“Zero Emission” Fossil Fuel Power Generation

: where are we heading?

Nick Otter

27th November 2007

FORUM ON FOSTERING INVESTMENT IN CLEANER ELECTRICITY PRODUCTION FROM FOSSIL FUELS

UNECE Geneva Switzerland

POWER

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Agenda

1st topic	Why is the topic so important?
2nd topic	What is it all about?
3rd topic	What is happening in Europe and elsewhere?
4th topic	What is the way forward?

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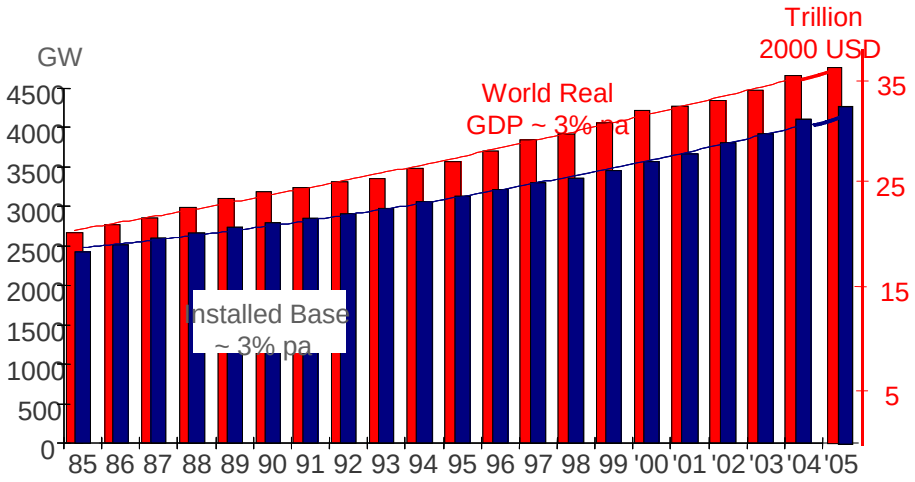
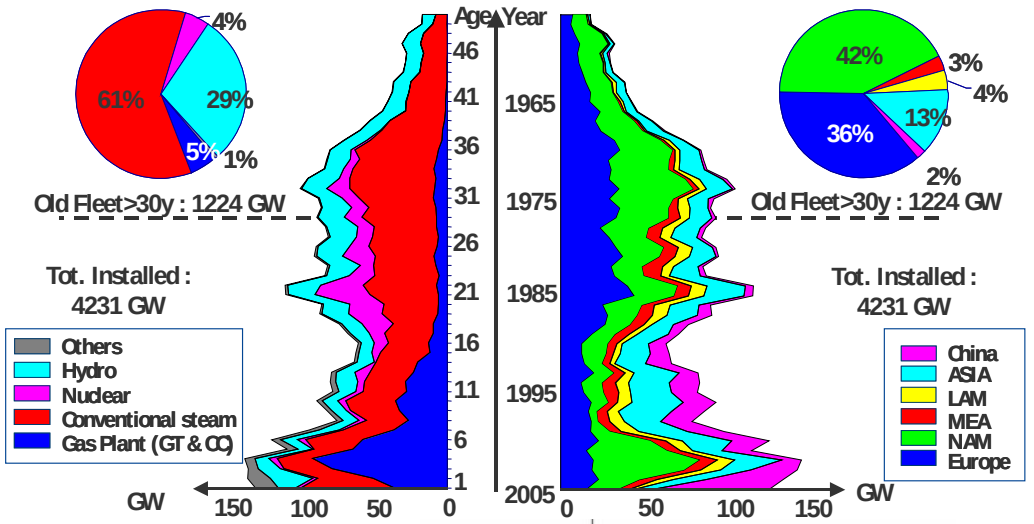
Market Driver : GDP Growth
Increasing demand for electricity



Growth of installed base is ~linked to GDP

29 % of installed capacity older than 30 years

Age pyramid of world installed capacity



Note: 180 GW missing due to unknown commission year,mainly Conventional ST, Hydro & Others
Source: Alstom, UDI

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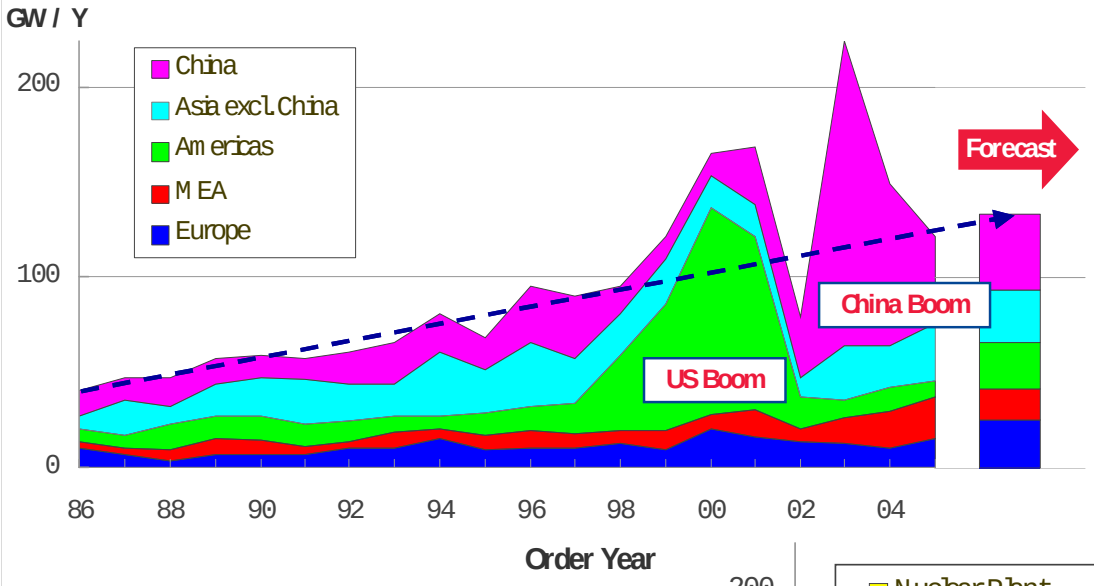
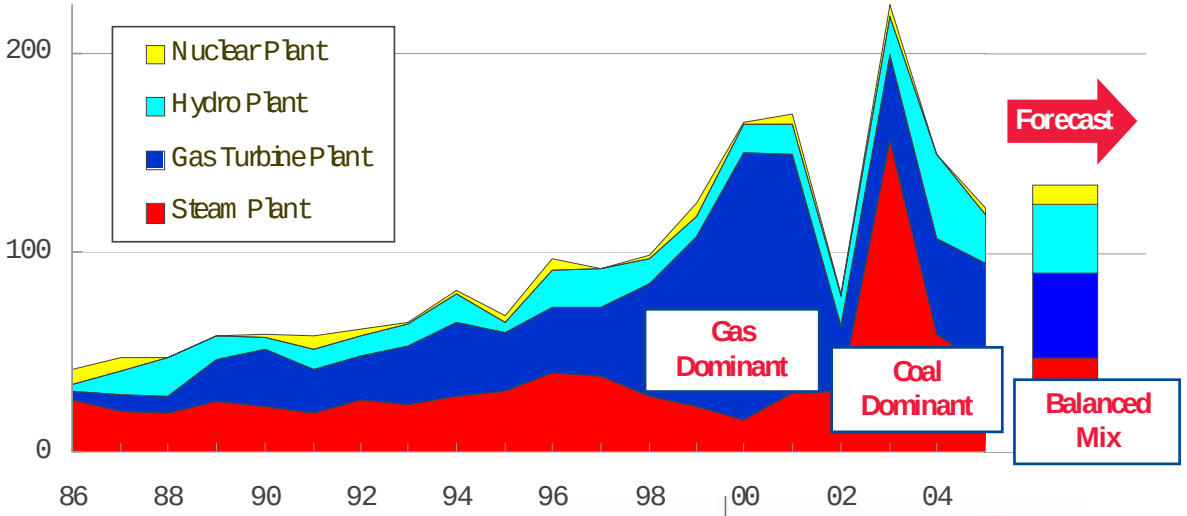
Market Driver : Geography
Successive peaks in fundamentally growing market

