Assessment of CO_2 capture technologies

Overview and results so far

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HiPerCap CO_2

SAFER, SMARTER, GREENER

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Introduction

Goal
General approach

Methodology

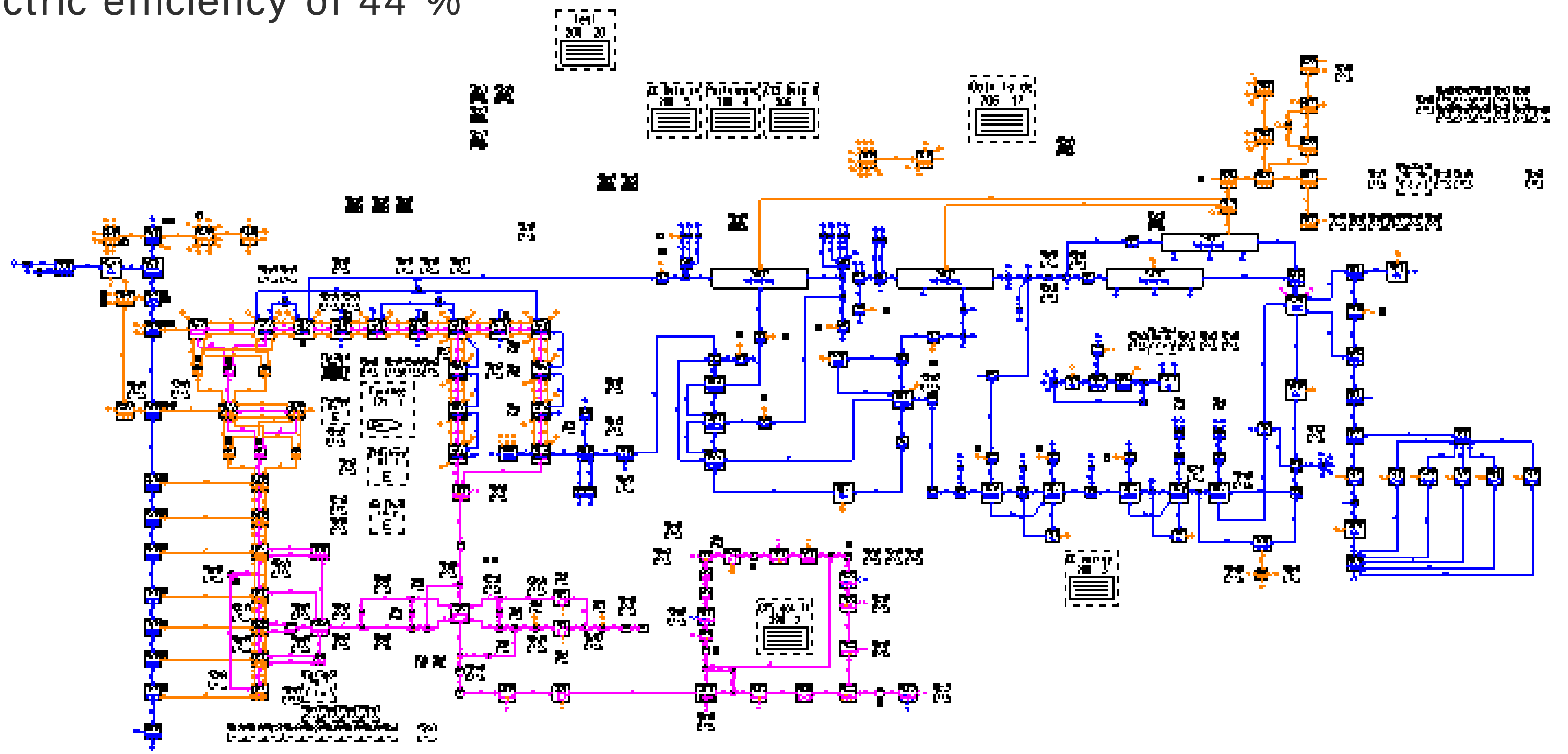
- Two step process:
  1. Assess if technologies are capable of reaching goal(s) set out in the project as knock out criteria
     - Environmentally benign
     - Capable to meet minimum requirements with respect to:
       - Treatment of flue gases
       - Use of utilities
       - Capable to meet target of at least 85% capture and CO_2 purity

