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Abated Gas Power

The Critical Contribution of CCS to the Future Power System

Andrew Green

ETI10 TEN YEARS OF INNOVATION 2007 — 2017

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- Energy System Analysis – the importance of CCS
- UK Power System – the value of CCS
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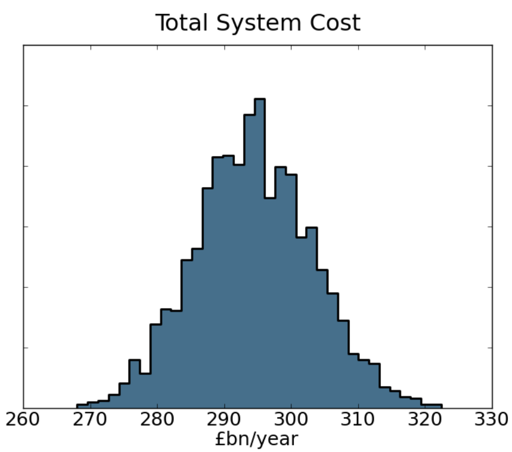
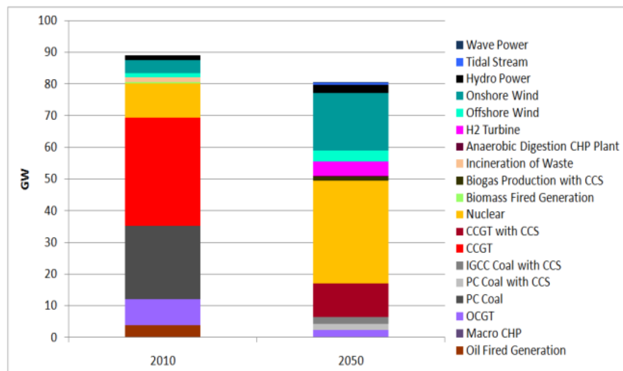
- Conclusions and next steps

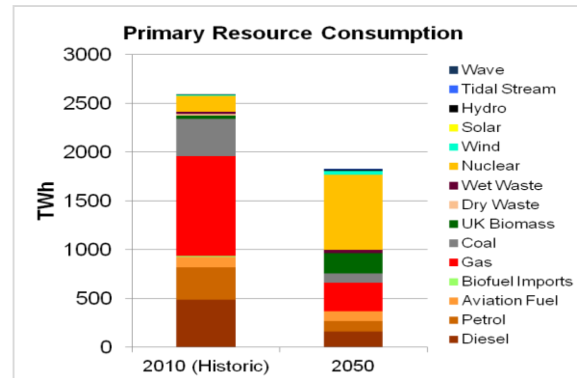
ENERGY SYSTEM ANALYSIS – THE IMPORTANCE OF CCS

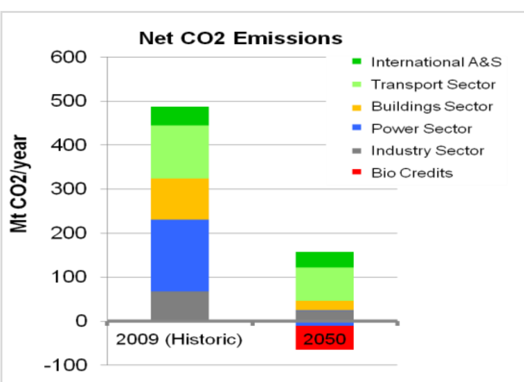
ESME – ETI's system design tool

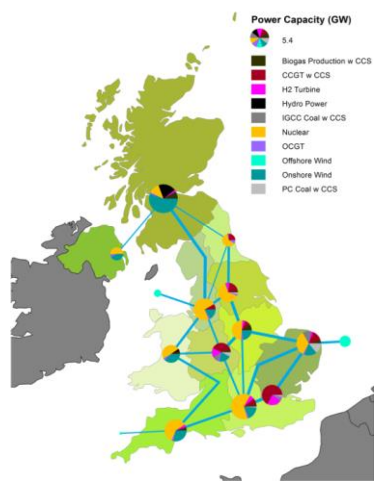
integrating power, heat, transport and infrastructure
providing national / regional system designs

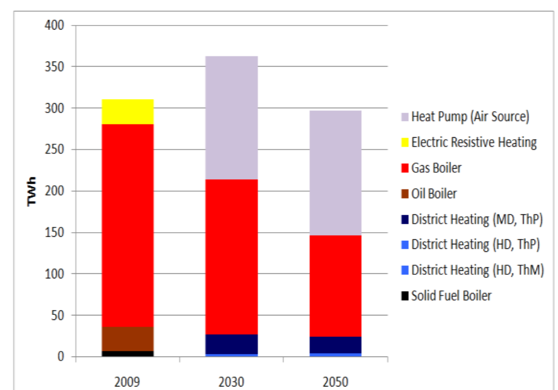












ESME example outputs

UK ENERGY SYSTEM TRANSITION

ANY LOW CARBON TRANSITION SHOULD INCLUDE CARBON CAPTURE AND STORAGE AND BIOENERGY

Including them halves the cost of meeting UK climate change targets

1 **REPLACEMENT NUCLEAR**
2 **EFFICIENCY MEASURES**
3 **ENERGY FROM WASTE**

Immediate large scale development focus should be on replacement nuclear, efficiency measures and generating energy from waste

