S4FE 2009 Conference : Rome 07 July 2009 :
Presentation by G.Dodero IPG Srl

Updating capture carbon technologies

in the framework of power generation

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1.0 Introduction (A):

Main topics dominating energy sector discussions today are:

- the environmental issues, chiefly the question of carbon emissions and global warming

- the security of energy supply , that is also the rather more urgent matter, but that is too often overlooked

The key urgent actions within energy sector are :

- reduction of the greenhouse gases emissions produced by fossil fuel combustion using the CCS (Carbon Capture & Storage) technologies

* increase of the fossil fuel reserves, basing on the fact that fossil fuels will be with us for long time to come, probably for the next 50 or 80 years at least. (today the estimated reserves are 65 years for gas & up 240 years for coal)

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1.0 Introduction (B) :

Using CCS technology, the CO2 produced by the fossil fuel combustion is captured and subsequently sequestrated first within the existing oil wells to enhance oil and gas production, but also within underground storage facilities as for example the aquifers. CCS has been used extensively by petrochemical companies, storing CO2 in Enhanced Oil Recovery (EOR).
Basing on first investigations aquifers have a storage capacity about 10 times in respect to the petrochemical wells.
Interesting to remember that CCS is used in US since 40 years to enhance oil and gas production. CCS structure is including in US :

- 2500 CO2 pipelines miles
- 4000 supplied wells

CO2 emissions :

- Advanced coal fired units : 0,8 Tonnes CO2/ MWh
- New natural gas fired combined cycles : 0,4 Tonnes CO2/ MWh

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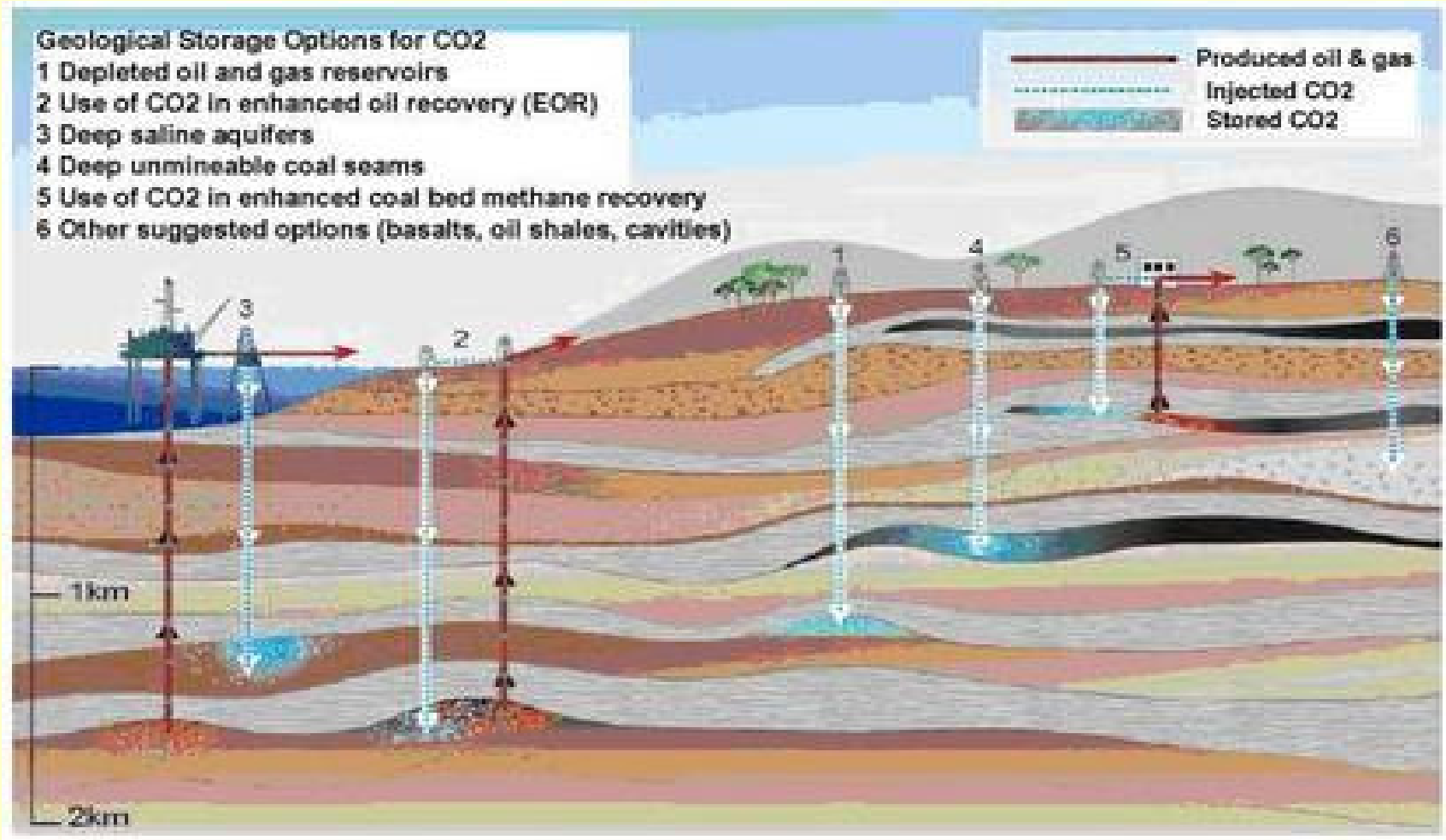
1.0 Introduction (C) : geological storage options for CO2 :



