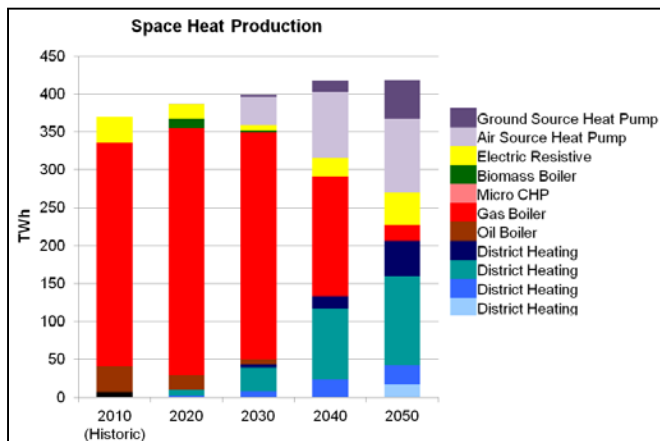


Architecture Overview





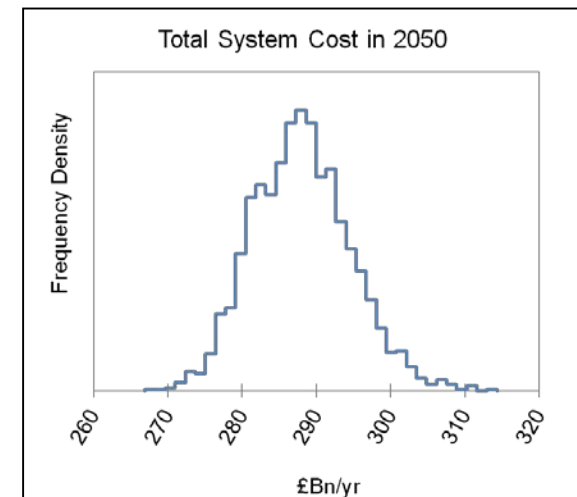
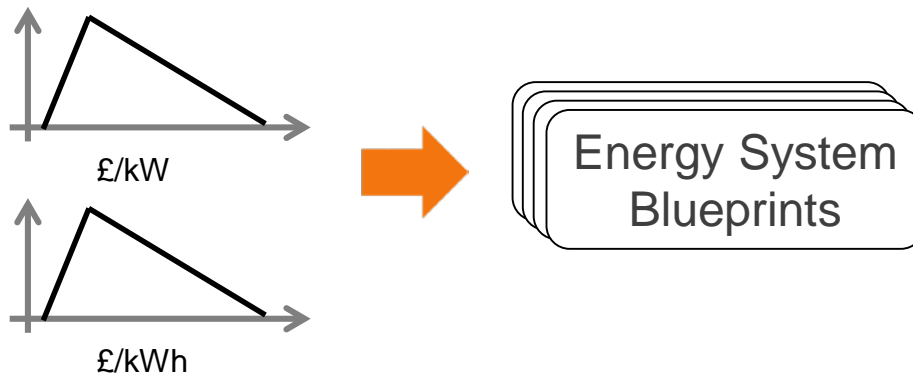
Typical ESME Outputs





ESME uncertainty analysis

- ESME is a Monte Carlo model
 - Ranges and probability distributions on uncertain inputs
 - Results are an ensemble of least-cost energy systems



