ELCOGAS

4TH EUROPEAN COAL DAYS

12-14 November 2013 (Brussels)

Coal gasification in Spain – the future of sustainable coal

Francisco García Peña – ELCOGAS Puertollano IGCC plant

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1. The ELCOGAS IGCC power plant

2. Lessons learnt for the future

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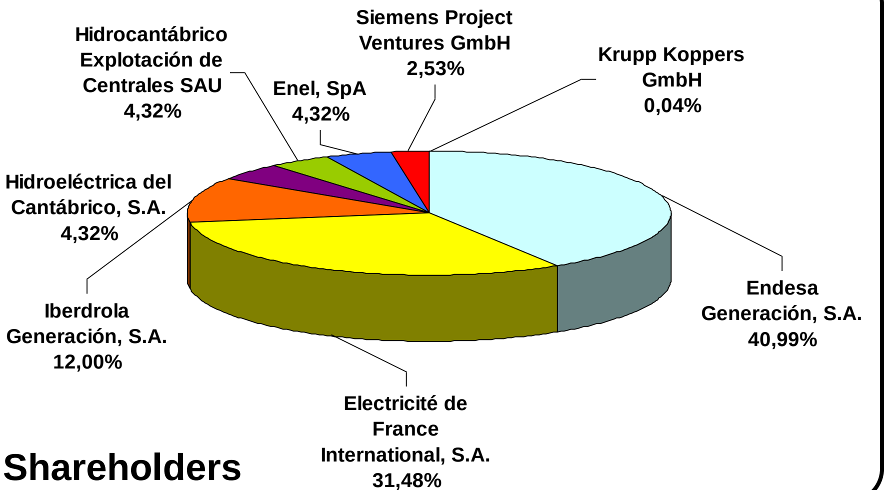
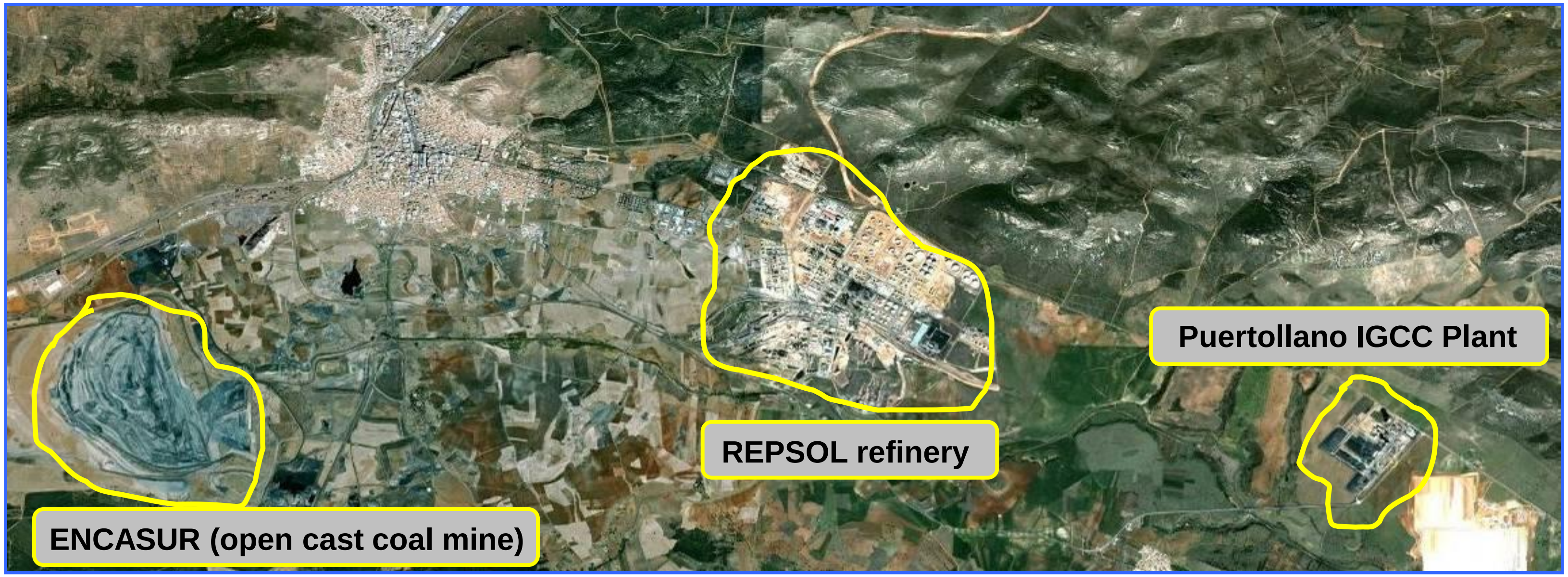
The ELCOGAS company

ELCOGAS is an Spanish company established in April 1992 to undertake the planning, construction, management and operation of a 335 MWe_{ISO} IGCC plant located in Puertollano (Spain)



Shareholders



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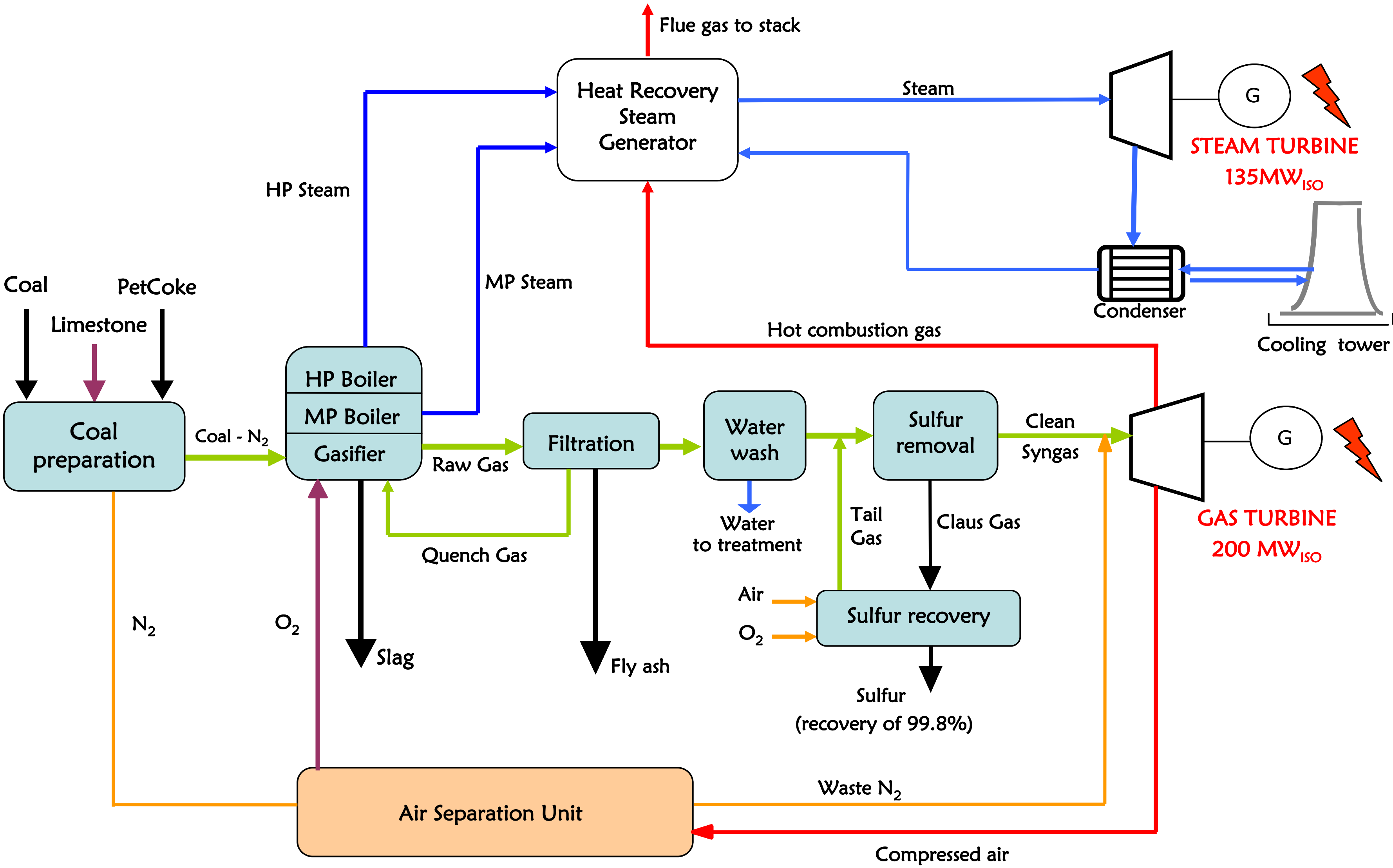
Description of the ELCOGAS IGCC process



Fuel design values

Fuel design is a mixture 50/50 of coal/coke which now is 45/55. Moreover some tests with biomass were undertaken (meat bone meal, grape seed meal, olive oil waste).