Definition of baseline

Power plant
Capture plant
Compression

Power plant

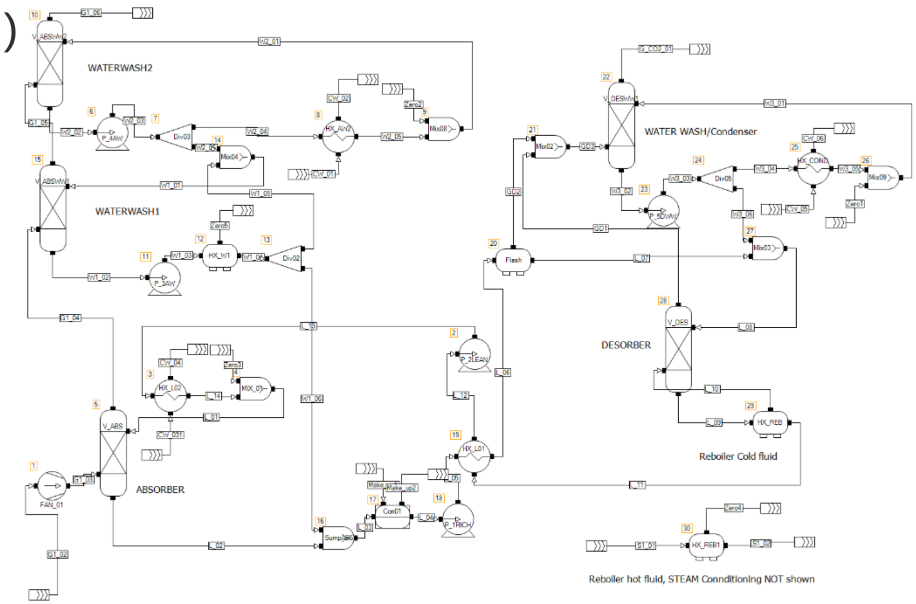
- 800 MWe advanced supercritical powerstation positioned inland
- Modelled by Uniper PROATES software
- Electric efficiency of 44 %



HiPerCap Power Station Model

Reference capture

- AMP-PZ solvent as used in CESAR project
- Modelled by Sintef – CO2SIM, Compression train modelled separately with aspen; outgoing pressure at 120 bar
- Key parameters:
- Energy:
  - 1,10 MJ·kg_{CO2}^{-1}·s^{-1} (or 0,3 MWh/tonCO_2)
  - 9,7 % efficiency loss of power station
  - SRD of 3 MJ·kg_{CO2}^{-1}
- Cost KPI
  - Baseline for other technologies
- Environmental:
  - Low degradation per kg CO_2
  - Harmful degradation products but prevented from emission to stack with two waterwash sections



Methodology - Assessment process

Technology scopes

- Designed to be transparent:
  - Scope 0: Laboratory data
  - Scope 1: input from scope 0 for process design
  - Scope 2/3: model/process design of full scale capture
  - Scope 4: Process integrated with capture train
  - Scope 5: integrated power and capture plant

