CO_2 Capture technologies and vision for cost reduction

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Chairman
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CCS Way Forward in Asia
ADB Asia Clean Energy Forum
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Greenhouse Gas R&D TCP

What We Are:

Part of the IEA Energy Technology Network since 1991

35 Members from 18 countries plus OPEC, EU and CIAB

Members set strategic direction and technical programme

Universally recognised as independent technical organisation

Current membership

BG GROUP
Chevron
TOTAL

ALSTOM
CIAB
EnBW
ExxonMobil
Masdar INSTITUTE

ieaghg
Evaluating technology options to mitigate greenhouse gas emissions

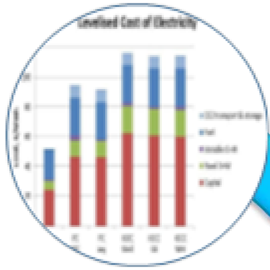
EPRI
JÜLICH FORSCHUNGSZENTRUM
DOOSAN Doosan Babcock
Statoil

BR PETROBRAS
INSTITUTO DE INVESTIGACIONES ELECTRICAS
JGC
RWE The energy to lead

Partner Organisations:

JCOAL Japan Coal Energy Center
CO_2 GeoNet
carbon sequestration leadership forum
SaskPower

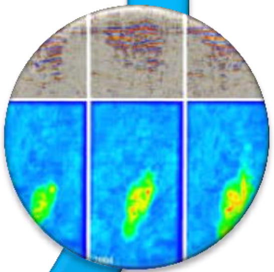
What do we do?



Assess Mitigation Options – Focus our R&D on CCS

Facilitate technology implementation

Our Core Activities Are:



Facilitate international co-operation

Disseminate our results as widely as possible

A Study by the IEAGHG

Assessment of Emerging Capture Technologies and their Potential to Reduce Costs

Study commissioned by UK DECC

Interim report published as an IEAGHG Technical Review (2014/TR4)

- Not subject to external peer review

Aim to publish as a "full IEAGHG report"

- External reviews have been obtained and revisions are being made
- Revised executive summary will be reviewed by IEAGHG ExCo members before publication

Study scope

Identify and review the main emerging capture technologies being developed for power plants

- **Post-combustion capture**
- **Pre-combustion capture**
- **Oxy-combustion**
- **Solid looping**

Assess current status and Technology Readiness Level (TRL)

Critically assess claims for energy requirements and cost reductions

Capture in non-power industries considered in less detail

Study did not involve detailed assessment of energy requirements and costs of plants with CO_2 capture

Technology readiness level

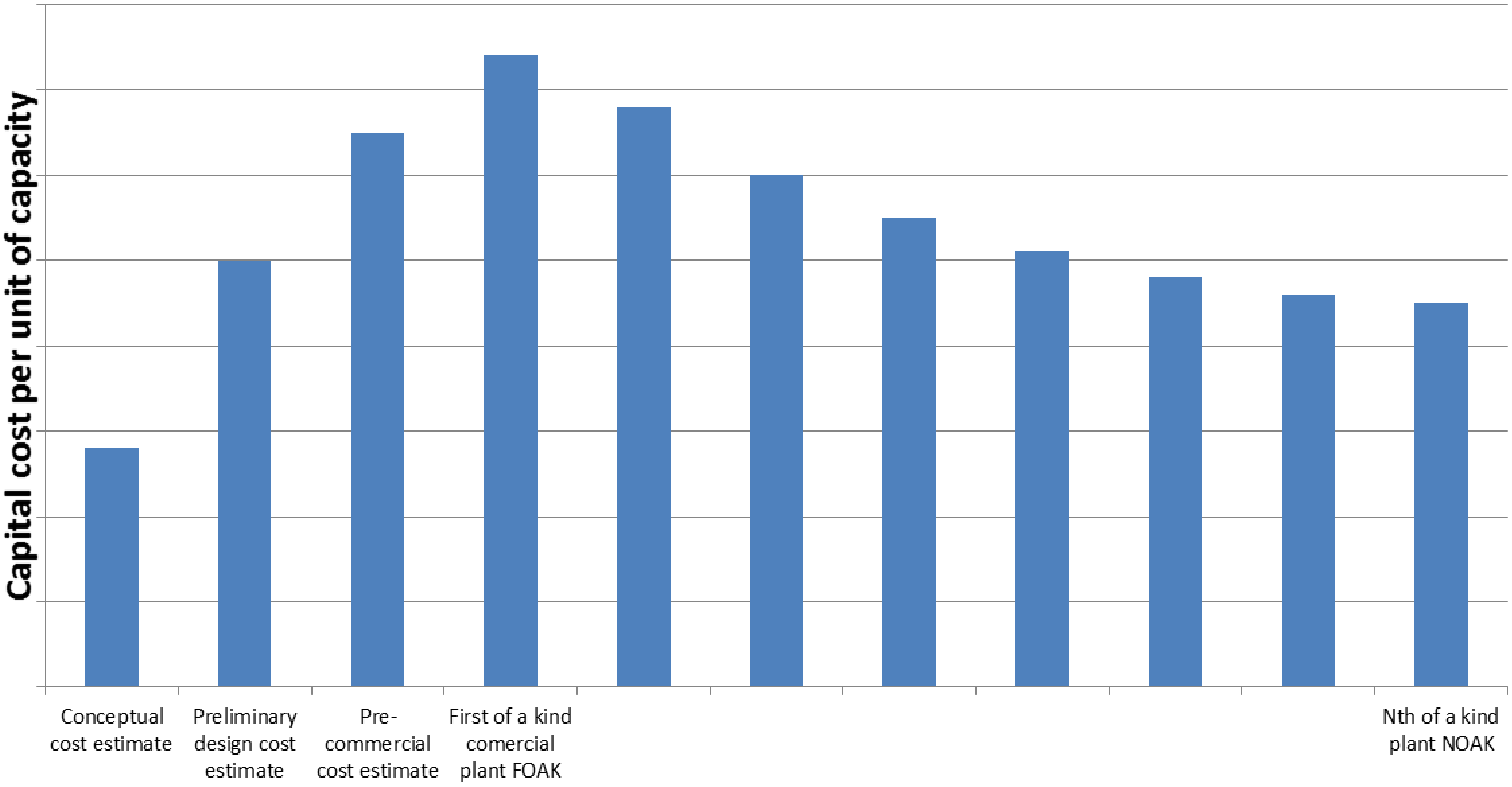
Demonstration	9	Normal commercial service
	8	Commercial demonstration, full scale deployment in final form
	7	Sub-scale demonstration, fully functional prototype
Development	6	Fully integrated pilot tested in a relevant environment
	5	Sub-system validation in a relevant environment
	4	System validation in a laboratory environment
Research	3	Proof-of-concept test, component level
	2	Formulation of the application
	1	Basic principles, observed initial concept