	COAL	PET COKE	FUEL MIX (50:50)
Moisture (%w)	11.8	7.00	9.40
Ash (%w)	41.10	0.26	20.68
C (%w)	36.27	82.21	59.21
H (%w)	2.48	3.11	2.80
N (%w)	0.81	1.90	1.36
O (%w)	6.62	0.02	3.32
S (%w)	0.93	5.50	3.21
LHV (MJ/kg)	13.10	31.99	22.55

With those fuels at 50:50, the whole plant demonstrated a gross efficiency of **47,2%** and a net efficiency of **42%**, under acceptance tests in 2000 year

Syngas composition

RAW GAS			CLEAN GAS		
	Real average	Design		Real average	Design
CO (%)	59.26	61.25	CO (%)	59.30	60.51
H_2 (%)	21.44	22.33	H_2 (%)	21.95	22.08
CO_2 (%)	2.84	3.70	CO_2 (%)	2.41	3.87
N_2 (%)	13.32	10.50	N_2 (%)	14.76	12.5
Ar (%)	0.90	1.02	Ar (%)	1.18	1.03
H_2S (%)	0.81	1.01	H_2S (ppmv)	3	6
COS (%)	0.19	0.17	COS (ppmv)	9	6
HCN (ppmv)	23	38	HCN (ppmv)	-	3

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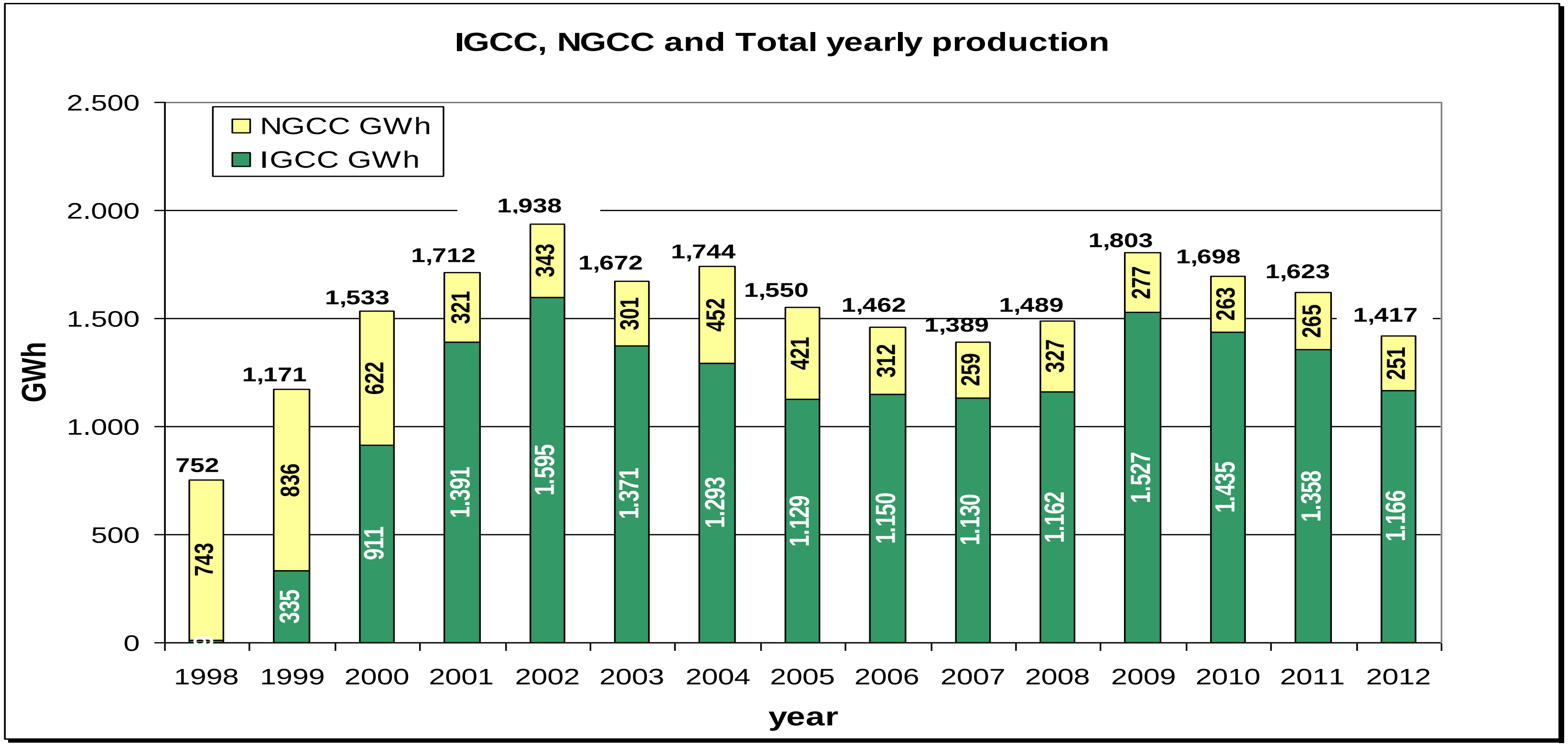
Operational data: Annual energy production



1st 5 years: Learning curve

2003: Major overhaul Gas Turbine findings

2004 & 2005: Gas turbine main generation transformer isolation fault

2006: Gas turbine major overhaul & candle fly ash filters crisis

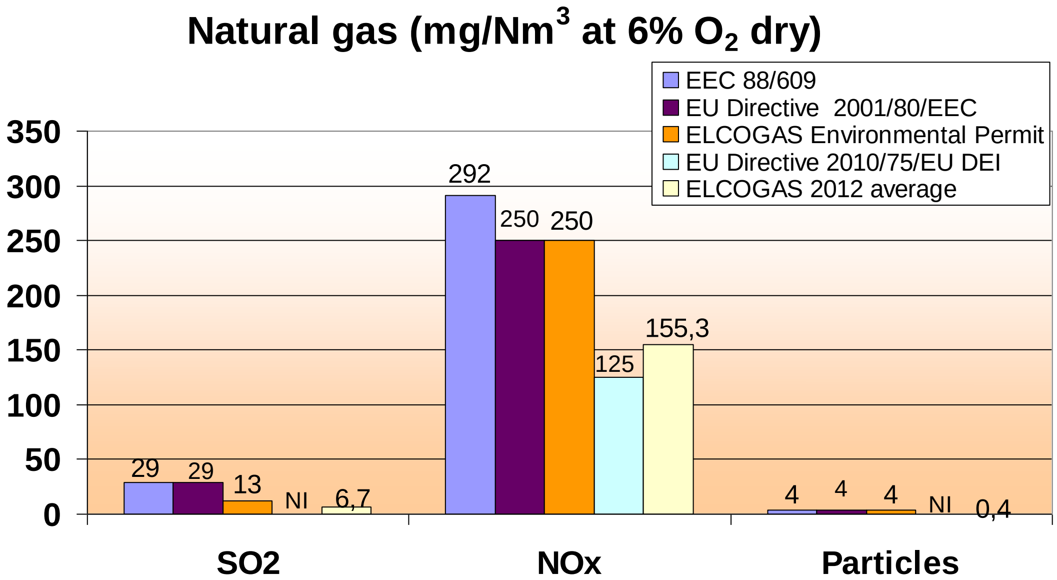
2007 & 2008: ASU WN_2 compressor coupling fault and repair MAN TURBO

2010: No operation due to non-profitable electricity price (30-40 days).

2011: 100,000 EOH Major Overhaul

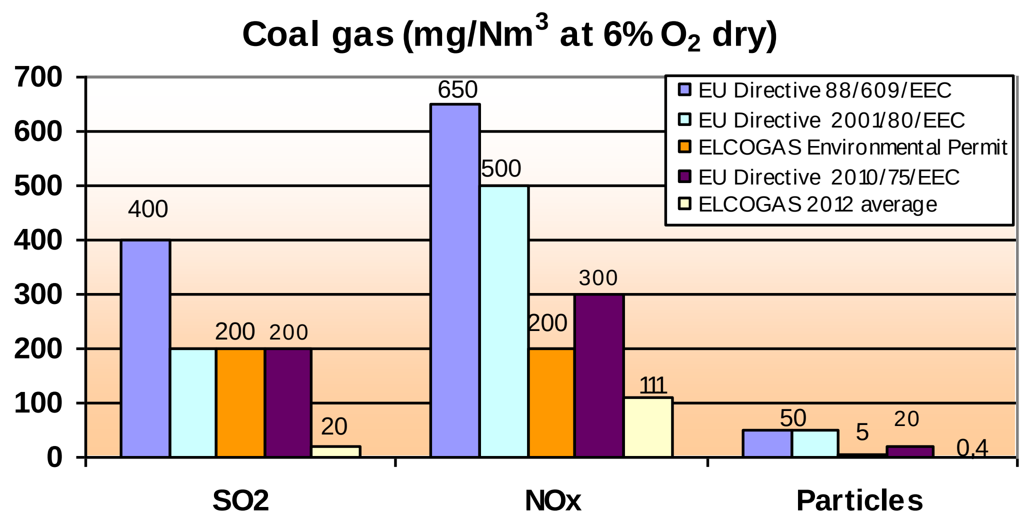
2012: **1,498 hours in stand-by due to regulatory restrictions. (3,969 in 2013)**

