Simultaneous CAPEX and OPEX optimization of a carbon capture plant

Combined-Cycle Gas Turbine case study

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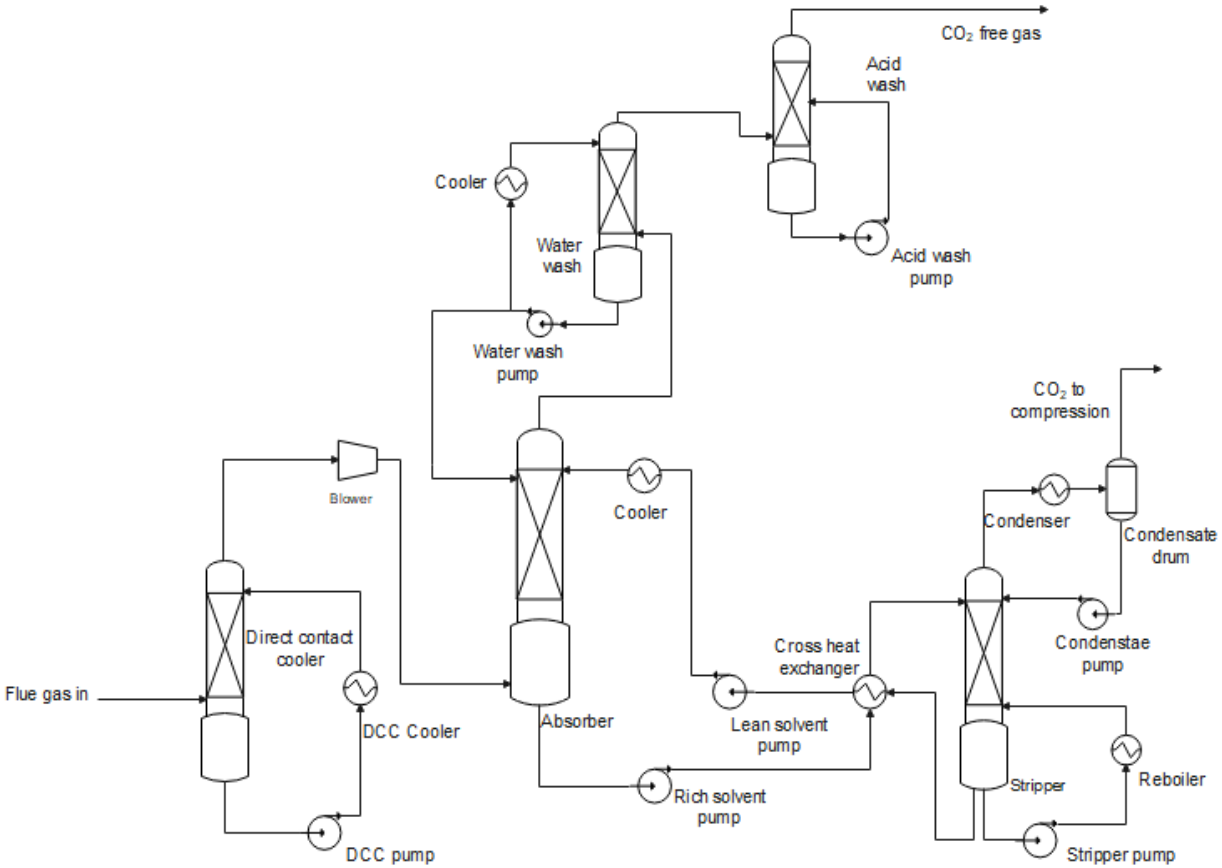
Carbon capture process



Flowsheet of Carbon capture process

- Conventional amine-based process
- Energy requirements for reboiler – solvent type, flue gas composition & process operating conditions.
- Typically, 2.5 to 3.6 MJ/kgCO_2
- CESAR1 less energy intensive than MEA
- CESAR1 reaction slower compared to MEA

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Cost analysis for carbon capture plant

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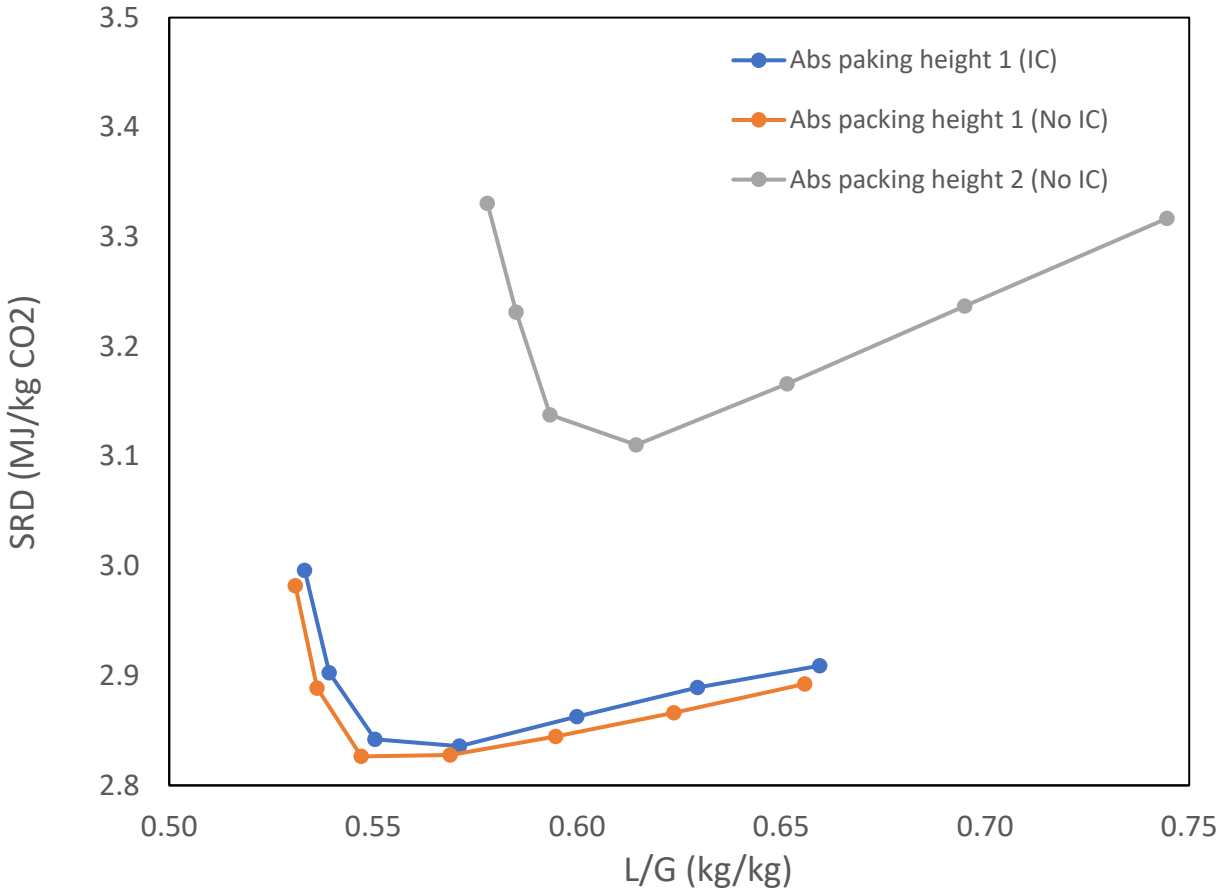
- First energy optimization, then estimation of cost for few selected cases.
- ProTreat® version 9.0 – New case study feature, run multiple configurations. New thermodynamic model for CESAR1 – avg. capture rates < 2% deviation[1].
- New cost estimation tool developed – simultaneous optimization of CAPEX & OPEX



[1]*Weinfeld et al. (2025), Development and plant validation of a CESAR1 solvent model with an emphasis on water wash conditions*

