IEAGHG
Overview and recent CCS activities

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Cheltenham, UK

MATESA Dissemination Day
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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

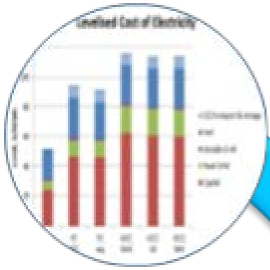
Members set strategic direction and technical programme

Universally recognised as independent technical organisation

Current membership

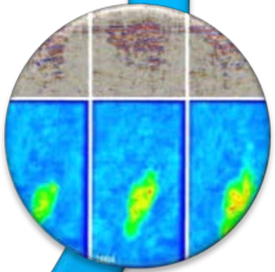
What do we do?

Our core activities are:



Assess mitigation options – Focus our R&D on CCS

Facilitate technology implementation



Facilitate international co-operation

Disseminate our results as widely as possible

Technical studies

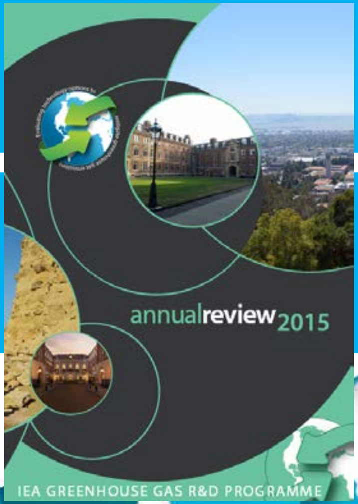
Technical and economic evaluations of technology options with the potential to mitigate GHG emissions

Available to individuals/organisations in all member countries and to all sponsor organisations upon publication

Available to those from non-member countries after a six month period

>250 in total on all aspects of CCS

12 – 15 technical reports each year



http://www.ieaghg.org/docs/General_Docs/Publications/Annual_Review_2015_Low_Res.pdf

Other dissemination activities

- Information papers (IPs)
- Blog
- Newsletter (weekly, quarterly)
- Webinars
- International Journal of Greenhouse Gas Control (IJGGC)

Latest from our **blog**

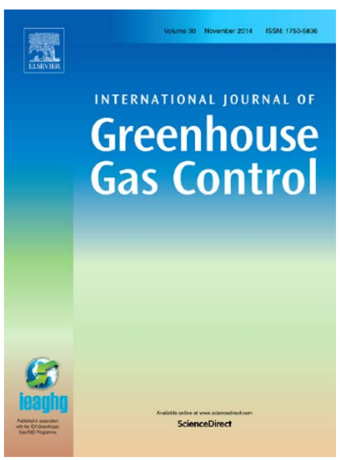
10/06/2016 Hitting new highs and lows and raised concerns
The US National Oceanographic and Atmospheric Administration (NOAA)...

09/06/2016 Public Sharing of Information on Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource
There was an excellent webinar today hosted by the Global CCS Institute on work from the UK's Energy Technologies Institute...

07/06/2016 Review of project permits under the London Protocol – An assessment of the proposed P18-4 CO_2 storage site
The London Convention and Protocol promotes the protection of the marine...

Full blog here

http://www.ieaghg.org/publications/blog



http://www.journals.elsevier.com/international-journal-of-greenhouse-gas-control/

http://www.ieaghg.org/publications/greenhouse-news

Networking activities

- 7 international research networks
- Conference series:
  - ➢ Greenhouse Gas Control Technologies Conference Series (GHGT)
  - ➢ Post-Combustion Capture Conference (PCCC)
  - ➢ Oxyfuel Combustion Conference (OCC)
- Summer School

groundlevel.org.uk

High temperature solid looping cycles network (HTSLCN)

Covering the following topics:

- Calcium and chemical looping
- Combustion / gasification / reforming
- Fundamentals / modelling / testing

Constantly >50 attendees, focus on academia

Moving to a 2-year format to align with the International Conference on Chemical Looping

Next meeting 4-5 September 2017 in Luleå, Sweden

2009

Oviedo

2010

Petten

2011

Vienna

2012

Beijing

2013

Cambridge

2015

Milan

Emerging CO_2 capture technologies

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

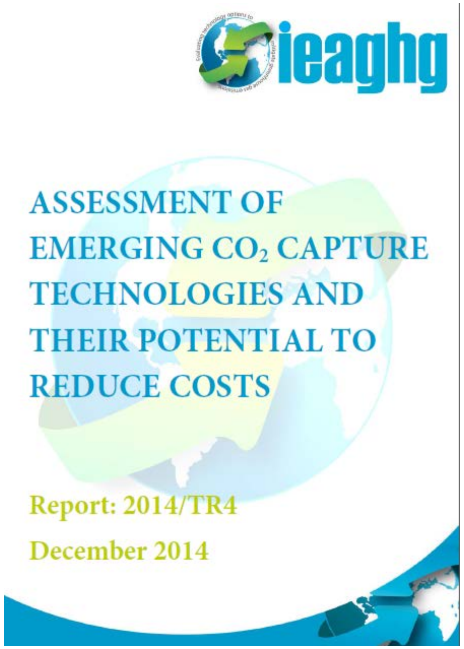
- Post-combustion capture
- Pre-combustion capture
- Oxy-combustion
- Solid looping