- This effectively automates a large amount of sensitivity analysis



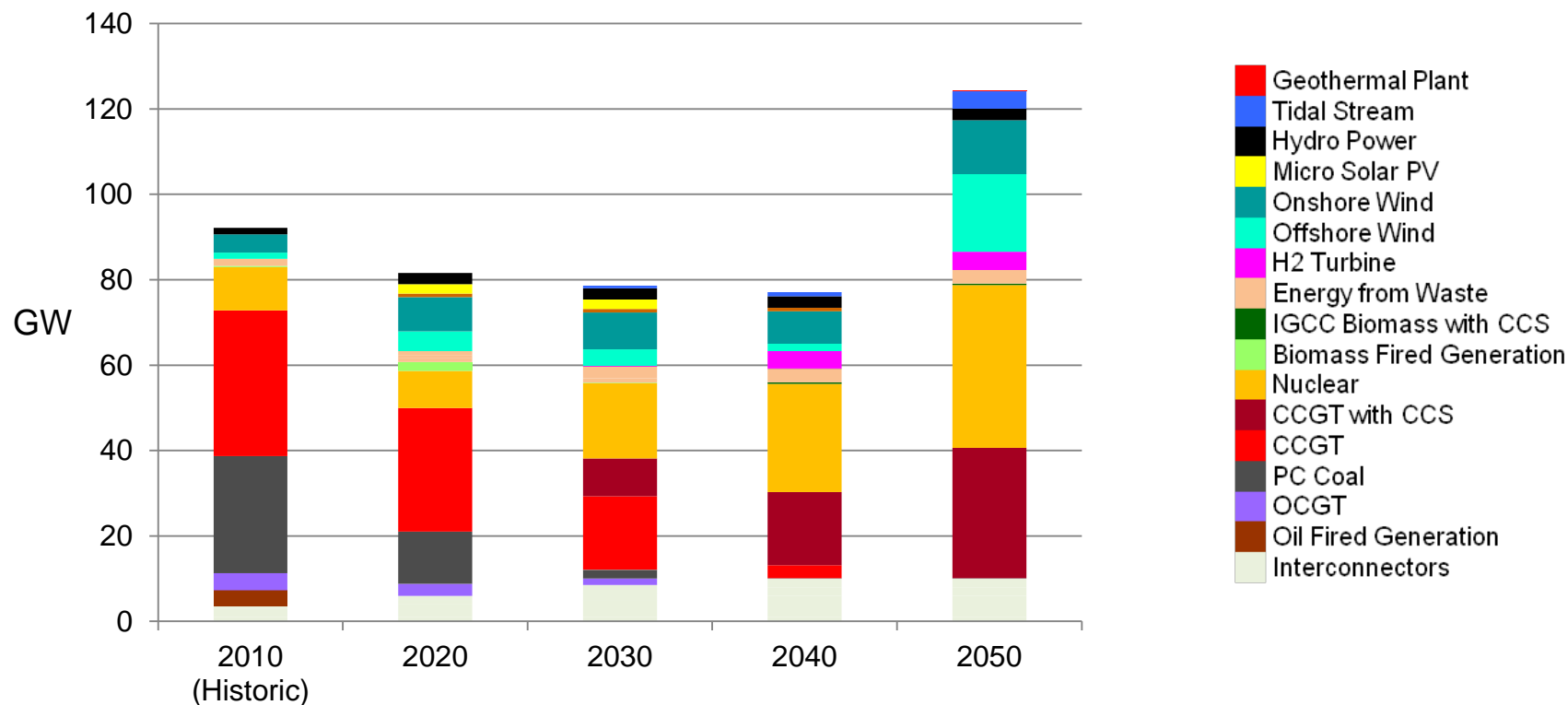
ESME uncertainty analysis

Examples of the assumptions used in ESME which are highly uncertain

1. Technology costs e.g. CCS power stations, Hydrogen Cars
Cost improvement for novel technologies, efficiency improvements, safety, ...
2. Fuel prices e.g. gas price, oil price, imported biomass price
International supplies, demand from other countries, shale gas, ...
3. Maximum UK resource for Biomass
Sustainability questions, public acceptance, farmer acceptance, yields, ...



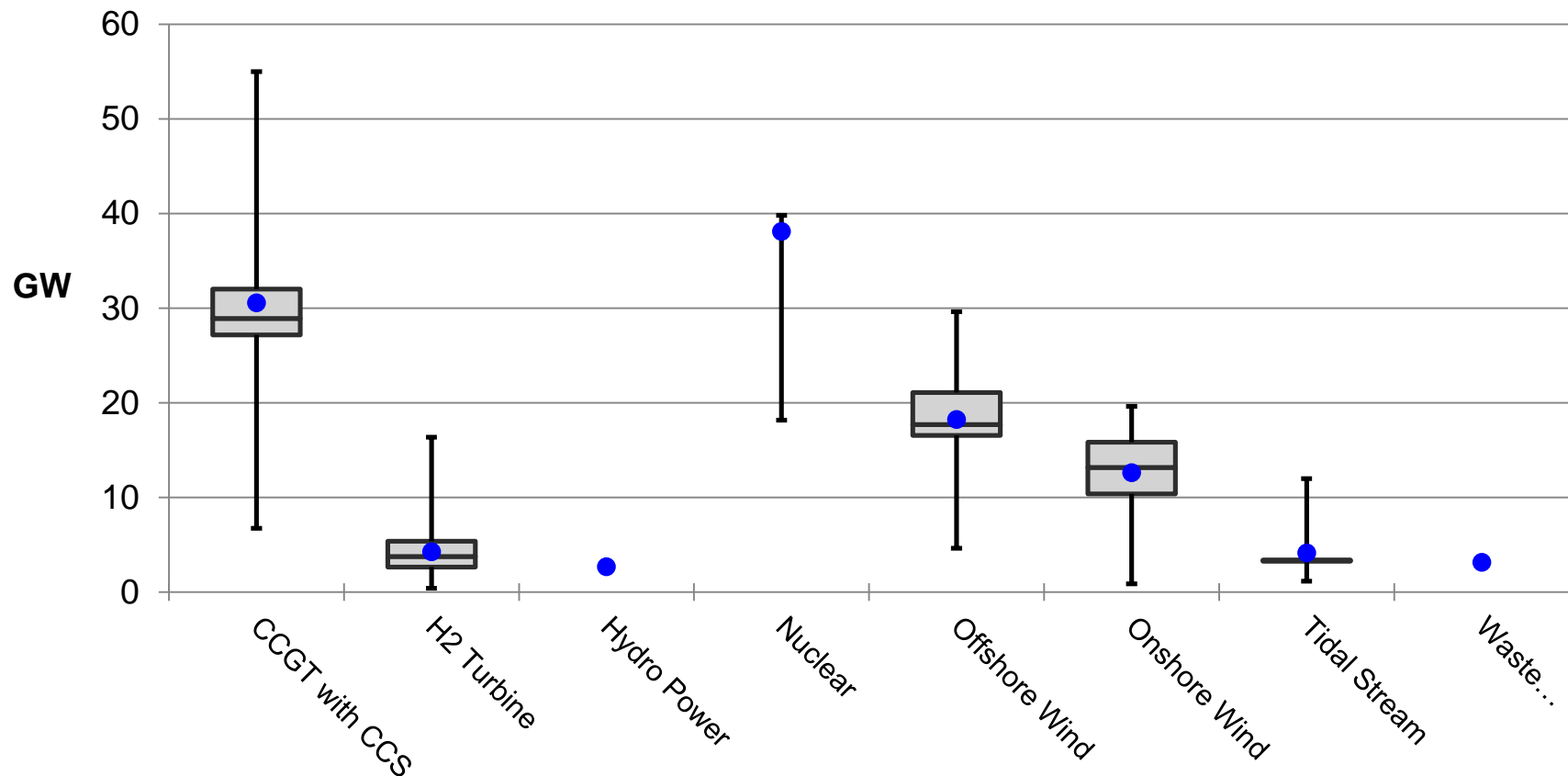
Electricity Generation Capacity (mean case)



