CO_2QUEST

CO_2 Purity from Different Carbon Capture Applications and Associated Cost and Performance

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16th-17th December 2015, Athens, Greece

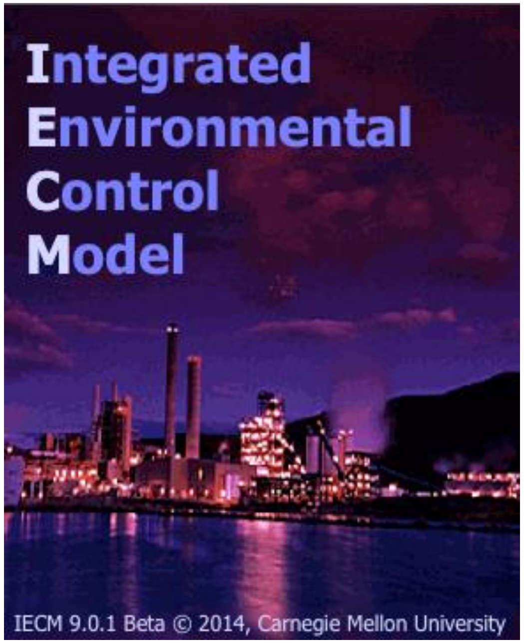
Objectives

- Develop an understanding of the dependence of capture cost on the required purity level.

- Perform scenario-based cost analysis with respect to impurities removal for the three main capture technologies:
    - **Oxyfuel combustion**
        - Compression and dehydration only
        - Double flash case
        - Distillation
    - **Pre-combustion**
        - Selexol and Rectisol solvents
        - Co-capture: CO_2 and H_2S are captured together in the same stream
        - Separate capture: CO_2 and H_2S are separated and processed
    - **Post-combustion**
        - With and without conventional pollution control devices

Method

- Techno-economic modelling using IECM – fossil fuel power plant cost and performance calculator.



\+ wider literature survey and assumptions for unavailable cases

- Aspen HYSYS® was used to compute technical parameters of oxyfuel CO_2 compression and purification unit scenarios.