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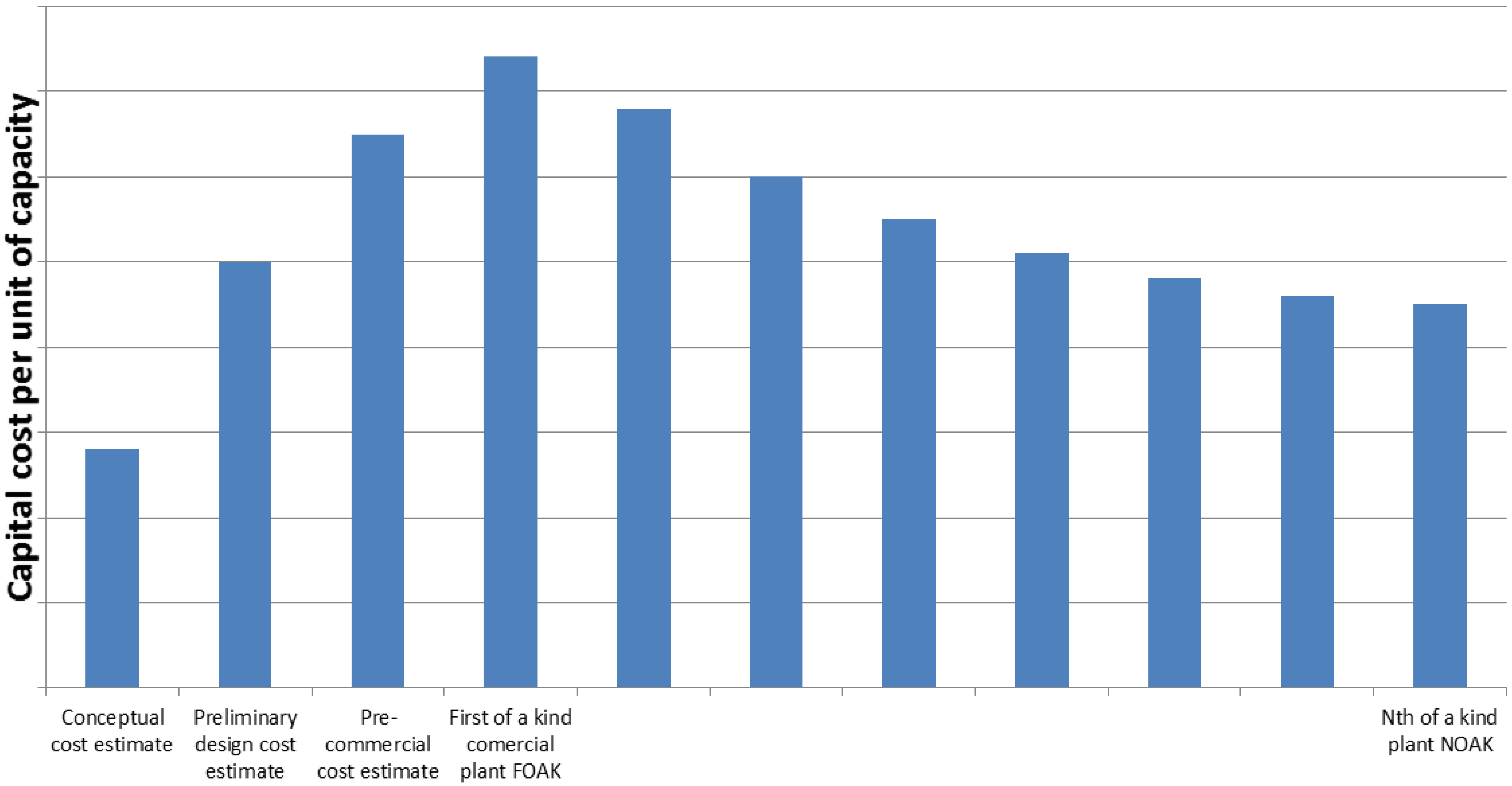
ASSESSMENT OF EMERGING CO_2 CAPTURE TECHNOLOGIES AND THEIR POTENTIAL TO REDUCE COSTS

