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# ETI 2050 low carbon energy scenarios and bioenergy opportunity

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# Agenda

- Energy Technologies Institute (ETI)
- Context
  - UK energy challenge out to 2050
- Meeting 2050 decarbonisation targets
  - Clockwork and Patchwork
- How does bioenergy fit
  - Proposed Humber gasification project



# The Energy Technologies Institute (ETI)

- The Energy Technologies Institute is a public-private partnership between global industries and UK Government
- The UK is facing increasing energy demands and stringent GHG emission targets out to 2050 (> 500 MtCO<sub>2</sub>e to 105 MtCO<sub>2</sub>e)
- This will require significant change to our energy system
- ETI was set up to identify and accelerate the development and demonstration of an integrated set of low carbon technologies to deliver this step change
- Part of a robust and affordable future energy system in the UK

## ETI members



**CATERPILLAR®**



**EPSRC**  
Pioneering research  
and skills



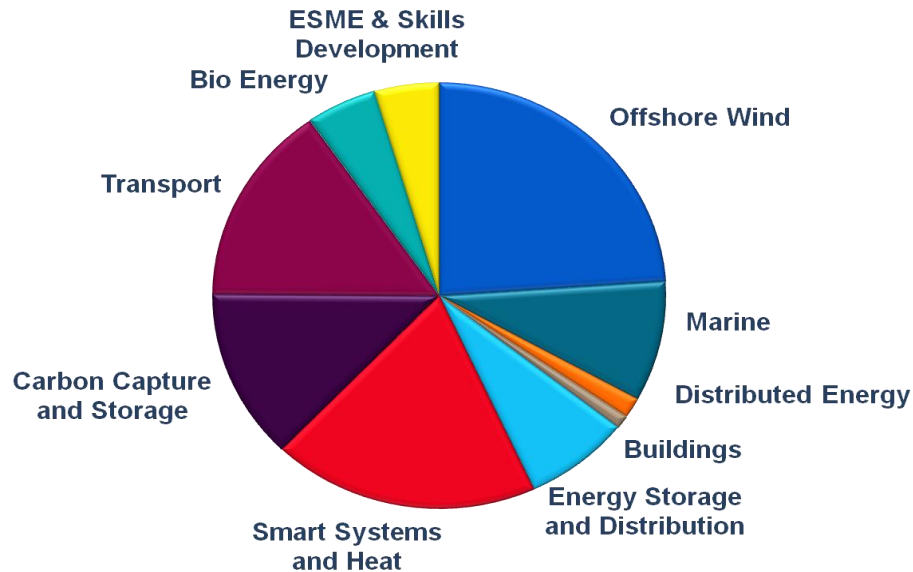
**Innovate UK**  
Technology Strategy Board

## ETI programme associate

**HITACHI**  
Inspire the Next



## ETI covers 9 technology programme areas & invests in projects at three levels

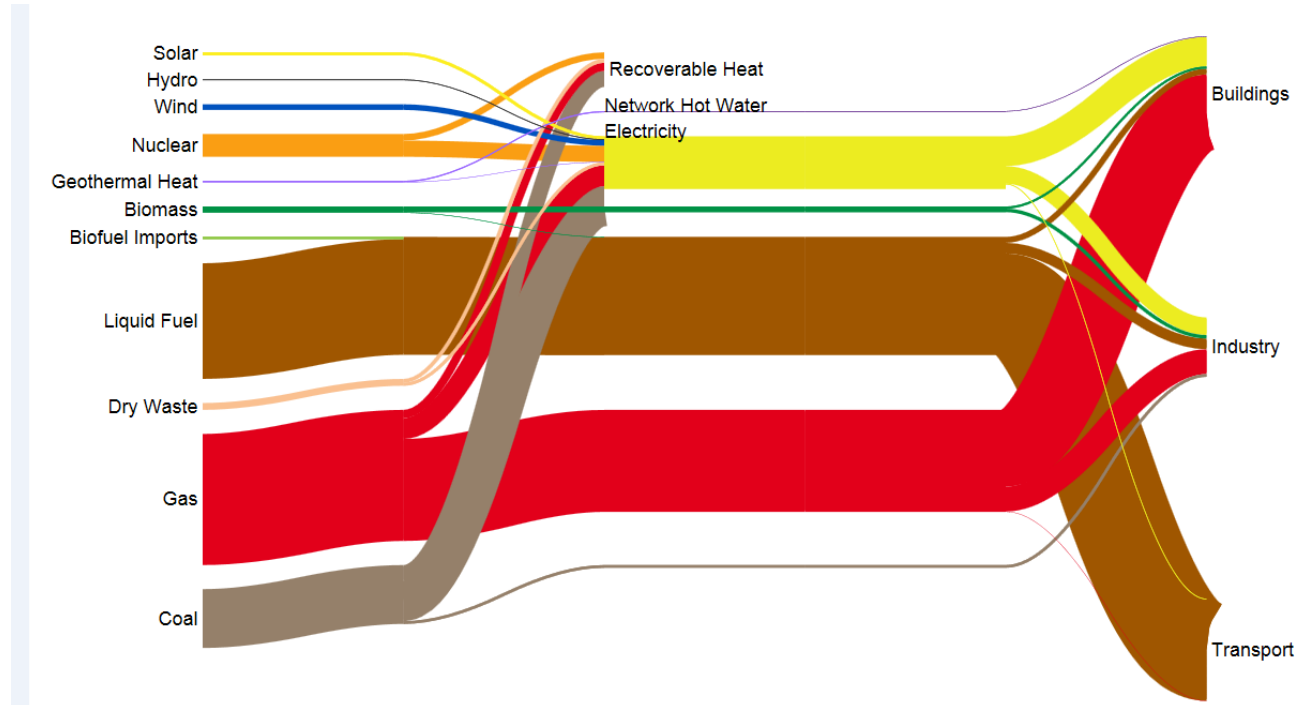


### Delivering...

- 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



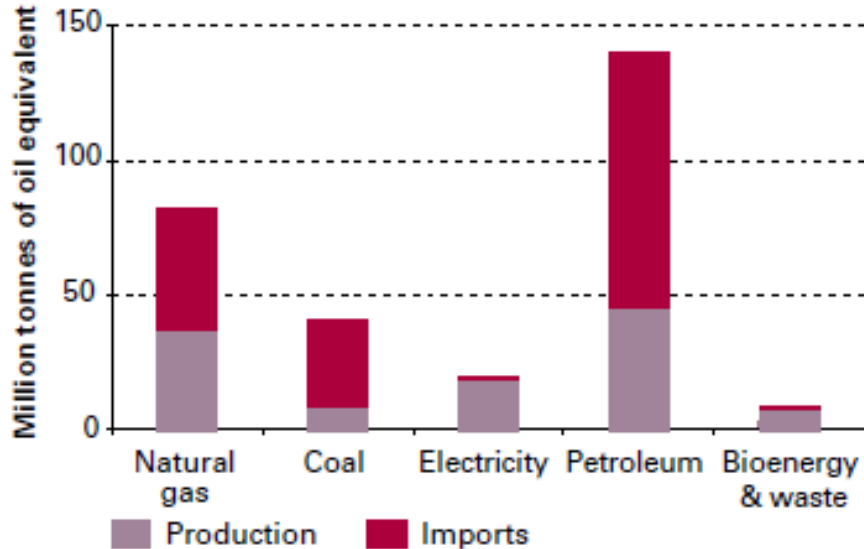
# UK (ESME) energy flows 2015





# Indigenous UK Primary Energy: Production and Imports 2013

Indigenous production and imports in 2013



- Bioenergy/waste excepted. most primary energy is imported
- Petroleum dominates - nearly 150 mtoe.
  - Small vehicle usage is around 37 MT with diesel use rising.
- Most electricity is indigenously produced (as expected).

