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Energy, Environment and Technology

Options to decarbonise the UK's energy needs for 2050



Agenda

- Introduction
- The context of energy
- The Energy Technologies Institute (ETI)
- The UK energy challenge
- Bioenergy
- Q&A



INTRODUCTION

Introduction

The context of energy
The Energy Technologies Institute (ETI)
The UK energy challenge
Bioenergy
Q&A



Who am I ?

- Chemistry, Heriot-Watt University
- Applied for sponsorship with Shell and British Nuclear Fuels
 - Sponsored by BNFL
 -but elected to join BP !
- 23 years with BP in UK and France
- MBA (University of Durham) in 2007
- Variety of team leader and project leader roles since 2003
- On secondment to Energy Technologies Institute (ETI) since 2011
 - Based at CEH, Lancaster until end 2014





THE CONTEXT OF ENERGY

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Who said...

“What we are now doing to the world, by degrading the land surfaces, by polluting the waters and by adding greenhouse gases to the air at an unprecedented rate - all this is new in the experience of the earth. It is mankind and his activities that are changing the environment of our planet in damaging and dangerous ways.”



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Margaret Thatcher, 8th November, 1989
Speech to the United Nations



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Margaret Thatcher, 8th November, 1989
Speech to the United Nations

But, two days before the speech, the UK blocked a proposal at a conference in the Netherlands for a 20% reduction in CO₂ emissions by 2005!