Order volumes by region



Future growth
- importance of developing countries

Future growth
- importance of fossil fuels in a balanced mix



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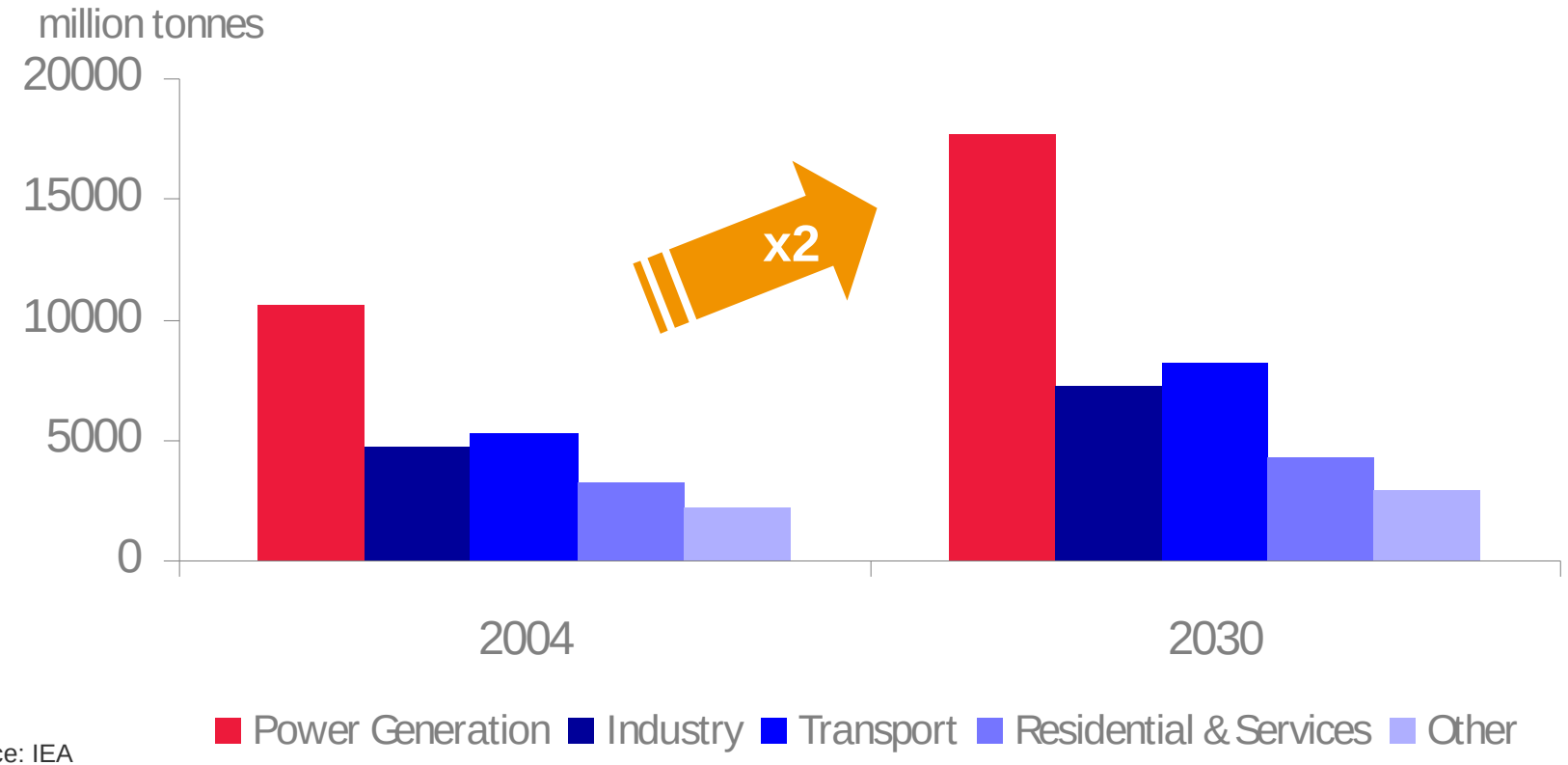
Market Driver : Environment
Power generation industry: a major contributor to CO_2 emissions

CO_2 emissions from fossil fuel combustion (reference scenario)



Source: IEA

* Includes agriculture and public sector
** includes international marine bunkers, other transformation and non-energy use

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“Take away” Messages Summary

- **Importance of clean use of fossil fuels, especially coal**
- **Importance of accelerating the take-up of clean fossil**
- **Importance of addressing regionally and worldwide**

  - **critical transitional issue for a sustainable energy future**
  - **an essential part of the portfolio**
  - **cannot ignore fossil fuels**

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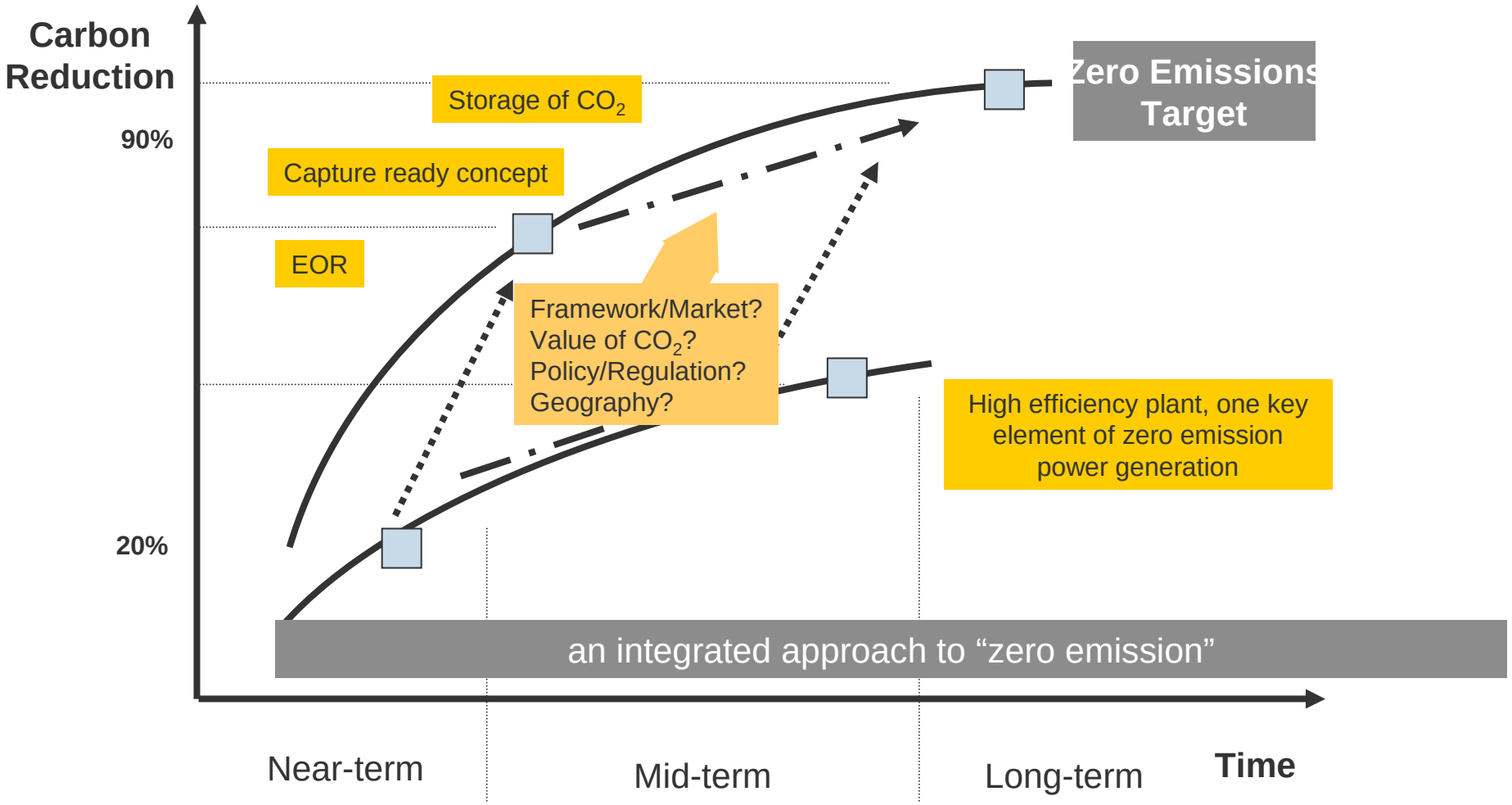
Pathway to zero emission power for fossil fuels



