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Petrolchimico

# Milano, 25 novembre 2015

# Advances in $CO_2$ capture technologies in coal-fired power and hydrogen plants

Milan, 25 November 2015



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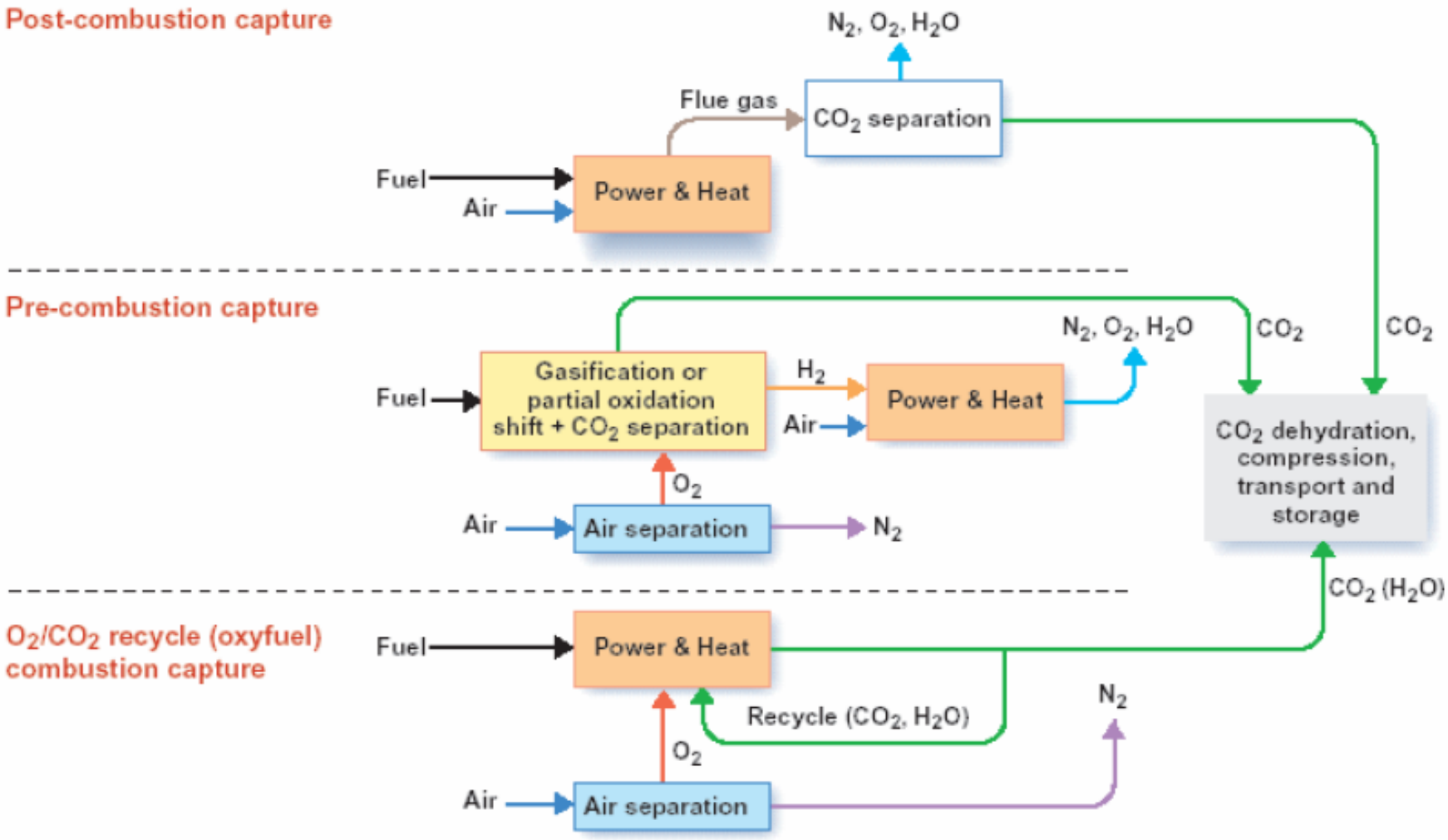
# 3 different process types are considered



# Introduction


## *Acknowledgement*

Fruitful cooperation with various technology suppliers and licensors, which provided an invaluable support for the success of the study


***List in alphabetical order*:**

- Air Products
- Alstom
- Cansolv
- Chiyoda Corporation
- Foster Wheeler
- General Electric Energy
- IHI
- Johnson Matthey
- Mitsubishi Heavy Industries
- Shell
- UOP

# Agenda

1. Study cases and main design bases
2. Key design features
3. Performance & TPC
4. Financial Analysis
5. Summary considerations

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# Study cases

| Type | Case # | Plant | $CO_2$ capture | Key technological features |
|---|---|---|---|---|
| Boiler-based | 1 | SC-PC | - | Alstom wet limestone scrubbing FGD |
| | 2 | SC-PC | 90% | Alstom wet limestone scrubbing FGD<br>CANSOLV solvent scrubbing |
| | 3 | Oxy<br>SC-PC | 90% | FW's CFB & FGD technology<br>Air Products' cryogenic purification unit |
| IGCC-based | 4.1 | IGCC | 90% | Shell coal gasification process, RC<br>UOP Selexol™ solvent scrubbing |
| | 4.2 | IGCC | 90% | General Electric, RSC<br>UOP Selexol solvent scrubbing |
| | 4.3 | IGCC | 90% | MHI, air-blown<br>UOP Selexol solvent scrubbing |
| $H_2$ & Power | 5.1 | IGCC+PSA | 90% | Two (2) E-class gas turbines (130 MWe) |
| | 5.2 | IGCC+PSA | 90% | Two (2) F-class (77 MWe) |
| | 5.3 | Boiler+PSA | 90% | PSA off-gas boiler-based |

# Main design bases

- Greenfield location in The Netherlands (EU): sea level and Tamb 9°C
- Eastern Australian bituminous coal: LHV is 25.87 MJ/kg (AR)
- Pulverised coal plants: 27 MPa/600°C/620°C
- IGCC plants: two state-of-the-art F-class, 50 Hz gas turbines
- Net power output of SC-PC without capture around 1,000 MWe
- SC-PC plants with $CO_2$ have same thermal capacity
- $CO_2$: P 11 MPa, $O_2$ 100 ppm, $H_2S$ 20 ppm, $H_2O$ 50 ppm
- Overall gaseous emissions

| Item | SC-PC cases(1) | IGCC cases(2) |
|---|---|---|
| NOx (as $NO_2$) | ≤ 150 mg/Nm$^3$ | ≤ 50 mg/Nm$^3$ |
| SOx (as $SO_2$) | ≤ 150 mg/Nm$^3$ | ≤ 10 mg/Nm$^3$ |