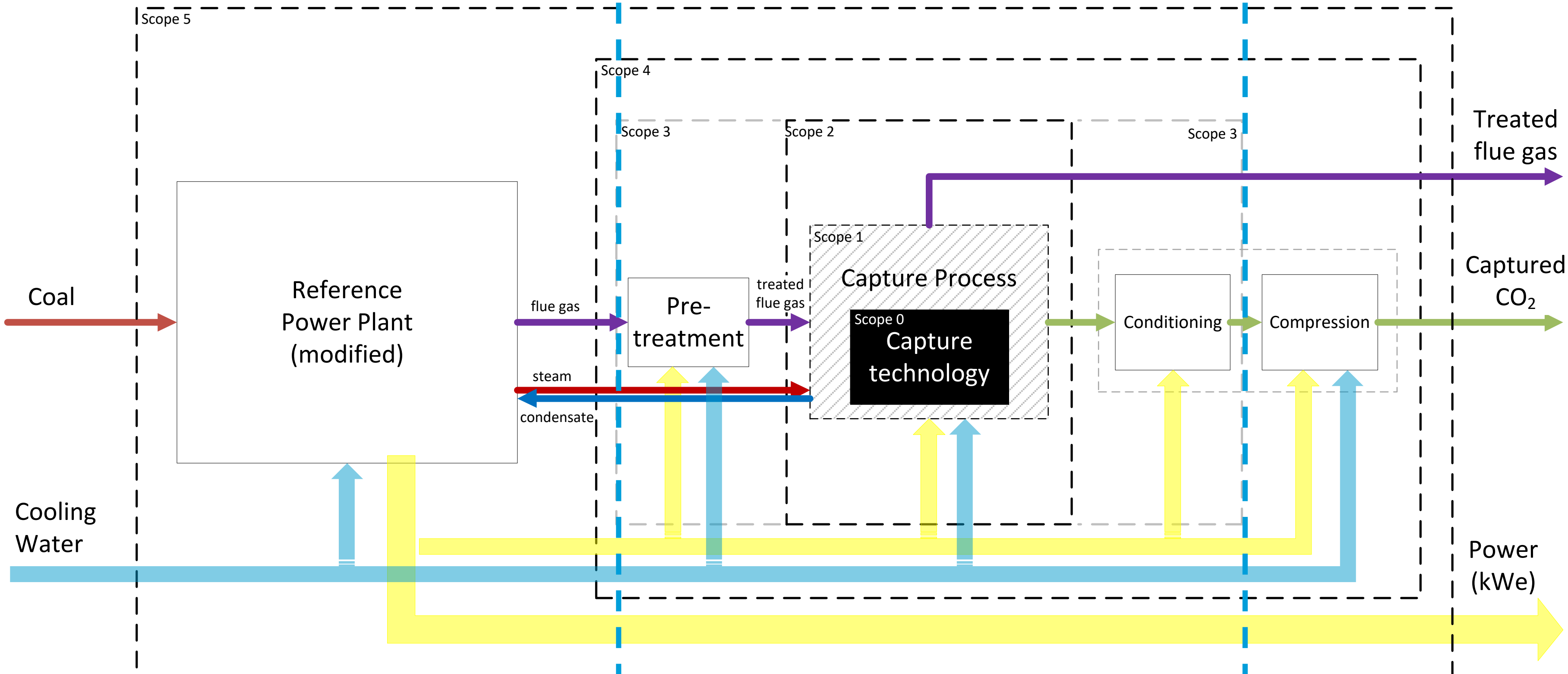
- Information on interfaces shared with assessment parties
- All data checked on:
  - Consistency
  - Product specification
  - Use of utilities
  - Minimum capture rate

