ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

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LCS-RNet

International Research Network for Low Carbon Societies and Low Carbon

Enabling Decarbonisation of the Fossil Fuel based Power Sector through CCS

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Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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Summary

- Introduction
- GHG Emissions and CCS role for climate change mitigation
- The status of CCS Projects in Europe
- Challenges and opportunities for CCS
- Conclusions

ENEA - The Italian National Agency for …

ENERGY

SUSTAINABLE DEVELOPMENT

NEW TECHNOLOGIES

HR: 2863 permanent staff
71 temporary staff
Headquarters in Rome
9 Research Centers
5 Research Laboratories
12 Local Officies
Brussel Liason Office

ENERGY

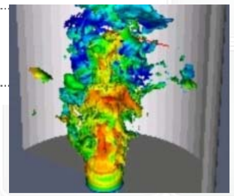
- Nuclear Fusion
- Nuclear Fission
- Renewable Energy Sources
- Energy Efficiency
- Advanced Technologies for Energy and Industry

NEW TECHNOLOGIES

- Radiation Applications
- Material Technologies
- Energy and Environment Modeling
- ICT

SUSTAINABLE ECONOMIC DEVELOPMENT

- Environmental Characterization, Prevention an Recovery
- Environmental Technologies
- Seismic Protection
- Radiation Biology and Human Health
- Sustainable Development and Innovation of the Agro-Industrial System



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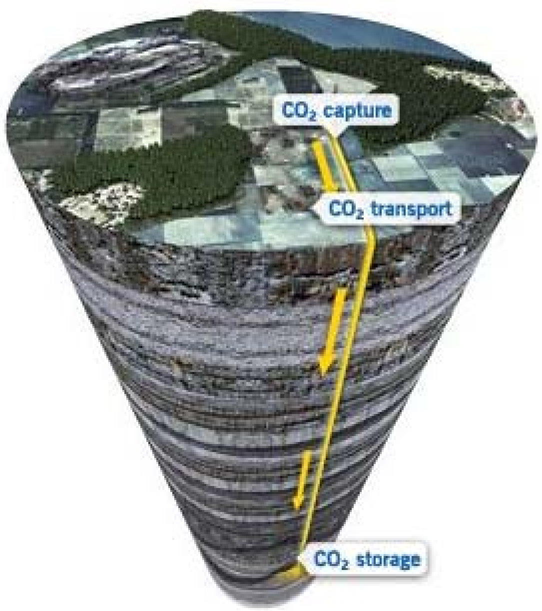
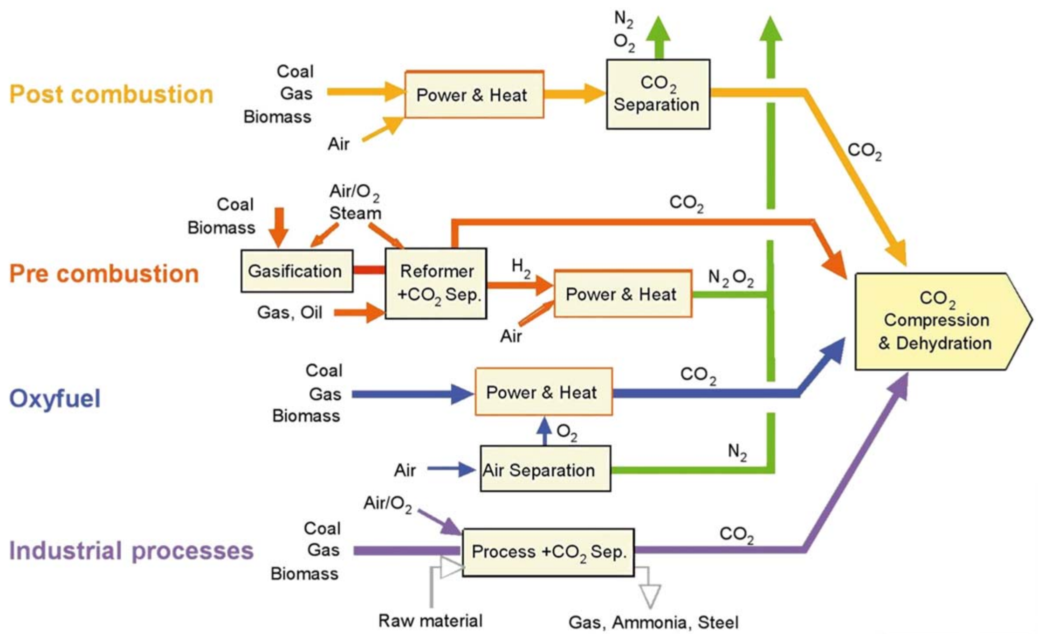
What is CCS?

Carbon capture and storage (CCS), which is sometimes called carbon capture and sequestration, prevents large amounts of carbon dioxide (CO2) from being released into the atmosphere. The technology involves capturing CO2 produced by power plants and large industrial plants, compressing it for transportation and then injecting it deep into a rock formation at a carefully selected and safe site, where it is permanently stored.





