



**“Carbon Capture & Storage”  
Siemens solutions for the  
emerging market.**

**Dr. Hermann Kremer  
Director Business Development CCS**

**Siemens Energy Sector**

## CCS: Siemens solutions for the emerging market

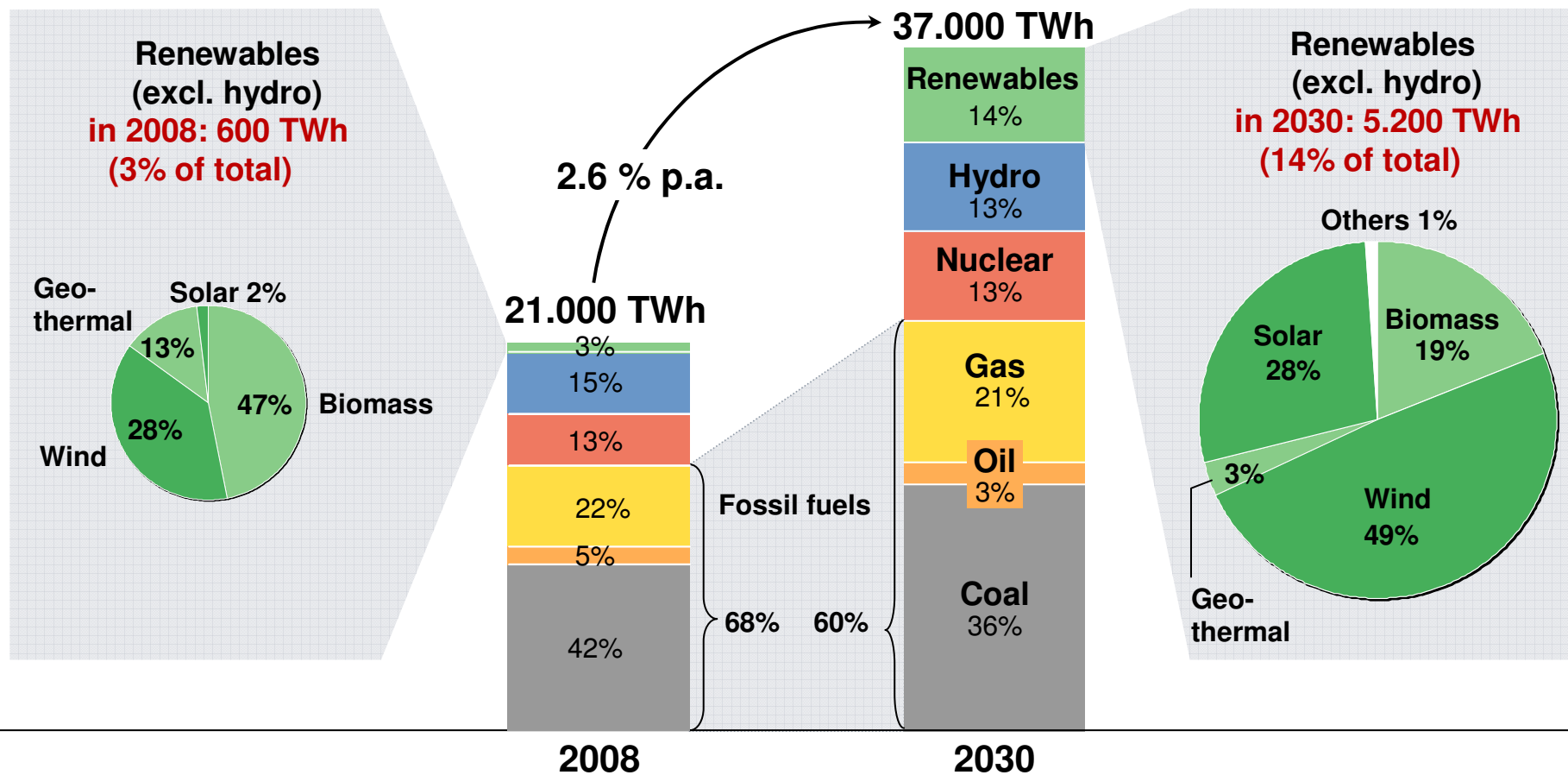
- Market & Investment Environment
- Innovative Power Generation Technologies
- CO<sub>2</sub>-capture technologies (overview)
- IGCC with Pre-Combustion Capture
- Post-Combustion Capture
- Capture-Ready / Retrofit solutions for SPP
- CO<sub>2</sub> Transportation and Storage

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# Renewables are gaining in importance – but fossil fuels will continue to be the mainstay

## Power Generation (in 1000 TWh<sup>1</sup>)

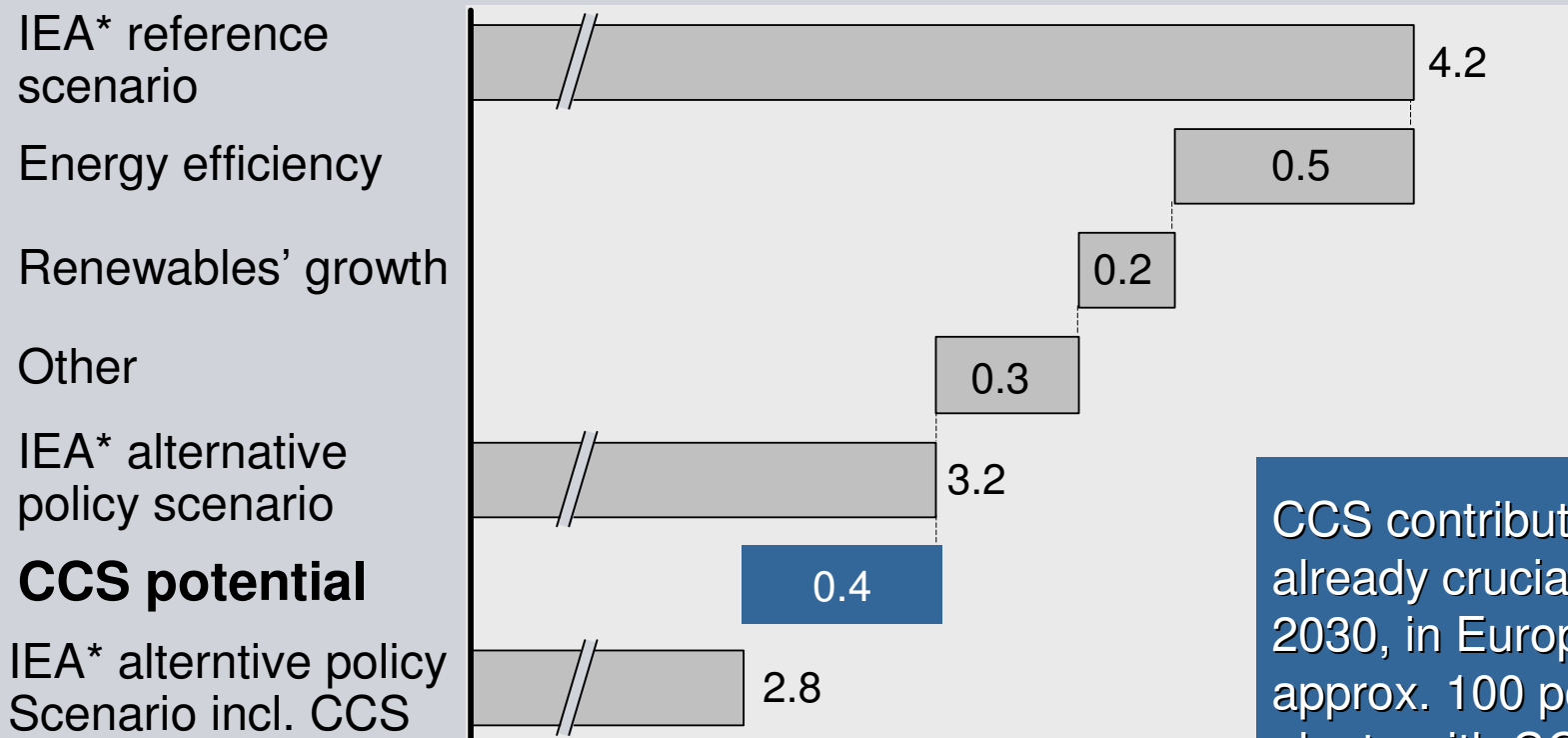


Quelle: Siemens Energy Sector, GS4 base case

<sup>1</sup> Terawatt-hours

# Energy efficiency and Carbon Capture & Sequestration (CCS) are key Solutions to Reaching Emission Reductions Targets **SIEMENS**

EU emissions, Gt CO<sub>2</sub>/year, 2030



CCS contribution already crucial in 2030, in Europe approx. 100 power plants with CCS !

Source: ZEP General Assembly, November 10, 2008, Brussels

\*IEA = International Energy Agency

It is globally accepted by now that CCS is indispensable for reaching global carbon emissions reduction targets.