Data 2014DC / Optimiser v3.4



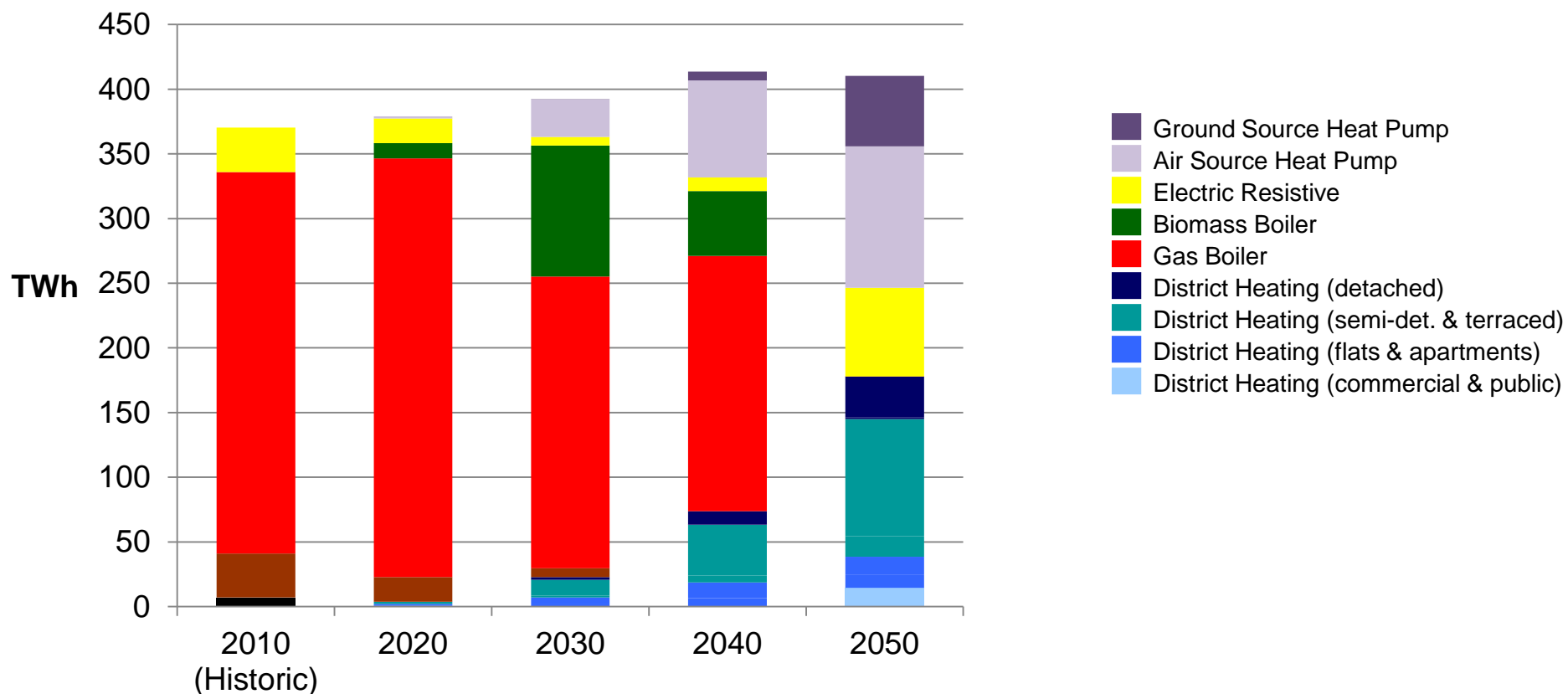
Spread of ESME results for 2050 power capacity





