Reducing the cost of carbon capture and storage,
London, 26th March 2013

Lowering the cost of electricity generation with CCS through CO_2 absorbers developments

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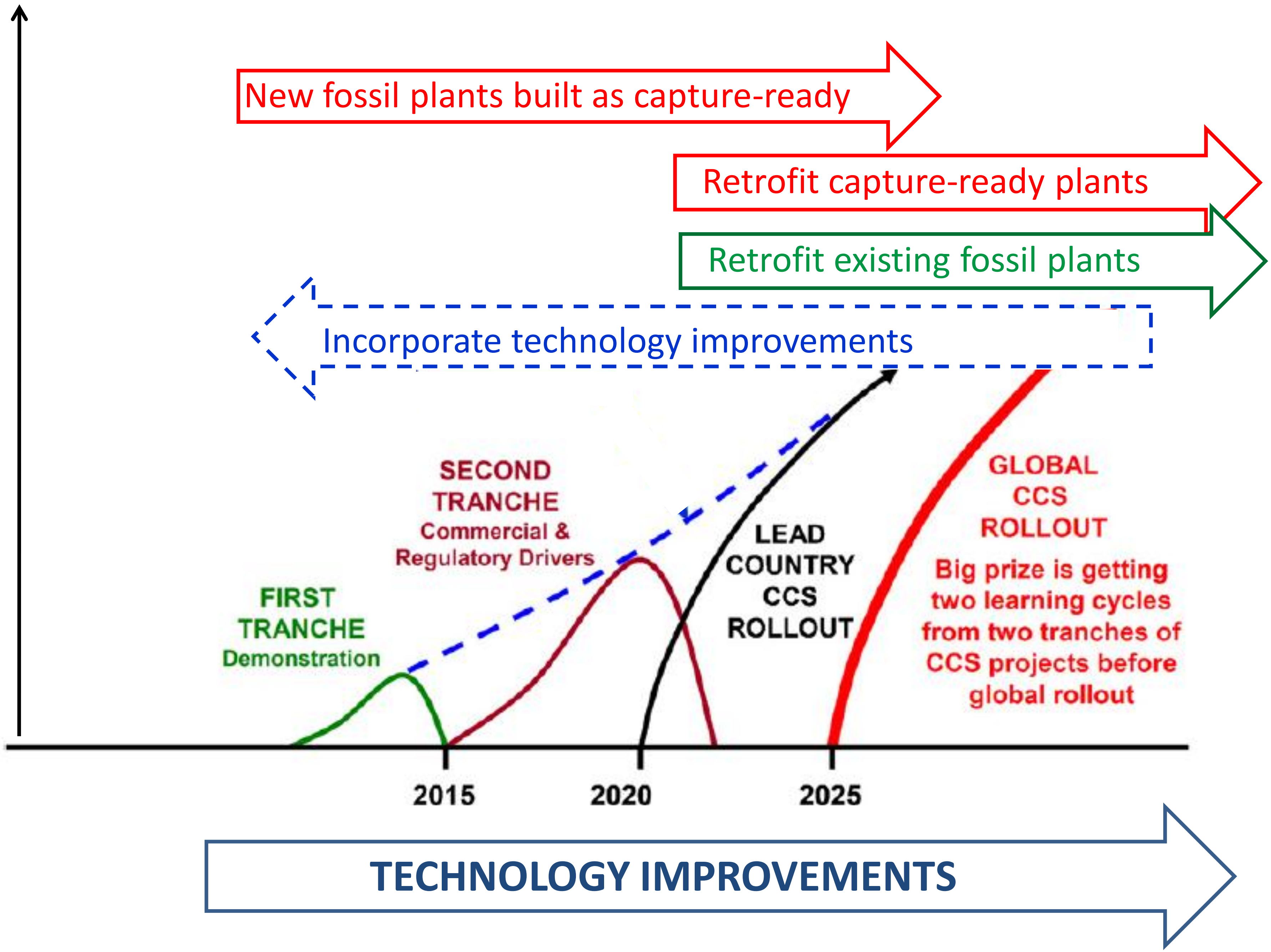
Acknowledgements: Dr Xi Liang, Dr Prashant Valluri,
Prof Jon Gibbins

