Cost of CCS and its value to the electricity system

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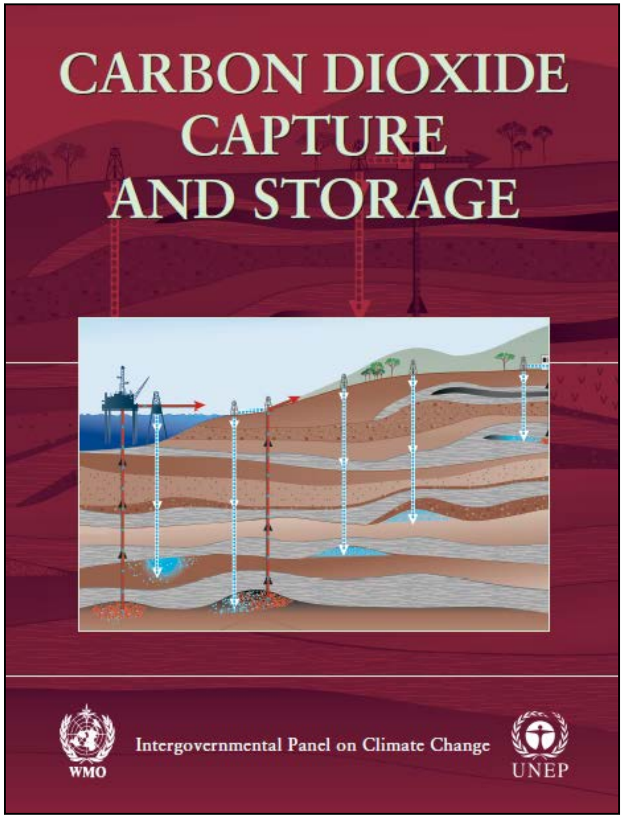
Outline of Talk

- Costs of CCS
  - Based on paper, "The cost of CO_2 capture and storage", Rubin, Davison and Herzog, International Journal of Greenhouse Gas Control, 2015
- Value of CCS
  - Based on IEAGHG Report 2017/09, "Valuing flexibility in CCS power plants", Contractors: Imperial College London [Niall Mac Dowell, Clara Heuberger et al]

The IPCC Special Report on CCS (SRCCS)

- Commissioned by IPCC in 2003; completed in December 2005
- First comprehensive look at CCS as a climate change mitigation option (9 chapters; ~100 authors)
- Chapter 8 includes a detailed review of cost estimates for CO_2 capture, transport and storage options



2015 cost update

(by Rubin, Davison and Herzog, *IJGGC*)

- Reviewed 16 recent cost studies published 2010-2014
  - All with multiple cases
- Compiled data from recent CCS cost studies in the U.S. and Europe for new power plants
- Adjusted all costs to constant 2013 US dollars
- Adjusted SRCCS costs from 2002 to 2013 USD using:
  - Capital /O&M cost escalation factors +
  - Fuel cost escalation factors (for COE)
- Compared recent cost estimates to SRCCS values

Capture system costs then and now -

- for new SCPC plants with post-combustion capture

Bituminous coals; 90% capture; all costs in constant 2013 US dollars)