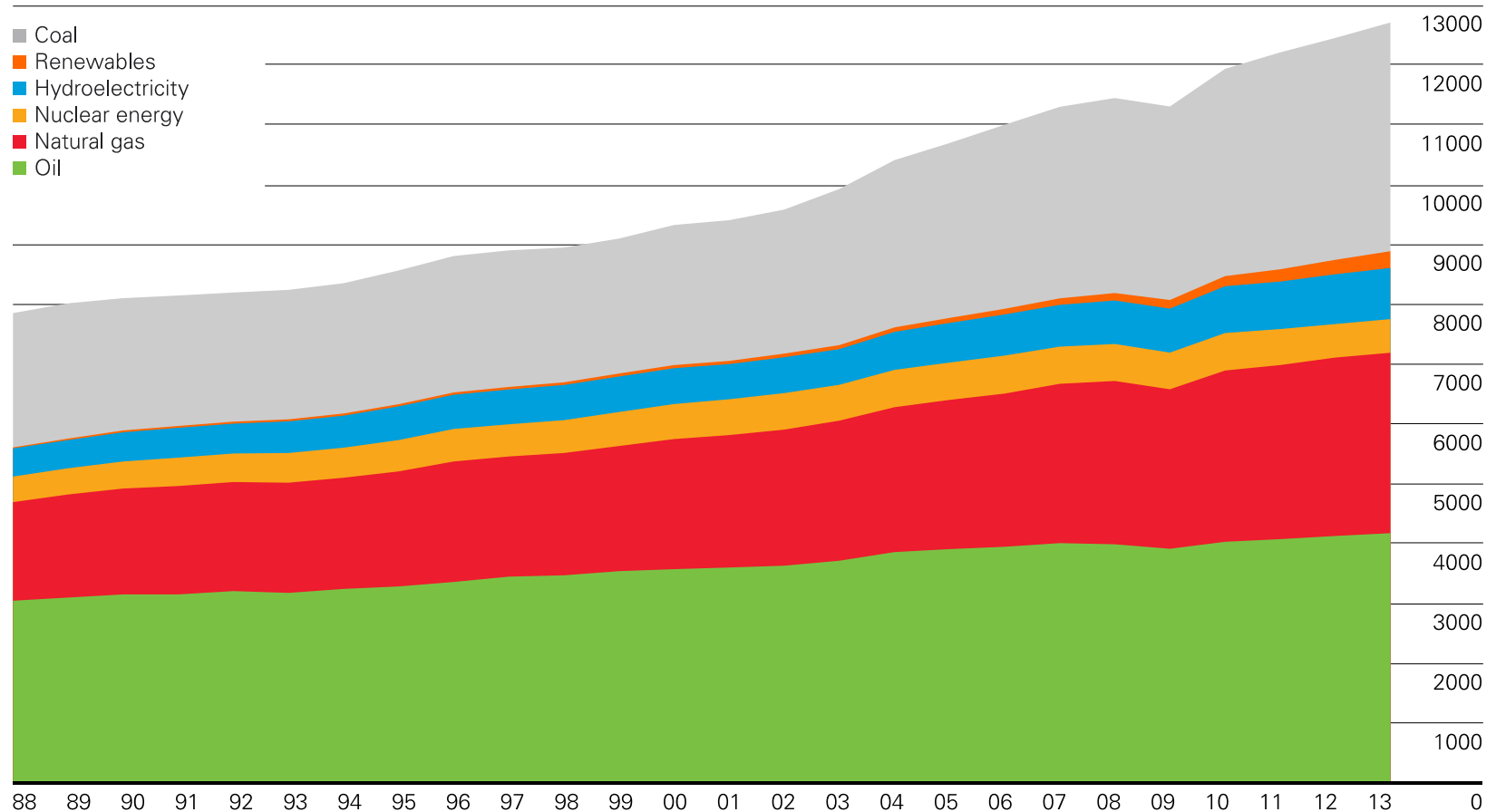
World Energy





Primary energy world consumption

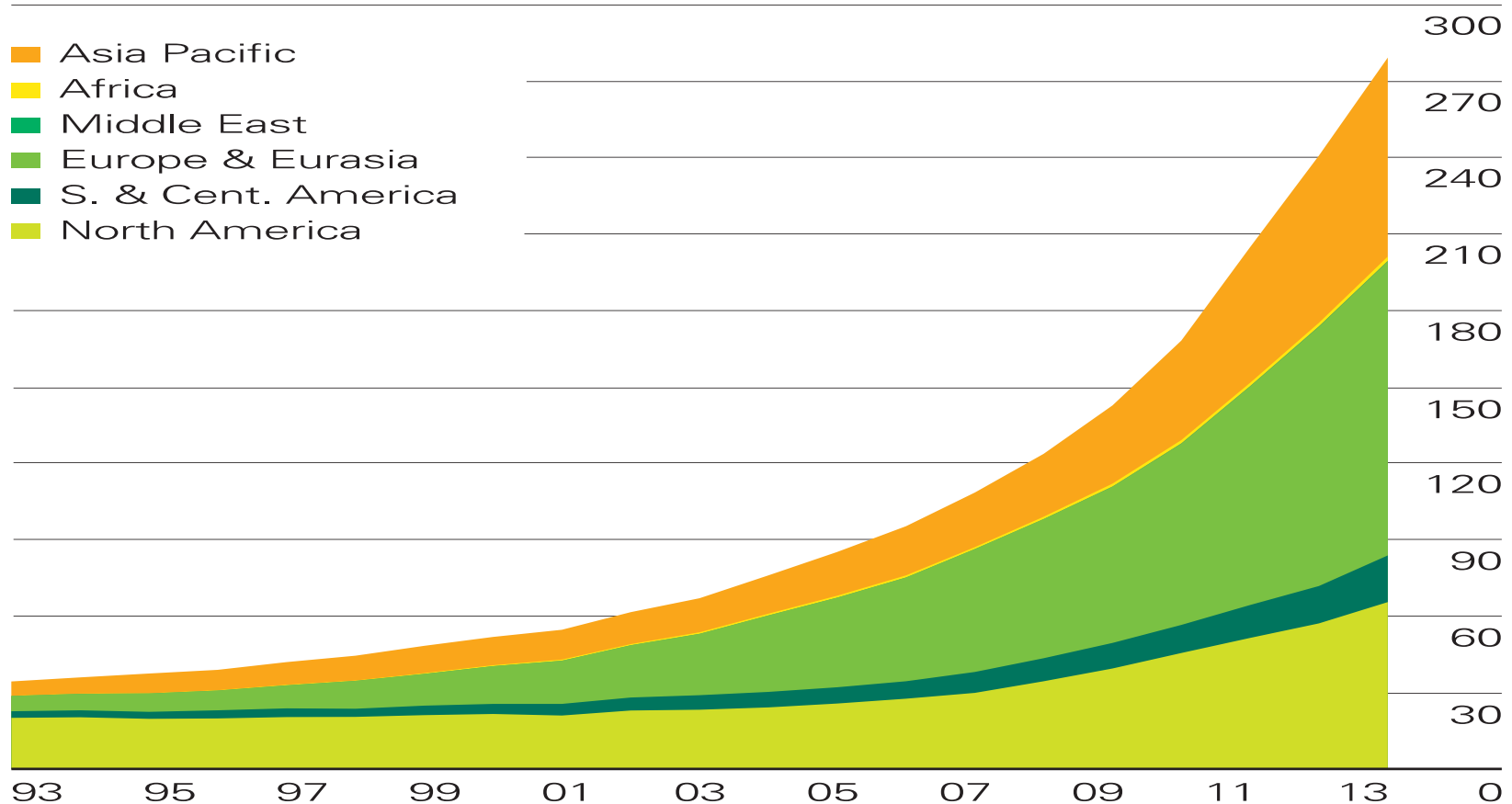
Million tonnes oil equivalent





Renewable energy consumption by region - Last 20 years

Other renewables consumption by region
Million tonnes oil equivalent

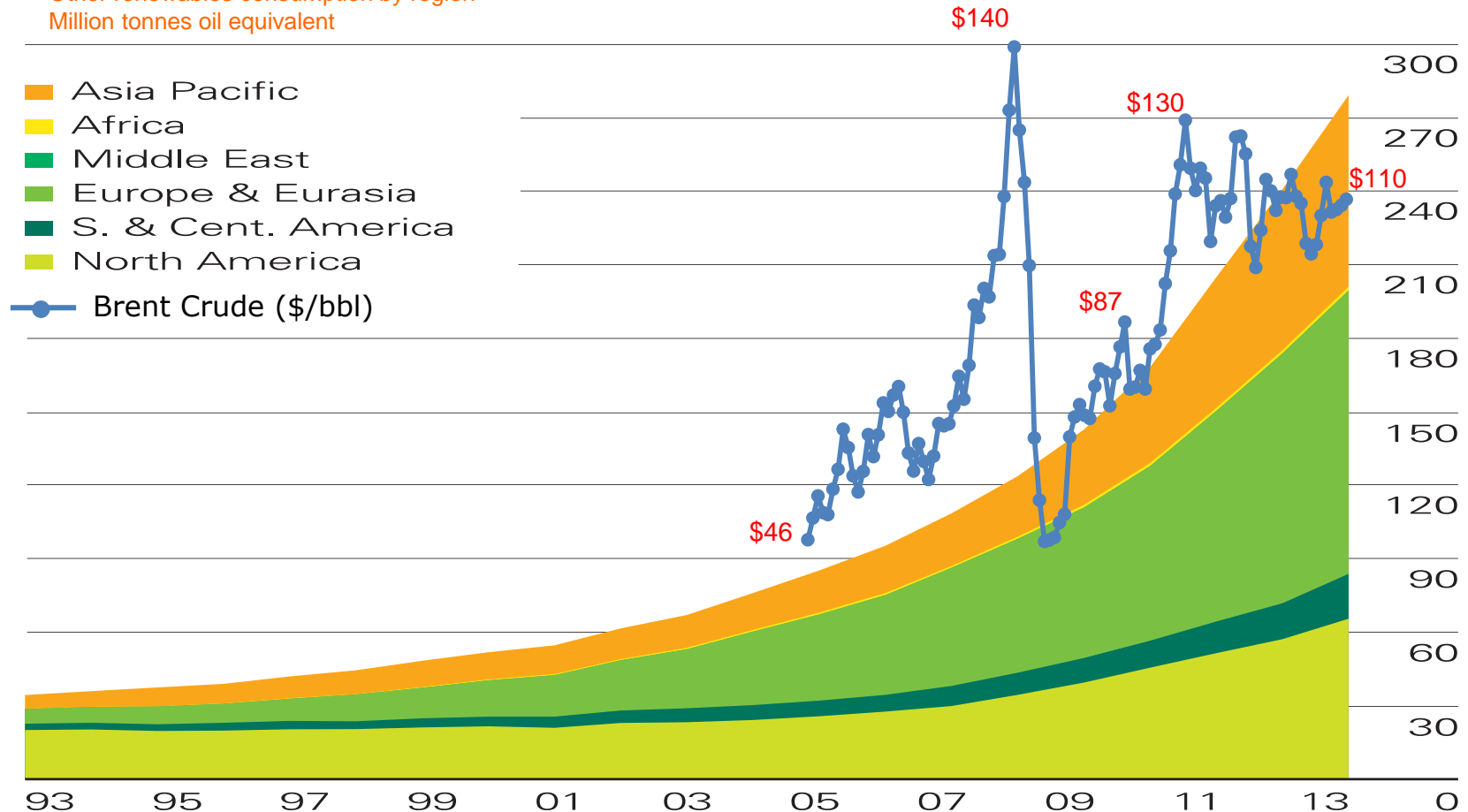


BP Statistical Review of World Energy 2014
© BP 2014



Renewable energy consumption by region - Last 20 years

Other renewables consumption by region
Million tonnes oil equivalent

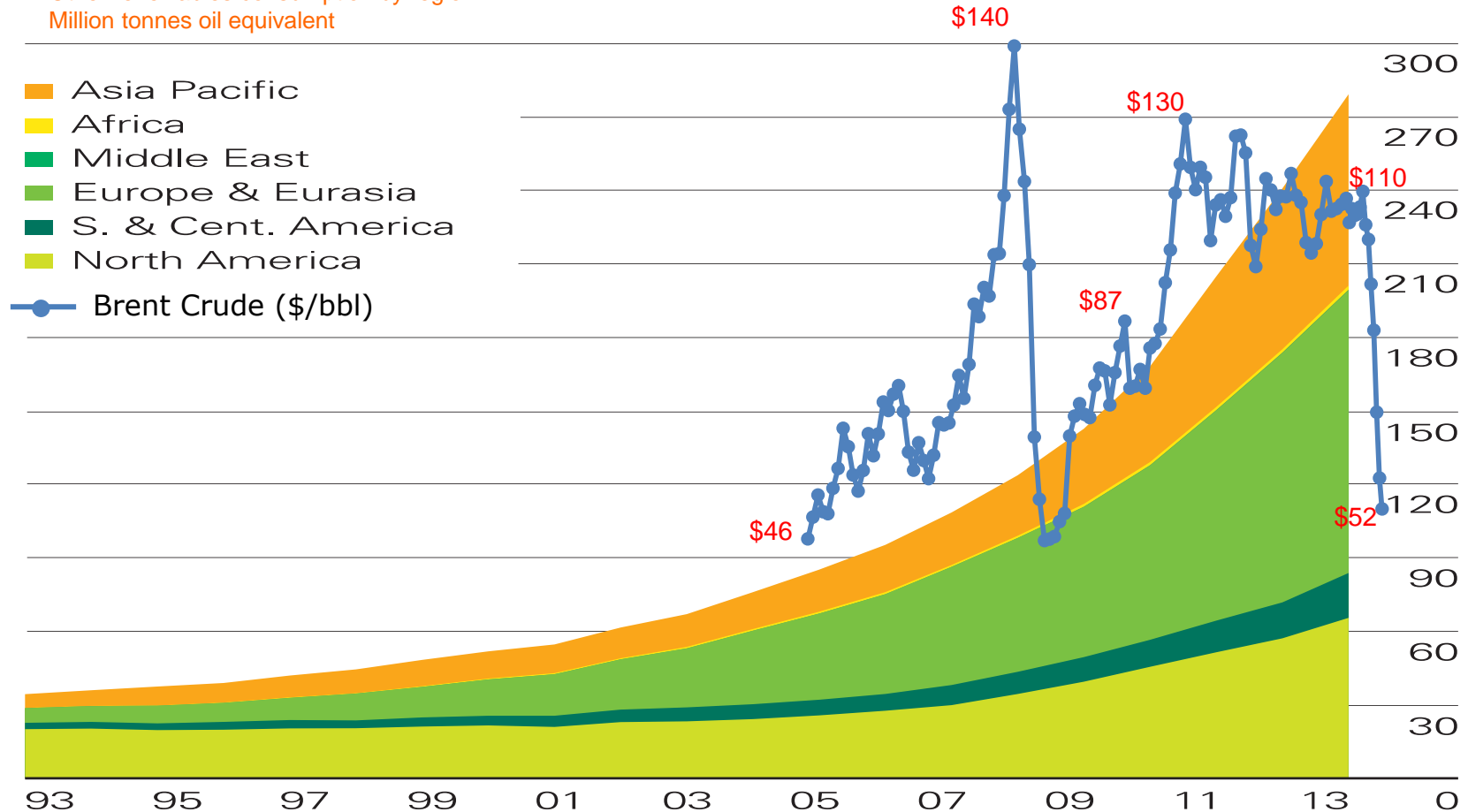


BP Statistical Review of World Energy 2014
© BP 2014



Renewable energy consumption by region - Last 20 years

Other renewables consumption by region
Million tonnes oil equivalent



BP Statistical Review of World Energy 2014
© BP 2014

"Let us begin with one basic idea: 250 years of growth based on the exploitation of fossil fuels has brought real benefits."