1-2%

GDP IN 2050

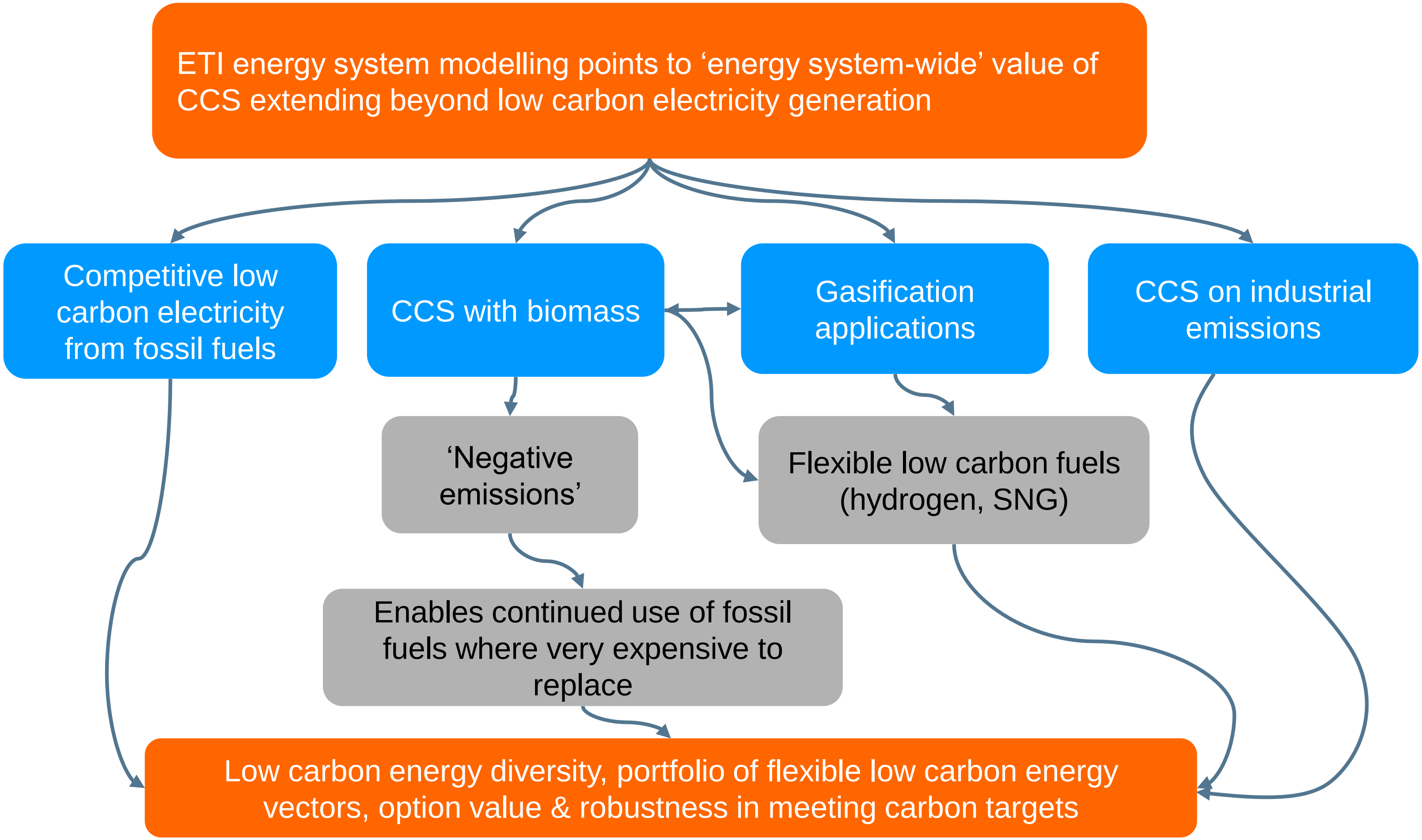
The UK can afford a 35 year transition to a low carbon economy – the cost of transition is in the range of 1-2% GDP in 2050

NO ONE TECHNOLOGY IS THE ANSWER

We need to develop a complementary basket of key technologies – the energy system transition does not depend on new revolutionary ideas, more the development, commercialisation and integration of known but currently underdeveloped technologies

The CCS Programme has consistently remained a central part of the ETI's activities over its 10 years of Innovation

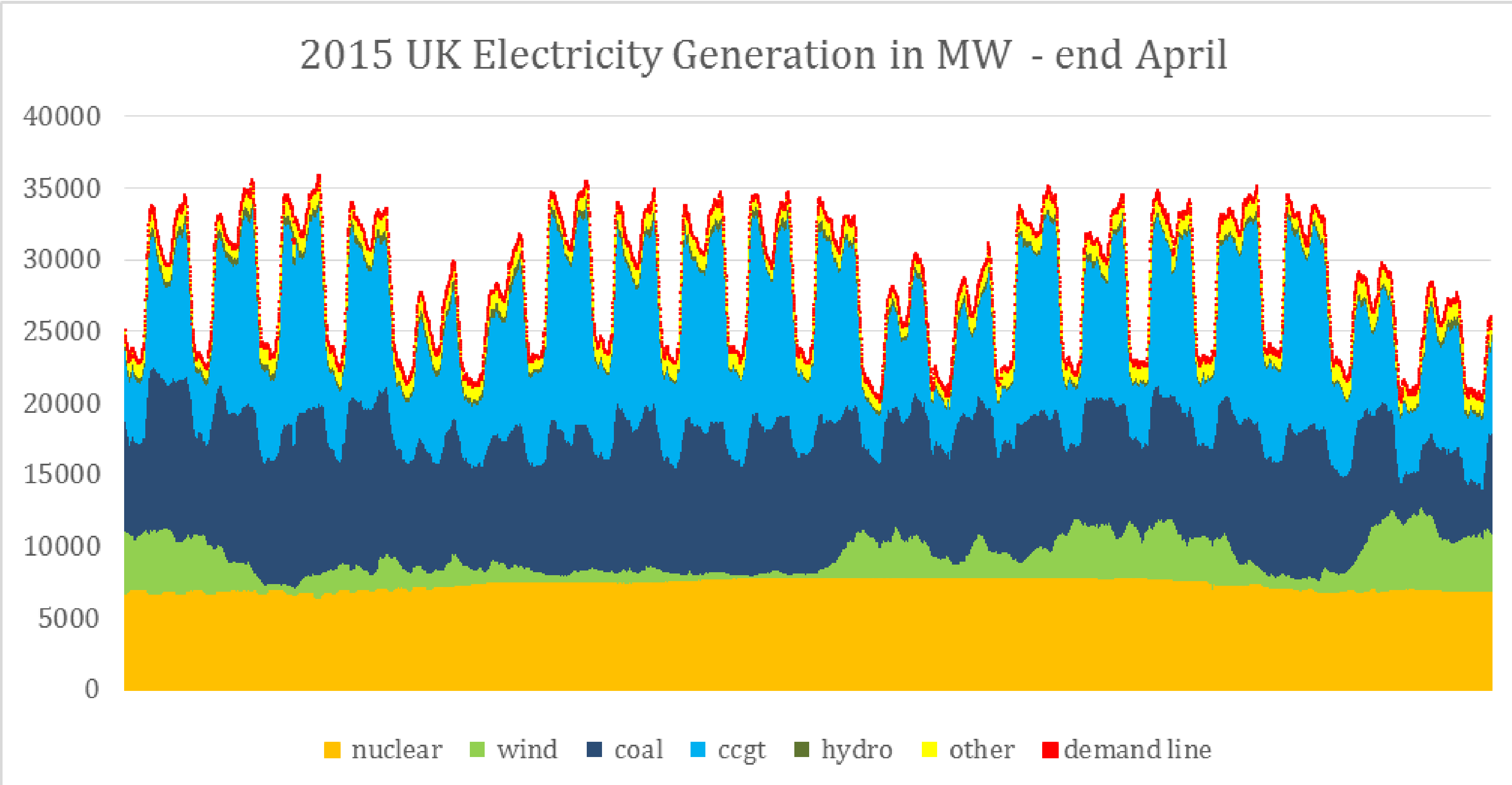
System perspective: CCS is valuable!