Space heating results from ESME

Space Heat Production

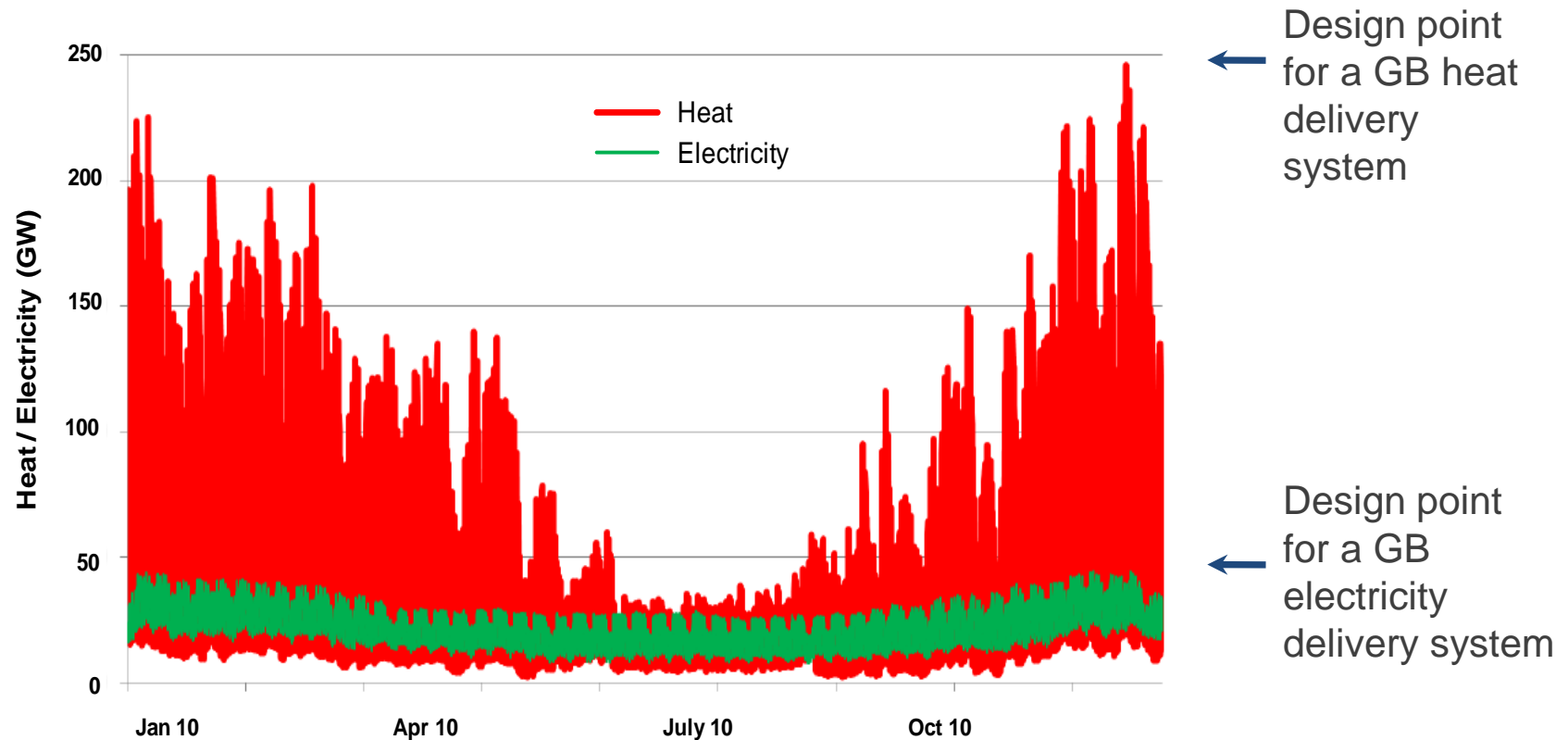




Heat demand variability in 2010

UK system has to cope with 6x heat demand swing

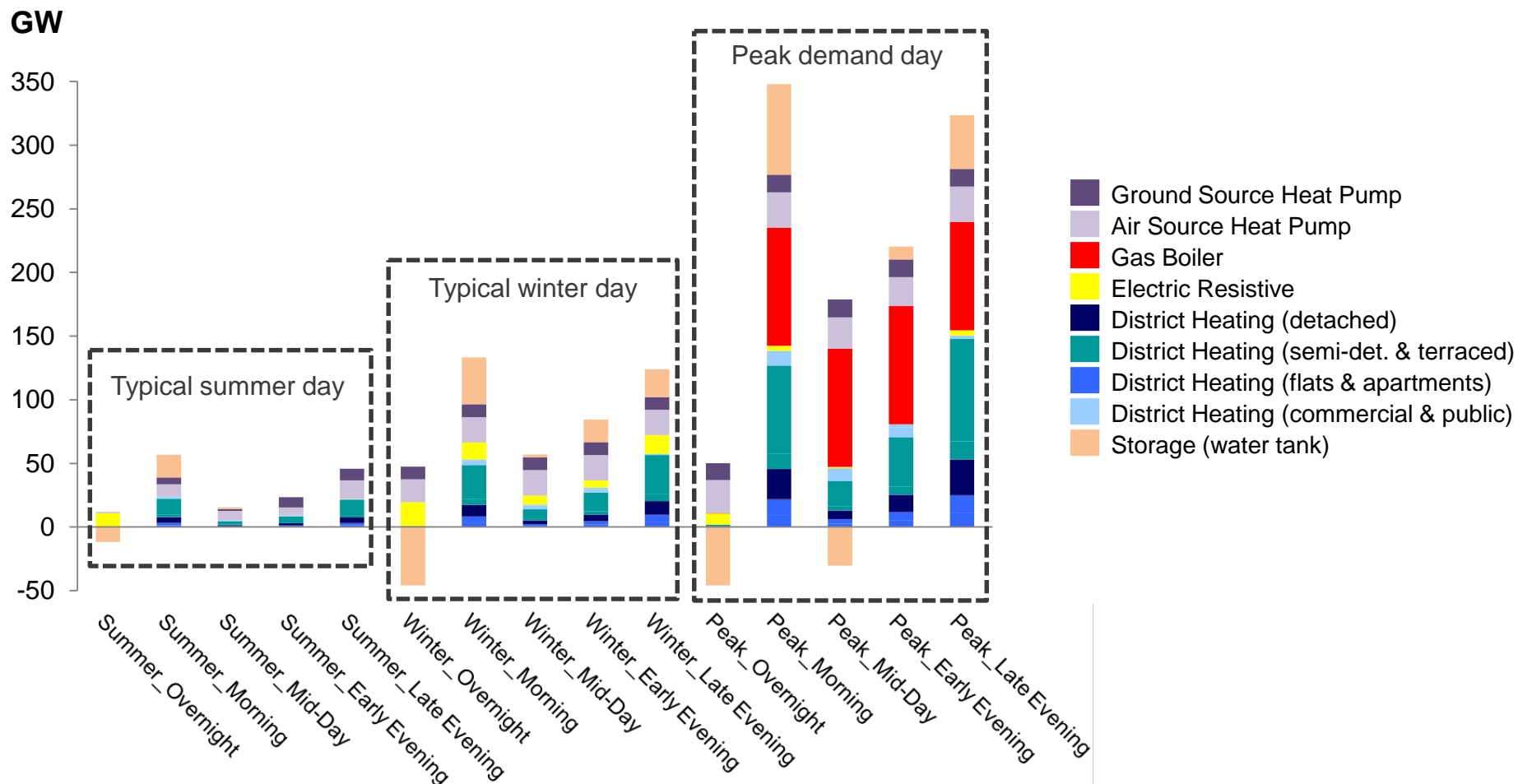
Existing gas distribution grid supports this



GB 2010 heat and electricity hourly demand variability - commercial & domestic buildings
R. Sansom, Imperial College