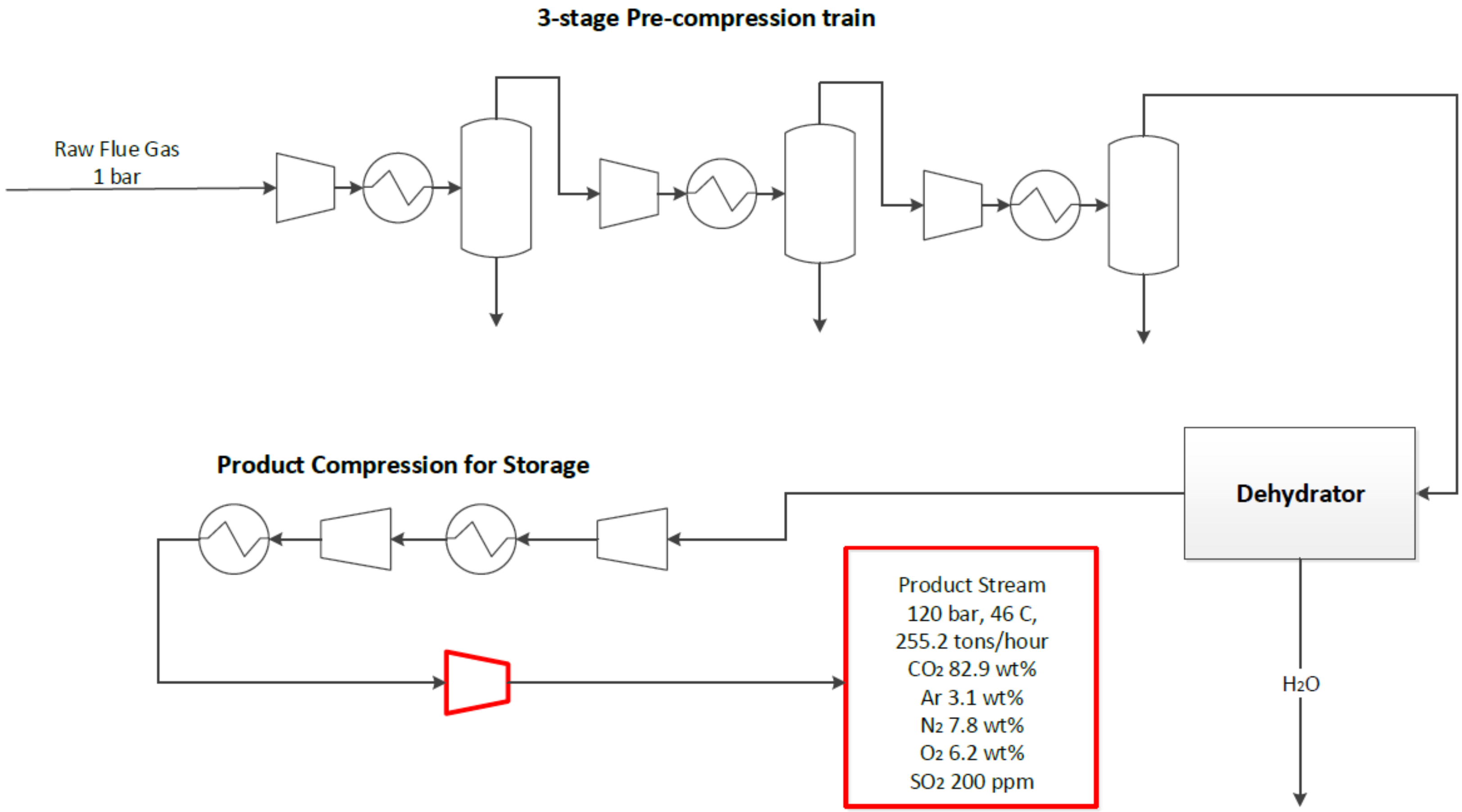
Coal Selection

	Appl. Low Sulfur
Rank	Bituminous
HHV (kJ/kg)	30420
Carbon (wt %)	71.74
Hydrogen (wt %)	4.62
Oxygen (wt %)	6.09
Chlorine (wt %)	0.07
Sulfur (wt %)	0.64
Nitrogen (wt %)	1.42
Ash (wt %)	9.79
Moisture (wt %)	5.63
Cost (€/tonne)[a]	**53.19**

[a] Currency: 2014 €

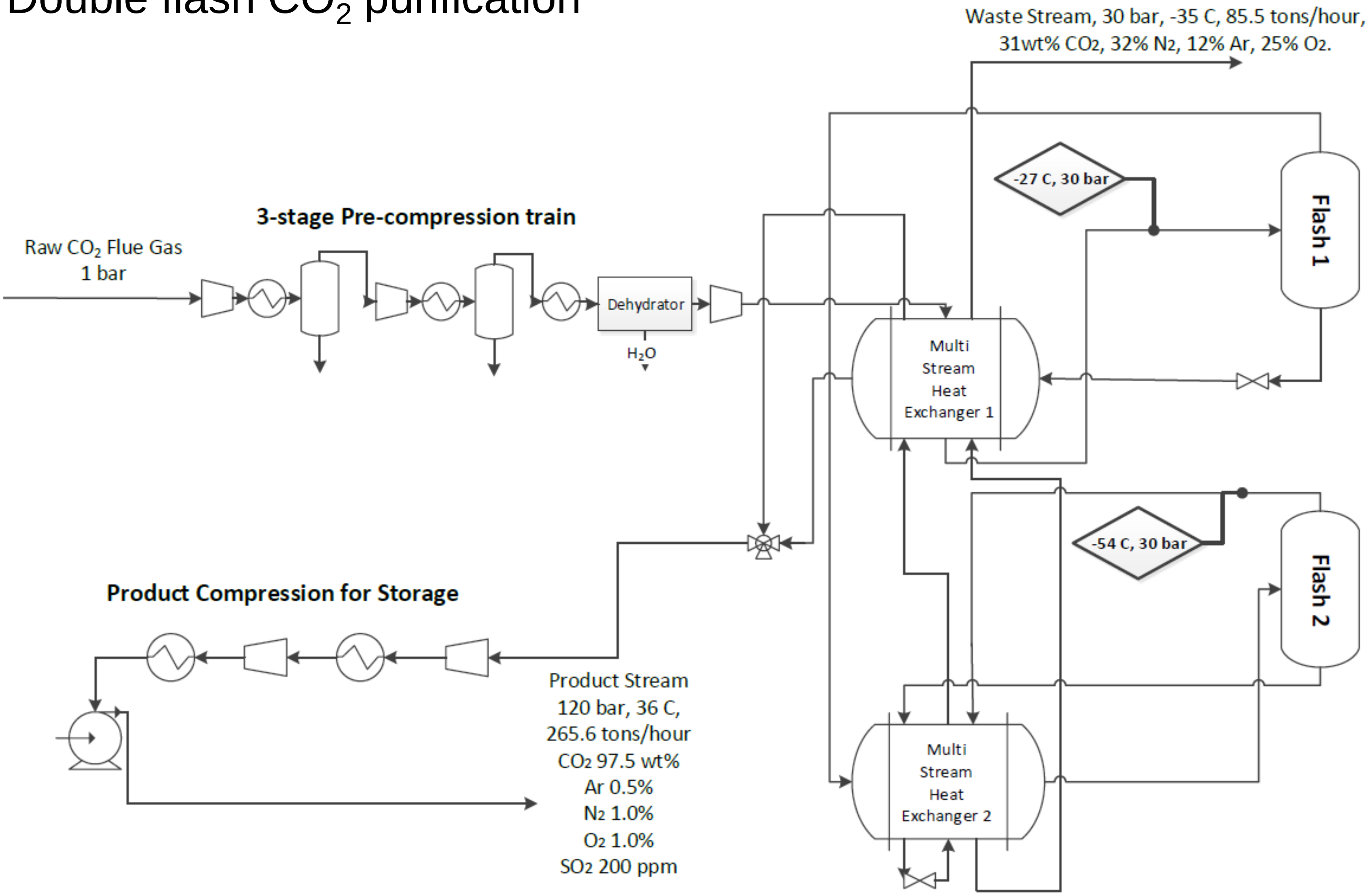
Oxyfuel CO_2 Compression and Purification Unit Aspen Hysys Modelling