Because CCS can achieve significant CO2 emission reductions, it is considered a key option within the portfolio of approaches required to reduce greenhouse gas emissions.

What is CCS and what is CCS enabling?

CCS technology involves three major steps:

Capture

The separation of CO_2 from other gases produced at large industrial process facilities such as coal and natural gas power plants, oil and gas plants, steel mills, cement plants, etc.

Transport

Once separated, the CO_2 is compressed and transported via pipelines, trucks, ships or other methods to a suitable site for geological storage.

Storage

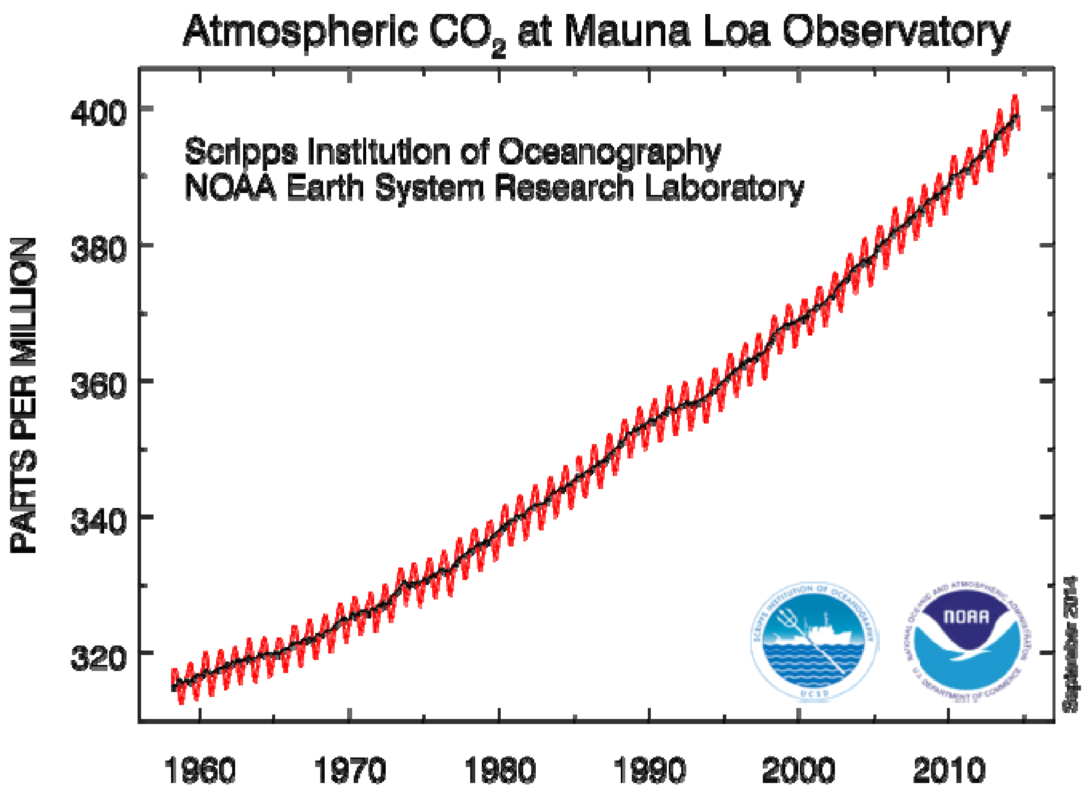
CO_2 is injected into deep underground rock formations, often at depths of one kilometre or more.

Enabling CCS

To provide resources for:
governments, regulators, policymakers, communicators and others interested in CCS…