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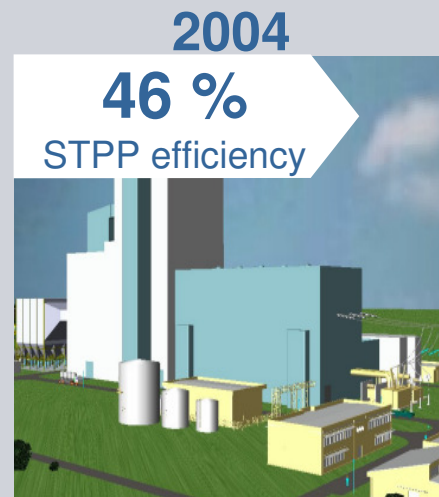
# Contribution of Steam Power Plant development towards environmental compliance



STPP Bergkamen  
designed for 747 MW



STPP Isogo 1  
designed for 600 MW



Reference STPP NRW  
designed for 600 MW



STPP 50plus (E.ON)  
designed for 500 MW

## Reduction of CO<sub>2</sub> emissions

Basis

- 11.8%

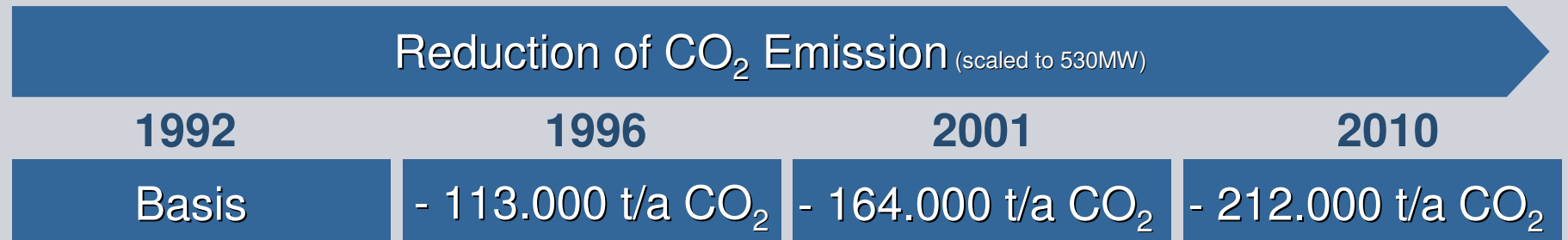
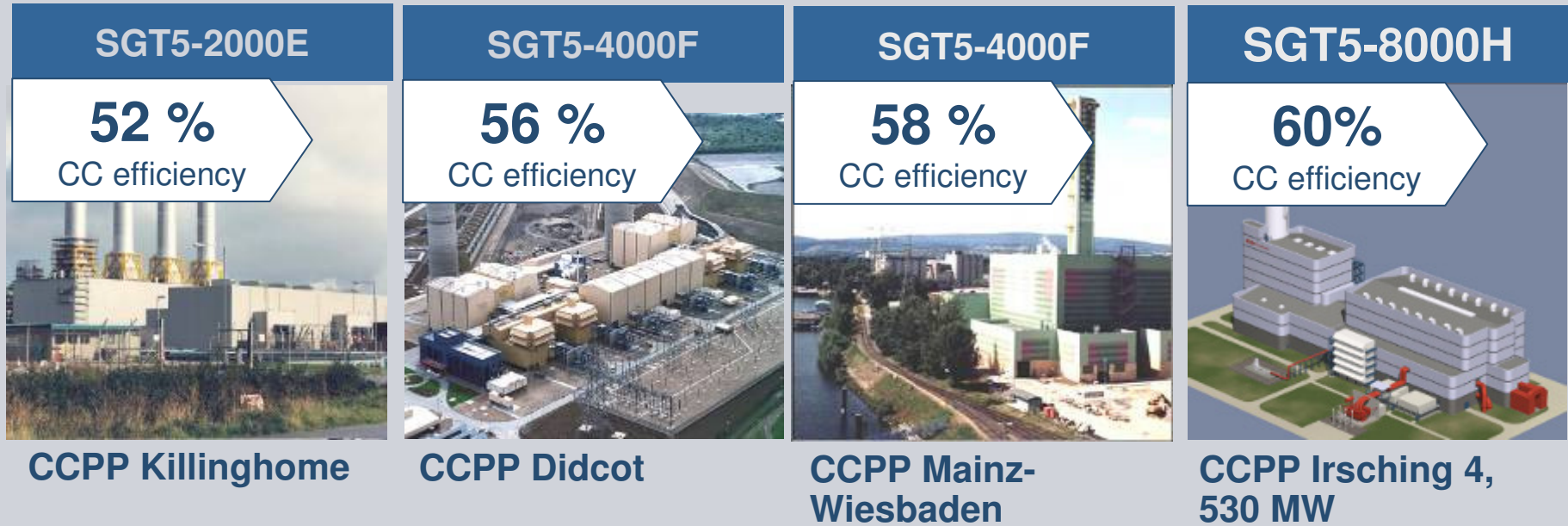
- 20.2%

- 25.0%

Increasing efficiency is the key driver to more environmental friendly STPPs, suppliers and generators need to strive for.

# Siemens Combined Cycle: Efficiency Evolution

**SIEMENS**



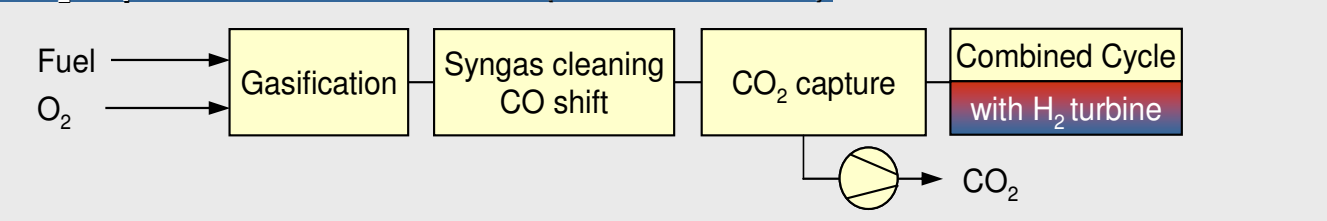


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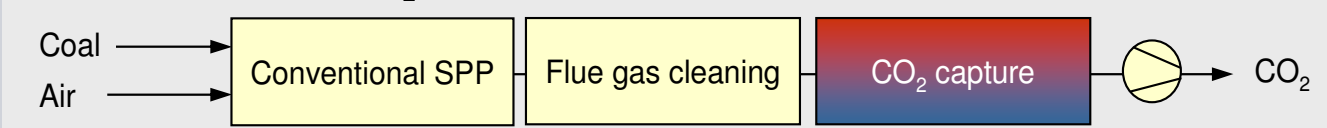
# Three technology pathways ready for implementation in CCS demonstration projects

## CO<sub>2</sub> Capture before Combustion (Pre-combustion)

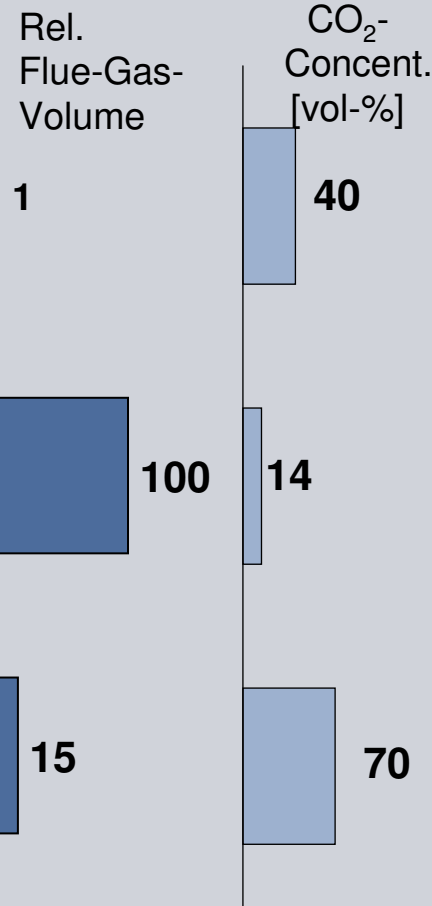
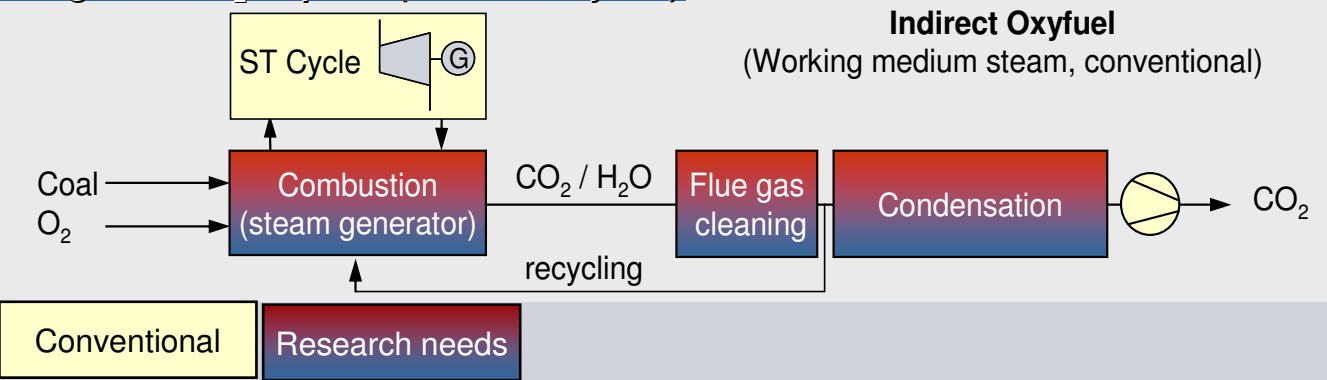