Report: 2014/TR4

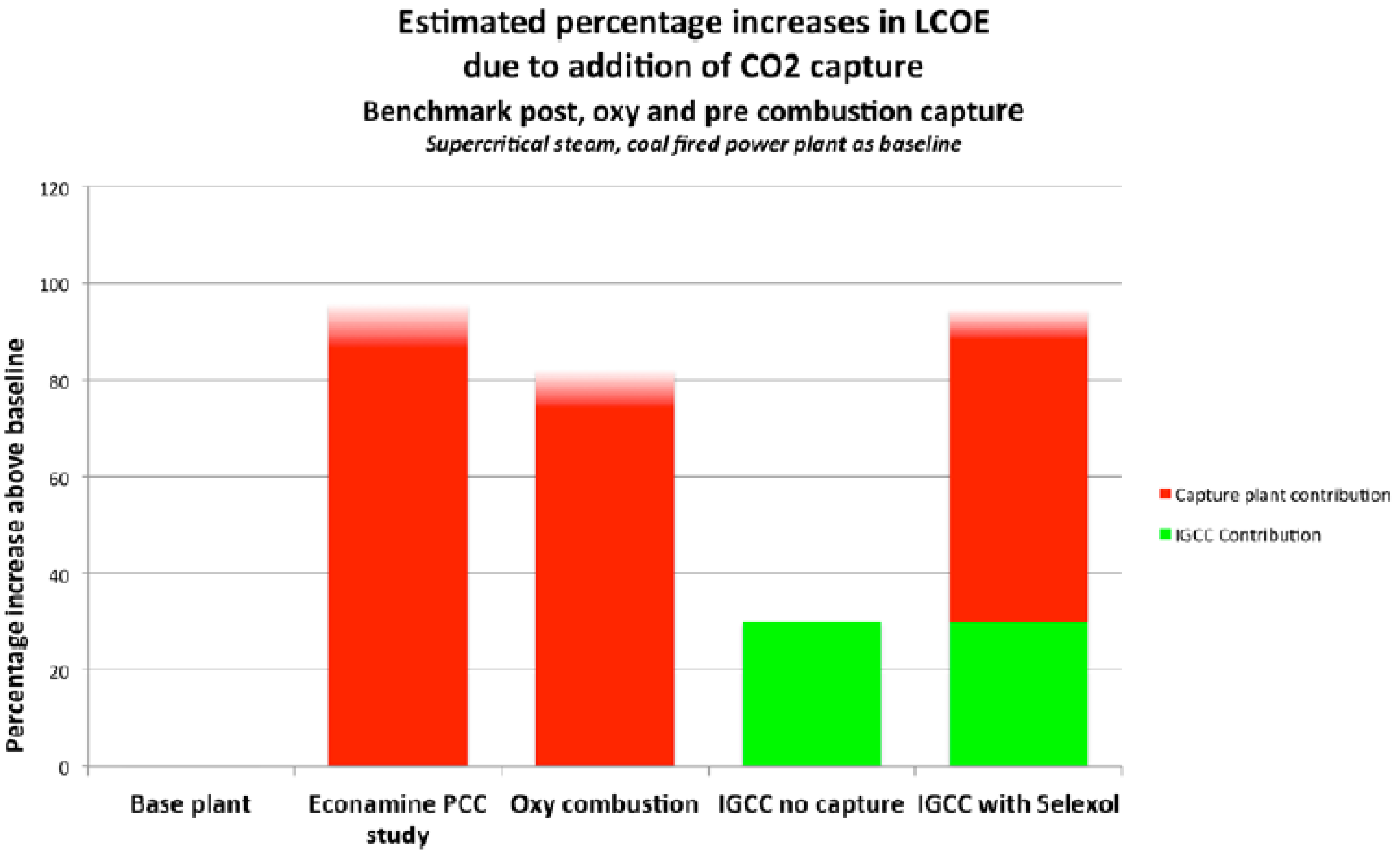
December 2014

http://www.ieaghg.org/docs/General_Docs/Reports/2014-TR4.pdf

Cost learning curve



LCOE for CO_2 capture technologies



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