~27% exported or used in marine bunkers

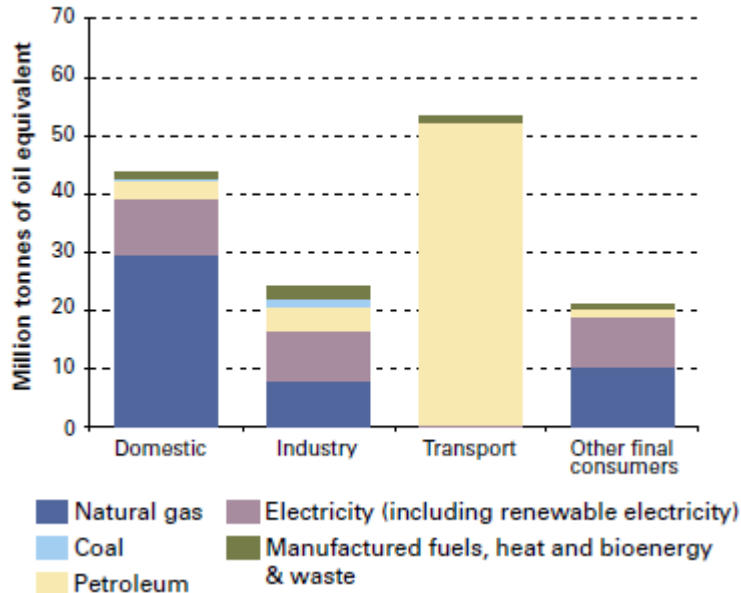
~16% lost on conversion

Total: 292.3 mtoe (12,277 PJ)



# Final UK Energy Consumption 2013

Final energy consumption in 2013



- 2013: 150.1 mtoe (6,304 PJ)
  - 1.2 mtoe higher than 2012
  - Reflecting slightly colder temperatures.
- Transport accounts for 35½% of all of the energy consumed in the UK
- Domestic sector accounts for 29% & industrial sector accounts for 16%



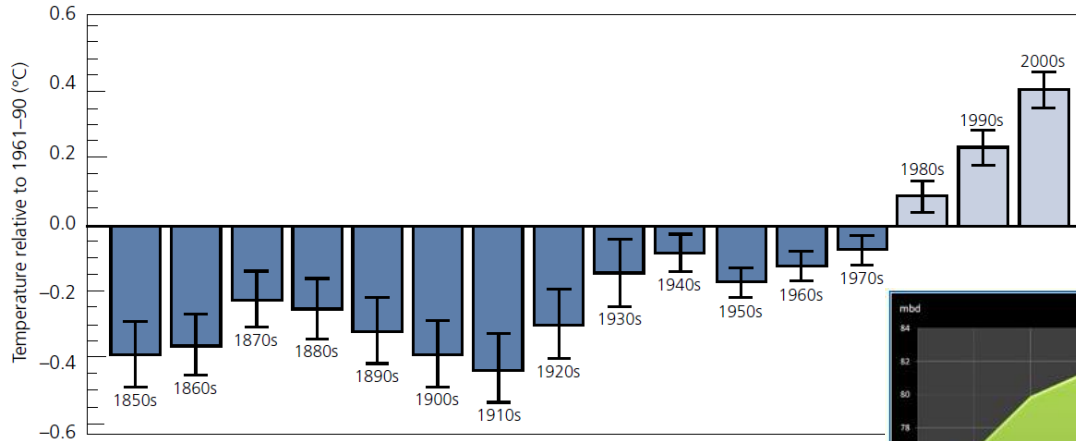
## Looking to the Future

- UK climate change act
  - By 2050, reduce UK's emissions by at least 80% compared to 1990 base level
  - Four carbon budgets since mandating stepwise emissions reductions of 50% below base level by 2027
- Action to date
  - Decarbonising power sector
  - Increasing energy efficiencies (especially households and vehicles)
- 2025-2050
  - Significant changes will be needed
    - Energy production and transmission
    - Use in buildings, transport and industry



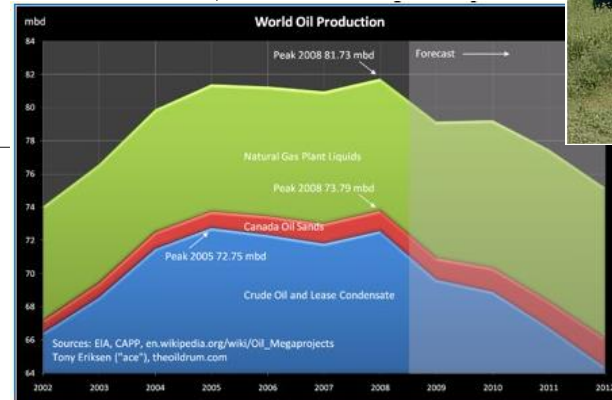


# Drivers for low carbon technologies and bioenergy



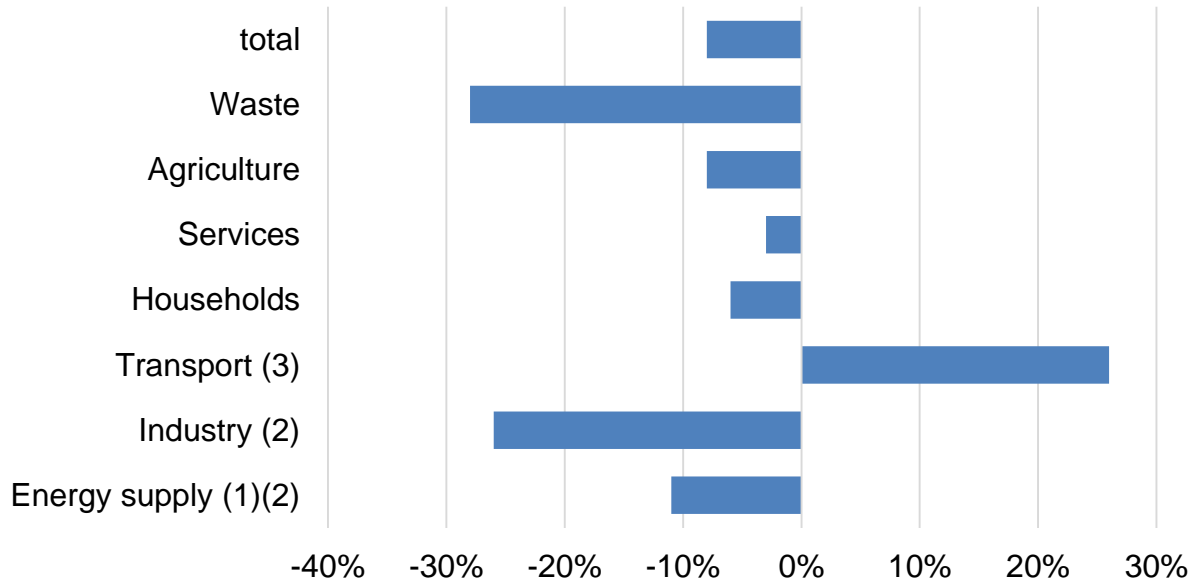
Observed global average temperature relative to 1961-90

Source: Met Office





## Changes in EU15 emissions compared to 1990 baseline (mtoe) – only in transport are emissions rising



1. Power & steam production and refineries.
2. Industrial boilers are allocated to industrial sectors.
3. Includes international aviation



# The UK Energy Challenge...

2010

62 million people

24 million cars

24 million domestic dwellings



2050

77-79 million people

35-43 million cars

80% still in use in 2050, growing to 38 million houses



- Over 90GW generation capacity (1MW to 3.9GW)
- Over 200 'significant' power stations .... average age > 20 years old
- 50% of power generation capacity held in 30 plants .... average age 30 years old

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



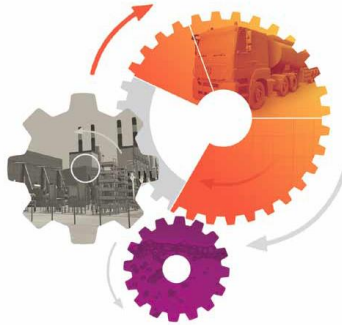
Need to design a future UK energy system which is sustainable, affordable and secure



## ETI Future Scenarios:

- well-coordinated national planning approach
  - versus
- a more 'organic' approach with distinct strategies at the regional level

### CLOCKWORK



### PATCHWORK

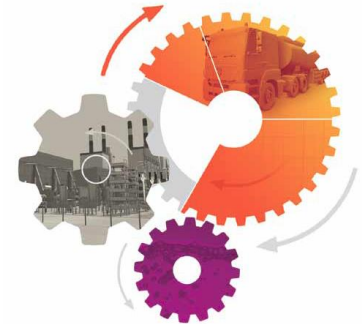




## Clockwork

- Represents a more centrally planned scenario with a well coordinated design of investments at the national scale
  - Allows new energy infrastructure to be installed like clockwork
  - Focus on coordinated design of national supply generation and shared infrastructure
  - There is social acceptance of the chosen solutions
- **Power:** regular and early new builds allows steady power sector decarbonisation
  - Nuclear, CCS, Renewables
- **Heat:** large scale district heating
  - Local gas distribution networks being slowly retired from 2040
- **Transport:** emissions offsetting allows more difficult and expensive to decarbonise sectors (i.e. transport) to be in early stages of transition by 2050 and vehicle type is similar to today (but higher efficiency)

## CLOCKWORK





## Patchwork

## PATCHWORK

- No central leadership role leads to a more “organic” patchwork approach of distinct regional energy strategies – action & leadership at multiple “levels”
- Greater societal engagement brings a bias towards renewables and projects that fit with local needs.
- Popular attention focussed on a range of social and environmental values influencing decision making processes
- **Power:** supply generation is a mix of national, regional and local assets - energy supply is renewables heavy, dominated by offshore wind supported by smaller scale technologies including the continued growth of solar
- **Transport:** limited role for emissions offsetting (negative emissions) leading to more extensive decarbonisation across all sectors including transport
- Cities/regions compete for central support
- Local energy needs tailored to local preferences and resources
- Patchwork of solutions overtime is integrated by central government.