ESME space heating results: typical vs peak





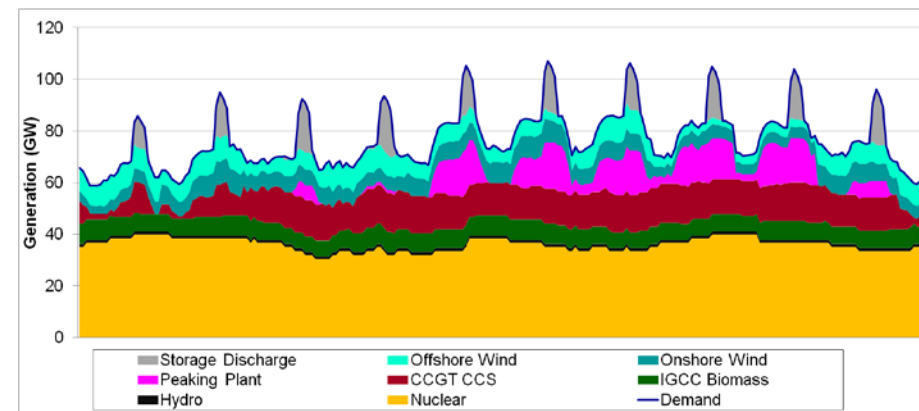
Sensitivity Analysis

Using the core ESME model:

- Monte Carlo results – ‘no-regret’ options, marginal choices
- 3 future UK demand cases – alternative socio-economic pathways for the UK
- Long list of “No technology X” sensitivities – opportunity cost metric
- Sensitivity to different CO₂ targets
- Sensitivity to improved/accelerated technology development

Beyond the core ESME model:

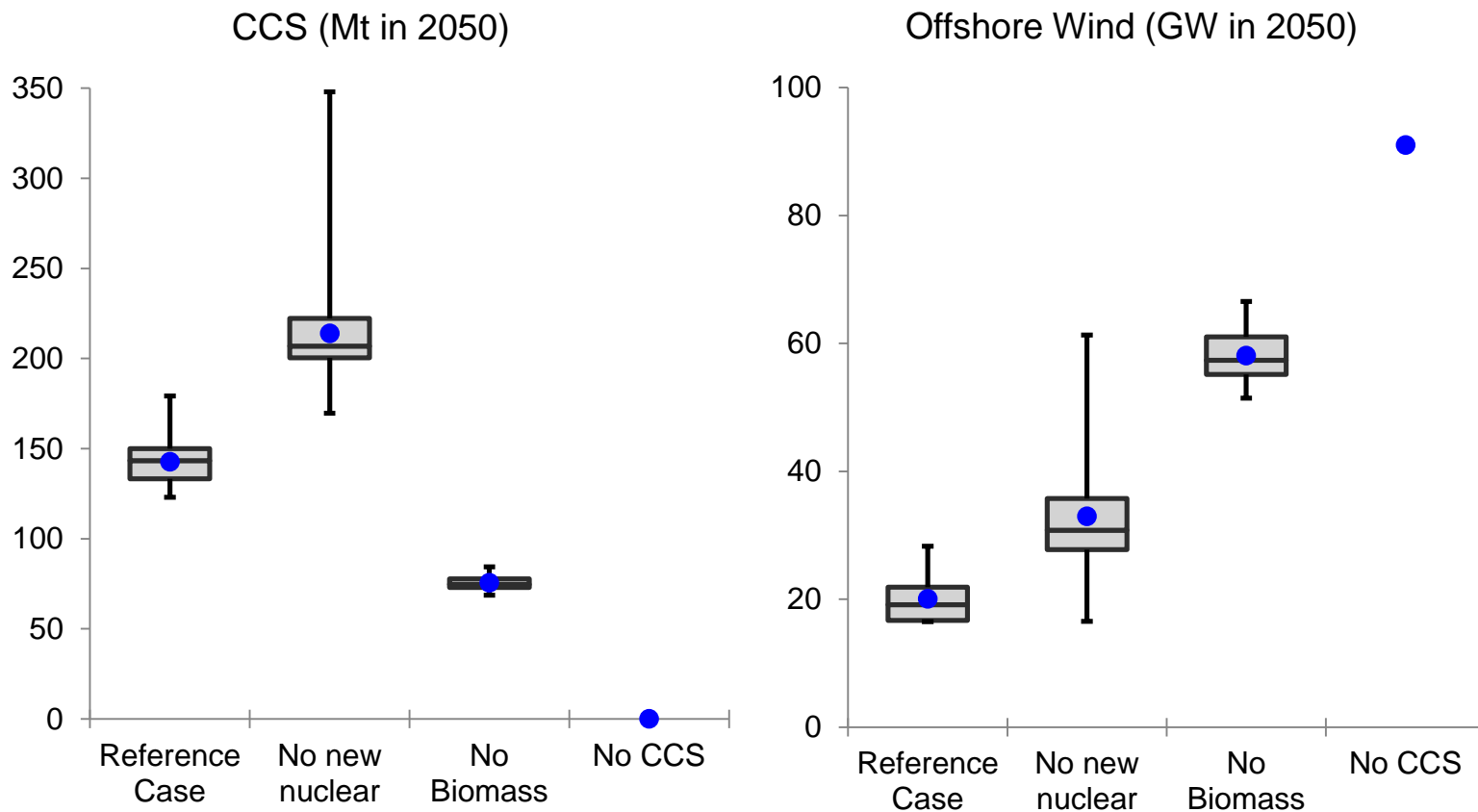
- Dispatch of the ESME electricity system is studied in PLEXOS
- More detailed buildings & heat optimisation
- More detailed peak day optimisation