ETI ESME analysis consistently shows doubling of cost of meeting 2050 targets without CCS: 1 – 2% GDP

UK POWER SYSTEM – THE VALUE OF CCS

Today’s UK Power System Requirements



Energy Mix - A team

BASELOAD

- Bullet Proof
- Dependable
- Large

Nuclear, Coal
sometimes gas

FLEXIBLE

- Ready for action
- Flexible Role
- Multiple Skills

Coal and Gas

INTERMITTENT

- Clean
- Less predictable
- Public favourite

Wind, Solar

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energy technologies institute

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Position by 2025 - 2030

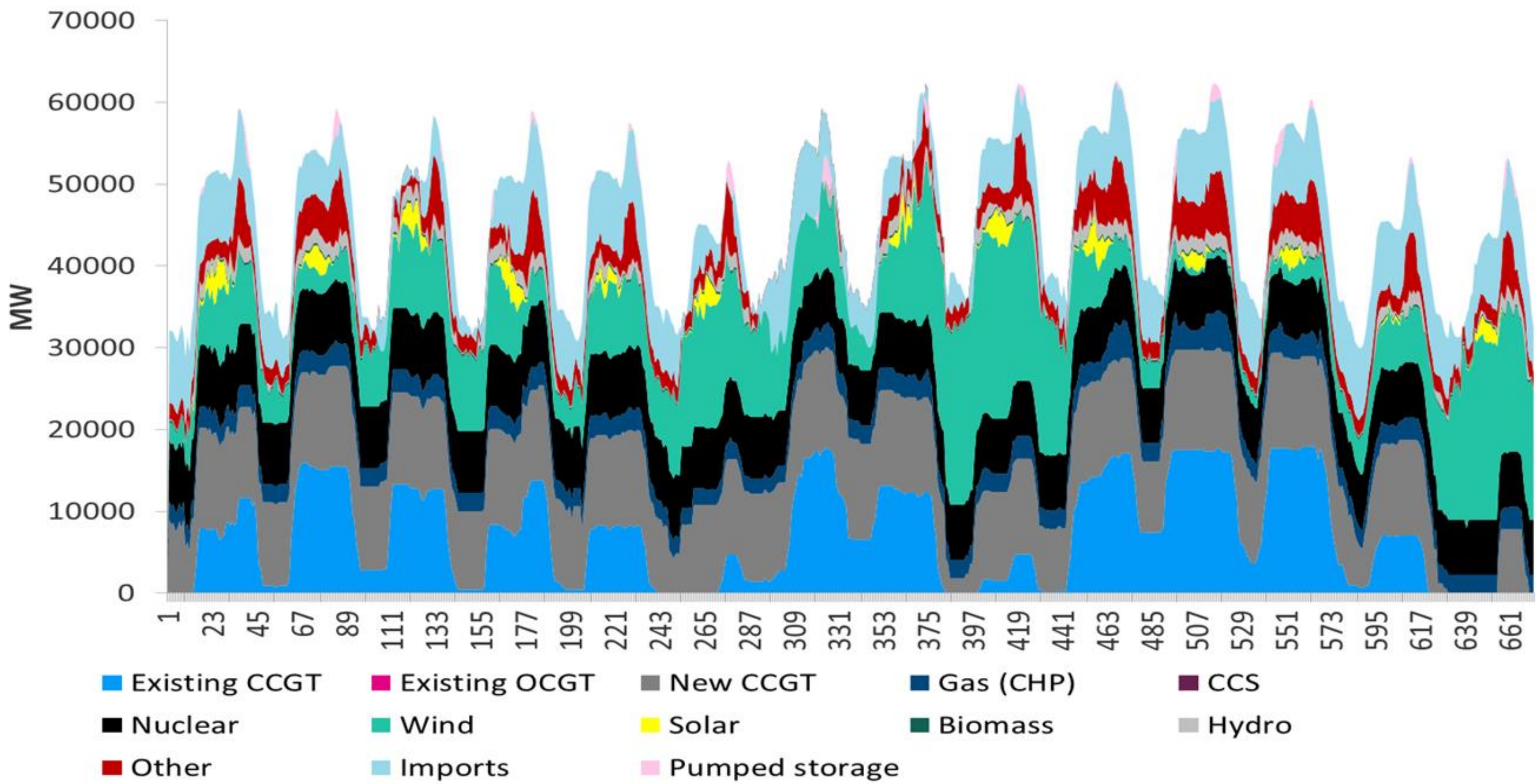
Outlook to 2030

- Need to keep the lights on – and halve the carbon intensity of generation by 2030
- Oldest gas, coal and nuclear shutting between now and 2025
- New nuclear (Hinkley Point) just about starting out – up and running in the late 2020s
- Steady increase in intermittent renewables
  - Remaining gas fleet likely to move towards lower load factors – backing up intermittents

- Increasing requirement for reliable, high merit order, dispatchable power
  - New build, unabated gas? Proving difficult to get away – and too much means too high carbon intensity
  - Interconnectors with Europe? Brexit impact??
  - Energy storage? Possibly help daily fluctuations, but what if high pressure sits over the UK for several days?

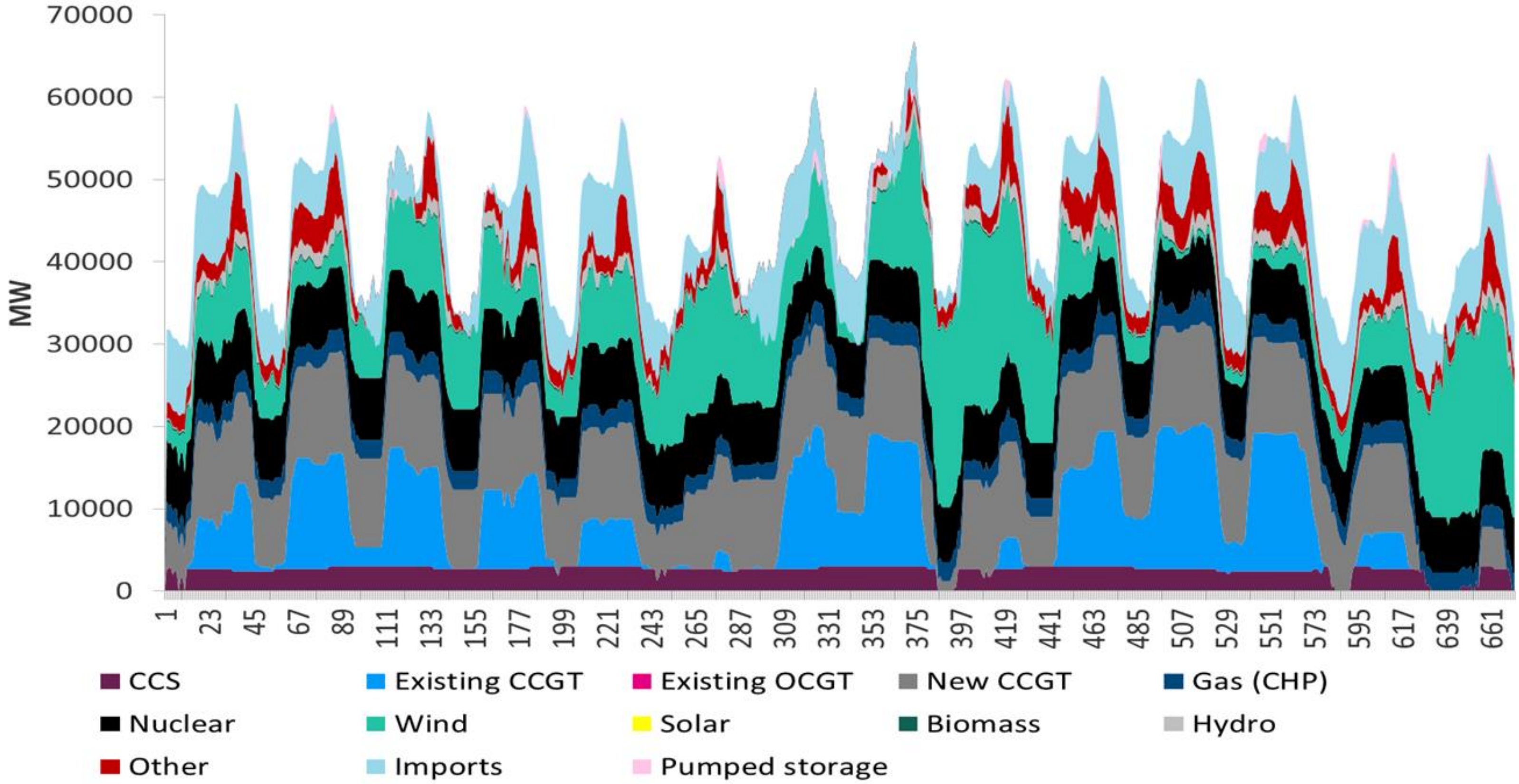
- Key opportunity for gas with CCS – and we need many 1000's of MW by the late 2020s