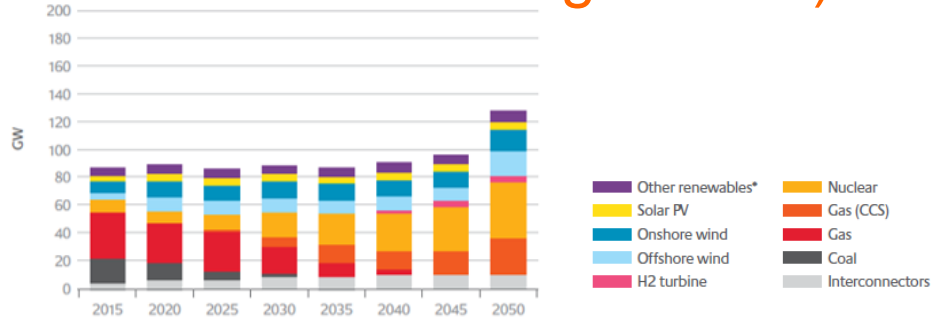
## Clockwork and Patchwork features and differences

- Electricity
  - Capacity to generate
  - Actual generation
- Space heating
  - Capacity to generate heat
  - Actual generation
- Transport
  - Car fleet
  - Fuel use
- Emissions comparison
- Costs to deliver



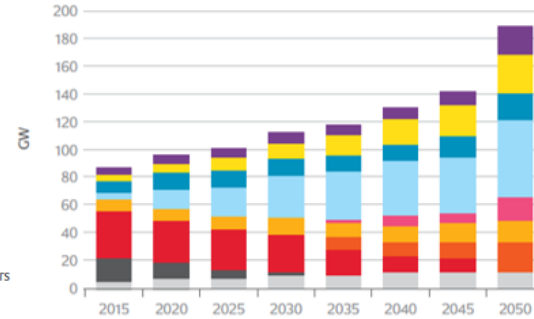
# Electricity capacity (to generate)

Clockwork



- Strong roles for nuclear and wind.
  - Nuclear provides 40GW of capacity by 2050
  - Offshore wind load factor increases to 50% - less back up needed
- Gas plants retrofitted/replaced with CCS from 2020's
- Coal use declines in 2020's
- Hydrogen takes over from gas for peaking capacity from 2030's
- Total capacity of ~130GW by 2050. Balance between nuclear, CCS and renewables

Patchwork

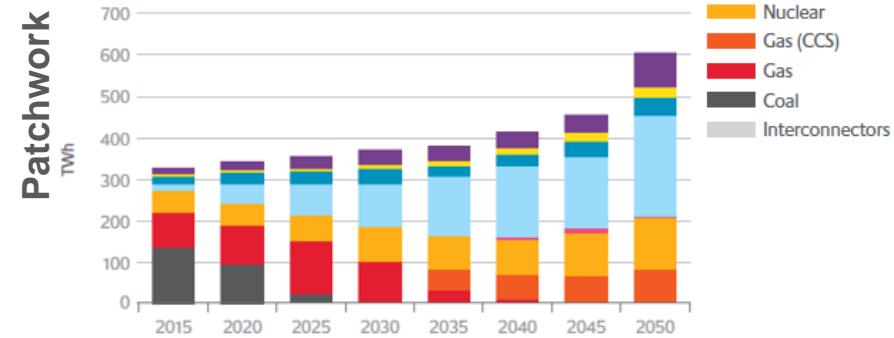
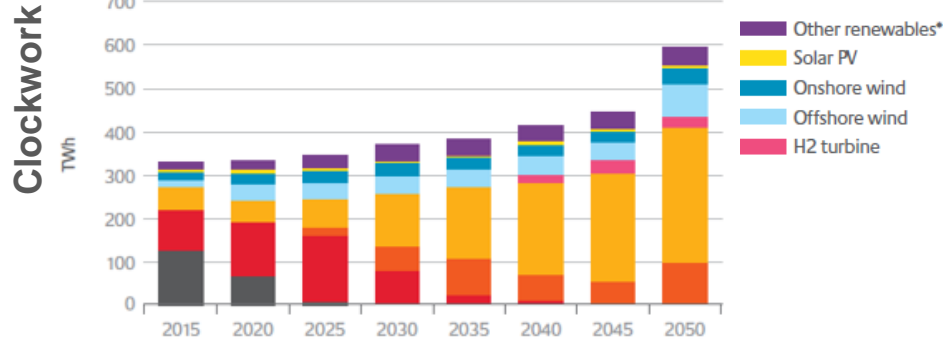


- Smaller role for nuclear: Nuclear replacement of existing capacity (16GW) – less investor confidence in nuclear
- CCS delayed until 2030's before replacing unabated gas plants
- Large role for wind: capacity reaches 75GW by 2050, mostly offshore
- Stronger role for H<sub>2</sub> turbines (17GW) to balance intermittent supply
- Solar provides 28GW, tidal 10GW and wave 4GW of capacity by 2050
- Total capacity of ~190GW by 2050 - more wind, solar, wave, tidal, H<sub>2</sub>; less nuclear, CCS





# Electricity generated

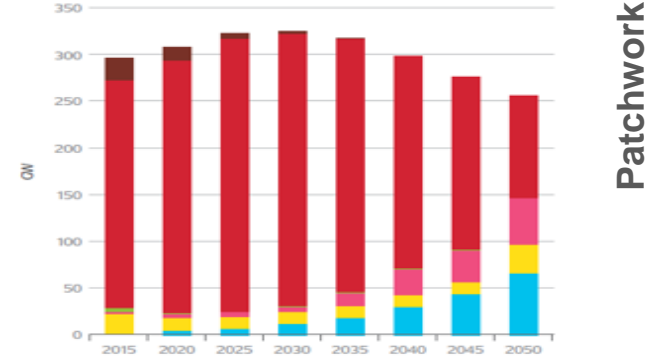
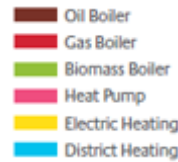
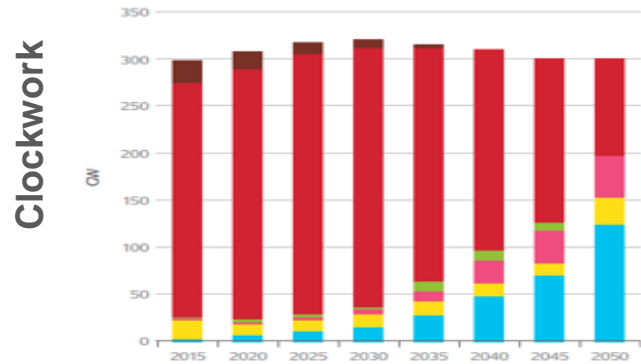


- Nuclear makes the largest contribution to supply (having the highest load factor)
- Gas with CCS has a seasonal role; providing base load through winter and more backup through summer
- Improvements to technology means new offshore wind turbines have a load factor of 50% by 2050 meaning a larger share of generation compared to onshore wind.

- Smaller role for nuclear; but still contributes ~20% of electricity generation in 2050
- Of the renewables, large role for offshore wind while generation from solar is very modest, given its low load factor of 11% in the UK.



# Space heat capacity



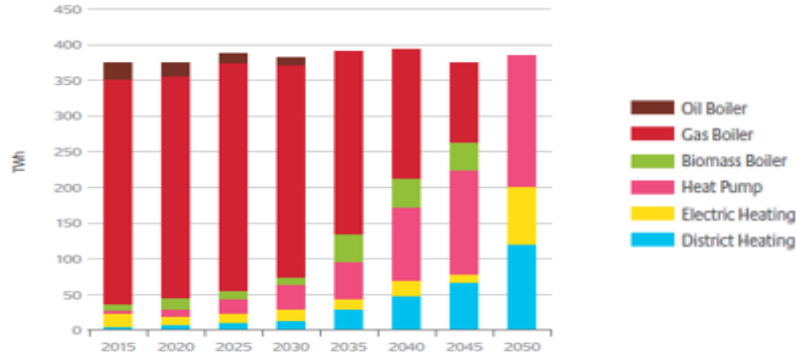
- Heat supply remains fairly constant despite increase numbers of homes and changing temperatures – technology improvements
- Strong role for district heating by 2050 (>40% of capacity)
- Early developmental role for biomass boilers
- Use of heat pumps increases
- Gas is relegated to back up capacity in parallel with reducing gas grid coverage

- Greater urbanisation, technology improvements reduce heat demand despite rising population
- DH use more modest but greater than today
- Similar role for heat pumps as for clockwork
- Gas use remains significant but declining with reducing gas grid coverage