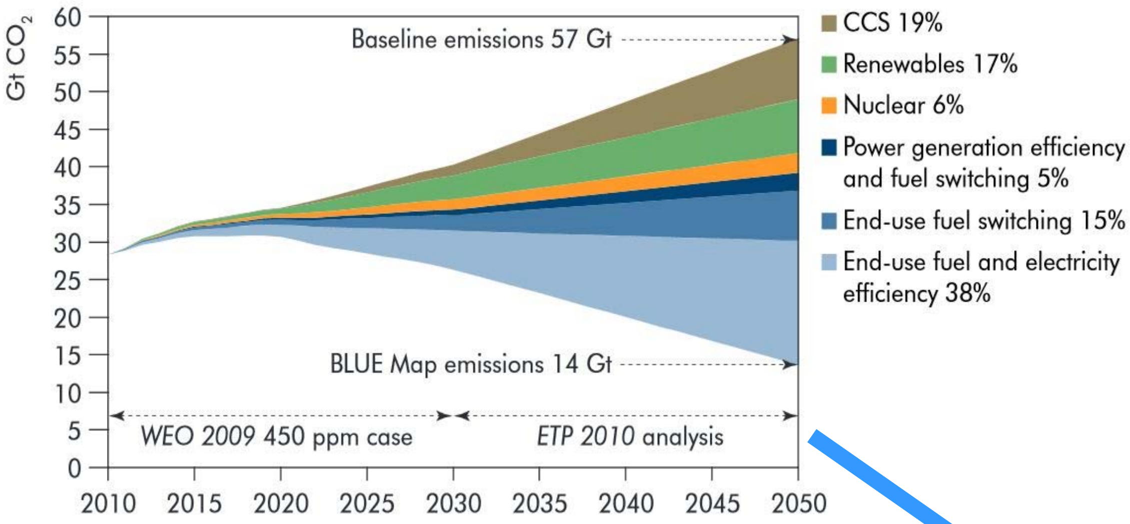
GHG Emissions and CO_2 concentration

Climate change has become a widely accepted challenge for our future growth and welfare. Increasing greenhouse gas emissions from human activities have been translated to a significant increase of the concentration of green house gases in the atmosphere.



…a clear and continuing increase of atmospheric CO_2 concentration is shown!

CCS's role for climate change mitigation

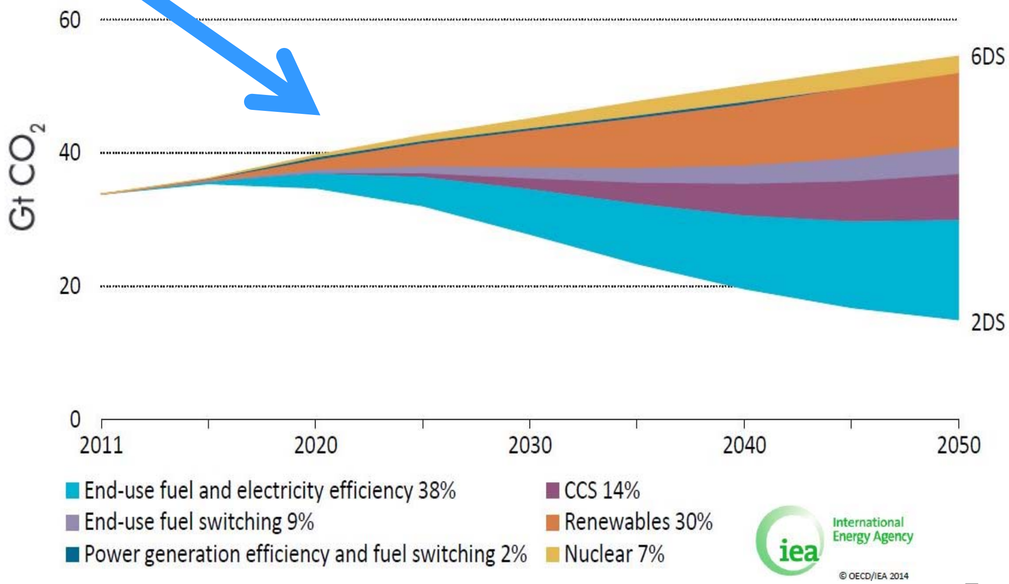


CCS can play its part… from the IEA newer 2S scenario CCS is expected to contribute an overall of 14% of the required emission reduction by 2050, with half of it to be realized in industry and the other half in the power sector.

IEA showed that in scenarios w/o CCS the total cost to halve CO2 emissions levels would increase by 70%. Therefore, the successful implementation of CCS in the future will be key to ensure an affordable energy supply at reduced costs.

There are a number of different possibilities to reduce greenhouse gas emissions in the future, the most obvious being energy efficiency and increased used of renewable energies.

However none of the possible technology options to reduce emissions can be seen as a silver bullet and a broad mix of measures will be necessary to achieve the required reductions.



The status of CCS Projects in Europe

Name	Region	Stage	Status	Capture type	Transport type	Transport details	Storage type	Storage details	Industry
C.GEN North Killingholme Power Project	Europe	Evaluate	Planned	Pre-combustion capture (gasification)	Pipeline	Onshore to offshore pipeline 151-200km	Dedicated Geological Storage	Offshore deep saline formations	Power Generation
Captain Clean Energy Project (formerly Caledonia Clean Energy Project)	Europe	Evaluate	Planned	Pre-combustion capture (gasification)	Pipeline	Onshore to offshore pipeline 351-400km	Dedicated Geological Storage	Offshore deep saline formations	Power Generation
Don Valley Power Project	Europe	Define	Planned	Pre-combustion capture (gasification)	Pipeline	Onshore to offshore pipeline 151-200km	Dedicated Geological Storage	Offshore deep saline formations	Power Generation
Peterhead CCS Project	Europe	Define	Planned	Post-combustion capture	Pipeline	Onshore to offshore pipeline 101-150km	Dedicated Geological Storage	Offshore depleted oil and/or gas reservoir	Power Generation
Rotterdam Opslag en Afvang Demonstratieproject (ROAD)	Europe	Define	Planned	Post-combustion capture	Pipeline	Onshore to offshore pipeline	Dedicated Geological Storage	Offshore depleted oil and/or gas reservoir	Power Generation
Sleipner CO2 Storage Project	Europe	Operate	Active	Pre-combustion capture (natural gas processing)	No transport required (i.e. direct injection)	Direct injection	Dedicated Geological Storage	Offshore deep saline formations	Natural Gas Processing
Snøhvit CO2 Storage Project	Europe	Operate	Active	Pre-combustion capture (natural gas processing)	Pipeline	Onshore to offshore pipeline 151-200km	Dedicated Geological Storage	Offshore deep saline formations	Natural Gas Processing
White Rose CCS Project	Europe	Define	Planned	Oxy-fuel combustion capture	Pipeline	Onshore to offshore pipeline	Dedicated Geological Storage	Offshore deep saline formations	Power Generation