Technology deployment

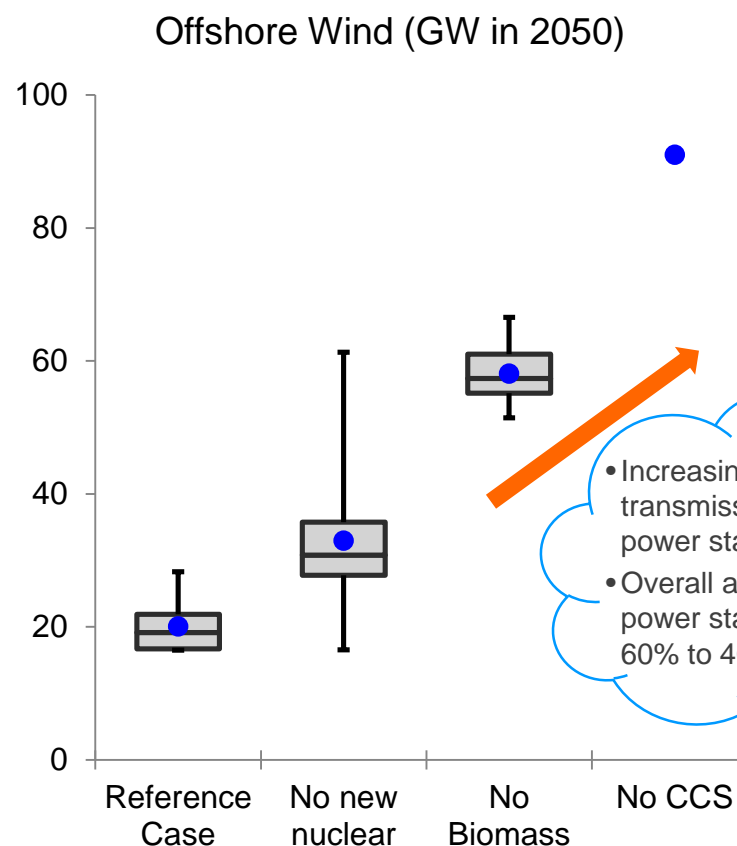
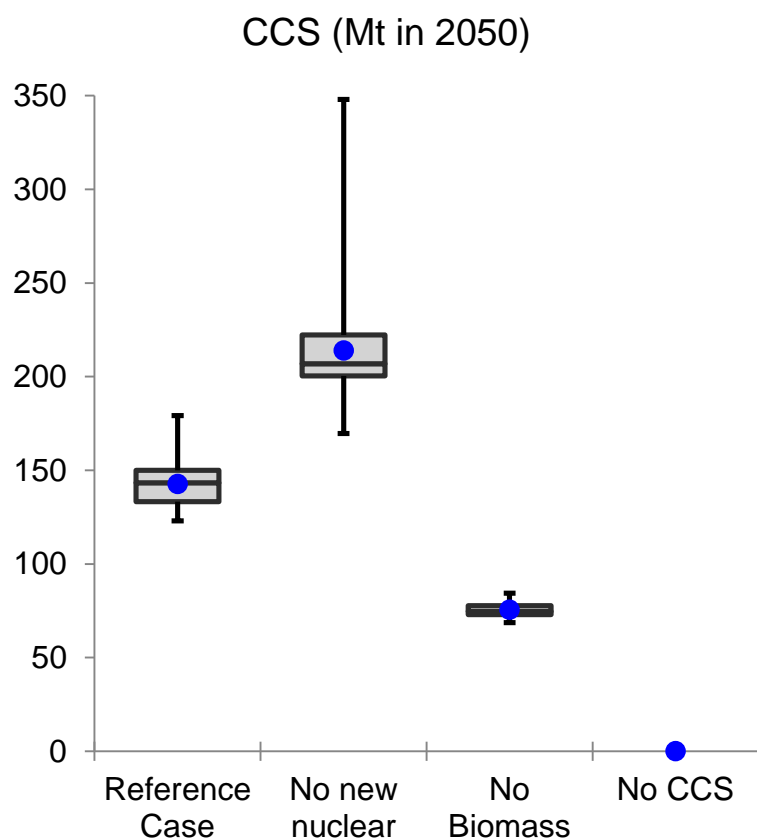
CCS appears a mainstay, offshore wind a critical hedge





Technology deployment

CCS appears a mainstay, offshore wind a critical hedge





Using 'opportunity cost' to measure role of a technology in the system

Opportunity cost of technology X is defined by two alternative scenarios:

- A. The least-cost energy system design using standard assumptions
- B. The least-cost energy system design if technology X unavailable

Opportunity cost = Total Cost (B) – Total Cost (A)