Operational data: Emissions 2012



Natural gas (NGCC)

Coal gas (IGCC)



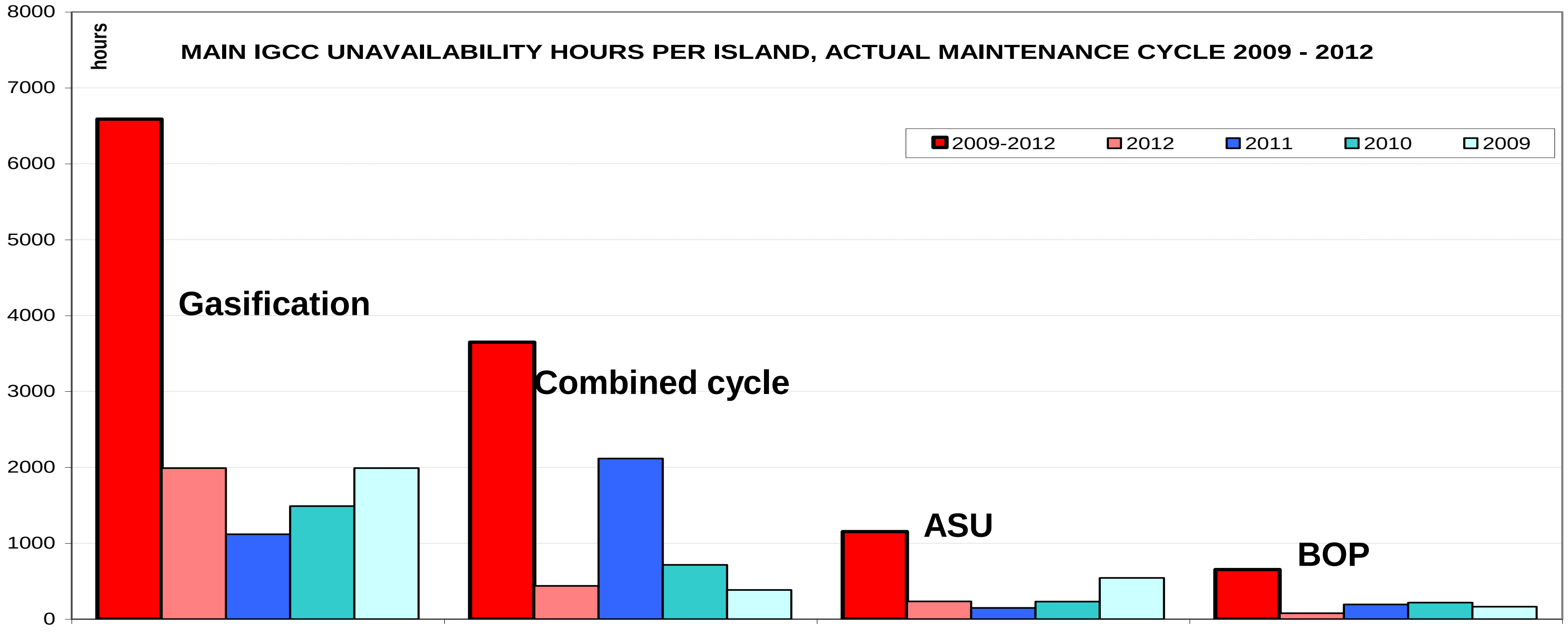
ELCOGAS power plant emissions in NGCC & IGCC modes

Operational data: Variable costs 2012

Fuel mode	Fuel	Consume (GJ_{PCS})	Production (GWh)	Heat rate (GJ_{PCS}/GWh)	Fuel cost (€/GJ_{PCS})	Partial cost (€/MWh)	Total cost (€/MWh)
GT	Natural gas	59.987	2,891	20.748	10,46	216,98	**216,98**
NGCC	**Natural gas**	**249.495**	**22,154**	**11.262**	**10,46**	**117,77**	**117,77**
NGCC + ASU	Natural gas	1.854.675	155,148	11.954	10,46	125,01	**125,01**
NGCC+ASU+ Gasifier (by flare)	Natural gas	351.147	33,373	10.522	10,46	110,03	**128,69**
	Coal	67.459		2.021	3,49	7,05	
	Petocke	195.947		5.871	1,98	11,61	
IGCC	**NG auxiliar consumption**	**257.700**	**992,811**	**260**	**10,46**	**2,71**	**26,30**
	Coal	**2.536.891**		**2.555**	**3,49**	**8,91**	
	Petocke	**7.368.734**		**7.422**	**1,98**	**14,67**	

Note: Net energy variable costs (average 2012)

Unavailability in 4 years maintenance cycle (2009–2012)

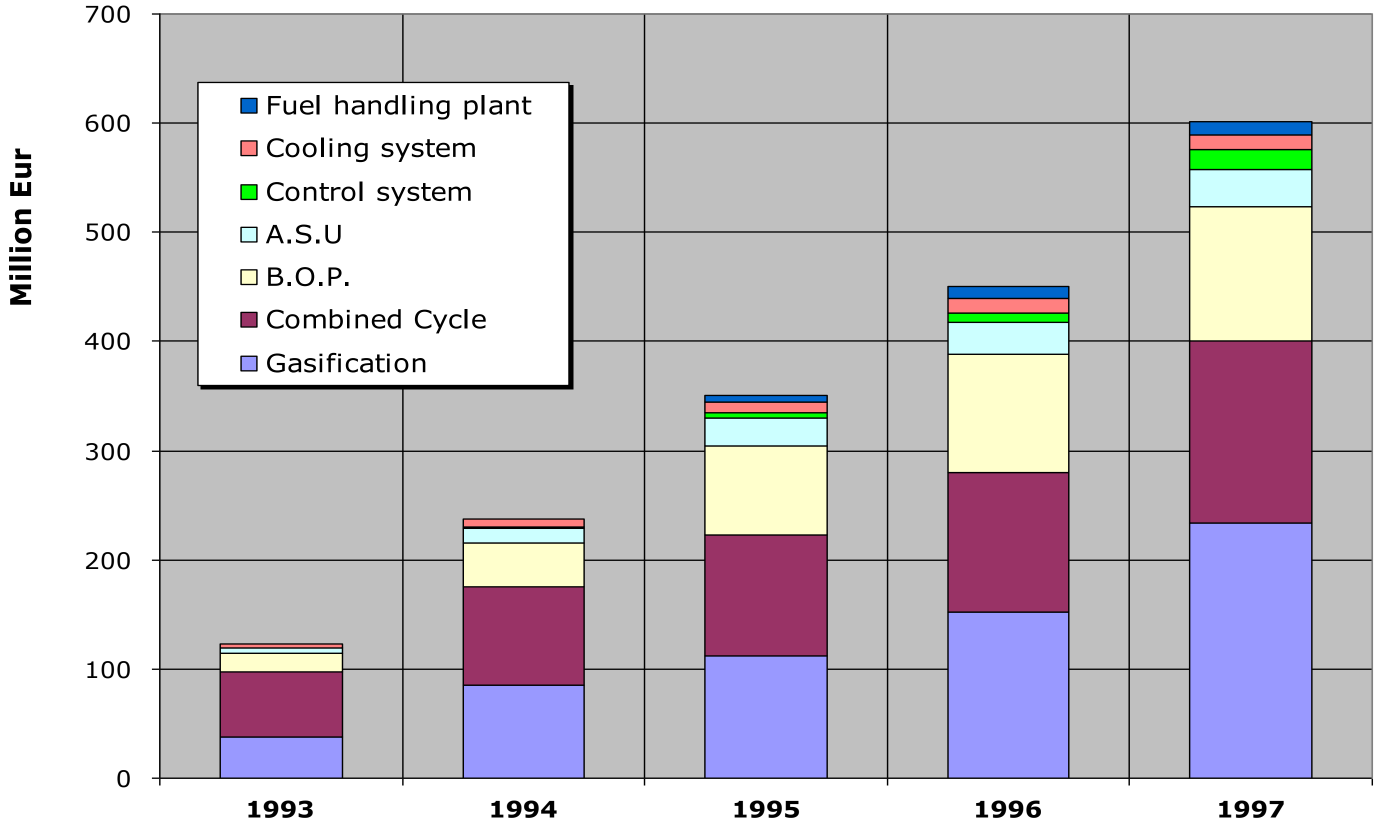


Technology at demonstration state

- First four large coal-based plants (USA & EU, 1994 - 1998) show 60-80% of IGCC availability (> 90 % considering auxiliary fuel)
- Main unavailability causes related with its maturity lack :
  - Auxiliary system design: solid handling, downtime corrosion, ceramic filters, materials and procedures
  - Performance of last generation turbines with syngas or natural gas
  - Excessive integration between units. High dependence and start-up delay
  - More complex process compared to other coal-based plants. Learning is necessary. IGCC power plants using petroleum wastes show higher availability than 92%