Approach to the assessment

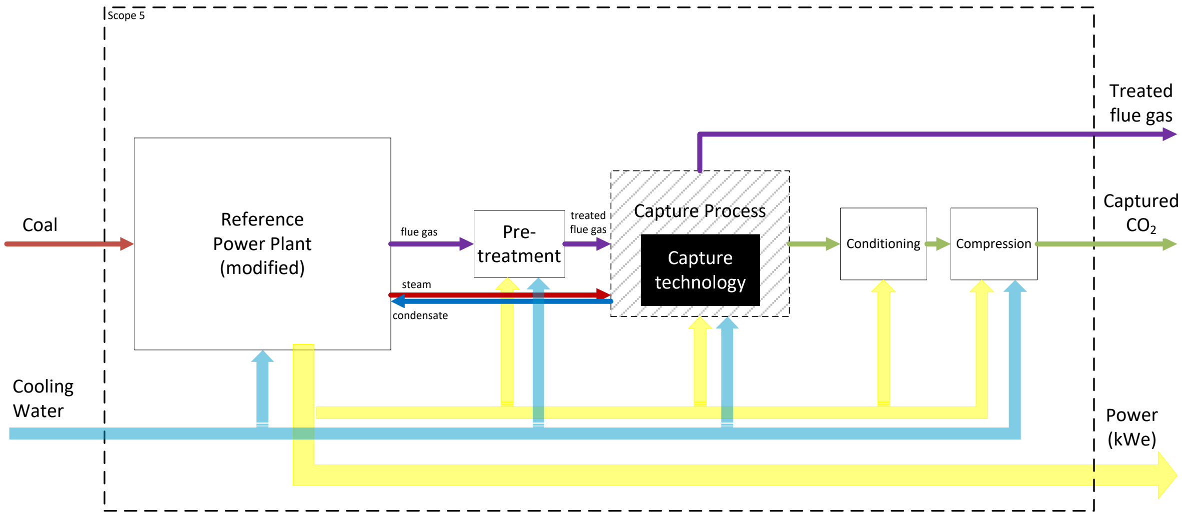
Responsibility of assessment parties

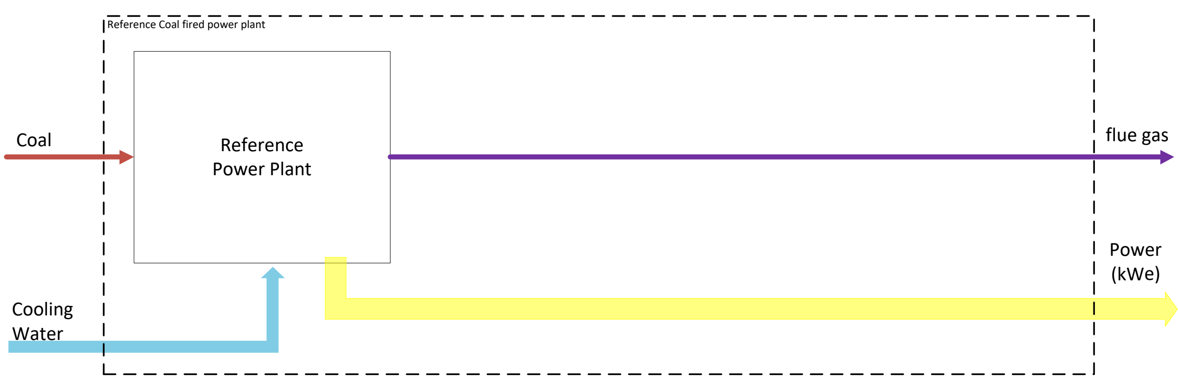
Responsibility technology developers

Responsibility of assessment parties



Scope of the assessment





Overall comparison

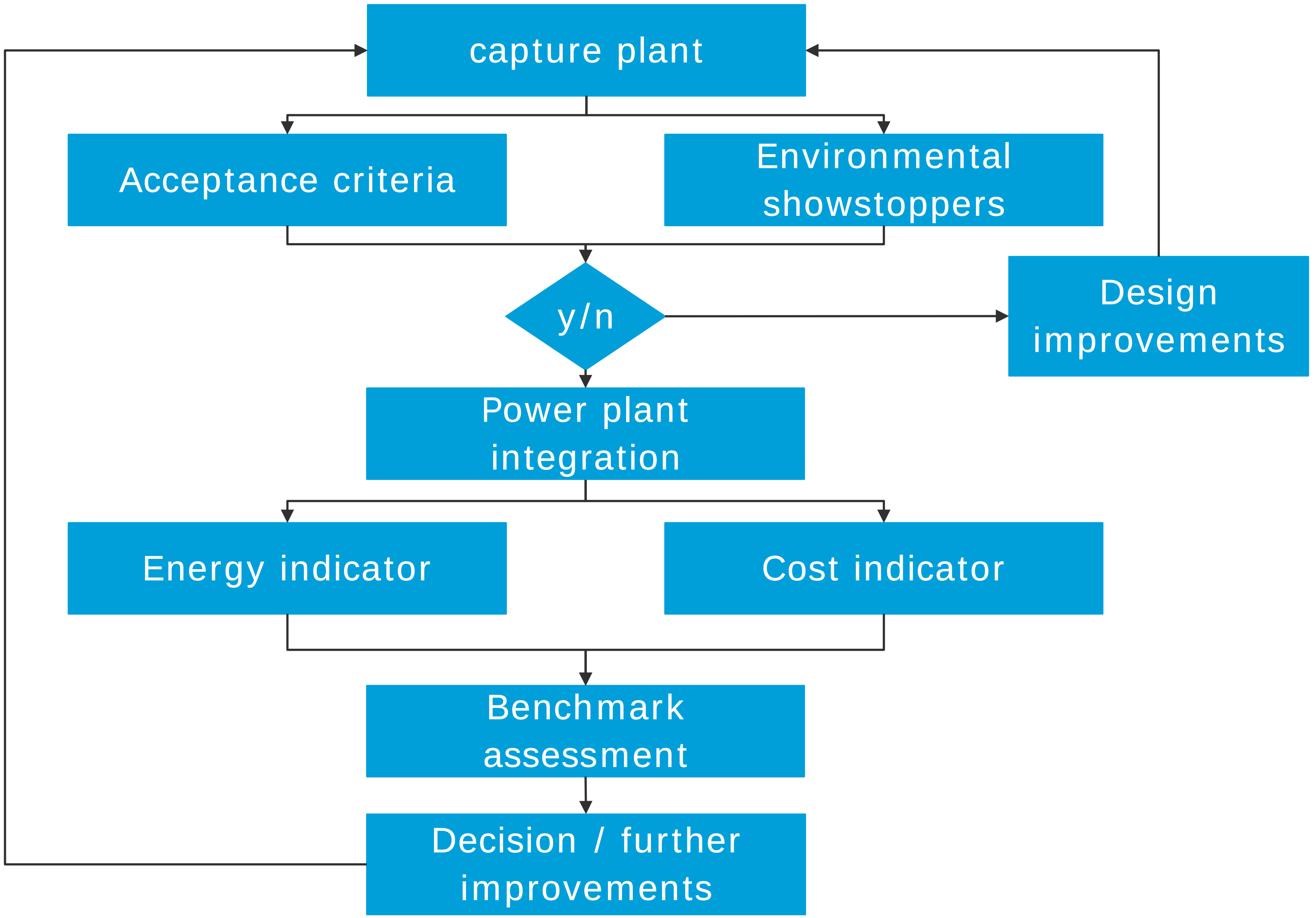
On level of key indicators the following performance can be determined:

Indicator Energy

Indicator Environmental

Indicator Cost

Methodology process



Methodology - Definition of indicators

Indicator Environment

- (Sub) Goal of the project:
  - Develop a process that is environmentally benign
- Possible via:
  - Use of environmental friendly solvents: e.g. Taurine, Sorbents
  - Membranes
  - Process design to minimize environmental impact
- Questionnaires proved the most accurate way to evaluate technologies at this stage:

Indicator Energy

- Many indicators that give information about performance of:
  - Solvents
  - Solvent regeneration
  - Energy use
- Key indicators use all information on capture plant performance
- Output information based on:
  - primary energy
  - produced energy per kg CO_2

- I

$$SEPAC = \frac{P_{ref} - P}{\phi_{CO_{2ref}} - \phi_{CO_2}}$$

- S … C) $[MW_e \cdot s \cdot kg_{CO2}^{-1}]$:

With
- P = net electric output of the power plant in MW_e
- ϕ_{CO2} = the emitted flow of CO_2 in kg_{CO_2}/s

Indicator Cost

Starting points:

- Technologies at different stages of development (lab to pilot)
- Possible to make cost estimates, but:
  - Tedious exercise for all technologies
  - Requires more info on equipment than available
  - large uncertainty on final development

Method developed to compare on equal basis

- Evaluation of aspects driving (drivers) the cost up or down both CAPEX and OPEX
- What is the impact of a driver on the total cost
- Comparison on base line reference case (CESAR1)

Cost KPI: Approach

- Compare a case with the reference case on:
  - the cost to build the capture plant
  - the cost to operate the capture plant at a power station.
- Three different impact categories

Impact on total costs	Cost category	Lower score	Upper score	Reference score (CESAR 1)
High	A	1	9	5
Normal	B	1	7	4
Low	C	1	5	3