Overview

- Origins of the project
- Reasons for development
- Methodology basis

Deployment of CCS needs to follow multiple pathways

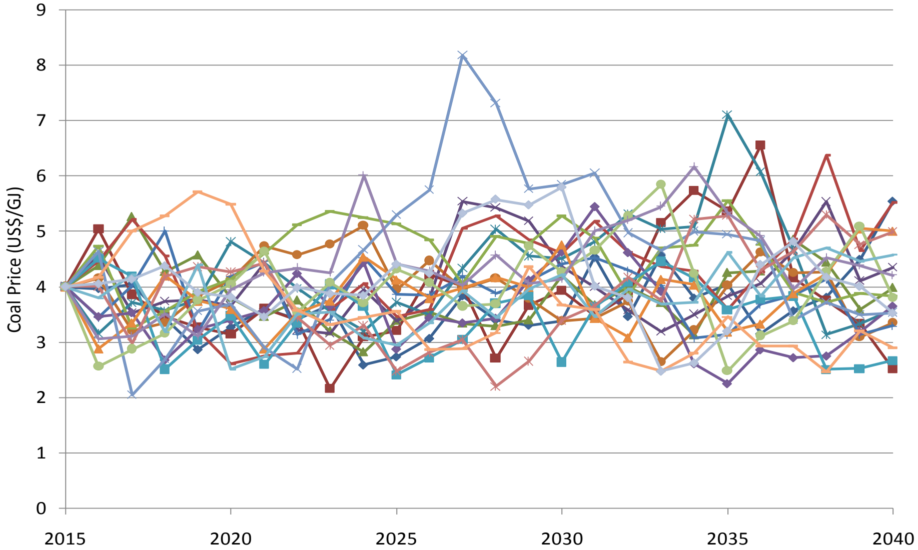


Future-proofing CCS power plants for technology developments

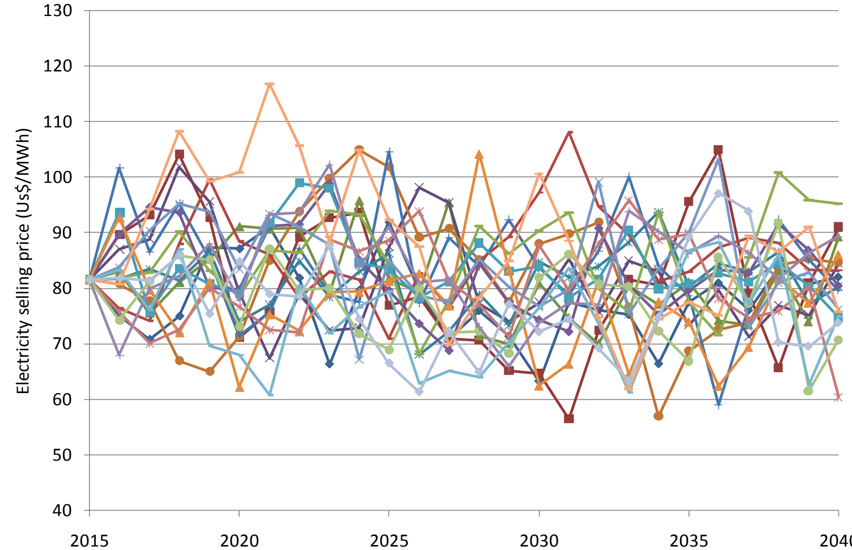
- **Motivations for future-proofing power generation asset - Utilities**
  - **Keep the plant license to operate by securing compliance with legislation**
    New solvent becomes Best Available Technology (e.g. for lower carryover in flue gas)
    Level of capture increases beyond ~ 90%
  - **Improve power plant economics**
    Increase plant capacity (MW sent out for sale)
    Raise efficiency
    Reduce exposure to carbon costs
    Reduce operating costs
    Enhance reliability and availability
- **Motivations for future-proofing power generation asset - Society**
  Technology options that allow developments that occur during the early stage of CCS deployment to be subsequently incorporated into new plants to lower the cost to society of electricity generation will potentially be worth billions to the UK over the next decades