Dispatch Analysis – 2 weeks in December 2030



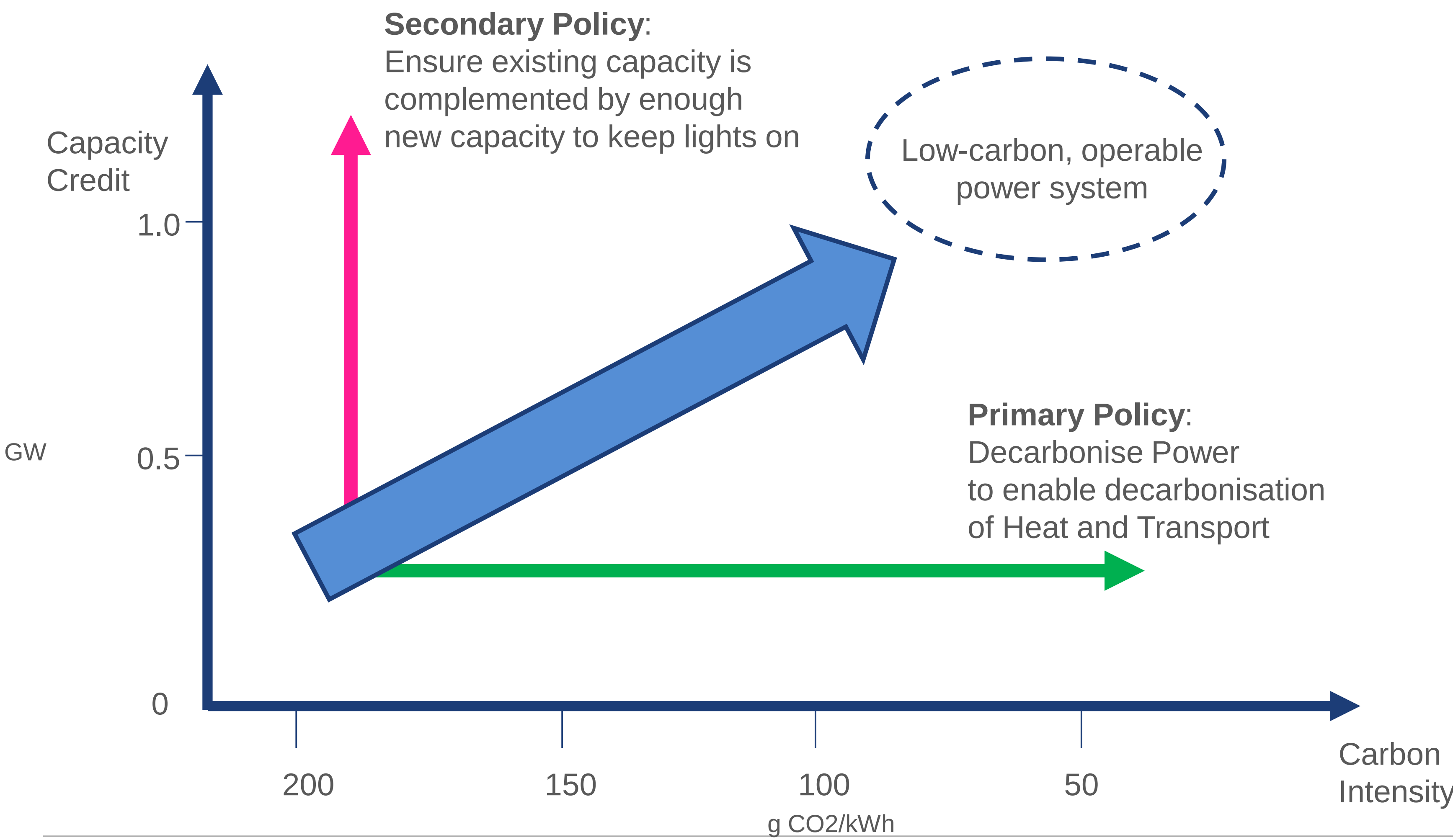
- Analysis undertaken by Baringa Partners
- Uses their 'Reference Case' – assumes development of the fleet without major new policy interventions
- Not compliant with 5th Carbon Budget

Dispatch Analysis – 2 weeks in December 2030 – with CCS



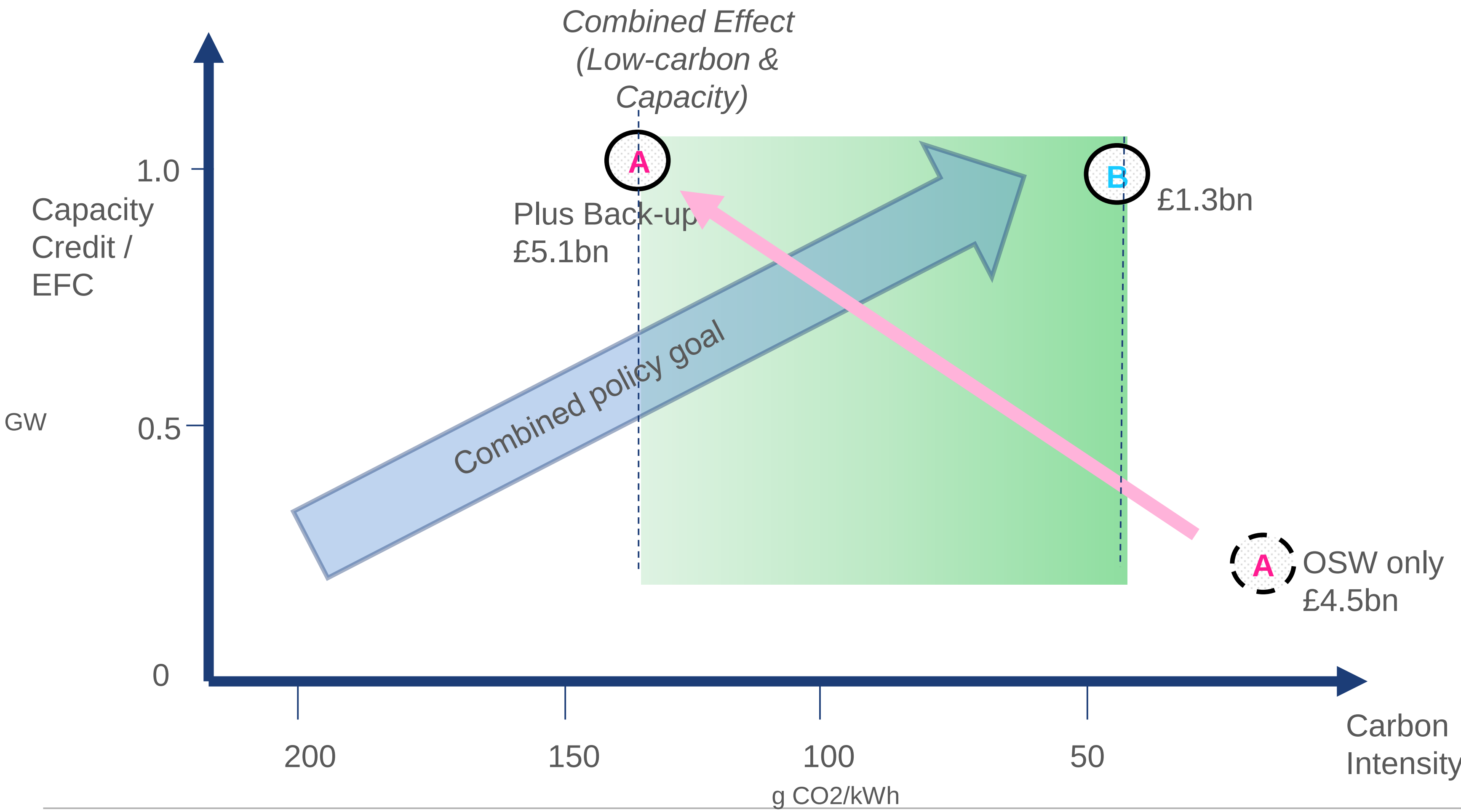
- 3GW of gas with CCS added to the fleet – no consequential reductions in other generating capacity
- CCS operates at near baseload – but reduces output in instances of low demand/high wind