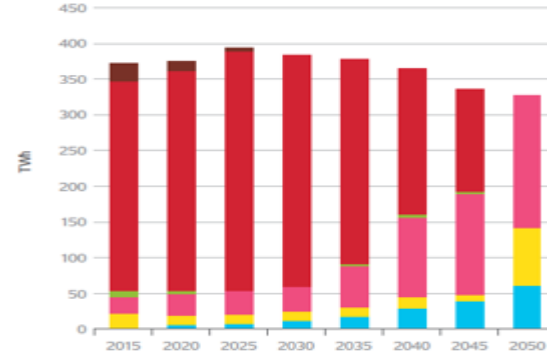
# Space heat generated

Clockwork



- Profound changes – total switch from gas; zero carbon technologies dominate by 2050
- Heat pumps run through the day (combined with heat storage) so their contribution is high compared to DH

Patchwork

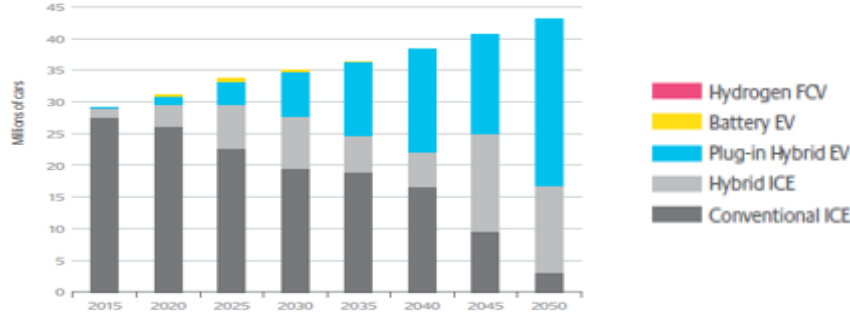


- Levelling off of indoor temperatures plus retrofit to some of the housing stock results in a drop in space heating demand.
- Majority of 2050 heating is heat pumps – smaller contribution from DH (cf Clockwork)
- Electric resistive heating is a significant provider – especially to provide top up heating combined with heat pumps



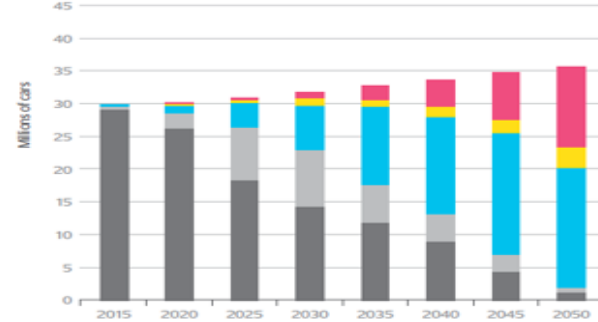
# Transport: car fleet

Clockwork



- By 2050, vehicle fleet grows to 43M vehicles (from ~29M)
- More and more low carbon vehicles from 2020's (esp. hybrids) because of continued emissions legislation
- Lack of battery EV range means uptake very low – plug in hybrids chosen instead
- New battery technologies allow longer PHEV ranges
- Expense of H<sub>2</sub> vehicles makes them unattractive.
- Use of conventional ICE's is extended by ongoing improvements.
- Dropping values of conventional cars may be an impediment to switching

Patchwork

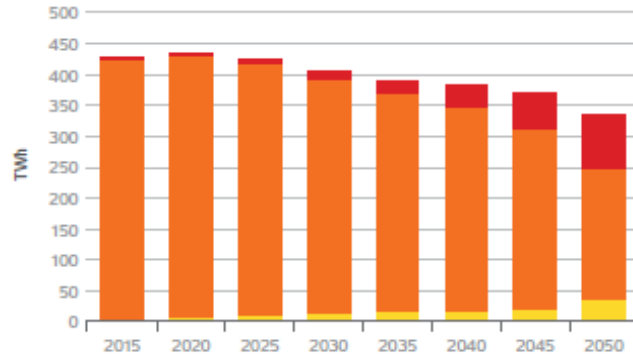


- Less well planned investments in power and heat (fewer negative emissions credits) means more decarbonisation of vehicles is needed in Patchwork.
- Vehicle fleet grows to 35M vehicles by 2050 – more urban living, increased costs – leads to more public transport use
- Legislation drives introduction and use of lower carbon vehicles from 2020's on.
- Wider range of vehicle types including hydrogen but H<sub>2</sub> vehicles may take time to develop (behind PHEV)
- Bigger role for Battery EV's
- Increased car sharing (stronger community involvement)



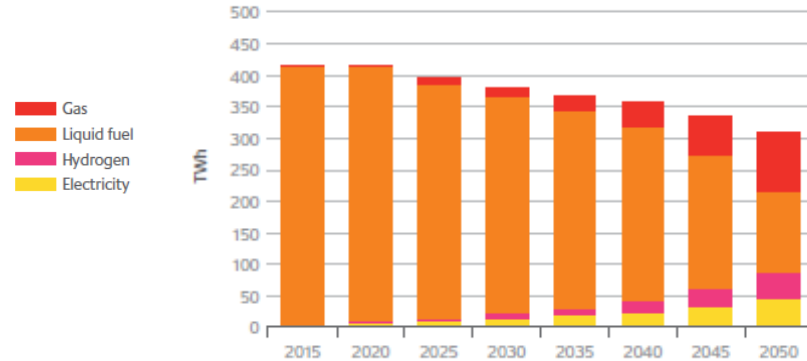
# Transport: road fuel consumption

Clockwork



- Strong use of PHEV's leads to increased use of electricity
- Small role for hydrogen
- Increased use of natural gas in heavy duty vehicles
- Support to existing liquid fuel supply chain may be needed to ensure geographical coverage

Patchwork

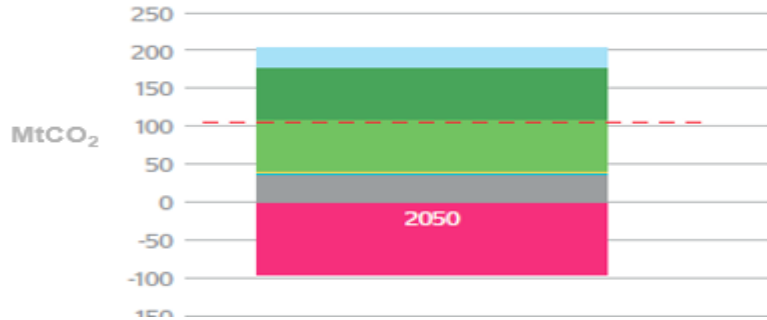


- Strong use of PHEV's leads to decline in liquid fuel use and, combined with battery EV's, electricity
- H<sub>2</sub> use is stronger than in Clockwork and accelerates liquid fuel use decline
- Increased use of natural gas in heavy duty vehicles
- Support to existing liquid fuel supply chain may be needed to ensure geographical coverage – some UK refineries may shut (aviation fuels still needed)

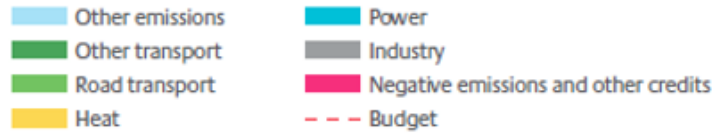
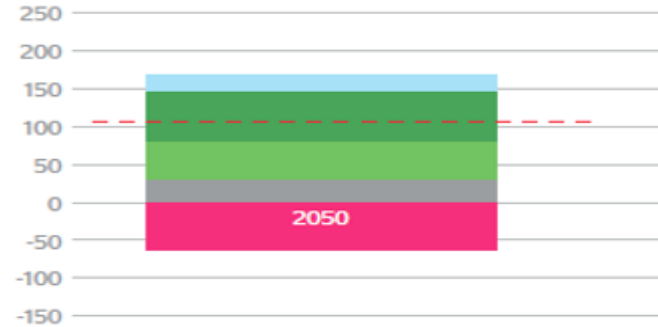


# Emissions comparison

Clockwork



Patchwork

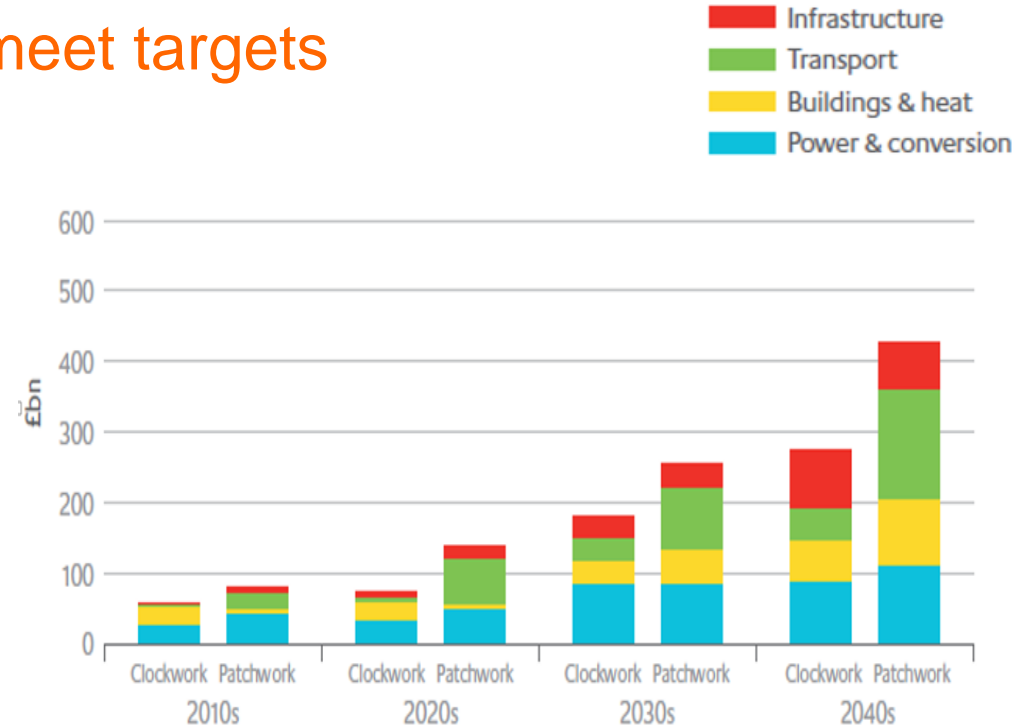


- Both scenarios target is 105 million tonnes of CO<sub>2</sub> in 2050
- Clockwork has 30 MT of extra negative emissions from implementation of biomass + CCS
  - This extra headroom helps avoid expensive abatement actions such as in transport
  - Provides more flexibility on transition