Future-proofing CCS power plants – How much is it worth?
Methodology

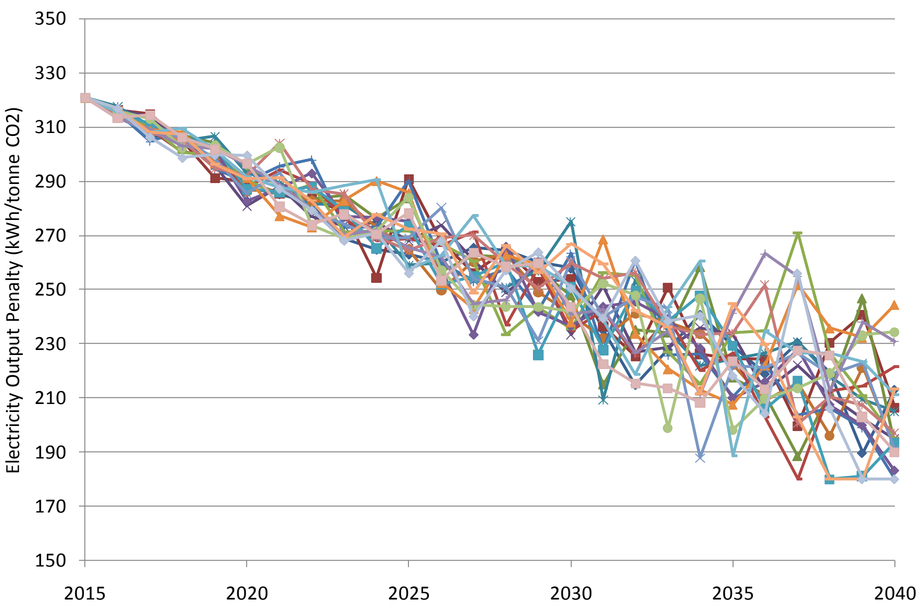
- **Real option Analysis (ROA)**
  - A real option is the right — but not the obligation — to undertake some business decision; it is typically the option to make, abandon, expand, or contract a capital investment.
  - ROA is often applied when an alternative, deterministic net present value method fails to capture value of an option involved in sequential decision-making
- **In this context**
  - The option is the right – but not the obligation – to undertake an upgrade of the capture technology of an existing coal plant with post-combustion capture.