Notes: (1) @ 6% $O_2$ volume dry. (2) @ 15% $O_2$ volume dry

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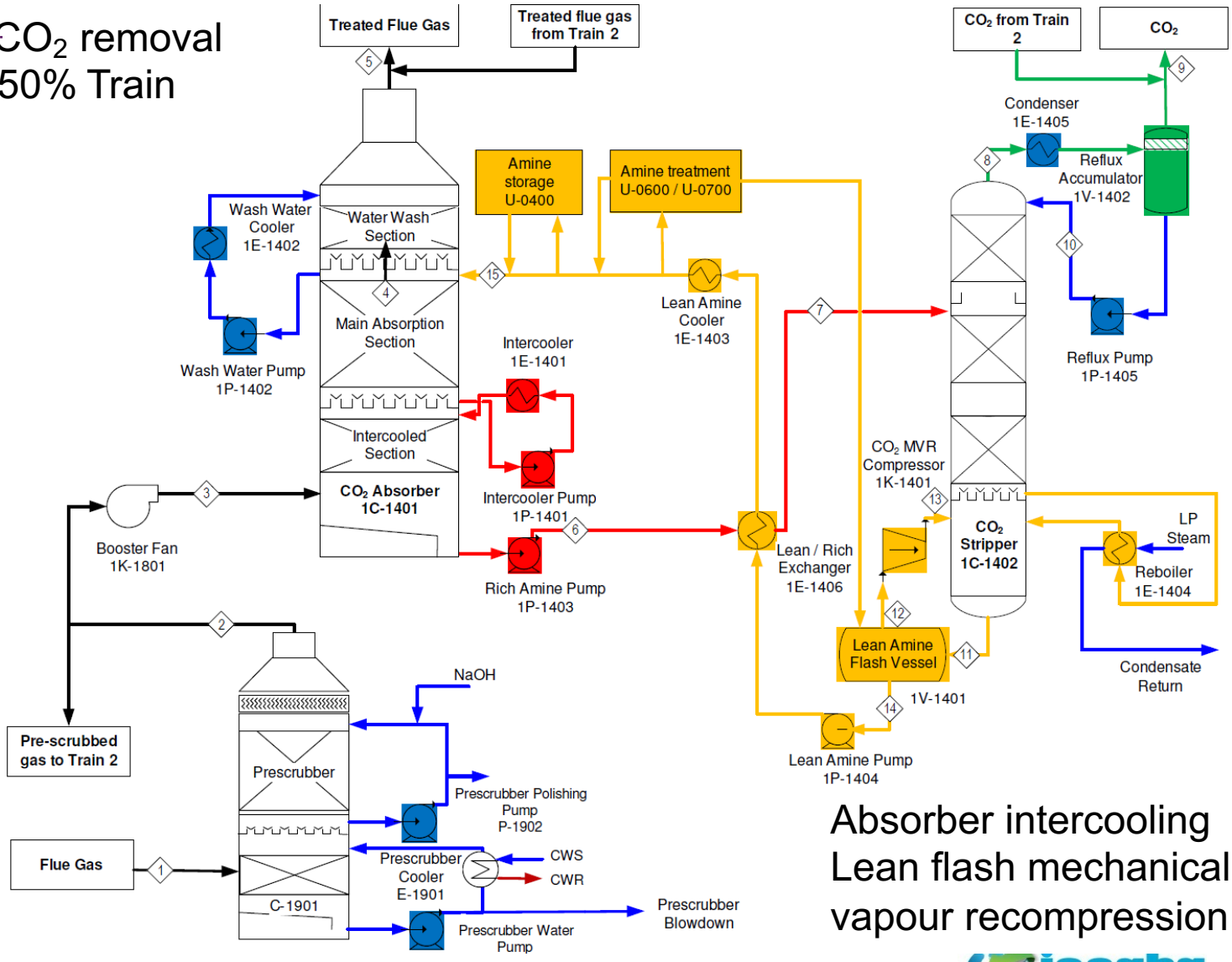
# SC-PC with $CO_2$ capture: Cansolv process