Two Policy Challenges



Two Policy Approaches

For a notional 1GW capacity investment in OSW+CCGT (Strategy A) and abated CCGT (Strategy B)

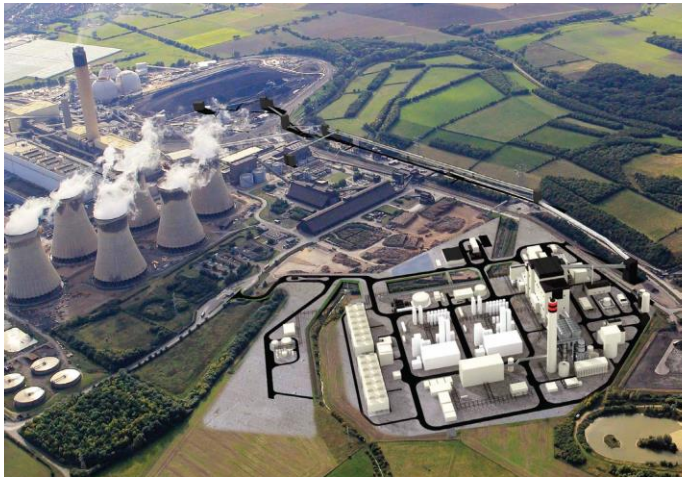


CCS IN THE UK – SOME RECENT HISTORY

…and how the ETI has responded

The UK – moving into a leadership position (2015 slide)

- Two major projects going through consenting and engineering design, with £1Bn government capital support:
- Peterhead
  - NE Scotland
  - Retrofit of gas station with post combustion CCS
  - Uses an existing gas pipeline to transport CO2 to a depleted gas reservoir (Goldeneye)
  - Led by Shell (capture and storage)
- White Rose
  - New coal fired unit based at Drax Power Station
  - Oxyfuel capture
  - New, oversized pipeline
  - Storage in large saline aquifer (Endurance)
  - Led by Capture Power Ltd (Alstom, Drax & BOC)
  - National Grid providing transport & storage
- ETI launched its 'Thermal Power with CCS Project'
  - Development of a low cost, low risk 'Phase 2' project utilising infrastructure created in one of the above



Pictures courtesy Shell & Capture Power Limited

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Pictures courtesy Shell & Capture Power Limited

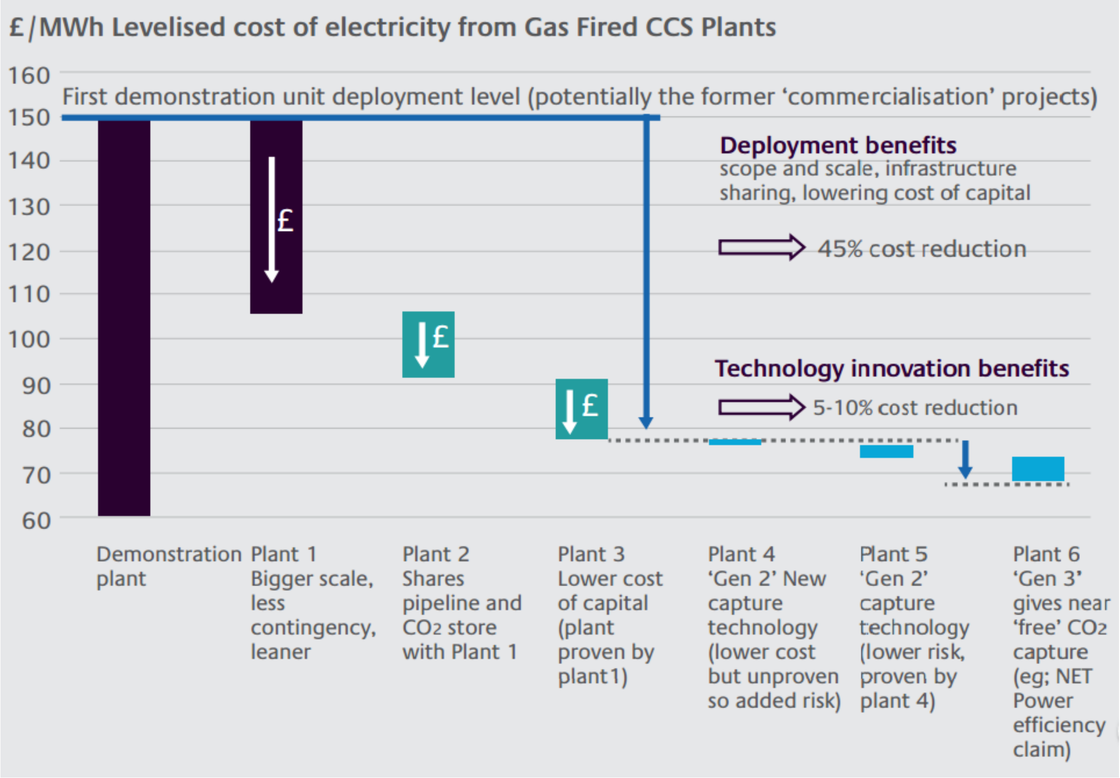
Cost reduction – Key drivers

- Post-November 2105 – ETI focussed its attention on how the apparently high costs of CCS could be reduced – and what a first commercial plant might look like

- Scale
  - reduce infrastructure cost/MW

- Location
  - minimise overall connection costs
  - Access to low cost, well-developed storage
  - Clustering to further enhance benefits of scale