Illustrative simulated paths for annual averaged coal price



Illustrative simulated paths for annual average electricity selling price

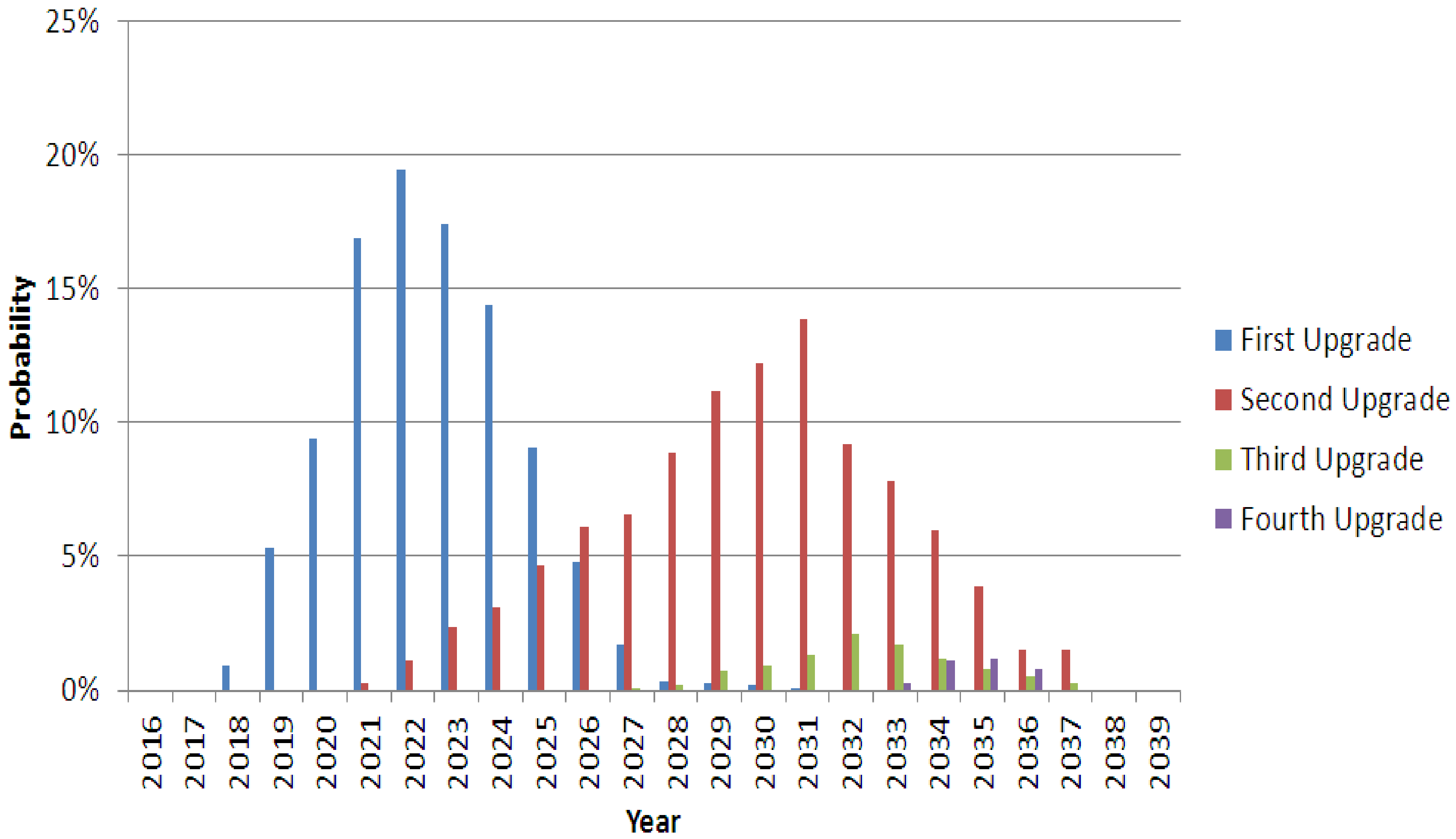


Illustrative simulated Paths for the Electricity Output Penalty (EOP) of post-combustion capture

Future-proofing CCS power plants – How much is it worth?

% of original capex	1%	2%	3%	4%	5%	6%	7%
Capital cost at Upgrade ($M)	17.6	35.1	52.7	70.2	87.8	105.3	122.9
Average value of the option ($M)	393	365	341	311	288	264	241
Average Value of the Option (% of total plant CAPEX)	22.4%	20.8%	19.4%	17.7%	16.4%	15%	13.7%
Impact on LCOE ($/MWh)	-2.76	-2.76	-2.74	-2.75	-2.75	-2.75	-2.76
Probability of upgrading twice or more	100%	100%	99.8%	94.8%	86.5%	77.0%	51.7%
Probability of upgrading three times or more	79.5%	39.2%	22.3%	9.5%	3.1%	0.2%	0%

Future-proofing CCS power plants – How much is it worth?



Probability distribution of exercising the option to upgrade the capture technology in a future-proofed CCS power plant

Future-proofing CCS power plants – Engineering options to incorporate new improved solvents