Nicholas Stern

"In our early warning system of 20 traffic lights, eight are now on red."

Ofgem

"One of the gravest problems in energy we inherited was a record of historic underinvestment in energy infrastructure that, if neglected, threatened an energy security crisis, particularly in electricity supply."

Ed Davey

"There is no 'Plan B' because we do not have a 'Planet B'."

Ban Ki-moon , 23-Sep-14

"New energy storage plant could 'revolutionise' renewable sector."

The Guardian, 08-Apr-15

"For the next two or three years, there is plentiful reserves, but the problem is the speed with which the situation could deteriorate."

Ofgem

"We absolutely can have growth and protection of the climate at the same time, and in doing so we will construct a much better form of economic activity and growth in terms of clean air, less-congested cities and so on,"

Nicholas Stern

"Can the world economy survive without fossil fuels?"

The Guardian, 08-Apr-15



Climate Change Act 2008

Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

The target for 2050:

1. It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline.
2. “The 1990 baseline” means the aggregate amount of—
 - a) net UK emissions of carbon dioxide for that year, and
 - b) net UK emissions of each of the other targeted greenhouse gases for the year that is the base year for that gas.





Act includes the following:

- **2050 Target.** The act commits the UK to reducing emissions by at least 80% in 2050 from 1990 levels. This target was based on advice from the CCC report: Building a Low-carbon Economy. The 80% target includes GHG emissions from the devolved administrations, which currently accounts for around 20% of the UK's total emissions.
- **Carbon Budgets.** The Act requires the Government to set legally binding 'carbon budgets'. A carbon budget is a cap on the amount of greenhouse gases emitted in the UK over a five-year period. The Committee provides advice on the appropriate level of each carbon budget which are designed to reflect cost effective path to achieving the long terms objectives. The first four carbon budgets have been put into legislation and run up to 2027.
- **The Committee on Climate Change** was set up to advise the Government on emissions targets, and report to Parliament on progress made in reducing greenhouse gas emissions. It includes the Adaptation Sub-Committee (ASC) which scrutinises and advises on the Government's programme for adapting to climate change.
- **A National Adaptation Plan** requires the Government to assess the UK's risks from climate change, prepare a strategy to address them, and encourage critical organisations to do the same. For more detail, visit the [UK adaptation policy page](#).



Act includes the following:

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THE ENERGY TECHNOLOGIES INSTITUTE (ETI)

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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

ETI members



CATERPILLAR®



 **Rolls-Royce**



EPSRC
Pioneering research
and skills


Department
of Energy &
Climate Change


Department
for Business,
Innovation & Skills

Innovate UK
Technology Strategy Board

ETI programme associate

HITACHI
Inspire the Next



What is the ETI?



ETI members



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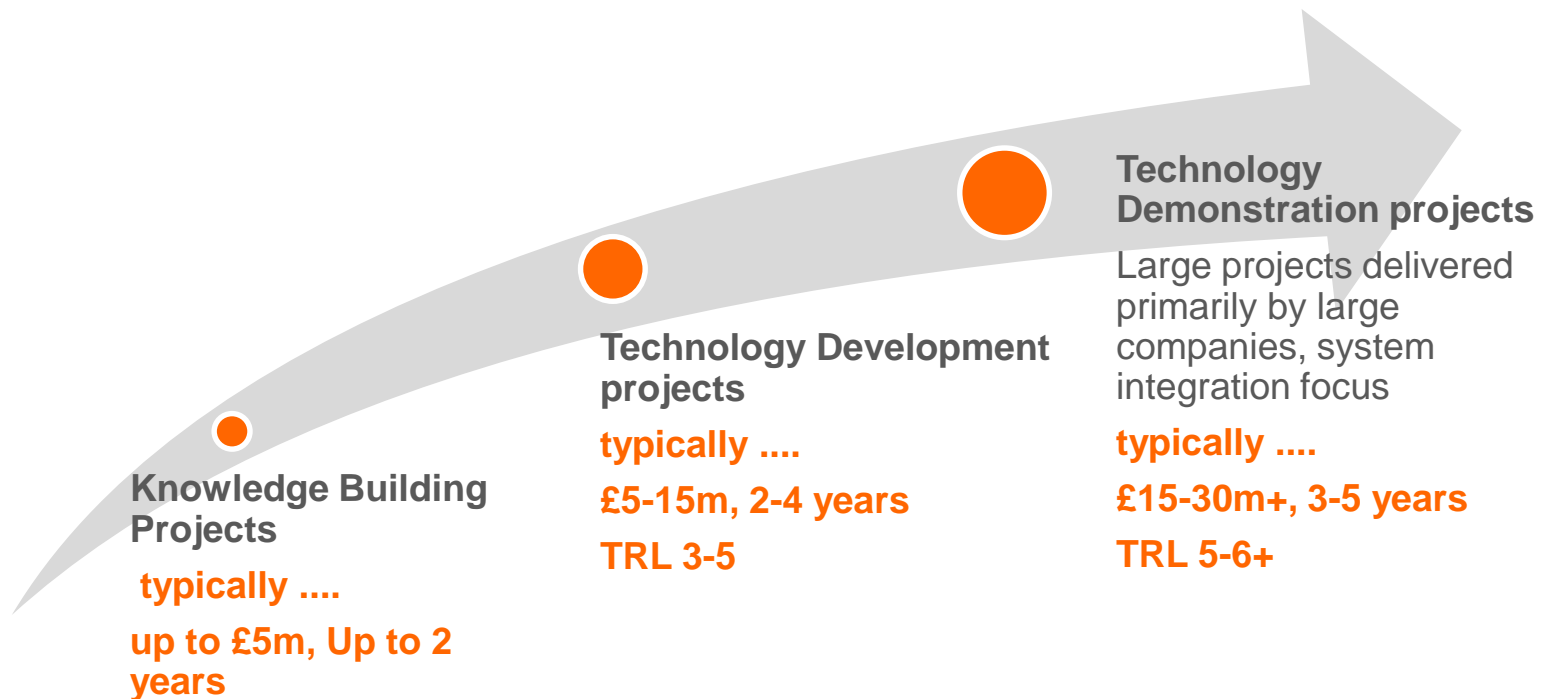
ETI programme associate

HITACHI
Inspire the Next



What does the ETI do?