- CO_2 Compression and Dehydration only



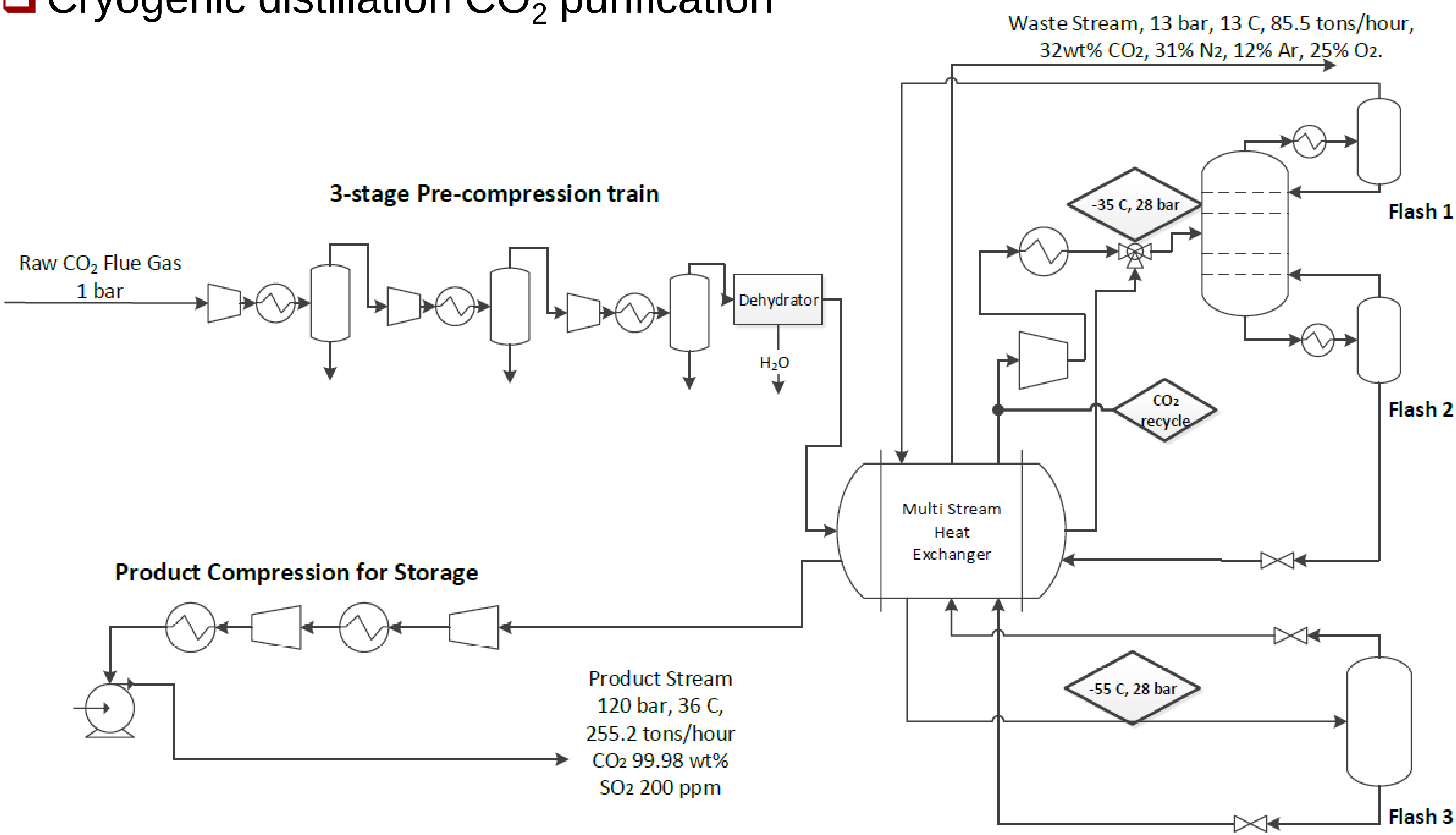
Oxyfuel CO_2 Compression and Purification Unit Aspen Hysys Modelling