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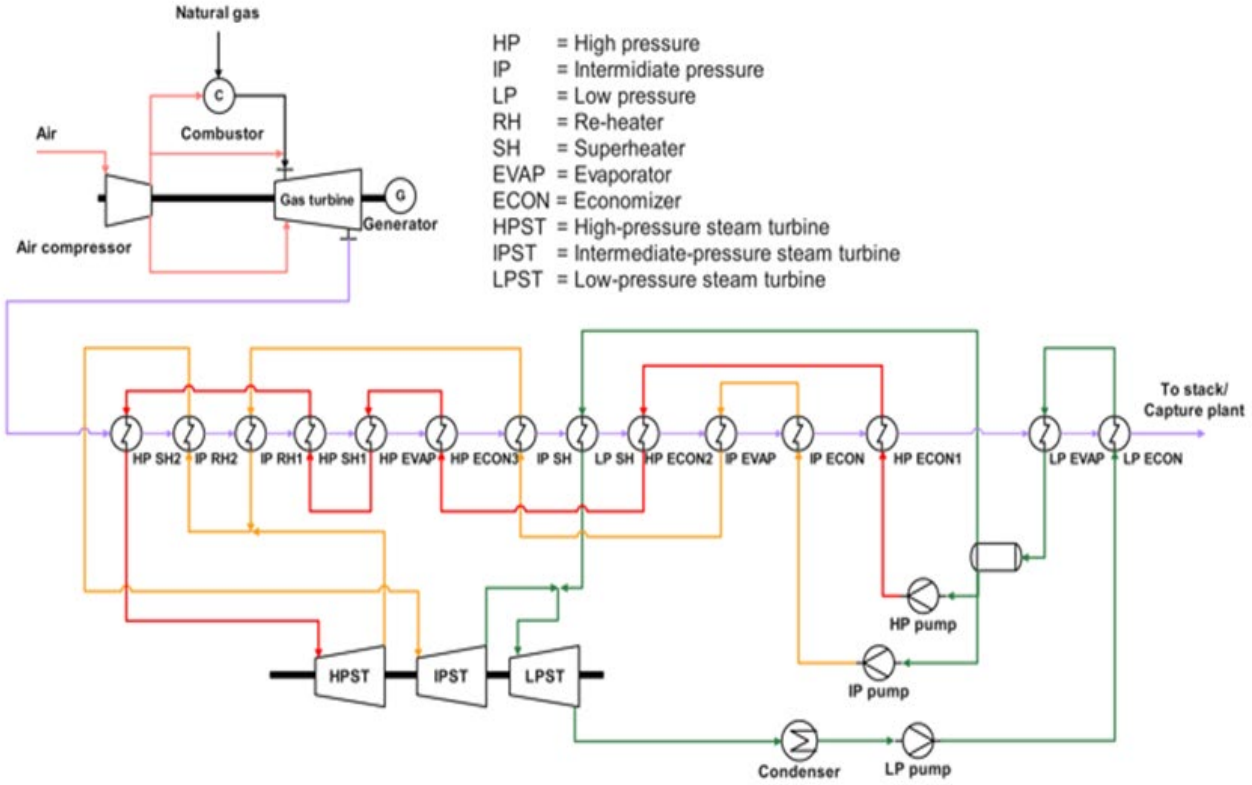
Combined Cycle Gas Turbine process



Without Carbon Capture		
Air compressor	MW	244.9
LP pump	kW	71.4
IP pump	kW	32.7
HP pump	kW	1311.0
Gas turbine	MW	507.5
LPST	MW	66.3
IPST	MW	46.6
HPST	MW	29.0
Net power output	MW	403.0

Z. Liu and I. A. Karimi, “Simulating combined cycle gas turbine power plants in Aspen HYSYS,” *Elsevier*, Jun. 2018.

CCGT Power plant with carbon capture

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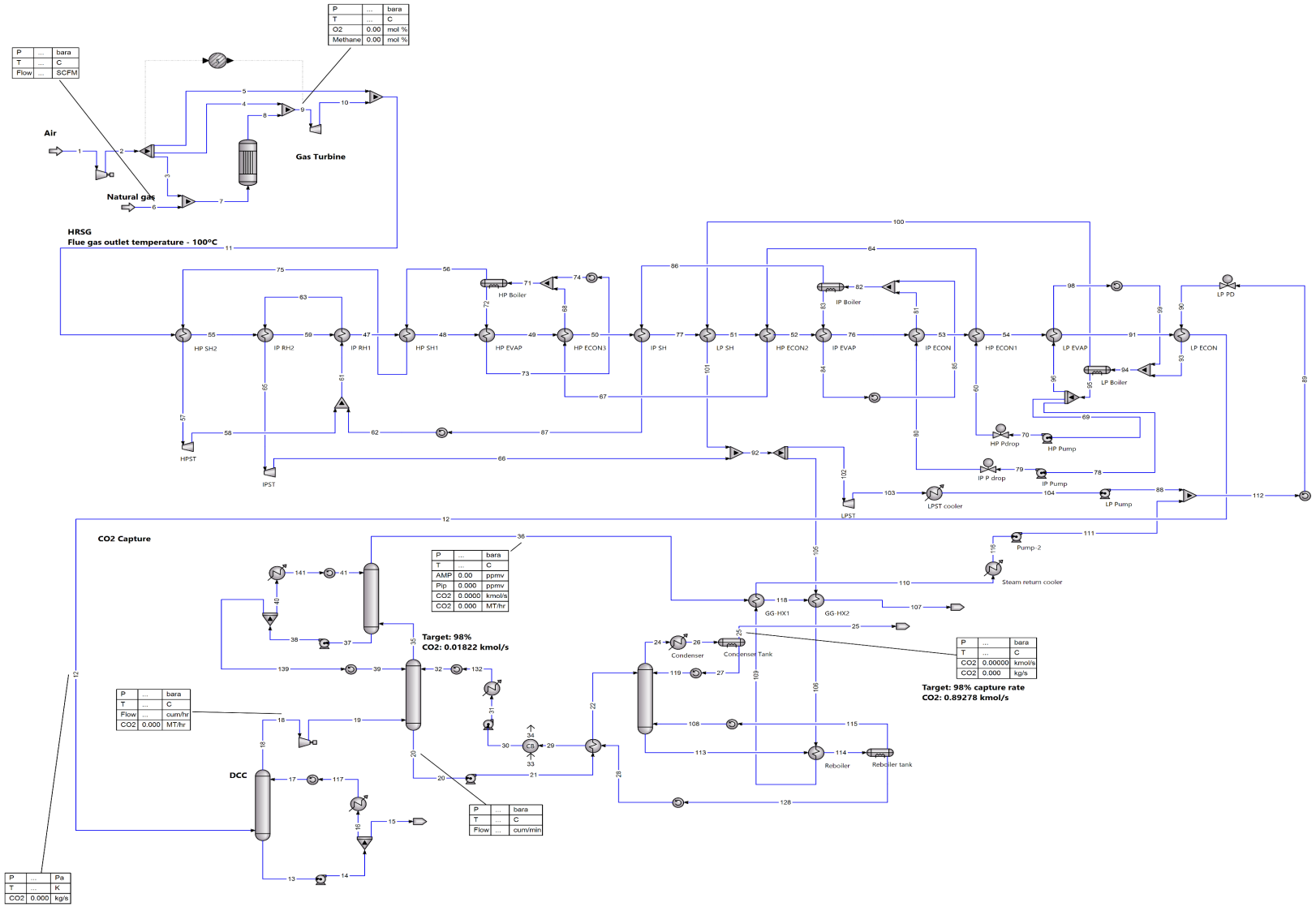

- Capture plant with CCGT plant modelled in ProTreat®
- Steam extracted from LPST
- Electricity required for pumps & blowers of capture process

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Capital Cost Estimate

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- Methodology for cost estimation described in [1].
- Class 4 type study – accuracy range between -10% to -20% (low side) to +20% to +30% (high side).
- Costs updated to current values using Chemical Engineering Plant Cost Index (CEPCI)

Assumptions for equipment cost calculation

Equipment	Type
Pumps	Centrifugal
Heat Exchangers	Flat plate
Columns (Process vessels)	Vertical
Vessels	Vertical
Column specifications	
DCC	Includes demister
Absorber	Includes demister, dry bed packing, Water wash and Acid wash section stacked at the top
Stripper	Includes dry bed packing

[1] R. Turton, J. A. Shaeiwitz, D. Bhattacharyya, and W. B. Whiting, *Analysis, Synthesis, and Design of chemical processes*, vol. Fifth Edition. 2018.