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

Solid looping processes

TRL 7 - 9

TRL 4 – 6

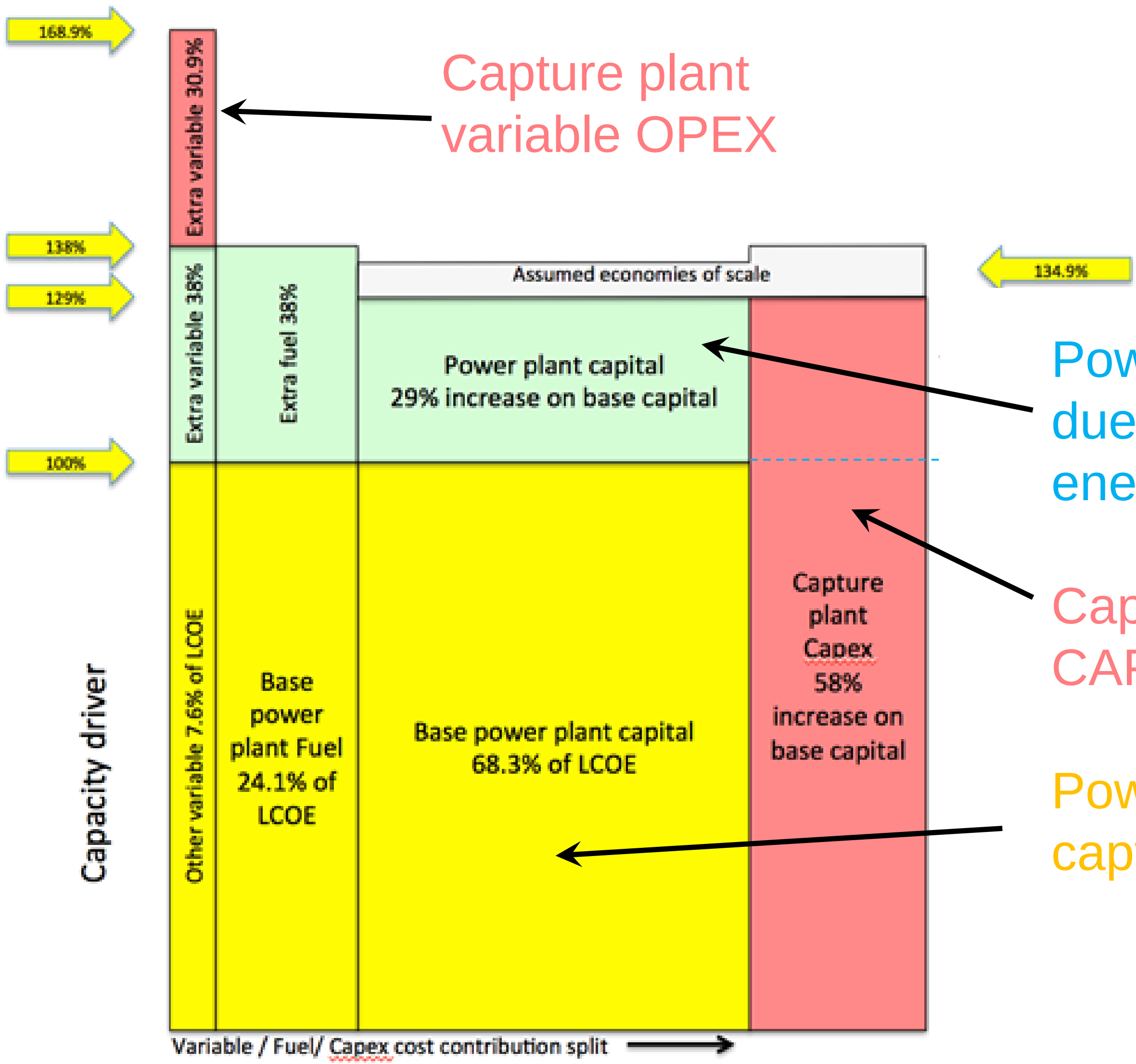
- Calcium carbonate looping (CaL)
- Chemical looping combustion (CLC)