Ref: GCCSI 2014

NER 300 projects

White Rose Carbon Capture and Storage (CCS) Project

Financed by €300 million under the European NER300 programme.

ALSTOM

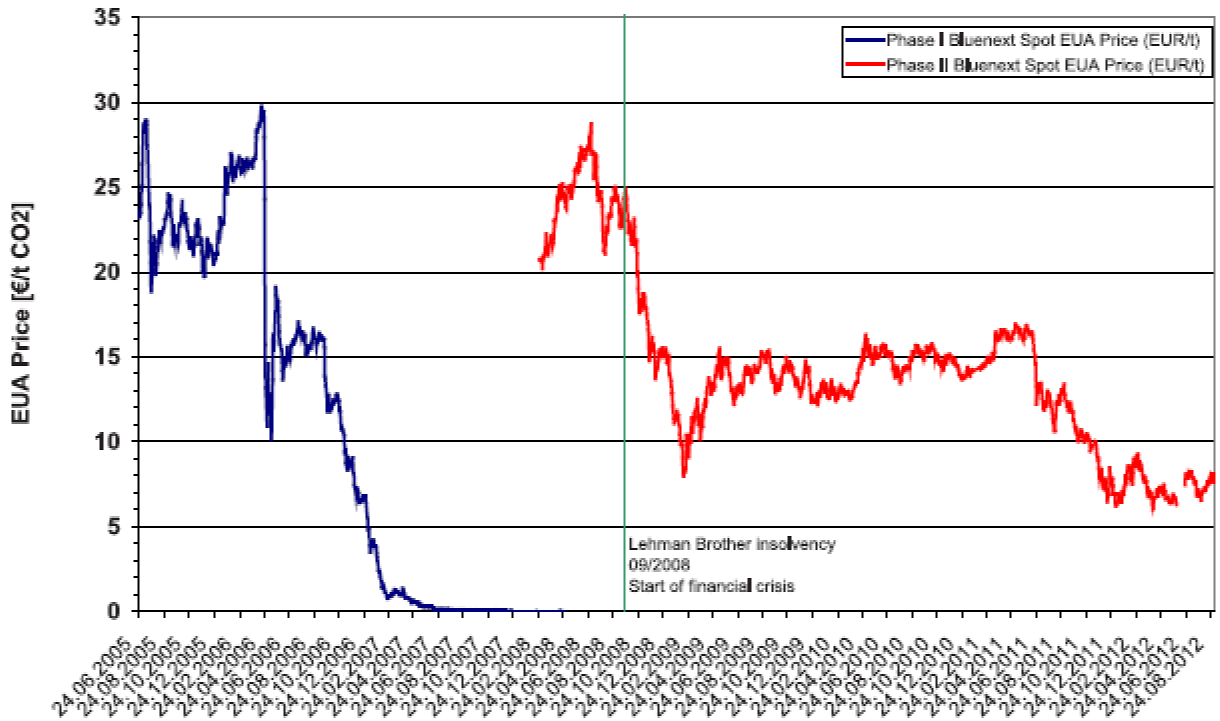
drax

BOC
A Member of The Linde Group

Located on	:	UK
Plant size	:	450 MWe gross output
Power plant technology	:	oxyfuel combustion,
CCS technology	:	90% of CO2 produced by the plant captured
Transport	:	by pipeline for permanent
Storage	:	off-shore beneath the North Sea seabed

CO2 spot price over time

When the CCS demonstration projects started planning in 2008, companies (and indeed, legislators and regulators) were expecting a further rise of certificate prices in the near future, giving a sound optimism that the savings in CO2 certificates will be able to compensate for the additional costs of CCS after the demonstration phase, therefore opening a business perspective for the technology. Certificate prices of 25 Euros per tonne of CO2 had been a common assumption and went into the economic calculations of the project proponents.



the certificate prices have declined since then and now languish at a price of around 5 Euros per tonne…

At this point the operational costs of the CCS chain is more expensive than the potential savings!