Performance and Cost Measures for New SCPC Plants w/ Bituminous Coal	Current Values			Adjusted SRCCS Values			Change in Rep. Value (Current –Adjusted SRCCS)	
	Range		*Rep. Value*	Range		*Rep. Value*		
	Low	High		Low	High		Δ Value	Δ%
Plant Performance Measures								
SCPC reference plant net power output (MW)	550	1030	742	462	758	587	**155**	***26***
Emission rate w/o capture (kg CO_2/MWh)	0.746	0.840	0.788	0.736	0.811	0.762	**0.03**	***3***
Emission rate with capture (kg CO_2/MWh)	0.092	0.120	0.104	0.092	0.145	0.112	**-0.01**	***-7***
Percent CO_2 reduction per MWh (%)	86	88	87	81	88	85	**2**	
Total CO_2 captured or stored (Mt/yr)	3.8	5.6	4.6	1.8	4.2	2.9	**1.7**	***57***
Plant efficiency w/o capture, HHV basis (%)	39.0	44.4	41.4	39.3	43.0	41.6	-0.2	***-1***
Plant efficiency w/ capture, HHV basis (%)	27.2	36.5	31.6	28.9	34.0	31.8	-0.2	***-1***
Capture energy reqm't. (% more input/MWh)	21	44	32	24	40	31	1.1	***3***
Plant Cost Measures								
Total capital reqm't. w/o capture (USD/kW)	2313	2990	2618	1862	2441	2040	**578**	***28***
Total capital reqm't. with capture (USD/kW)	4091	5252	4580	2788	4236	3333	**1247**	***37***
Percent increase in capital cost w/ capture (%)	58	91	75	44	73	63	**13**	
LCOE w/o capture (USD/MWh)	61	79	70	64	87	76	**-6**	***-8***
LCOE with capture only (USD/MWh)	94	130	113	93	144	119	**-6**	***-5***
Increase in LCOE, capture only (USD/MWh)	30	51	43	28	57	43	**0**	***-1***
Percent increase in LCOE w/ capture only (%)	46	69	62	42	65	56	**5**	
Cost of CO_2 captured (USD/t CO_2)	36	53	46	33	58	48	**-3**	***-6***
Cost of CO_2 avoided, excl. T&S (USD/t CO_2)	45	70	63	44	86	67	**-4**	***-6***

(Source: Rubin, Davison, Herzog, 2015)

Total capital cost of SCPC plants

Compared to adjusted SRCCS, recent plant-level TCR is higher by:

- **28% w/o capture**
- **37% w/ capture**

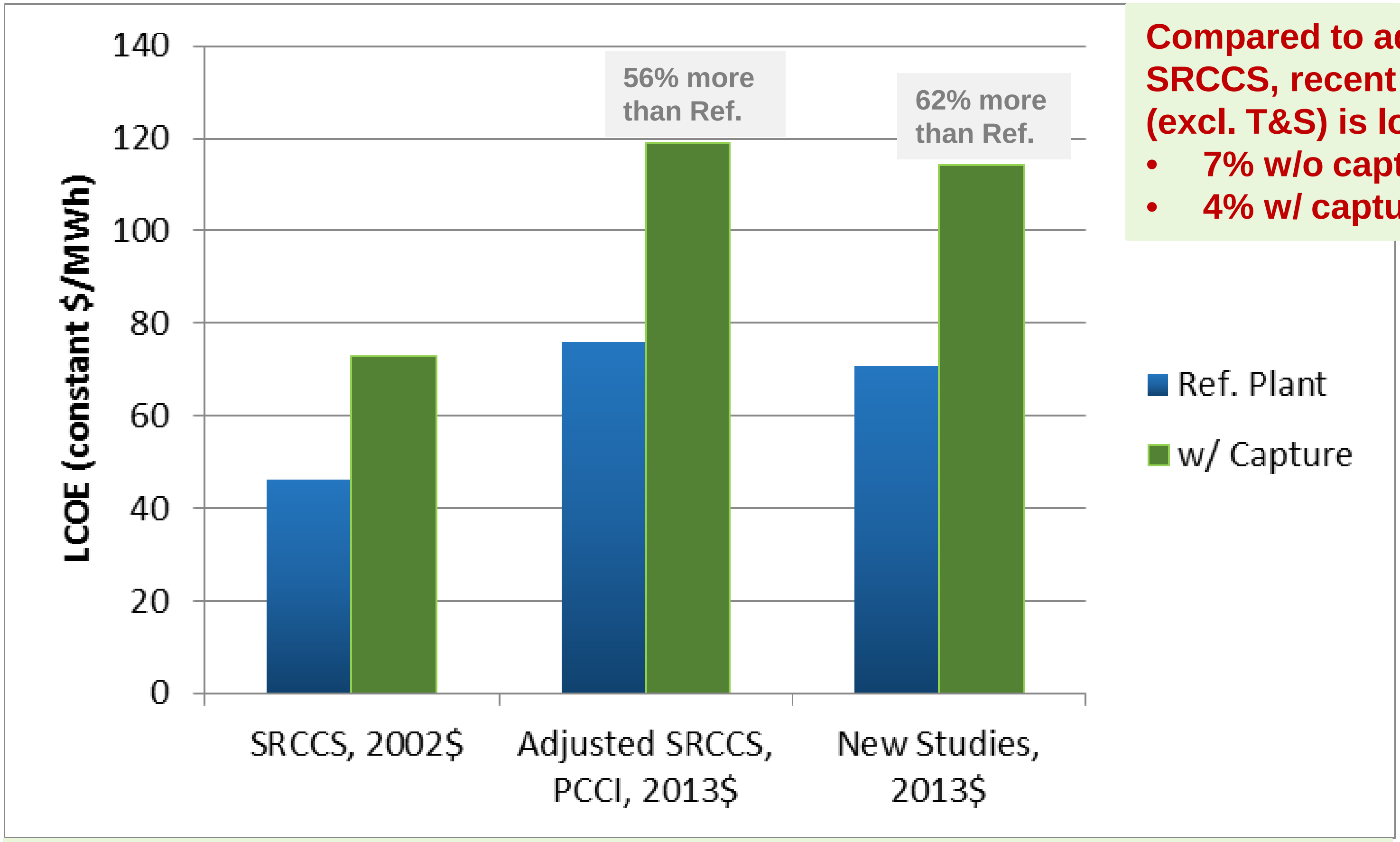
Significant increases in capital cost for capture systems since SRCCS:

- **52% higher for SCPC**

(representative values of cost ranges across studies)

LCOE for SCPC plants

(representative values, excluding transport & storage costs)



Compared to adjusted SRCCS, recent LCOE (excl. T&S) is lower by:

- **7% w/o capture**
- **4% w/ capture**

This assume plants are fully dispatched whenever they are available; lower lifetime capacity factors will result in higher LCOEs

Differences a function of key assumptions

- Basic power plant design parameters such as net plant efficiency, CO_2 emission rates, and CO_2 capture rates have not changed appreciably since the SRCCS
- Some assumptions affecting CCS costs have changed:
  - Average power plant sizes without CCS are about 10% to 25% larger than in SRCCS studies
  - Assumed capacity factors are higher (by **10 %-pts for PC plants**, 2 %-pts for IGCC plants, and 8 %-pts for NGCC)
  - Fixed charge factor are lower (by about **30% for SCPC**, 20% for IGCC and 10% for NGCC)
  - Parameter values often differ for plants with and w/o CCS
  - Increased focus on potential for utilisation via CO_2–EOR
- In addition, capital costs and the costs of fuel have both increased

Total plant LCOE (2013 $/MWh)

(for CO_2 capture, transport and geological storage)

Case	NGCC post-combustion capture	**SCPC post-combustion capture**	IGCC pre-combustion capture
Without EOR			
SRCCS (adjusted)	56 – 110	**94 - 163**	92 – 150
Recent Studies	63 – 122	**95 - 150**	112 – 148
With EOR credits			
SRCCS (adjusted)	48 – 100	**76 – 139**	77 – 128
Recent Studies	48 – 112	**61 – 121**	83 – 123

LCOE ranges are roughly unchanged
(particularly for SCPC, while some increases for NGCC and IGCC)

Mitigation costs (2013 \$/tCO_2 avoided)

(for CO_2 capture, transport and geological storage)

Case	NGCC post-combustion capture*	**SCPC post-combustion capture***	IGCC pre-combustion capture*
Without EOR			
SRCCS (adjusted)	64 – 136	**45 - 114**	(Not available)
Recent Studies	59 – 143	**46 - 99**	53 - 137
With EOR credits			
SRCCS (adjusted)	38 – 107	**17 – 77**	(Not available)
Recent Studies	10 – 112	**(5) – 58**	3 – 102

*** Reference plant for all cases is a SCPC plant with no CCS**

Mitigation costs also are roughly unchanged

(some decreases for NGCC and SCPC)

Potential for further cost reductions

With

- Sustained R&D
- Learning from experience
- Strong policy drivers that create markets for CCS technology – *a combination of carrots and sticks*

analysis indicates that substantial reductions in the cost of electricity ($/MWh) and the CO_2 mitigation cost ($/tCO_2$ avoided) can be made