Critical piece of hardware	Description of performance lock-in	Possible future-proofing strategies	Relevant solvent properties
Cross flow heat exchanger	- Increased temperature pinch at higher solvent flow rates lead to increased solvent energy of regeneration	- Space in heat exchanger structure for additional surface area if necessary	Heat capacity Enthalpy of absorption Reaction kinetics Vapour liquid equilibrium Diffusivity of CO_2 in solution Diffusivity of reaction products Viscosity Density Surface tension
Desorber column	- Inability to operate at elevated operating pressure or below atmospheric	- Reinforce mechanical structure for elevated pressure/sub-atmospheric operation - Maximise pressure design rating where codes allow this to be done at minimal cost.	Enthalpy of absorption Thermal stability
Absorber column	- Inability to operate with improved solvents requiring more surface area and/or residence time	- Provision for additional, unpacked, height in the absorber - Space for (additional) intercooling infrastructure	Reaction kinetics Vapour liquid equilibrium Diffusivity of CO_2 in solution Diffusivity of reaction products Viscosity Density Surface tension
CO_2 Pipeline	Inability to transport additional CO_2 at increased capture levels.	Strategies to compress and transport 95% or higher of the likely future CO_2 production from the plant (these will depend on the number and size of compressors fitted and the pipeline system downstream)	N/A
Heat recovery system into power cycle feed water heating train	- Inability to benefit from increased heat recovery at lower steam extraction level from power cycle	- Space for additional heat exchanger in compressor train(s) and/or for additional condensate and heating medium flows - Space for additional boiler condensate circulating pumps or for change of impellers/motor size.	Heat capacity Temperature of regeneration Enthalpy of absorption Mass transfer properties

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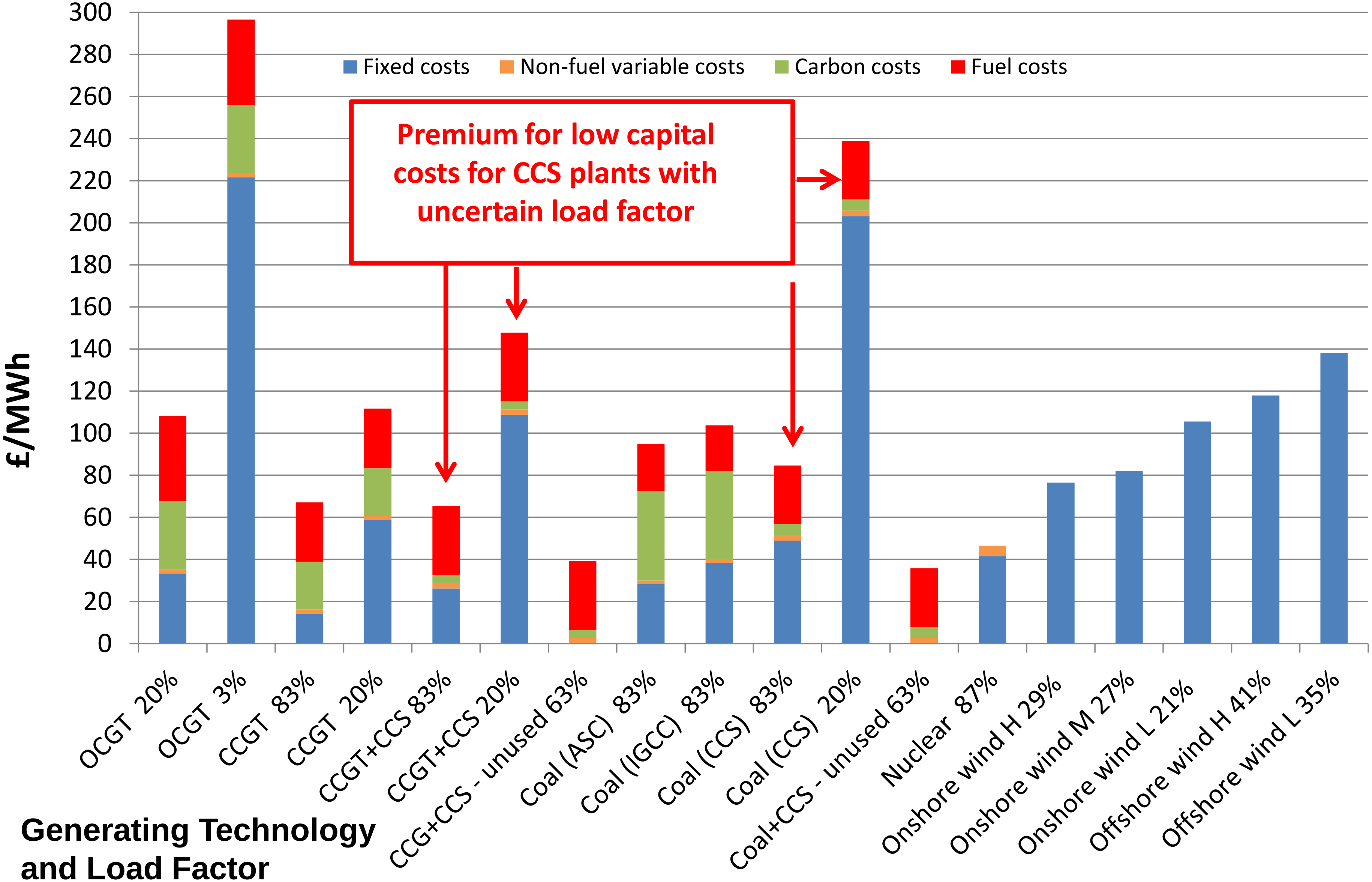
Costain and Edinburgh CO_2 absorber project (RECAP) Overview