Operational data: Costs

ACCUMULATED INVESTMENT COSTS

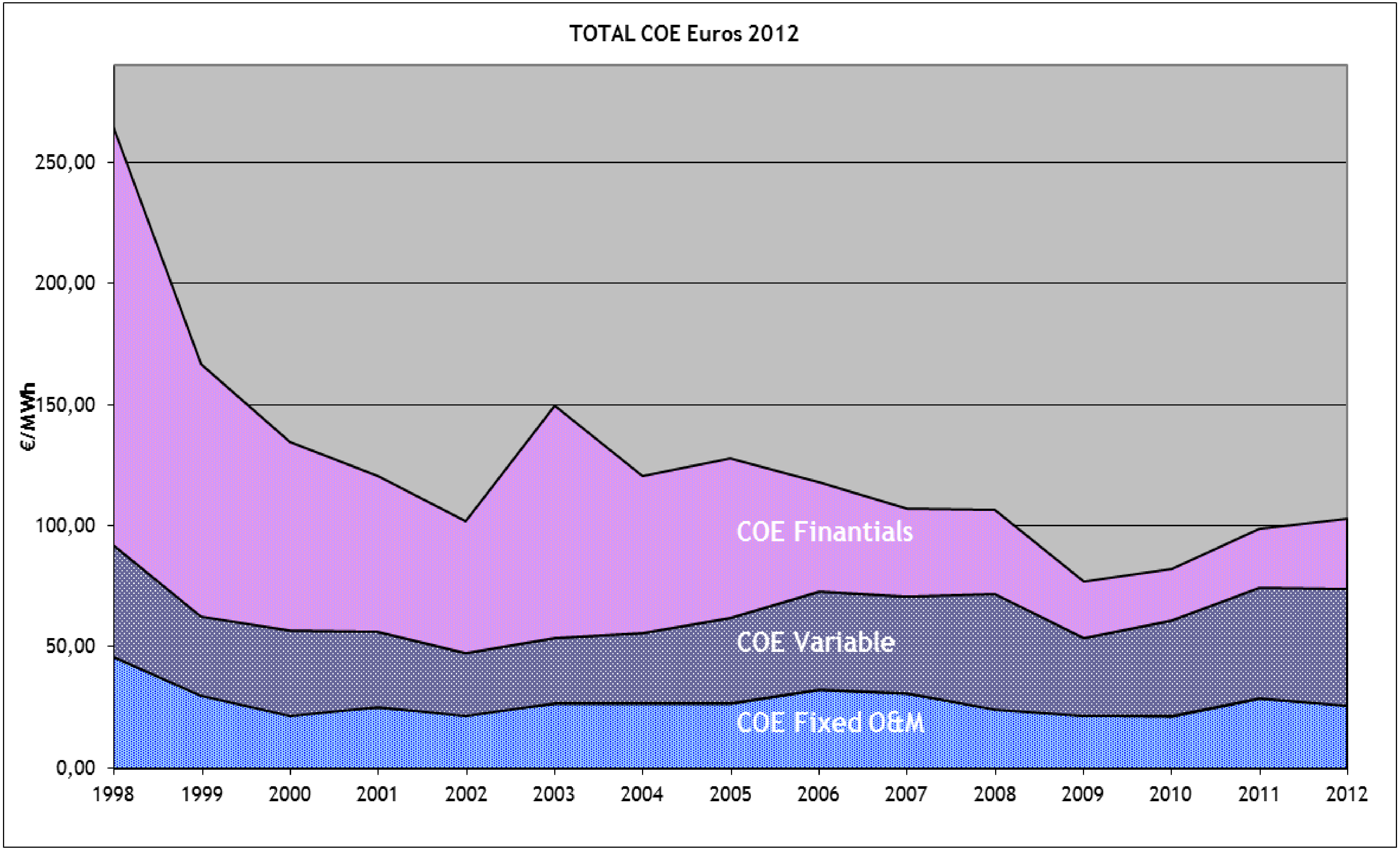


REPRESENTATIVE YEAR (2008) OPERATING COSTS, WITHOUT FINANCIAL COSTS:

Total: **83,602 k€ (57.98 €/MWh)**

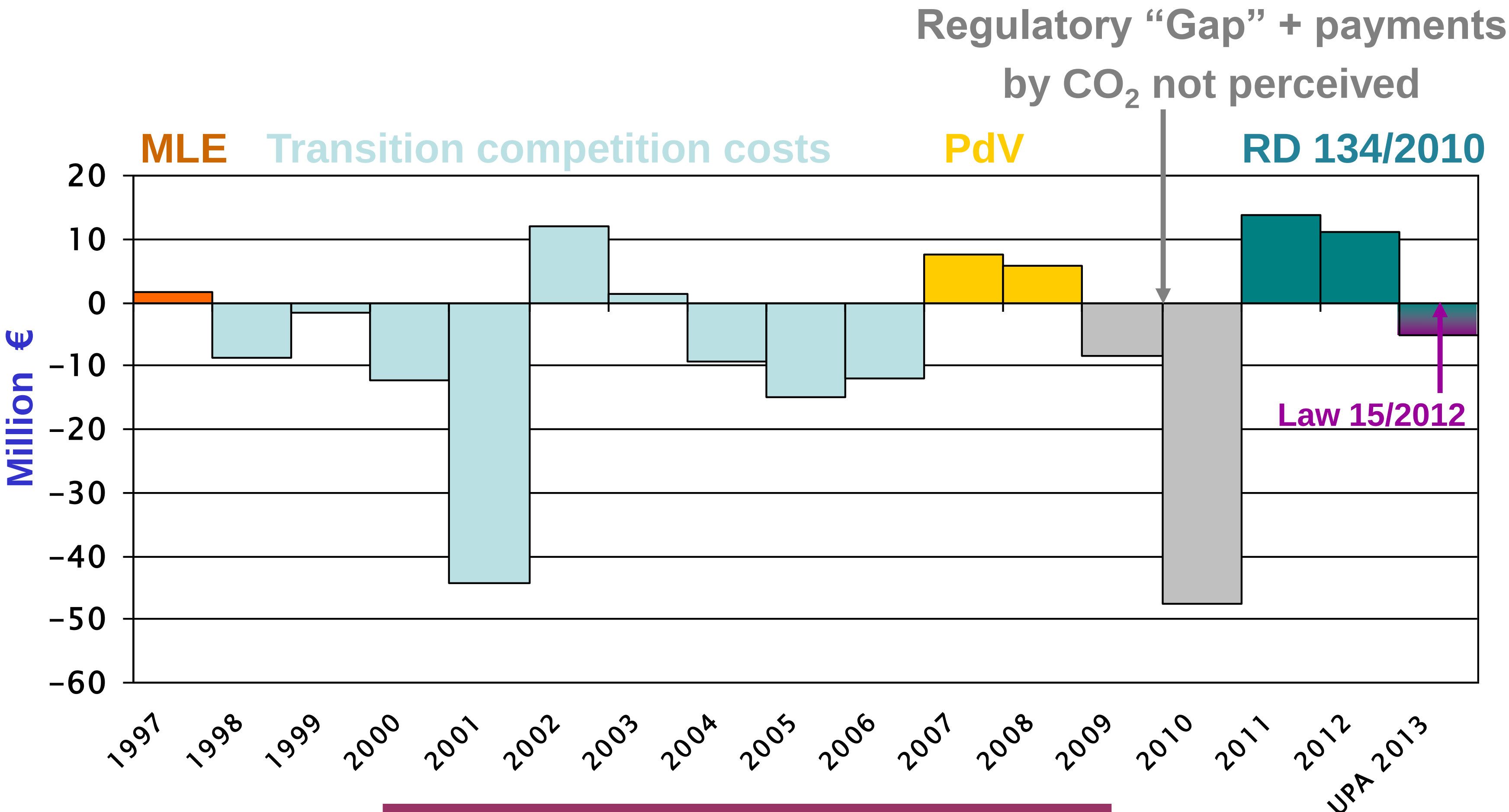
- **Fixed costs:**
  - Total: 29,326 k€ (20.39 €/MWh)
- **Variable costs:**
  - Fuels: 54,276 k€ (37.59 €/MWh)

Cost Of Electricity ($€_{2012}$/MWh)



Operational data: Economic results

Benefit or lost before taxes is directly related to the existing regulatory framework



