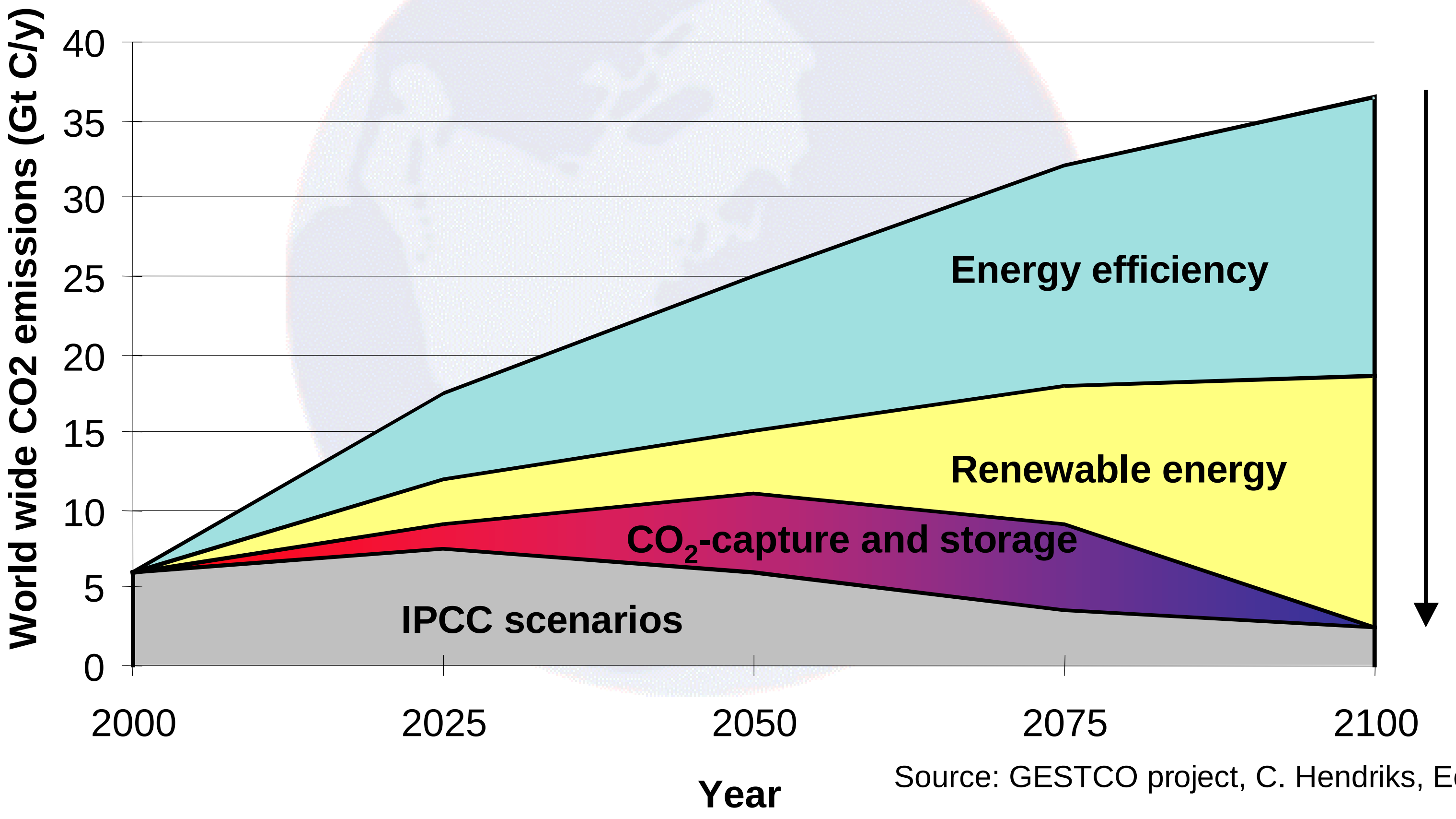
CO_2 capture and storage (CCS)

Techno-economic studies

Role of CCS for limiting GHG in the atmosphere



Source: GESTCO project, C. Hendriks, Ecofys

Cost of CCS

How much it costs to avoid a tonne of carbon dioxide entering the atmosphere?