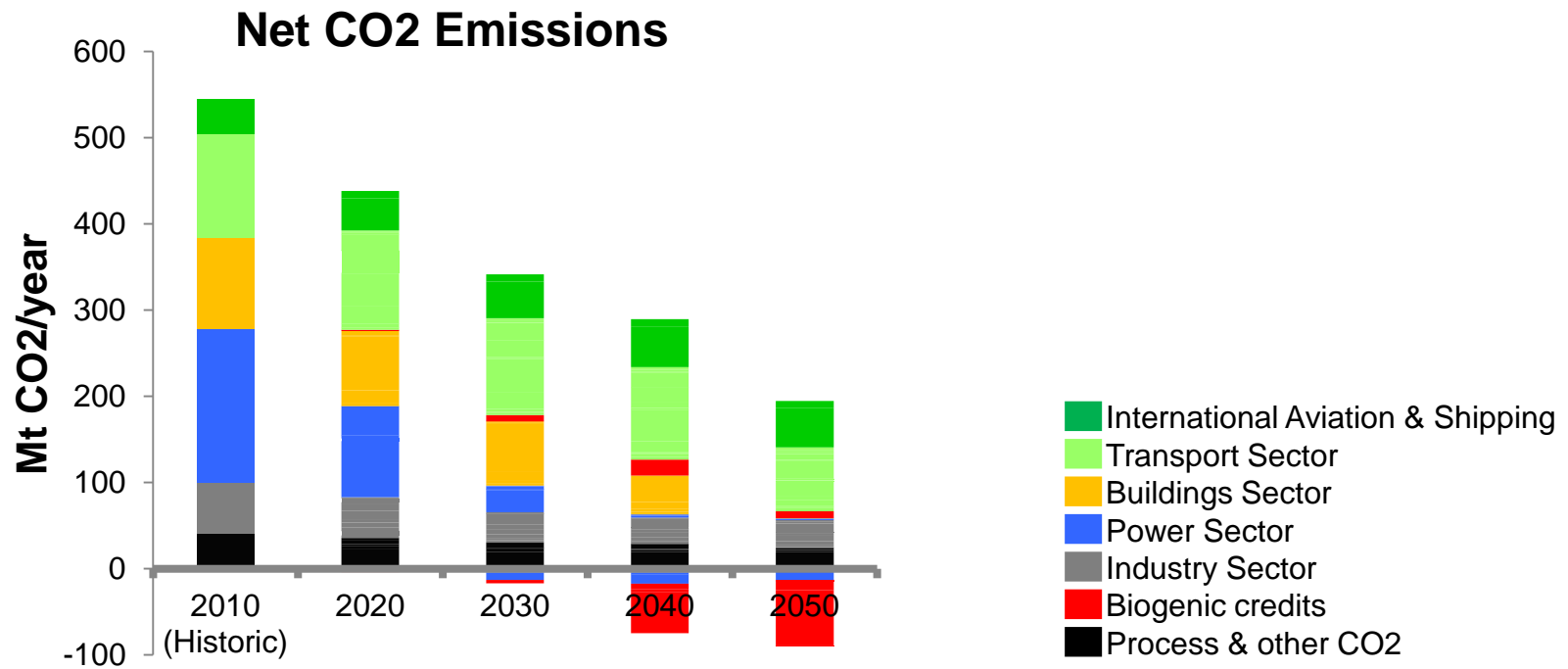
= 0 if technology X is not present in the reference case (System A)

> 0 if technology X is present in System A.

Magnitude of the opportunity cost depends on the relationship between System A and System B: 'substitution' or 'reconfiguration'



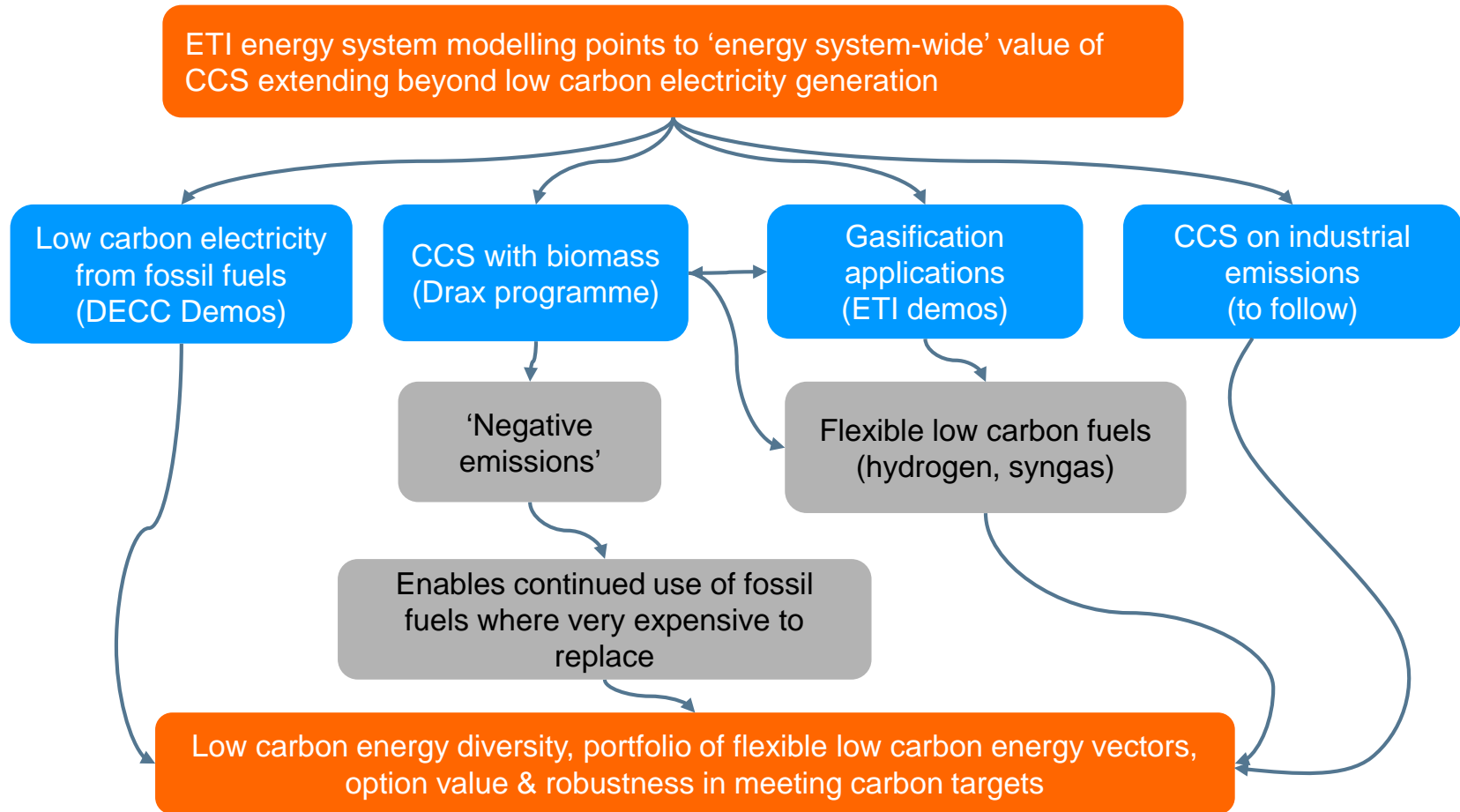
CCS and Biomass consistently have the highest opportunity costs