Source : Bellona CCS web

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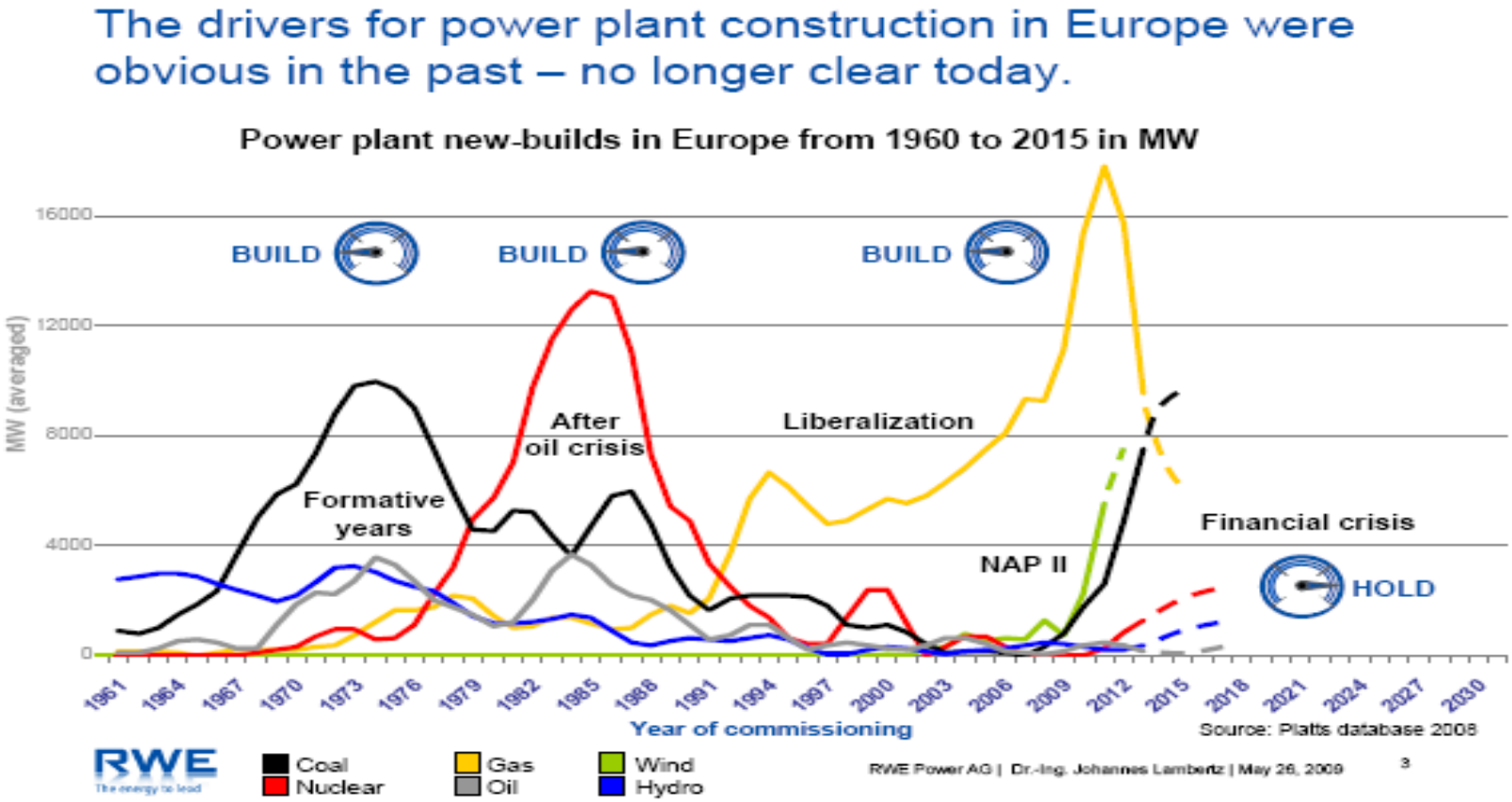
2.0 Power plant new construction programmes in Europe (A):



