Gas fired power plants with CCS to support Power Industry GHG strategies

Vauhini Telikapalli

11th Annual Carbon Capture Utilization and Sequestration Conference

Pittsburgh, May 2 2012

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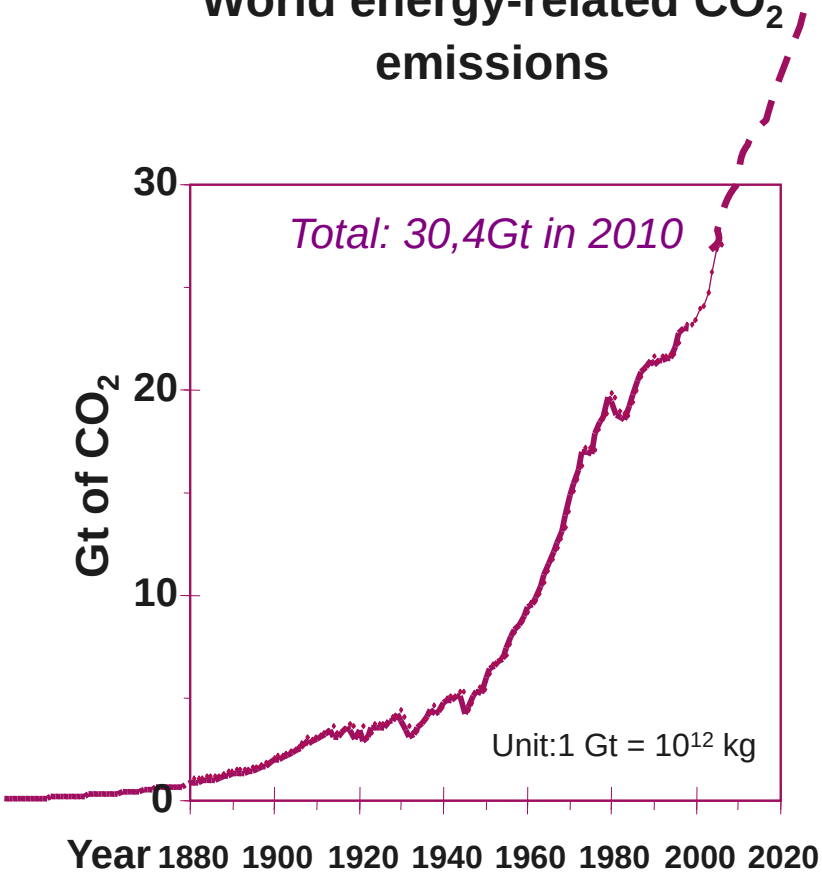
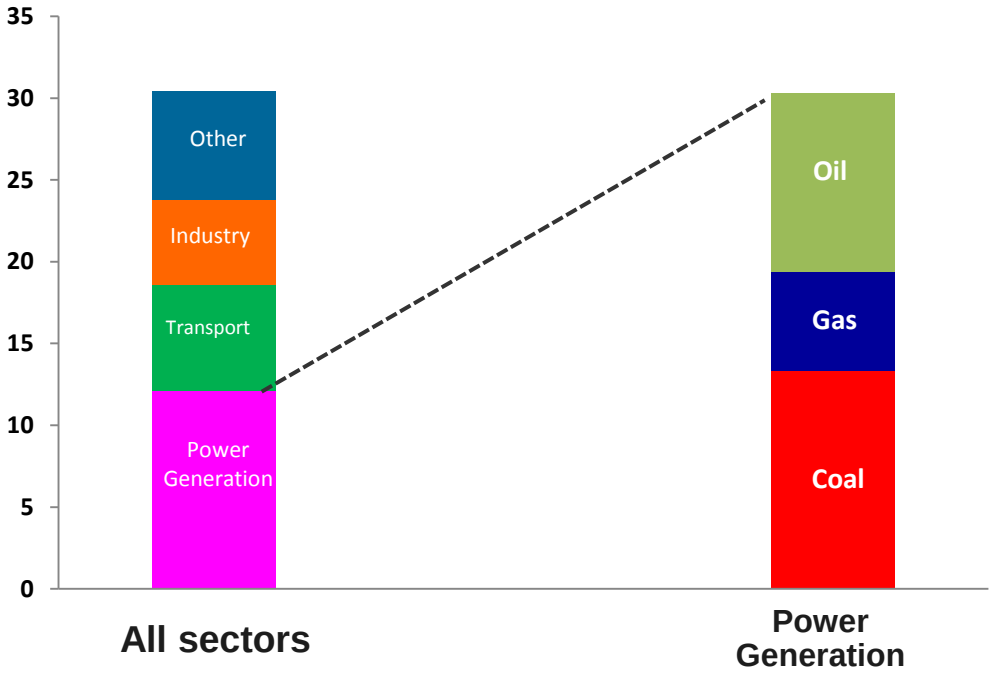
Power Generation - CO_2 emissions