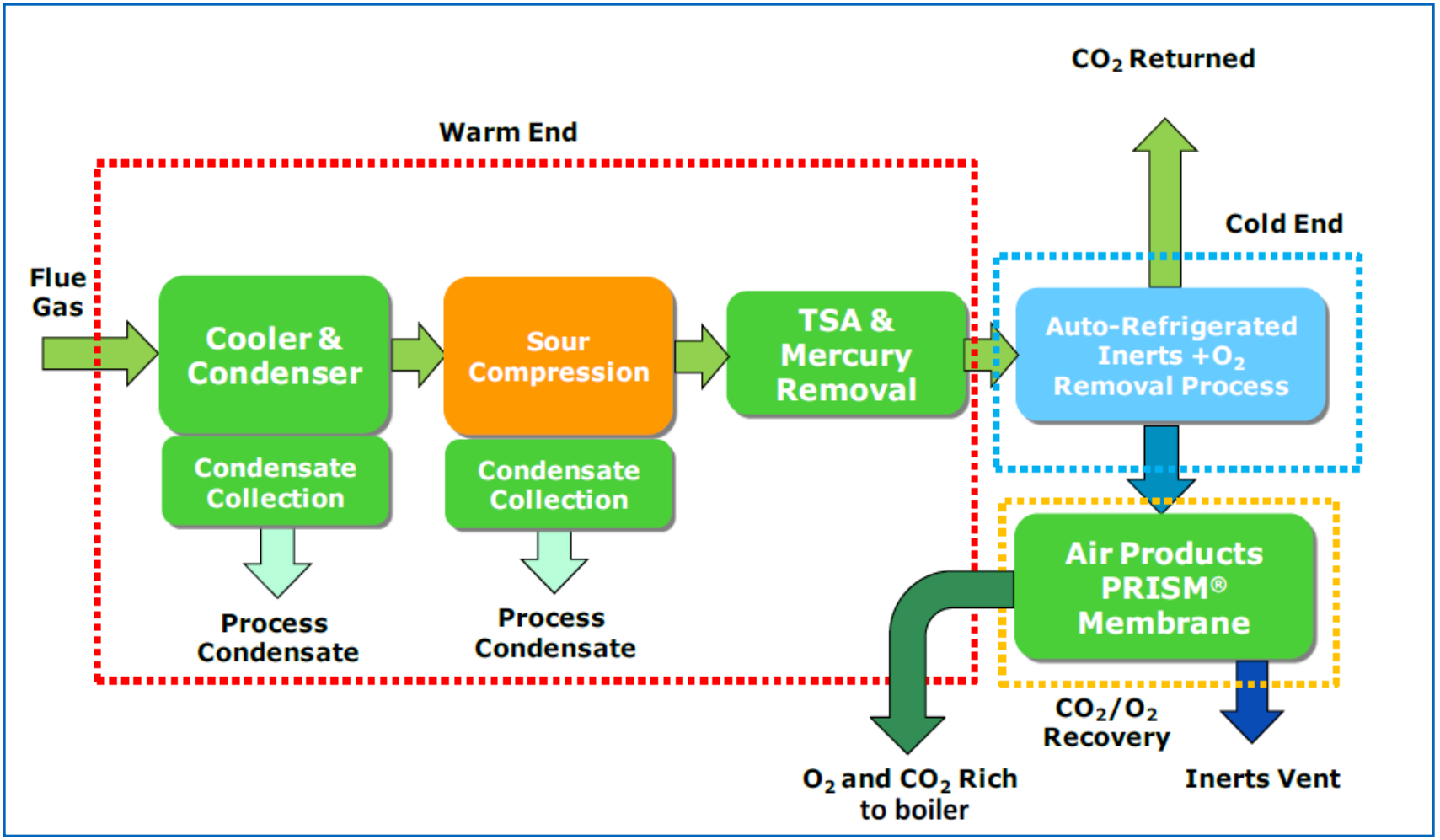
~~90% $CO_2$~~ removal
2×50% Train



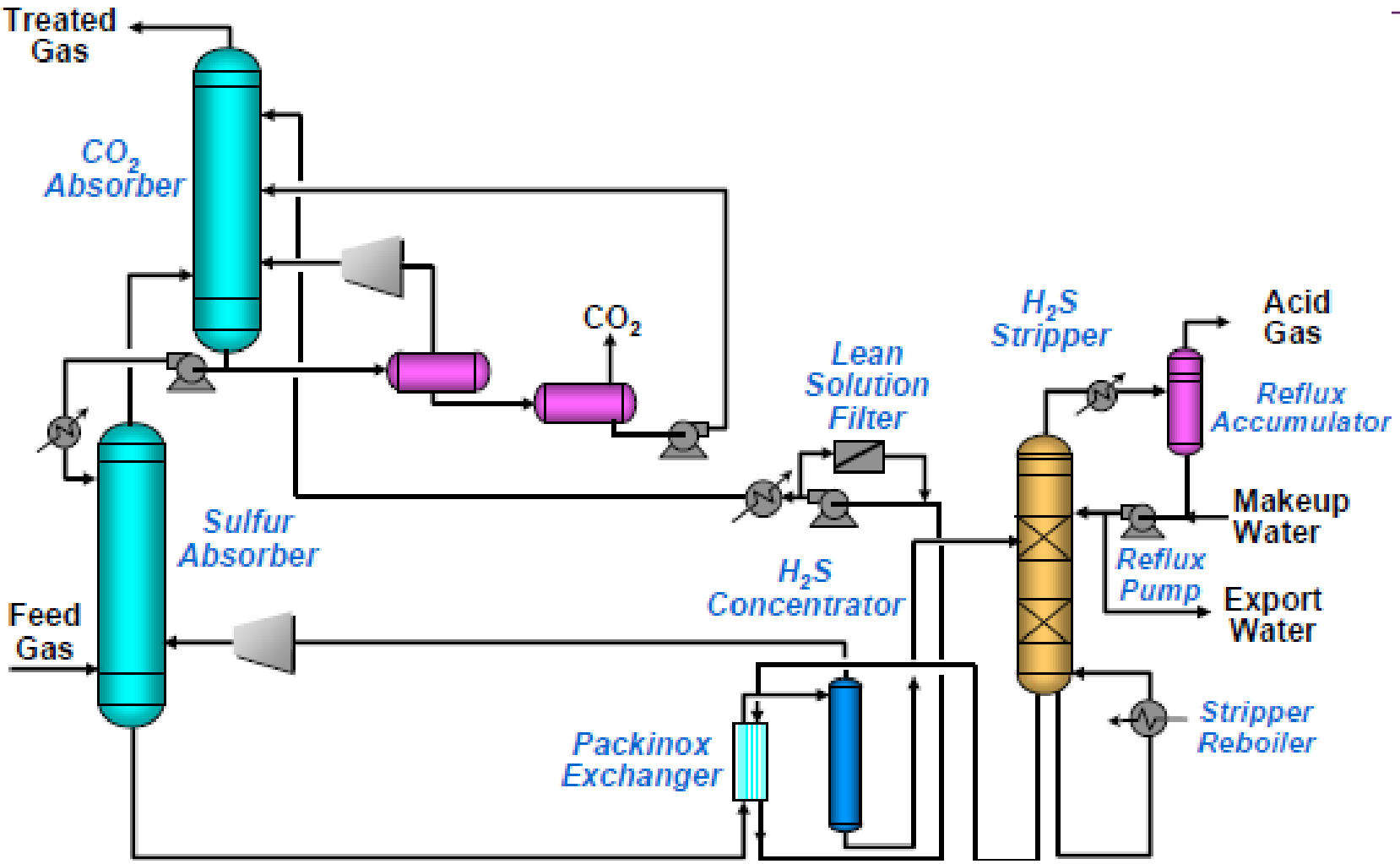

Absorber intercooling
Lean flash mechanical vapour recompression

# Oxy-combustion and CPU

## Air Products' process



# IGCC with $CO_2$ capture: UOP process (Selexol)




Source: http://www.uop.com/?document=uop-selexol-technology-for-acid-gas-removal&download=1