US$/t CO_2 avoided	Natural Gas Combined Cycle reference plant	Pulverized Coal reference plant
Power plant with capture and geological storage		
Natural Gas Combined Cycle	40-90	20-60
Pulverized Coal	70-270	30-70
Integrated Gasification Combined Cycle	40-220	20-70

IPCC Special Report on Carbon Dioxide Capture and Storage, September 2005

Cost of CCS (2)

Costs of Enhanced Oil Recovery instead of normal geological storage can be obtained by subtracting:

Ø 20 to 30 US$/t CO_2

How much CCS would increase the cost of electricity, compared to current prices?

Ø 0.02 to 0.03 US$/kWh

IPCC Special Report on Carbon Dioxide Capture and Storage, September 2005

Cost of CCS and efficiency penalty

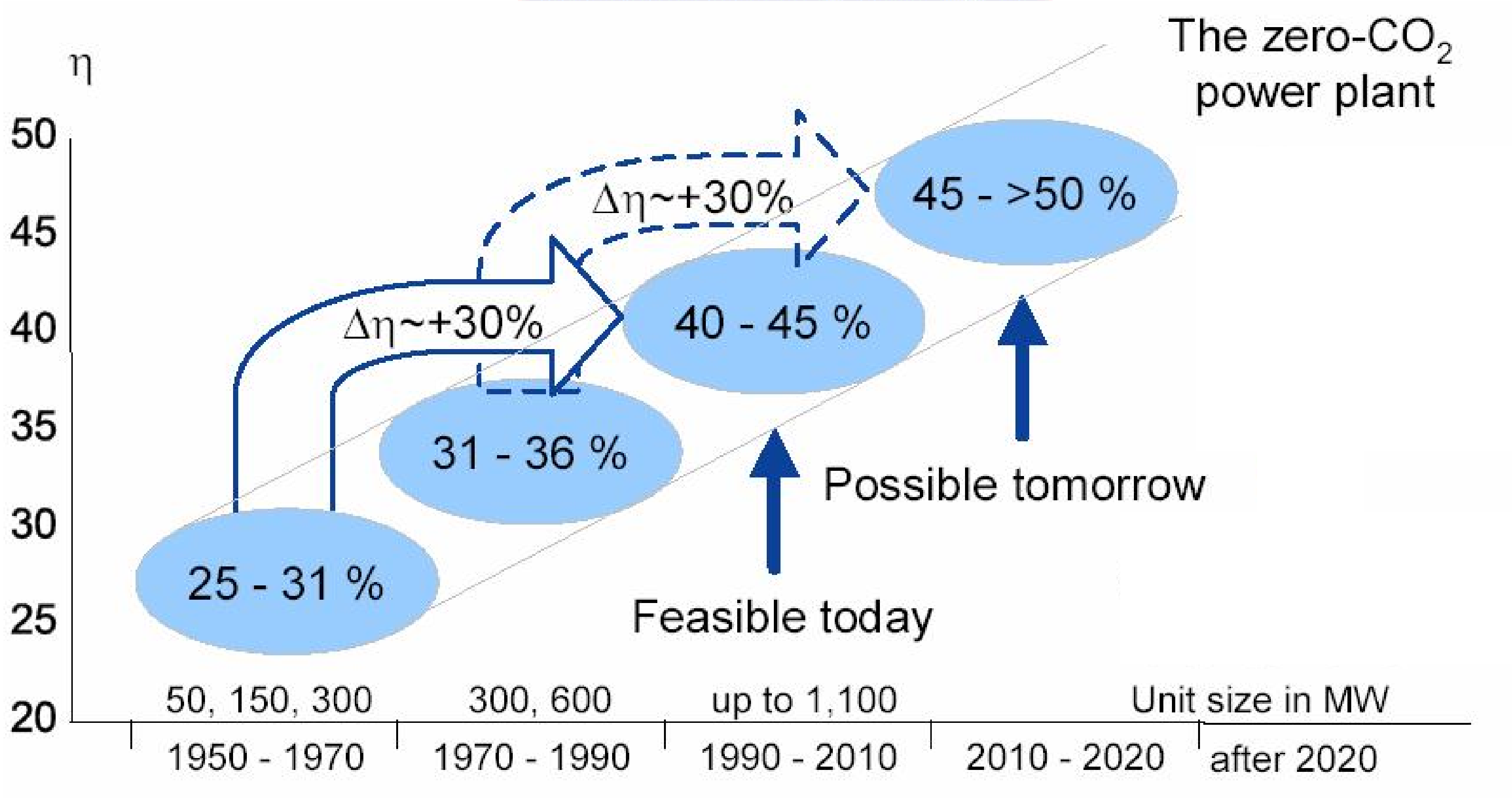
Cost of CCS mainly due to CO_2 capture cost (70% of the CCS costs)