Σ Losts: Million € 110.7

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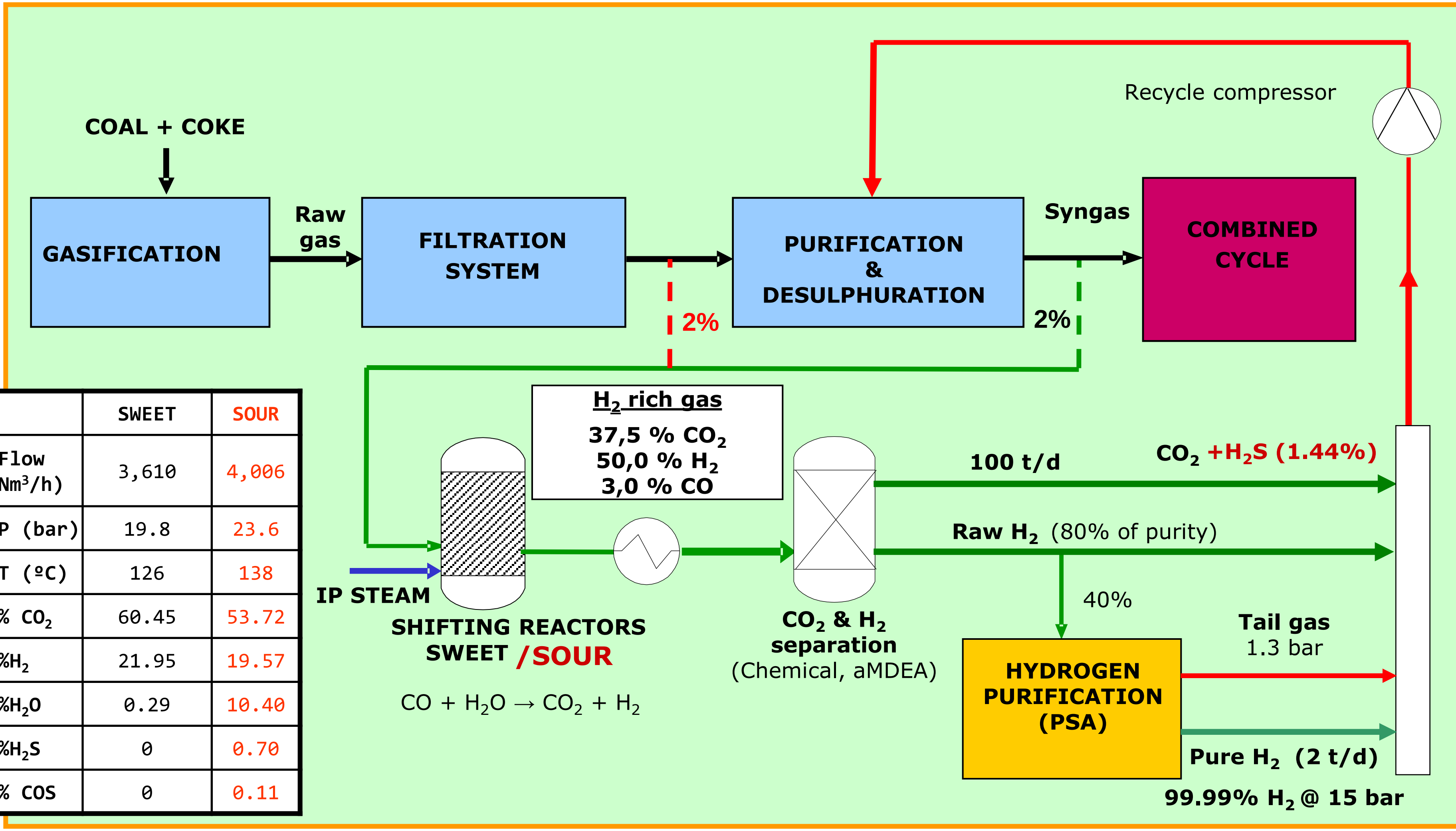
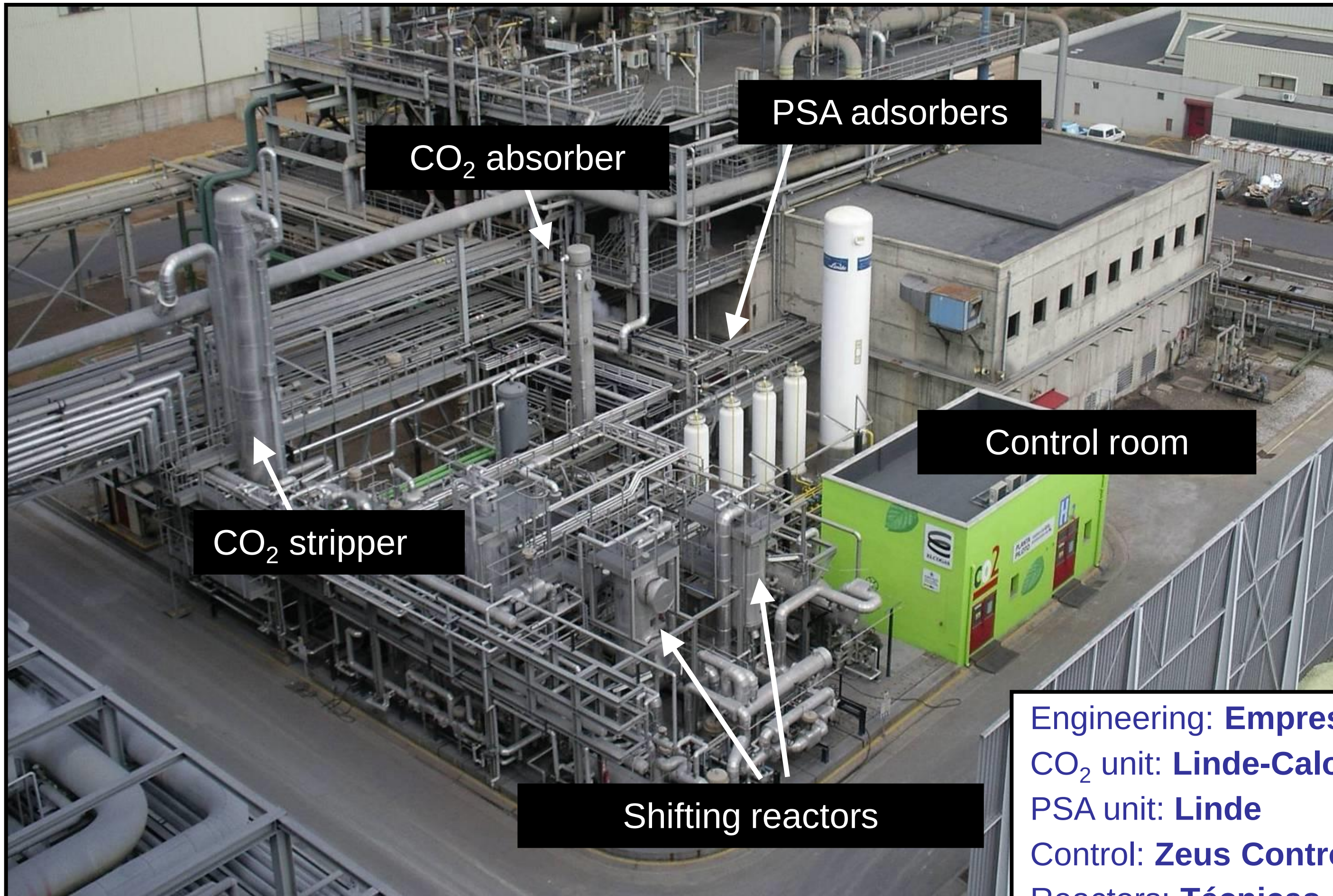
CO_2 capture & H_2 production: pilot plant



	SWEET	SOUR
Flow (Nm^3/h)	3,610	4,006
P (bar)	19.8	23.6
T (ºC)	126	138
% CO_2	60.45	53.72
%H_2	21.95	19.57
%H_2O	0.29	10.40
%H_2S	0	0.70
% COS	0	0.11

CO_2 capture & H_2 production: pilot plant



Engineering: **Empresarios Agrupados**
CO_2 unit: **Linde-Caloric**
PSA unit: **Linde**
Control: **Zeus Control**
Reactors: **Técnicas Reunidas**
Catalysts: **Johnson Matthey**
Construction: **Empresas locales**

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Flexibility of feeding and products

Preselected biomass

Battery of biomass co-gasification tests

Test Month/Year	BIOMASS	Biomass dosage ratio (% wt)	Biomass (t)	Test Duration (h)
2001	**Meat Bone & Meal**	1-4.5%	93.3	15
2007-2009	**Olive oil waste**	1-2 %	1,572.8	800.3
2008		4%	652.1	154
Mar 2009		6%	395.8	64.4
Jun 2009		8%	383.9	46
Sept 2009		10%	656.6	62
Nov-Dec 2011	**Olive oil waste**	2%	218.1	106
Oct-Nov 2012		4%	409.3	153.5
Oct 2012	**Grape Seed Meal**	2%	179.3	127
Nov-Dec 2012		4%	425.7	119.5
		TOTAL	**4,987.3**	**1,647.7**

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What is gasification?

Gasification itself is not the core, neither the root of the project nor plant problematic.