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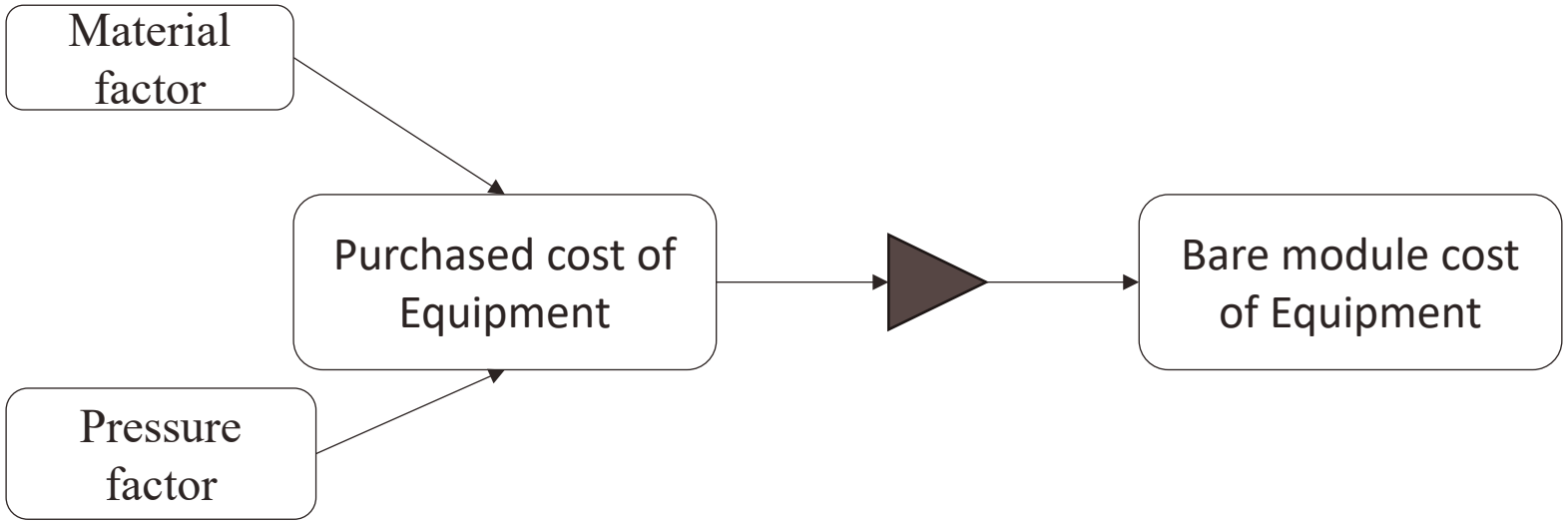
Cost estimation of equipment

Module costing Technique used for estimating bare module cost of equipment.



- Purchased cost of base equipment – carbon steel and ambient pressure operations
- Bare module : correction factors , installation costs

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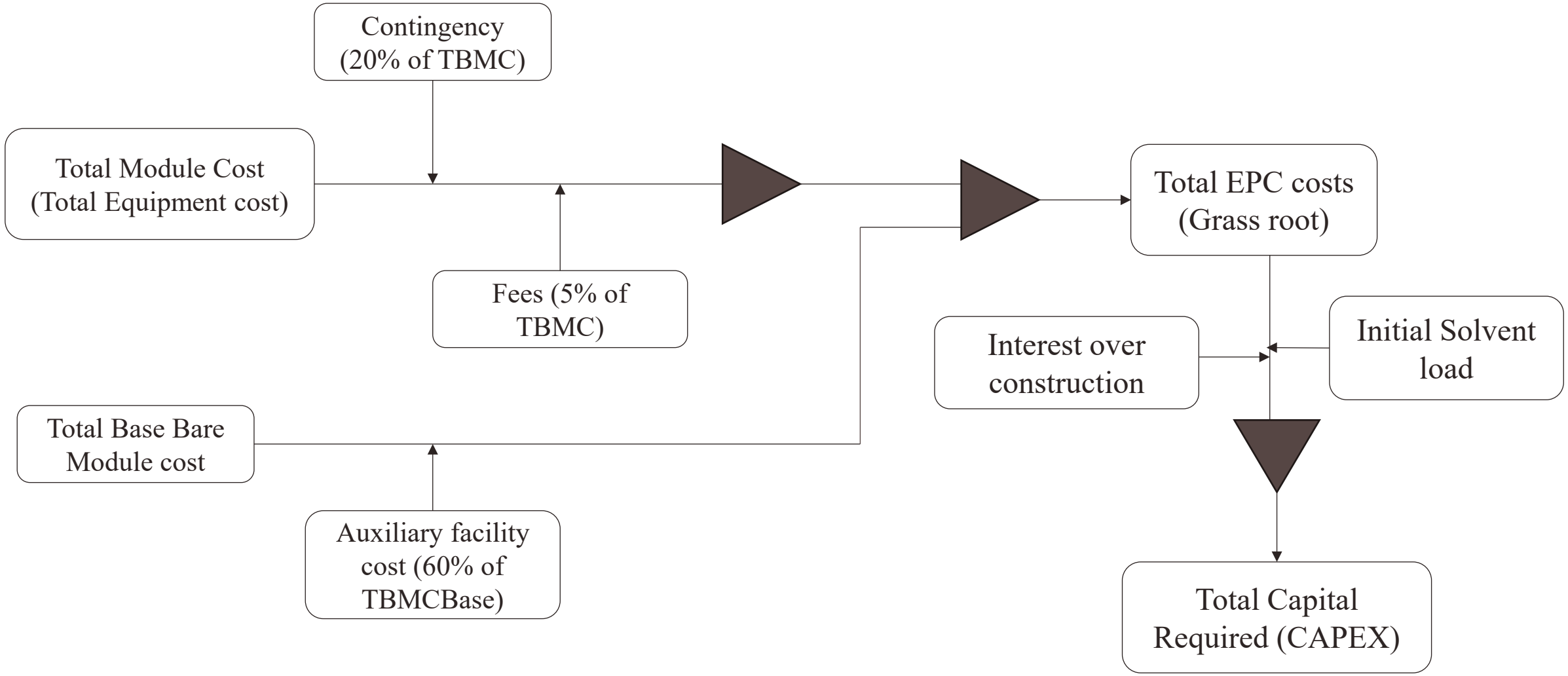
Total CAPEX estimation



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Estimation of OPEX

Variable OPEX

	Price	Unit
Electricity	64	EUR/MWh
Cooling Water	0.02	EUR/ton
Process Water	0.177	EUR/ton
Cost of AMP	8000	EUR/ton
Cost of Piperazine	8000	EUR/ton
Cost of MEA	2000	EUR/ton
NaOH (DCC)	850	EUR/ton
H2SO4 (acid wash)	1500	EUR/ton
Chemical Handling	500	EUR/ton