Source: EPRI

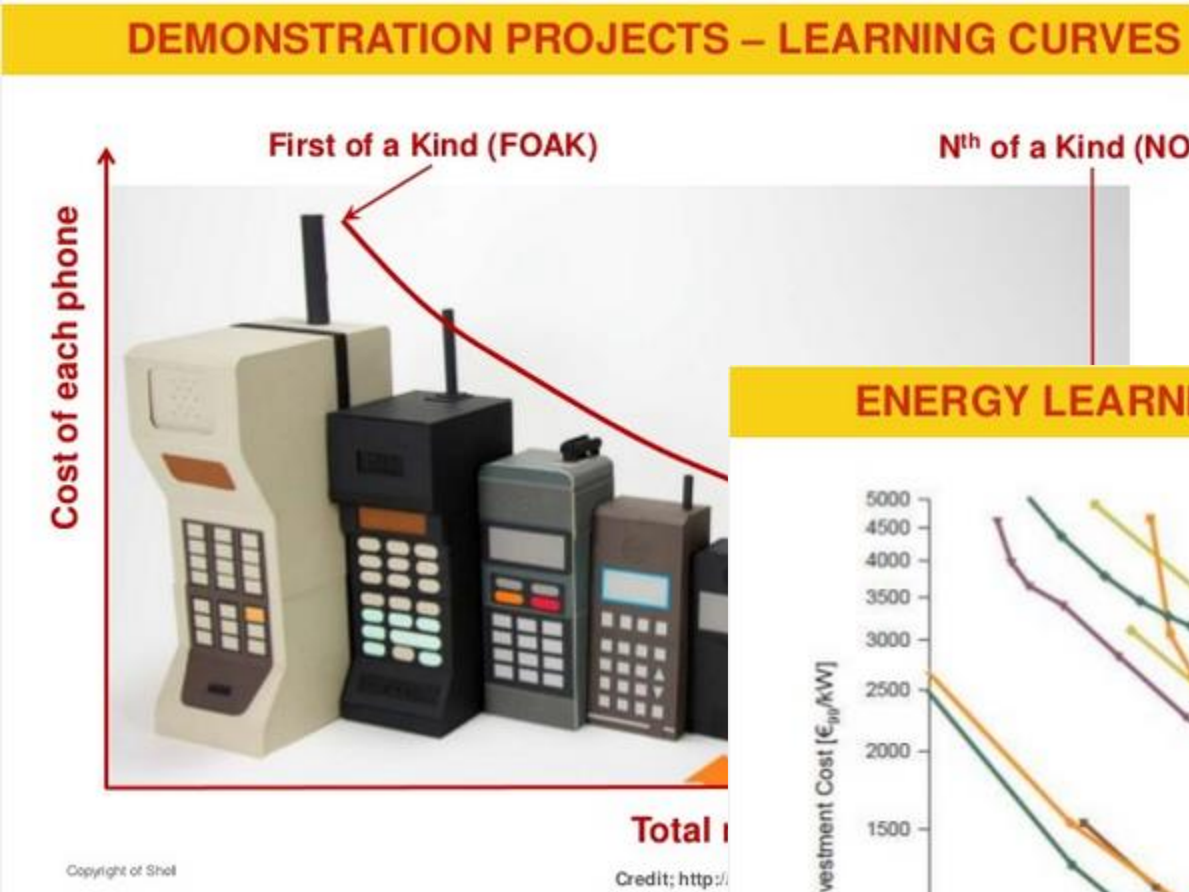
Note:

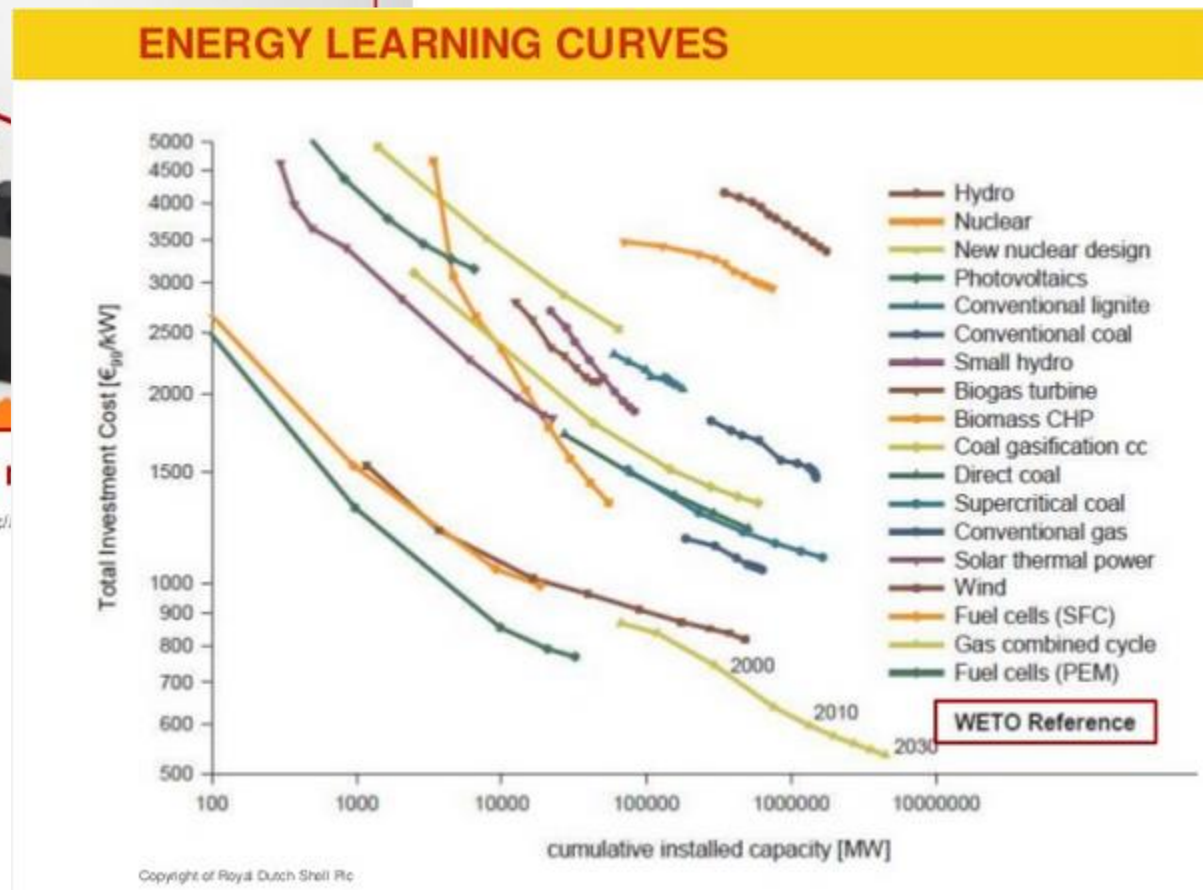
- *TRL is not necessarily an indication of the amount of time and effort required to achieve commercialisation*
- *TRL 9 does not necessarily represent the be-all and end-all*