Efficiency drop

- **11 to 22% for Natural Gas Combined Cycle power plants**
- **14 to 25% for IGCC**
- **24 to 40% for Pulverized Coal power plant with supercritical steam cycle**

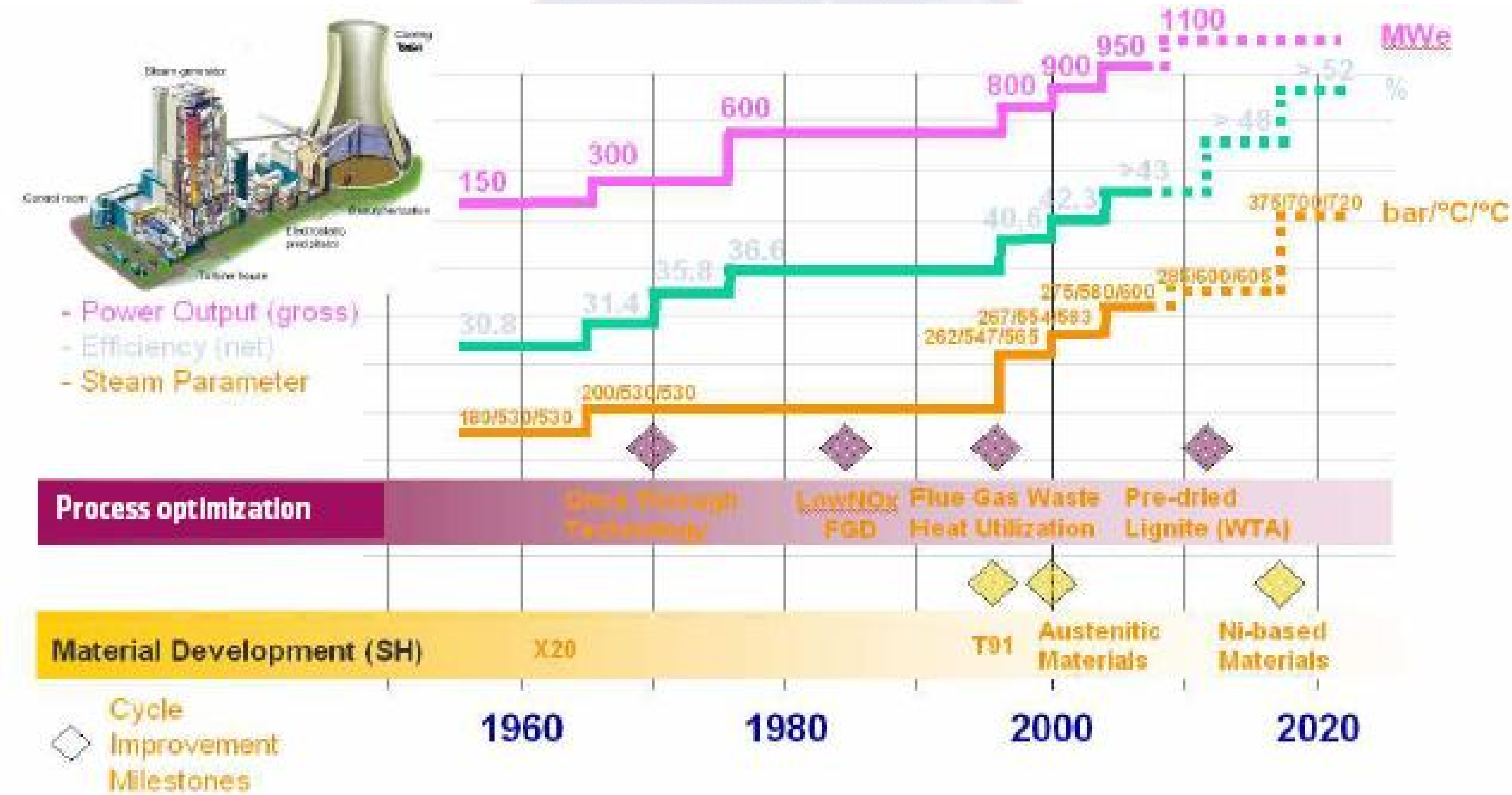
IPCC Special Report on Carbon Dioxide Capture and Storage, September 2005