- Technology
  - Use of proven technologies reduces risk and cost of capital



From 'ETI Insights Report 'Reducing the Cost of CCS'
http://www.eti.co.uk/insights/reducing-the-cost-of-ccs-developments-in-capture-plant-technology

September 2016: The Oxburgh Report

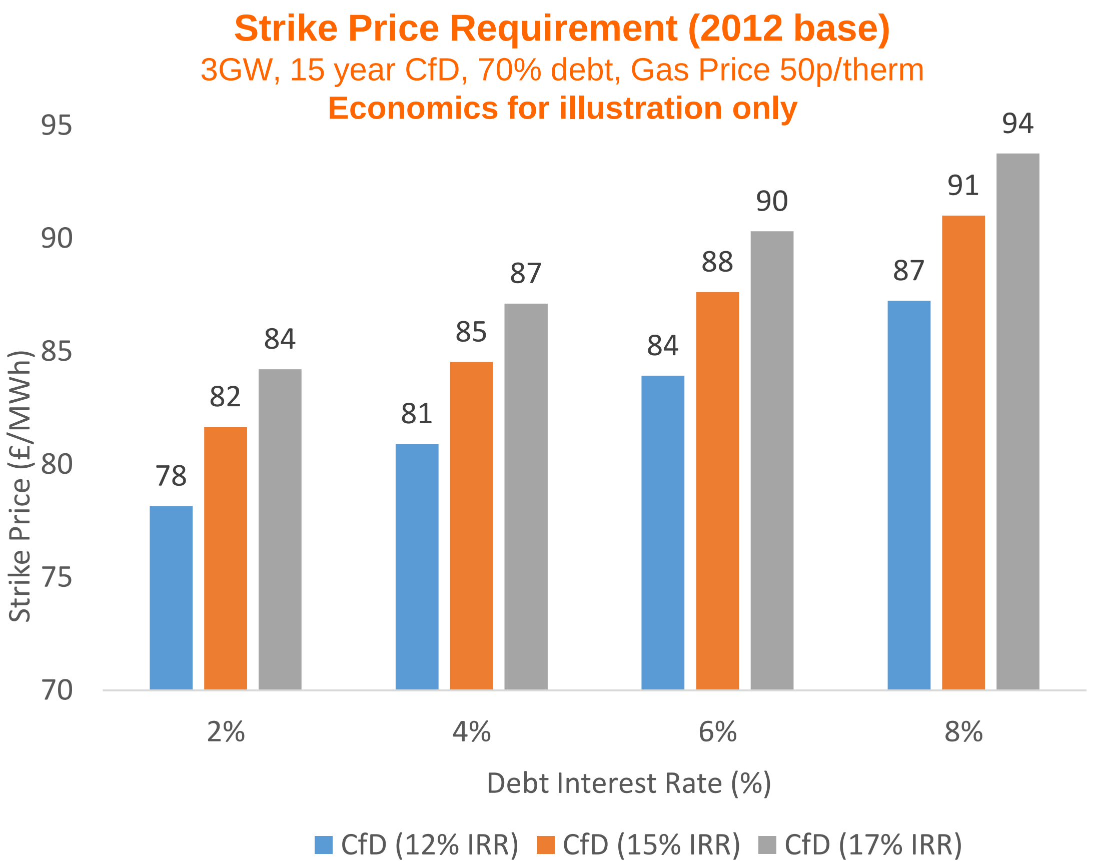
Key Messages from Oxburgh	ETI View
CCS has enormous value because it addresses multiple sectors	Fully aligned with ETI analysis
Need to build around clusters to get value for money	Fully aligned with ETI analysis
Power first – and it should be large scale gas with CCS	Fully aligned with ETI analysis
CCS can deliver £85/MWhr Strike Price from the word go	Challenging, but not impossible depending on the project – and the business model. Need more robust cost data to back this up
Requires government-owned ‘Devco(s)’ for both capture and storage	The logic is clear – but is it a step too far for government? Is there still a potential industry-led model which could work?

http://www.ccsassociation.org/news-and-events/reports-and-publications/parliamentary-advisory-group-on-ccs-report/

Is £85/MWhr achievable?

- ETI has developed an investment model to indicate potential strike prices
- Cost base from earlier work by the ETI
- Depending on assumptions, ~£75 – 95/MWhr is achievable

- Health warnings:
  - Cost base from relatively high level design & costing by Amec Foster Wheeler
  - Numbers sensitive to assumed rates of return and gas price



Remember - it’s not just about Strike Price!

- Scheme Revenue = A + B + C + D

- Where:
  - A is the baseload operation revenue (from CfD)
    - Should not directly compare CCS Strike Price with Offshore Wind and Nuclear – CCS has reduced system integration and balancing costs
  - B is additional revenue from unabated operation
    - Extra 0.5GW generation in situations of high demand
  - C is additional revenue from grid ancillary services
    - e.g. short term operating reserve
  - D is wider revenue and option value (e.g. enabling industrial CCS, EOR)

ADDRESSING THE CREDIBILITY OF THE COST BASE

Thermal Power with CCS - Generic Business Case

The key objective of the Project is to enhance the evidence base on the **realistic cost and performance** of a large scale, low-risk CCGT with CCS Scheme, with such cost and performance being **convincing to a wide range of stakeholders**. This will be achieved by bringing together best available design information and benchmarking data for such a Scheme. More specifically the Project will:

- Produce an outline power scheme and template CCGT plant specification;
- Identify the most promising location options, capable of development of a large scale (ultimately 2GW plus) Gas CCGT with CCS project, which minimises development cost/risk and transport & storage costs;
- Develop **robust P50 and P90 total project costs** for a 'template' CCGT with best-in-class amine, post-combustion CCS, located at the selected locations, benchmarked against actual project costs. Produce probabilistic cost models of the complete Scheme costs;
- Determine realistic operating costs for such a Scheme, taking into account its likely operation within a future energy system.

A word about scale…

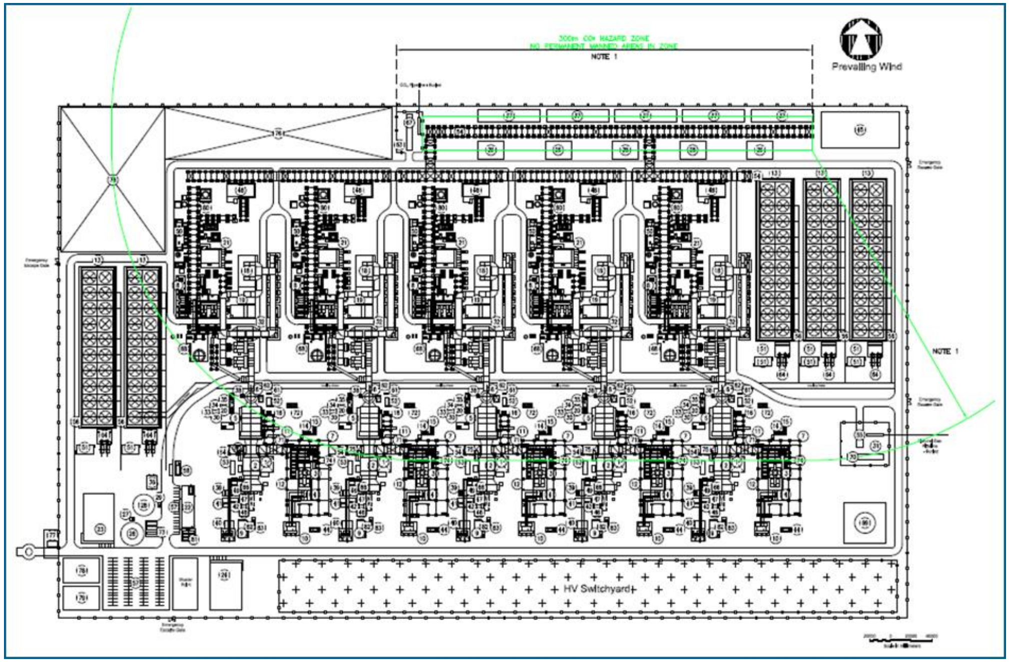
- We are looking at a scheme that is (or has a planned trajectory to develop) a large scale, 2 – 3 GW power with CCS scheme
- Why so big?