Cost learning curve

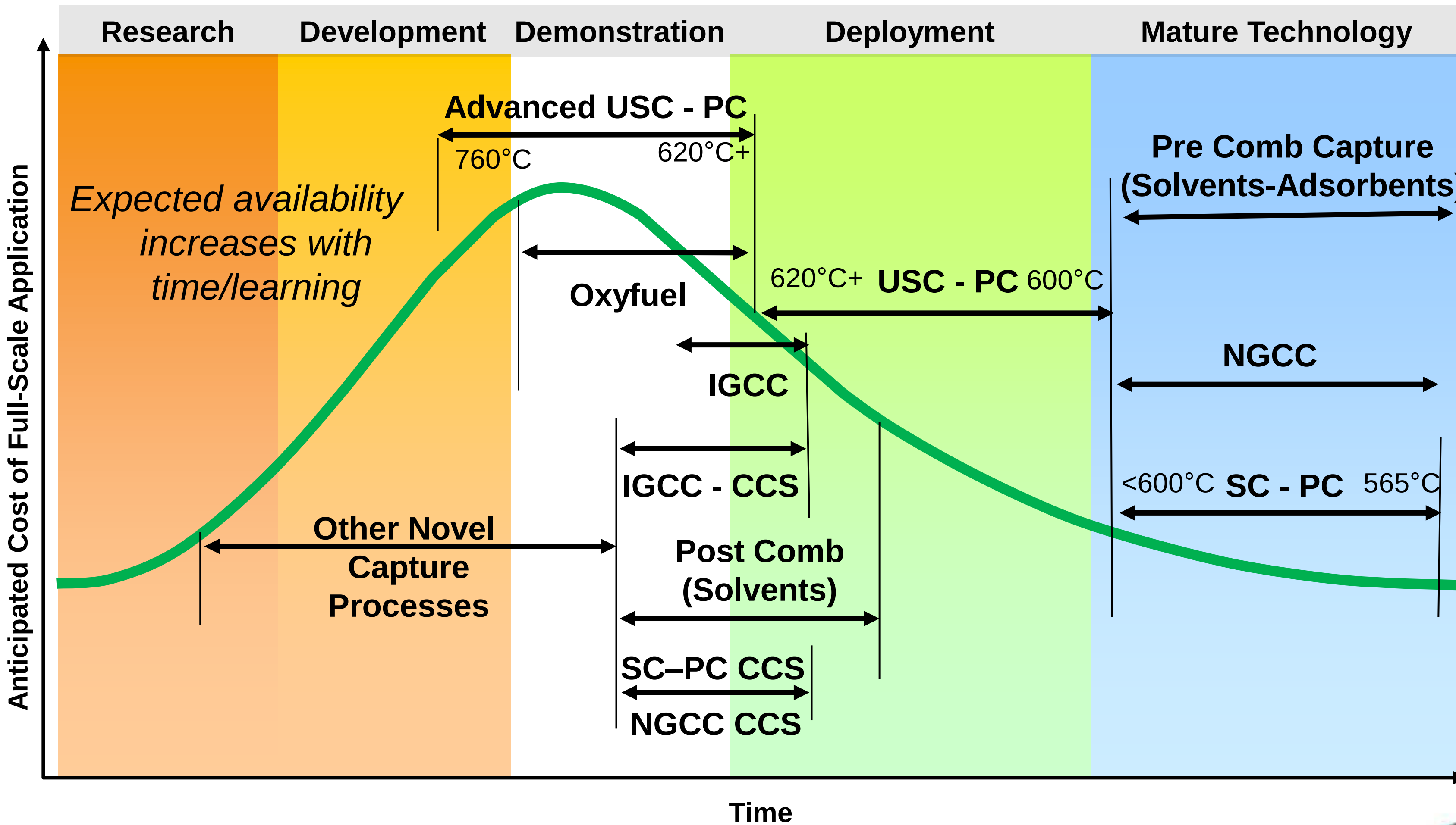


Other cost learning curves

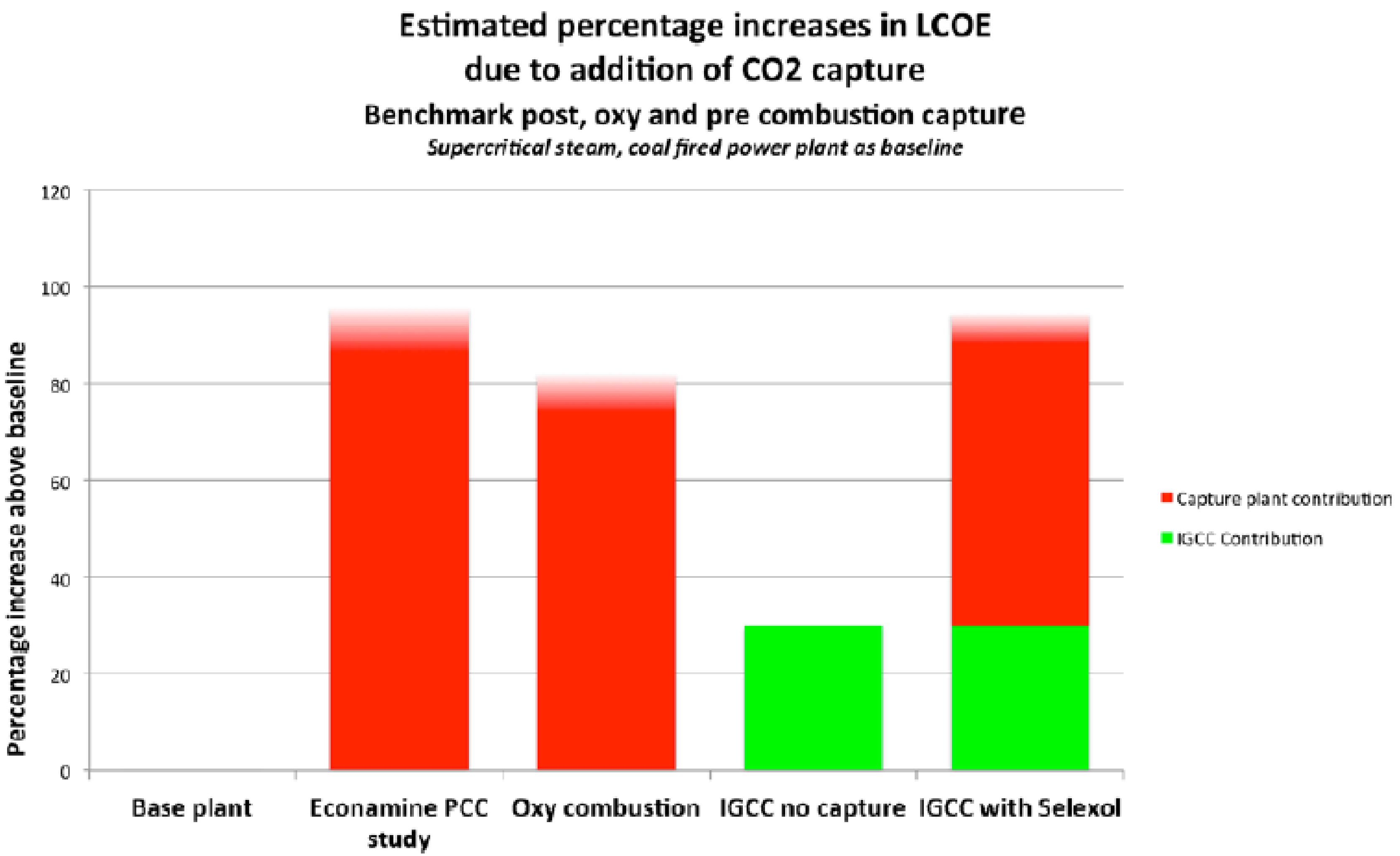




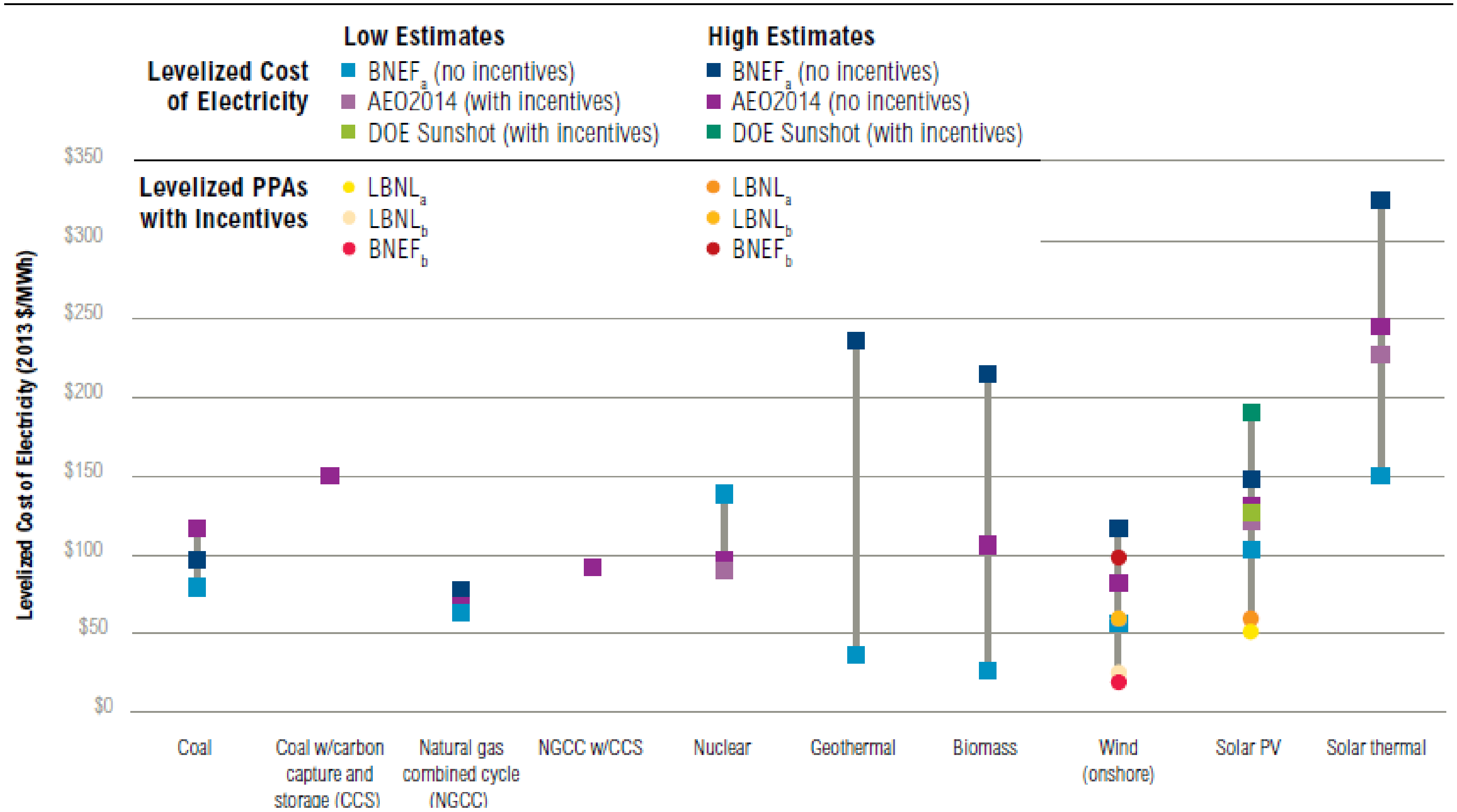
Status and cost of power & CO2 capture technologies



Estimated LCOE increase



Electricity cost and policy



Source: USDOE

IPCC AR5 – Role of different low carbon energy technologies

	Mitigation cost increases in scenarios with limited availability of technologies [d] [% increase in total discounted [e] mitigation costs (2015–2100) relative to default technology assumptions]			
2100 concentrations (ppm CO_2-eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy
450 (430 to 480)	138% (29 to 297%) 4	7% (4 to 18%) 8	6% (2 to 29%) 8	64% (44 to 78%) 8

Drivers for cost of capture

Capital cost of capture equipment

- Capital charges, cost of maintenance etc.

Increased fuel consumption

Increased specific capital cost of the host power generation process due to increased fuel consumption

Increased variable operating costs

- Capture solvent make-up etc.

→Early stage assessments tend to focus initially on energy consumption

- Can be evaluated more scientifically
- A major contribution to capture cost

Energy consumption

CO_2 separation

- Theoretical work for post-combustion capture from coal fired power plant flue gas: 0.15 GJ/t CO_2
  - Equivalent to <1.5% points of power plant efficiency
- Scope to reduce energy consumption but all processes need a significant driving force to reduce equipment size
- Some capture processes use energy that is otherwise wasted