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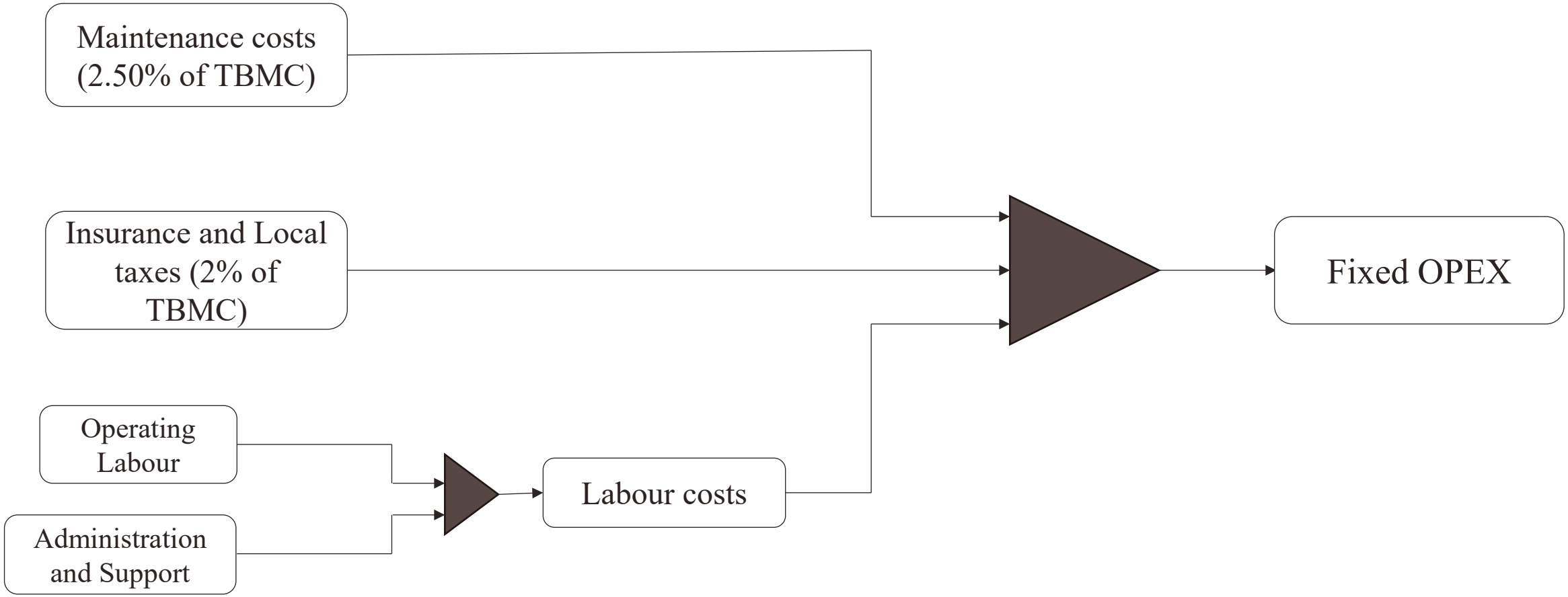
Estimation of Fixed OPEX



Cost parameters to compare cases

- Operation hours – 8000 hours in a year

- Annualized CAPEX (€/year) :

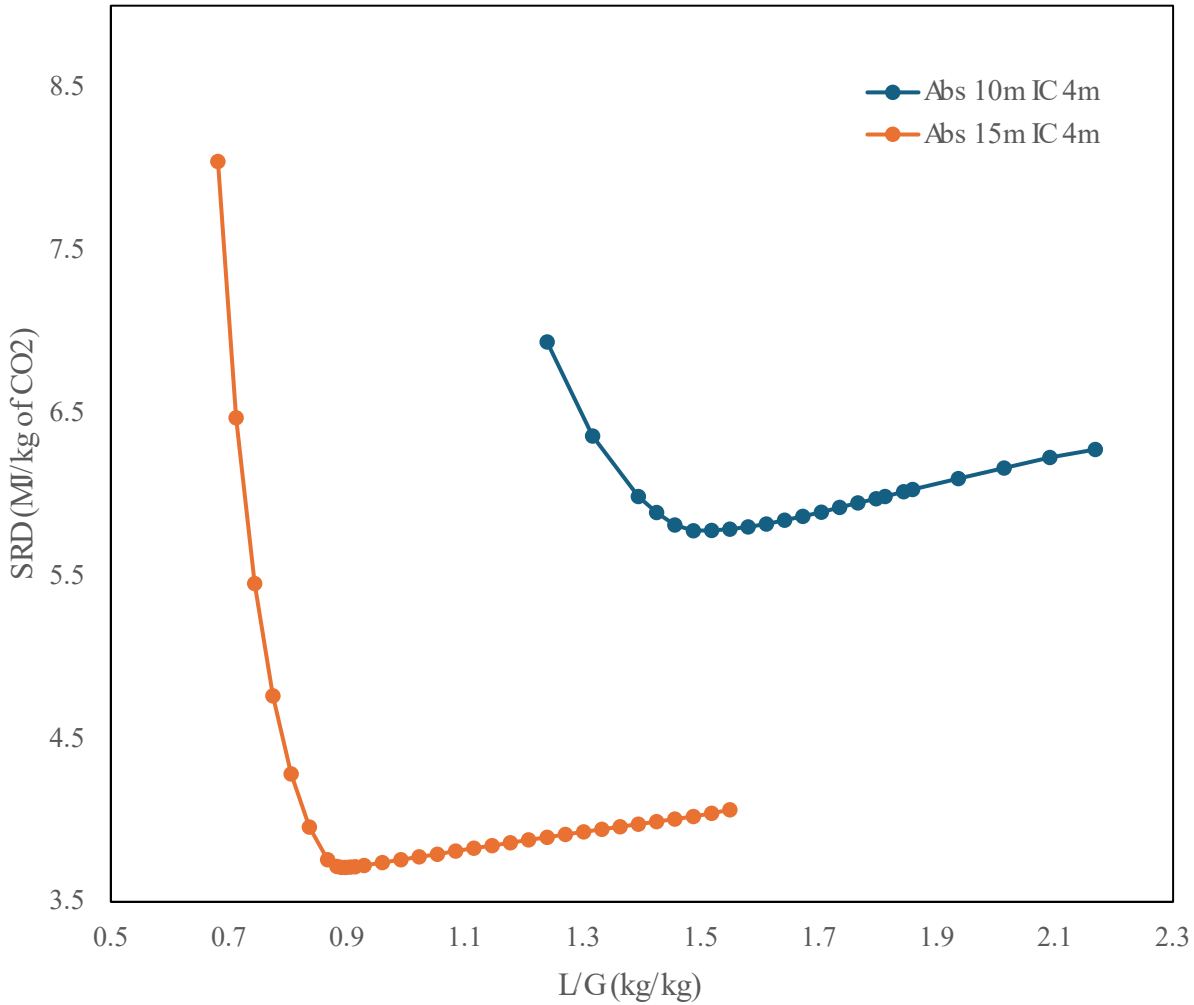
Project lifetime – 25 years
Discount rate (to account for time value of money) – 6%

- OPEX (summation of Fixed and Variable) [€/year]