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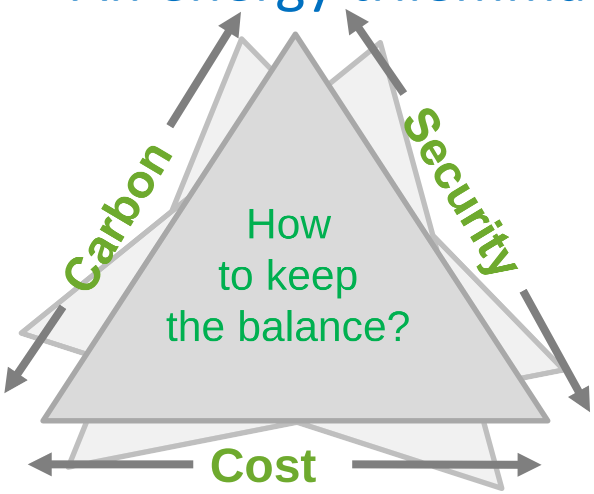
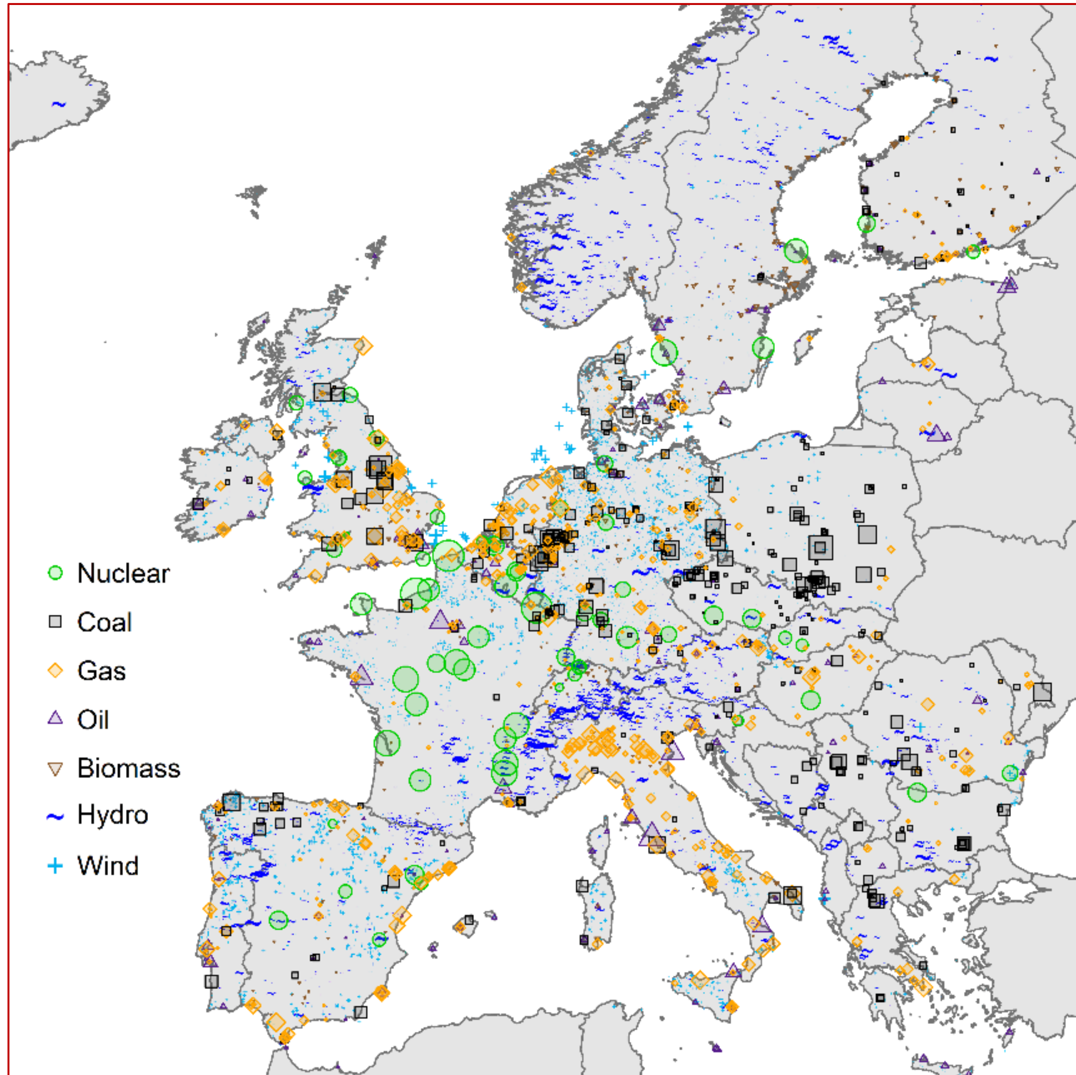
The electricity system