- Double flash CO_2 purification



Oxyfuel CO_2 Compression and Purification Unit Aspen Hysys Modelling

- Cryogenic distillation CO_2 purification

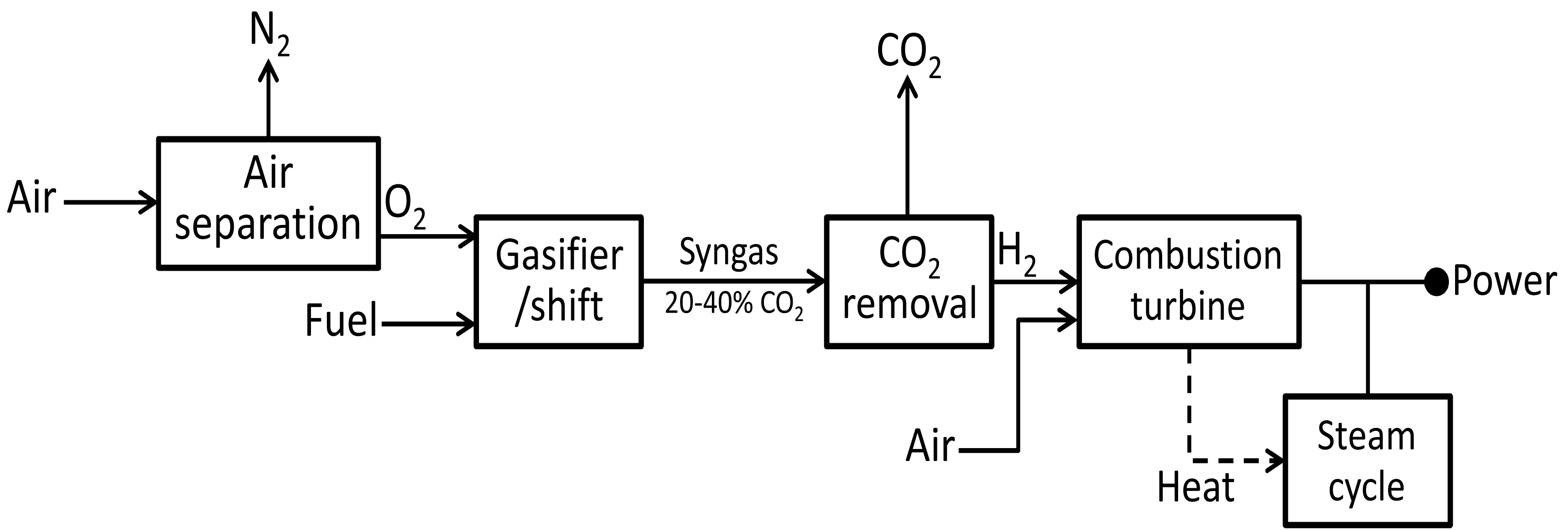


Oxyfuel combustion capture scenarios

	Compression and dehydration only	Double flash	Distillation
Gross power output (MW_e)	400	400	400
CO_2 capture efficiency (%)	100	92	90
CO_2 product stream (Mt/year)	2.88	2.25	2.16
CO_2 purification unit energy (kWh/tonneCO_2)	103	150	172
Net power output (MW)	310	270.6	265.8
Net plant efficiency, HHV(%)	33.81	29.51	28.99
Capacity factor (%)	96.5	96.5	96.5
Fixed charge factor (%)	17.21	17.21	17.21

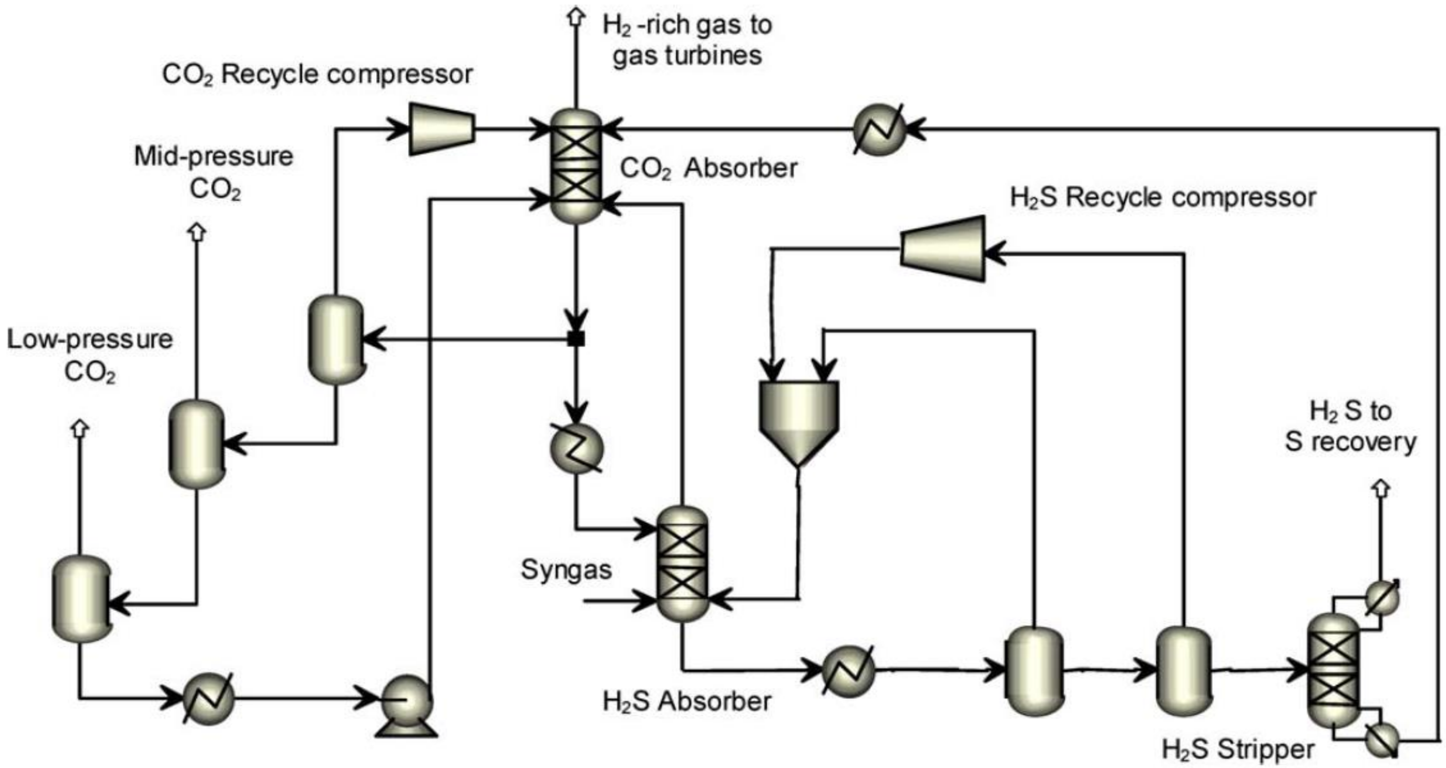
- Supercritical boiler; electrostatic precipitator particulate control system and wet FGD system SOx removal units (85% removal efficiency) are included.