Note : Figure presented by RWE Ceo at Power Gen 2009 Conferences Cologne, May 26

2.0 Power plant new construction programmes in Europe (B):

Sudden drop of new combined cycles construction due to the following reasons :

- high price of the natural gas tied to oil price of about six months before

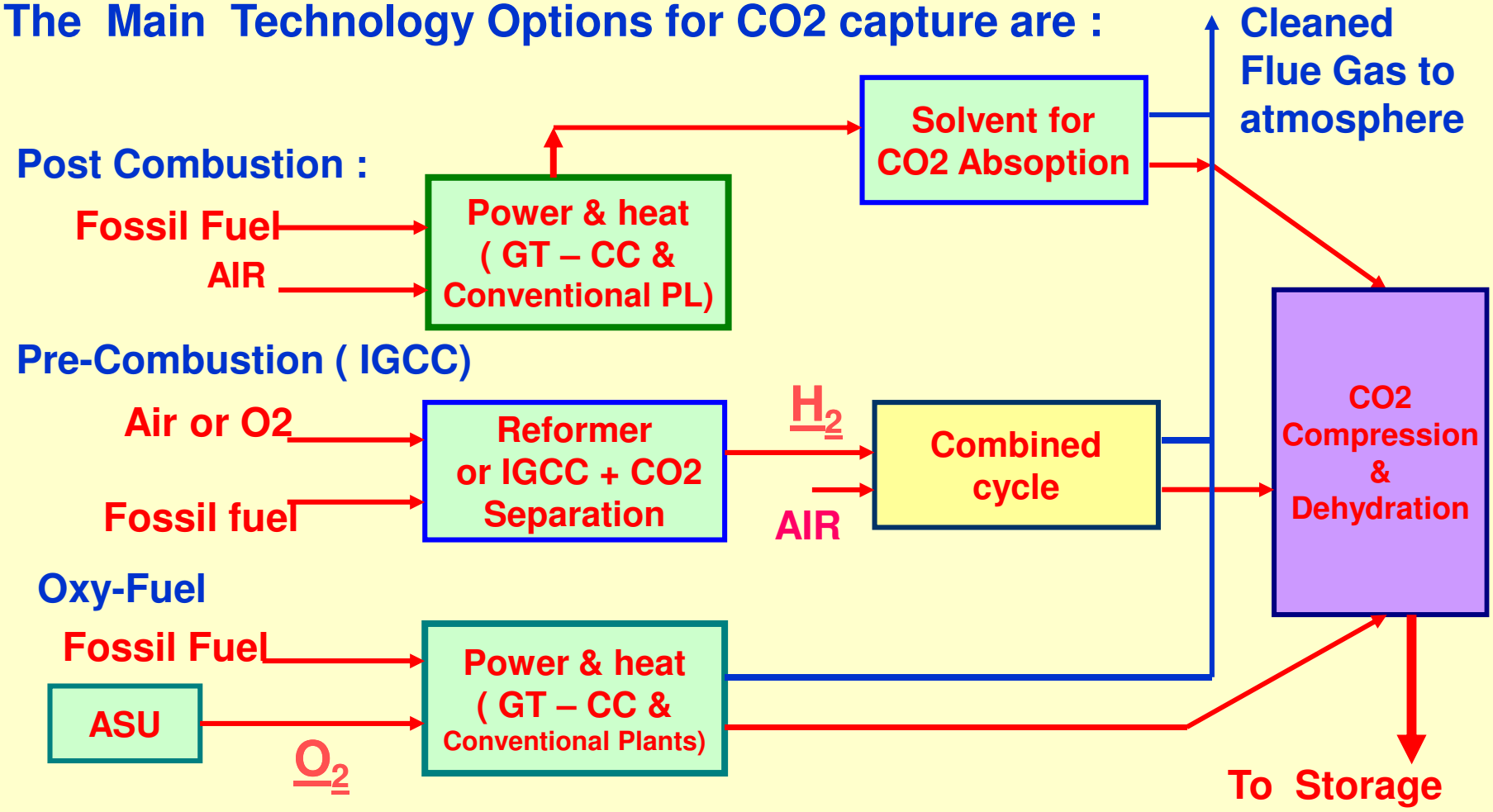
- high cost of maintenance mainly of the gas turbines.
Many IPPs close long term maintenance agreements with the gas turbines manufacturers , including availability guarantee, etc
and contractor penalties, payable as liquidated damages. But it is not easy to agree a perfect contract and this protection costs a lot of money.