## Capital spend/decade to meet targets

- Chart shows where spending is needed each decade to meet each scenario
- Negative emissions delivery reduces Clockwork costs
  - less infrastructure required
- Patchwork costs also higher due to
  - Expensive transport investments
  - Earlier deployment of new technologies in Clockwork
- Both scenario costs fall between ETI probabilistic modelling outcome of 1-2% of GDP for reasonably optimised systems.





# Infrastructure: what we might see

## 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 CO<sub>2</sub> transport infrastructures
- Support for petrol station supply network

## 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 – support for petrol station supply network





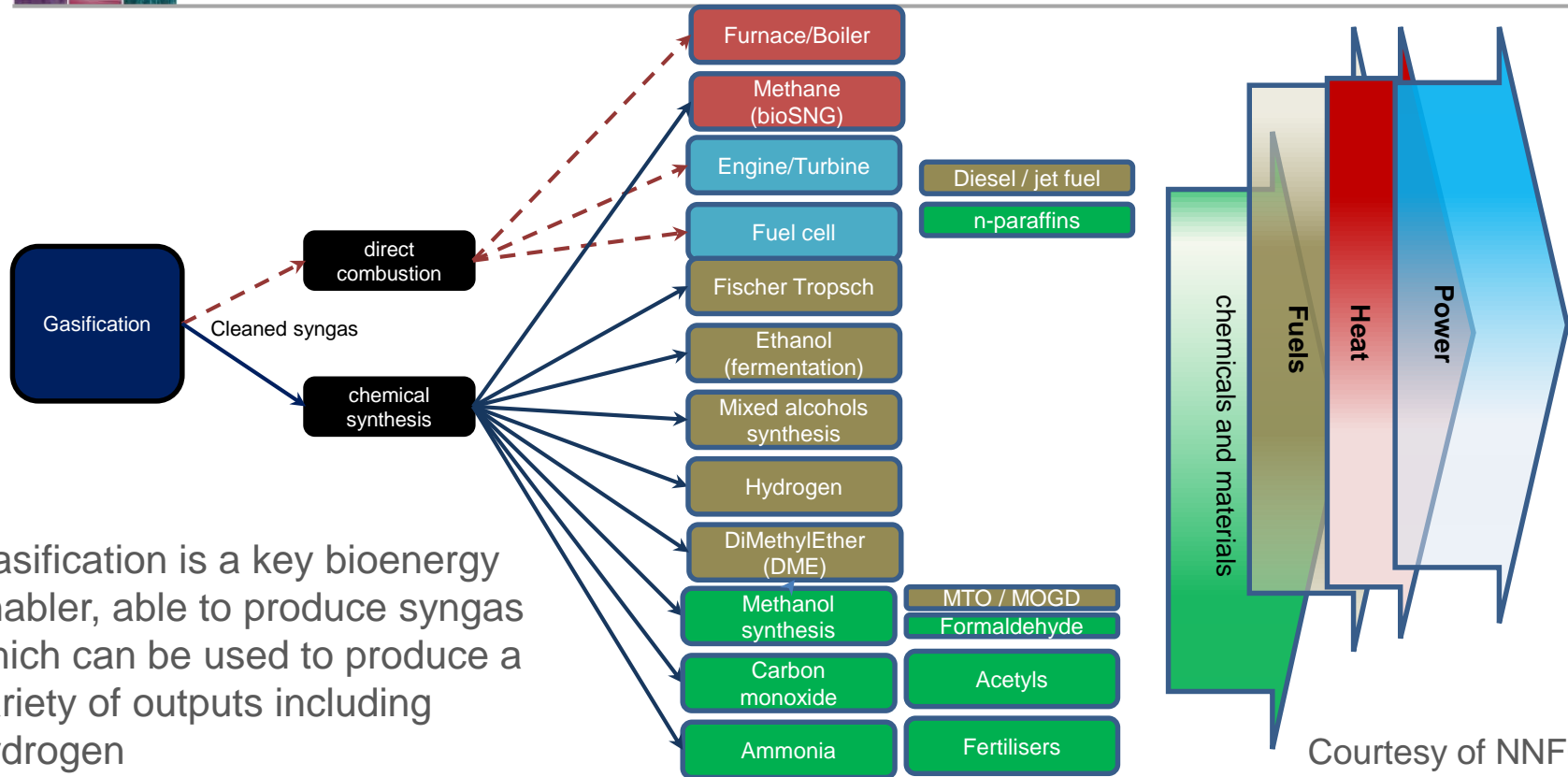
# How can bioenergy fit into these future scenarios

## Clockwork

- Flexibility, dispatchability
- Linkage with CCS for negative emissions
- Increased UK electricity demand
- Hydrogen demand (for integration with CCS to provide negative emissions)
- Biomethane demand (especially for use in heavy duty vehicles)
- District Heating demand and hence for smaller scale CHP plants linked into DH networks
- Demand for jobs

## Patchwork

- ditto
- ditto – but will plants be in right places?
- ditto
- Hydrogen demand (for use in hydrogen fuelled turbines for power and in transport)
- Possible demand for synthetic biofuels (e.g. ethanol, aviation fuel)
- ditto
- District Heating demand (smaller than in Clockwork)
- ditto

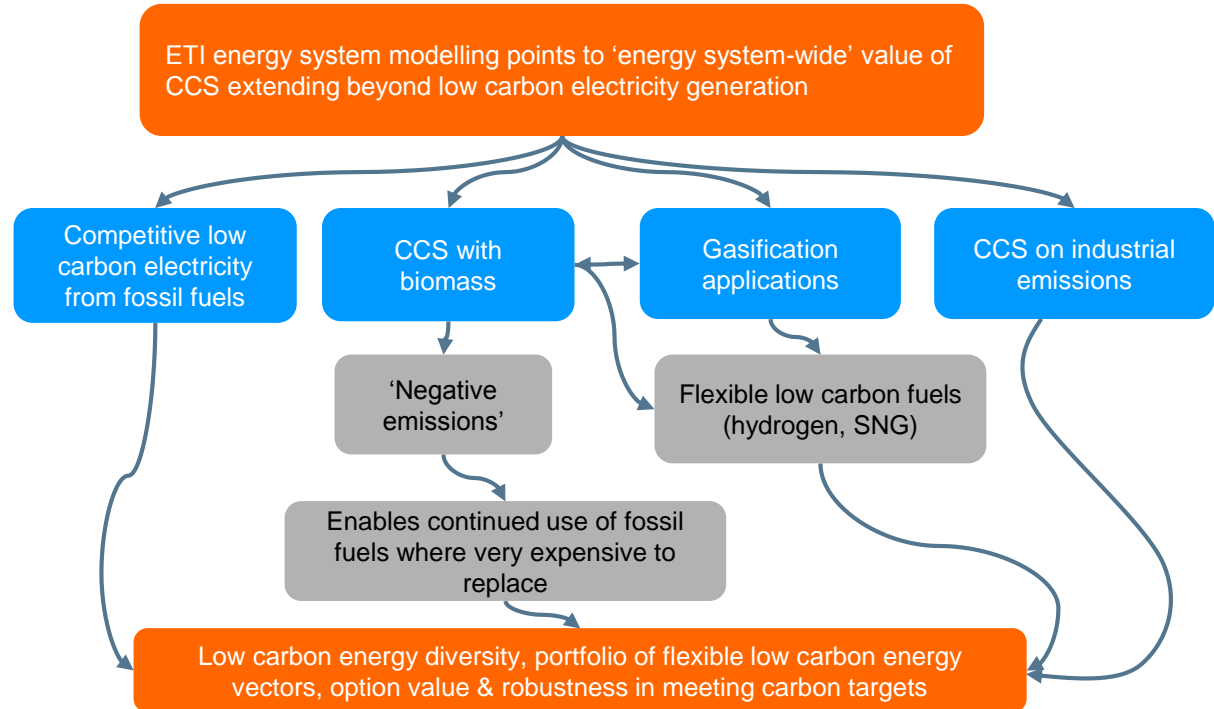


Gasification is a key bioenergy enabler, able to produce syngas which can be used to produce a variety of outputs including hydrogen