Pre-combustion
Integrated Gasification Combined Cycle



Pre-combustion
Integrated Gasification Combined Cycle

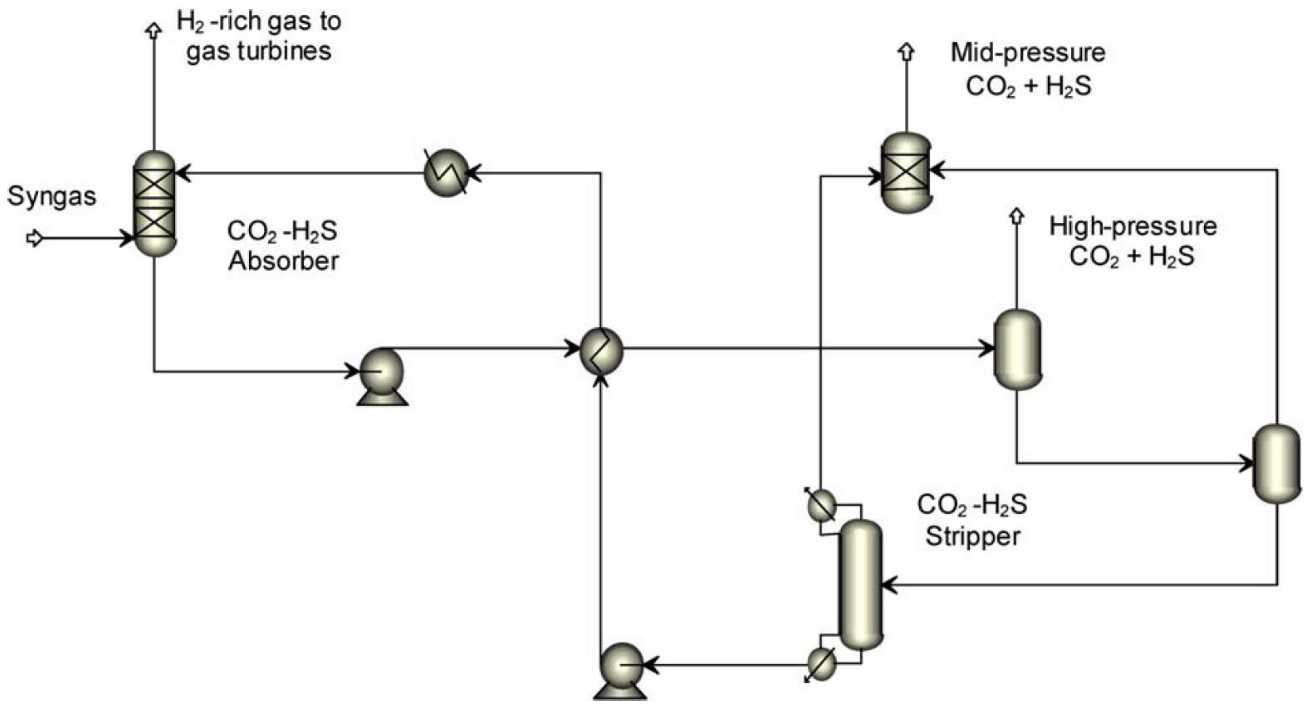
- Selexol™ solvent process with separate capture of sulfur species and CO_2



Ordorica-Garcia, G., Douglas P., Croiset, E., and Zheng, L., Technoeconomic Evaluation of IGCC Power Plants for CO_2 Avoidance, Energ. Convers. Manage. 47, 2250-2259, 2006.