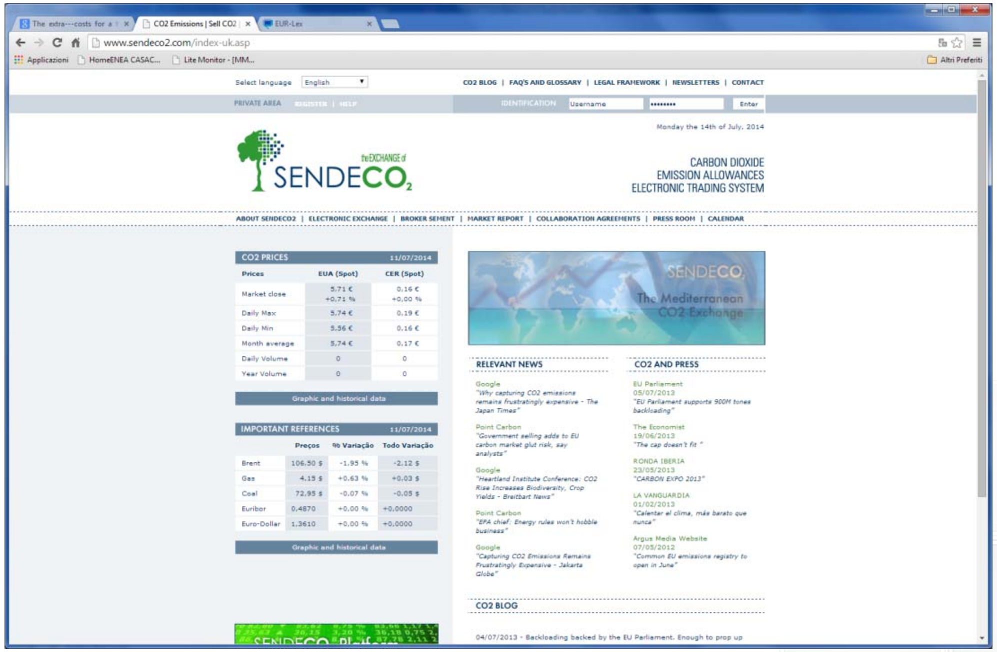
Without additional European or National support, the demanding CCS demo program of the EU, having at least 5-6 demo projects running in 2015, will fail.

The bourse for European Unit Allowances

SENDECO2, is the European bourse for European Unit Allowances (EUA) and Carbon Credits (CER's)

The main goal of SENDECO2 is to contribute significantly in the improvement of the environment through the reduction of the real CO2 emissions.

SENDECO2 has been active since 2005 and is the reference for the Portuguese, Spanish and Italian markets. SENDECO2 grants a unique European liquidity where all the participants, as establish by European Union directive, can freely trade European Allowances and Carbon Credits