- Strike Price – ‘maximises’ economies of scale (particularly for T&S)
- Strategic, low carbon, dispatchable UK power asset
  - Similar scale to Hinkley Point C?
  - ~ 4 - 6% of UK power demand
- Substantial, guaranteed gas demand for suppliers (~ 300 - 450 Mscf/d)
- Significant, reliable CO_2 source to establish onshore hub (6 – 10 Mtpa CO_2)

Project Team

- SNC-Lavalin – Prime Contractor
  - Matt Wills (Project Manager)
  - Kannan Sreenivasan (Chief Technologist)
  - Andrew Collinson (Power Industry Consultant)
- AECOM – Subcontractor (Site Selection)
  - Andy Cross (Site selection & consenting)
- University of Sheffield Energy 2050 - Subcontractor (Policy Advice & Peer Review)
  - Matthew Billson (Policy advice)
  - Jon Gibbins/Mohammed Pourkashanian (Technical challenge)

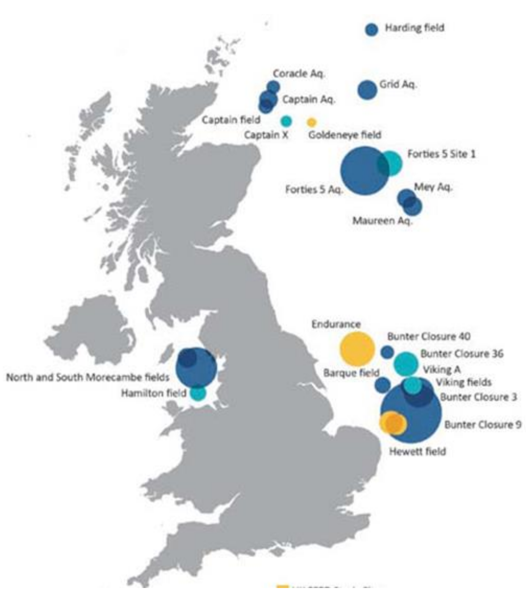
Template Plant Specification

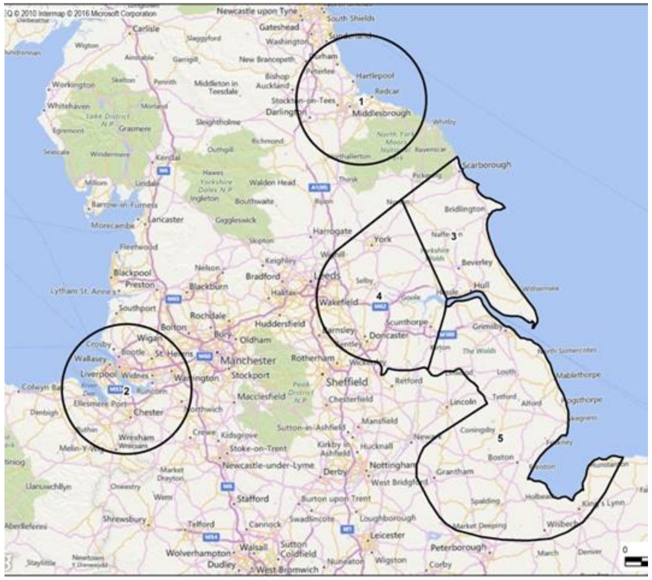


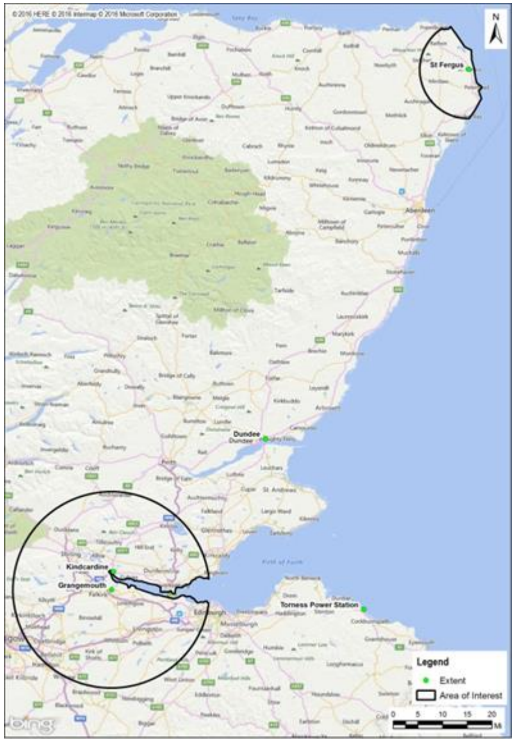
- Based on 5 x latest, largest H/J Class GT – nominal 500MWe
- 5 individual trains (GT+ST+Generator+Absorber+Stripper+Compressor) – only cooling/services shared
  - Provides ‘chunky’ flexibility
  - Individual units align with ‘largest proven’
- Capture plant based on ‘best in class’ engineered amine solvent (e.g. Cansolv)
  - Based on scale up of published Peterhead design
- Total output ~ 3.5GW unabated, 3.0 GW abated
- Full chain costs estimates will be provided for 1, 2, 3, 4, and 5 train schemes

Site Selection (1)

- Identify Search Regions
- Identify potential brownfield sites (long-list)
- Assess potentially available site area