- In addition maintenance of CC increases if the CC is used in cycling operation.

So for the time being electric utilities are more interested to make use of CCS within coal fired units.

3.0 Making a choice among existing processes used in other sectors (A) :

The Main Technology Options for CO2 capture are :



3.0 Making a choice among existing processes used in other sectors (B) :

From chemical and/or petrochemical sectors :

* Solvents and gasification processes
* CO2 capture and sequestration
* Transformation of CO2 into stable carbonate minerals
* Advanced chemical looping and advanced O2 separation

From Technical Gas Sector :

* Air separation sector

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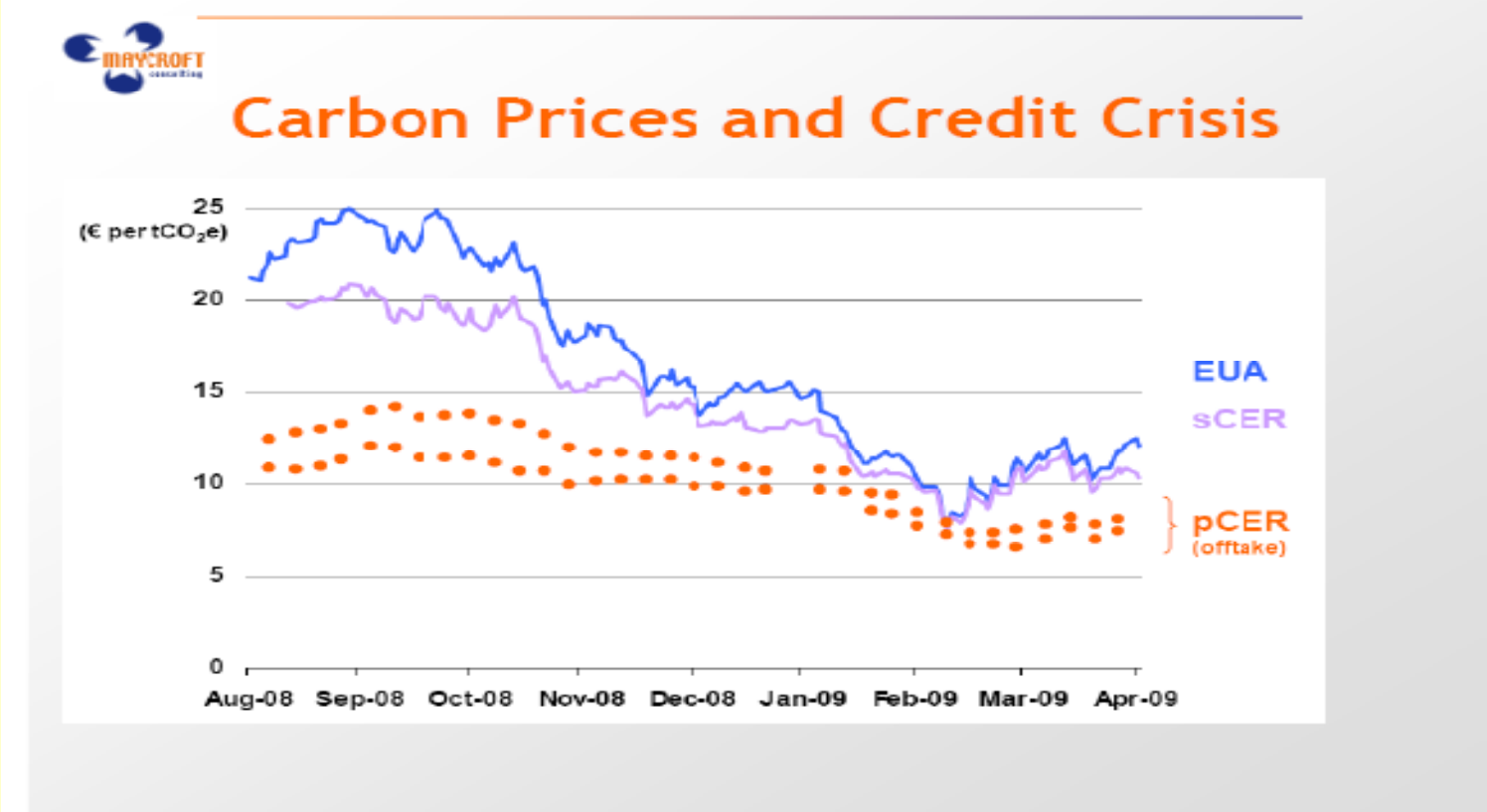
4.0 Carbon emission trading : Updating carbon prices :