World energy-related CO_2 emissions



Adapted from CDIAC

2010 World energy-related CO_2 emissions by sector



IEA / WEO 2011

40% of global CO_2 emissions from power generation & 20% from gas fired plants

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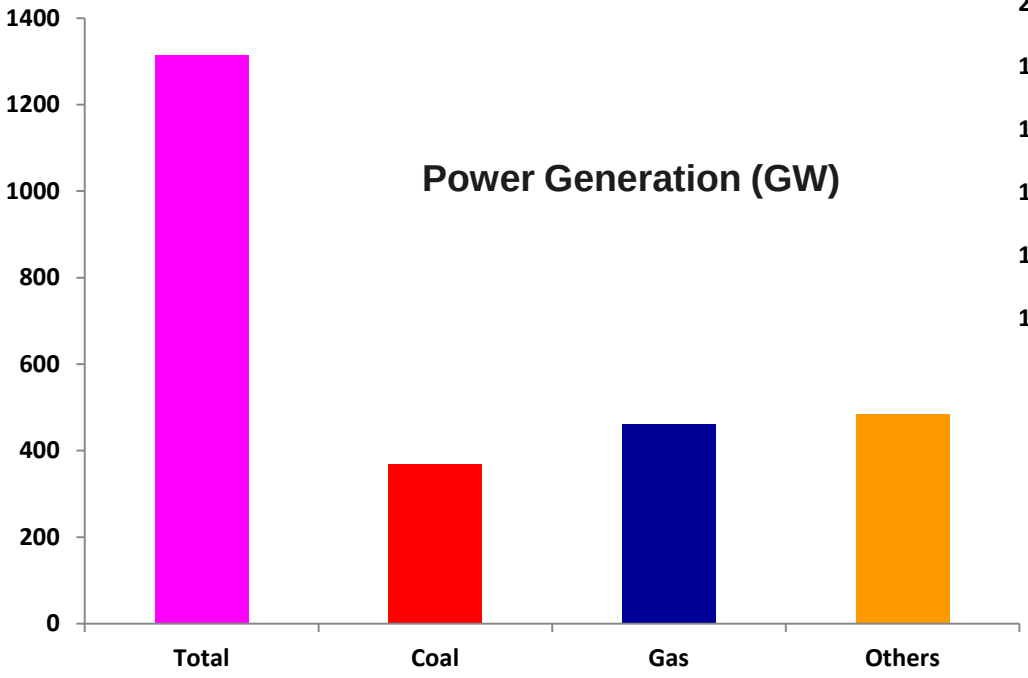
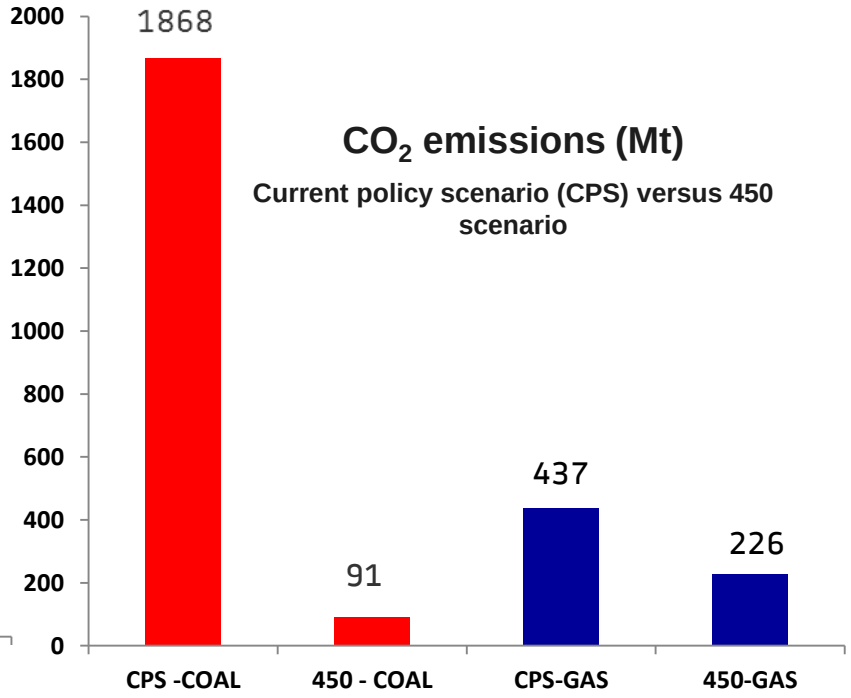
CO_2 challenge – Power Generation in US (2035)





Others: Nuclear, renewables, Hydro, geothermal, wind, solar, biomass & waste, CSP

- **63% of total power generation from fossil fuels**
- **CO_2 emissions in CPS scenario: coal 81% and gas 19%**
- **CO_2 emissions in 450 scenario: coal 28% and gas 69%**