- Total cost in [€/year] : Annualized CAPEX + OPEX

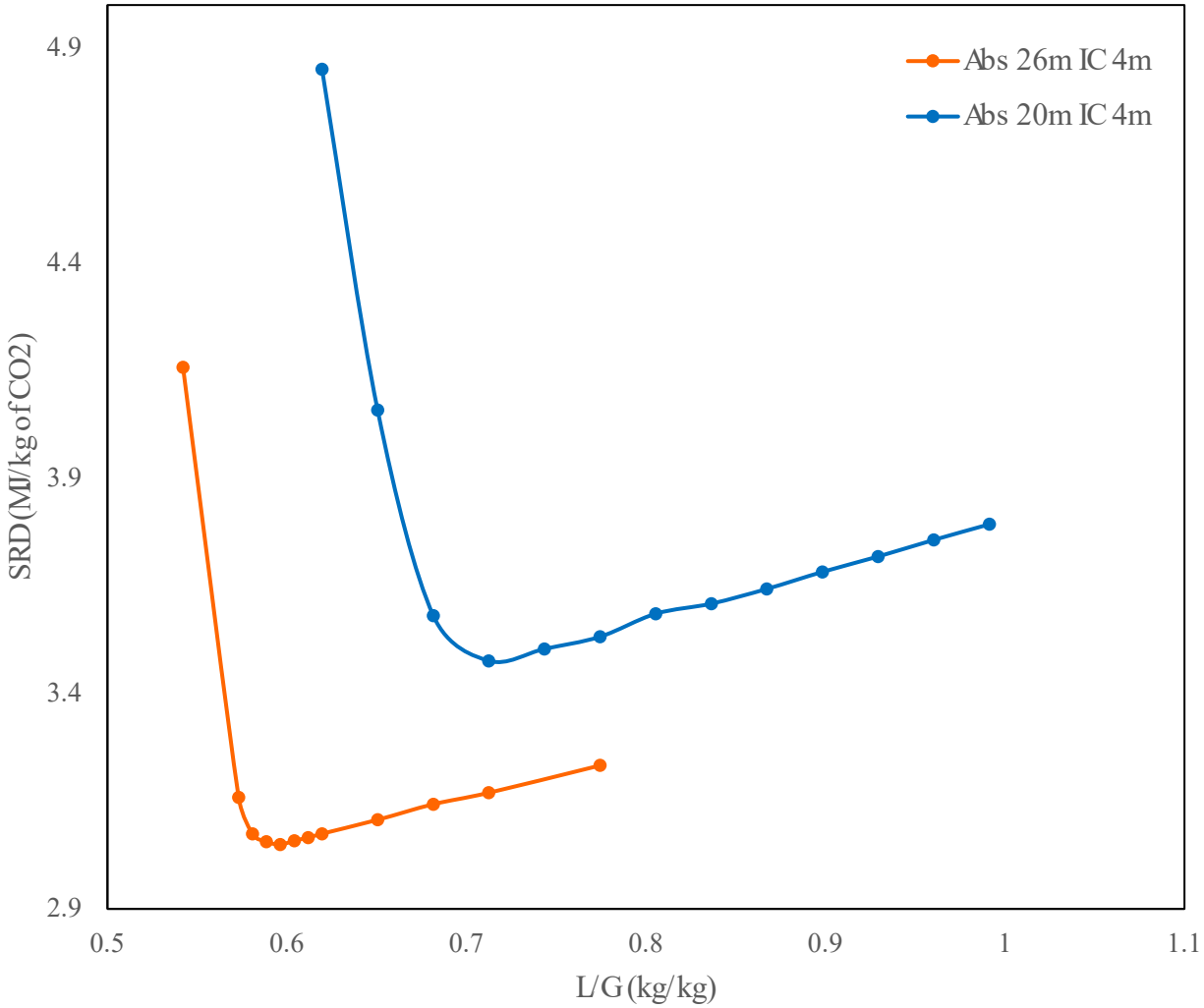
- Revenue loss : Loss in power output due to capture process taken in consideration

MEA Case study



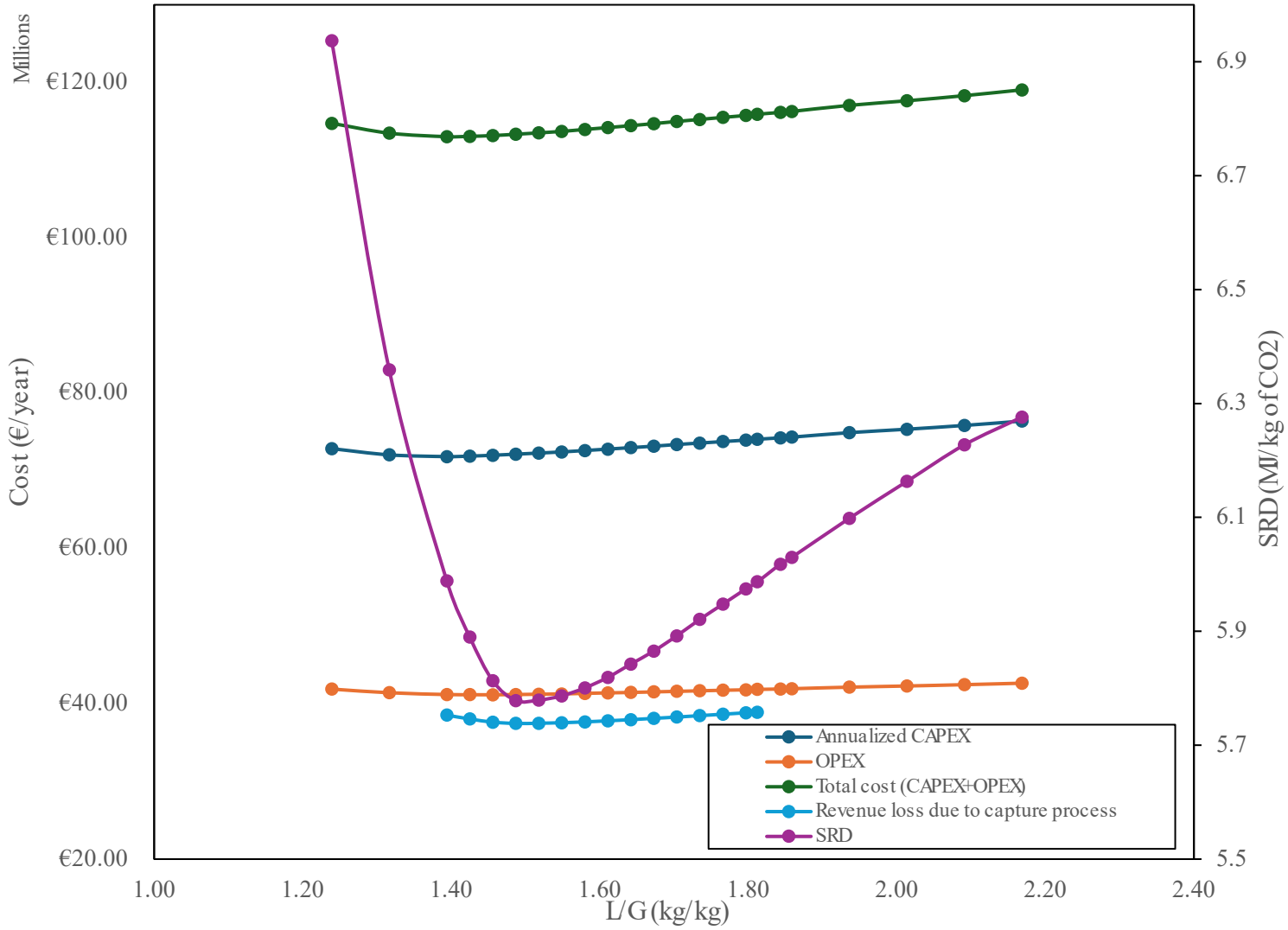
- Case study : input parameter varied – solvent flowrate
- Two cases : Absorber packing height 10m & 15 m with IC @ 4m
- DCC packing – 4m, Stripper packing – 20m
- Capture rate : 95%
- SRD optimum for 10m ; 5.77 MJ/ kgCO_2
- SRD optimum for 15m ; 3.71 MJ/ kgCO_2