Source : Presented by Mr. K. Walet Maycroft at Carbon Emissions Trading 2009 Conference Varsavia 1st July 09

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5.0 Overview of CCS main processes and technologies :

	Post combustion Processes	Oxy-fuel Processes	Pre-combustion IGCC Processes	Chemical Looping Processes
1st Generation processes (2012 – 2020)	Absorption Processes : • Amines • Ammonia	Oxyfuel : Low O2 concentration	CO2 separation Upstream GT (also combined CO2 +H2S sep.	----------
2nd Generation processes (2030)	A) Carbon capture Membranes B) New absorbers : Amino acid salts (Siemens) ; others C) Hybrid solutions D) Adsorption proc. E) Physical separ. • cryogenic • org./inorganic solv.	Oxyfuel : • Low O2 Concentration • ITM - Ionic transport membranes	• New combined O2 Production • Hydrogen fired Gas Turbines improvements	• Fluidized bed solutions • Others bio process under study
3rd Generation processes (2030)	Carbonate Looping		CO2 high temperatures Separation membranes	

6.0 What criteria will adopt electric utilities in selecting the CO2 capture processes :

A) Electric Utilities :

* E. Utilities request high availability and low maintenance processes, also due to the high competitiveness of their sector.

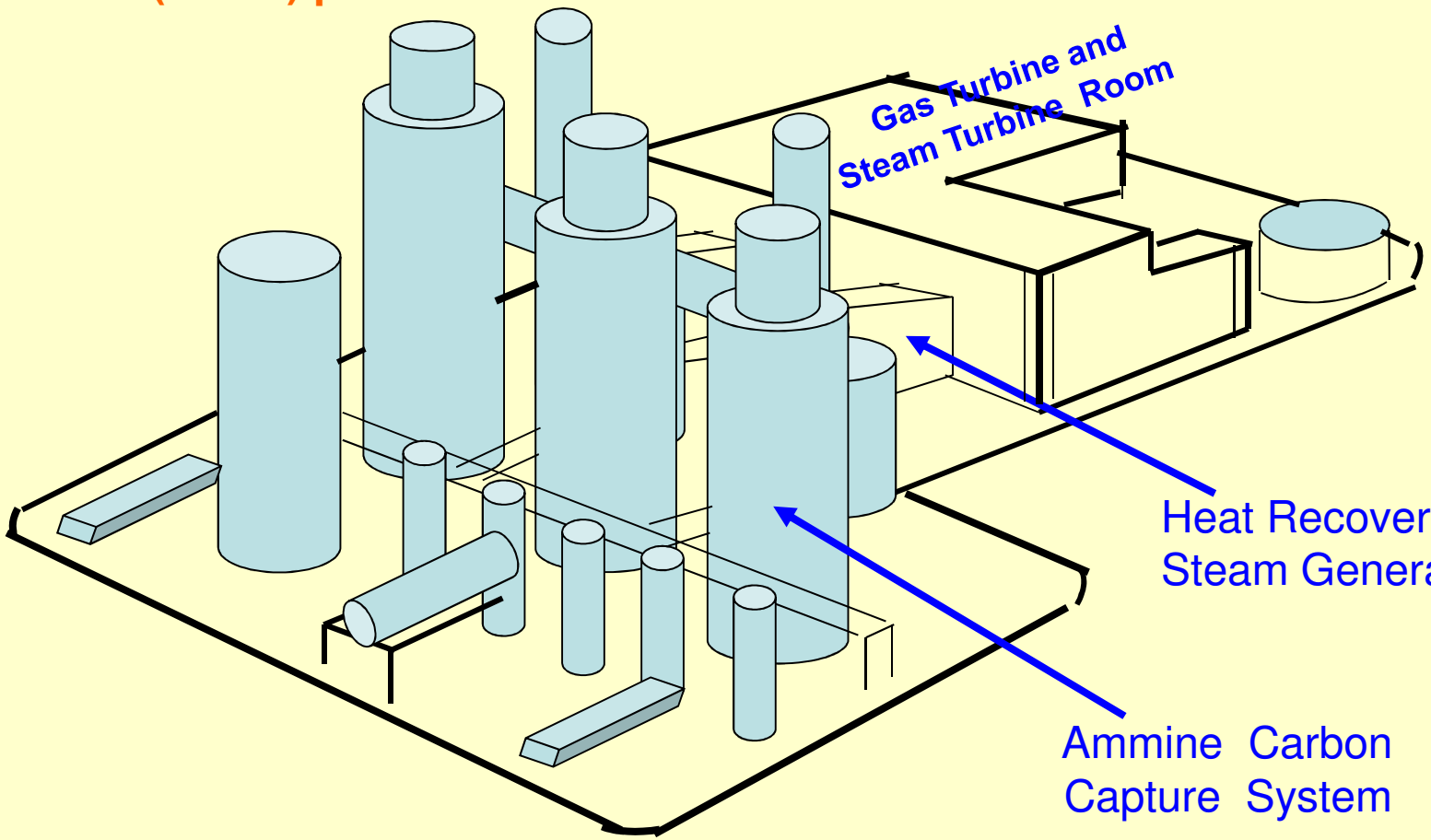
* E. Utilities operation staff do not have familiarity with complex chemical processes they do not like, because these processes often involve important safety problems (for example solvent toxicity). Mainly for these reasons utilities for the De-SOx adopted, among many alternatives, the most simple limestone – gypsum technology