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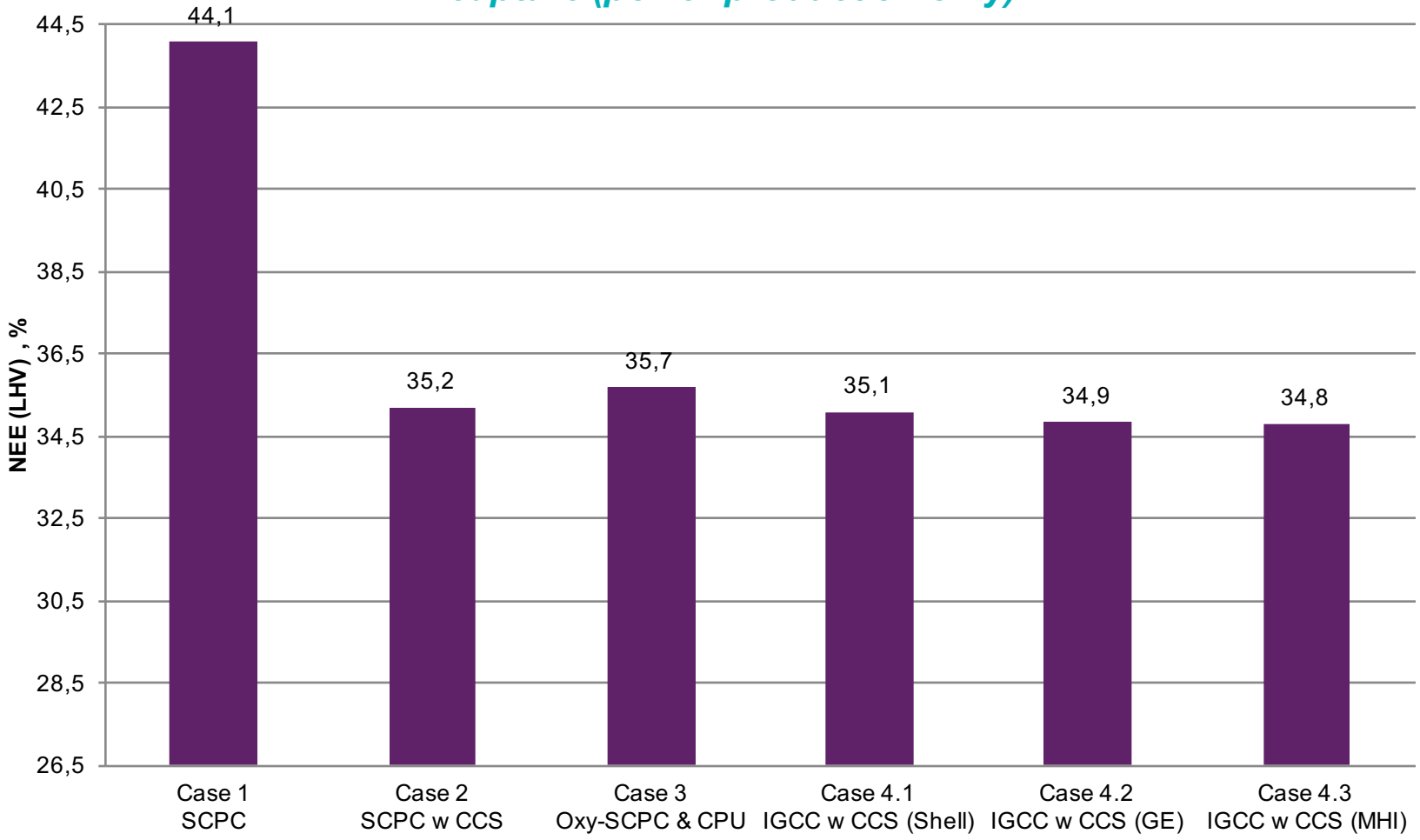
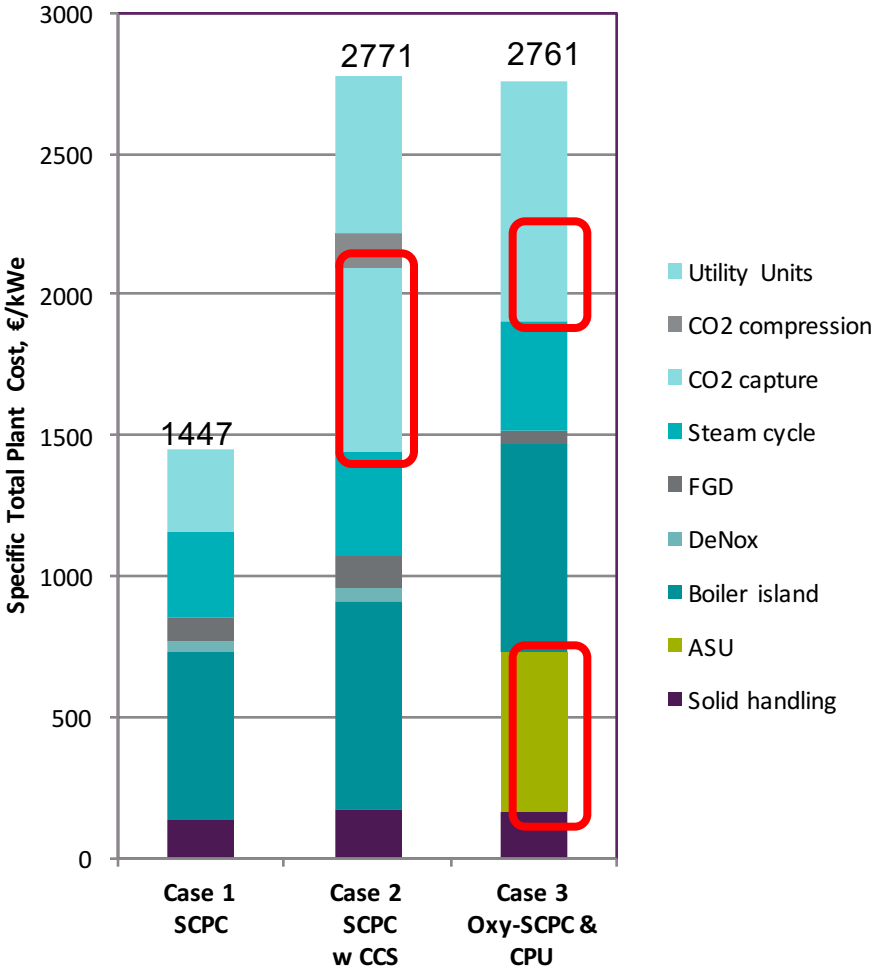
# Power production with and without $CO_2$ capture

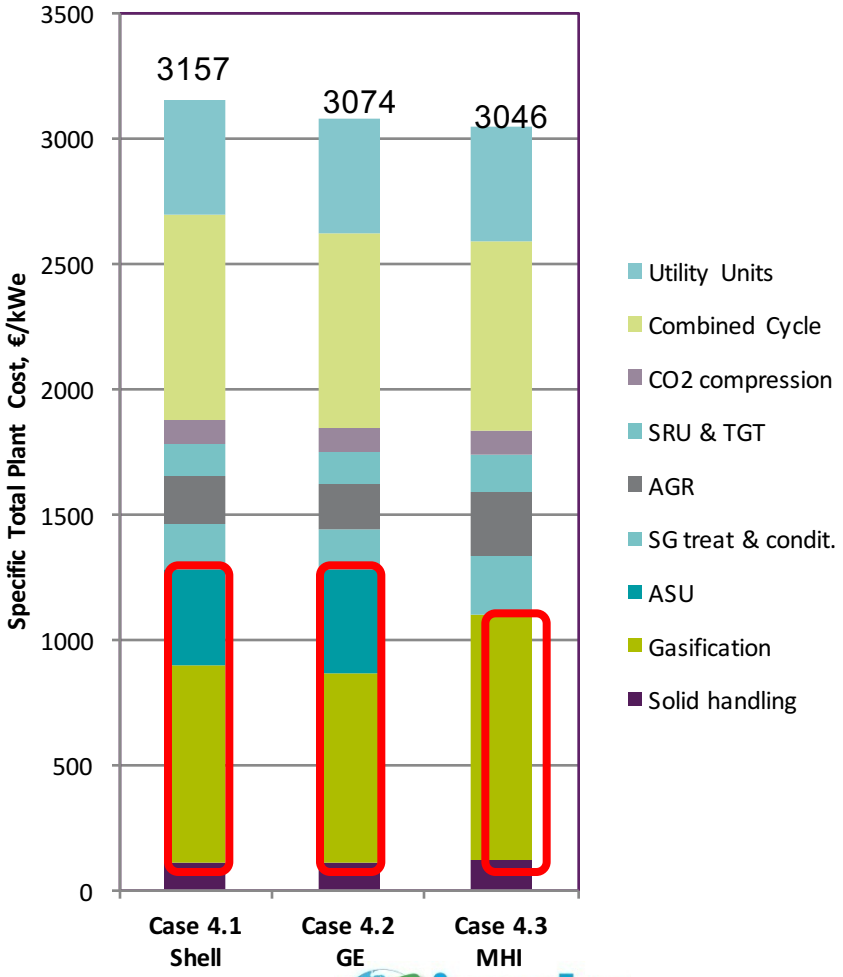
***Net electrical efficiency loss is about 9% points compared to the SC-PC case without capture (power production only)***