ETI Invests in projects at 3 levels

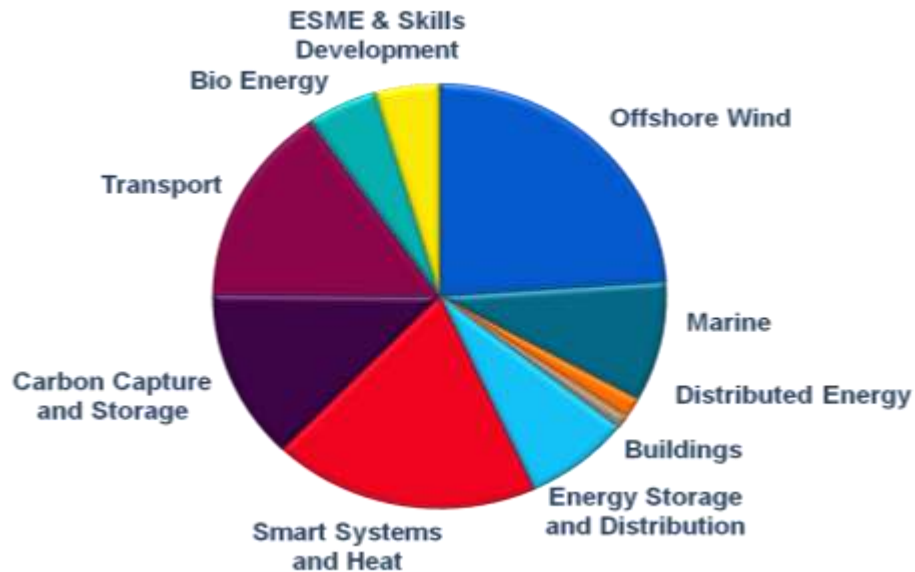




ETI Invests in 9 technology programme areas at three investment levels



Cross-cutting Projects – ETI Internal



Delivering...

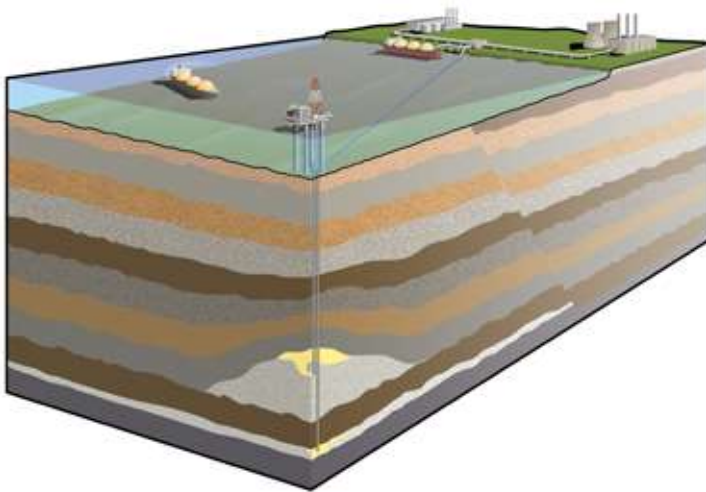
- New knowledge
 - Up to £5M / 2 years
- Technology development
 - £5-15M / 2-4 years / TRL 3-5
- Technology demonstration
 - £15-30M+ / 3-5 years / TRL 5-6+
- Reduced risk

[illegible]



CCS

A key lever - particularly combined with bioenergy
Long development time requires early start



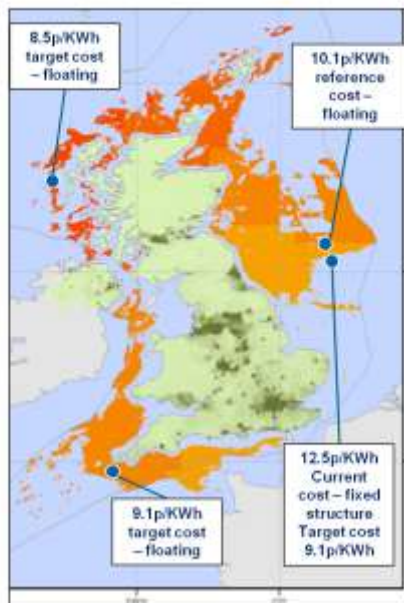
- Potentially very wide use
 - Power
 - Hydrogen and 'Synthetic Natural Gas' (SNG) production
 - Heavy industry
- ETI investing over £60m in enabling CCS for coal, gas and biomass
 - Improved separation technologies
 - Storage appraisal
 - Transport system design tools



Offshore Wind

The marginal power technology and an important hedging option – cost reduction is critical

UK has high winds in 50-100m water
Average wind speeds over UK waters which are 50-100m deep
Range - from 9-12 m/s light orange to deep red

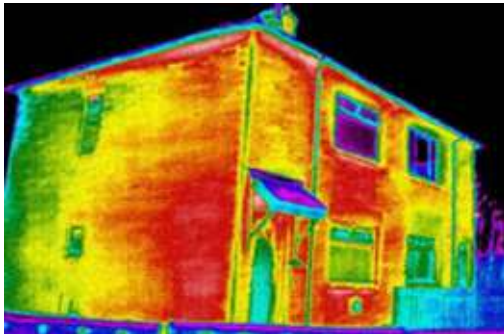


- DECC cost reduction task force has identified routes to achieving £100/MWh by 2020 –
 - Contract and project structures
 - Financing and risk management
 - Technology innovation
- ETI has already invested £40m in technology development projects to target further cost reductions
- ETI has launched £30m of new projects to develop next generation, low cost, deepwater floating platform and very long blade turbine technology
- ETI Targeting ~£90/MWh post 2020 through applying these technologies in high wind speed areas off UK west coast
- (£100/MWh = 10p/KWh, £90/MWh = 9p/KWh)



Buildings and Transport

All future emission reduction scenarios utilise efficiency improvements



- Waste heat recovery
 - Building insulation
 - Efficient vehicles
 - Energy systems management
-
- ETI targeting through system demonstration and technology development projects
 - ‘Smart systems’ £95m+
 - Marine and Land Heavy Duty Vehicle efficiency £30m+
 - Plus, ongoing ETI projects in building refurbishment , energy management systems and energy storage



THE UK ENERGY CHALLENGE

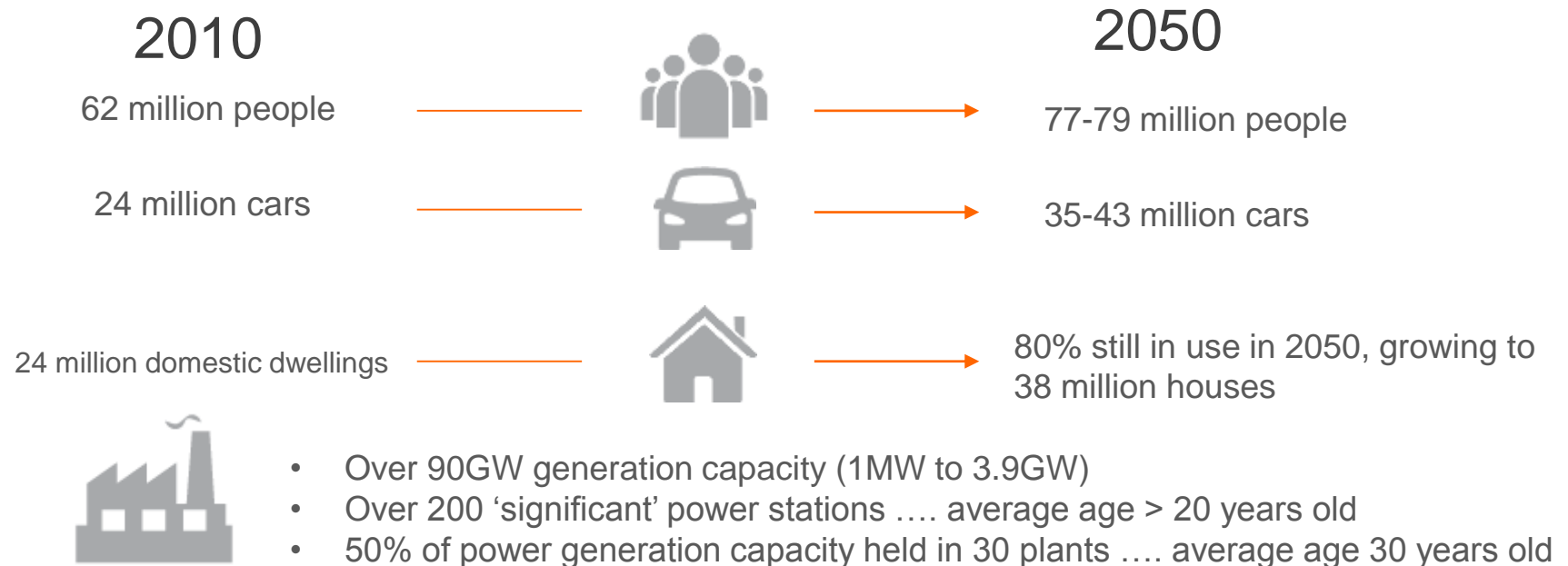
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**“ BY 2025, CHOICES MUST BE MADE
REGARDING INFRASTRUCTURE DESIGN
FOR THE LONG-TERM. CLOSING DOWN
OUR OPTIONS TOO SOON COULD PROVE
UNNECESSARILY COSTLY FOR THE UK,
BUT THE BIGGER THREAT IS FAILING TO
BUILD UP THOSE OPTIONS AT ALL ”**





The UK Energy Challenge...