B) Chemical, petrochemical and technical gas sectors (CP&TGs) :

* CP&TGS are interested to collaborate on this challenge, but technology transfer is not easy and needs time.

* CP&TGS usually select their processes according to different cost- benefit criteria in respect to E. Utilities also because their profit could be also very high.

7.0 Evaluating the main Post-Combustion technology options (A): Amine (MEA) process :

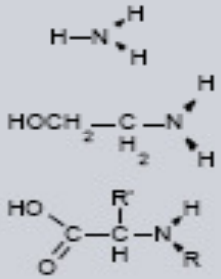


Here the overview of an ammine **unit post combustion process** for a 800 MWe combined cycle. Its volume is **huge and also MEA is toxic.**

7.0 Evaluating the main Post-Combustion technology options (B): amino acid salt process: this technology looks an interesting opportunity :

SIEMENS

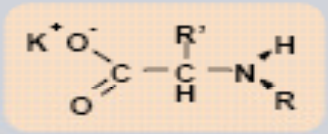
Amino acid salt is the basis of our solvent



Ammonia

MEA

Amino acid



Amino acid salt

No vapor pressure

Chemically stable

Naturally present

Salts have no vapor pressure	Negative ion is less sensitive to O_2	Amino acids are naturally present
• No thermodynamic solvent emissions • Not inflammable • Not explosive • Odorless • No inhalation risk	• Low degradation	• Biodegradable • Nontoxic • Environmentally friendly

Solvents based on amino acid salts are economic, have low environmental impact and are easy to handle.