CO_2 compression

Miscellaneous power

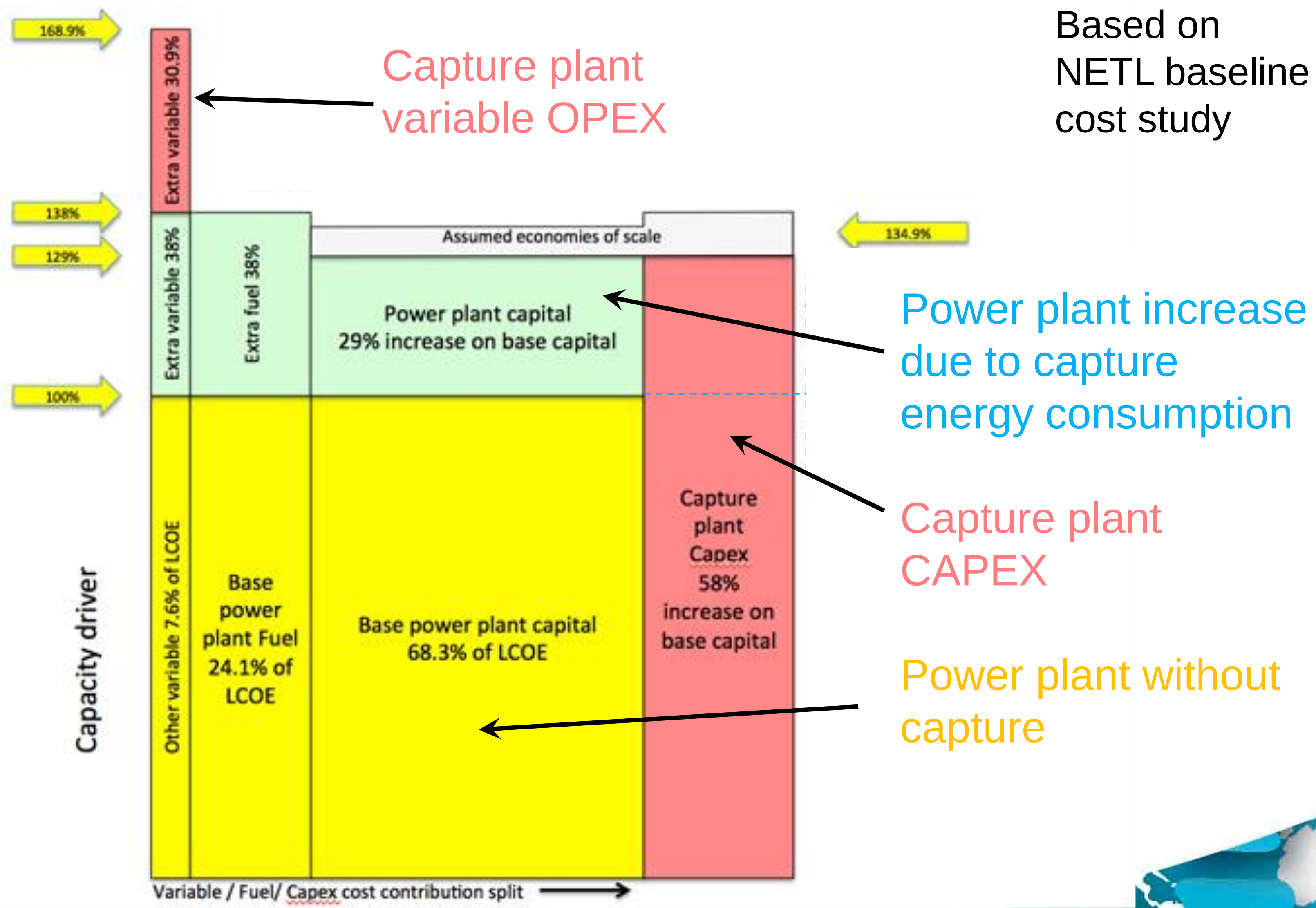
Other losses

- E.g. shift conversion for pre-combustion capture

Post-combustion capture

Contributions to cost of electricity

Based on NETL baseline cost study



Post-combustion capture

TRL 7 – 9

- Benchmark amine scrubbing
- Improved conventional solvents

TRL 4 – 6

- Bi-phasic solvents
- Precipitating solvents
- Polymeric membranes
- Temperature swing adsorption

TRL 1 - 3

- Enzyme catalysed adsorption
- Ionic liquids
- Room temperature ionic liquid (RTIL) membranes
- Encapsulated solvents
- Electrochemically mediated absorption
- Vacuum pressure swing adsorption (VPSA)
- Cryogenic capture
- Supersonic inertial capture

Pre-combustion capture

TRL 1 - 3

- Low temperature separation

TRL 4 – 6

- Hydrogen separation membranes
- Sorption enhanced water gas shift (SEWGS)
- Integrated gasification fuel cells (IGFC)

TRL 7 – 9

- IGCC with Selexol

Oxy-combustion capture

TRL 1 - 3

- Oxy-combustion gas turbines: other cycles

TRL 4 – 6

- O_2 production: ion transport membrane (ITM), O_2 transport membrane (OTM), ceramic auto-thermal reforming systems (CARS)
- Oxy-combustion gas turbines: water cycle

TRL 7 – 9

- Benchmark coal oxy-combustion

Solid looping processes

TRL 7 - 9

TRL 4 – 6

- Calcium carbonate looping (CaL)
- Chemical looping combustion (CLC)