## CO<sub>2</sub> Capture after Combustion (Post-combustion)

Conventional PP with CO<sub>2</sub> scrubbing



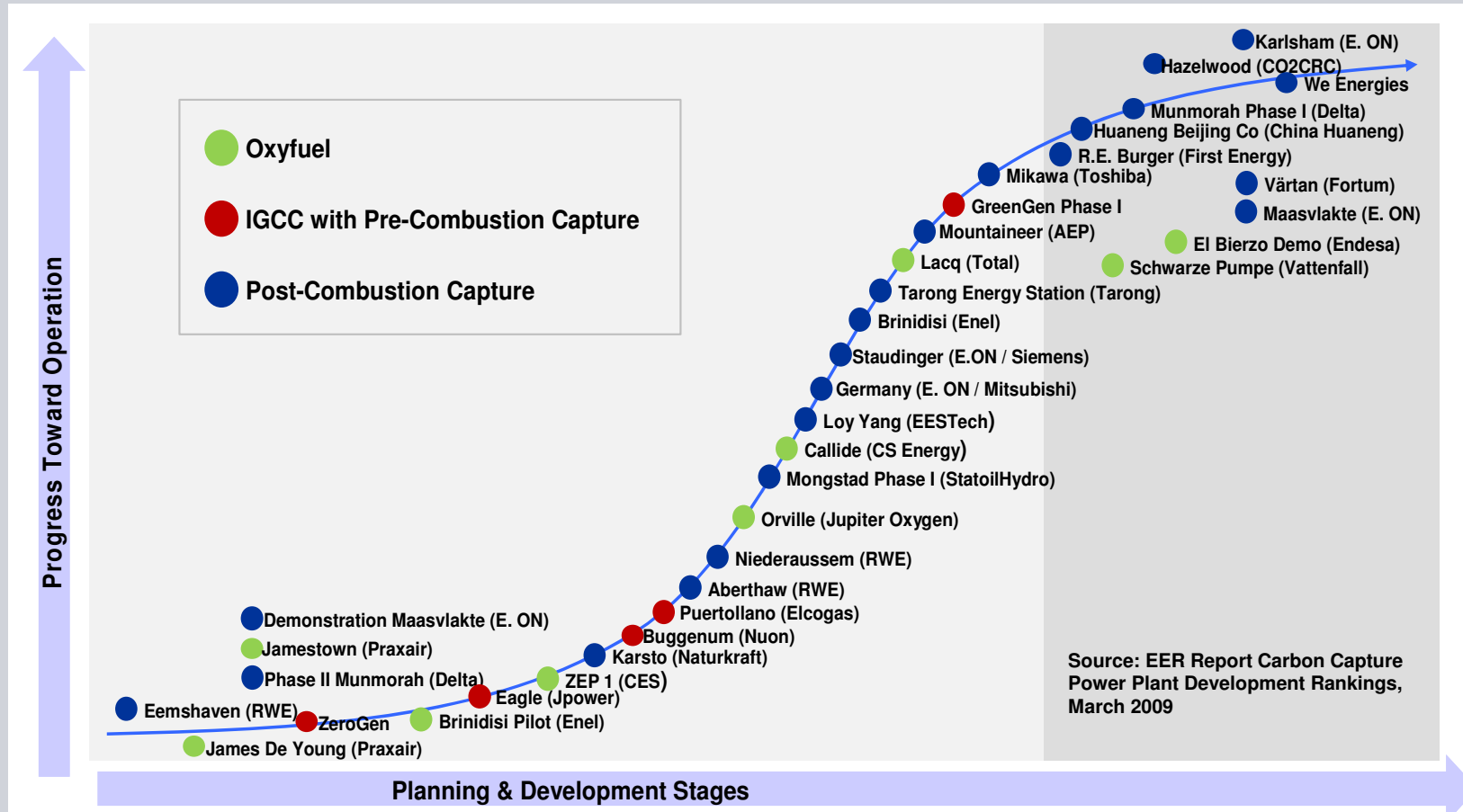
## Integrated CO<sub>2</sub> Capture (Indirect Oxyfuel)



**In addition many new ideas.....but need more time, not available before 2020.**

# Carbon Capture Development Rankings

## Status of Pilot-, Demonstration Projects (<100 MW in scale)



65 CCS projects are globally in development stage,  
Post-Combustion preferred solution for retrofits.

**CO<sub>2</sub> Scrubbing proven technology,  
but Post-combustion capture need new or modified solvents and processes**

**CO<sub>2</sub> Scrubbing in the Processing Industries**

- **CO<sub>2</sub> Absorption/Desorption is proven technology in the chemical processing and in the oil & gas industries**
- **Licensed technology is integrated in the chemical production processes**
- **The climate change/carbon capture discussion has initiated a world wide technology development push**

**Physical Absorption**

**“high partial pressure of CO<sub>2</sub>”**



**For Pre-combustion carbon capture in IGCC proven gas treatment processes are available**

**Chemical Absorption  
integrated in chemical plant**

**“lower partial pressure of CO<sub>2</sub>”**



**For Post-combustion carbon capture new or modified solvents and processes are needed**

## Siemens preferred solutions for CO<sub>2</sub> capture

### IGCC / Pre-combustion carbon capture

Gasification technology with multi-fuel capability for new power plants

- Technology “ready for implementation”
- Alternative route for chemical / fuel production, hydrogen economy
- Mastering higher technological and contractual complexity with “Siemens phased project execution offer”.

### Post-combustion carbon capture

Scalable market introduction, Demoplants with slipstreams, minimize upgrade risk in process trains

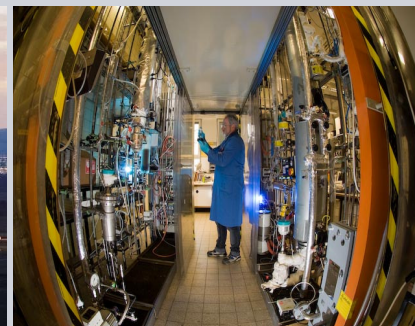
- Enhancement potential for solvents, scrubbing process and for integration into the power plants
- For retrofit and new fossil fired power plants
- Siemens develops amino acid salt based process and has established partnership for aqueous ammonia process.



Siemens Fuel Gasifier



Siemens IGCC in Puertollano (E)



Siemens scrubbing process test lab



Post-Combustion carbon capture plant design

Siemens solutions will be ready for the implementation in the upcoming CCS demonstration projects.

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- **IGCC with Pre-Combustion Capture**
- Post-Combustion Capture
- Capture-Ready / Retrofit solutions for SPP
- CO<sub>2</sub> Transportation and Storage

# IGCC Combines the Best of Advanced Coal and Natural Gas Combined Cycle Power Plants

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## Steam Power Plants



- Use low cost domestic fuel

## Natural Gas Fired Combined Cycle Power Plants



- Higher efficiency
- Lower Emissions

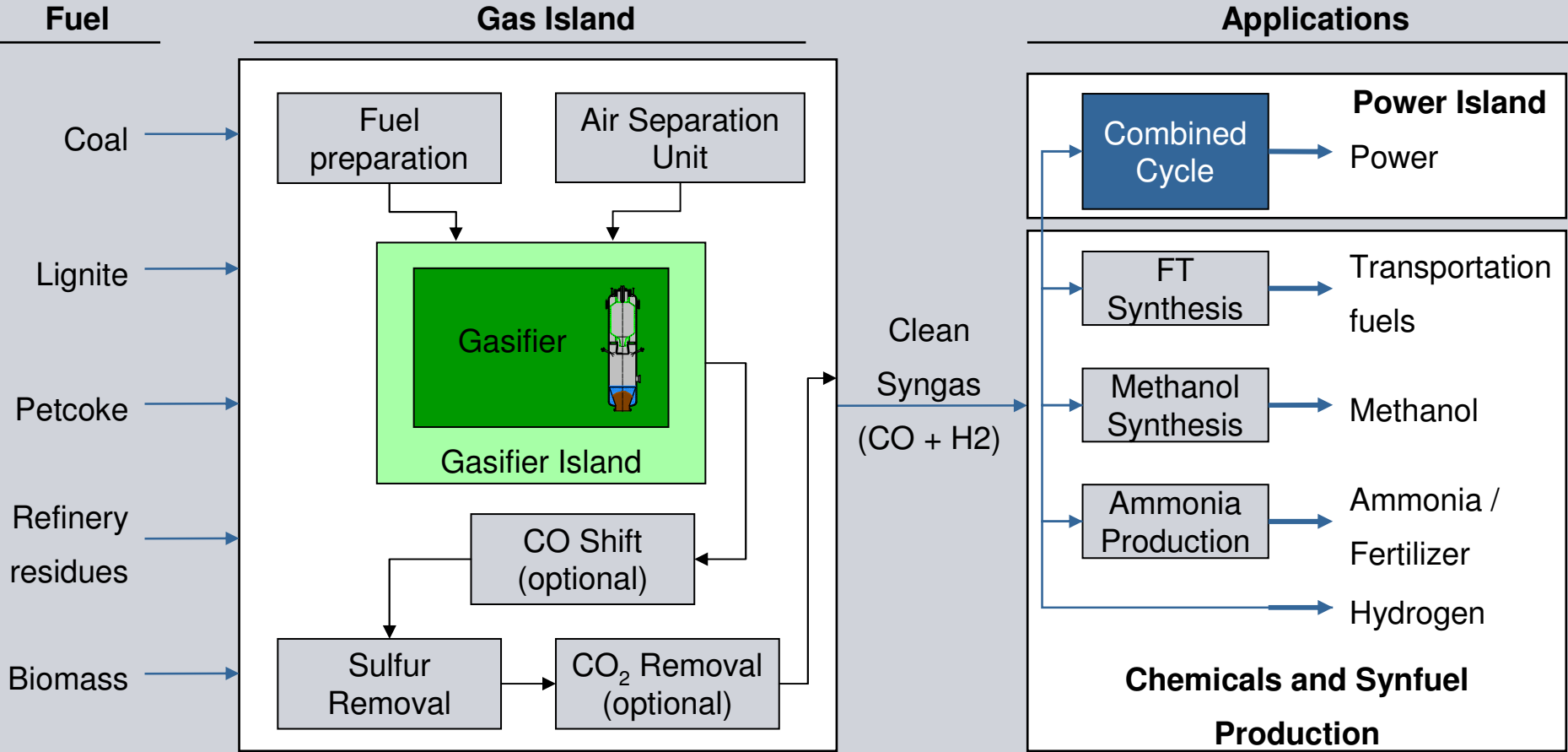
## Integrated Gasification Combined Cycle Plants