- 12 months Research & Development project supported by DECC CCS Innovation Programme – Start Feb 2013
- Develop novel ways to build CO2 absorber columns with an emphasis on modularisation
- Options to implement future solvents in existing CCS power plants to keep lowering the cost of low-carbon electricity.
- Reduce the Engineering, Procurement and Construction costs of CO2 absorber columns

ILLUSTRATIVE LEVELISED COST OF ELECTRICITY BREAKDOWN



Based on *Redpoint: Decarbonising the GB power sector: evaluating investment pathways, generation patterns and emissions through to 2030, A Report to the Committee on Climate Change, September 2009.*
2008 capital costs, assumed £30/tCO_2 carbon price, gas price £12.5/MWh_{th}, coal price £6.25/MWh_{th}. 10% interest rate

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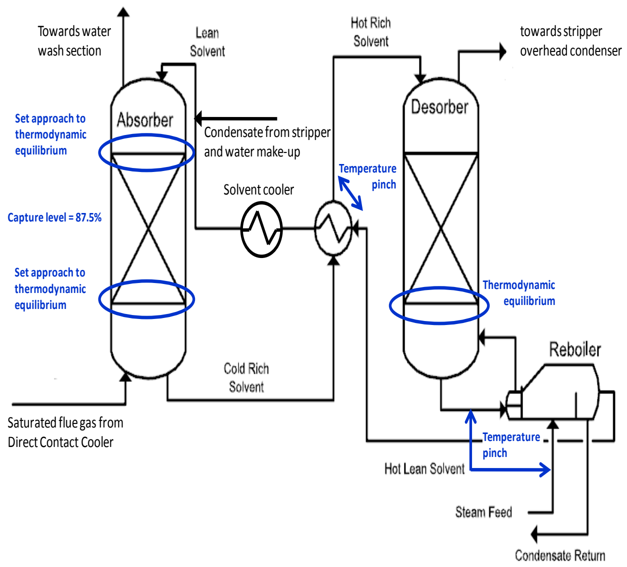

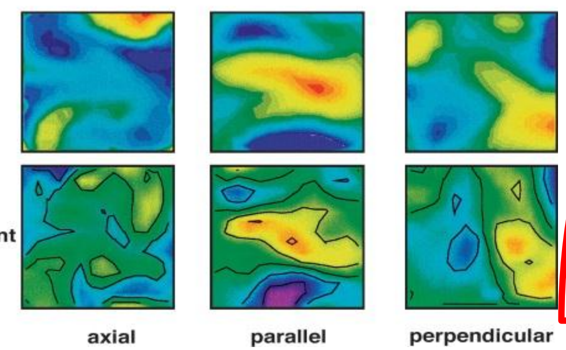

- to process models
- Layouts
- Reliability & Safety
- Mechanical design
- Design for construction
- Lead time
- Equipment costs
- Installation costs
- Cost Breakdown

From fundamental models of two phase flow in packings

Value Engineering

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