TRL 1 - 3

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

Post-combustion capture

Contributions to cost of electricity



Based on NETL baseline cost study

Power plant increase due to capture energy consumption

Capture plant CAPEX

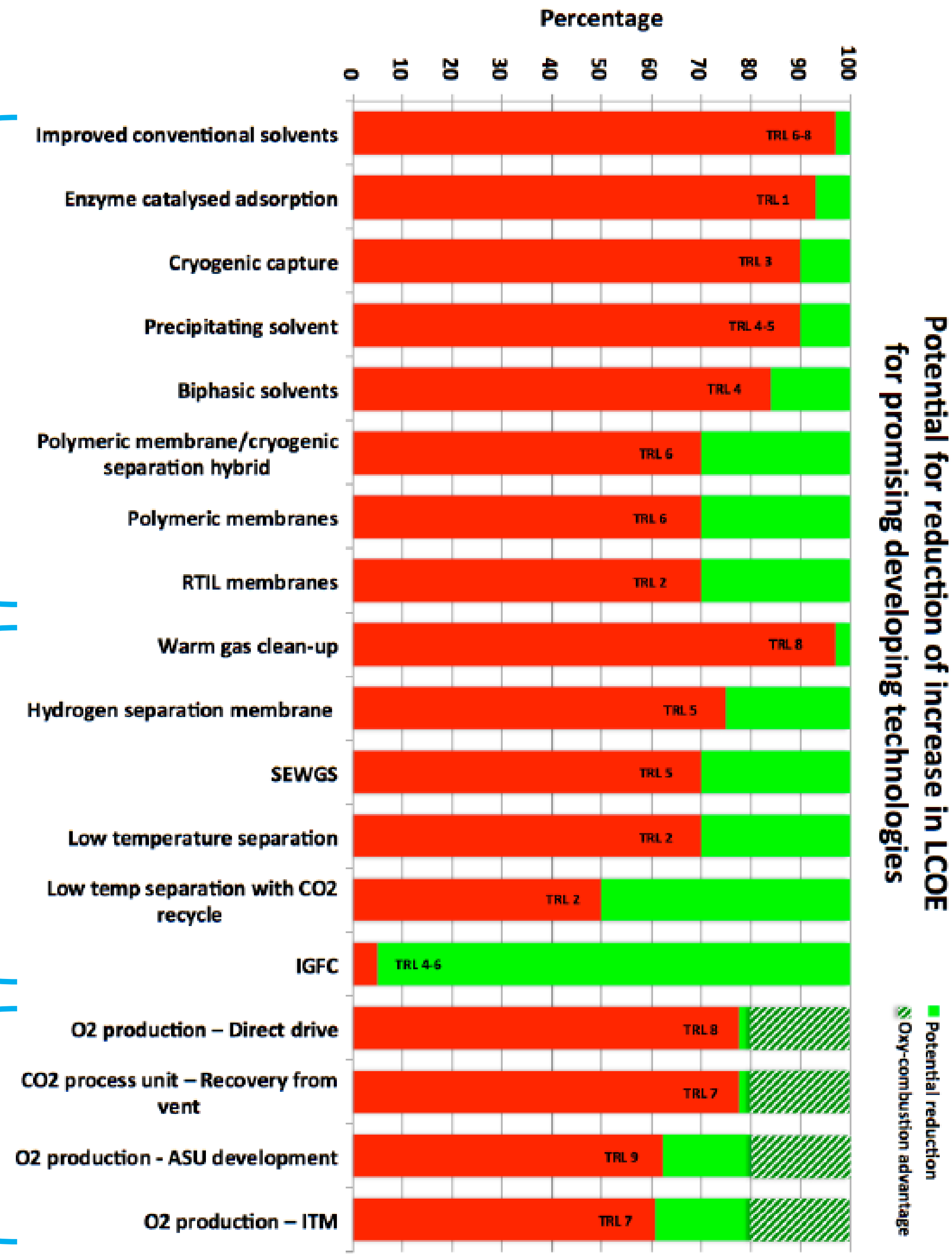
Power plant without capture

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

CO_2 capture in natural gas production by adsorption processes

- Main objectives:
  1. Evaluate utilisation of PSA process for CO_2 removal from NG
  2. Perform techno-economic comparison of PSA with a reference process, i.e. solvent scrubbing
  3. Investigate candidate materials for kinetic adsorbents
  4. Provide recommendations for future work
- PSA unit design will not include final and detailed process optimisation
- Innovation of this work:
  - Novel process design not reported in literature so far

Existing technologies

Membrane

- Hollow fibre modules
- Flat sheet spiral modules
- + straightforward, low energy and footprint
- - pre-treatment, fouling

Cryogenic

- + well known, deliver of NG at pipeline spec, flexibility
- - avoid freezing below triple point, azeotrope, costs
- Suitable for LNG

Adsorption

- Temperature swing
- Pressure swing
- + lower energy demand and OPEX
- - Limited materials, CO_2 removal in R&D

Solvents

+ well known, suitable for range of conditions, removes CO_2 and H_2S to ppm
- - High energy demand, degradation

Conditions

Raw NG conditions and composition	
Temperature [°C]	40
Pressure [bar]	70
CH_4 [vol%]	83
C_2H_6 [vol%]	4.6
C_{3+} [vol%]	2.4
CO_2 [vol%]	10
Sweet NG specifications	
Temperature [°C]	40
Pressure [bar]	70
Lower heating value (LHV) [MJ/kg]	39
CO_2 content [mol%]	≤ 2.5
CO_2 stream specifications	
Temperature [°C]	40
Pressure [bar]	110
CO_2 purity [vol%]	≥ 95

3 cost KPIs:

1) NG sweetening
2) CO_2 removal w/ and w/o CO_2 conditioning, transport and storage
3) CO_2 avoidance

Reference case: aMDEA

- Chemical solvent based NG upgrading process modelled with ProTreat v4.2
- 45wt% MDEA + 5wt% PZ (aMDEA)
- Regeneration mainly by pressure release
- Temperature of lean solvent feed to absorber is set >10°C higher than dew point of sweet gas
  - Avoid co-adsorption of potential heavy hydrocarbons