Increased efficiency is necessary for CCS



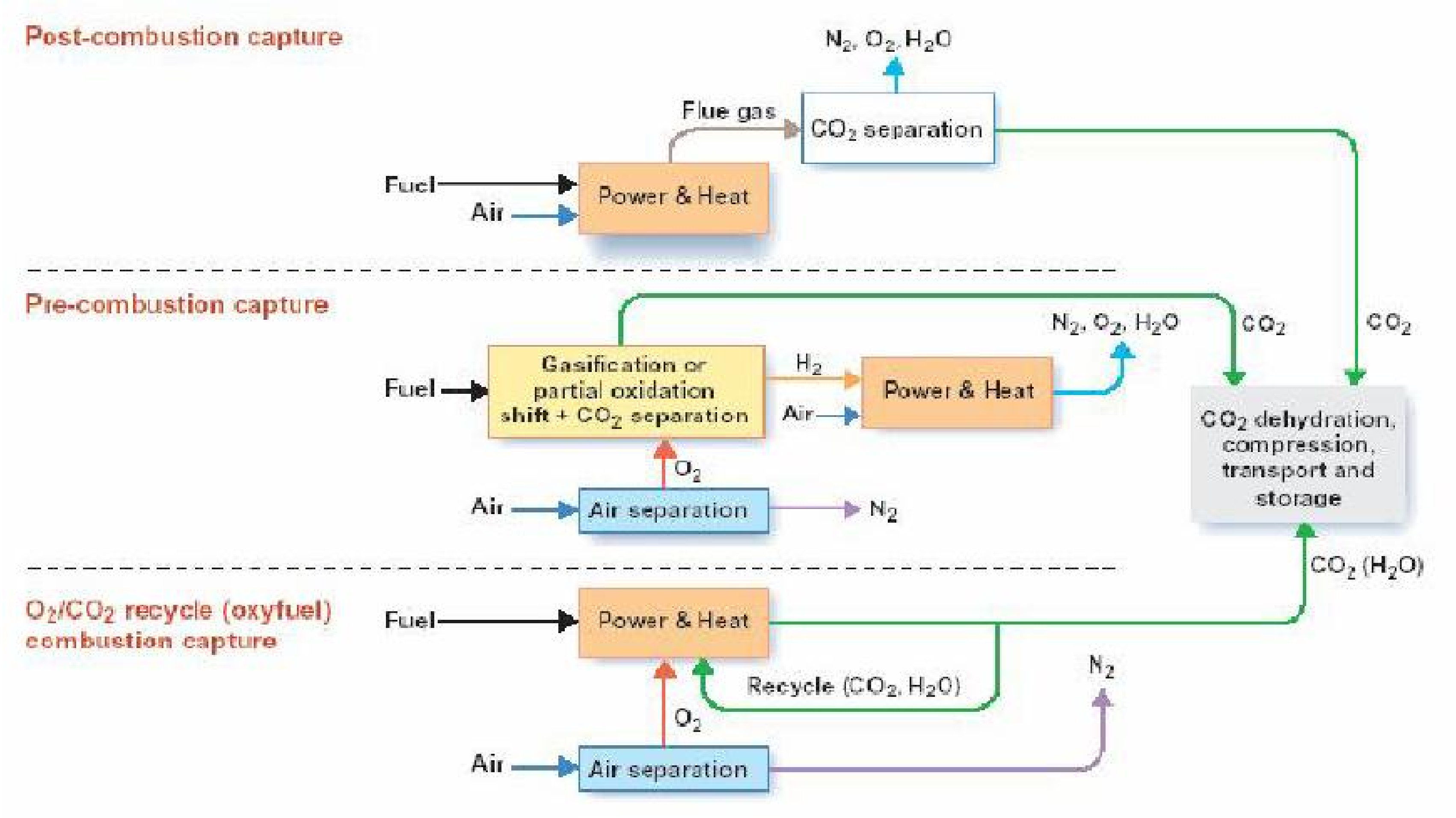
Eurocoal

Advanced cycle for new power plants



Alstom

Three types of CO_2 capture processes

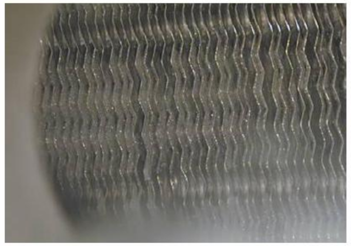


Post-combustion capture

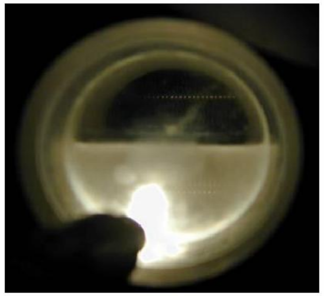
Consist of separating the CO_2 from the exhaust gases using a solvent for example. The most advanced technology today.

Post-combustion capture solutions:

- **absorption (amine, chilled ammonia …)**
- **adsorption**
- **frosting/defrosting at low temperature**
- **…**



CO_2 frosting on the evaporator fins.



Liquid CO_2 after defrosting.

Oxy-combustion capture

Consist of burning a fuel in oxygen instead of air. The gases produced by the oxy-combustion process are mainly water and CO_2, which is easy to capture at the end of the process

A new and promising form of oxy-combustion:

Ø chemical looping

Pre-combustion capture

Gasification of a fuel rich in carbon (coal for example) into a synthetic gas (carbon monoxide and hydrogen)

Several stages of transformation and purification are then needed to transform the gas, remove the CO_2 and obtain a stream of pure hydrogen that can then be burned in a combined cycle power station

CCS deployment

Proposition of ZEP Technology Platform:

- **up to 12 large-scale demonstration plants with CCS built by around 2015 with the objective of developing CCS until 2020**

Performances and costs of the power plants with CO_2 capture

	Net Power	Efficiency (LHV)	CO_2 capture	Capital cost	Electricity cost