- Low emissions compared to conventional coal options
- High efficiency
- Fuel flexibility
- Co-Production of H<sub>2</sub> and other products
- Potential to capture CO<sub>2</sub> at a lower cost

Main driver today: CO<sub>2</sub> Capture & Storage

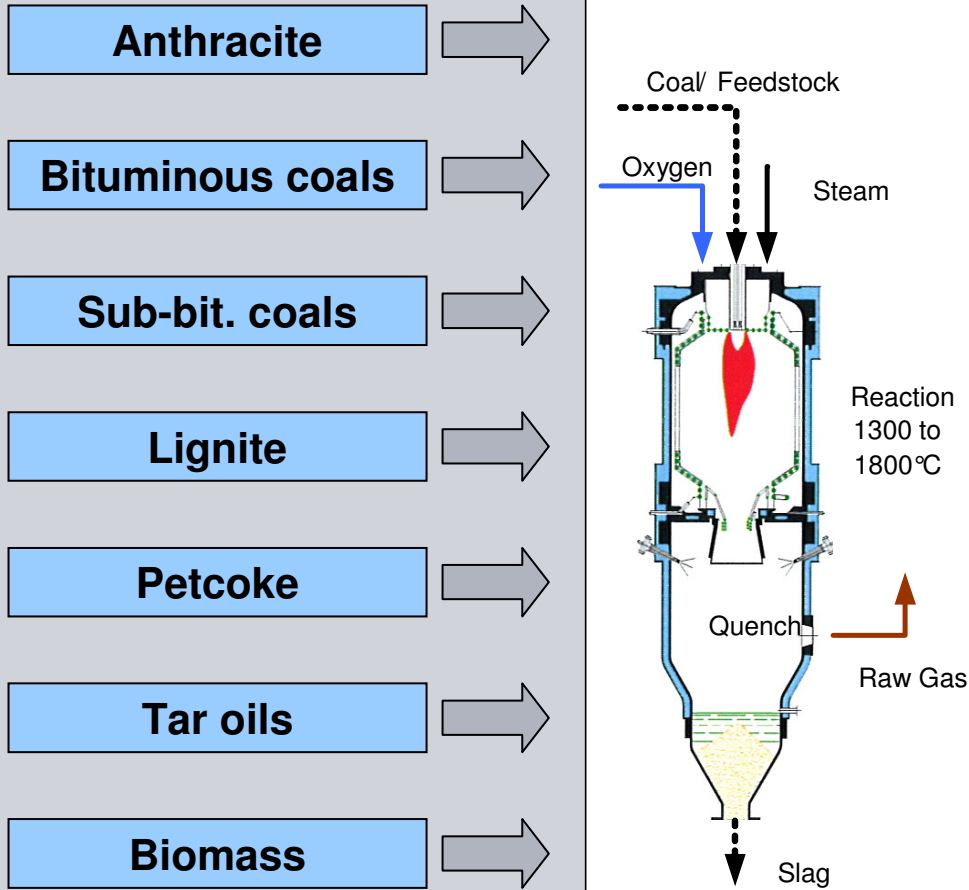
**IGCC Plant design and Siemens scope**



Siemens Basic Engineering & Design
  Siemens Supply of Key Equipment
  Siemens EPC



**Siemens Fuel Gasifier (SFG)**

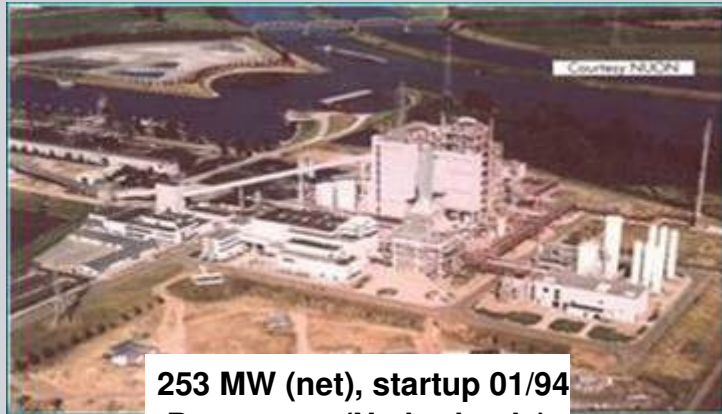


- >20 years of successful operation
- More than 100 gasification tests performed with more than 60 different feedstocks
- Coals from Australia, Germany, Canada, South Africa, China,...
- Used to determine gasification behavior for fuels with difficult ash properties

Test results confirm that SFG offers widest fuel flexibility.

SFG gasifier technology is well-suited for IGCC-CCS applications.

## Existing Coal-Based IGCC Power Plants



**253 MW (net), startup 01/94  
Buggenum (Netherlands)**



**262 MW (net), startup 10/95  
Wabash River (Indiana/USA)**



**298 MW (net), startup 12/97  
Puertollano (Spain)**



**250 MW (net), startup 09/96  
Polk Power (Florida/USA)**

Siemens was involved in all European coal-based IGCC plants.

## Siemens Gasification Experience

	Gasifier Size	Start-up	Fuel	Products
<b>Schwarze Pumpe (Germany)</b>	200MW <sub>th</sub>	1984	lignite, natural gas, tar oils, and waste	syngas for methanol and power
<b>Siemens Test Center (Germany)</b>	5MW <sub>th</sub>	1996	hard coal, lignite, slurries	syngas
<b>BASF Seal Sands (UK)</b>	30MW <sub>th</sub>	2001	liquid chemical residuals	fuel gas
<b>Vřesová (Czech Republic)</b>	175 MW <sub>th</sub>	2008	tar oils, liquid residuals	syngas for IGCC



**Schwarze Pumpe**



**Seal Sands**



**Vřesová**



**Siemens Test Center**

## Current Projects World-wide

	Gasifier Size	COD	Fuel	Products	Status
<b>Shenhua Ningxia (PR China)</b>	5 x 500 MW <sub>th</sub>	2009	bituminous coal	syngas for poly-propylene	Engineering finished & Construction in progress
<b>Secure Decature (USA)</b>	2 x 500 MW <sub>th</sub>	2010	bituminous coal	SNG	Engineering finished & Construction in progress
<b>Jincheng (PR China)</b>	2 x 500 MW <sub>th</sub>	2010	anthracite	ammonia / fertilizers	Engineering finished & Construction in progress
<b>EPCOR Power, Inc. Canada</b>	1 x 500 MW <sub>th</sub>	2015	bituminous coal	IGCC	FEED in progress
<b>Australian Energy Company (AEC)</b>	2 x 500 MW <sub>th</sub>	2014	lignite	ammonia / fertilizers	Technology selected

# Coal-Based Power Generation IGCC vs. Steam Power Plants

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## ▶ IGCC: Advantages

- higher potential for efficiency improvements
- benefits from advances in gas turbine technology
- fuel / product flexibility
- lower emissions
- more suitable for CO<sub>2</sub>-capture (pre-combustion)

## ▶ IGCC: Challenges

- reliability/availability
- investment cost



Steam power plants are the benchmark for coal-based power generation.