TRL 1 - 3

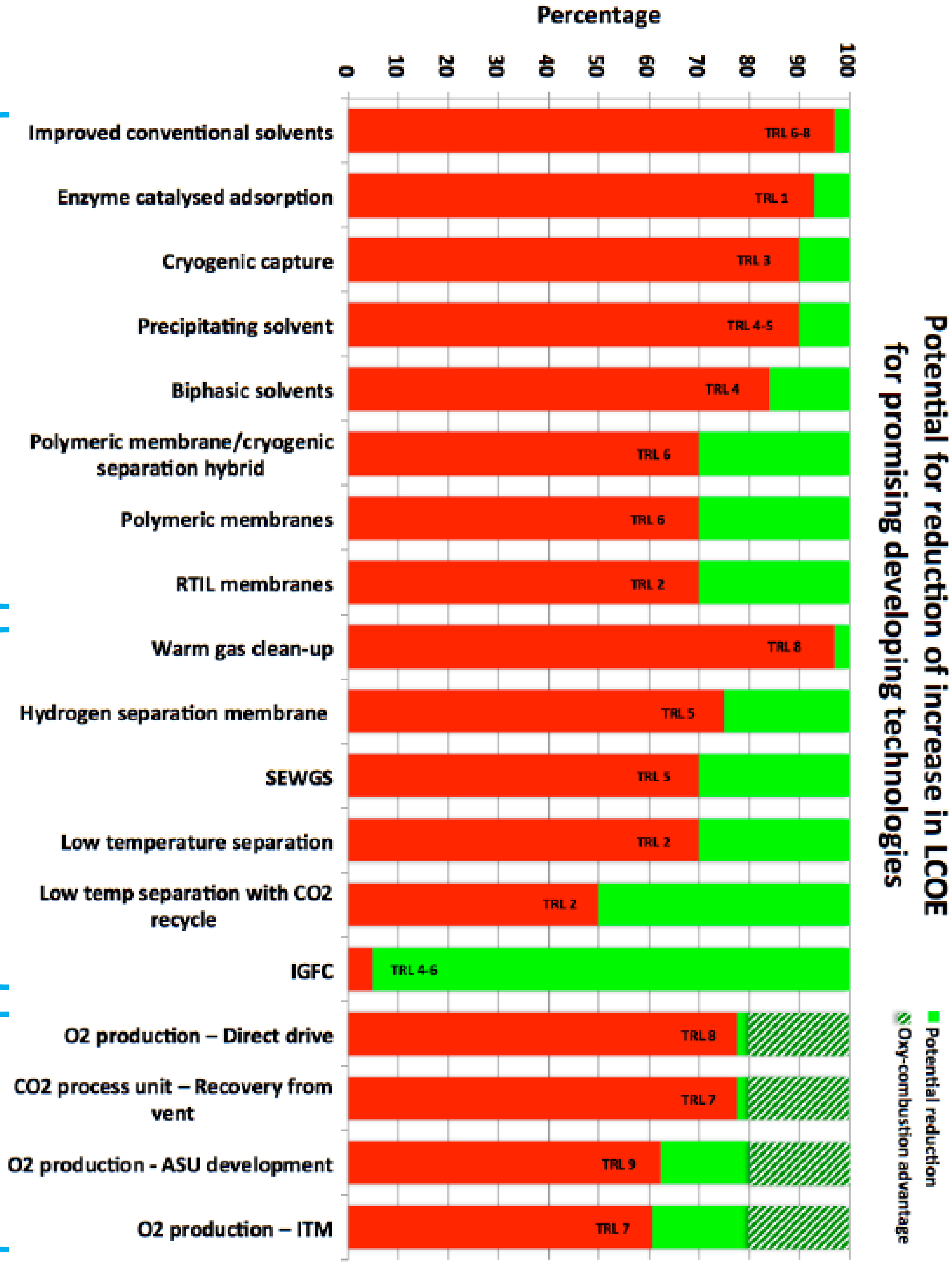
- Sorption enhanced reforming (SER)
- Chemical looping gasification (CLG)
- Chemical looping with oxygen uncoupling (CLOU)
- etc.

Summary

Post-combustion capture

Pre-combustion capture

Oxy-combustion capture



Conclusions

Many new technologies for CO_2 capture are being developed

Estimated costs of new capture technologies are subject to high uncertainty, especially at low TRLs

Processes in which CO_2 capture is a more integrated part of the power generation process show high potential for energy and cost reduction but have significant development hurdles

- E.g. solid looping combustion, oxy-combustion turbines and fuel cells

Thank you, any questions?

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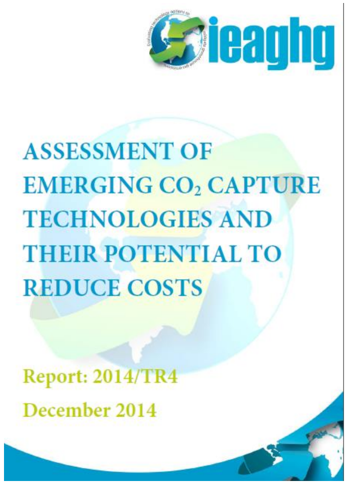

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ASSESSMENT OF EMERGING CO_2 CAPTURE TECHNOLOGIES AND THEIR POTENTIAL TO REDUCE COSTS

Report: 2014/TR4

December 2014

http://www.ieaghg.org/publications/technical-reports