CESAR1 case study

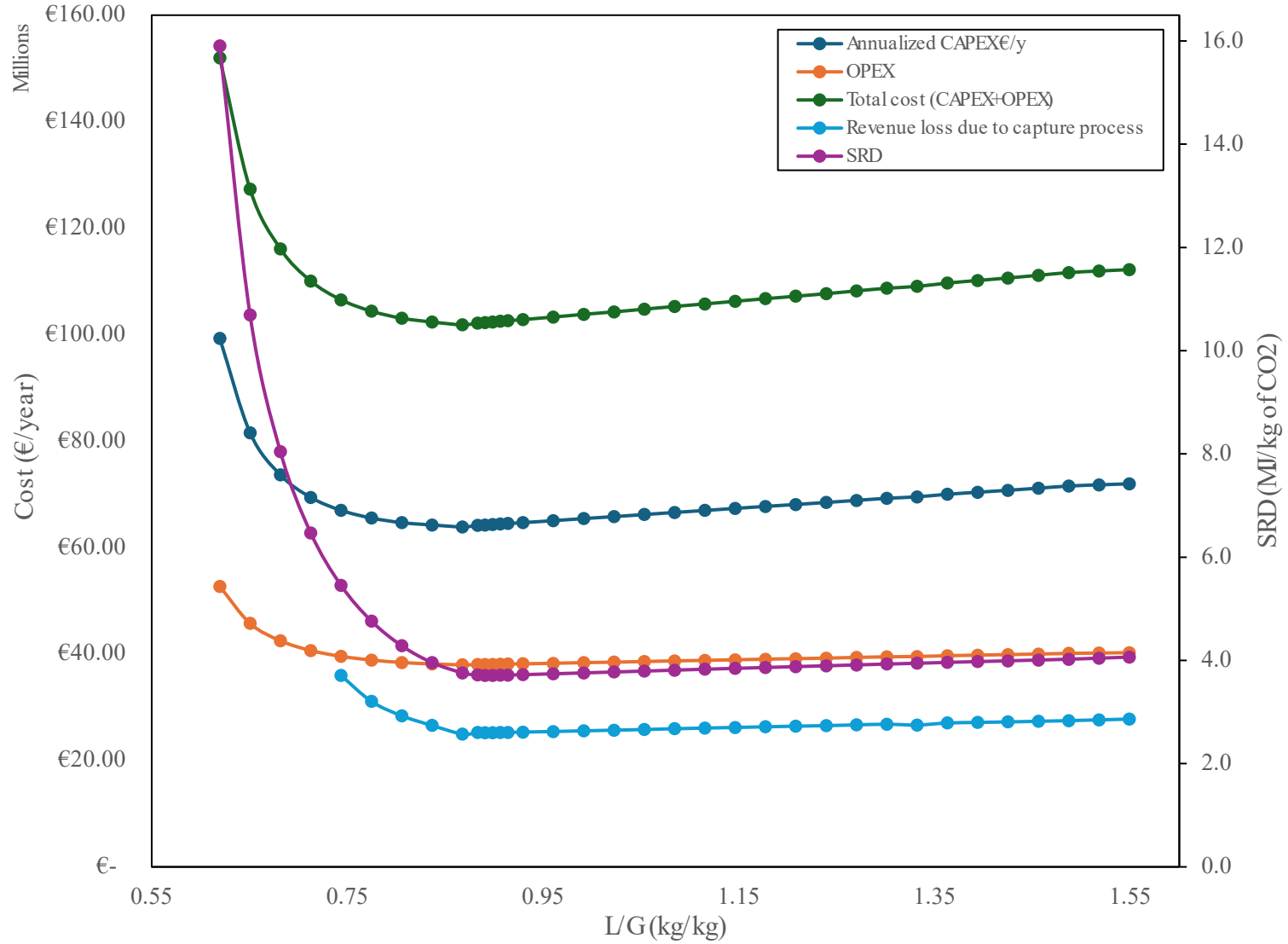


- Case study : input parameter varied – solvent flowrate
- Two cases : Absorber packing height 20m & 26 m with IC @ 4m
- DCC packing – 4m, Stripper packing – 20m
- Capture rate : 95%
- SRD optimum for 20m ; 3.47 MJ/ kgCO_2
- SRD optimum for 26m ; 3.05 MJ/ kgCO_2