Demand is growing, assets are ageing, prices are rising... irrespective of the UK's GHG emission reduction targets

➡ Need to design a future UK energy system which is sustainable, affordable and secure

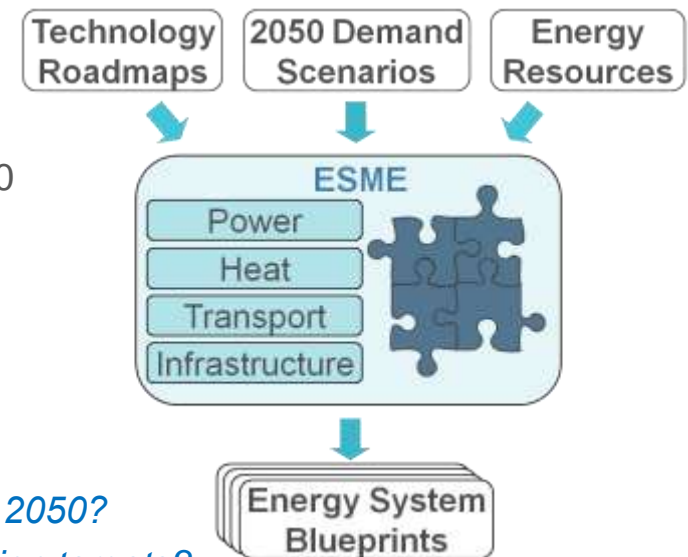


ETI's 'ESME' model of the UK energy system



A national energy system design tool with sufficient spatial and temporal detail to understand system engineering challenges.

- A least-cost optimisation, policy neutral tool
- Can model pathway and supply chain constraints out to 2050
- Probabilistic treatment of key uncertainties enables less mature technologies to be assessed



Example questions ESME would be used to inform

- *What might be 'no regret' technology choices and pathways to 2050?*
- *What is the total system cost of meeting the energy and emission targets?*
- *Where should new generating capacity optimally be located?*
- *What are the opportunity costs of individual technologies or sectors (e.g. bioenergy)?*



ETI Future 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 4th March





ETI Future Scenarios

A well-coordinated national
planning approach...

...versus...

...a more 'organic' approach with
distinct strategies at the regional level.

CLOCKWORK



PATCHWORK





2050 ...

- UK population 76M
- South East UK economic centre of gravity
- London continues as key global financial and business centre
- Industrial output increases – shift continues towards value added products
- Large, energy-intensive industries declining
- Increasing disposable incomes and confidence
- Households prepared to pay for carbon abatement
- Need to balance decarbonisation against lifestyle disruption and economic growth
 - Drives implementation of cheaper solutions from a systems perspective



Decisions will need to be made

- Four carbon budgets to date mandated a 50% reduction to 2027
- Action to date
 - Decarbonising UK power sector
 - Encouraging energy efficiency in households and vehicles (lesser extent)
- Strong contributors, but insufficient alone for longer term
- 2025-2050: major changes needed
- Existing low-carbon technologies and infrastructures need to be deployed
 - not reliant on improbable breakthroughs or wildcard technologies
- Society needs to accept (and ideally desire) low carbon solutions
- What needs to be done to ensure informed decision making:
 - Provide real options by developing and proving technologies
 - Proving new business models
 - Building supply chains
 - Understanding societal needs



Clockwork

- Represents a more centrally planned scenario with a well coordinated design of investments at the national scale
 - New energy infrastructure installed “like clockwork”
 - Focus on coordinated design of supply and infrastructure
 - Social acceptance of chosen solutions
- Regular and early new builds allows steady power sector decarbonisation
 - Nuclear, CCS, Renewables
- Large scale district heating
 - Local gas distribution networks slowly retired from 2040
- Emissions offsetting gives headroom
 - Breathing space for transport

CLOCKWORK





Patchwork

- No central leadership role leads to a more “organic” patchwork approach of distinct regional energy strategies
 - Society actively engaged in decarbonisation
 - Popular attention focused on range of social and environmental values
- Supply generation: national, regional and local mix
 - Energy supply renewables heavy, dominated by offshore wind
- Limited role for emissions offsetting
 - Leads to more extensive decarbonisation across all sectors including transport
- Cities/regions compete for central support
- Local energy needs tailored locally
- Patchwork of solutions overtime is integrated by central government.

PATCHWORK





Infrastructure

Clockwork

- Early development of 2-3 nuclear power plants
- Tighter coupling of electricity supply and demand
- Planned district heating networks in cities starting out of key areas
- Heat pump roll-out in off-gas grid areas
- Earlier (and different to Patchwork) development of CO₂ transport infrastructures

Patchwork

- Electricity upgrades happen in a series of poorly planned surges
- Electricity distribution networks will need to cope with excess supply (in summer)
- DH and heat pump rollout spread is in clusters, similar to recent solar roll out driven by specific local factors (word of mouth, effective sales forces)
- Introduction of hydrogen refuelling infrastructure



Summary of Clockwork and Patchwork

- The UK can achieve an affordable transition to a low carbon economy over the next 35 years – with abatement costs in the range of 1-2% of GDP by 2050 with potential to achieve the lower end with effective planning.
- The UK must focus on developing and proving a basket of the most promising supply and demand technology options – limits implementation risks
- Key technology priorities include **bioenergy**, carbon capture and storage, new nuclear, offshore wind, gaseous systems, vehicle efficiency and efficiency / heat provision for buildings
- It is critical to focus resources in the next decade on preparing these options for wide scale deployment – crucial decisions on infrastructure design for the long term need to be made by the mid 2020's.
- Carbon capture and storage and **bioenergy** are especially valuable – use negative emissions to offset pressures from more difficult to carbonise sectors (e.g. aviation, shipping)
- 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.



Key messages

- An affordable transition to a low carbon energy system is possible over 35 years
 - 1-2% of GDP by refining, commercialising and integrating known but currently underdeveloped solutions
- CCS and bioenergy have great potential and are key
 - Cost of £90bn/year each if not developed
 - Negative emissions alleviate pressure in more difficult sectors, especially transport
- UK must prepare over the next decade
 - Major investment is required to develop and prove key technology options by the mid 2020's
 - Opportunity for economic advantage in global market place
- Crucial decisions must be made regarding infrastructure design for the long term to avoid wasting investment
- Significant policy intervention will be required to support key technologies where a pure market approach is unlikely to be effective
 - E.g. **bioenergy**, CCS, nuclear
 - Public sector investments have to generate investor and consumer confidence.