8.0 : Oxy combustion : probably the best choice today for coal fired units (A):

This technology is one of the most interesting options for the so called " Zero Emission Power plants". In this case CO2 recovery from conventional pulverized coal fired plants is done using oxygen instead of air for fuel combustion.

Oxy-fuel technologies can be split into two alternative processes :

- Low oxygen concentration system (LOCS)
- High oxygen concentration system (HOCS)

Literature indicates that within the LOCS, the technology of our interest, furnace absorption increases by some 10 – 12% due to an increase in radiating power of the hot flue gas and that the furnace exit gas temperature also is reduced. Approximately one third of the boiler exit flue gas feeds the CO2 compression system via the gas cooler and the CO2 treatment. The remaining two-thirds of this flue gas is returned to the boiler unit by a flue gas recycle (FGR) fan to moderate the combustion temperatures.

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8.0 :Oxy combustion : probably the best choice today for coal fired units (B):

This technology looks the most interesting for the following reasons :

• oxyfuel technology is used with success since long time in blast furnace processes. IPG finalized a study in 1986 on behalf of Snam Progetti (Saipem) relating the use of O2 enriched air within coal fired units.

• all additional components introduced to enable oxyfuel CO2 capture are well proven and commercially available also for large power plants.

• the maintainability of an Oxyfuel PF Power Plant will not differ significantly from an Air-fired PF Power Plant

• During start up LOCS reduces the need of support flames

Important additional advantage of this oxyfuel technology : we can design the unit both for oxyfiring and airfiring operations, including the opportunity to switch from airfiring operation to oxyfuel operation also during commercial service. Oxygen production during the night using low cost kWh

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9.0 CCS : Costs and potential for Cost reductions within ZEP: This are tentative Costs(CAPEX & OPEX) overview of the possible options:

Likely Technologies	Total investment (€/kW)	Efficiency No CCS (%)	Efficiency Loss With CCS (%)	Starting Year	Capture Efficiency (%)	Capture Cost (€/t CO2)	c€/kWh Cost No CCS	c€/kWh Cost with CCS	Additional c€/kWh cost
A) Post Combustion									
A1) Coal Steam cycle	1850	45	10	2010-2015	90	30	3,75	5,70	1,95
A2) CC Fuel price :3.4€/GJ	900	58	9	2010-2015	90	33	4,40	6,45	2,05
B) Pre-combustion (coal)	2400	42	6	2010-2020	97	30	4,80	6,90	2,10
C) Oxy-fuel (LOCS)									
Coal steam cycle (02 prod. In the night)	1900	45	9,7	2010	95	25	3,75	5,60	1,85

10.0 CO_2 treatment, purification and compression :

On this regard it is important to establish what maximum level of impurities could be accepted based , in case of CO_2 storage, on the impact of these impurities within the different storages or CO_2 uses options.

CO_2 is a difficult gas to compress because it is like a liquid at its supercritical conditions that are 72.95 barg and 24.47 ℃ . Large volumes of CO_2 are compressed in urea plants and significant experience exists among compressor manufacturers.

A large number of compressors in CO_2 service having discharge pressures ranging from about 80 barg to 200 barg are used within the urea plants worldwide.

Integral geared multistage centrifugal compressors, initially developed to maximize compression efficiency in large air plants, are now used in urea plants for CO_2 service.

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11.0 Transportation of recovered CO2 to disposal sites & CO2 storage (A) :

CO2 would be also transported to a disposal site via pipeline. We examined various transportation concepts for these pipelines, including supercritical lines and liquid CO2 lines. Costs that are very terrain-dependent and increase in case of difficult terrain appear to be lowest for supercritical pipelines.

CO2 pipe Diameter Inches	CO2 Transported Capacity ton/day	**Average Tentative Capital cost Million €/100 km**	Equivalent Coal unit size MWe	Cost Euro/kW – 100 km
24	30,000	80	2 x 800	50
16	15,000	60	800	75
10	7,500	50	400	125
10	5,600	50	300	166