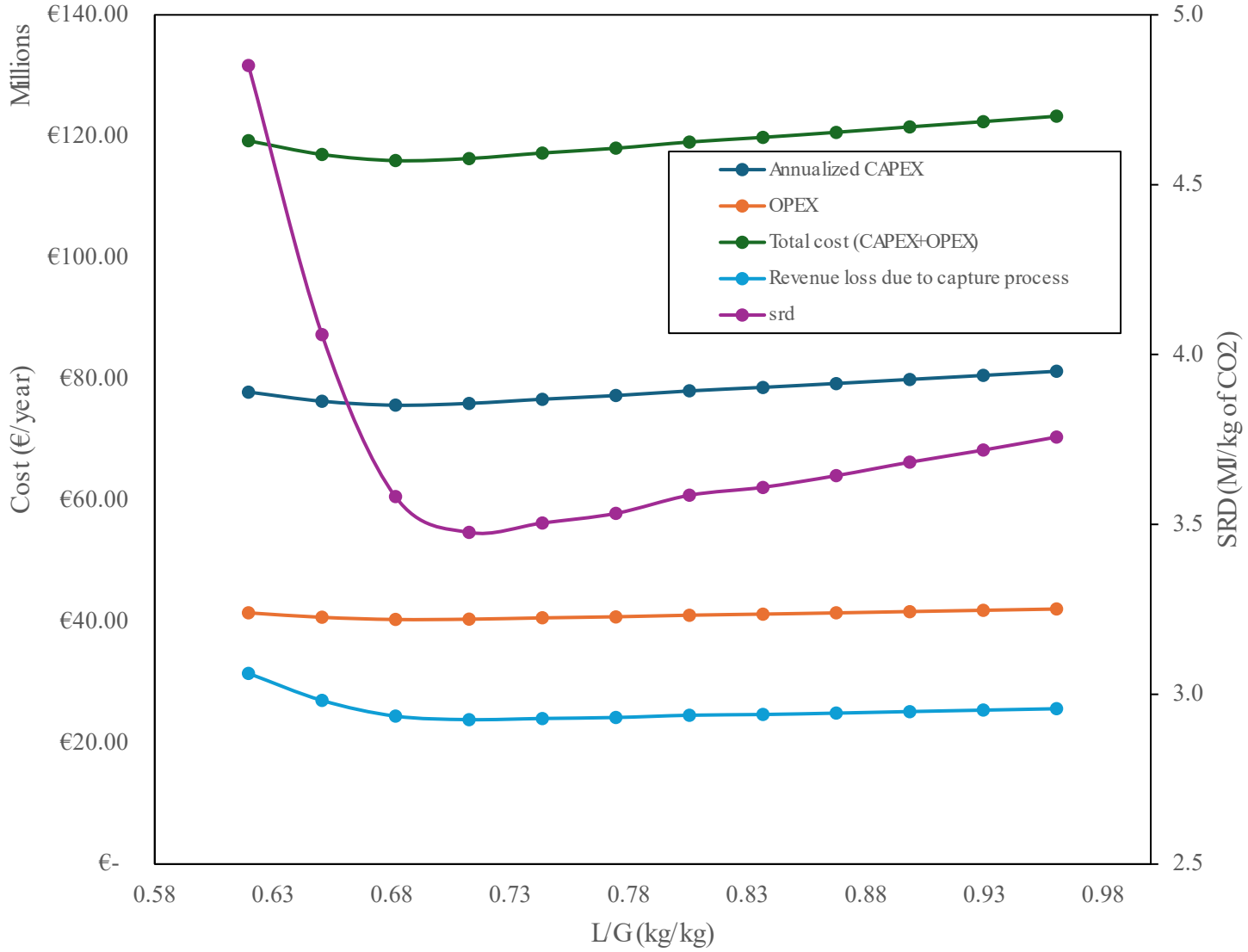
MEA case – Abs 10m IC 4m case



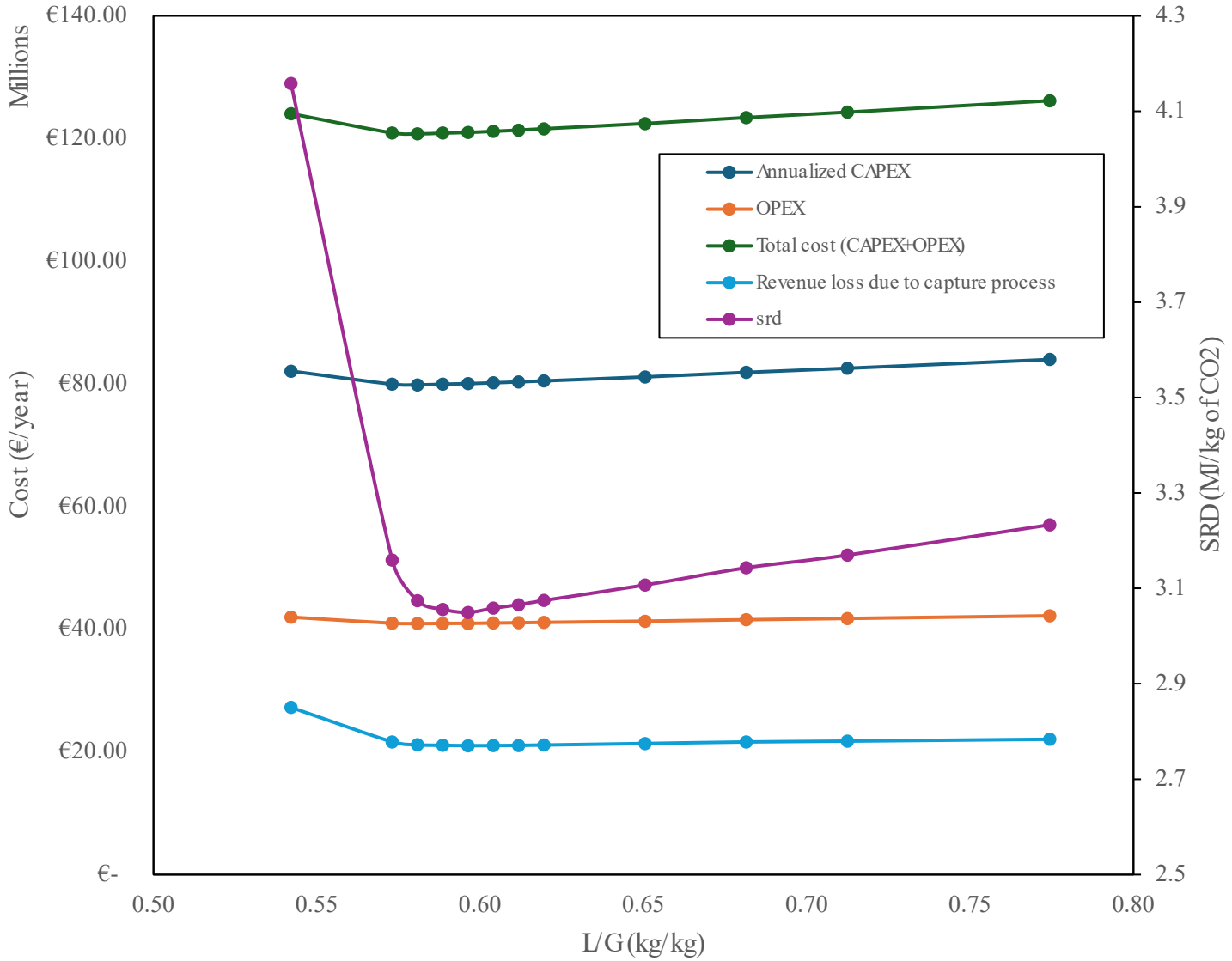
MEA case – Abs 15m IC 4m case



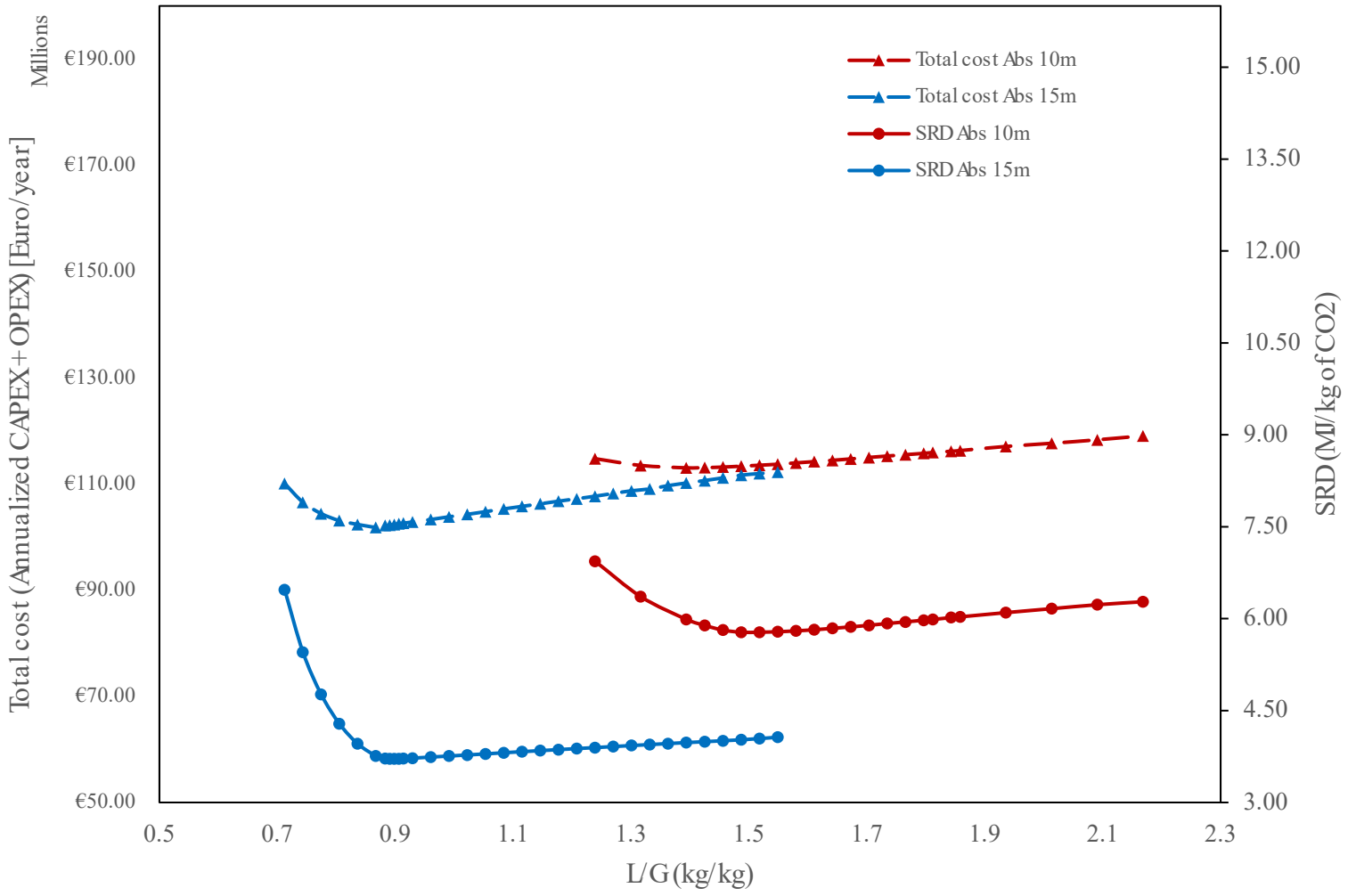
CESAR1 case – Abs 20m IC 4m case



CESAR1 case – Abs 26m IC 4m case



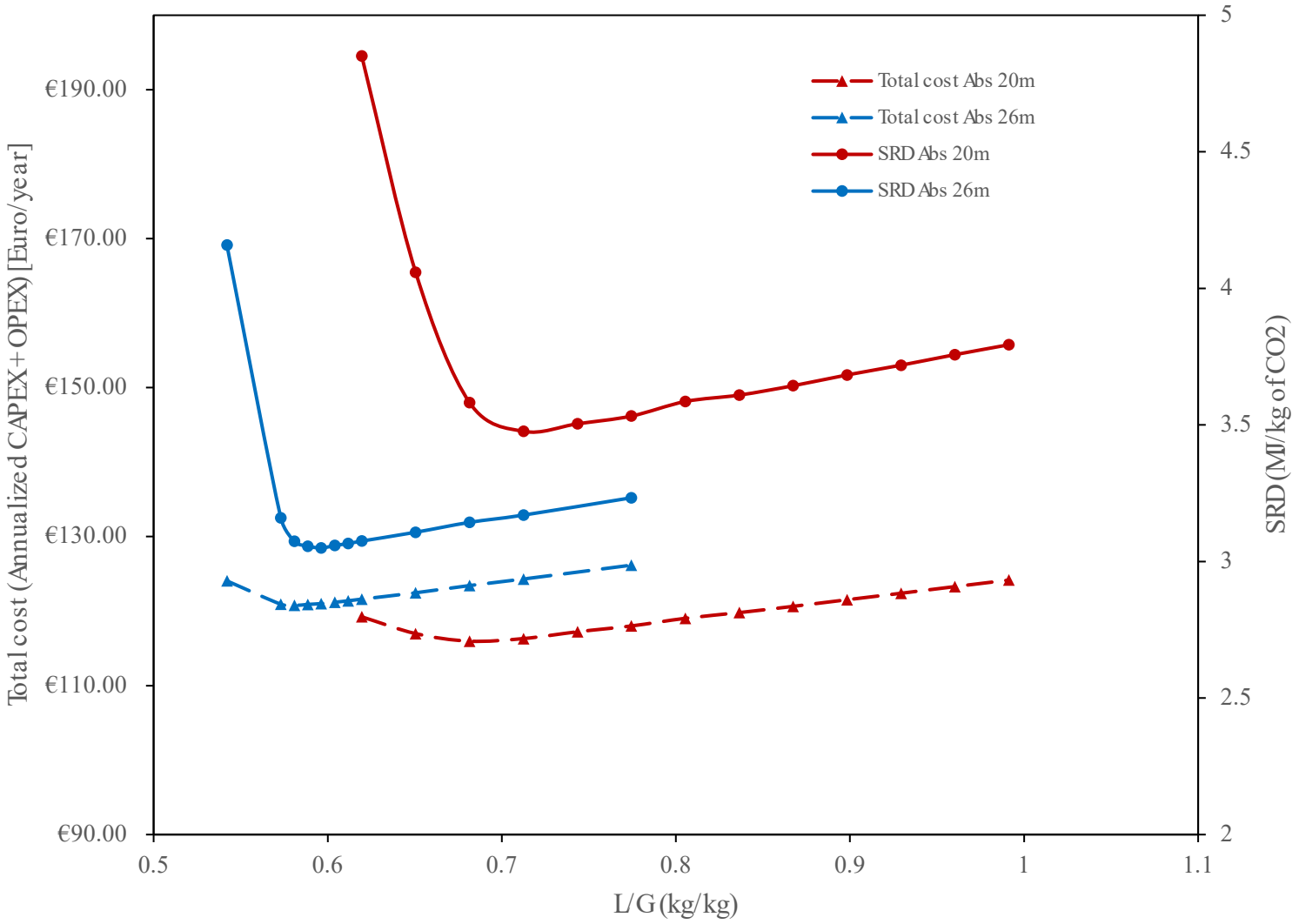
Comparison of Total cost for MEA cases



SRD lower for 15m Absorber packing height :
3.71 MJ/ kgCO_2
Total cost higher : 102.4 M€/y

SRD higher for 10m Absorber packing height :
5.77 MJ/ kgCO_2
Total cost lower : 113.3 M€/y

Comparison of Total cost for CESAR1 cases



SRD lower for 26m Absorber packing height :
3.05 MJ/ kgCO_2
Total cost higher : 121.0 M€/y

SRD higher for 20m Absorber packing height :
3.47 MJ/ kgCO_2
Total cost lower : 116.3 M€/y

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Conclusion

- Minimum reboiler duty results in lowering variable OPEX but not the total cost of capture plant.
- Taller columns contribute to larger CAPEX, which increases Fixed OPEX and the resulting Total Cost.