	MW	%	%	€/kW	€c/kWh
Post combustion capture					
Pulverised coal	761.0	35.5	85	1645	5.39
CFB	614.4	35.5	85	1552	5.34
PCFB	688.4	32.5	85	1788	5.55
Oxycombustion					
Pulverised coal	741.3	37.5	93	1882	5.46
Pre-combustion capture					
Future Energy gasifier	665.2	34.7	85.8	1706	5.41
Shell gasifier	628.8	34.5	85.2	1917	5.94
Foster Wheeler gasifier	686.6	34.1	82.9	1795	5.64

Load factor: 85%
Annual discount rate: 10%
Plant operating life: 25 years
Reference coal price: 1€/GJ
2005: 1€ = 1.3 US$ (1.17 US$ by December)

Source: CO_2 capture in low rank coal power plants (IEA GHG 2006/2)

Comparison with and without CO_2 capture and costs of avoiding CO_2 emissions

	Without capture	With capture	Difference due to capture
Plant performance			
Fuel input, MW (LHV)	1729	1729	0
Gross power output, MW	842	758	-84
Ancillary power consumption and losses, MW	50	148	98
Net power output, MW	792	610	-182
Efficiency and emissions			
Thermal efficiency, % (LHV)	45.8	35.3	10.5
Increase in fuel use per kWh, %			30
CO_2 capture efficiency, %		85	
CO_2 emissions, g/kWh	872	170	702
CO_2 captured, g/kWh		962	
Costs			
Capital cost, €/kW net power	1006	1567	561
Electricity cost, €c/kWh (excluding CO_2 storage)	3.46	5.39	1.93
Cost of CO_2 avoidance, €/tCO_2 (excluding storage)			27.5

Source: CO_2 capture in low rank coal power plants (IEA GHG 2006/2)

More performances and costs data in excel sheets

Next steps:

- **homogenize data (units)**
- **consolidate data with new studies or interview of experts**

Thank you for your attention