Cost KPI drivers

- What drives the cost of a capture plant

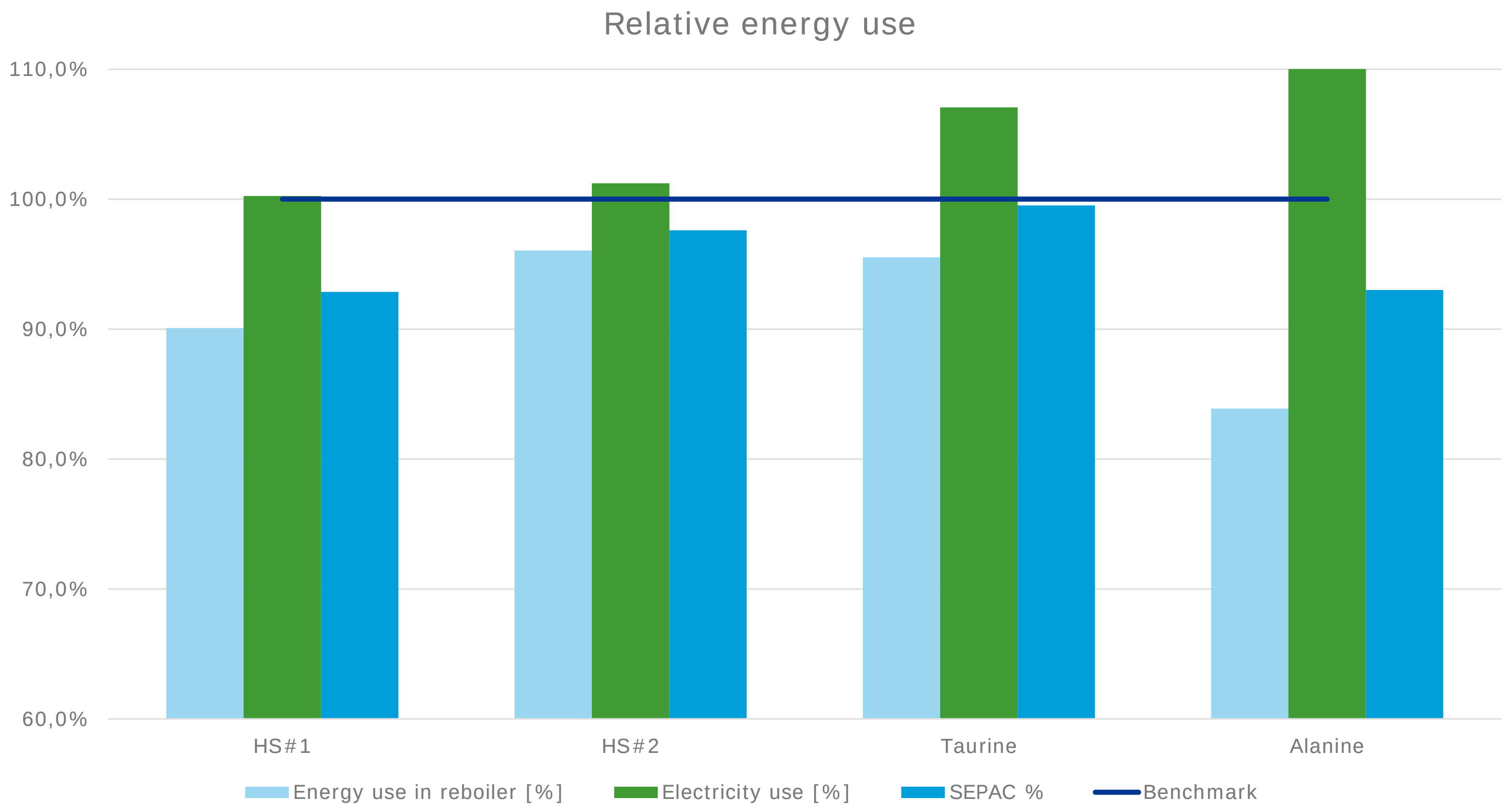
Cost category	Score of reference case
Complexity (category A)	5
Footprint (category C)	3
First fill (category C)	3
Special materials (category C)	3
TOTAL CAPEX score	14
Availability (category A)	5
Flexibility (category B)	4
Efficiency / Energy penalty (category A)	5
Consumption rate (category A)	5
Additional consumables (category C)	3
Maintenance (category A)	5
Emissions (category C)	3
TOTAL OPEX score	30

Results of the assessment

Energy - Example

		Power Plant	Including reference capture plant	Including alanine capture plant
Net energy Output	MW	746	581	593
Unit Efficiency (NCV)	%	44,1	34,4	35,1
SEPAC	MWs/kg	-	1,10	1,02
Modified	MWh/ton CO_2		0,30	0,28
Energy reduction	%	-		7,3
SPECCA	kJ/kg	-	3280	2968
Modified	kgCoal/kgCO_2		0,13	0,12
Energy reduction	%	-		9,5
EP	%	-	9,7	8,99
Energy reduction	%	-		7,4