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# Siemens competencies for fossil power generation with carbon capture

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## Power Plant Technology



## Chemical Engineering



## CO<sub>2</sub> Compression



## Air Quality Control



## Instrumentation & Control Systems



## O&M Services

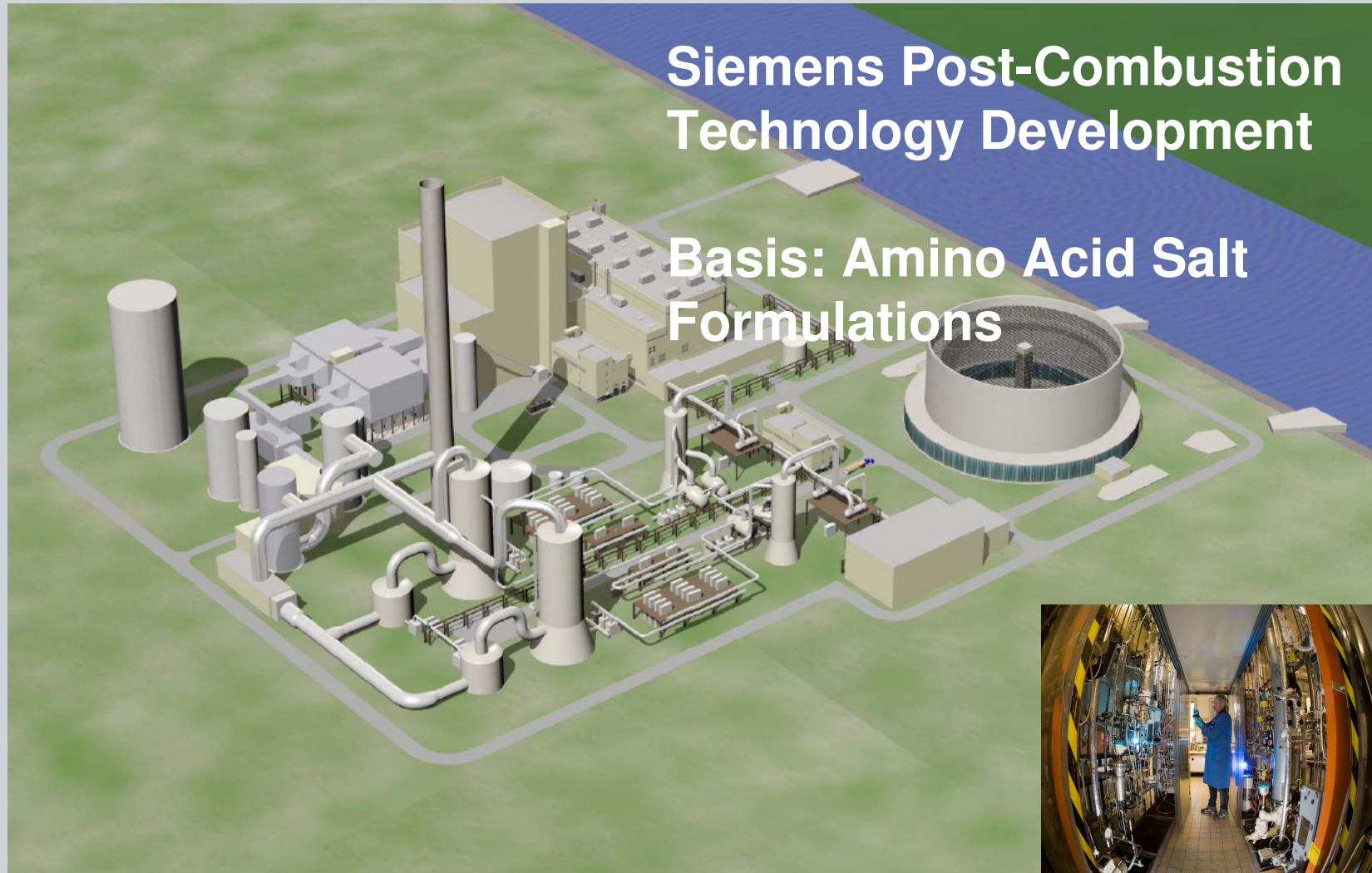


Alliance with POWERSPAN

Siemens proprietary 2<sup>nd</sup> generation Post-Combustion process

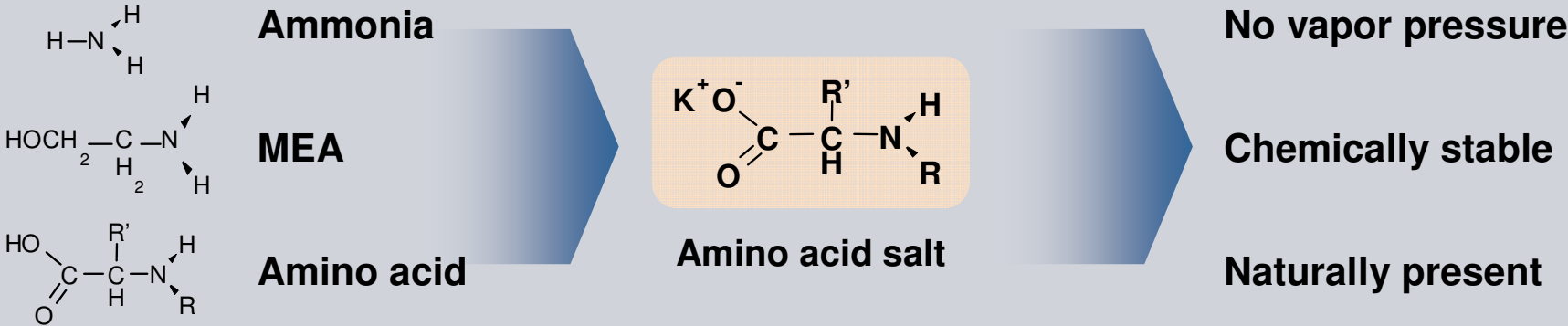
# Siemens Post-Combustion Carbon Capture Technology for Steam Power Plants

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Amino acid salt is the basis of our solvent



**Salts have no vapor pressure**

- No thermodynamic solvent emissions
- Not inflammable
- Not explosive
- Odorless
- No inhalation risk




**Negative ion is less sensitive to O<sub>2</sub>**

- Low degradation

**Amino acids are naturally present**

- Biodegradable
- Nontoxic
- Environmentally friendly



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

# Siemens lab plant for CO<sub>2</sub> capture tests at Frankfurt Hoechst Industrial Park



Desorption column

Reboiler made of glass so that boiling retardation effects can be recognized

Synthetic gas flue gas mixtures

Absorption column with operating pressure up to 10 bar

Fully automated DCS system NDIR CO<sub>2</sub> analytic

Siemens Energy runs a fully automated lab plant for CO<sub>2</sub> capture for 24/7 operation.

# Siemens Post-Combustion Capture Process

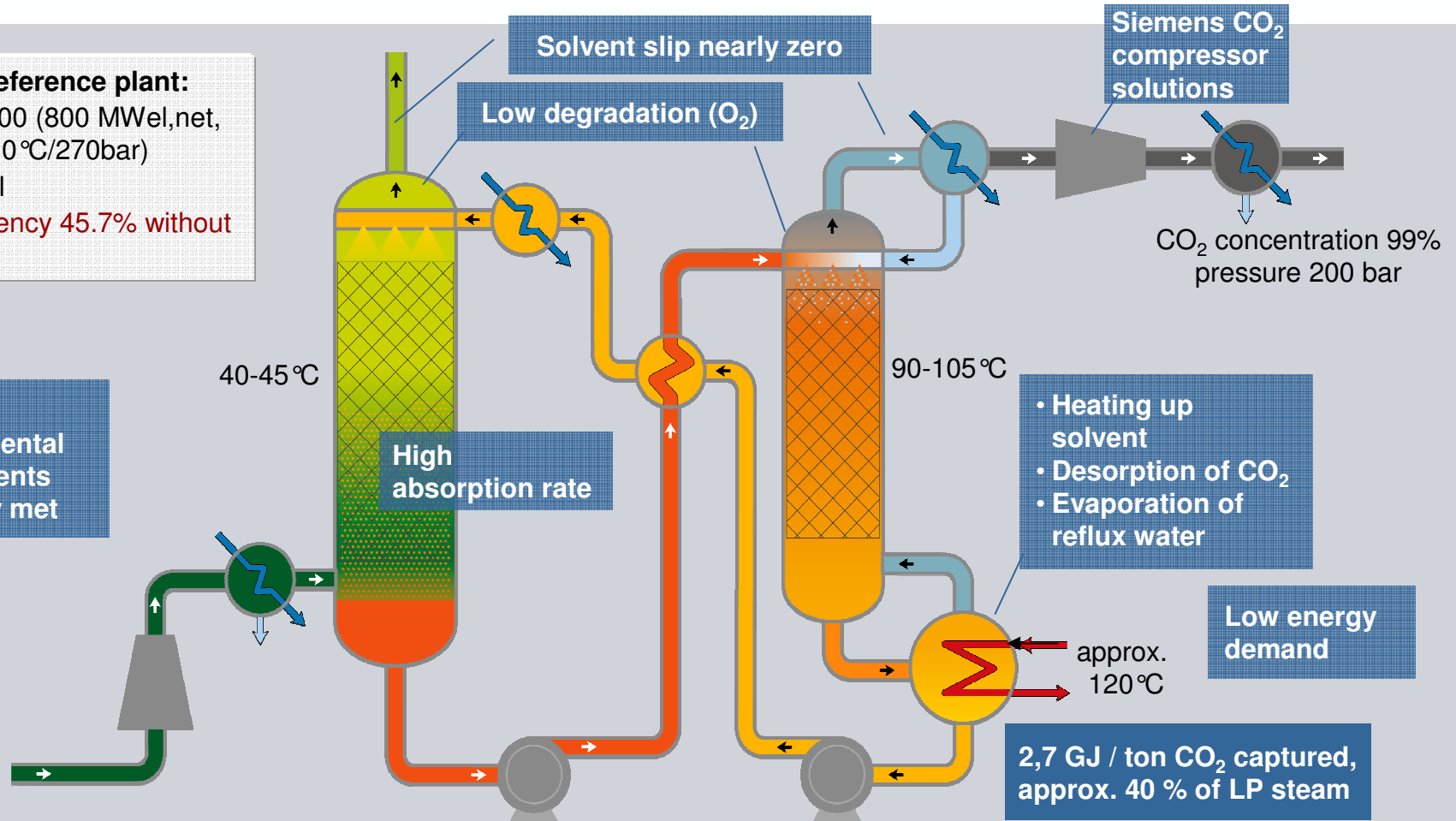
## Current development status

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### Non-CCS reference plant:

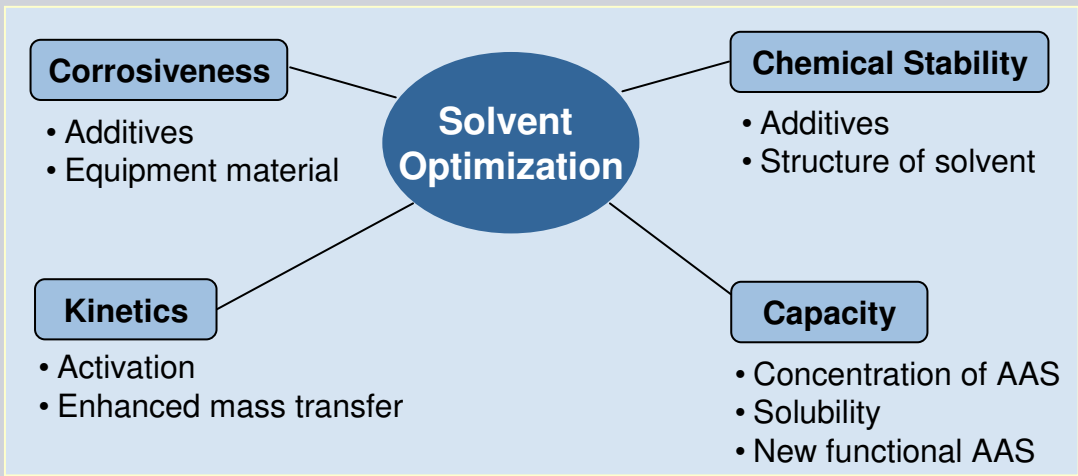
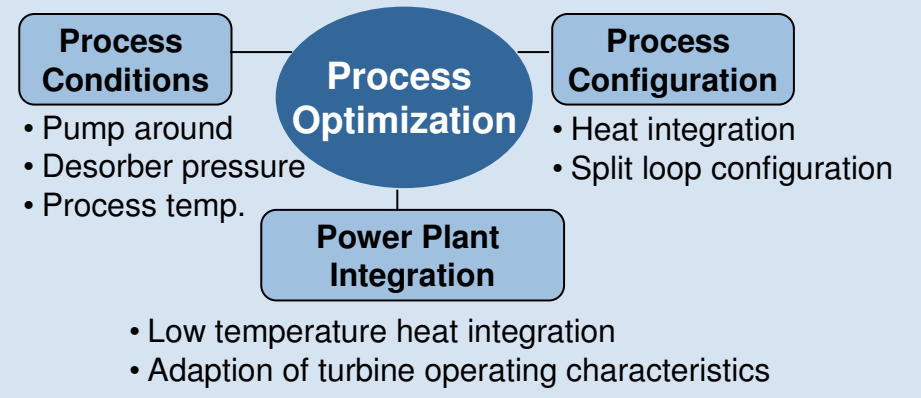
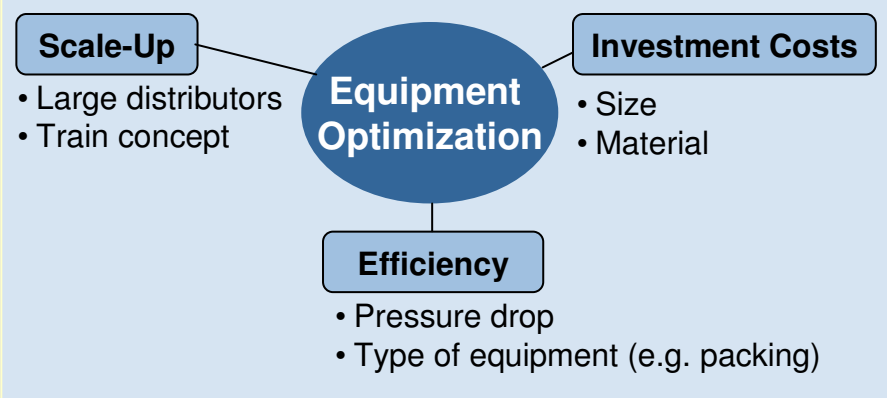
- SSP5-6000 (800 MWeI,net, 600°C/610°C/270bar)
- Hard coal
- **Net efficiency 45.7% without CCS**

Stringent environmental requirements are easily met



The efficiency is approx. 9 %-pts. lower than the reference hard-coal fired power plant, CO<sub>2</sub> compression (200 bar) included.

**Further process improvements in several development fields are ongoing**



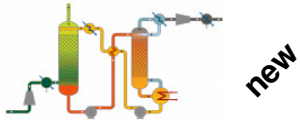
**Lab-proven**

**Improved design**  
 $\Delta \eta$  -9.2%-pts.  
 2.7 GJ/ton CO<sub>2</sub>

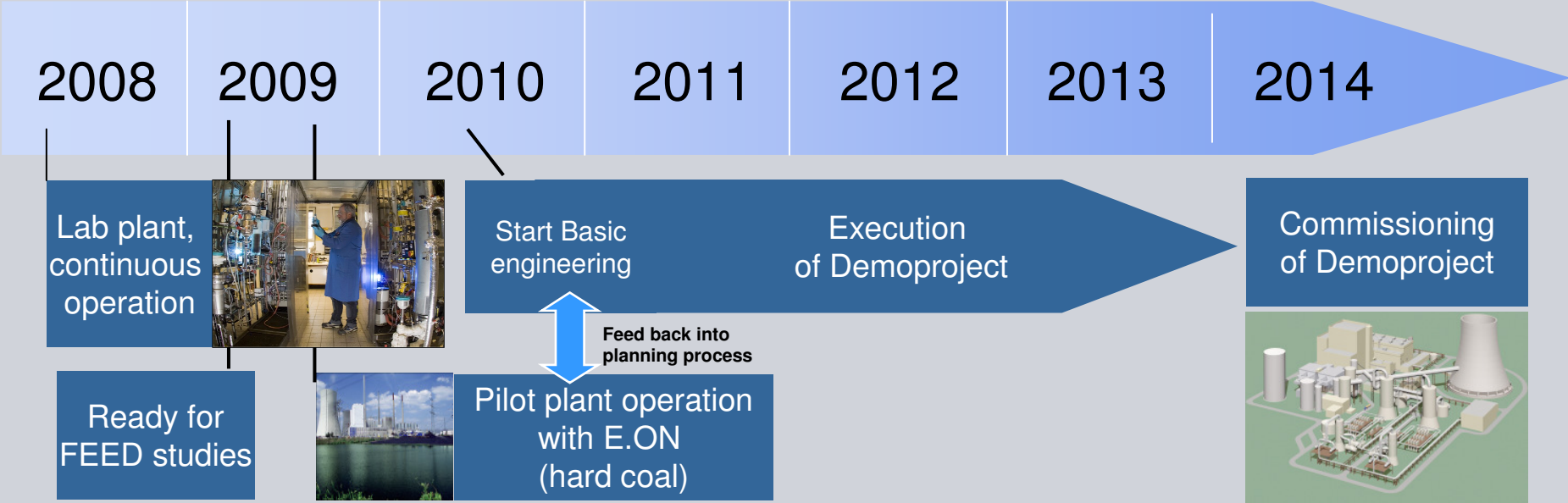
Lab pilot plant in operation since two years,  
 pilot plant at E.ON power plant (Staudinger) will start operation in August 2009.

# Major next steps on the way to a full scale post-combustion demo plant

Improved process layout:  
9.2%-pts efficiency drop



- Post-Combustion Capture is preferred solution for retrofits of coal fired power plants, application for CCPP's under development.
- Scalable market introduction with „slipstream demoprojects” one train 100 to 150 MW (absorber diameter 10 to 12 m).
- Multi train concepts for full scale Post-Combustion Capture plants.



Siemens Post-Combustion Technology ready for the implementation in demonstration projects.

# ECO<sub>2</sub> Carbon Capture Solution Collaboration between Powerspan and Siemens

**SIEMENS**



Powerspan Alliance  
Burger Commercial Unit - 50 MW (Feb 2004)

## ▶ Siemens Scope

- Absorber Design/Supply
- Process Mechanical Scope
- Detail Design/Purchase/Supply

## ▶ Powerspan Processes

- ECO-SO<sub>2</sub> Only
- ECO is NO<sub>x</sub>, SO<sub>2</sub> & Hg
- ECO<sub>2</sub> is CO<sub>2</sub> Capture Process

## ▶ Powerspan Status

- ECO Ready for Commercial Awards
  - AMP Ohio to utilize
- ECO<sub>2</sub> – Pilot Unit operational Summer 2008
- Feed Studies
  - First Energy Burger
  - NRG Indian River
  - Basin Antelope Valley
  - Basin NextGen
- CO<sub>2</sub> Demo MOU's
  - 125 MW Size
  - NRG Texas
  - Basin Antelope Valley

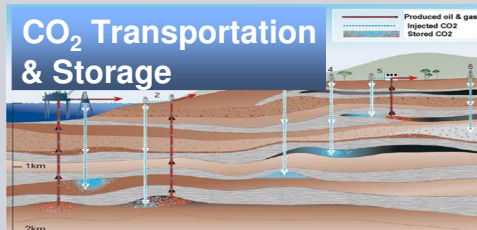
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# EU Climate change Package December 2009

## Capture ready assessment mandatory for new fossil power plants >300 MW

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- Indication and evaluation of potential storage sites reasonably accessible to the project.
- Evaluation of viable transportation options.