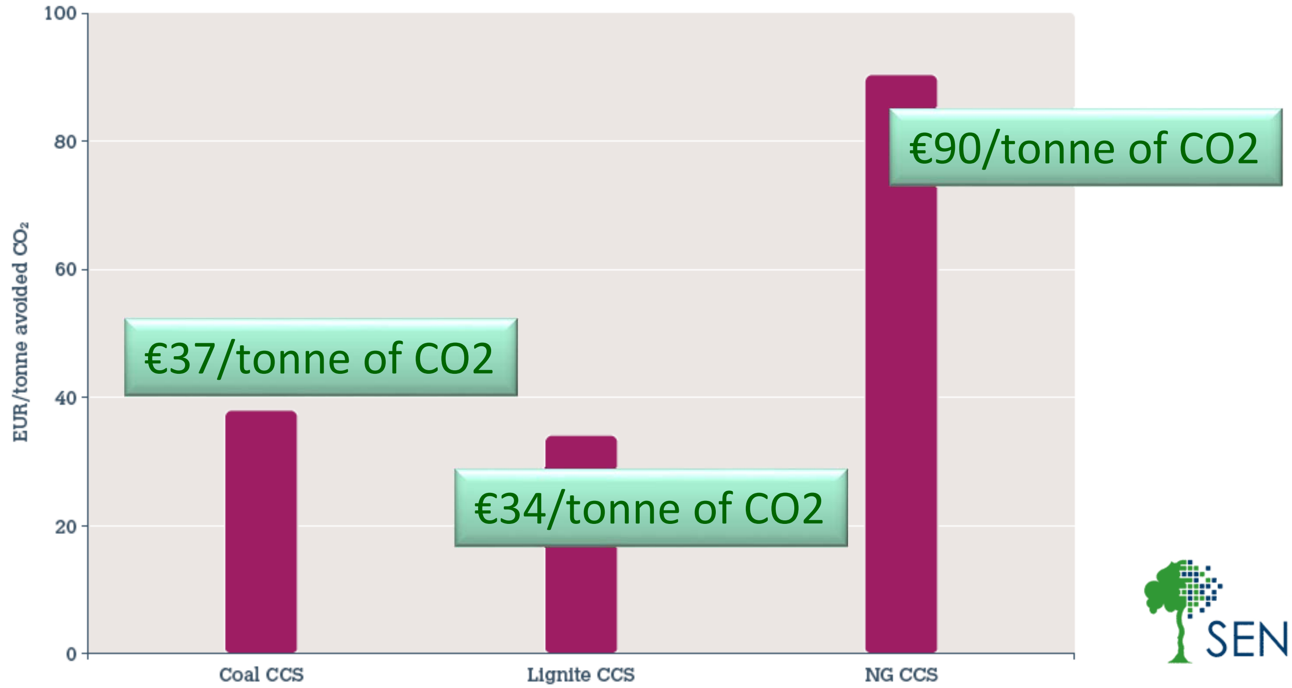
Legal Framework

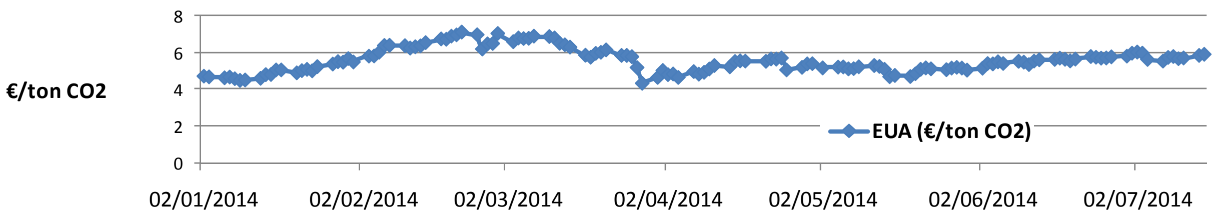
Commission Decision 2007/589/CE, July 18th
Establishes the guidelines for the procedures to control and communicate green house gas emissions.

Directive 2003/87/CE
Establish the European Union Emission Trading Scheme.

EUA break-even cost

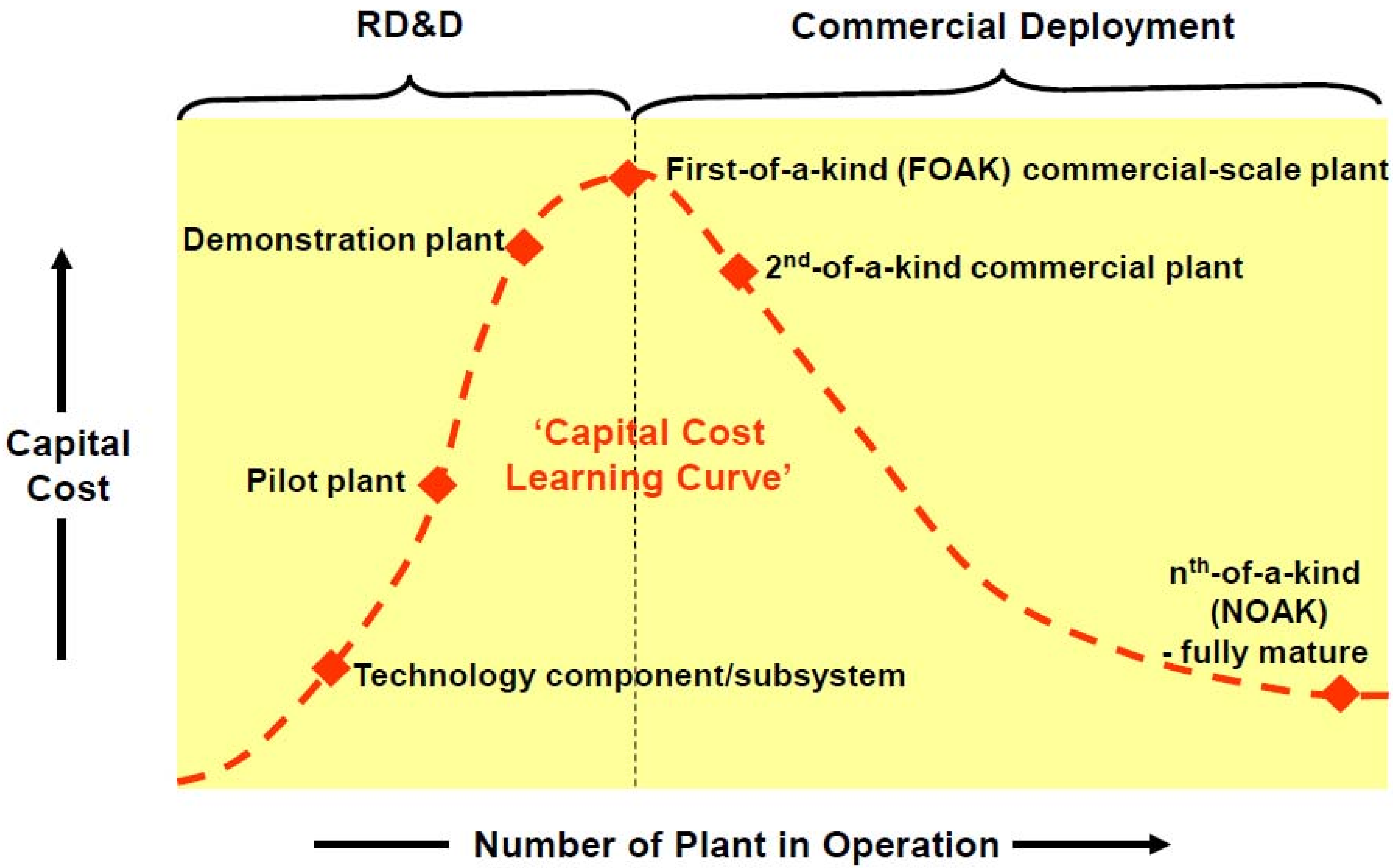
CO2 avoidance costs for possible plants commissioned in the mid 2020s – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view