# Specific Total Plant Cost Twice the cost of the SCPC without capture

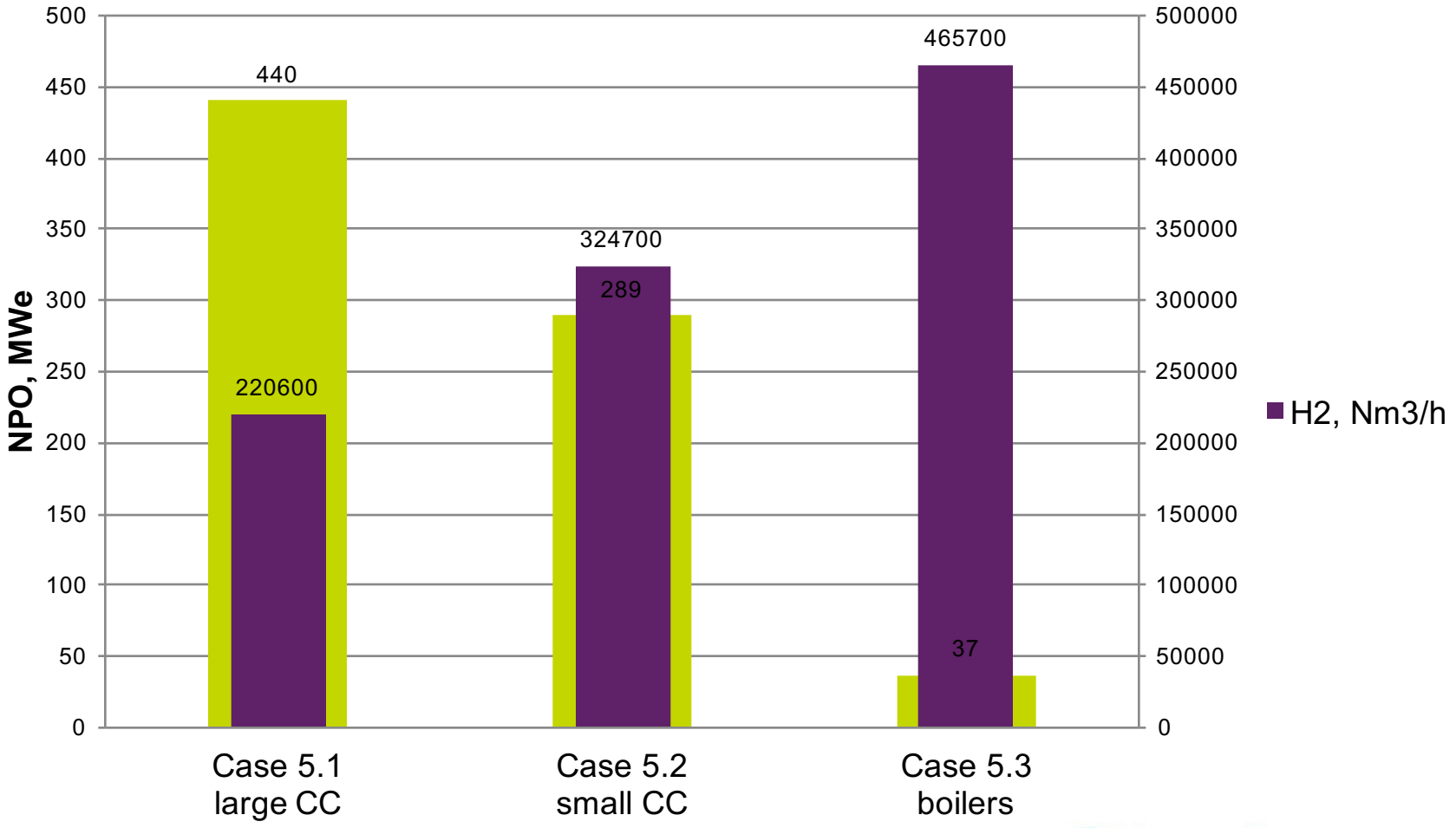
***TPC defined in general accordance with the White Paper "Toward a common method of cost estimation for $CO_2$ capture and storage at fossil fuel power plants" (March 2013), produced collaboratively by authors from EPRI, IEAGHG, MIT, IEA, GCCSI, Vattenfall et al.***