Each country's fuel choices depend on:

- its indigenous resources
- the political context
- public acceptability

An energy trilemma

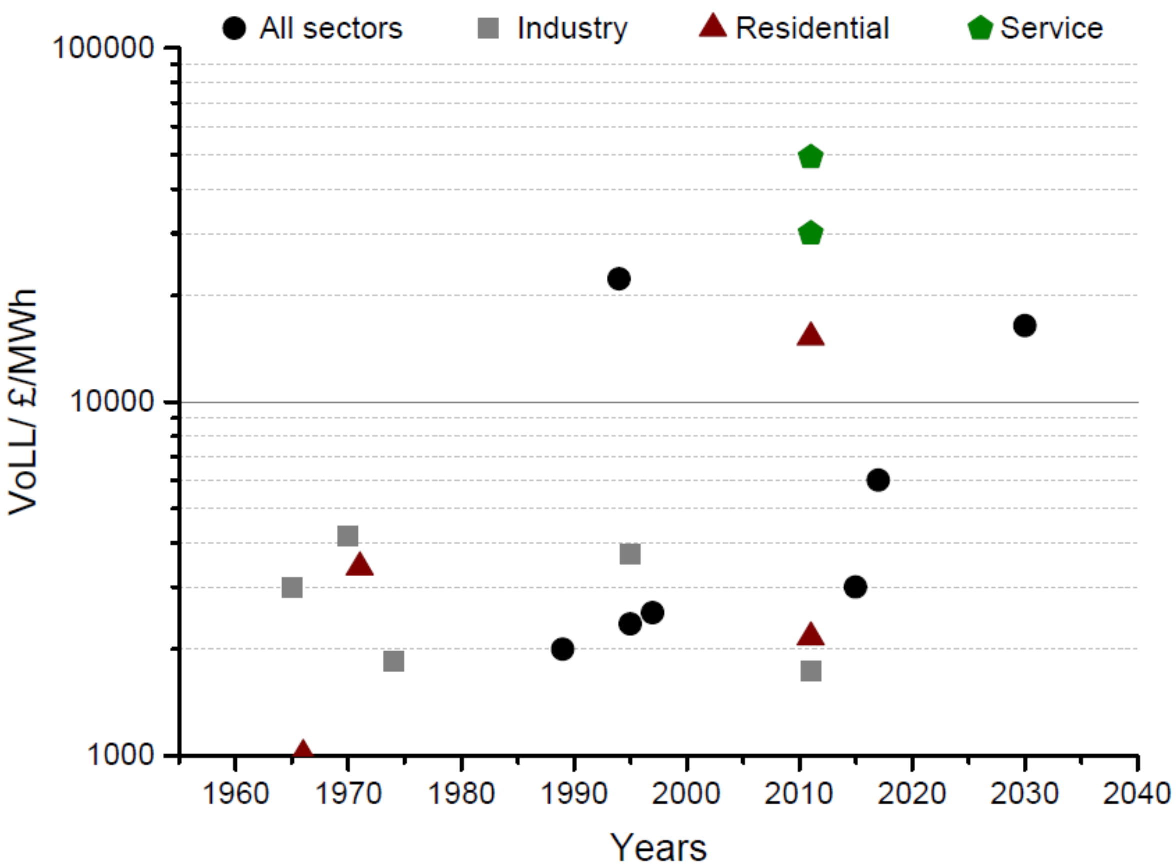




Source: Bassi, S., Boyd, R., Buckle, S., Fennel, P., et al., Bridging the gap: improving the economic and policy framework for Carbon Capture and Storage in the European Union: Policy brief