Ref: ZEP 2011

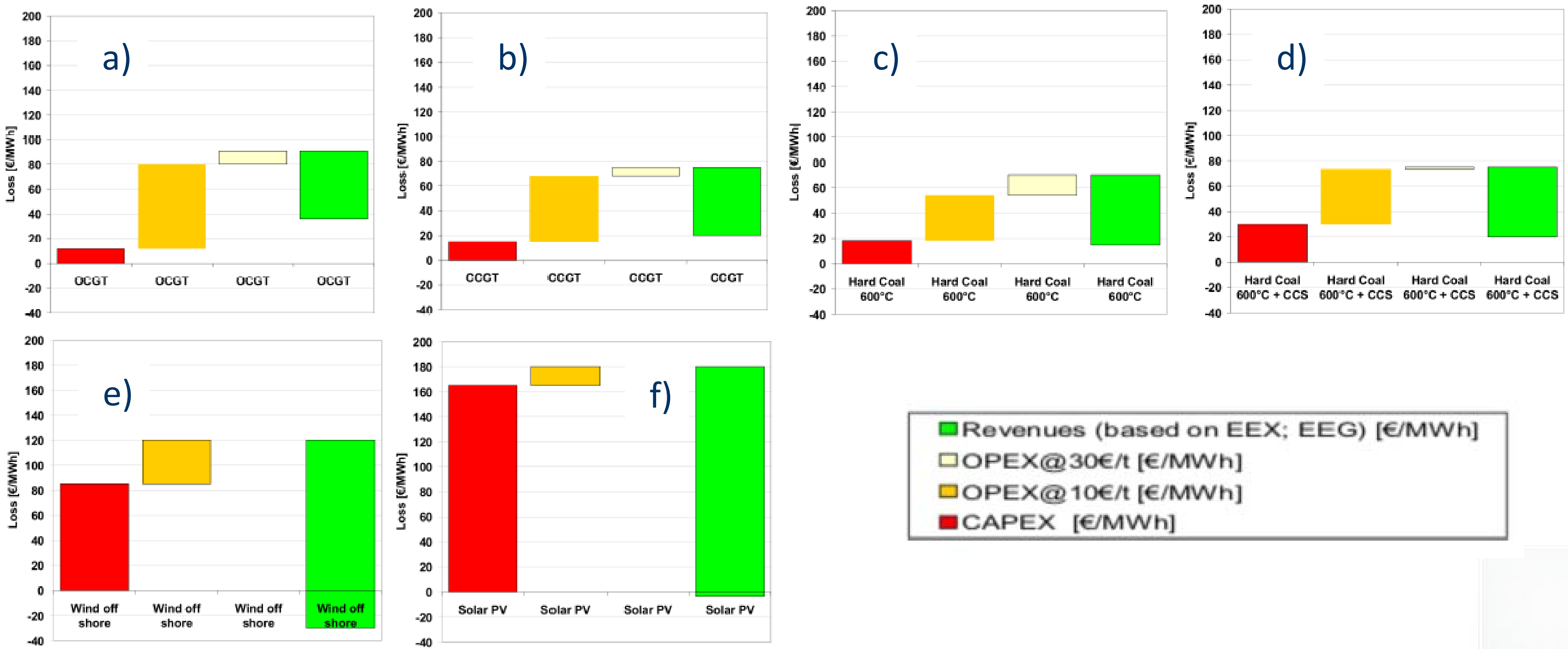
CCS Demo costs: FOAK → NOAK



Cost / Revenues benchmarking with RES

Economics of electricity generation technologies

a) Open Cycle GT, b) Comb Cycle GT, c) Coal, d) Coal with CCS, e) Wind offshore; f) Solar PV.



The cost for electricity from PV and offshore wind is clearly more expensive than the fossil alternatives with or without CCS. Due to the high and secured revenue stream from the feed in tariffs, however these higher generating costs are more than overcompensated by the higher revenue streams.