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Specific CO_2-Emissions of Coal Power Plants

CO_2 impact of efficiency increase

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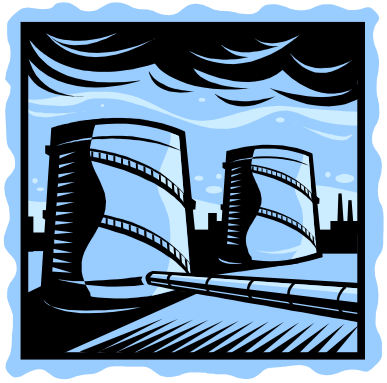
Process Chain of Carbon Capture and Storage

Power Plant with CO_2 Capture

CO_2

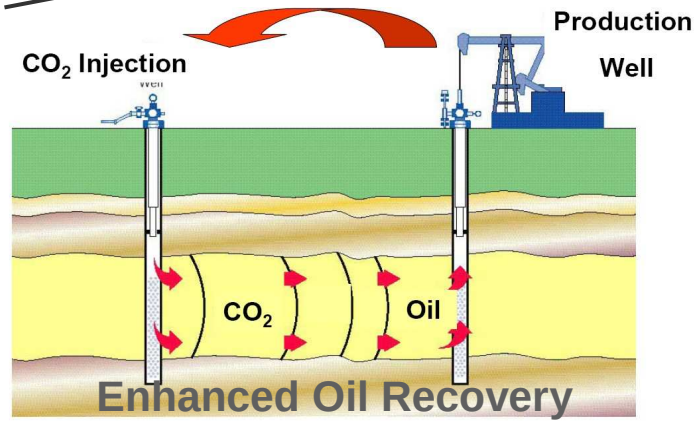
Pipeline

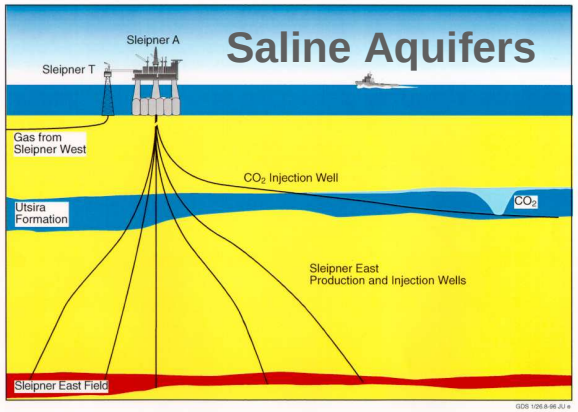


CO_2

Underground Storage

Storage Options





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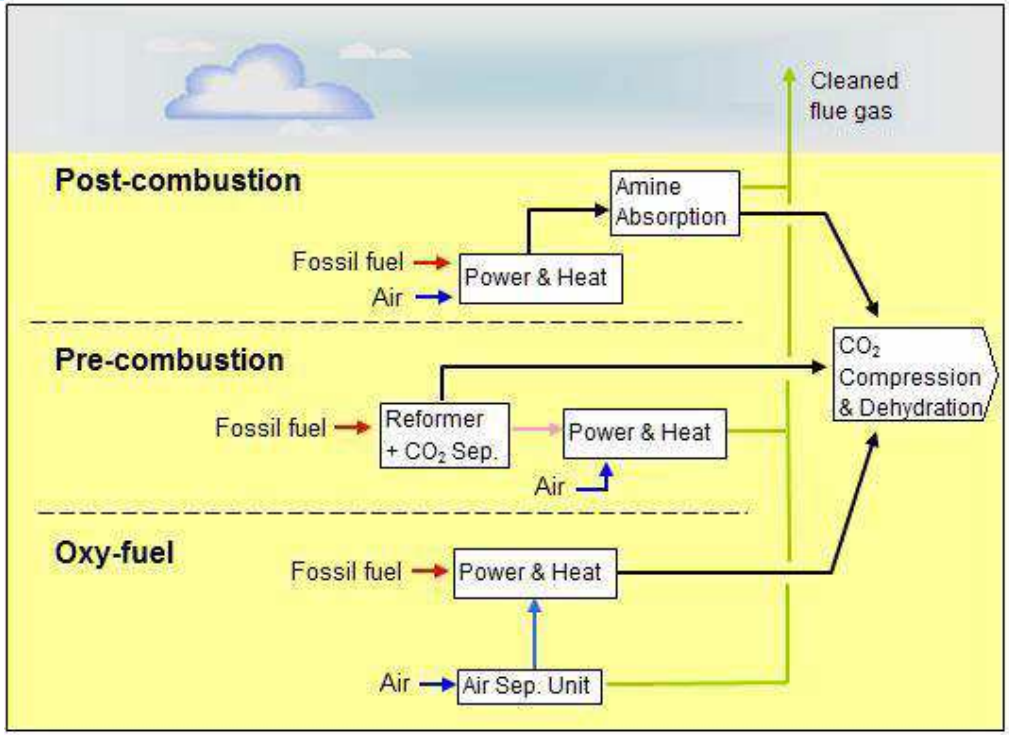
Carbon Capture Technologies



- Accepted need for a portfolio approach
- All technologies need to be addressed
- Retrofit and new plant application

Main goal : Cost of CO_2 avoided: < 20 €/t CO_2

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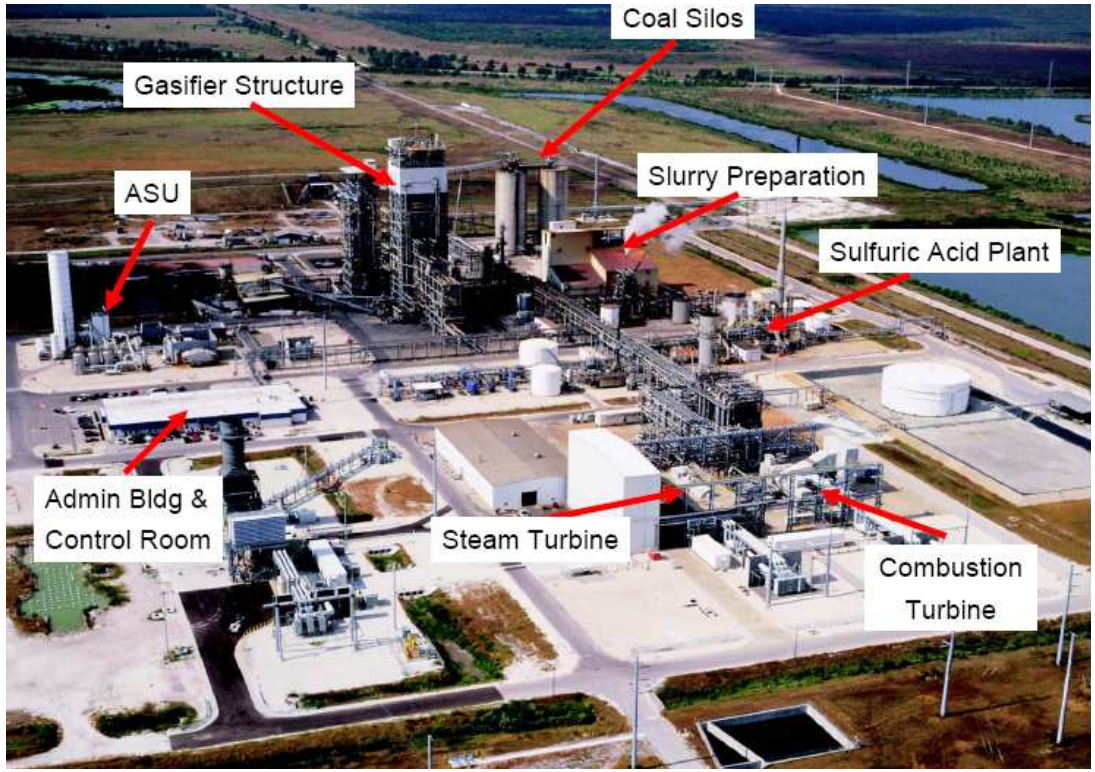
CO2 CAPTURE SOLUTIONS
Pre Combustion Solution for New Plants: IGCC+Capture