IEA / WEO 2011

Massive CO_2 emissions reduction needed on both Coal and Gas

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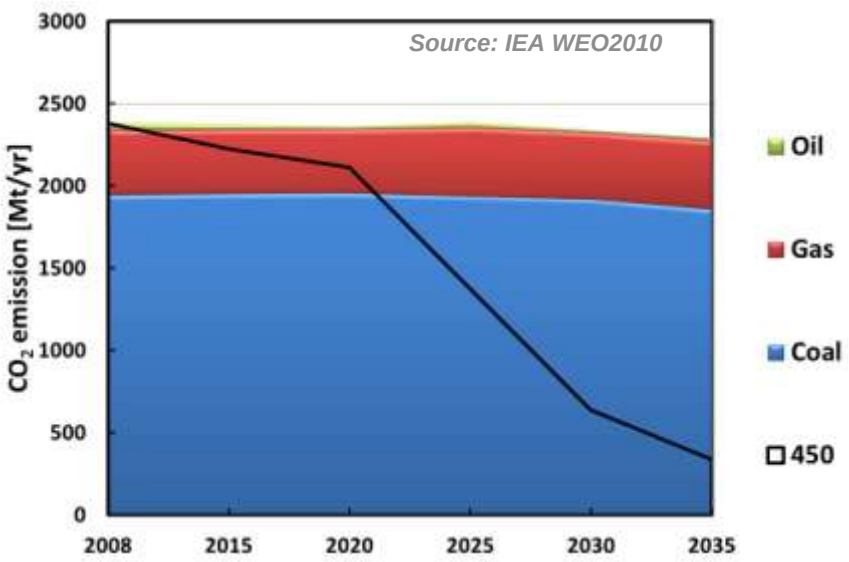
The case for CCS on Gas

IEA's WEO2010 scenarios for US CO_2 emission from Power Generation (2008-2035)

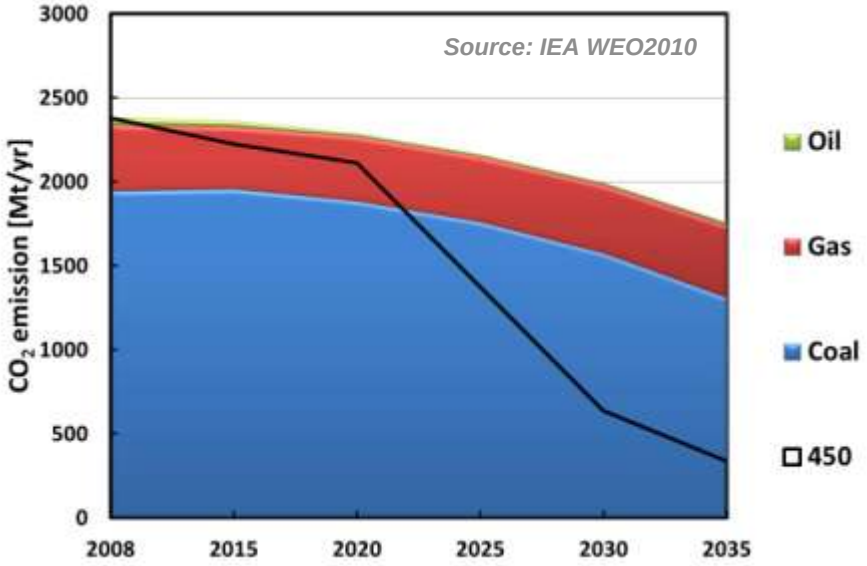
- No new policy in place

"*Current Policies Scenario*"



- New policies under consideration set in place
- Phase out of Coal to the benefit of Gas
- Demand side management

"*New Policies Scenario*"



Applying CCS on Gas is a must to limit the impact of climate change

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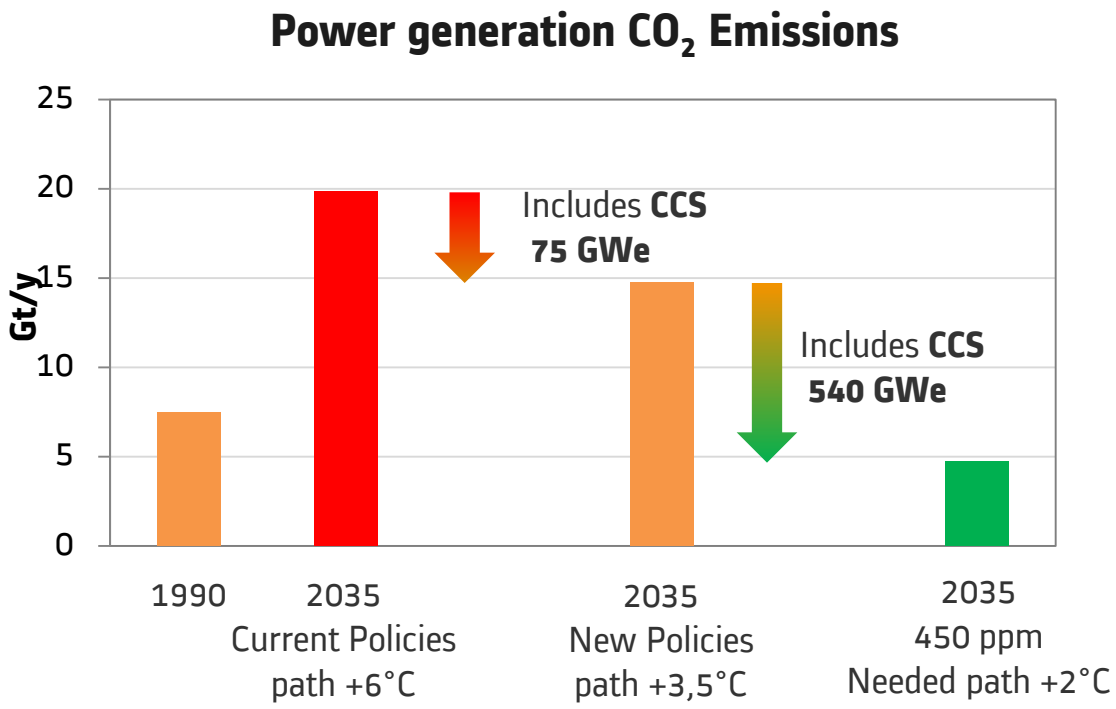
CCS is essential for Power generation