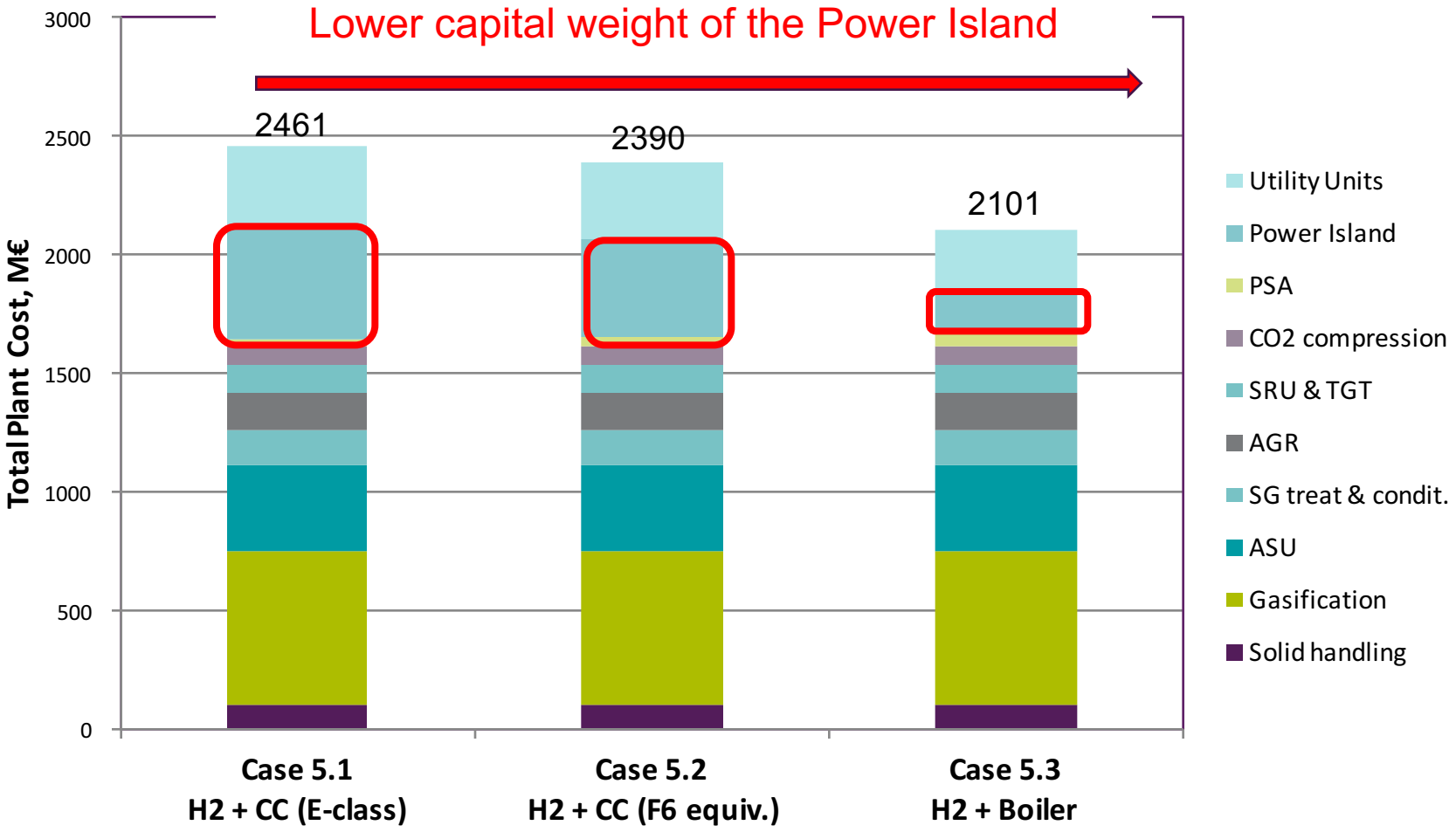
# Hydrogen and Power co-production

***With same coal input, different designs produce different amounts of power and hydrogen***



# Hydrogen and power co-production

***The higher the hydrogen production, the lower the TPC (and NPO)***



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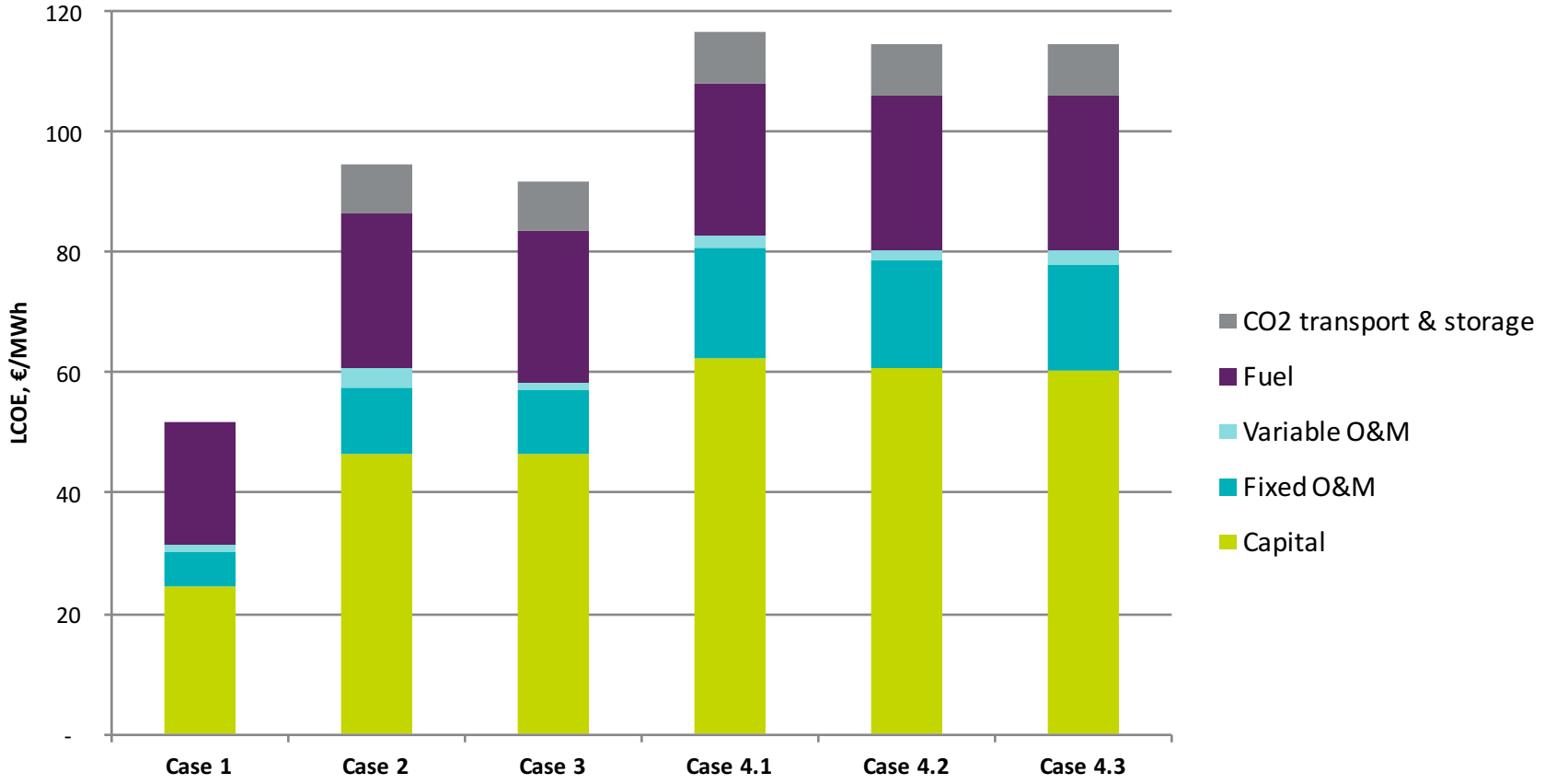
# Financial analysis

## *Main macroeconomic assumptions*

| Item | Unit | Data |
|---|---|---|
| Coal cost | €/GJ (LHV) | 2.5 |
| Discount Rate | % | 8 |
| Plant life | Years | 25 |
| Financial leverage | % debt | 100 |
| Maintenance cost | % of TCR | 1.5% (SCPC)<br>2.5% (IGCC) |
| Load factor | % | 90% (SCPC)<br>85% (IGCC) |
| $CO_2$ transport & storage cost | €/t | 10 |
| $CO_2$ emission cost | €/t | 0 |
| Inflation Rate | % | constant |

# Levelized Cost Of Electricity

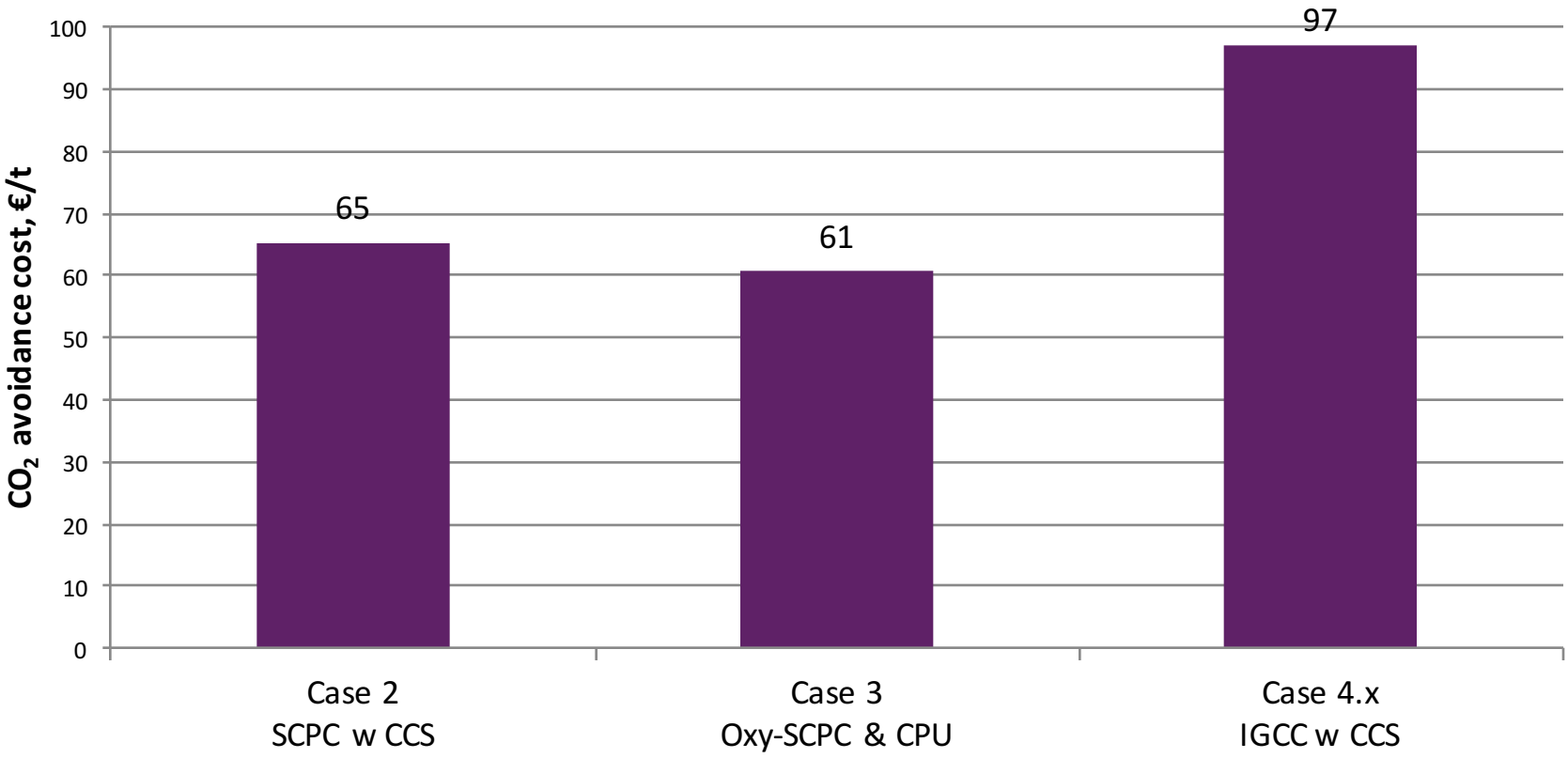
***SC-PC w/ CCS: ~ 93 €/MWh***
***IGCC w/ CCS: ~ 115 €/MWh***