Coal gasification



Tampa Electric Company, Polk Power Station, 252 MWe, Mulberry, USA (FL)

- CO2 Capture technology is proven and economical in other industries
- High Capital and Operating Costs
- Limited operation flexibility
- Plant retrofit: not generally possible
- Landspace 1,5 x PC plant for same MW

Hydrogen-fired gas turbines

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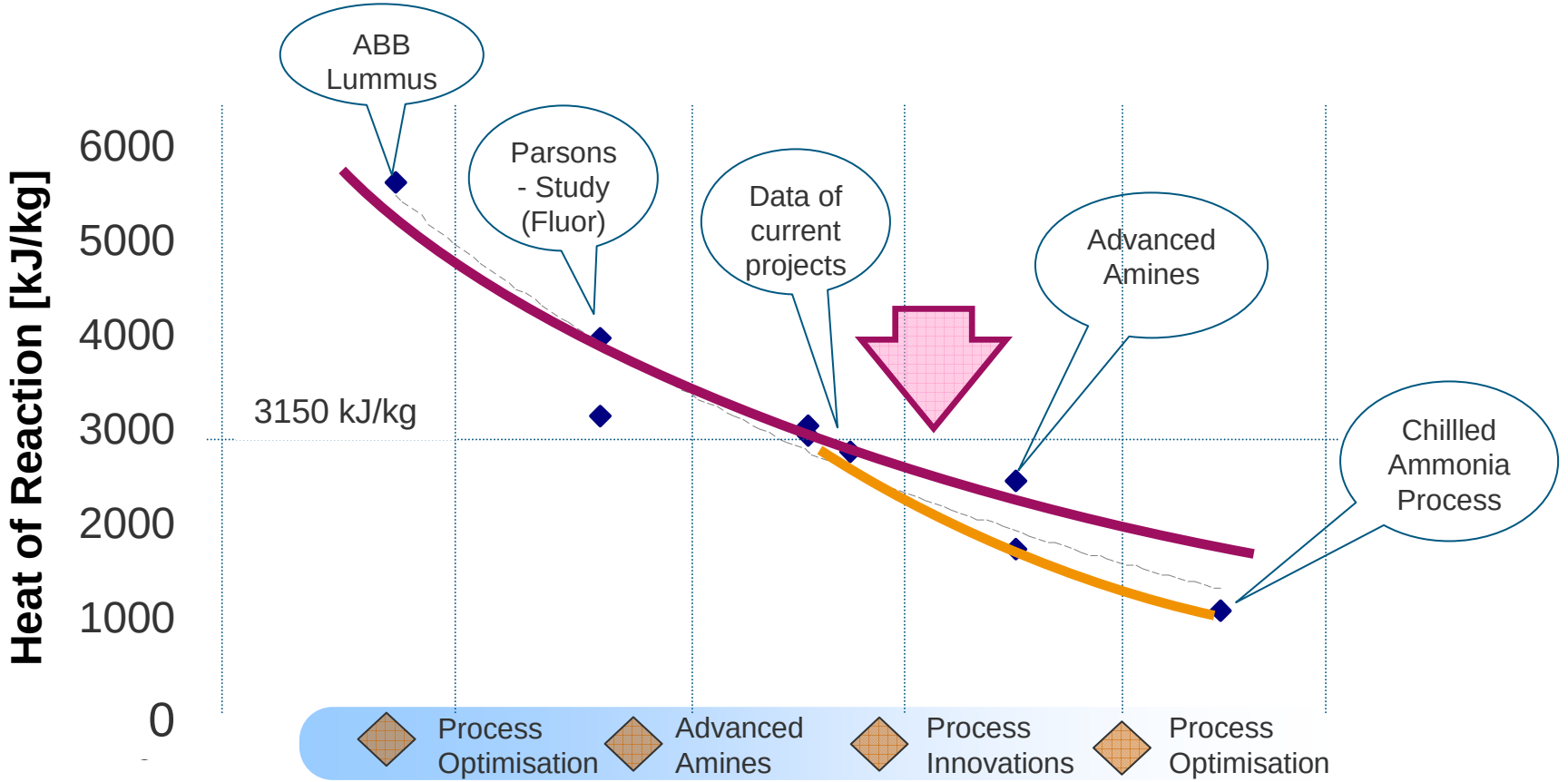
Going down the “Experience Curve” for Post Combustion CO2 Capture



CO_2 €/T **45-35** **35-25** **25-15**
(not including transport and storage)

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Development Plan of Chilled Ammonia Process

2006 | 2007 | 2008 | 2009 | 2010 | 2011

Main Steps

1 Laboratory Scale
- *First technical hypotheses*

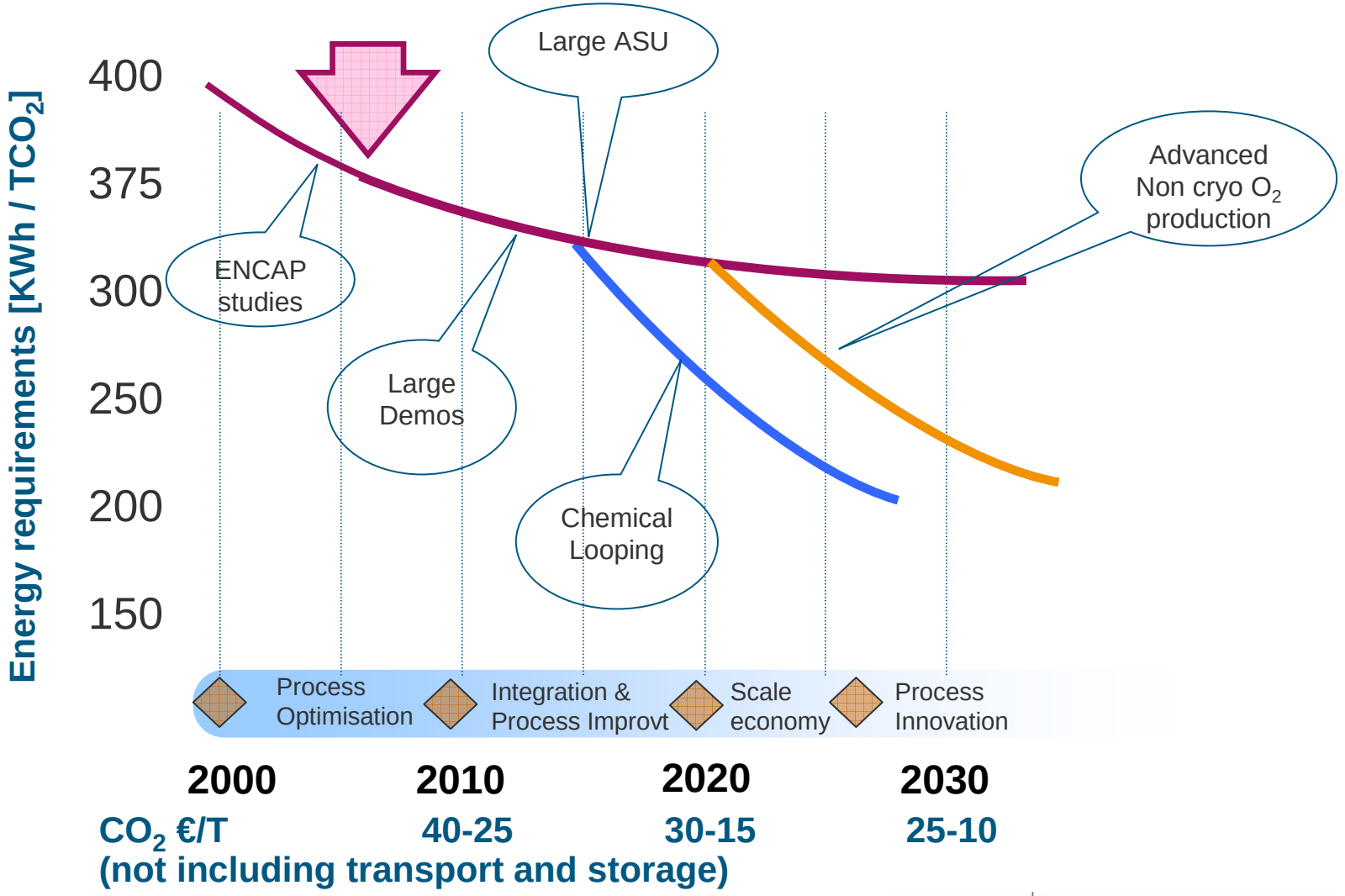
2 Large Bench Scale (0,25 MWt)
- *Optimize absorber design*
- *Establish absorber removal rate*
- *Demonstrate limited ammonia emissions*