Source : Alstom analysis from IEA WEO 2011

12 CCS pilots
5 large-scale demo in development

CCS: 18% of emissions savings in 2035 in the 450 ppm scenario

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Alstom activity on demonstrations
1st and 2nd Generation CCS

Tests complete

AEP Mountaineer
US - 58 MWth
Chilled Ammonia, coal

Dow Chemical Co.
US -2 MWth
Adv. Amines - coal

EoN Karlshamn
Sweden - 5 MWth
Chilled Ammonia–Fuel oil

WE – Energie
US - 5 MWth
Chilled Ammonia, Coal

In Commission /Start up

TCM Mongstad
Norway - 40 MWth
Chilled Ammonia - Gas

EDF – Le Havre
France – 5 MWth
Adv. Amines - Coal

Operating

Vattenfall Schwarze-Pumpe Germany-
30 MWth Oxy - Lignite

Total Lacq
France - 30 MWth
Oxy - Gas

Alstom Labs Växjö
Sweden – 0.25 MWth
Post C. – multi purpose

Alstom BSF Windsor
US - 15 MWth
Oxy - coals

DOE/Alstom Windsor
US – 3 MWth
Chemical looping - coal

RFCS EU -Darmstadt
Germany –1 MWth
Chemical looping - coal

Large-scale projects- under development

PGE Belchatow
Poland – 260 MWe
Adv. Amines - Lignite

UK oxy CCS demo (Drax)
UK - 426 MWe
Oxy – coal

Getica - CET Turceni
Roumania – >250MWe
Chilled ammonia - Lignite

Datang- China
Oxy 350 MWe lignite,
Post 350 MWe eq. coal

NER300: **Applied for EU ETS New Entrant Reserve funding**

Selected for receiving EEPR funding

, May 2, 2012

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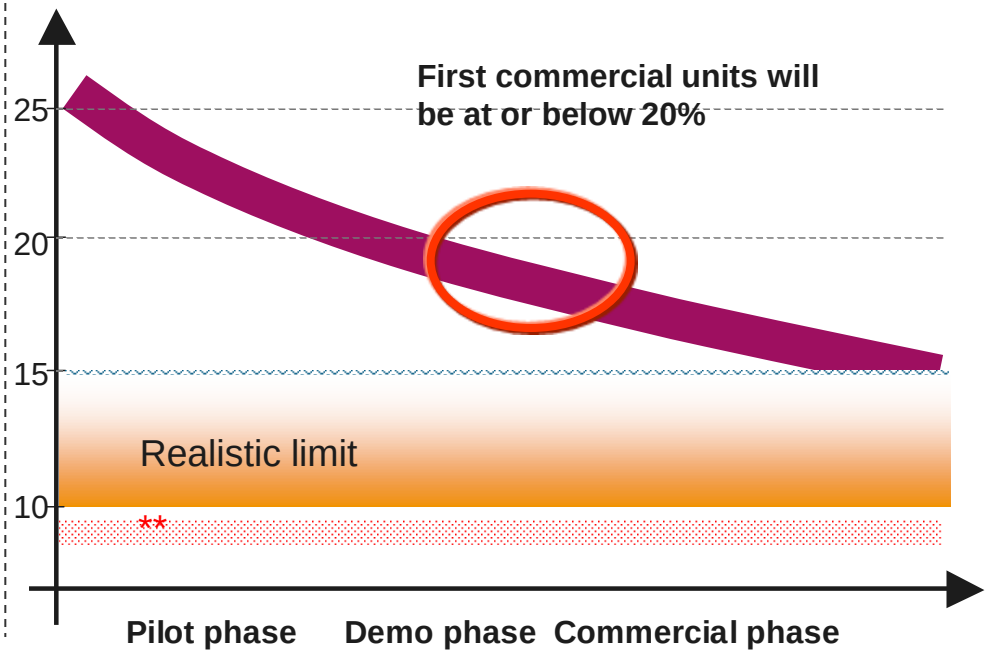
What we have achieved