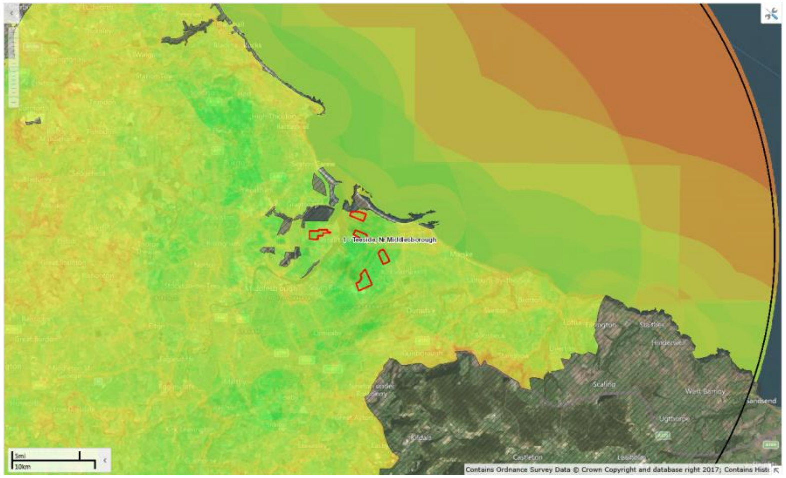


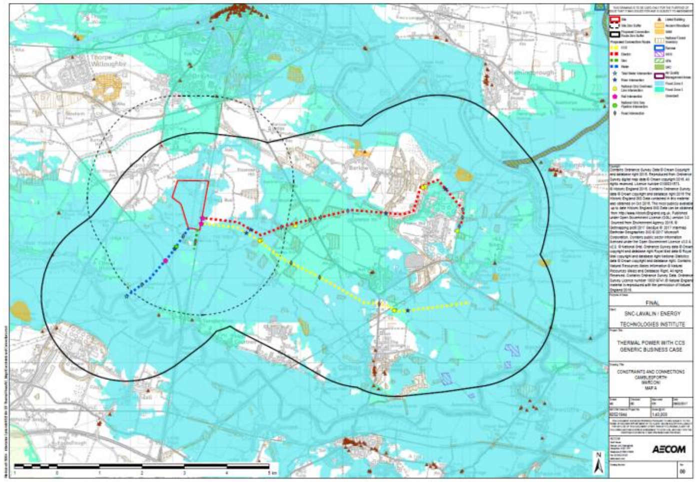




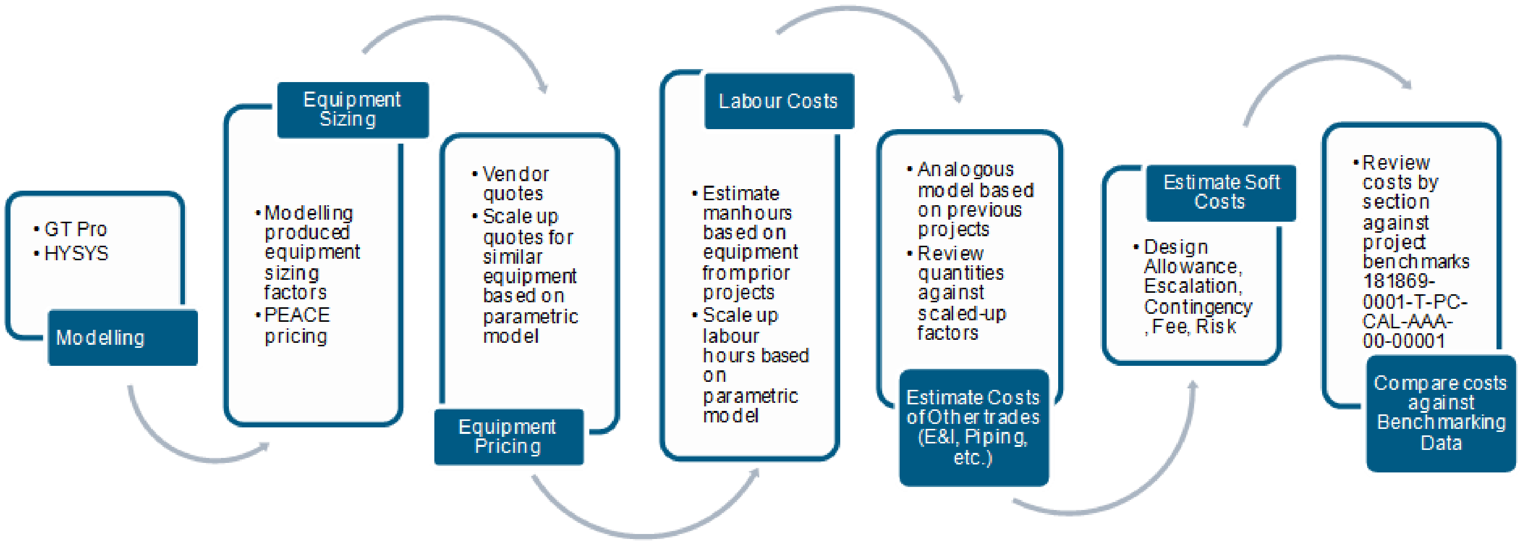
Site Selection (2)

- Site scoring using GIS model
- Ranking and down-selection of potential brownfield and greenfield sites (short-list)
- Development assessment for short-listed sites
- Identification of 'preferred sites' for each region
- One representative site used for region-specific costing

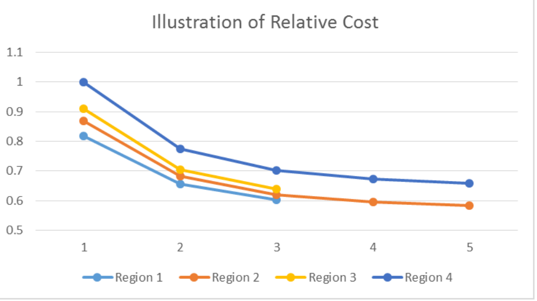




Cost estimation methodology



- Much greater level of detail than ‘conventional’ study estimates – does not rely of factored estimates
- Access to directly relevant cost information from ‘as built’ plant and firm EPC quotes
- Detailed consideration of margins/contingencies/risk factors from EPC and owners’ perspectives
- Site-specific costing for each region
  - Ground/local conditions
  - Gas, cooling water, electricity and CO_2 connections
  - Transport & Injection into selected store for each region
- 5-4-3-2-1 trains (where possible)
  - some regions limited to 3 trains for various reasons



Generic Business Case – Future Work

- Complete review of capital cost estimate

- Complete work on operating costs
  - Working on detailed cost breakdown, not just factored estimates
  - Considering how operating in the market might impact the operating costs (e.g. start up/ shut down

- Further work on dispatch analysis nearing conclusion – will inform opex work

- ETI will undertake financial modelling to reassess potential strike process/commercial returns

- ETI will publish summary report in late Q3/early Q4, with further detail to follow in 2018

CONCLUSIONS AND NEXT STEPS

Conclusions

- CCS can bring substantial value to the UK and potential investors in support of the UK meeting its CO_2 reduction targets

- Gas power with CCS can be a competitive low carbon electricity source, but can also provide a unique contribution to the power mix which adds significant value beyond a simple strike price comparison with other technologies

- The ETI is delivering a comprehensive evidence base on the realistic cost and performance of a large scale, low-risk CCGT with CCS Scheme, which the ETI believes will be convincing to a wide range of stakeholders

- The ultimate value of CCS will come from its application across multiple sectors and applications, but ETI analysis shows that this should be led by the implementation of large scale, power with CCS, to provide investable initial projects, meet UK needs for a reliable, low carbon power system and provide the necessary scale and reliability of CO_2 supply to develop Transport and Storage infrastructure

- The challenge now is commercial – not technical – to develop a first commercial gas with CCS power scheme

The next step –
How does this get turned into reality?

- The ETI CCS Programme will be largely completed by the end of 2017 – we will have completed our 10 year mandate
- We believe that this work will provide a blueprint and compelling evidence for government and industry stakeholders for a large scale, strategically important, first commercial gas power with CCS scheme in the UK
- Furthermore we believe that, with the appropriate support package and learning the lessons from previous CCS competitions, an industry-led, full chain CCS project could become a reality
  - We are working with our public and private sector members and other stakeholders to achieve this

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