**Bituminous Coal: 2,5 €/GJ (LHV); Discount rate: 8%**
**$CO_2$ transport & storage: 10 €/t; 90% / 85% capacity factor (SC PC/gasif); Constant €, 2013.**

# $CO_2$ avoidance cost

***About 63 €/t for boiler based – About 97 €/t for IGCCs***



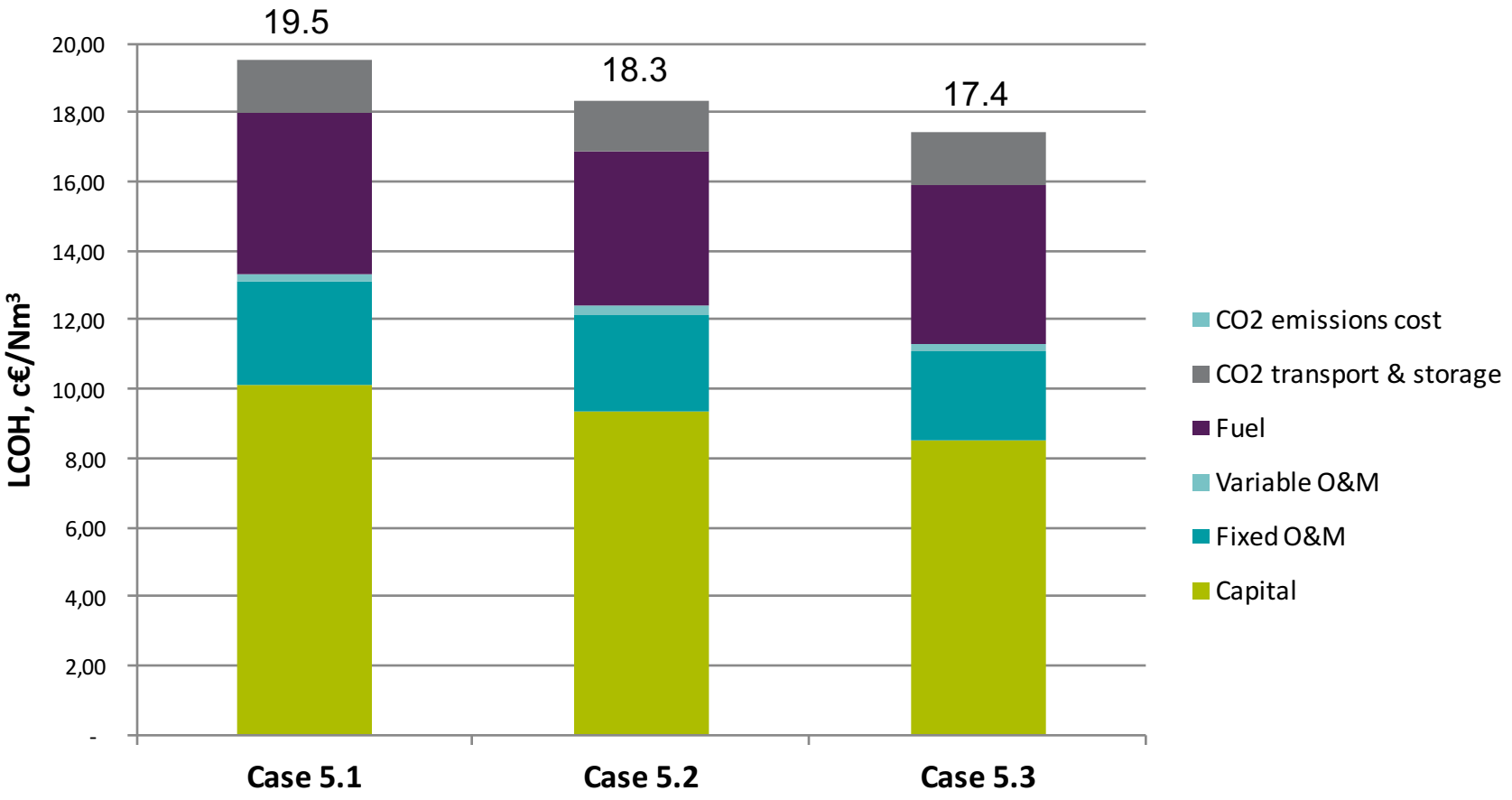

**Reference Plant: Case 1 (SC-PC without $CO_2$ capture)**

**Bituminous Coal: 2,5 €/GJ (LHV); Discount Rate: 8%**

**$CO_2$ transport & storage: 10 €/t; 85% load factor; Constant €, 2013.**

# LCOH (for price of electricity= ~ 115 €/MWh)

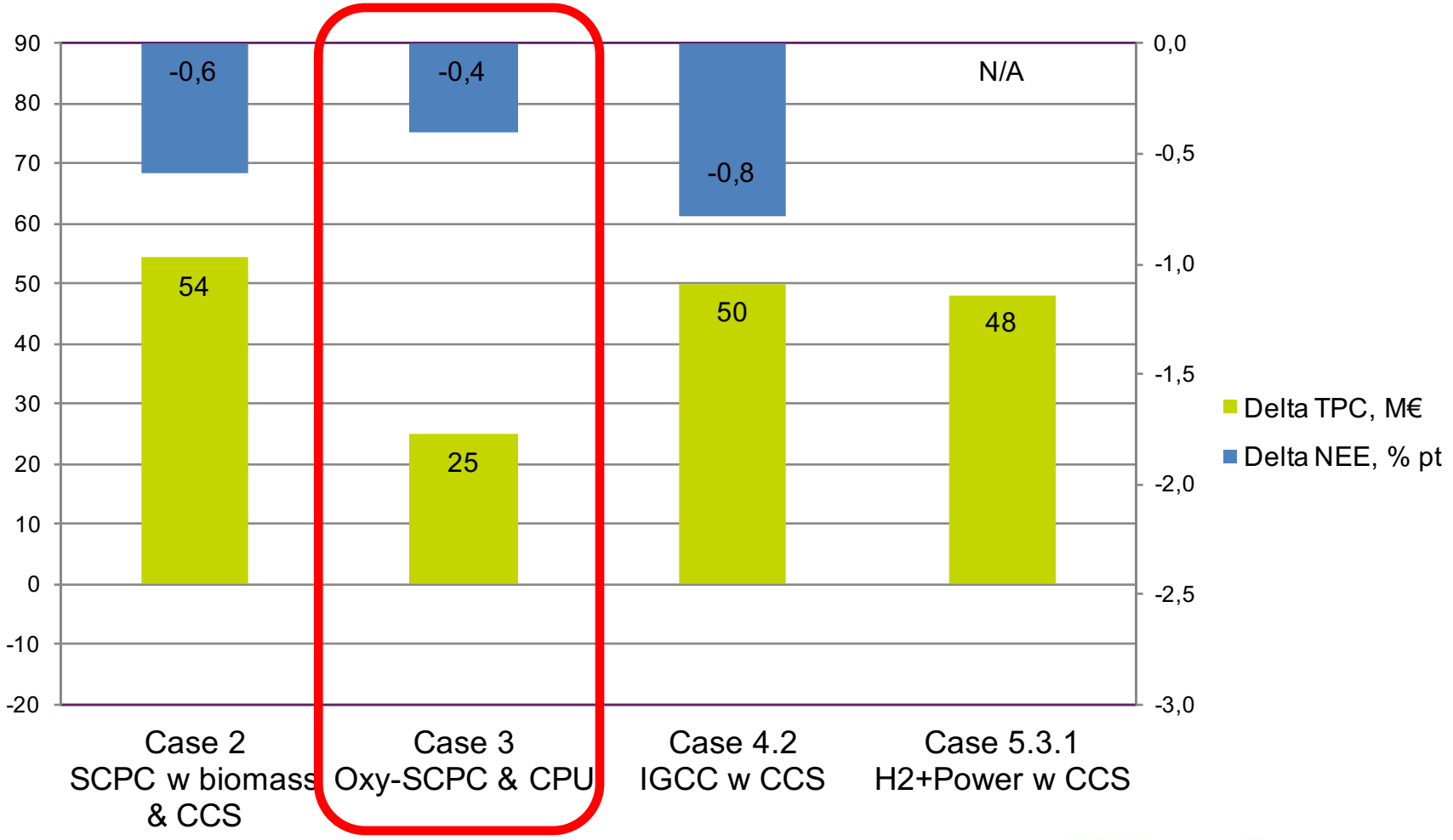
***Lower for higher hydrogen production cases***
***(higher capital of the Power Island not refunded by the higher power)***



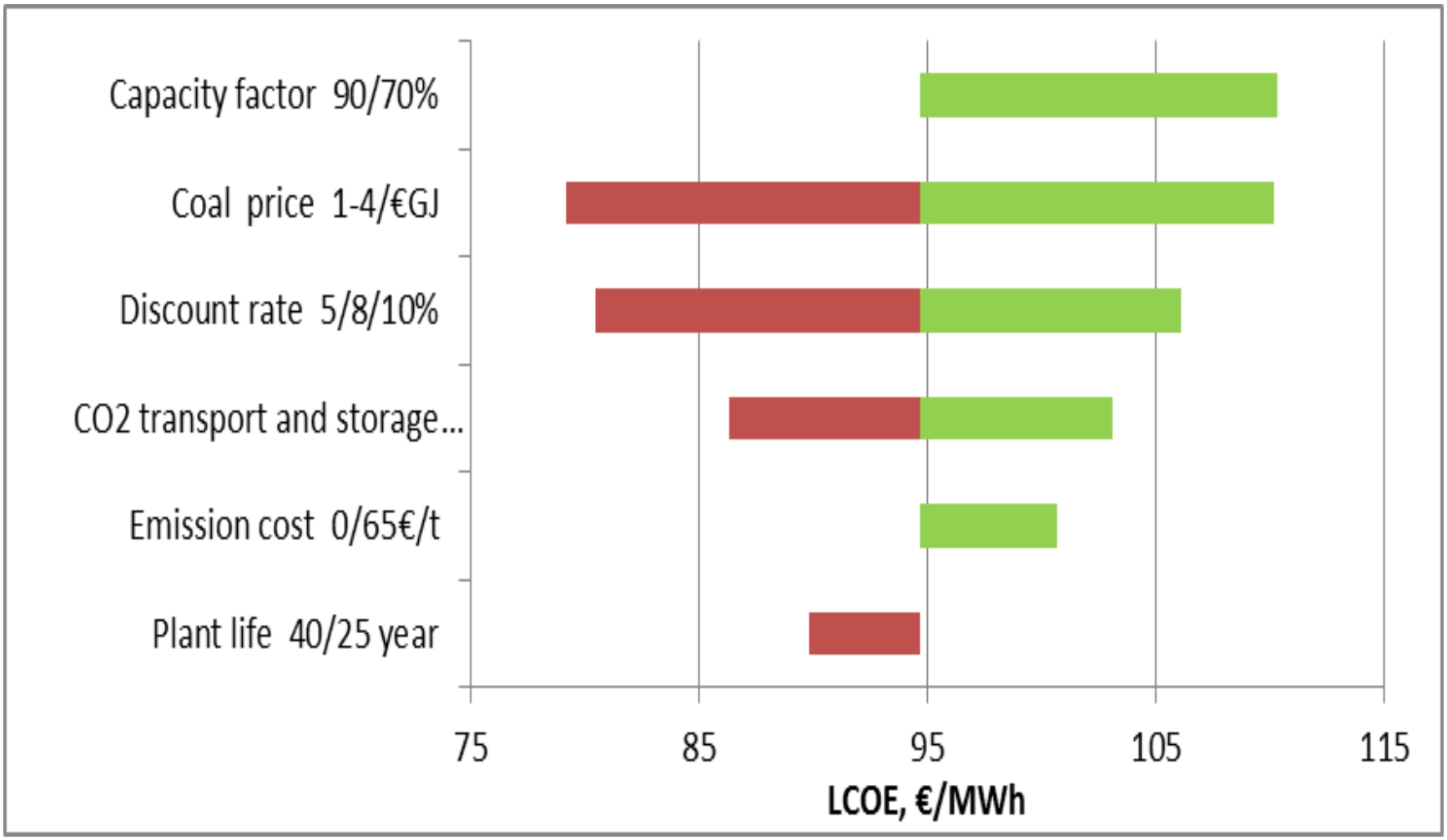

**Bituminous Coal: 2,5 €/GJ (LHV); Discount Rate: 8%**
**$CO_2$ transport & storage: 10 €/t; 85% load factor; Constant €, 2013.**

# Near zero emission cases

## *Particularly favorable in oxy-combustion power plants*



# Sensitivity of LCOE (post combustion capture)



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# Summary considerations

***$CO_2$ capture at coal-fired power and hydrogen plants***

- Study has provided an up-to-date assessment of performance and costs of various coal fired power and hydrogen plants, with and without capture of the generated $CO_2$

- The three leading capture technologies lead to a worsening of both the plant performance (-9% pt. NEE) and the specific total plant cost (twice the cost of the SCPC w/o capture)

- Only an incentive scheme ranging from 65 €/t (boiler-based cases) to 100 €/t (IGCC-based cases) of captured $CO_2$ would make the investment economically viable

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