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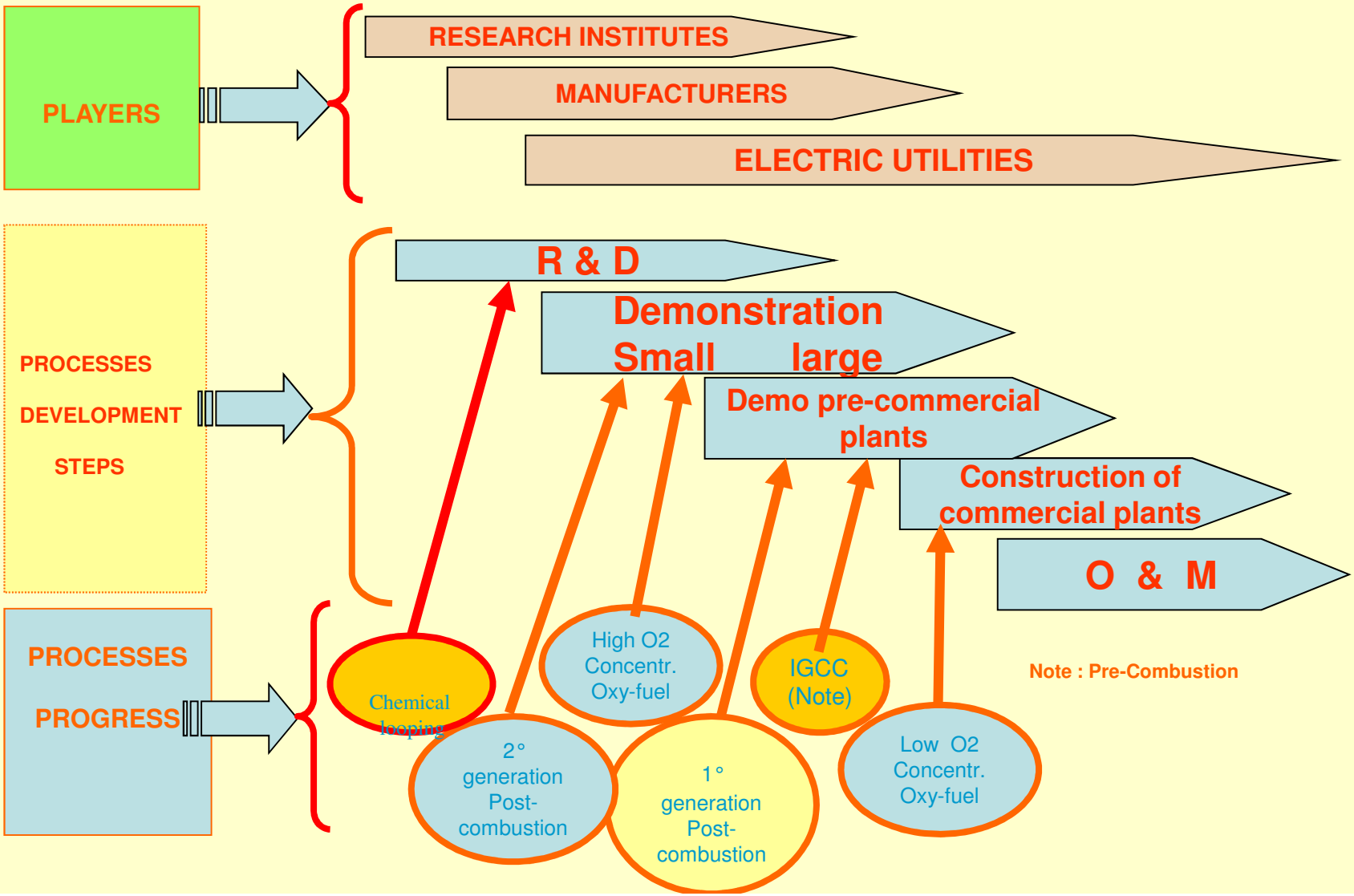
12.0 Conclusions (Overview of the CC technology advancements situation) (A):



12.0 Conclusions (B):

- Europe is moving to play a key role as technology leader in CCS sector
- Low oxygen concentration oxy-fuel technology look for the time being within new coal fired conventional plants the most effective, safer and least expensive option.
- We are confident that new concepts already identified, but not validated, up to now will be developed by 2012- 2015 and implemented beyond 2020
- Other recommendations made by the ZEP (zero emission project) platform :
  - * Maximizing cooperation at national, European and international level
  - * Supporting long-term R&D into advanced, innovative concepts for implementation of the next-generation technologies

12.0 Conclusions (C):

The future of CCS and of carbon emission trading will have of course a future, because :

“ carbon market is a political market”