Courtesy of NNFC



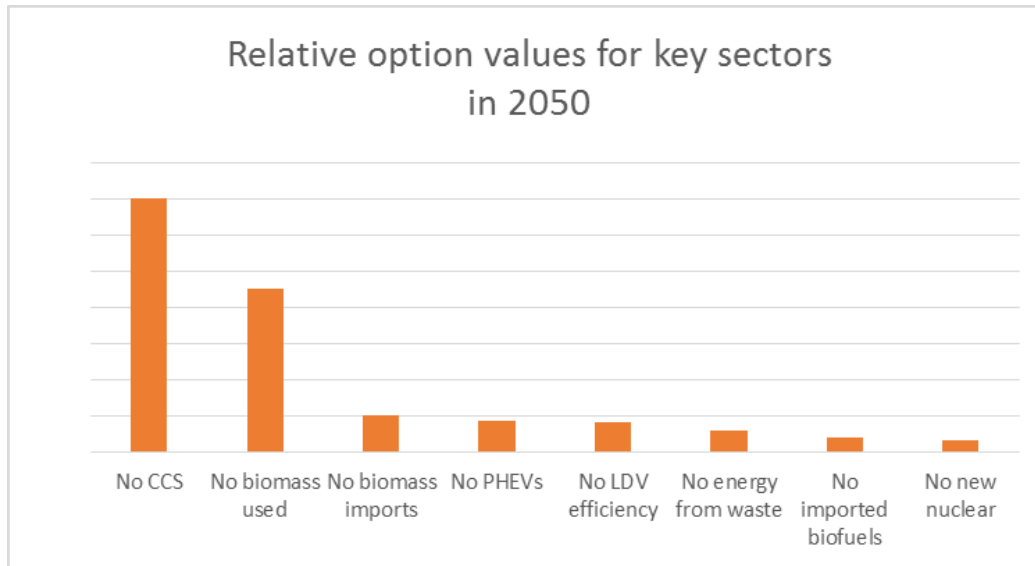
Biomass combined with Carbon Capture and Storage (CCS) remains the only credible route to deliver negative emissions, necessary to meet the UK's 2050 GHG emission reduction targets.





## 2050 affordability

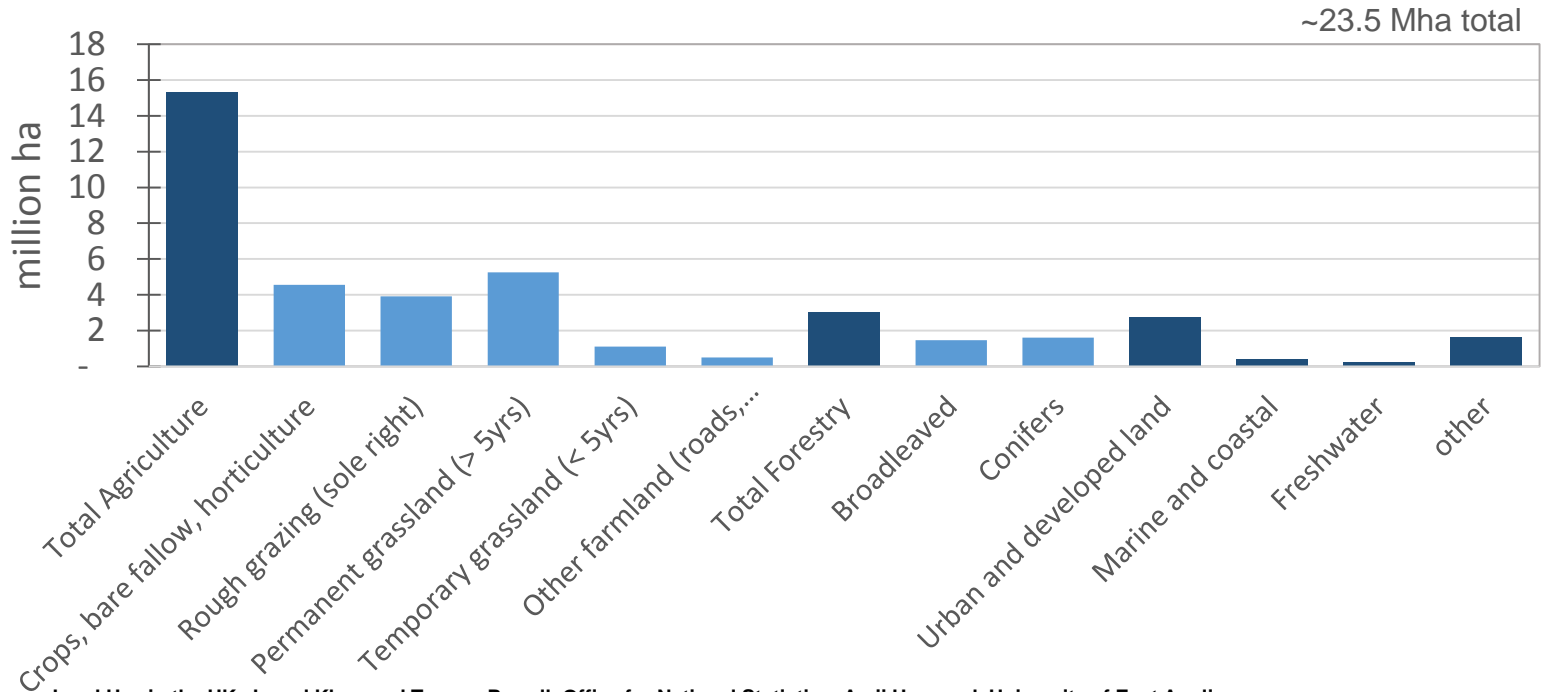
ESME enables us to assess the likely cost of different future UK energy systems, and the opportunity costs of not pursuing particular pathways:



- Future UK energy system cost > £200 billion between now and 2050
- Mix of biomass with CCS, gas-fired CCS, hydrogen turbines, nuclear, hybrid vehicles and liquid transport fuels, offshore renewables and retrofitting
- Biomass used to generate hydrogen, power, heat, transport fuels and negative emissions
- It is likely to be very hard to deliver an *affordable* low carbon energy system without Bioenergy or CCS



# Physical asset account for land use in the UK 2010

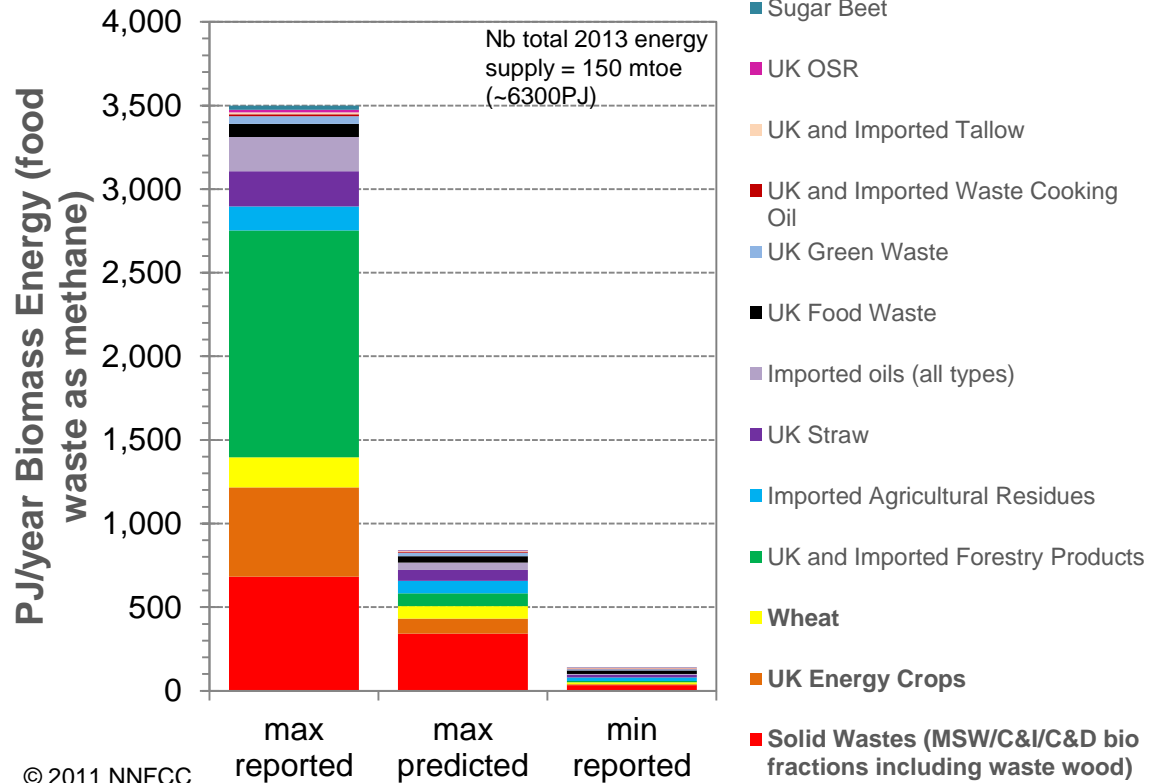


Land Use in the UK, Jawed Khan and Tamara Powell, Office for National Statistics; Amii Harwood, University of East Anglia



# Estimated potential

- DECC Bioenergy Strategy: about 12% of 2050 UK total primary energy demand could be met by indigenous UK produced biomass
- ETI RELB looking at hectares potentially available
  - Results to be examined in combination with bioVCM tool
- Generally there is insufficient feedstock of any one kind
  - Waste is the largest resource





# Energy From Waste



- Project profiling waste arising's in the UK
- Evaluated different conversion technologies
- Identified technology development opportunities in the area of gasification and gas clean up

## Project Partners

CATERPILLAR



Cranfield  
UNIVERSITY



shanks.waste solutions.