BIOENERGY

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Bioenergy

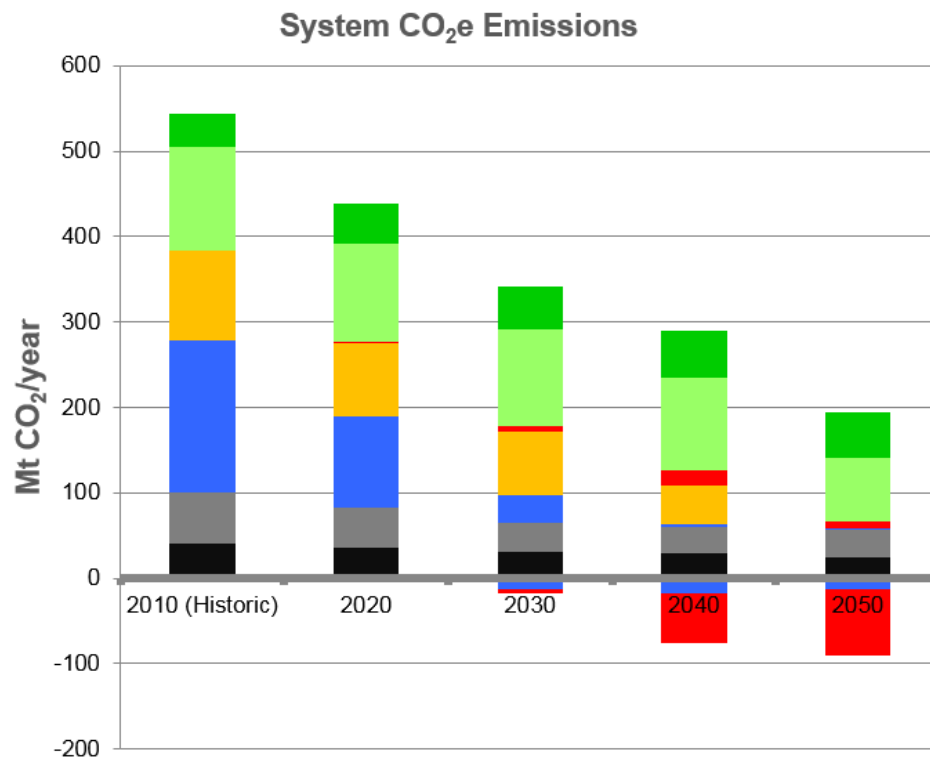
A key lever – particularly with CCS. Requires sustainable supplies – both imports and indigenous



- Major potential for creating ‘negative emissions’ via CCS
- Could support a range of conversion and utilisation routes
 - Hydrogen
 - SNG
 - Heat
- ETI investing in soil science, logistics and value chain models
- Informing decisions
 - “what do we grow ?”
 - “where do we grow it ?”
 - “how do we handle it ?”



The role of bioenergy in the UK energy system



- Lowest cost decarbonisation pathways identified: power, buildings, industry
- Negative emissions from bioenergy with CCS offsets the need for expensive interventions elsewhere in the energy system:
 - Aviation and shipping
 - Transport (passenger vehicles)





The benefits of bioenergy...

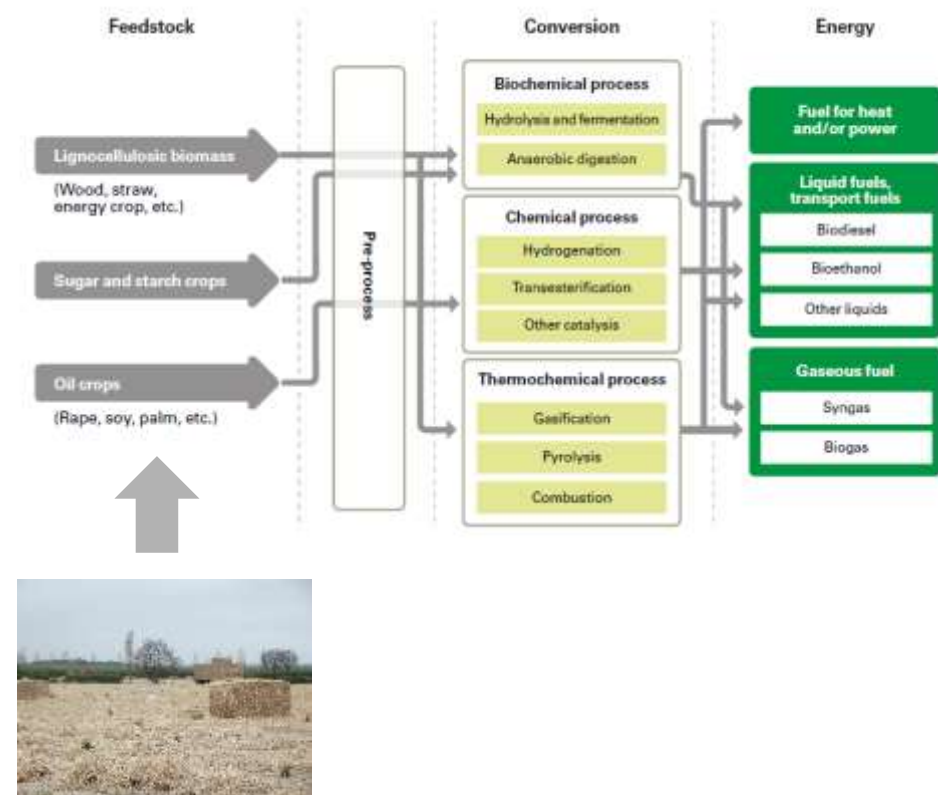
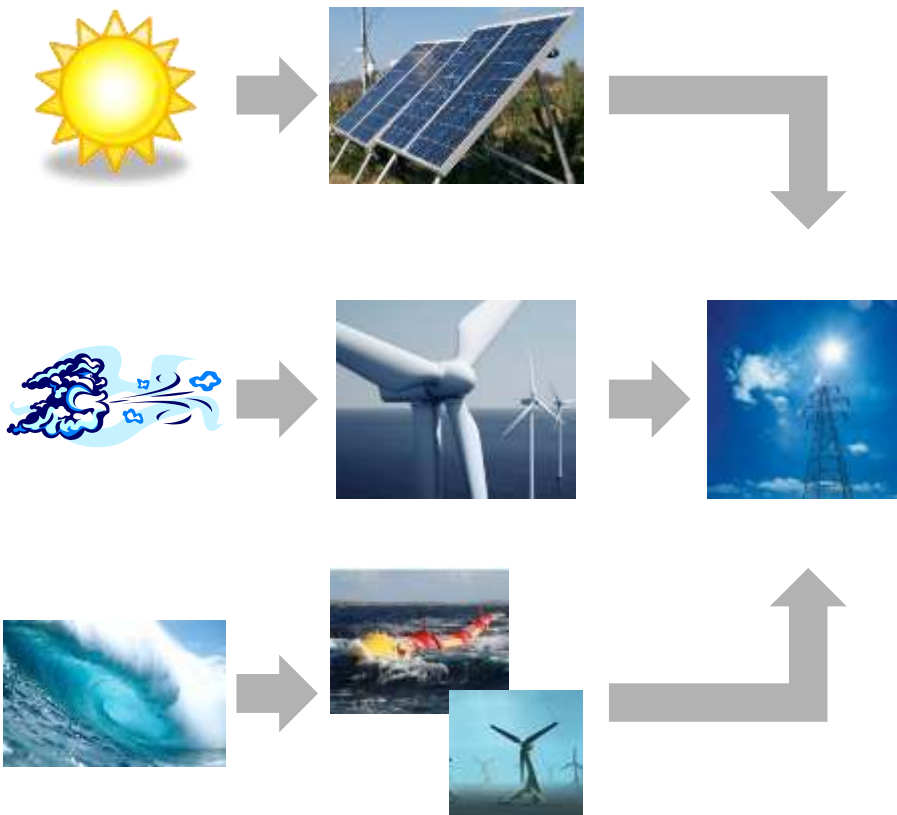
- 50-100 MtCO₂e negative emissions with CCS¹
- Could deliver 10-12% UK energy by 2050^{2,3}
- Flexibility in terms of end vectors
- Scalability of application
- Multiple feedstocks – potential supply chain benefits
- Energy security if domestically sourced
- Sector could generate up to 50,000 jobs by 2020⁴
- Wider UK growth opportunities of £19 billion⁵



- 1 – ESME analysis
- 2 – UK Bioenergy Strategy
- 3 – CCC Bioenergy Review
- 4 – NNFCC - UK Jobs in the Bioenergy Sector by 2020
- 5 – LCICG BioTINA