PSA process - adsorbent

- Adsorbent selection is the main and initial task in the specification of a PSA unit
- A direct reliable method of selecting adsorbents is currently not available → experience
- Two issues influence selection:
  1. Non-linear isotherms for CO_2
  2. Co-adsorption of CH_4
- To limit adsorption of CH_4 → kinetic adsorbents
  a. Titanosilicates → commercially available, samples not
  b. Carbon molecular sieve (CMS) → readily available, so used here

PSA process - model

- Several commercial programmes available
- This study used gPROMS
- Two approaches to PSA modelling
  1. Simulate performance of entire PSA by solving a model for only one column
     - Straightforward
     - Limited accuracy
  2. Simulate performance of PSA with a dynamic model of the whole system
     - Very detailed
     - High computation time (up to 20h for one pass)
     - Providing the right initial conditions is critical for convergence due to strong variation of conditions in a PSA

PSA process – iterative cycle design

4-column	
2x pressure equalisation	60% CO_2 purity

6-column	
3x pressure equalisation	40% CO_2 purity

7-column	
3x pressure equalisation	45% CO_2 purity

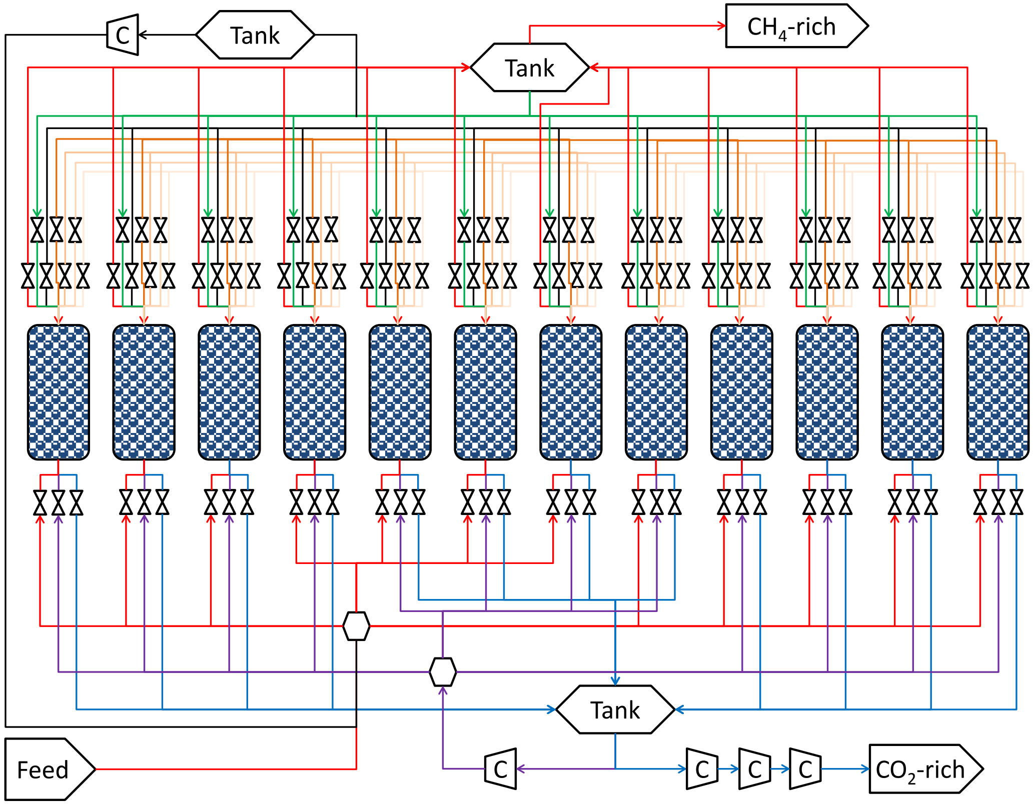
12-column, multi-feed	
3x pressure equalisation	69% CO_2 purity

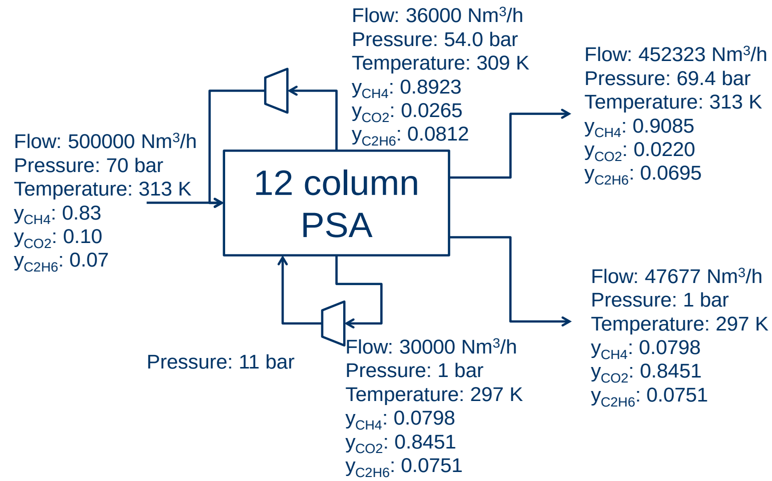
12-column, multi-feed	
4x pressure equalisation	73% CO_2 purity