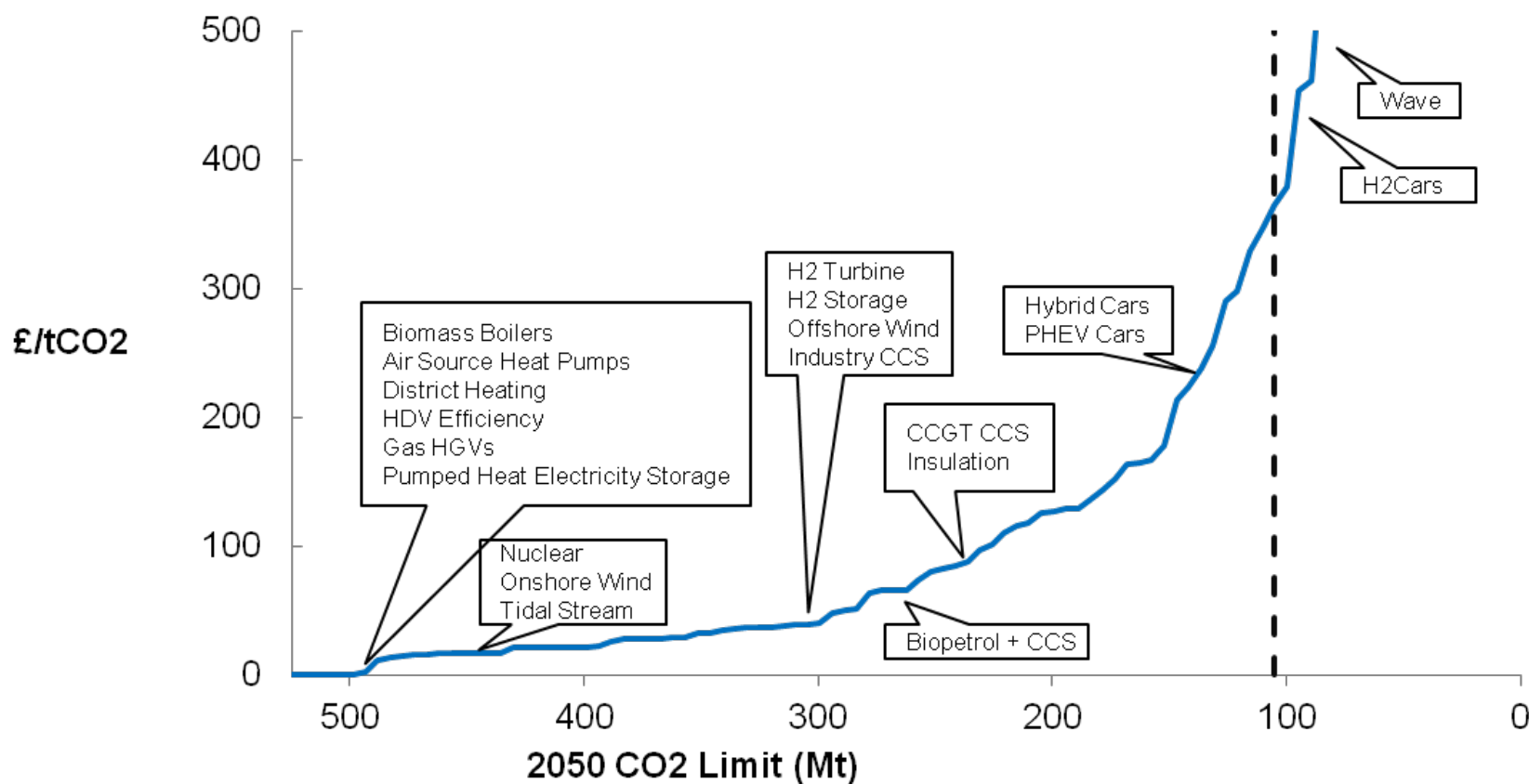
CCS is high value as it creates options

application of the same infrastructure for power, industry, enabling bioenergy usage and H2 production





ESME Abatement Curve





Potential implications for the UK...

Abatement costs

UK's challenging 2050 CO2 target appears affordable with intelligent national energy system design and investment in technology development

Efficiency measures

waste heat recovery, building insulation, and efficient vehicles make a contribution under all emission reduction scenarios

ETI targeting through SSH (£100m) and HDV (£40m) projects

Nuclear

mature technology and appears economic under most emission reduction scenarios - primarily an issue of deployment (planning / licensing, supply-chain, finance etc)

Cost impacts post-Fukushima need clarification – international approach needed

Bioenergy

major potential for negative emissions via CCS and might include a range of conversion routes – H2, SNG, process heat

ETI investing in science, logistics and value models

SSH – Smart Systems and Heat programme

HDV – Heavy Duty vehicle Efficiency programme

Offshore Renewables

the marginal power technology and an important hedging option

ETI investing in next generation, low cost, deepwater platform and turbine technology demonstrations

CCS

a key technology lever given potential wide application in power, hydrogen and SNG (gas) production, and in industry sector

ETI investing in separation, storage and system design – for coal, gas and biomass

Natural gas

a key 2050 destination fuel for power, space heating, industrial process heat and potentially for heavy duty vehicle transport applications

ETI addressing through SSH and HDV efficiency programmes

Hydrogen

potentially important energy vector providing system flexibility (CCS and storage) and light vehicle transport applications

ETI determining energy system flexibility benefits of using H2



Registered Office
Energy Technologies Institute
Holywell Building
Holywell Park
Loughborough
LE11 3UZ



For all general enquiries
telephone the ETI on
01509 202020.



For more information
about the ETI visit
www.eti.co.uk



For the latest ETI news
and announcements
email info@eti.co.uk



The ETI can also be
followed on Twitter
[@the_ETI](https://twitter.com/the_ETI)