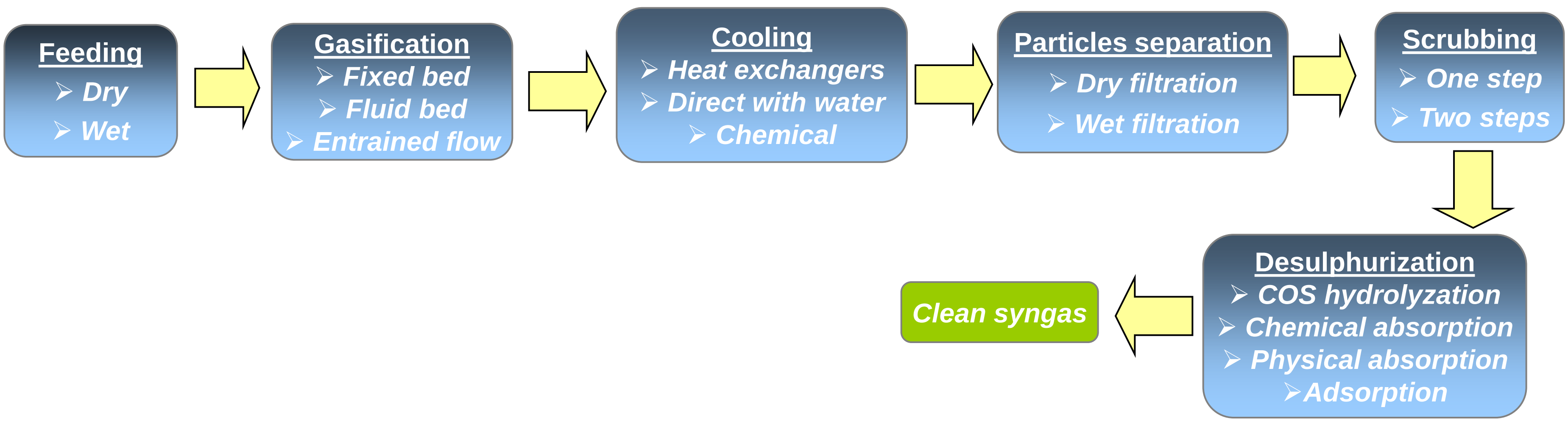
On the contrary, they are the design & detailed engineering of the auxiliary systems.

Each plant is different because they depend on:

- Available raw fuel
- Chosen gasifier technology
- Expected use of syngas
- Environmental regulations

So, Engineering & O&M expertise are crucial

➢ Syngas production by gasification. Processes



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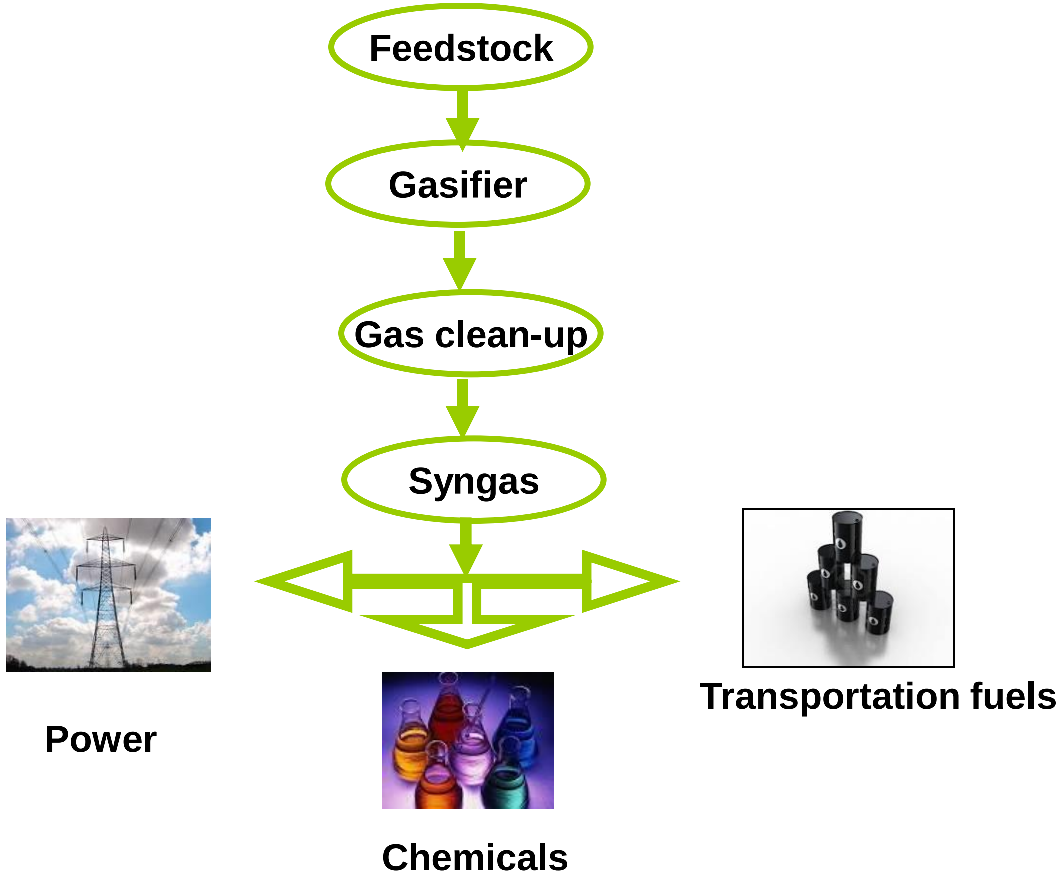
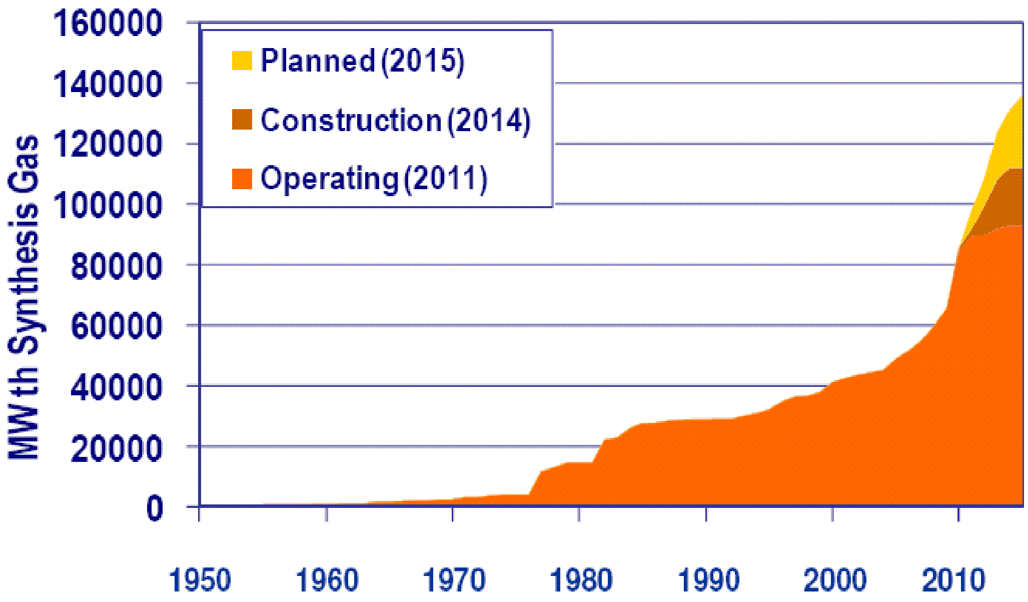
Gasification flexibility

Selection of the best gasification technology depending on:

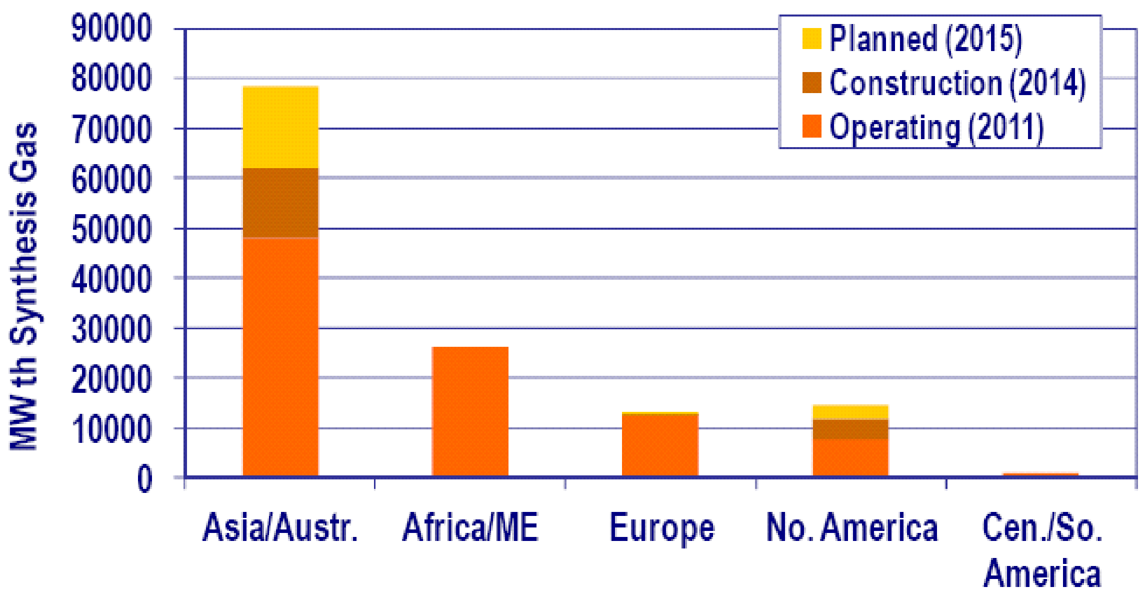
- **Fuel (C content, LHV, available quantities)**
- **Gasifier size required to obtained a competitive product**
- **Products required (H_2, Chemicals, Fischer-Tropsch liquids, energy w/ CO_2 capture, ..)**