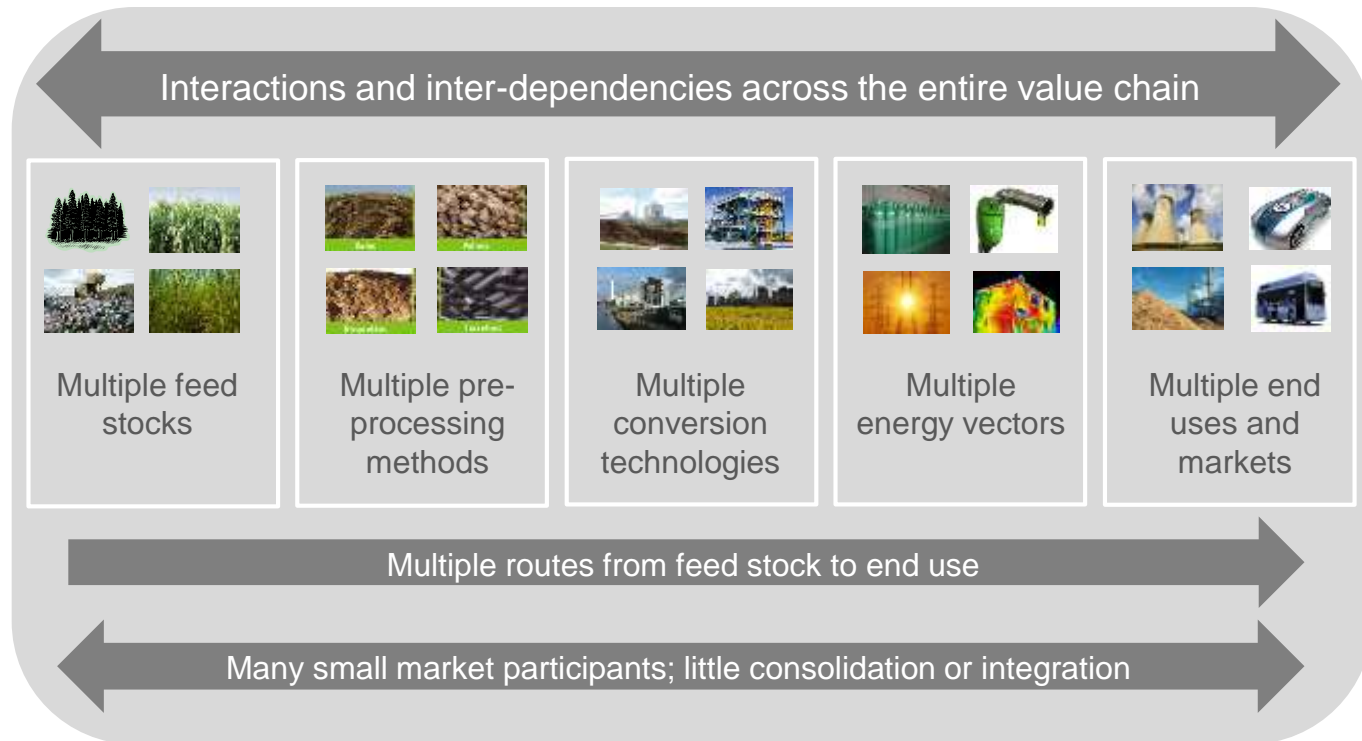


Renewable Energy Pathways





The bioenergy landscape is complex and the UK value chain is fragmented





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Winner of the Pulitzer prize

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Biomass and bioenergy

Biofuels are not a green alternative to fossil fuels

Biofuels and bioenergy take up finite land resources at the cost of food production and carbon storage and doesn't guarantee carbon emissions cuts

Andrew Steer and Craig Hanson
Dr Steer is president of the WRI.
Hanson is the WRI's global director of food, forest and water programmes

Thursday 20 January 2015 14:06 GMT

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Why biomass is key to the UK's energy future

In an interview with James Quinn, Drax chief executive Dorothy Thompson explains why the times are a-changing at the UK's largest electricity power station



Do we have resources in the UK?



2009 Estimate of **Underutilised** Land, T-Sec Bio-Sys

2006 Estimate of **Unused** Land, EEA, ADAS

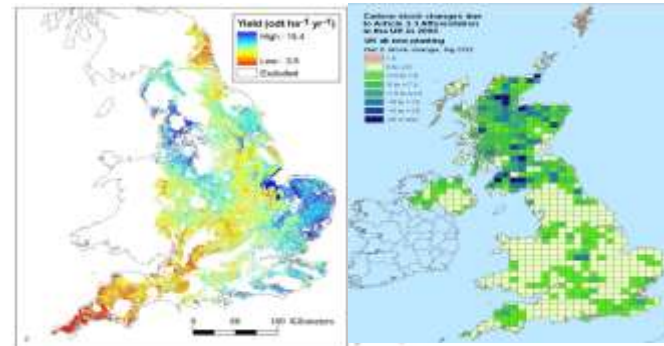
2003 Estimate of **Easy to Convert** Land

Current amount of energy crops ca. < 10k ha

Comparison across Europe

Germany, Italy: Over 30% Forest Cover

Sweden, Finland: Over 65% Forest Cover



Aylott et al, University of Southampton, 2010

Forestry Commission, 2007

Production on 3.5 million hectares of underutilised land, combined with biomass residues, could provide up to **10% of UK energy demand**. On inaccessible and/or steeply inclined land, forestry could be grown to further absorb CO₂ from the atmosphere.



Ecosystem Land Use Modelling Project (ELUM)



Aim: to develop a spatial model of the UK, which can be used to assess the impact of Land Use Change (LUC) to biomass production

- Unique “measured and modelled” approach
- Extensive field trials in the UK looking at soil carbon and greenhouse gas emissions
- £4 million over 3 years



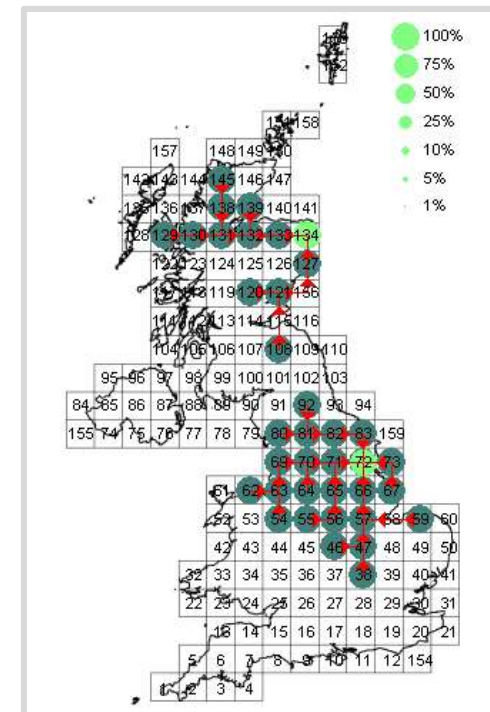
Outcome: identify the **sustainable** LUC transitions, **quantify how much** biomass can be produced sustainably, and **where** it should be produced



Bioenergy Value Chain Modelling (VCM) Project



- Spatial, decadal model for UK out to 2050
- Optimise value chain based on max energy, min cost, min GHG emissions
- Test system sensitivities to:
 - Technology cost and performance
 - Resource availability – including imports
 - Build out rates / planting rates

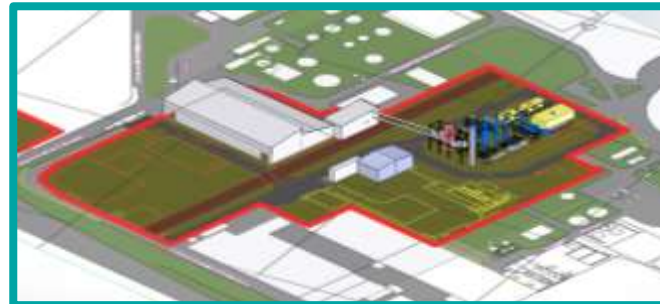




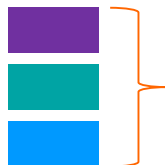
Waste Gasification (WG) project

Waste to energy

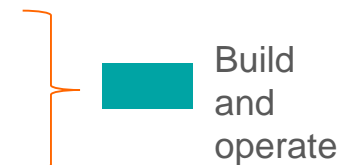
- Key drivers: low carbon energy and landfill diversion (landfill tax)
- Potential to provide 4-6% UK electricity
- Significant opportunity for smaller / more local units
- Town scale – 50-200 kt/ye (5-20 MW)
- 1 or 2 projects – ca. £10-15 million/ea



Design study



- Integrated system (MRF – engine)
- > 25% electrical efficiency
- > 80% availability