	Reached CO_2 capture rate	Reached CO_2 purity
 **We Energies Pleasant Prairie** USA - Coal - Chilled Ammonia	90%	>99%
 **AEP Mountaineer Process Validation Facility** USA - Coal Chilled Ammonia	75-85%	>99.9%
 **Dow Chemical Co. Charleston** USA - Coal - Advanced Amines	90%	>99.5%
 **Vattenfall Schwarze Pumpe** Germany - Lignite & Bit. Coal - Oxy	90%	>99.7%

Energy penalty [%] on net MWe



Pilot operation confirm CO_2 capture works and performances are improving

*Theoretical limit assumes ideal separation and compression processes (110bar): isentropic, no losses

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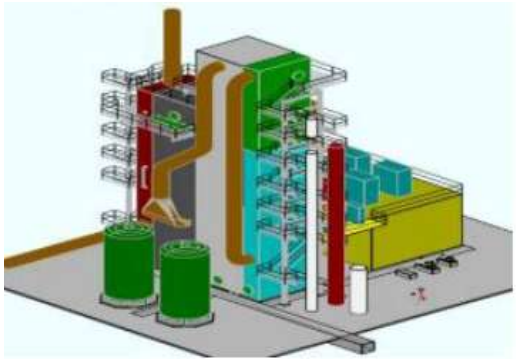
Mongstad Validation Pilot - Norway



3D Model of Capture facilities

End-October 2011 - 80% completed

CO_2 Technology Centre Mongstad

- 75.12% Gassnova, 20% Statoil, 2.44% Shell, 2.44% Sasol
- Flue gases from natural gas CHP plant and a Residue catalytic cracker RCC plant.
- Designed to capture 82000 t CO_2/year from RCC plant and 22000 t CO_2/year from CHP plant
- Implemented learning from MTN-1
- Project schedule:
  - Engineering started June 09
  - Plant Commissioning schedule: Q2 2012
  - Start-up for testing: Q3 2012
  - Testing period for 12-18 months
- To be used as pre-qualification for Carbon Capture Mongstad (CCM)

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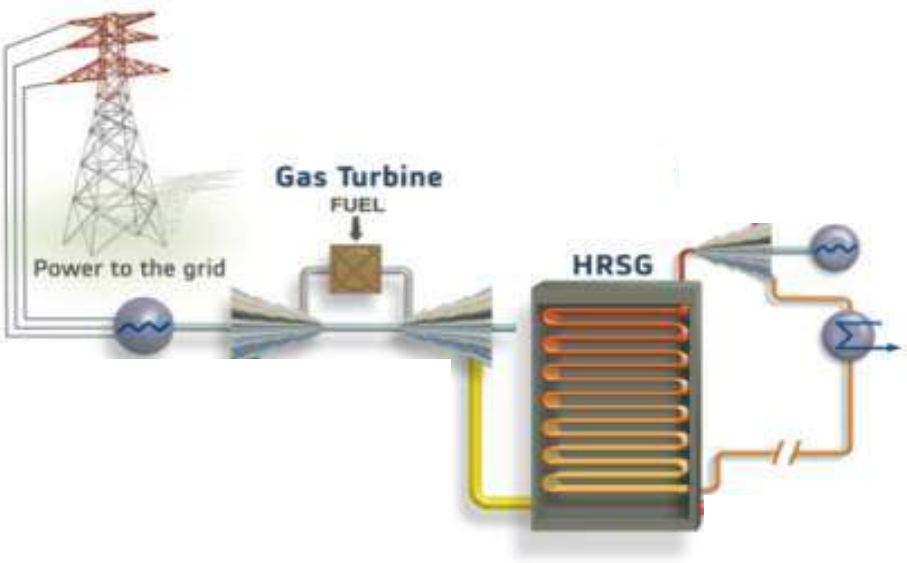
Alstom CCS solution for Gas – KA26 CCPP concept