Gasification deployment



❖ **Accumulated world gasification capacity**

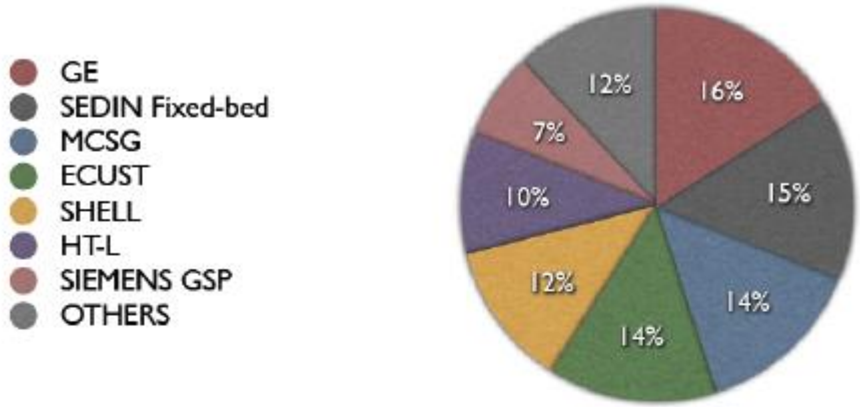


❖ **Gasification by region**

*(Fuente: **Higman Consulting, 2012**)*

Gasification deployment

Gasification Market Shares in China



Data source: ASIACHEM

- by syngas capacity
- including all constructed plants and contracted projects, as of Q3 2011

China Gasification Market Outlook 2011-2015

Products	Capacity Million tonne/year	Syngas Demands Nm^3/hour	Number of gasifiers (3000 tonne/day per gasifier)
Coal to Liquids (CTL)	12	9,710,000	50
Coal to Olefins (CTO)	6	3,660,000	19
SNG	25 x 10^9 Nm^3	8,710,000	45
Ammonia	13	4,471,000	23
Methanol (excluding CTO)	10	2,290,000	12
Methanol to Ethylene Glycol (MEG)	3	1,500,000	8
Total		30,341,000	157

(Fuente: EPRI, 2012)

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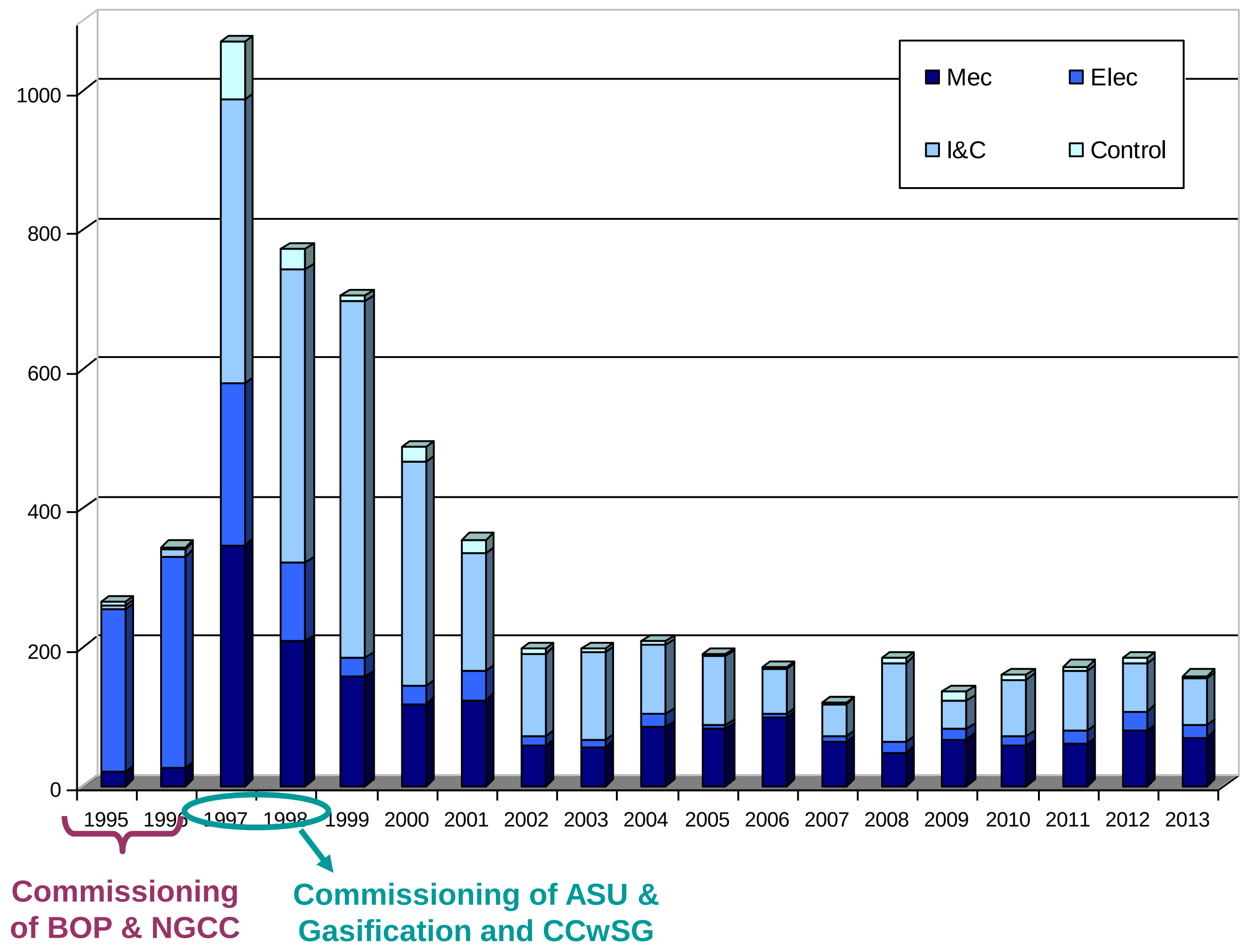
Engineering plant modifications

ANNUAL EVOLUTION OF APPROVED DESIGN CHANGES



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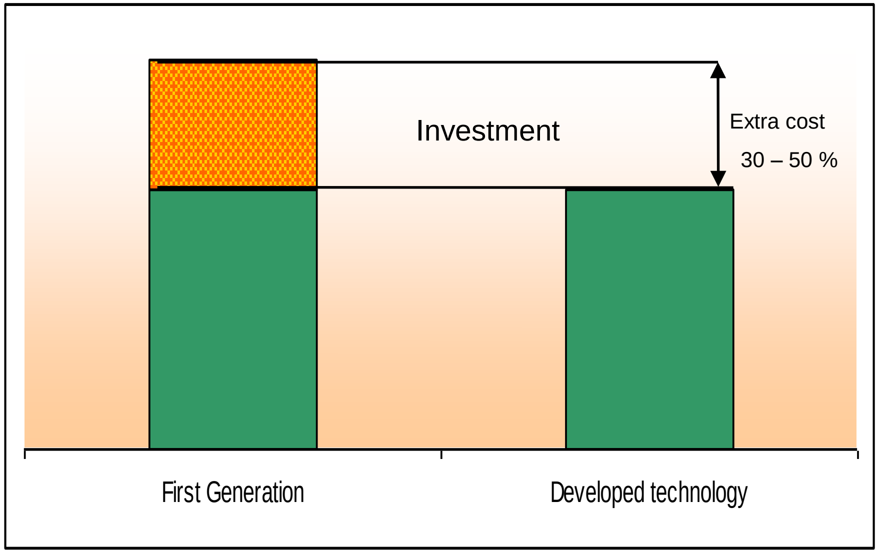
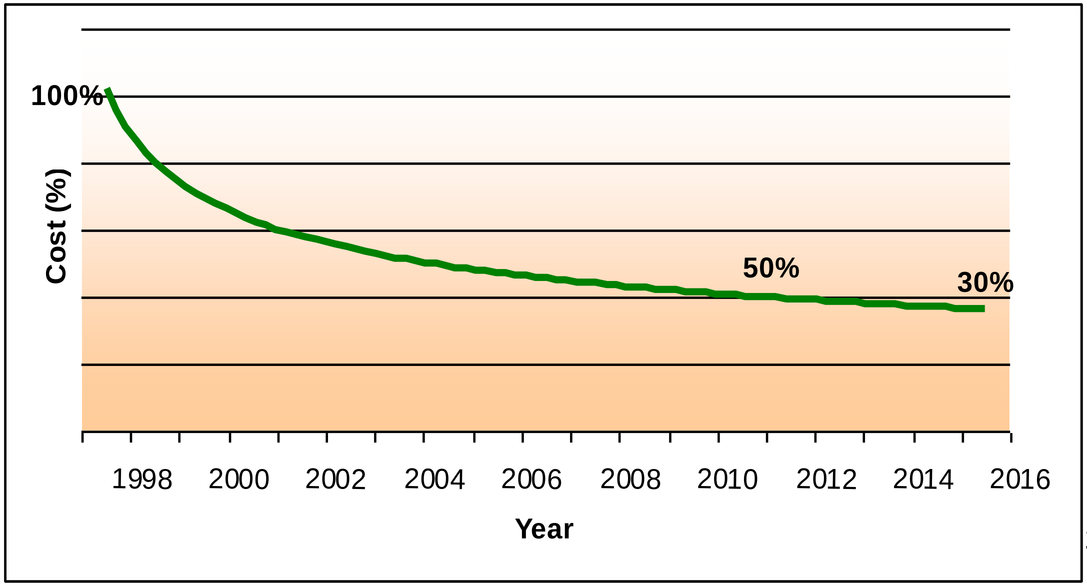
“Demonstration project“