3 Field Pilot Scale (5 MWt)
- *Validate key performance parameters*

4 Demonstration Scale (30-40 MWt)
- *System reliability*

5 Utility Scale (+200 MWt)
- *Integration*

Going Down The Experience Curve for Oxy Combustion CO2 Capture



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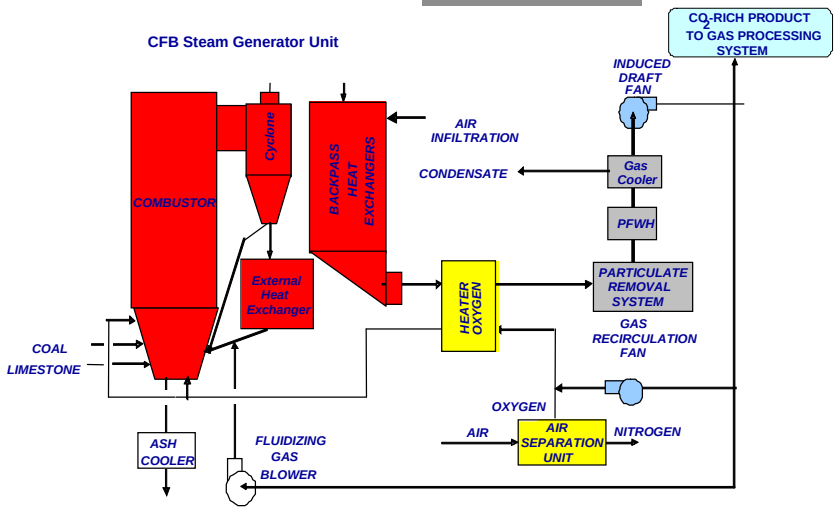
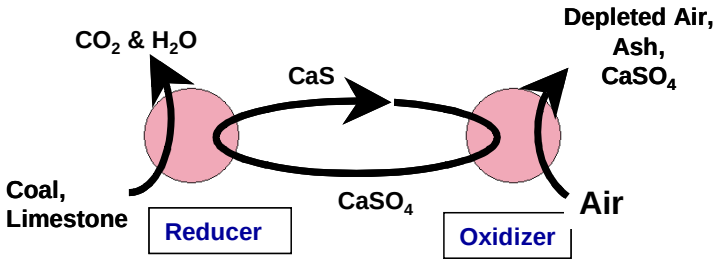
Advanced Capture Processes

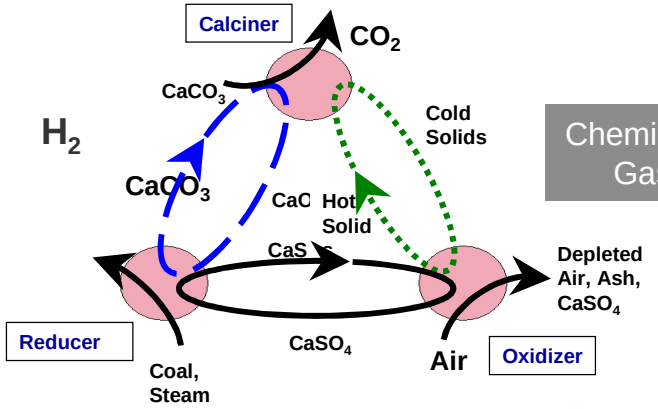
- **Oxygen Fired CFB**
- **Chemical Looping**
  - Combustion
  - Gasification

O_2 fired CFB





Chemical Looping Combustion



Chemical Looping Gasification

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Long term products: Oxy-fired PC, Oxy-fired CFB and Chemical Looping

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 - 20
Oxy-fired PC	1 Lab scale tests (500kWt)												
					2 Demonstration scale tests (30MWt)								
													3 Utility scale tests (250MWe)
													4 Commercialization
Oxy-fired CFB	1 Pilot scale (3MWt)												
													2 Demonstration Scale tests (10-40MWe)
													3 Utility scale tests (>150MWe)
													4 Commercialization
Chemical Looping	1 Bench tests (10-100 kWt)												
													2 Pilot scale (1-3 MWt)
													3 Demonstration scale tests 10-20 MWe
													4 Utility scale 50-100MWe
													5 Com

Source : ALSTOM analysis

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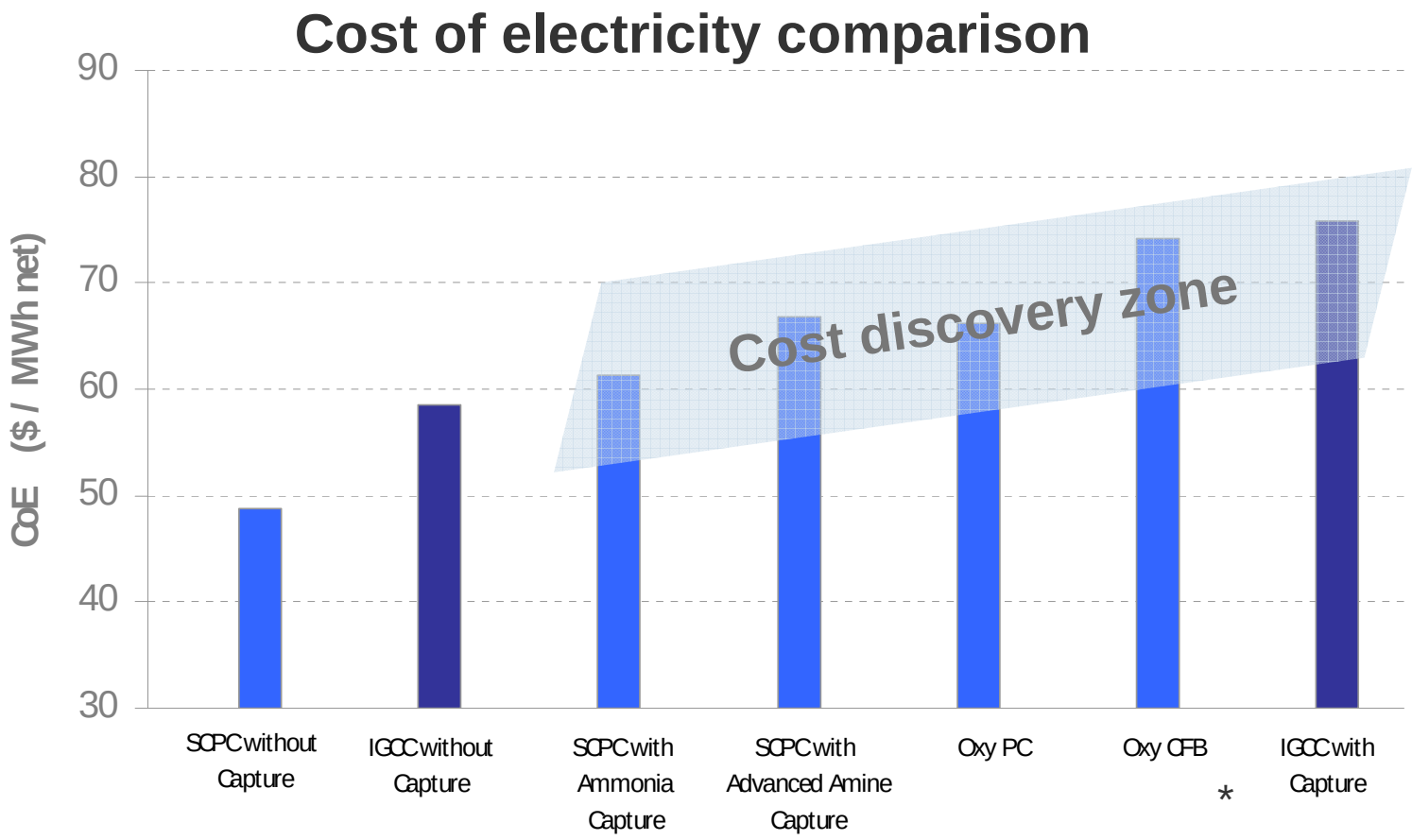
Carbon capture technology comparison