CO_2
Absorption Solution
Pumps
Blower
Generator
Condenser
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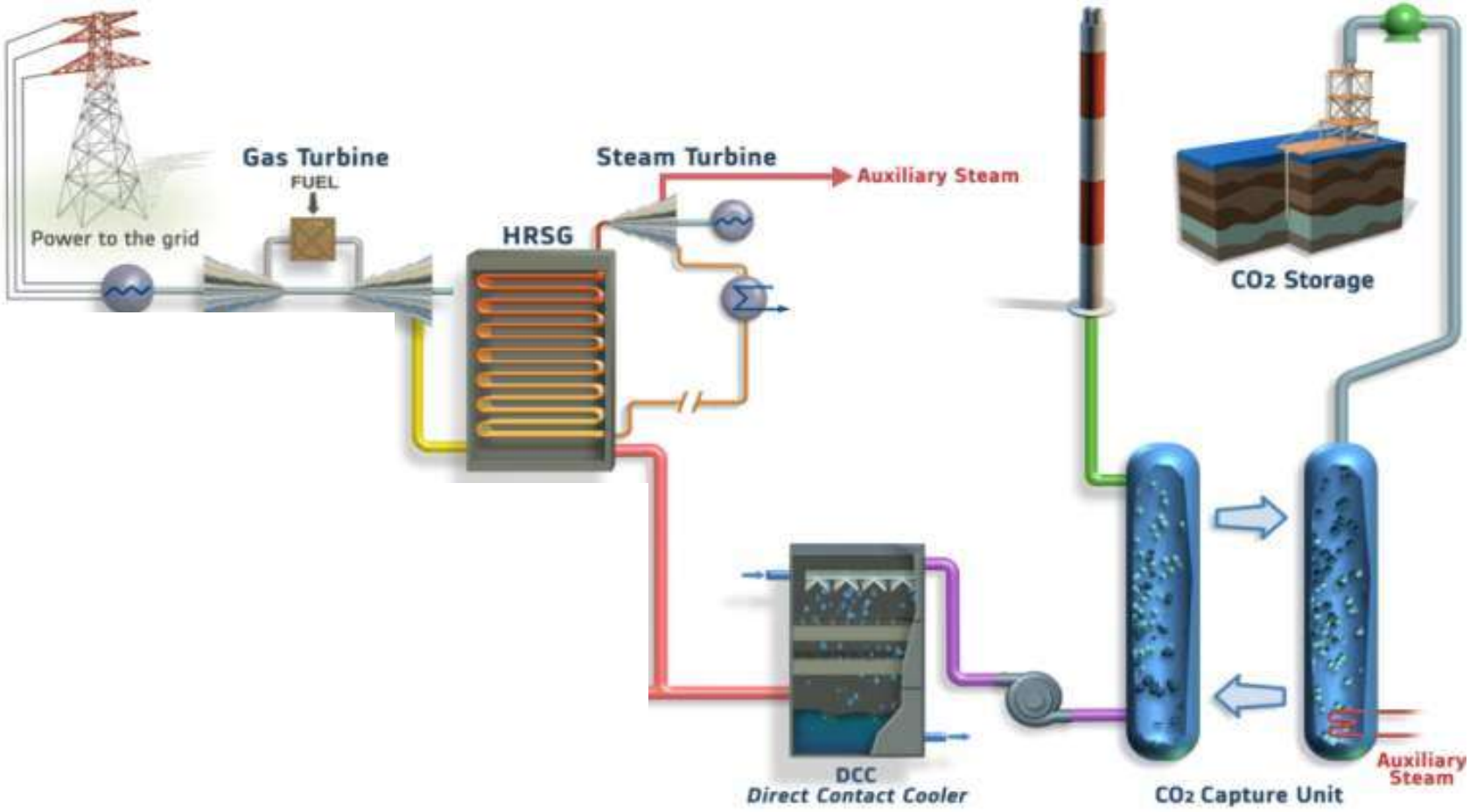
Alstom CCS solution for Gas KA26 with CCS concept



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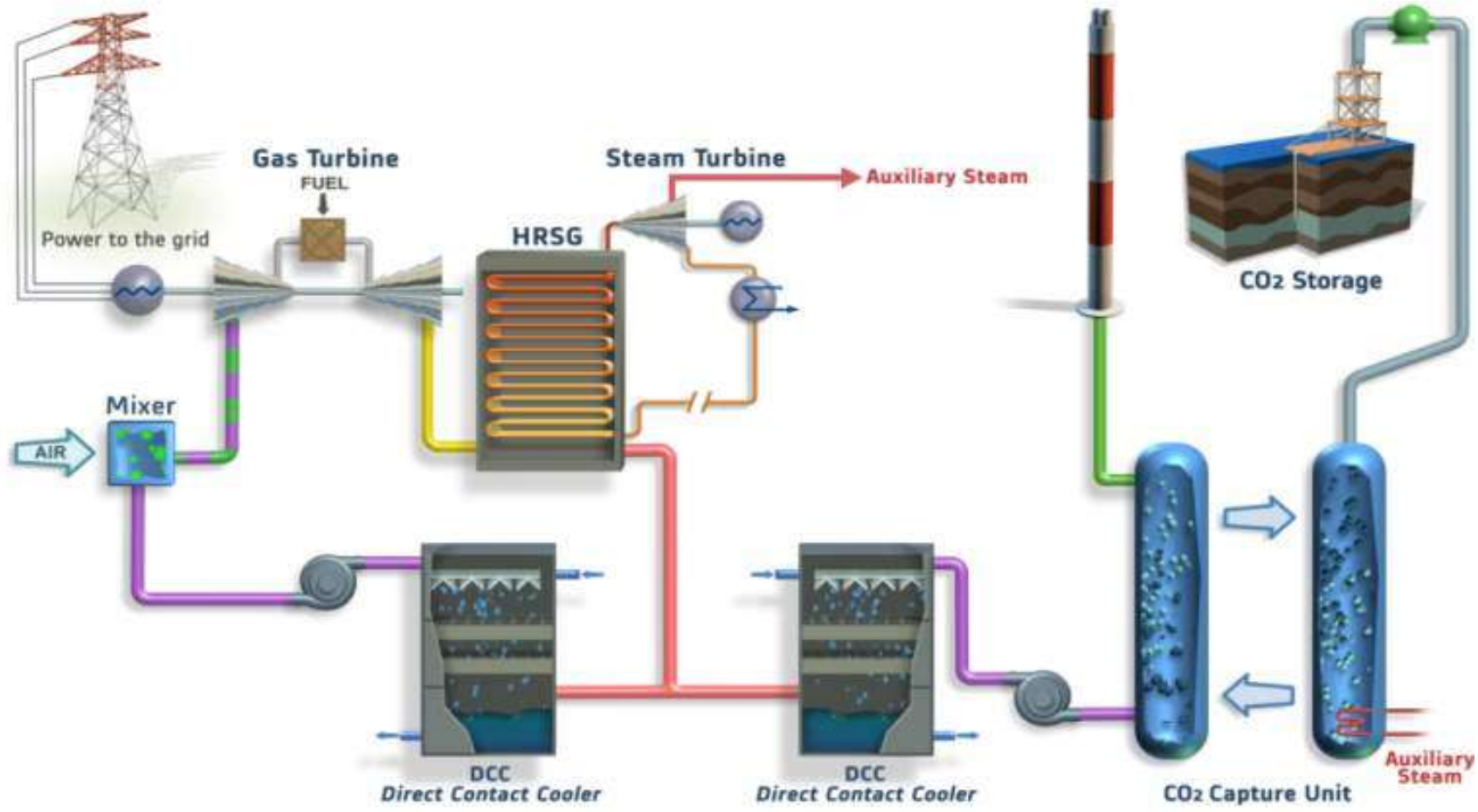
Alstom CCS solution for Gas KA26 with CCS and Flue Gas Recirculation concept