Pre-combustion
Integrated Gasification Combined Cycle

- Selexol™ solvent process with co-capture of sulfur species and CO_2



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Pre-combustion capture scenarios

	Selexol™ co-capture*	Selexol™ separate capture*,**	Rectisol® separate capture*,**
Gross power output (MW_e)	343.3	343.3	343.3
CO_2 capture efficiency (%)	95	95	95
CO_2 captured (kg/MWh)	806.7	885.3	916.3
Net power output (MW)	295.2	268.7	259.6
Net plant efficiency, HHV(%)	33.83	30.78	29.73
Capacity factor (%)	96.5	96.5	96.5
Fixed charge factor (%)	17.21	17.21	17.21

* Based on GE quench gasifier (1+1 spare), 1 GE 7FB gas turbine.

*,** 98% sulfur removal efficiency via hydrolyser and physical solvent system; sulfur recovery via Claus and Beavon-Stretford plants.

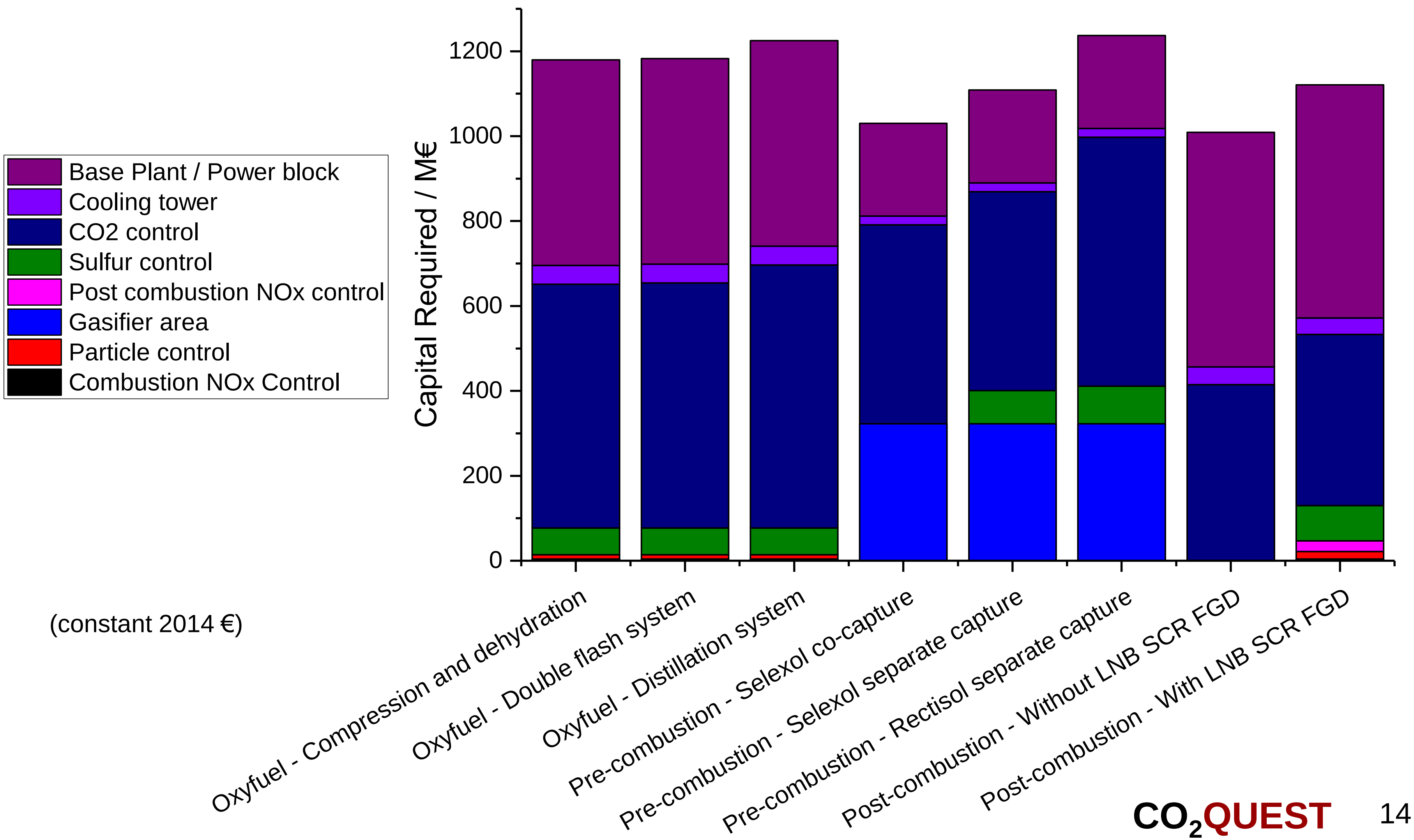
Post-combustion capture scenarios

	ESP particulate control only*	With NOx control by LNB/SCR and SO_2 control by wet-FGD **
Gross power output (MW_e)	400	400
CO_2 capture efficiency (%)	90	90
CO_2 captured (kg/MWh)	1078	1094
Net power output (MW)	321.6	313.8
Net plant efficiency, HHV(%)	25.95	25.66
Capacity factor (%)	96.5	96.5
Fixed charge factor (%)	17.21	17.21

* Supercritical boiler; electrostatic precipitator particulate control system included.