* Based on a 400 MWnet design, versus 650 Mwnet for other technologies

A portfolio of technologies must be validated at large scale

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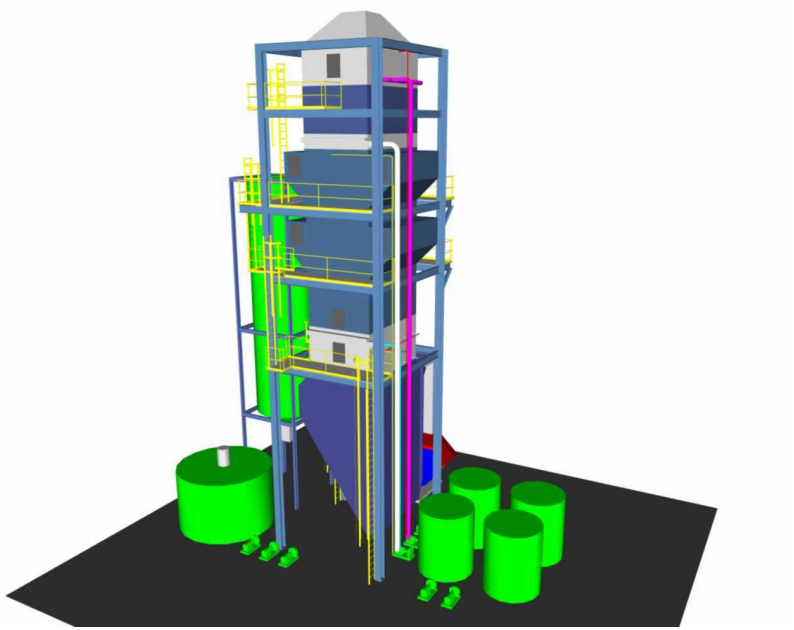
……. multi-pollutant control

- Integrated APC system based around commercially proven and reliable technologies
- Uses readily available reagents
- Produces reusable byproduct(s)
- Superior cost/performance ratio:
  - Extremely compact design
  - Fewer moving parts reduces maintenanc
  - Superior environmental performance
- Targeted emissions levels:
  - SO_2: 0.02 lb/MMBTU (> 99.5%)
  - Hg: 1.0 lb/TBTU (> 90%)
  - PM: 0.01 lb/MMBTU (99.99%)
  - NO_x: 0.05 lb/MMBTU w/SCR



Controls SO_x, $PM_{10}/PM_{2.5}$ Mercury & NOx

Not just CO_2

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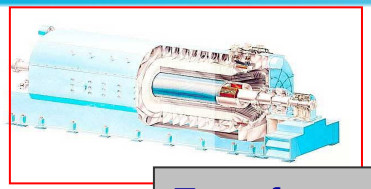
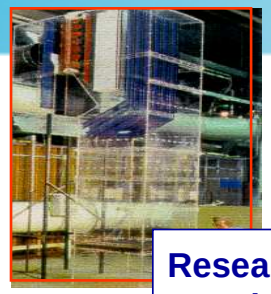
…….. overall system performance and reliability



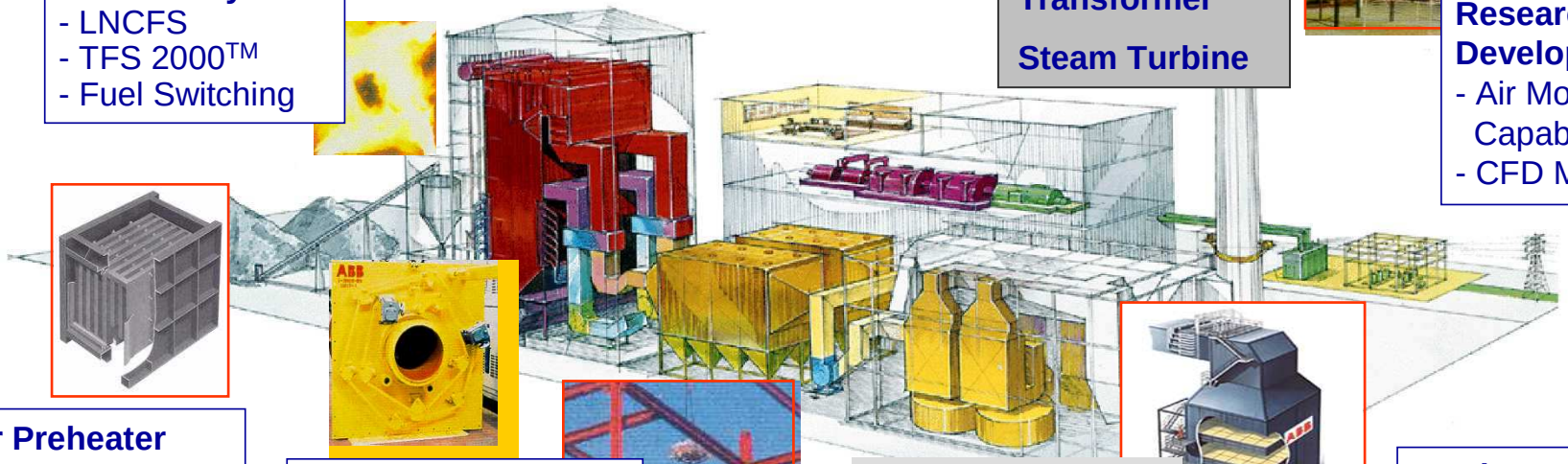


Transformer

Steam Turbine

Low NOx Systems
- LNCFS
- TFS 2000™
- Fuel Switching

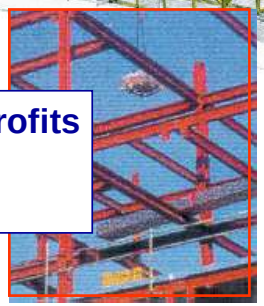
Research and Development
- Air Modeling Capabilities
- CFD Modeling



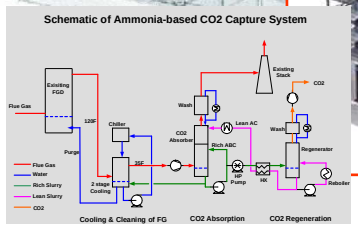
Air Preheater

Mills

Burner NOx Retrofits
- RSFC™
- P2™



Construction



CO_2 Capture

Environmental Systems
- SNCR
- FGD
- Precipitators
- Scrubbers

Importance of System Integration : more complex plant

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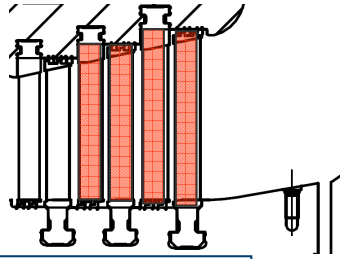
.....preparing the way forward : CO_2 "Capture Ready" Plant

Control system adaptation

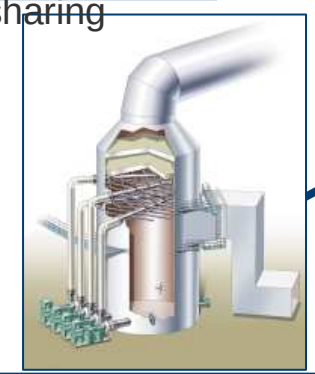
Optimisation
Of the cooling system
Recovery of heat in the
CO2 capture and compression



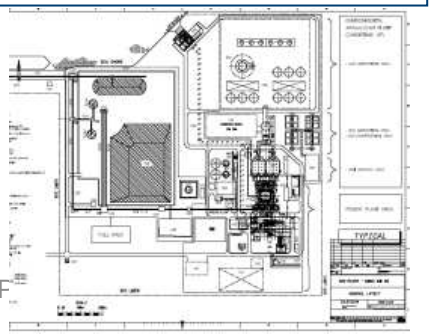
Provisions for steam extractions
Including provisions for adding stages
In the IP cylinder of the steam turbine

Optimisation of the
Boiler surfaces
according
Modifications of the
heat load sharing