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Alstom CCS Cost Study – Key Assumptions

- **Levelised Cost of Electricity (LCOE) study based on typical regional new build plant (Europe, NAM, Asia), including T&S**
- **NAM:**
  - PRB Coal: 275 bar, 600/620 C, 837MWe net output at 46% efficiency
  - Gas: (combined cycle), 2-1 MS 850MWe net output at 60% efficiency
- **Coal and gas combined cycle plants assumed on base load for the reference case**
- **Capture technology (CO_2 capture rate of 90%)**
  - Coal: Oxy-fuel and Post combustion capture (Lignite and Bituminous)
  - Gas: Post Combustion with Flue gas recycle
- **Considers LCOE with CCS and over 25 year economic life, present day costs.**
- **Benchmarked Rubin curves to evaluate learning curves until 2030**

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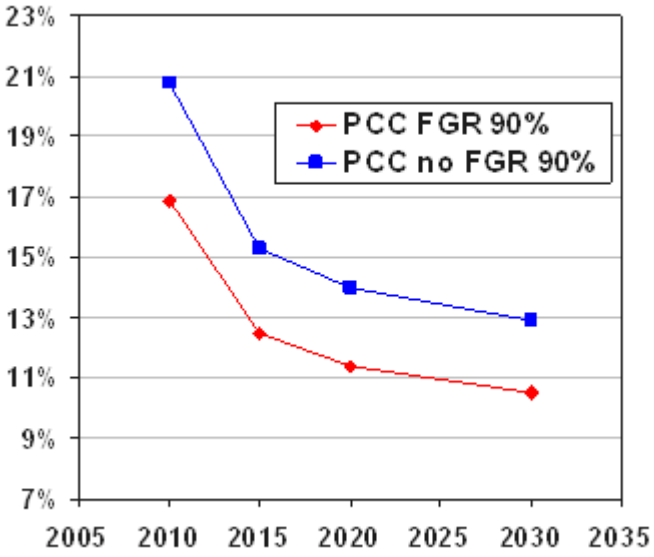
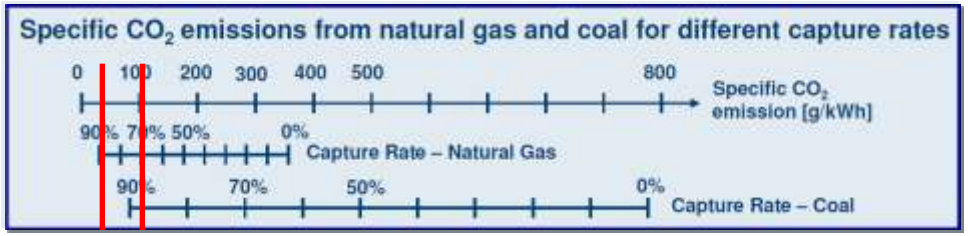
Energy penalty – Impact of FGR and Capture Rate on KA26





Source: Alstom
Note : EU Reference Plant, 1xVL 1-1 SS, cooling temperature = 13°C, more than 99% CO_2 purity

$$\text{Energy Penalty [\%]} = \frac{\text{Net power output w/o CCS [MWe]} - \text{Net power output w/ CCS [MWe]}}{\text{Net power output w/o CCS [MWe]}}$$