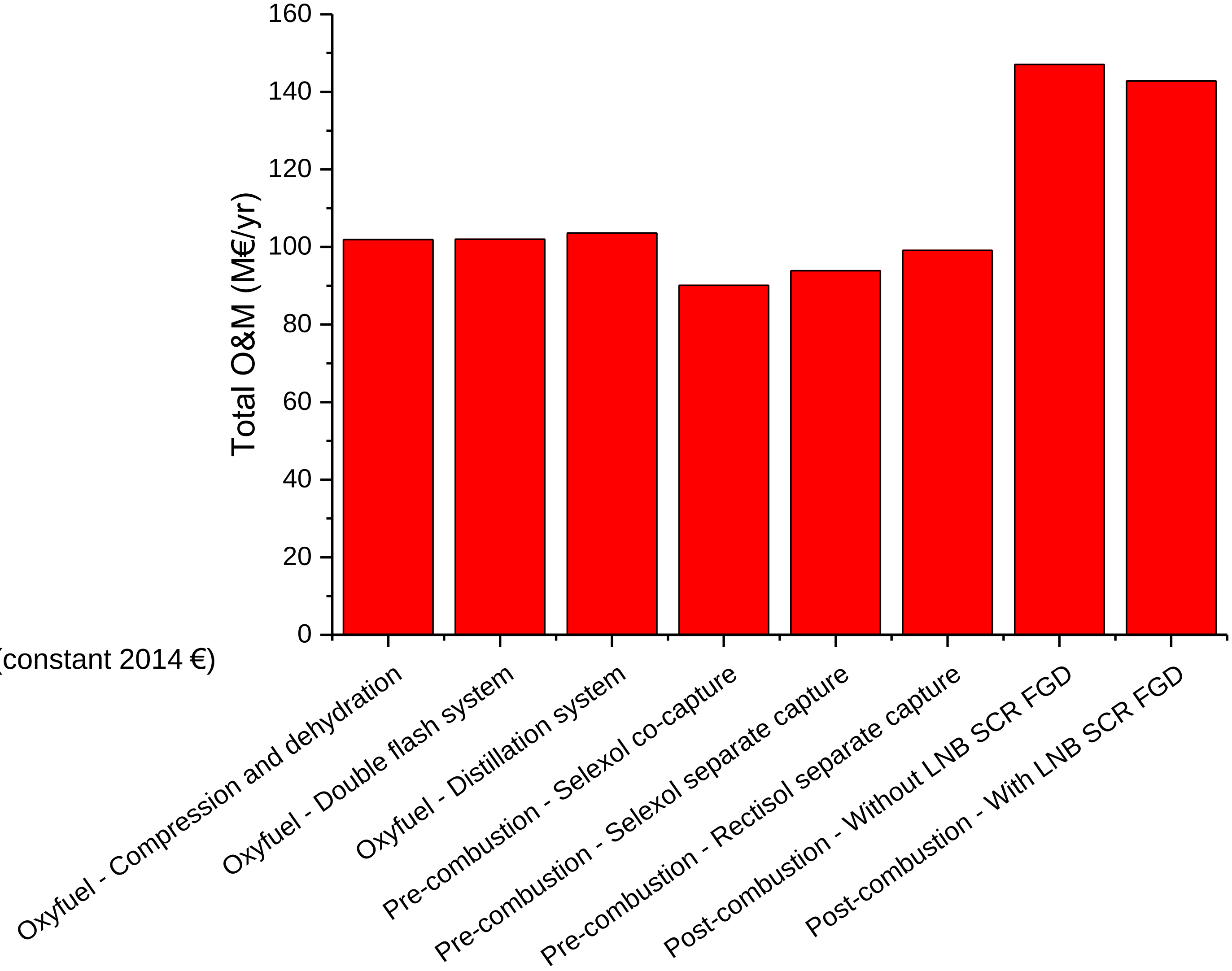
** Supercritical boiler; electrostatic precipitator particulate control system, in-furnace NO_x controls, hot-side SCR and wet FGD SO_2 control included.

Total capital costs



(constant 2014 €)

Total O&M costs



(constant 2014 €)

Cost of Electricity (COE)

$$\text{COE}\ (€/MWh) = \frac{(\text{TCC})(\text{FCF})+\text{FOM}}{(\text{CF})(8760)(\text{MW})} + \text{VOM} + (\text{HR})(\text{FC})$$

TCC = Total capital cost (€)

FCF = Fixed charge factor (fraction)

FOM = Fixed operating & maintenance costs (€/yr)

VOM = Variable O&M costs, excluding fuel costs (€/MWh)