Where does the energy go



Energy results

Case	SEPAC	Energy Reduction
CESAR 1 BASE	1,10	0%
Task 1.1 – PRLD	1,36	-24%
Task 1.1 –DMMEA	1,09	1%
Task 1.2 – Taurine	1,07	2%
Task 1.2 –Alanine	1,02	7%
Task 1.3 – Sol1	1,04	5%
Task 1.3 – Sol2	1,10	0%
Task 2.2 – FBTSA (HE1)	2,13	-95%
Task 2.2 – MBTSA	1,61	-47%
Task 3.1 – FSCM1	1,34	-22%
Task 3.1 – FSCM2	1,34	-22%
Task 3.2 – Ion1	1,29	-18%
Task 3.2 – Ion2	1,55	-41%

Cost example

Cost category	Score of reference case	Score of alanine case
Complexity (category A)	5	5 (0)
Footprint (category C)	3	3 (0)
First fill (category C)	3	4 (+1)
Special materials (category C)	3	2 (-1)
TOTAL CAPEX score	14	14
Availability (category A)	5	4 (-1)
Flexibility (category B)	4	4 (0)
Efficiency / Energy penalty (category A)	5	7 (+2)
Consumption rate (category A)	5	3 (-2)
Additional consumables (category C)	3	3 (0)
Maintenance (category A)	5	3 (-2)
Emissions (category C)	3	4 (+1)
TOTAL OPEX score	30	28

Cost results

	CAPEX	OPEX	Total	Total normalized
CESAR 1 BASE	*14*	*30*	*74*	*100*
Task 1.1 – DMMEA	10	26	62	84
Task 1.2 – Alanine	14	28	70	95
Task 1.2 – Taurine	15	27	69	93
Task 1.3 – Sol 1	11	26	63	85
Task 1.3 – Sol 2	12	27	66	89
Task 2.3 – MBTSA	12	24	60	81
Task 3.2 – ION 1	8	24	56	76
Task 2.2 – FBTSA	13	25	63	85

Total = CAPEX + (2 x OPEX)

- The results show that none of the novel capture technologies outperforms the CESAR 1 reference case on Cost KPI.

Overview of energy and cost

Energy KPI

Rank	Case	Capture rate (%)
1	Task 1.2 – Alanine	90
2	Task 1.3 – Sol 1	90
3	Task 1.2 – Taurine	90
4	Task 1.1 – DMMEA	90
5	Task 1.3 – Sol 2	90
6	***CESAR 1 BASE***	**90**
7	Task 3.2 – ION 1	85
8	Task 3.1 – FSCM 1	85
8	Task 3.1 – FSCM 2	85
10	Task 1.1 – PRLD	85
11	Task 3.2 – ION 2	85
12	~~Task 2.3 – MBTSA~~[1]	71
13	Task 2.2 – HE1	85

Cost KPI

Rank	Case
1	***CESAR 1 BASE***
2	Task 1.2 – Alanine
3	Task 1.2 – Taurine
4	Task 1.3 – Sol 2
5	Task 1.1 – DMMEA
6	Task 1.3 – Sol 1
7	Task 2.2 – HE1
8	~~Task 2.3 – MBTSA~~[1]
9	Task 3.2 – ION 1

[1] Task 2.3 – MBTSA case do not meet the minimum requirements

Evaluation and benchmarking

- The assessment of the Energy KPI for the novel capture technologies, shows that none of the technologies outperforms CESAR 1 by 25 %.
- The best performing novel capture technology has a 7,2 % lower energy penalty compared to CESAR 1.

- The assessment of the Cost KPI for the evaluated capture technologies, indicates that the costs are higher compared to the CESAR 1 case.
- Given that the capture technologies are novel and that the focus has been on developing more energy efficient and more environmentally benign processes, this result is not surprising.

Future Work

- Evaluation of work in Work package 5
  - Task 1.2 - Alanine
  - Task 1.3 - Sol 2
- Finalise methodology

Thank you

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