Significant improvement when utilizing FGR technology

Target for 2030: less than 10% energy penalty with 90% capture

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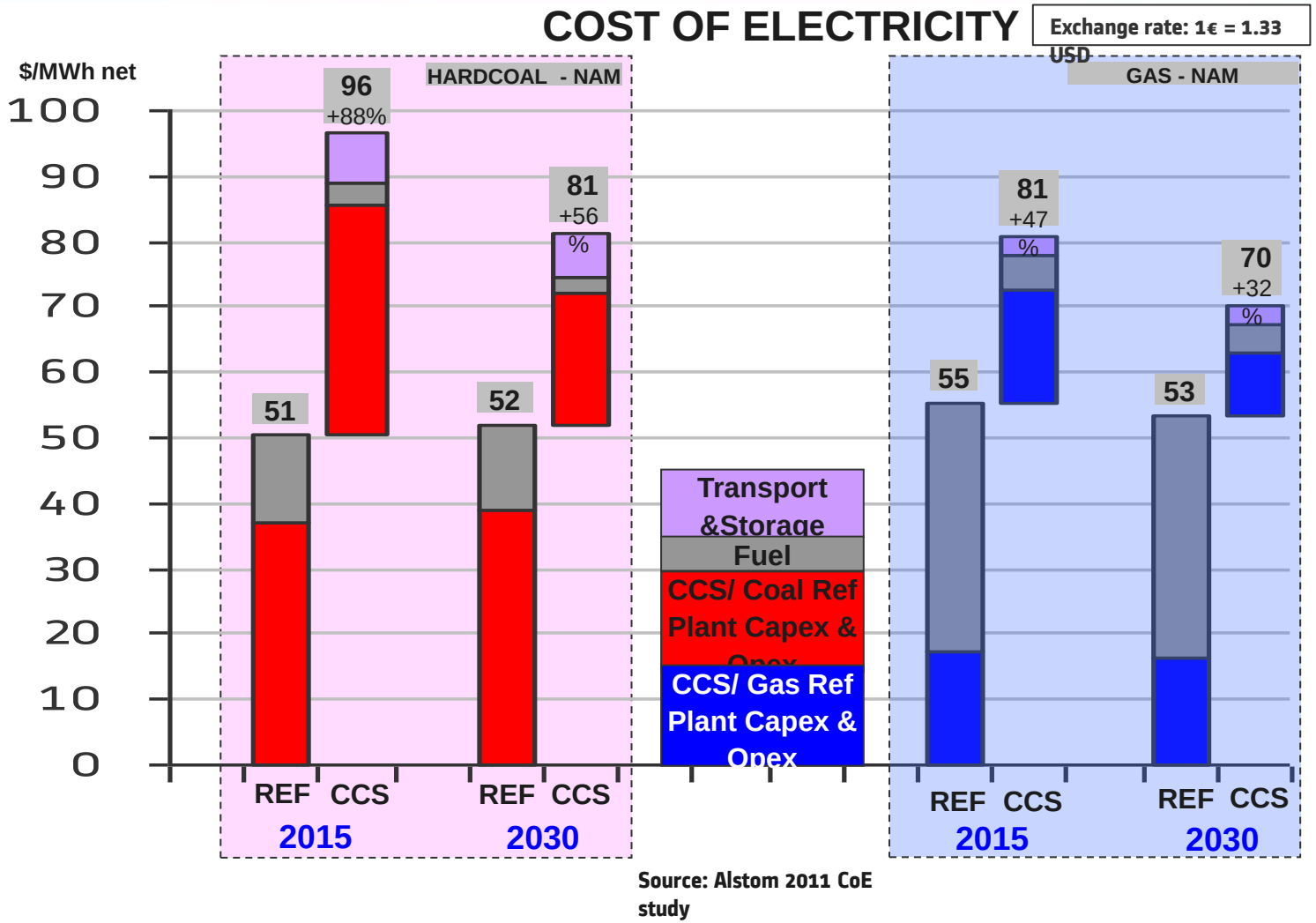
CCS on gas is cost competitive (CoE) as compared to coal



Source: Alstom 2011 CoE study

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CCS – Challenges and Needs

Political / Policy	**Political will to establish global CO_2 targets** **Regional and National Energy Policies for CCS** **Robust regulatory frameworks**
Legal	**CCS Legislation (Capture, Transport and Storage)** **Permitting/consent regimes** **Capture ready requirements**
Environmental Health & Safety	**Emissions and waste standards for CCS (Capture technology)** **CO_2 specifications for Transport and Storage** **Storage site validation**
Economic	**Current power spreads do not support CCS** **CCS financial incentives c.f. Renewables** **Market mechanisms (Cap & trade, EPS, Carbon taxes, etc)**
Commercial	**CCS demonstration at commercial scale (bankability)** **Long term Storage liability** **Public acceptance (NIMBY'ism)**

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Final Remarks

- Decarbonisation of Power is a critical part of meeting global CO_2 emissions reduction
- CCPP with CCS has lower LCOE than coal with CCS
- Alstom has invested significantly in developing CO_2 capture technologies and is on track to go commercial by 2015/16.
- A stable business framework and regulations are needed for CCS to play its role along all other forms of decarbonised energy sources.
- Financial support is necessary both for capital costs and through preferential tariff support for large scale technology demonstration

Alstom is committed to being a key partner on the CCS value chain

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