Provision for auxiliary
Power consumption



Provisions in arrangement planning



Improve gas clean up
Or possibility to add
cleaning

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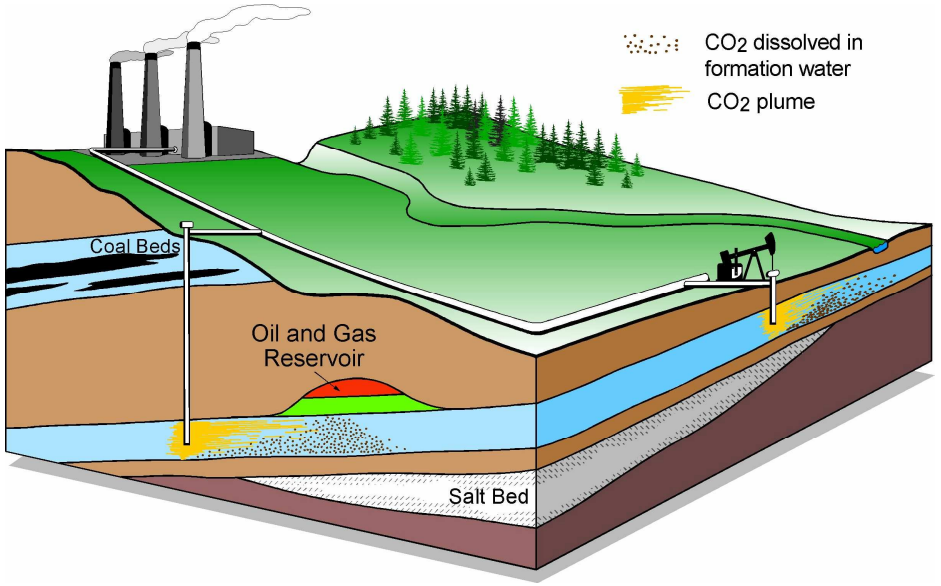
CO_2 Transport and Storage

Key Issues

- Infrastructure Requirement
- Cost Reduction
- Public Acceptance
- Safe and Effective Storage
- Developing the Legal, Regulatory & Fiscal Framework



Safety and acceptance of CO_2 storage

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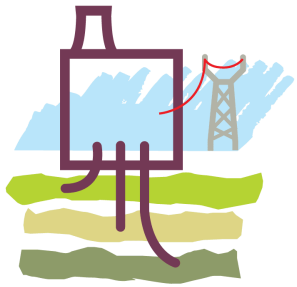


ETP ZEP :
Set-up and Vision

MAJOR EUROPEAN ACT

The Vision: To enable European fossil fuel power plants to have zero emission of CO_2 by 2020.

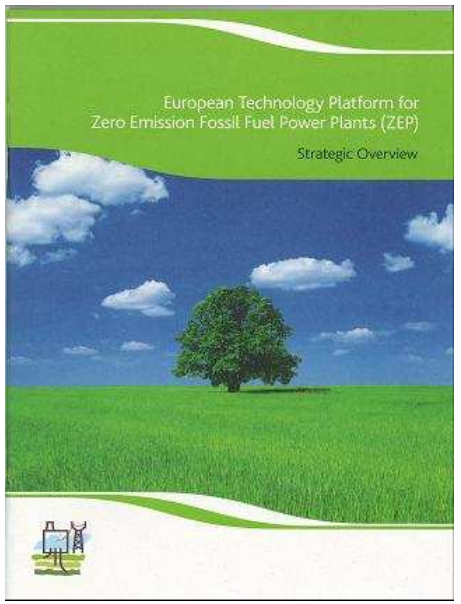
- **Primary task to set and implement strategic research agenda (SRA) and deployment document (SDD) as a major European action**
- **Advisory Council formed in June 2005, updated June 2007 : individuals represent**
  - **6 Generators**: E.ON, Endesa, Enel, Energi E2, RWE, Vattenfall
  - **6 Equipment suppliers**: Ansaldo, ALSTOM, Air Liquide, Foster Wheeler, Doosan Babcock, Siemens
  - **5 Oil and Gas**: BP, Shell, Statoil, Total, Schlumberger
  - **6 Research**: BGS, CIRCE, IFP, Polish CMI, GEUS, TU-Hamburg
  - **3 NGOs**: Bellona, E3G, WWF
  - **1 Financeer**: Morgan Stanley
  - Chair: Kurt Haege/Vattenfall Vice-Chairs: Olivier Appert/IFP, Gardiner Hill/BP, Charles Soothill/ALSTOM, Frederic Hauge/Bellona
- **Formally launched : 1st December 2005**
- **First General Assembly, Brussels : 12-13th December 2006**
- **Second General Assembly, Paris : 3rd October 2007**

ETP ZEP :
Strategic Recommendations

SRA : set a major R&D action to reduce costs and risks of deployment

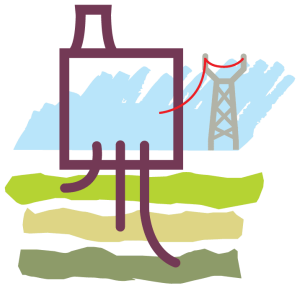
SDD : accelerate the market for efficient zero emission power plant

- Urgently implemen10-12 integrated large scale CCS demonstration projects EU-wide
- Establish a robust technology action across whole of CO_2 chain
- Kick start the CO_2 value chain with urgent short and long term commercial incentives
- Establish a regulatory framework for storage
- Gain public support through a comprehensive public information campaign