Value of electricity availability

- The Value of Lost Load (VoLL) defines the cost of electricity demand not being met in £/MWh$_{lost}$
- VoLL is used by power suppliers, investors, government to determine electricity pool prices, "reliability prices, "reliability investments"
- Electricity dependency ↑ and volatile electricity generation ↑
  ⇒ VoLL ↑



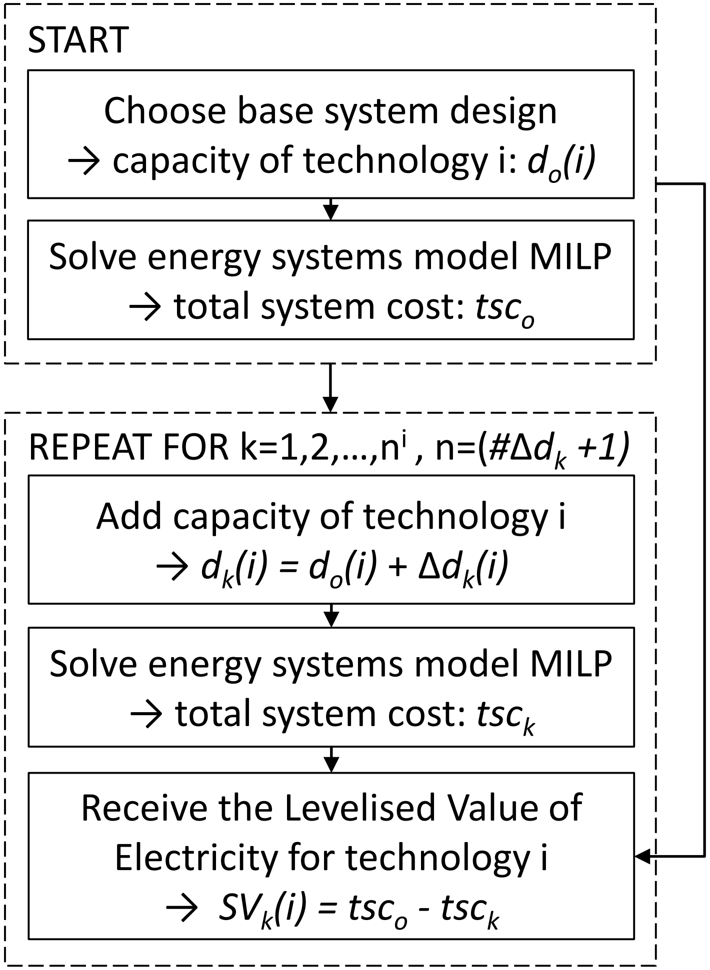
See FlexEVAL report for data sources

System Value

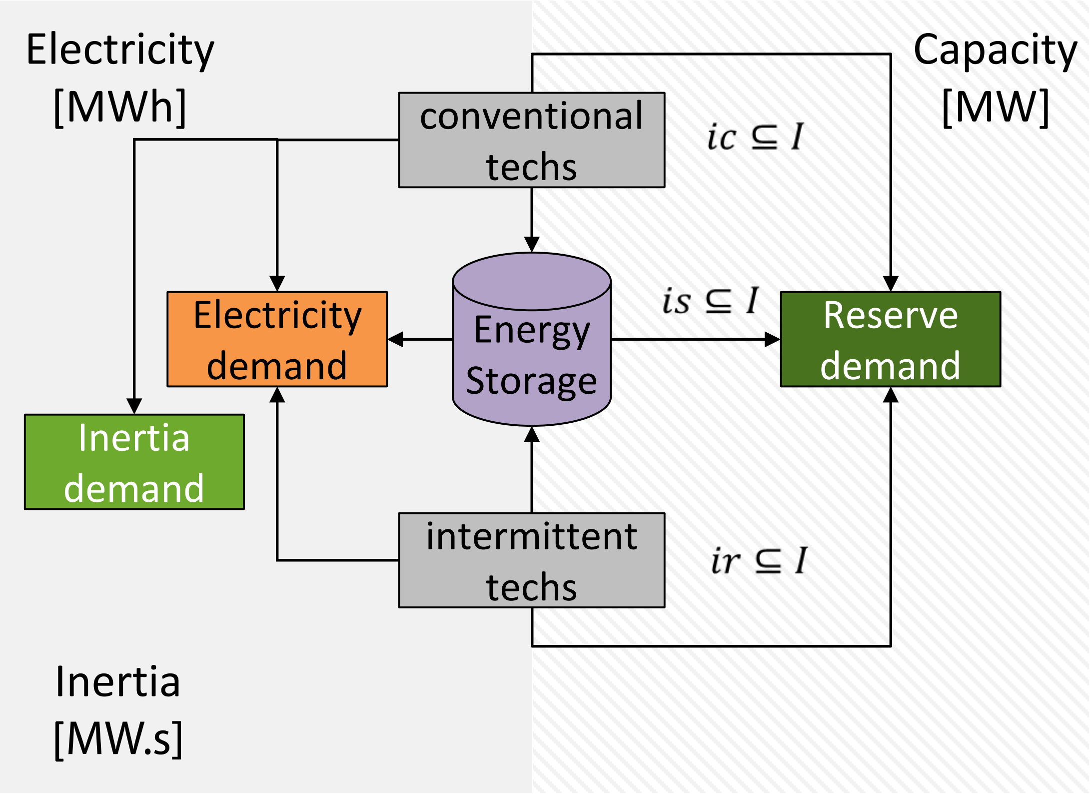
The value of a power technology can be quantified as reduction in total system cost resulting from its deployment.

The System Value (SV)

- accounts for system dynamics (e.g. "cost of intermittency", "associated carbon")
- is not a constant value (like the LCOE, CAPEX, OPEX, etc.)
- is a function of prevalent technologies in the system, demand, emissions target, etc.



Electricity systems model



Which technologies are the most valuable?

- What type of generators, storages, interconnectors?
- Where to build them?
- How to operate them?
- How to transport electricity between demand zones?

Several assumptions made due to:

- Computational expense
- Lack of reliable data
- Inherent in modelling approach
- Answer the questions asked

Flexible CCS power plant

Two aspects:

1. Operational flexibility
   - Ramping rates, load following capability, start-up and shut-down times
   - Complement intermittent generation

2. System flexibility
   - Ability to connect and balance power supply with power demand
   - Ability to provide a particular service, e.g. delivering electricity or spinning reserve

Model constraints

Storage:

Energy storage was not considered as an option

Learning:

No reductions were made to capital or operational costs over time as a result of learning

Interconnectors:

A simplified approach was taken – import only assumed, with no account taken of market price

While these constraints will impact on the quantitative results, the authors believe that, qualitatively, the findings remained valid.

Findings

Flexible CCS power plants:

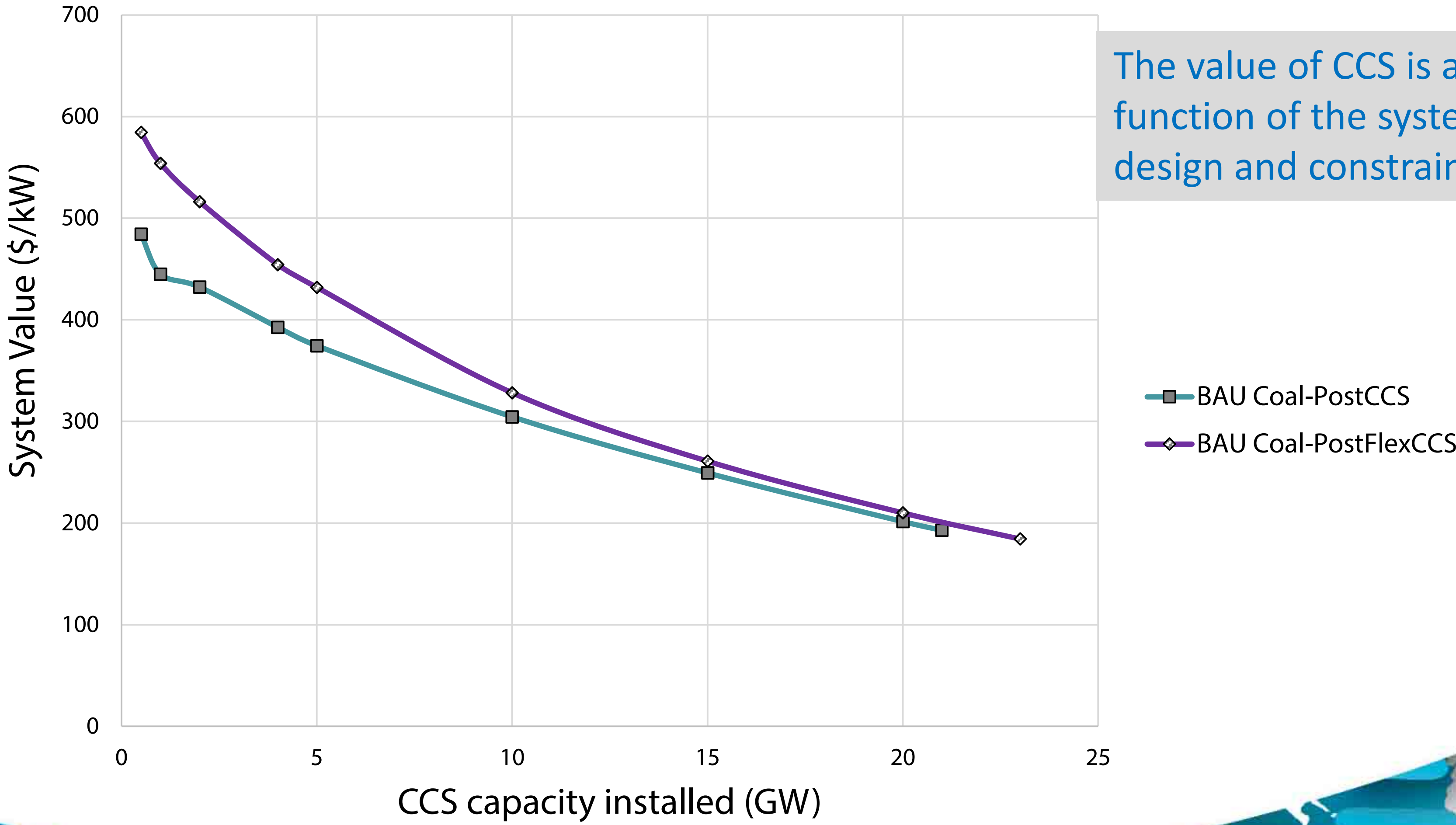
- provide additional value to the electricity system of the future
- complement intermittent renewable capacity
- facilitate increased intermittent renewable generation
- provide system-wide benefits critical to reducing the cost of the electricity system

Integrating CCS technologies with intermittent renewable capacity:

- is instrumental to reducing the total system cost
- enables both a low-carbon and a low-cost future electricity system.

Example of results

System Value of coal post-combustion CCS under BAU electricity demand in 2050



The value of CCS is a function of the system design and constraints.

Conclusions

From a whole-systems perspective, while CCS technology costs are high, the study concluded that the benefits of flexible CCS technologies on the costs and the carbon intensity of power generation were indisputable.

However:

To achieve these benefits, carefully designed policies and incentives would be essential.

Some reflections

- Conventionally, cost (and particularly LCOE) is the key metric used when comparing power generation technologies
- However, the other side of the equation is ‘return on investment’ or the ‘value’ the technology brings
- ‘Value’ may cover several categories:
  - Technical: e.g. Operational flexibility
  - System: e.g. Value to electricity system
  - Economic & social: e.g. Impact on GDP, jobs, welfare, international trade, …
- IEAGHG considers the ‘value’ of CCS important to explore further

Thank you

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