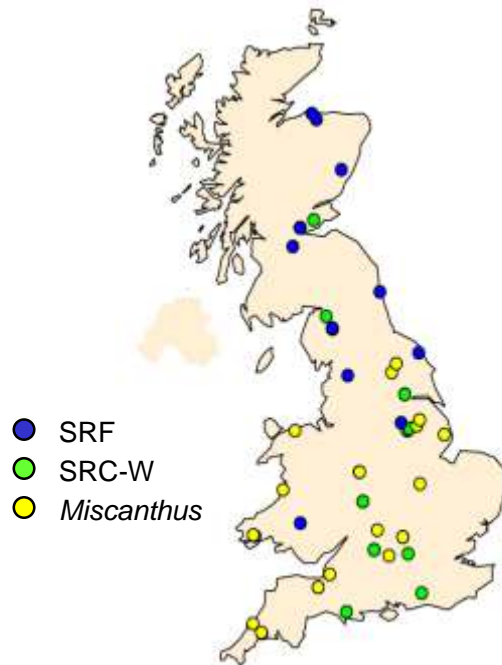


“Focus on real-life bioenergy”





Soil Carbon Stock Change Assessments



- Bioenergy crop(s) + reference control
- Over 3-year period targeted ca. 70 land-use transitions to bioenergy on commercial farms
- Main focus on *Miscanthus*, SRC Willow and Short Rotation Forestry
- Soil core sampling at 2 depths

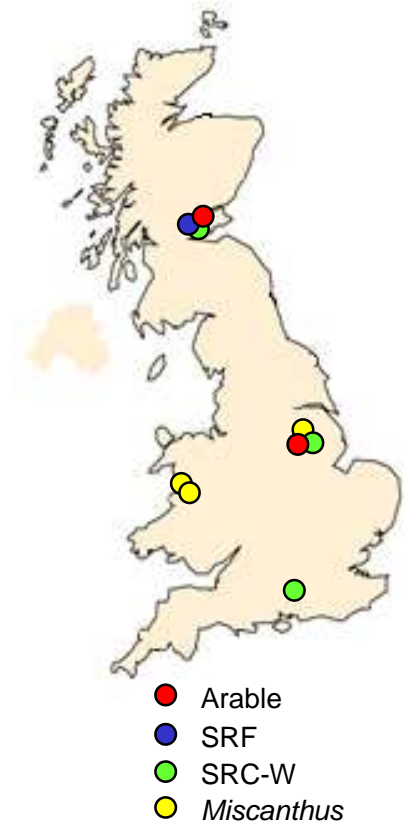




Greenhouse Gas Network Sites

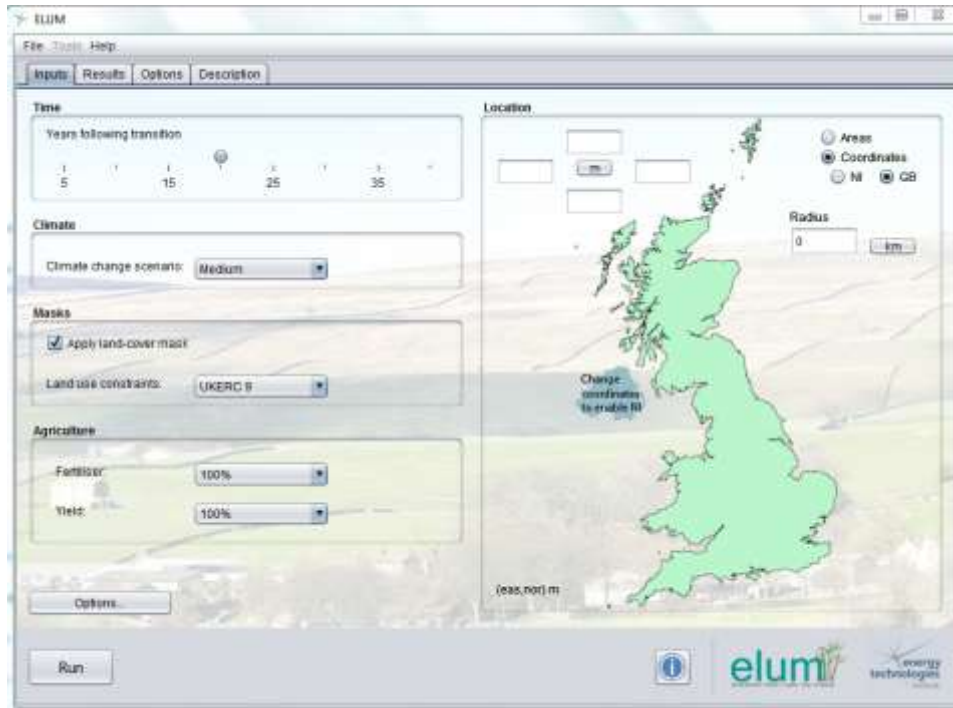
Produce soil GHG budget over 24 months on a variety of commercial-scale sites

- *SRC Willow, Miscanthus, SRF, Wheat, Barley, OSR, Grassland*
- Studies of 12 UK land uses:
 - Soil GHG from Static chambers
 - NEE from 8 Eddy Covariance Systems
- ^{13}C Tracer studies
- *Miscanthus* genotype studies
- Novel GHG technologies





ELUM Ecosystem Modelling Tool



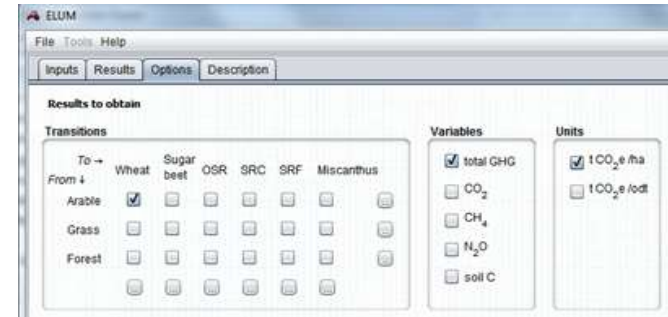
- Predict impact of bioenergy LUC in the UK on soil C and GHG emissions
- GIS based carbon opportunity map, identifying locations for biomass planting on basis of net C benefit to/from soil

The model will assess the soil C and GHG balance for UK bioenergy crops after land-use change over a 50 year period considering soil type, region and climate change

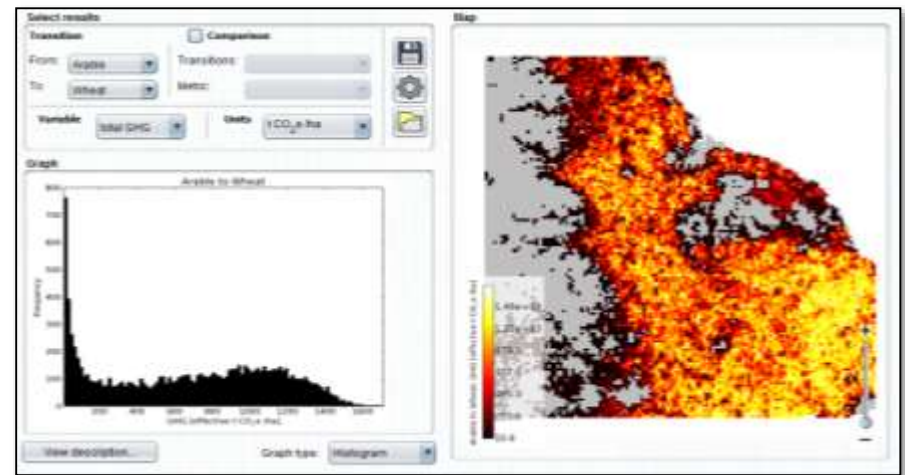


Land uses and results from Ecosystem Modelling Tool

- Land-use changes:
 - Change from: arable, grassland, forestry
 - Change to: wheat, sugar beet, OSR, SRC, SRF, Miscanthus
- Variables:
 - Cumulative change in CO₂, CH₄ and N₂O and soil C
 - All results expressed relative to no transition
- Results shown as:
 - Map at end of time period
 - Time series of total values for selected area



Note: Test simulation





QUESTIONS & ANSWERS



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