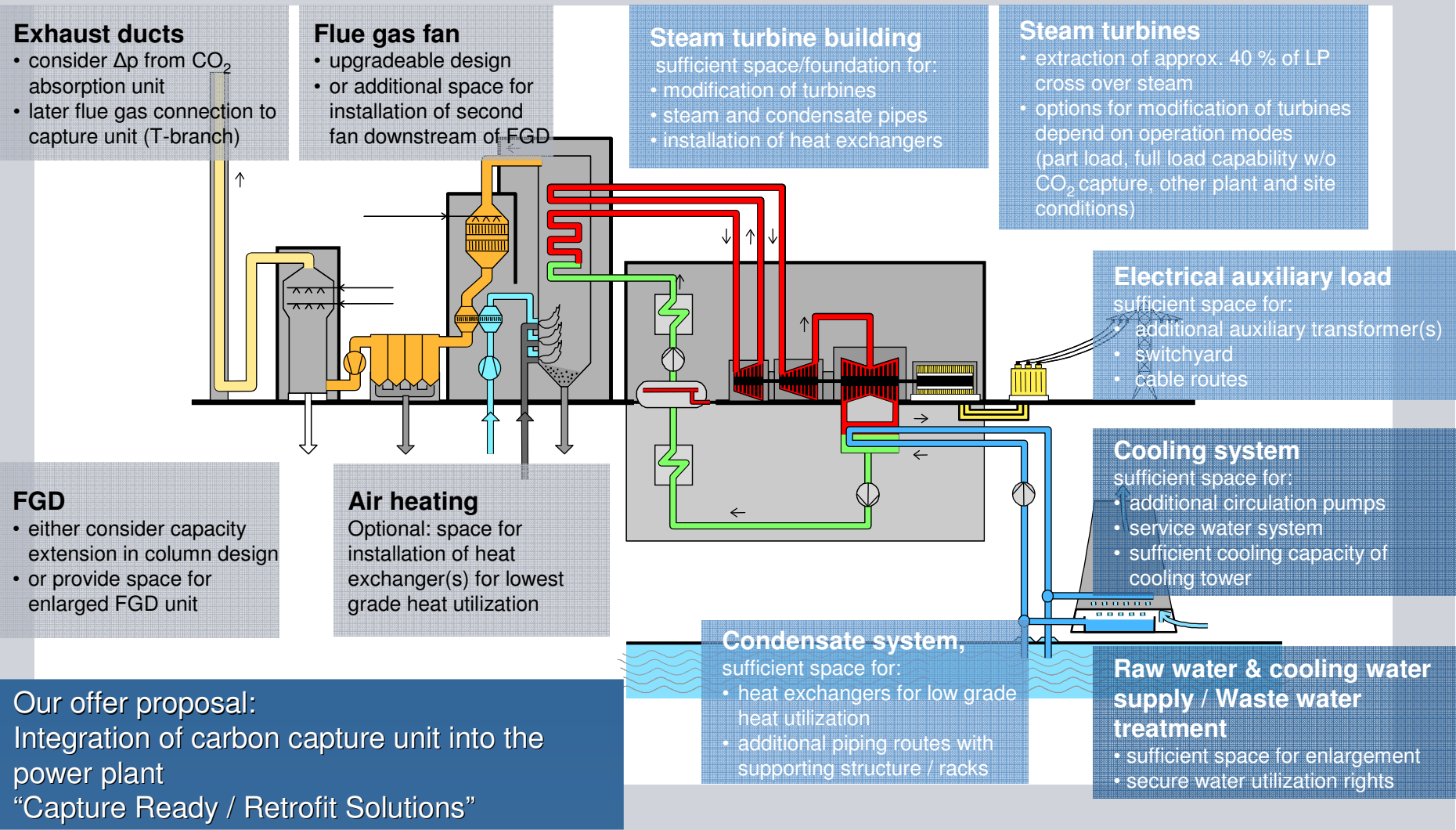
- Reservation of sufficient area on the site for the later retrofit of the CO<sub>2</sub> capture unit with CO<sub>2</sub> compression, for all plant integration measures and for retrofit-construction period.
- Assessment of the economic and technical aspects for the later retrofit and integration of the CO<sub>2</sub> capture unit – different options for the respective retrofit strategies.
- Selection of “best-available-capture-technology”, capture ready concepts for technology routes are deviant.

Delivering capture readiness should not result in a plant operating inefficiently until CCS is fitted.



# Capture Ready Requirements

All measures defined - reference Siemens steam power plant layout SSP5-6000



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# Siemens CO<sub>2</sub> compression solutions possible machine and driver combinations



Steam turbine



Gas turbine



E-motor



gear type

- up to 160 - 200 bar
- 7 to 8 compression stages



+

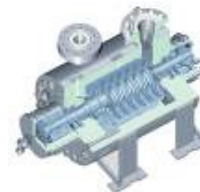


gear type +  
vertical split

- up to 300 bar



+

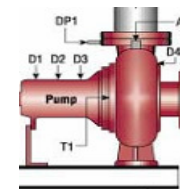


horizontal +  
vertical split

- up to 300 bar



+

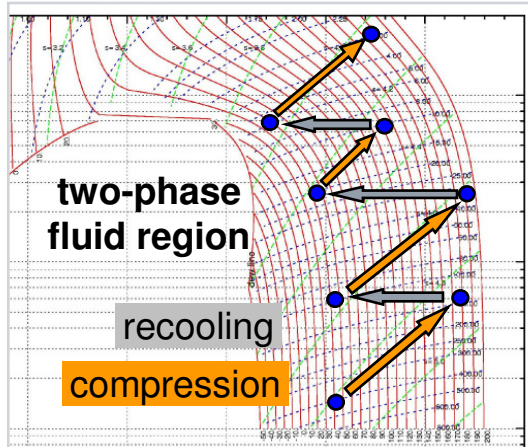


gear type +  
hds vertical compressor

- up to 300 bar

# Siemens CO<sub>2</sub> compression solutions: comparison of single-shaft vs. gear-type compressor

160  
bar

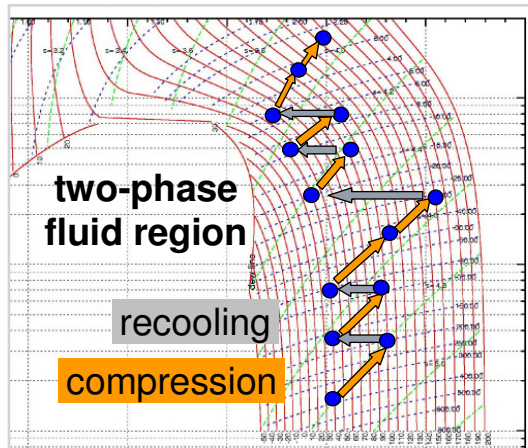


single-shaft compressor,  
two casings,  
three intercoolers

**$P_i = 13,1 \text{ MW}$**   
**100%**  
**(110.000 kg/h)**



160  
bar



gear-type compressor,  
one gear-casing, 8 stages,  
5 intercoolers

**$P_i = 11,7 \text{ MW}$**   
**89%**  
**(110.000 kg/h)**



**Significant efficiency advantage of gear type compressor**

# Siemens CO<sub>2</sub> compression solutions: gear-type compressor for Hammerfest LNG



Package lift into the barge



Partial compressor view /  
shop testing

## STC-GV(40-6)

- Power: 10. MW
- Mass flow: 105. t/h CO<sub>2</sub>
- Suction: 1. bar
- Discharge: 61. bar
- 2 process stages
- Dry Gas Seals
- Package weight: 230. t



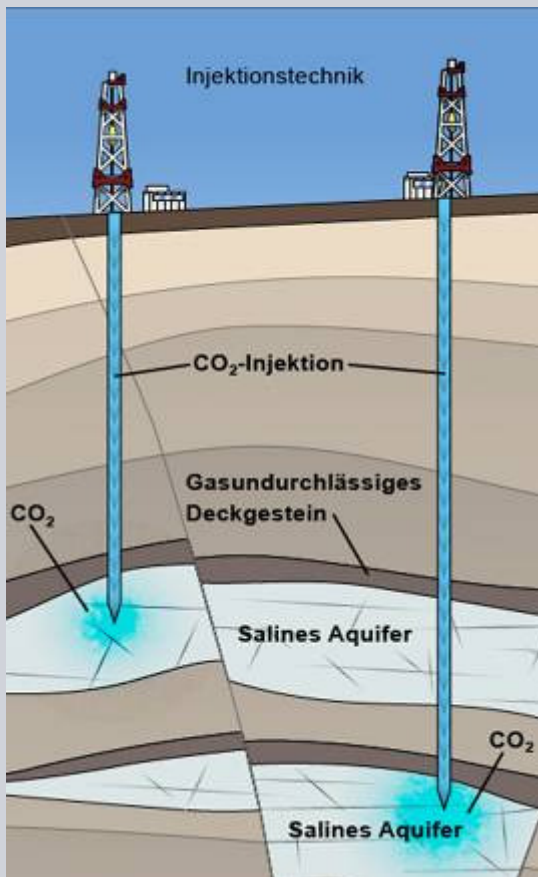
Barge installation in Cadiz



LNG terminal status Oct, 2006 close  
to Hammerfest / North Norway

<http://www.statoil.com/STATOIL.COM/snohvit/svg02699.nsf>

## CO<sub>2</sub>-Storage



Grafik: IZ Klima

- Three CO<sub>2</sub>-Storages with > 1 Mio t CO<sub>2</sub>/year in operation
- Experiences with „Enhanced Oil Recovery (EOR)“ since decades, Texas' Permian Basin more than 11.000 approved injection facilities
- Oel- and gas industry in USA has installed >5.000 km CO<sub>2</sub> pipelines
- Potential storages currently under evaluation
- Storage capacity in Europe approx. 40 bis 400 Gt\*
- Required storage capacity in Europe up to 2050 ca. 20 Gt\* .