- Cost of the capture plant depends on configurations – taller columns, with/without Inter-coolers.
- For a given configuration, capture plant costs remain relatively stable for most of the points on SRD curve, rising noticeably only at the extremes where SRD increases sharply.
- ProTreat v9 case study feature allows for simulating multiple points (approx.30-40) in 10-15 minutes. All the necessary output variables can be generated, allows for calculating cost of each point on SRD curve. Reduces the time taken to evaluate cost of capture process for multiple configurations.

Upcoming tasks

- Explore different configurations, vary Stripper height, compare setups with and without Inter-coolers using this method.

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Thank You

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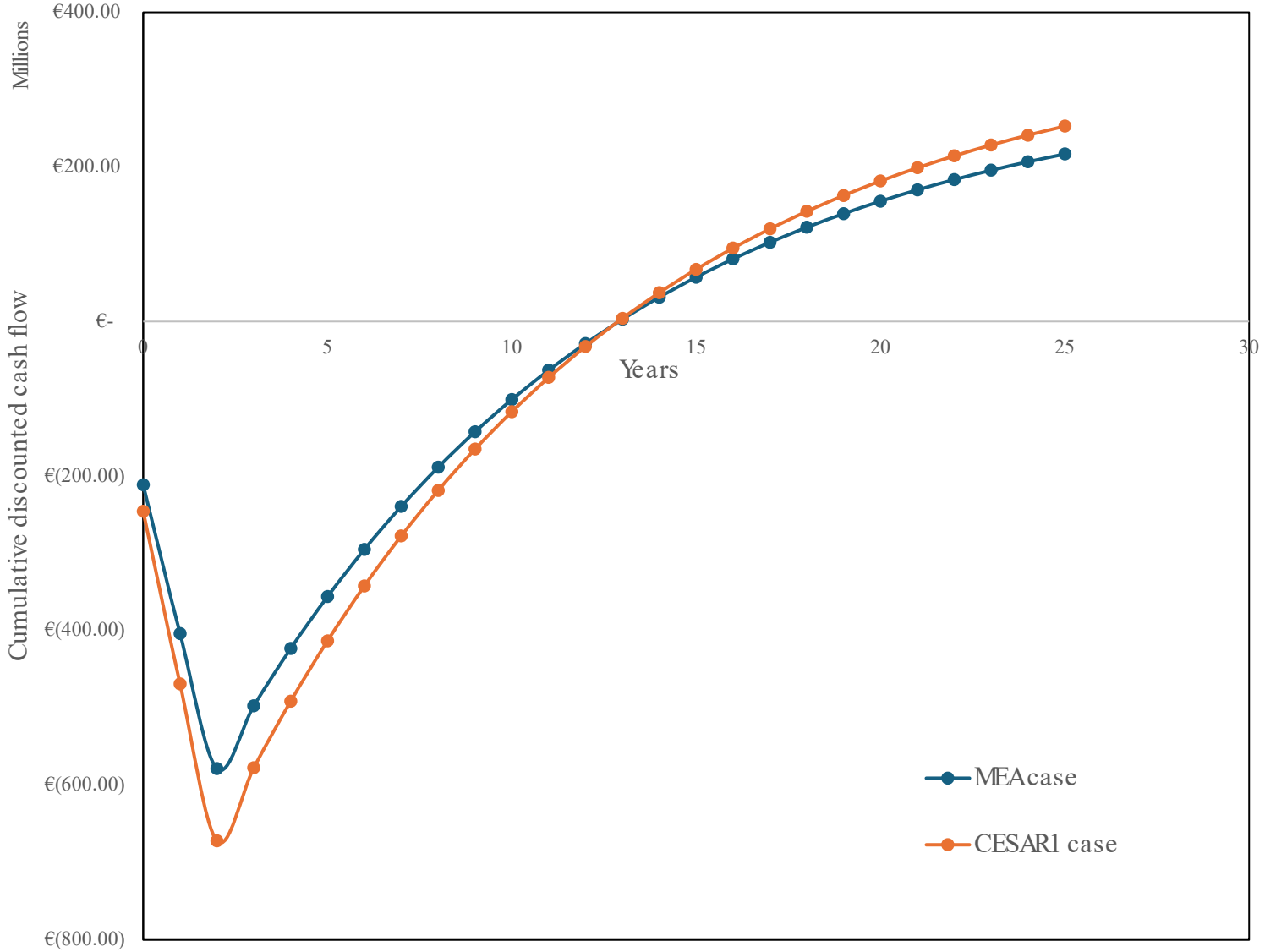
BACKUP slides

Cash flow analysis



ETS price : 85€/t
Discount rate : 10%
Electricity selling price : 64 €/MWh