## Waste system analysis

- About 90MT of UK waste is energy bearing
- Key waste streams are MSW and C&I – C&D is about 70% non combustible
- C&I contains more paper and card than MSW – due to different recycling targets
  - Both contain large percentages of thin film plastics with high CV
- Plastics contribute significantly to waste CV – economically favourable to extract energy from these providing efficiency is high enough
- But, waste streams will always contain some recyclable materials as these can't be continuously recycled

	England	Wales	Scotland	Northern Ireland	Total
<b>MSW</b>	29.1	1.8	2.1	1.1	34.1
<b>C&amp;I waste</b>	58.7	3.6	8.1	1.6	72.0
<b>C&amp;D waste</b>	89.6	12.2	11.8	1.7	115.3
<b>Total</b>	177.4	17.6	22.0	4.4	221.4





# Opportunity assessment

- Projected achievable electrical generation is approximately **25TWh** per year
  - Equivalent to 5-8% of UK electricity demand
- Advanced EFW technologies can potentially contribute to a net decrease 5 to 10 MTCO<sub>2</sub>e/year at midpoint technology conversion and waste arisings scenarios
- High total conversion efficiency technologies drive highest GHG savings
- Focus on town and village scale technologies, especially gasification/pyrolysis
  - City scale well served by incineration
  - Cost effective syngas clean-up is essential for community scale systems
- Integrating thermal and AD technologies would maximise resource efficiencies
  - Requirement for higher efficiency, low cost, AD plants that can be integrated

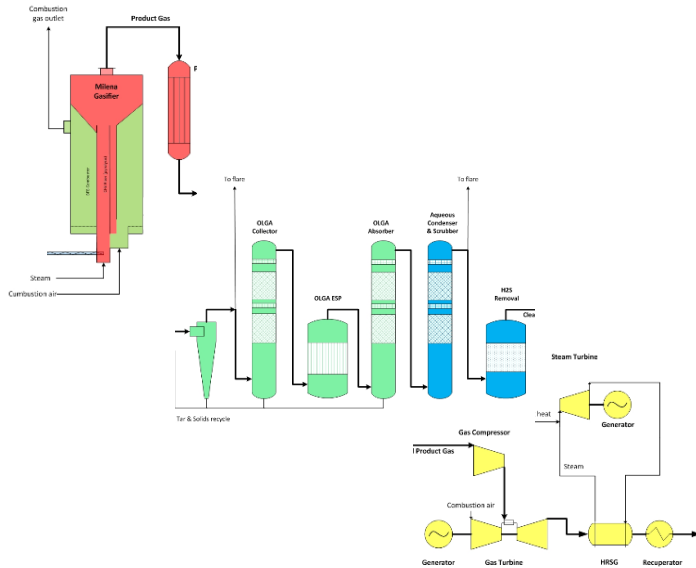
	City	Town	Village	Rural
Av Population	500,000	<b>50,000</b>	5,000	500
% UK Population	34%	<b>43%</b>	21%	2%
Waste kT/yr (MWe)	500 (75)	<b>50 (8)</b>	5 (0.8)	0.5 (0.1)
Potential number of plants	76	<b>946</b>	4,544	4,544



# Waste Gasification Project Phase 1

Aim: Competition to design an economically and commercially viable, efficient energy from waste gasification demonstrator plant in the 5-20 MWe scale range.

- Three companies commissioned to deliver their design
- Designs supported with a combination of laboratory and pilot scale testing on different feedstocks and through process modelling
- £2.8 million over 1 year
- Launched April 2012



Outcome: Delivery of three process (de-risked) designs, site identification, Planning and Permitting





# Selection Process

- **Project Review meetings:-** 26-27<sup>th</sup> February 2014
  - Structured technical review of the final deliverables ✓
  - Technology (Confidence it can work as defined) ✓
  - Deliverability (Confidence the teams can deliver the project goals) ✓
  - Exploitation (Confidence the team understand how to maximise the benefits) ✓
- **Selection panel:-** 5<sup>th</sup> March 2014
  - Pre meeting scoring process ✓
  - Formal sessions assessing and comparing the projects in three key areas ✓
    - Technology
    - Deliverability
    - Exploitation
  - Final recommendation to ETI Executive Board 7<sup>th</sup> March 2014 ✓
- **Phase 2 contract negotiations**
  - 2014-15
- **Phase 2 contract announcement**
  - Summer 2015

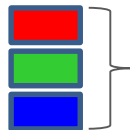


## Waste Gasification Phase 2



- The ETI is about to start investing in the development of advanced gasification projects incorporating syngas clean enough to be used in engines and/or gas turbines.
- Construction is expected to start in Q3 2015.

Phase 1  
Design study



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



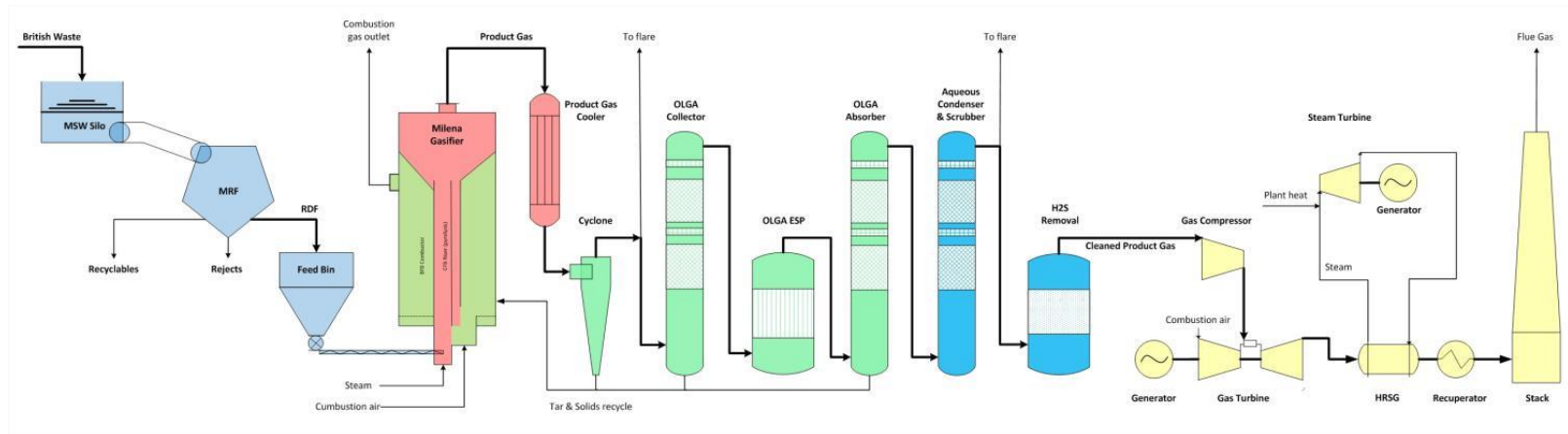
Phase 2  
Build and  
operate



# Royal Dahlman Project Proposal - Grimsby

## Royal Dahlman

- Site location: Humberside (Grimsby)
- ~ 7MWe Combined Cycle Gas Turbine plant
- Milena indirect gasifier plus low temperature Olga syngas cleaning