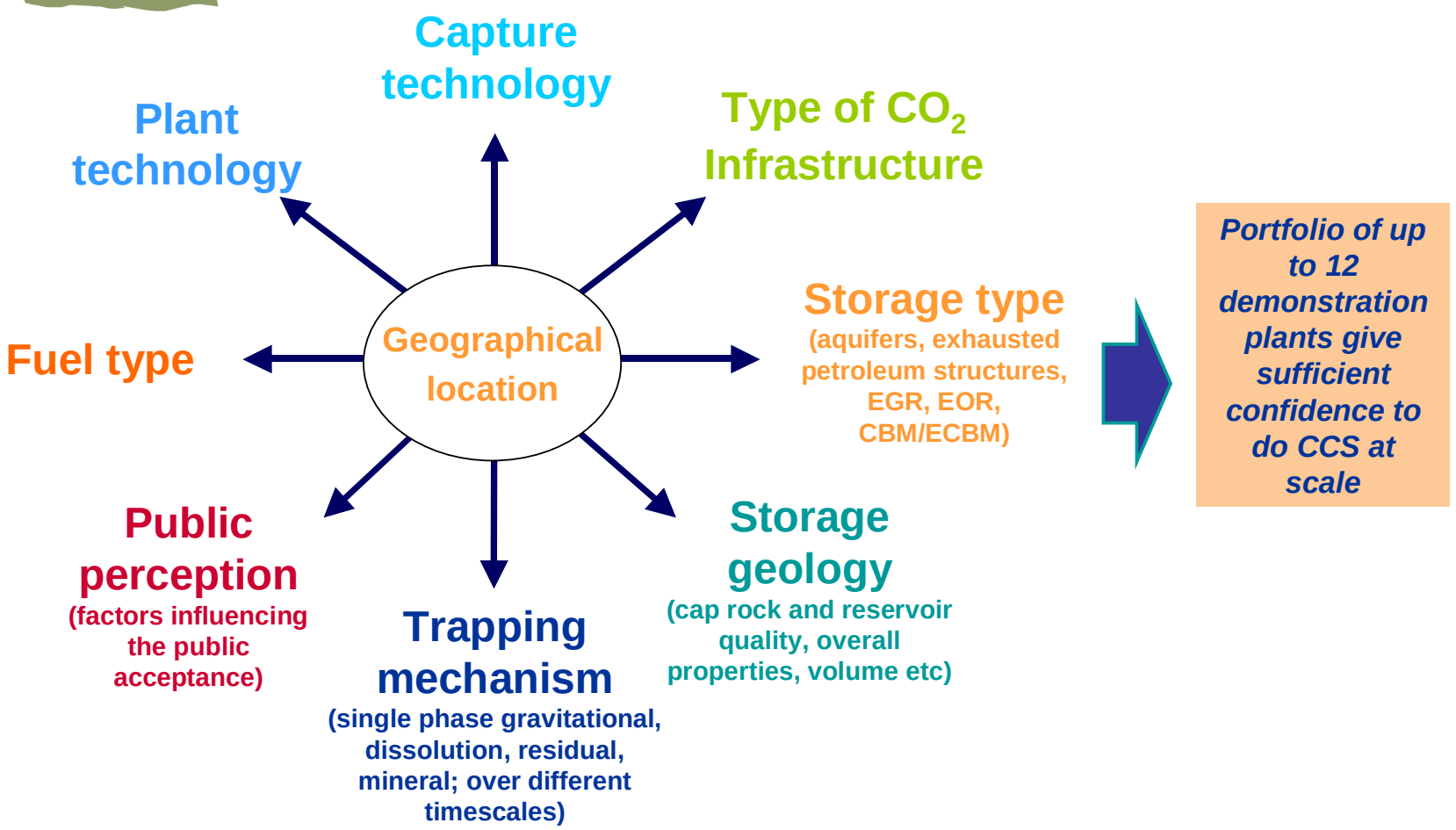


Output from EU 2007 Spring Council

- **EU Energy Policy for Europe 2007-2009**
  - "underlines importance of substantial improvements in generation efficiency and clean fossil fuel technologies"
  - "urges Member States and EC to work towards strengthening R&D and developing the necessary technical, economic and regulatory framework to bring environmentally safe CCS to deployment with new fossil-fuel power plants, if possible by 2020"
  - "welcomes intention of EC to establish a mechanism to stimulate the construction and operation by 2015 of up to 12 demonstration plants of sustainable fossil fuel technologies in commercial power generation."
- **EU Strategic Energy Technology [SET] Plan**
  - priority item for Spring 2008
  - specific reference to CCS as part of plan



ETP ZEP :
Scope of the EU Flagship Programme



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Worldwide Engagement

- **Carbon Sequestration Leadership Forum (CSLF)**
  - CSLF Technology Route Map
  - CSLF Project Portfolio
  - CSLF Stakeholder engagement

Australia	Japan
Brazil	Mexico
Canada	Netherlands (new)
China	Norway
Colombia	Republic of Korea (new)
Denmark (new)	Russian Federation
European Commission	Saudi Arabia (new)
France (new)	South Africa (new)
Germany (new)	UK
India	USA
Italy	Greece (applied)

- **G8 Action Plan**
  - Financial Mechanisms/World Bank
  - `Capture Ready` Technology/IEA
  - CCT data base and worldwide case studies

- **IPCC Special Report on CCS**
  - Summary for Policy Makers : issued Sept06
  - Topic embraced by 2007 IPCC Report : Feb07

Thrust for co-ordination and engagement

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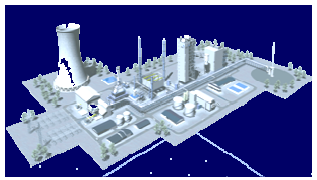
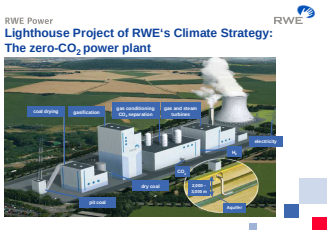
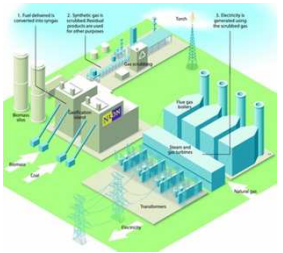
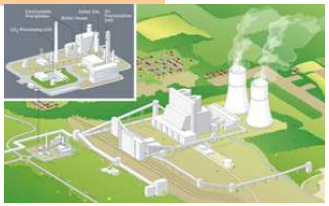
Industry oriented actions : large scale demonstration







Industry getting ready ……
many projects being announced
…… but the right regulatory and fiscal conditions needed



A portfolio of technologies must be validated at large scale

Acknowledgement to RWE, EON, SSE, NUON, Vattenfall, TOTAL, Statoil

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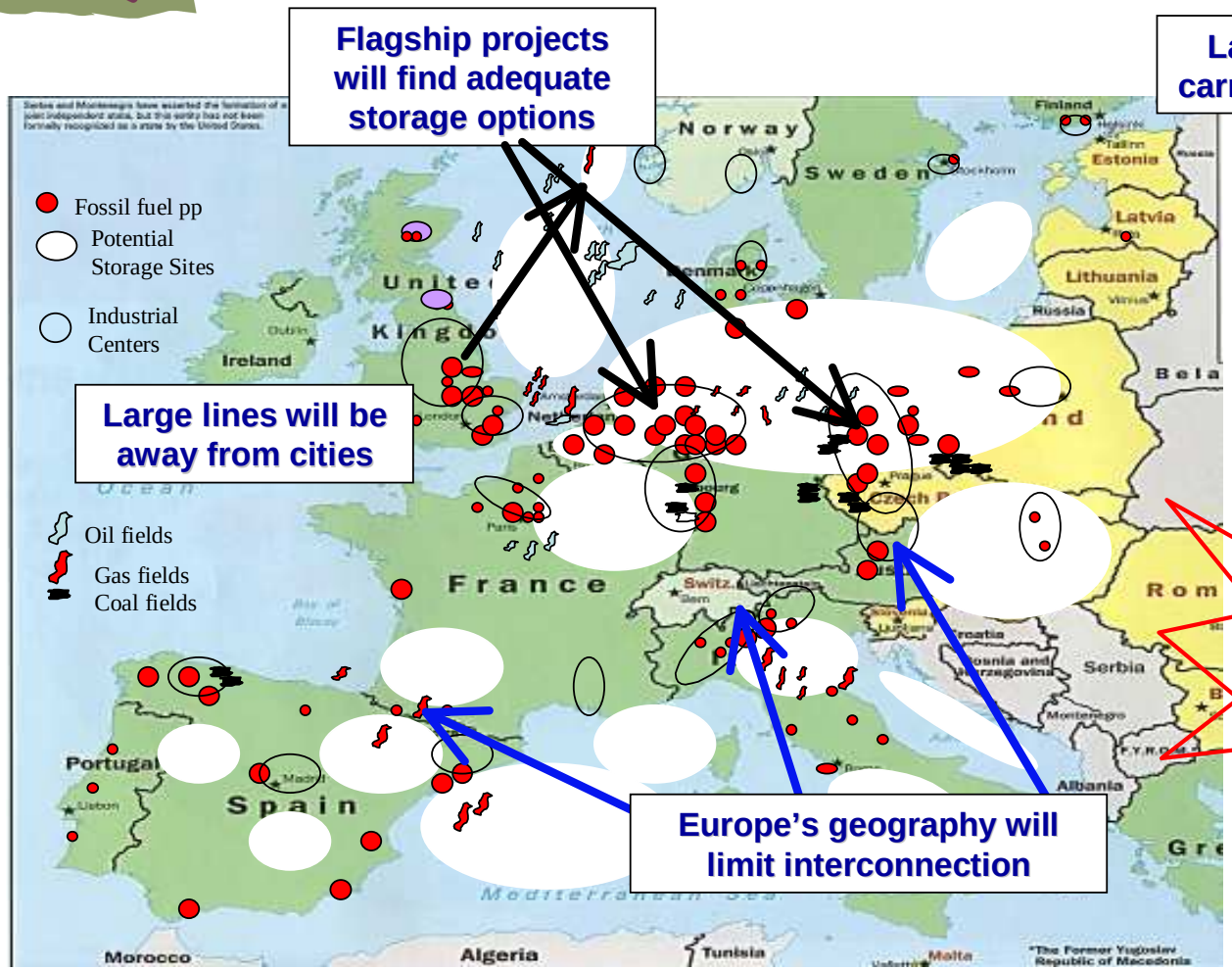
ETP ZEP :
Importance of pan-EU infrastructure/storage



Concluding Remarks

- **Importance of clean use of fossil fuels**
  - a critical transitional issue in getting to a sustainable energy future
  - an essential part of the portfolio
- **Importance of accelerating the take-up of clean fossil**
  - need for incentives for early action on `zero emission` power plant
  - stable financial and regulatory framework to get “many of a kind”
- **Importance of addressing issue worldwide**
  - use of high efficiency technologies, and …….
  - ……. prepare the way `zero emission`
    - retrofitting of high efficient coal plant with capture to avoid “carbon lock-in”
    - how to ensure new plant is “capture ready”
    - use of low carbon technologies for new plant

Urgent need for action

thank you for listening

27th November 2007

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