Investment costs at ELCOGAS. Learning



REGULATORY SUPPORT is essential in a technology demonstration project at commercial scale

Total production cost



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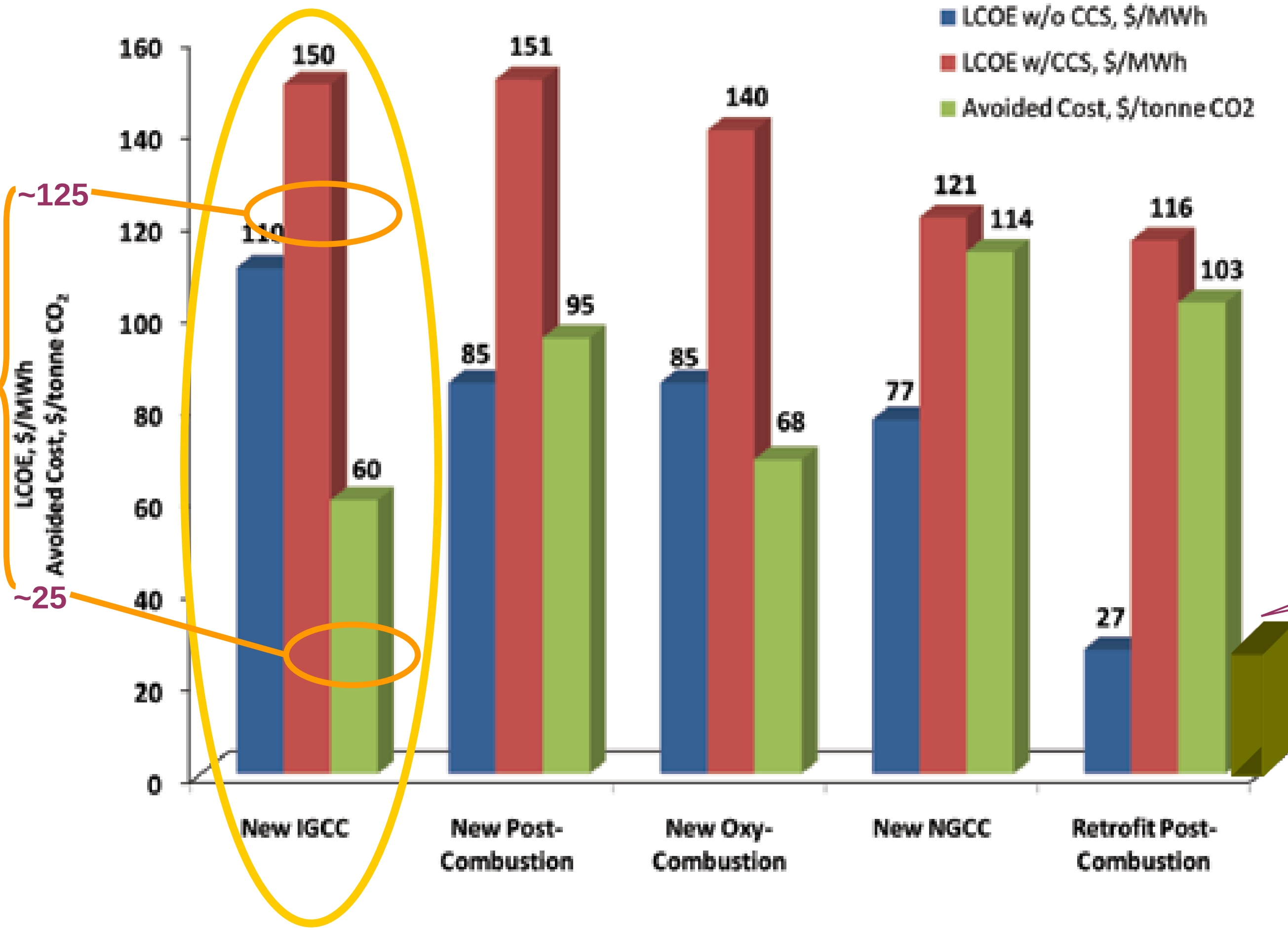
CO_2 capture: Real experience at ELCOGAS

Comparison between costs of CO_2 capture technologies

With **acid CO_2 capture & current status of technology**



30 for ELCOGAS **retrofitting**

Source: *DOE/NETL CCS RD&D ROADMAP (December 2010)*

Real experience at ELCOGAS: results and learning

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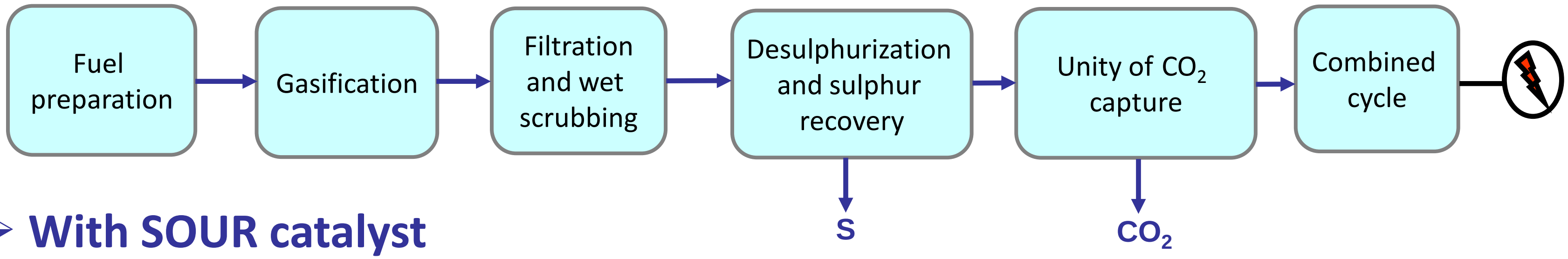
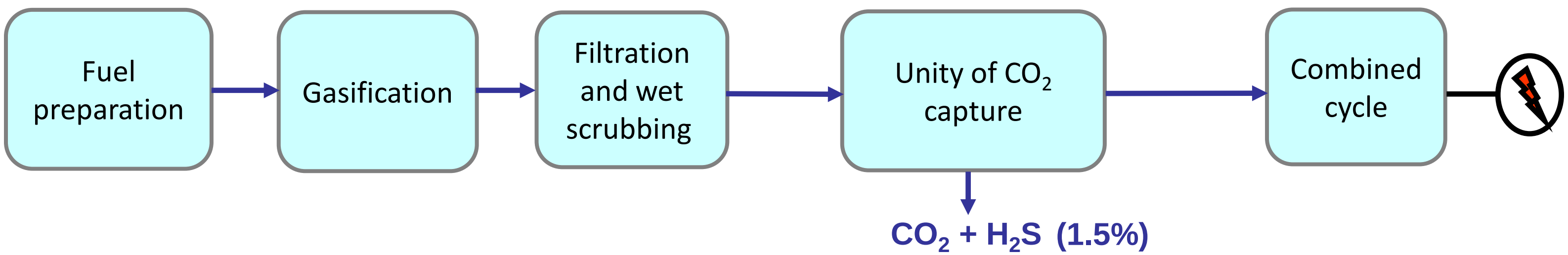
CO_2 capture in IGCC plants

➢ **With SWEET catalyst**



➢ **With SOUR catalyst**



Based on our CO_2 capture pilot plant, we have scaled the cost of a CO_2 capture unit at scale 1:1 about 350 M€. Approximately, it represents the cost of the desulphurization and sulphur recovery units in an IGCC w/o CO_2 capture.

By installing an IGCC with CO_2 acid capture to store or use CO_2 together with ~1.5% H_2S, the investment costs are similar to those w/o CO_2 capture. And the only penalty is the decreasing efficiency: From 42 → 33% currently

and from 50 → 44% near future

Summary

• Technology at commercial demonstration scale power plant requires a **long term regulatory frame**

• **IGCC** with or without CCS is a promising technology with the **minimum variable costs and the best environmental performance and** it can be adapted to multifuel and polygeneration

• Following IGCC generation must **learn from existing plants**

• Main **burden** for deployment is **high investment requires** a long term **regulatory frame**

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THANK YOU FOR YOUR ATTENTION

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