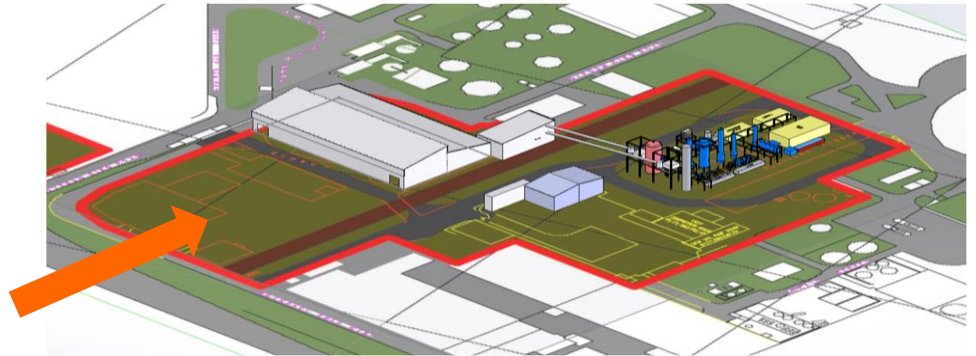
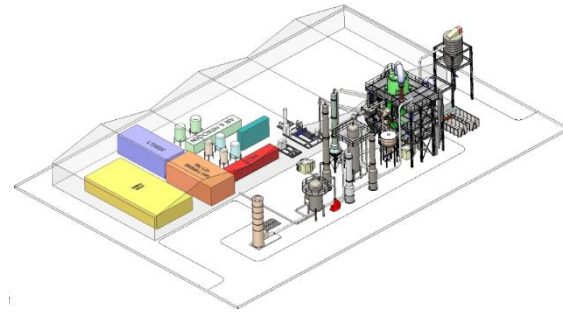




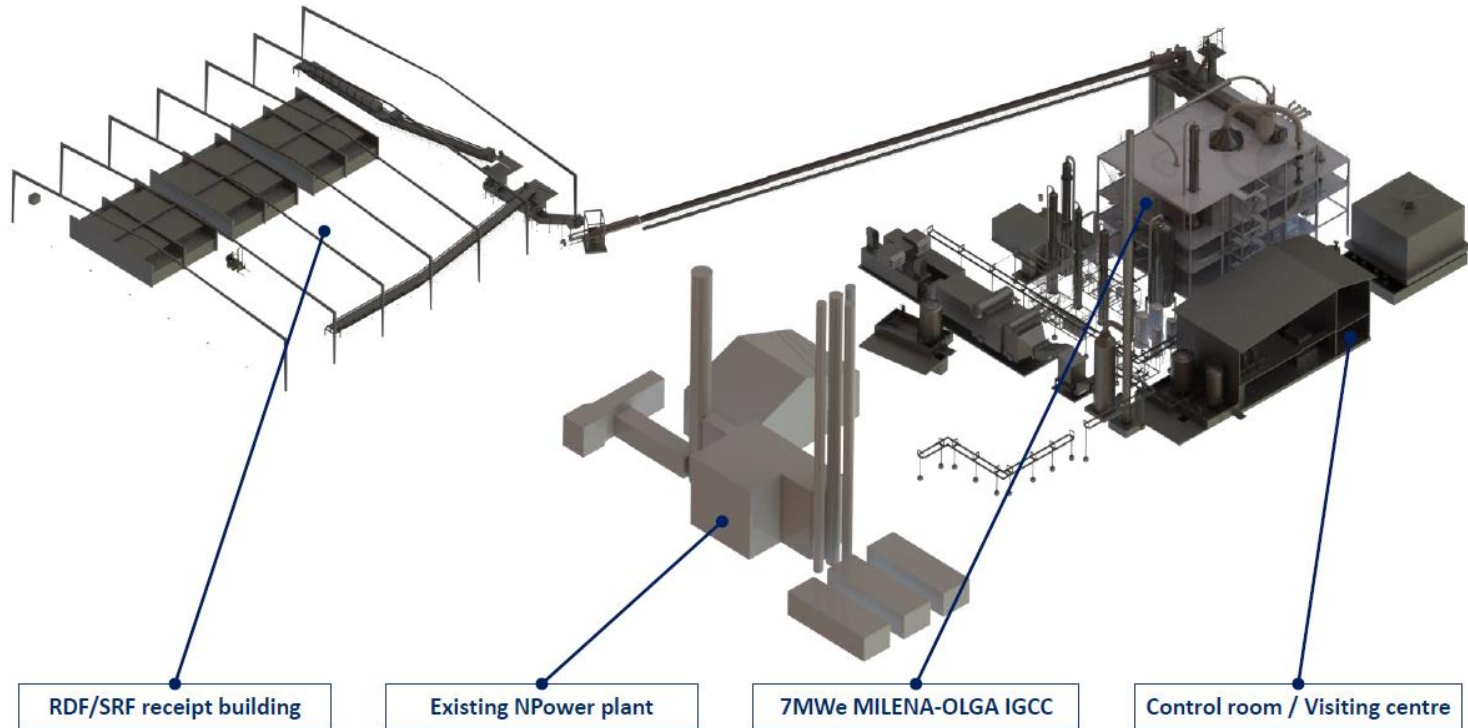


# Tioxide site, Moody Lane, Grimsby



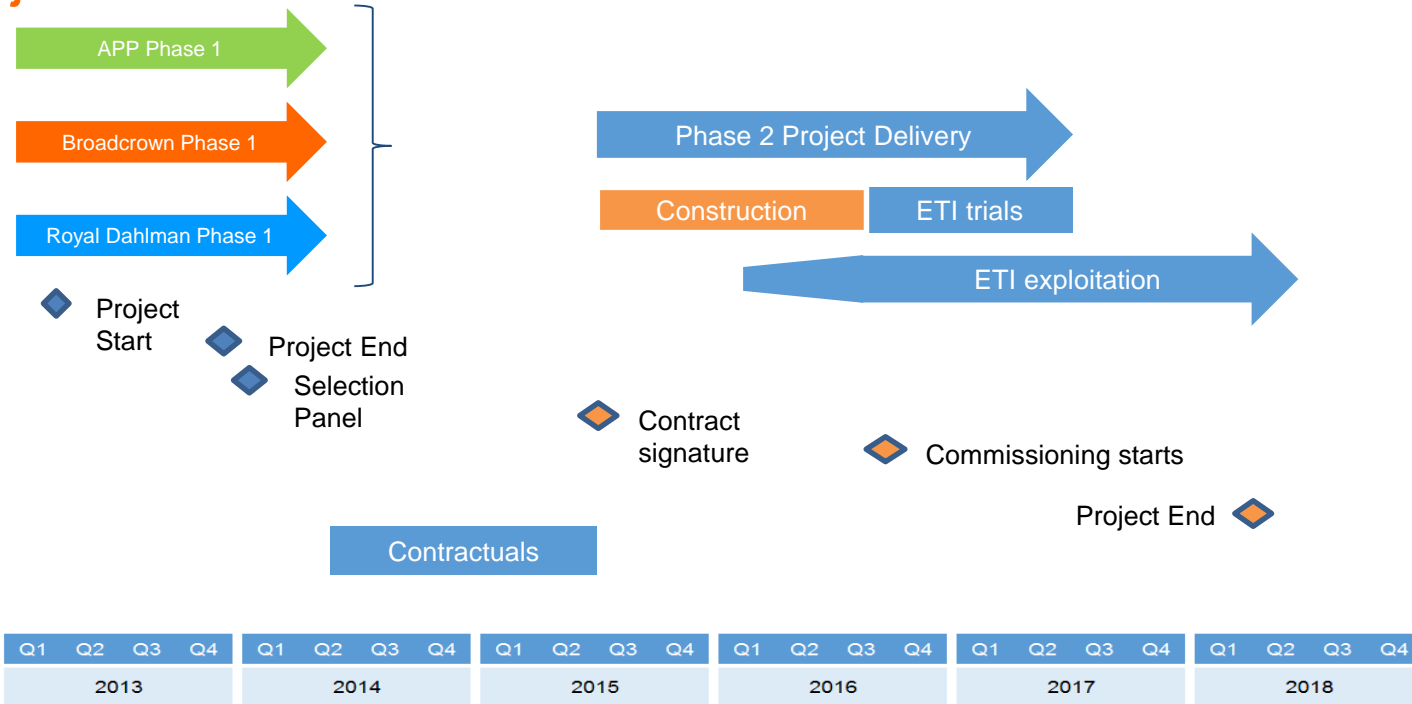








# Projected timeline





# Summary

	Genuine carbon savings / Negative emissions	Best Use (vectors)	Optimal value chain combos	Policy, regulatory / other support
	✓			✓
	✓	✓	✓	✓
 Waste Gasification		✓	✓	
	✓		✓	
<b>EUB</b>				✓
<b>Feedstock and Pre-processing</b>		✓	✓	
	✓	✓	✓	✓

- UK must prepare over the next decade – crucial decisions must be made in the mid 2020's
  - Opportunity for economic advantage
- Policy intervention will be required where a pure market approach may not work (e.g. bioenergy, nuclear)
- Bioenergy has a pivotal role to play in delivering an affordable UK energy system transition out to 2050 – this can be achieved
- Bioenergy, especially combined with CCS, has great potential and is a key element
- ETI is delivering numbers of projects to understand:
  - Scale of potential carbon savings from bioenergy
  - Best ways to use bioenergy in the future energy system
  - Optimal value chain combinations
- Waste Gasification project, potentially Grimsby



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