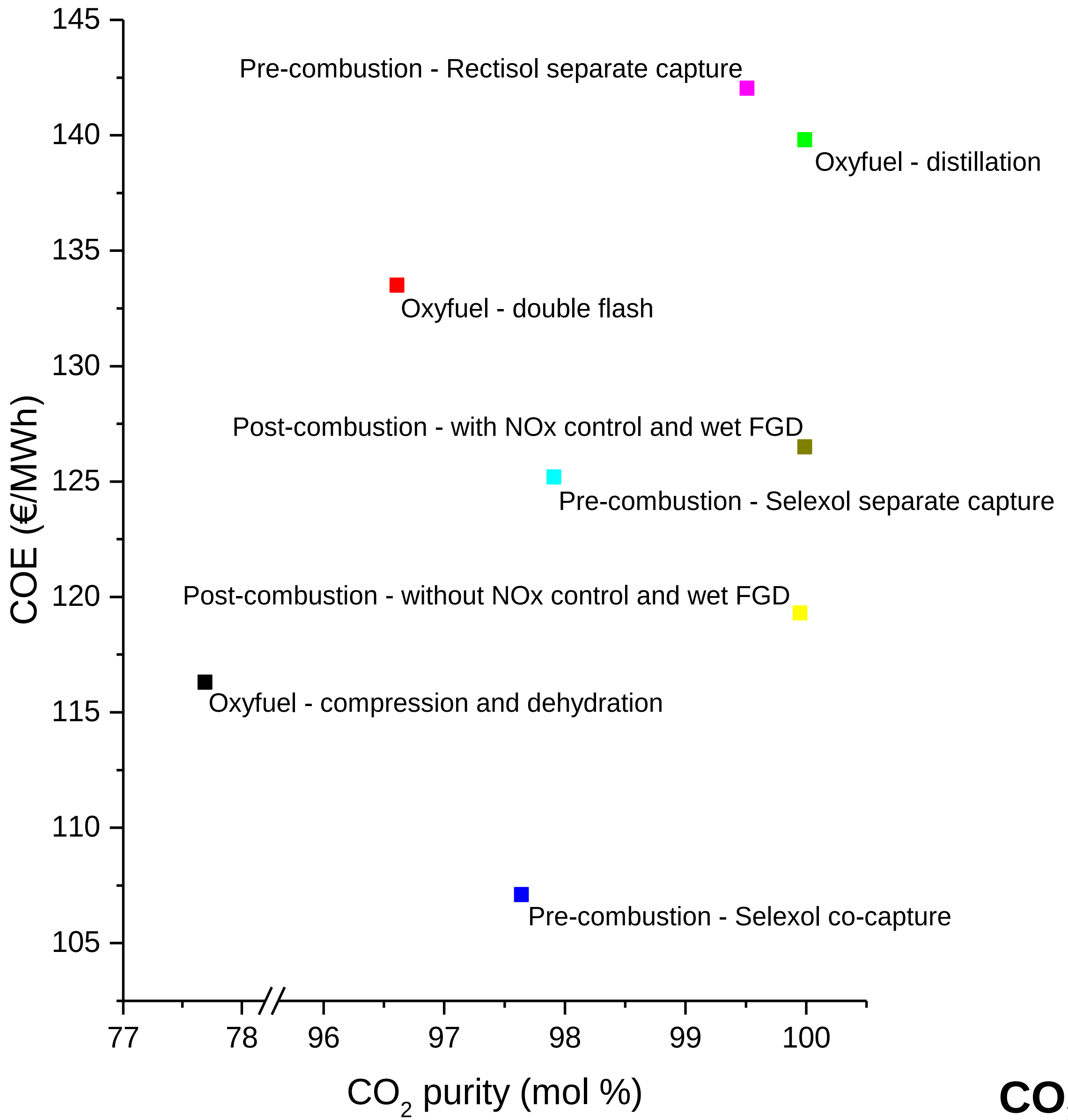
HR = Power plant heat rate (MJ/MWh)

FC = Unit fuel cost (€/MJ)

CF = Annual average capacity factor (fraction)

MW = Net power plant capacity (MW)

Cost of Electricity vs. CO_2 Purity



(constant 2014 €)

Concluding remarks

- Lowest cost technology is pre-combustion capture using the Selexol™ physical solvent with co-capture of impurities technology
  (97.64 mol% CO_2, 3794 ppm_v H_2S, 1.7 mol% H_2, 0.2 mol% CO…)

- Highest estimated cost technology is pre-combustion capture using Rectisol® solvent and with separate capture of sulfur impurities.
  (99.51 mol% CO_2, 1.5 ppm_v H_2S, 0.295 mol% H_2, 0.07 mol% CO…)

- Highest purity technologies jointly oxyfuel-distillation and post-combustion capture with LNB SCR and FGD (99.99 mol% CO_2) with the latter being cheaper.

- Other factors may also affect cost and also CO_2 product purity, including coal selection, retrofit versus new build, and mode of operation of the power plant.

- Gas fired power-plants are likely to produce high purity CO_2 cheaply

Acknowledgements and Disclaimer

The research leading to the results described in this presentation has received funding from the European Union 7th Framework Programme FP7-ENERGY-2012-1-2STAGE under grant agreement number 309102

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