12-column, multi-feed, light gas recycle	
4x pressure equalisation	85% CO_2 purity

Target: 95%

PSA process – final cycle design

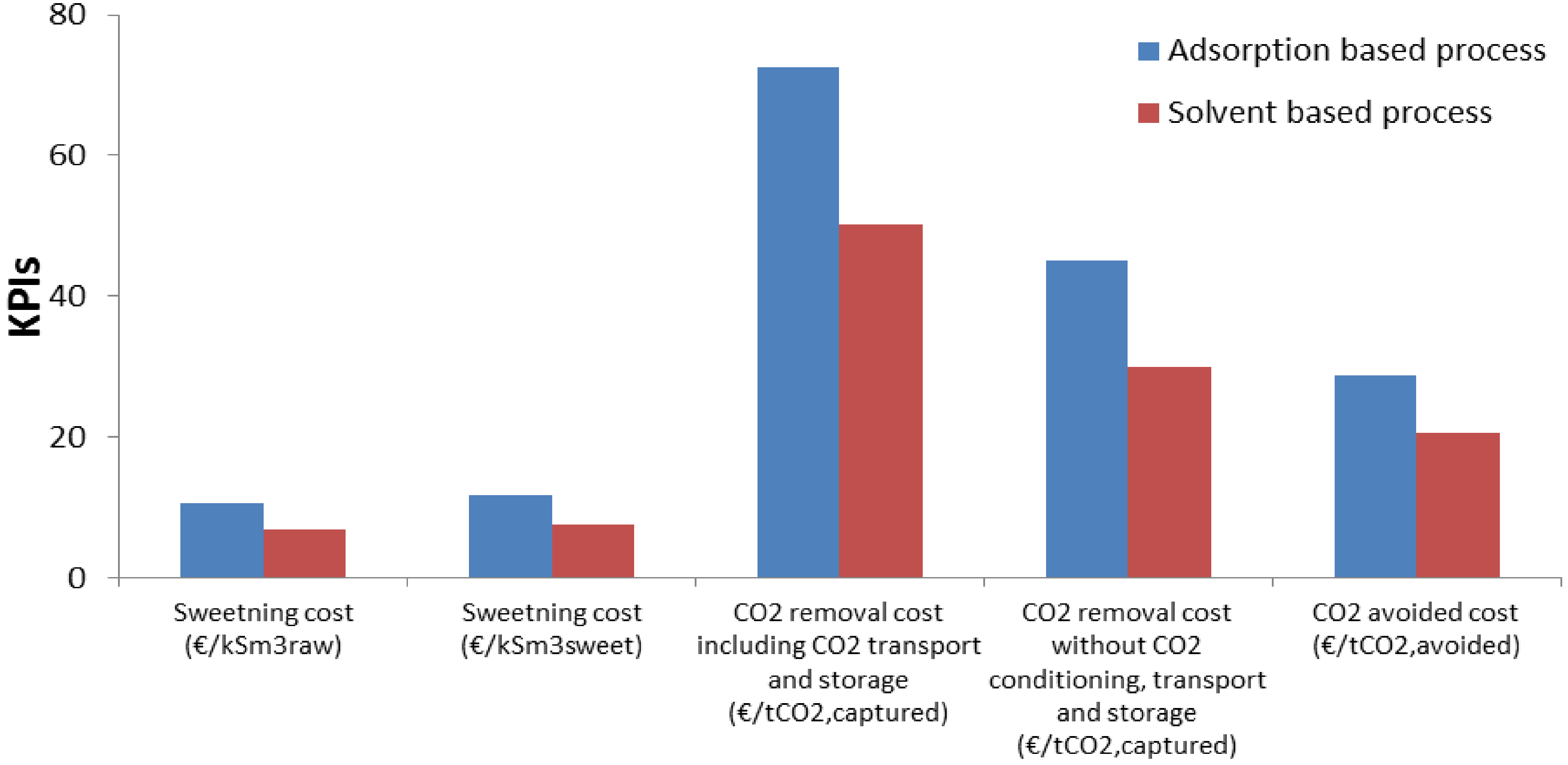




C1	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	
C2	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	
C3	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	
C4	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓
C5	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	
C6	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓
C7	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	
C8	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	
C9	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	D1 ↑	D2 ↑	
C10	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑	
C11	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑
C12	FEED ↑	D1 ↑	D2 ↑	D3 ↑	D4 ↑	PP ↑	R ↑	B ↓	Pu ↓	Pu ↓	E4 ↓	E3 ↓	E2 ↓	E1 ↓	Pr ↓	FEED ↑