Challenges and opportunities

Economics and Financing

- The recession in Europe together with a significant increase in renewable electricity production triggered by subsidies has undermined the Emission Trading System.
- Cleaning up power plants or industrial installations by CCS will require additional investments for equipment and will increase the operational costs of the plants.
- Support schemes such as the **European EEPR program and the NER-300** support for CCS demonstration projects are not sufficient to make the project work.
- Additional national support by capital grants and/or feed in tariffs will most likely be necessary to bring demo projects to a positive investment decision.
- The cost for adding CCS at demonstration plant scale of 250 MWel will typically be in the range of 500-1000 Million Euros

Regulation

- **The EU CCS Directive** provided the legal framework **for the storage of CO_2** in the EU. However, to be applicable in the different Member States (MS), the EU directive needs to be. Fortunately most MS with demonstration projects under way had to transpose it into national law but with some delays.

- Project developers are facing, in addition, the challenge that there remain significant **uncertainties regarding the liabilities and the handover processes and requirements after** the CO_2 storage phase has been completed.

- A critical issue with the liabilities is linkage to the ETS Directive, so that for every tonne of CO_2 which might leak an emission certificate has to be surrendered (at what time/price?).

Pubblic Support

- **Renewable energies** have the highest support rate in general even if all large scale infrastructure projects are heavily debated.
- A key challenge with all infrastructure projects is the fact, that advantages and disadvantages for any individual need to be balanced with the advantages and disadvantages for the society. Carbon capture and storage as a new technology has still to explain and to prove its merits to the public, requiring the testing and application of the technology at demo scale.
- All this has caused severe delays for demo projects planning to store CO2 onshore.
- There is still a strong belief in the general public that the electricity supply can be shifted completely to fluctuating renewable energies and therefore CCS might not be necessary. However people tend to ignore the fact that **electricity from renewables together with the necessary reinforced grids and energy storage will be more costly than allowing CCS** in the electricity mix.
- European industry has to compete internationally and significantly higher electricity prices will reduce the competitiveness of the industry, which is the key driver for economic growth and jobs in Europe.

Technology

- **Significant progress has already been made**, bringing down the energy penalty from 17% point to values of around 8% points.

- It is expected that significant further learning effects can be realized, based on the experience from demo projects and further R&D.

- **The contribution from CCS on a member state level depends on local conditions**, e.g., access to local fuels like lignite, and whether or not onshore storage will be allowed. By many authors excluding on-shore storage in aquifers, the CCS will be centralized around the North Sea.

- **Natural gas fired conventional power plants is likely to be a serious competitor to coal CCS** in the short to medium term providing large emission reduction opportunities by fuel shifting from existing coal power plants to new high efficient gas fired combined cycles. Such development can be a barrier for early deployment of CCS and could result in a delay in commercialization of CCS.

Conclusions

1) The introduction of carbon sequestration technologies will result in an increase in a number of costs:

- **Increased capital costs** for each plant to be equipped with carbon separation/capture.
- **Additional** capital costs for CO2 **transport and storage**.
- Increased fixed operational costs and increased variable costs
- Additional operating costs for CO2 transport and storage.

2) There is currently no clear difference between any of the three CO2 capture technologies (post-combustion, pre-combustion and oxy-fuel), that could be competitive once successfully demonstrated:

LCOE **70-120 $/MWh** Levelised Cost of Electricity is the main quantitative value

Conclusions

3) **Sensitivity analysis shows Fuel/Investment costs as main factors influencing total costs**

capital cost dominates (plant load factor, reducing running hours result in much higher cost)

4) The associated **EUA break-even cost** corresponds to a price of €34/tonne of CO2-€90/tonne of CO2 for gas. At an EUA price of €35/tonne of CO2, coal-fired CCS power plants are therefore close to becoming commercially viable

5) **CCS requires a secure environment for long-term investment**

Based on current trajectories, the price of Emission Unit Allowances (EUAs) under the EU Emissions Trading System will not, be a sufficient driver for investment after the first generation of CCS demonstration projects is built (2015-2020).

Steps to be taken

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Enabling policies

are required in the intermediate period – after the technology is commercially proven, but before the EUA price has increased sufficiently to allow full commercial operation.

The goal

to make new-build power plants with CCS more attractive to investors than w/o (ZEP).

Fluctuating generation

with the growing share of renewable power fossil fuel power plants have to increasingly shift their role from providing base load power to providing fluctuating back up power. The challenge is to gain operational flexibility for fossil fuel power (and CHP) plants.

Key challenges

in the short term are geological storage and the application to industrial sectors other than power , that has to deliver half of the global emissions reduction from CCS by 2050 (see last CALL FOR COMPETITIVE LOW-CARBON ENERGY - LCE-15-2015).

All recent studies and roadmaps have proven the importance of CCS, even if not fully recognized by the general public. It is therefore important to ensure that CCS can keep its momentum to deliver from 2020 onwards. Therefore at least 2 or 3 demonstration projects have to be realized in Europe still during this decade.

Thank you for kind attention

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