\*Source: \*McKinsey, CCS - Assessing the economics, Sept. 2008

Experiences for CO<sub>2</sub> transport and storage, further R&D and implementation of required infrastructure is needed.



**HANNOVER  
MESSE**  
20.-24. APRIL 2009

**SIEMENS**



**“Many thanks for your kind  
attention”**



**You need more information ?  
Please contact:**

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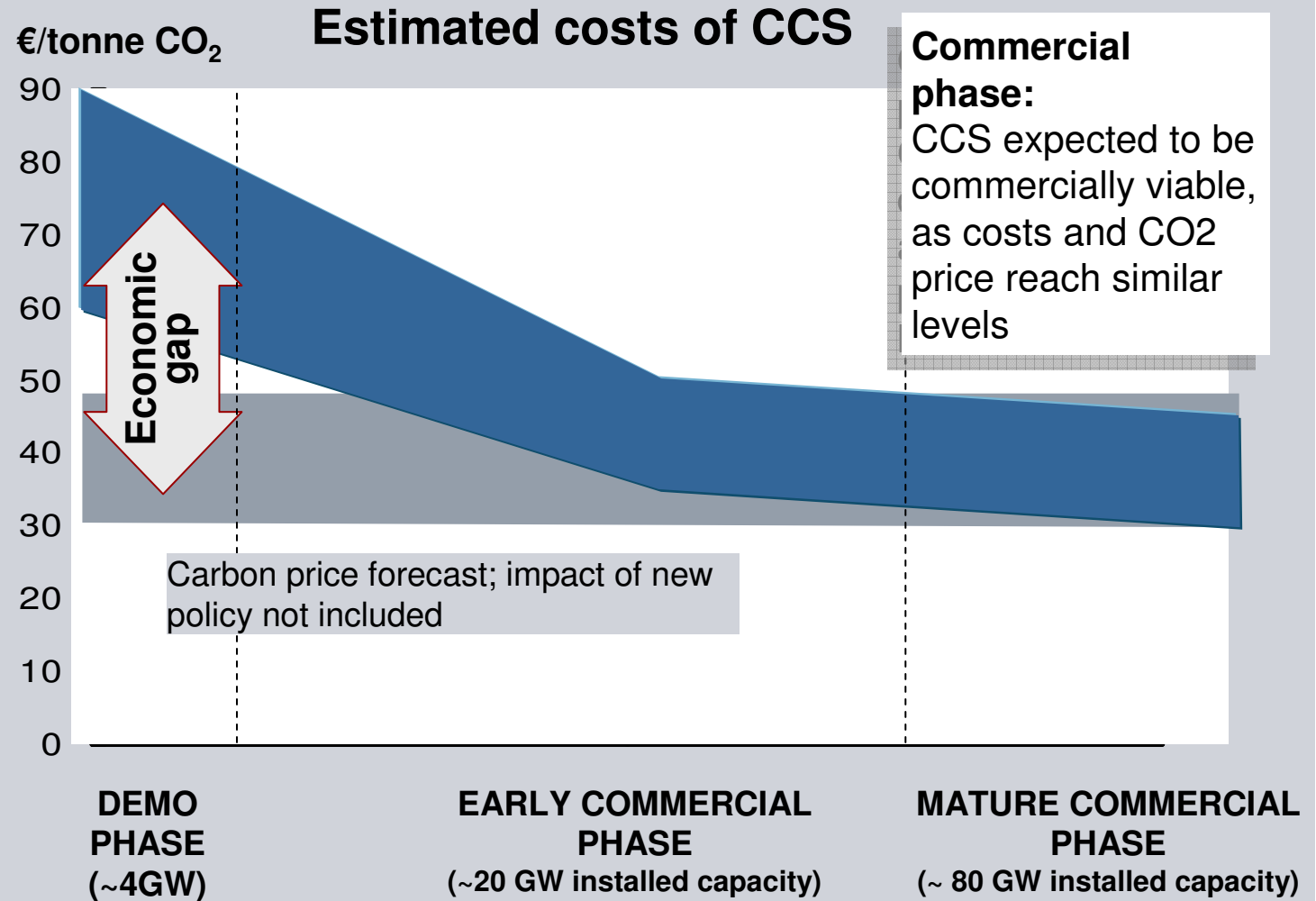
**Back-up**

# Proposal ZEP November 2009

## Demonstration Phase Requires Funding to Fill the Economic Gap



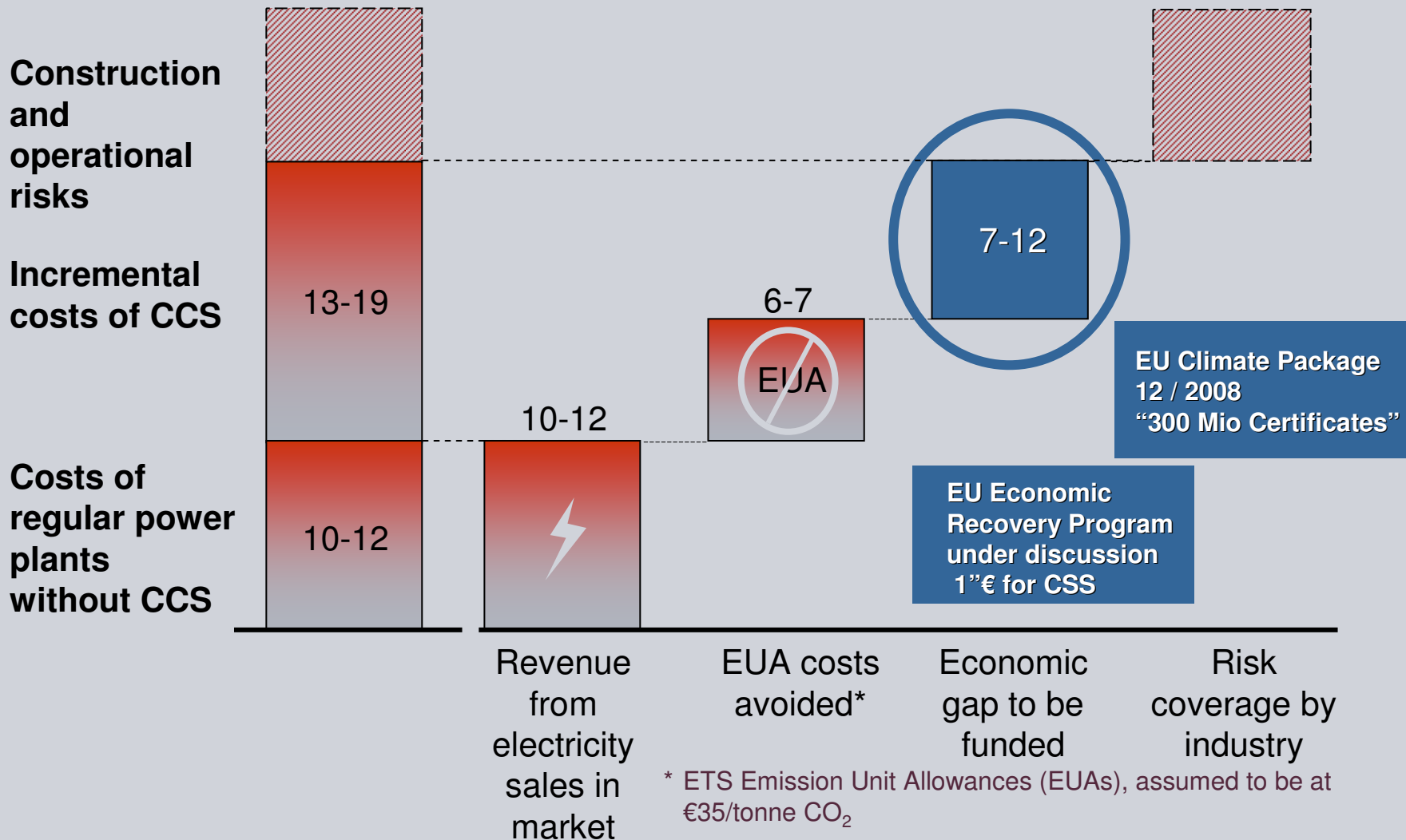
**Demonstration phase:**  
CCS not economically viable. Public contribution necessary for some portion



# Proposal ZEP November 2009

10-12 Demonstration Projects = €7 Billion - €12 Billion in Funding

Present value over lifetime, € billion



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