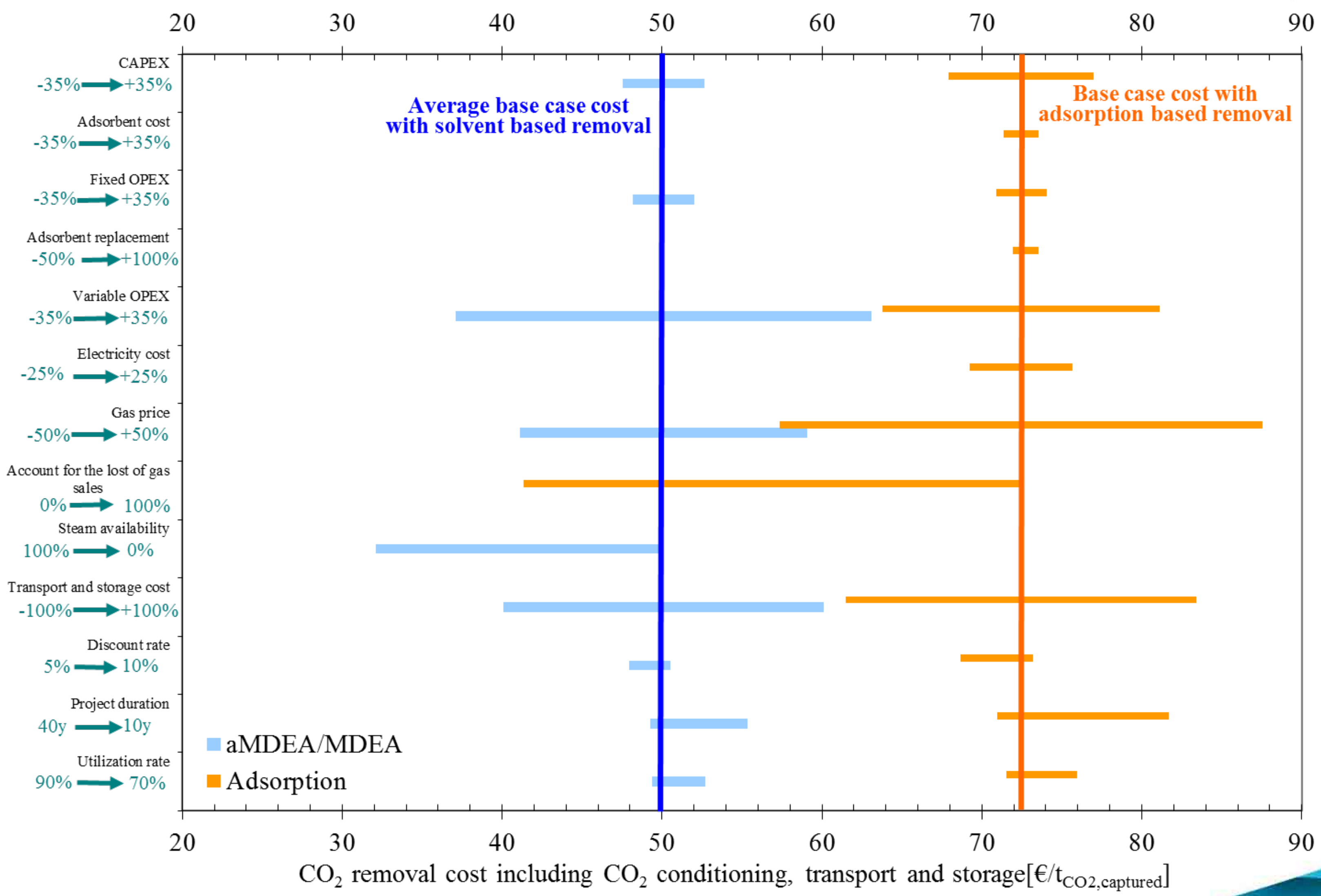
- Final 12-column multi-feed with four pressure equalisations and light gas recycle
- Process flow diagram with internal recycles and tanks

PSA – aMDEA cost comparison



- Differences between PSA and aMDEA mainly due to loss of NG

Cost sensitivity analysis



Conclusions

- Iterative pathway was applied to find a PSA cycle design with maximum CO_2 purity
- Final design is a 12-column multi-feed cycle with 85% CO_2 purity → first design for 70 bar and 500 000 Sm³/h
- CO_2 removal and NG sweetening costs are ~50% higher than for the reference aMDEA amine process
- Identified materials worth of future investigation
- Process not yet optimised → ample room for improvement → combined approach of material and process optimisation can bring down cost significantly

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Thank you, any questions?

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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Registration opens 6 April 2016

Draft technical programme 1 June 2016

Early bird registration closes 13 July 2016

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Confédération suisse
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