UNFCCC

Technical workshop on modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activity

CO2 Capture Technologies

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Presentation Overview

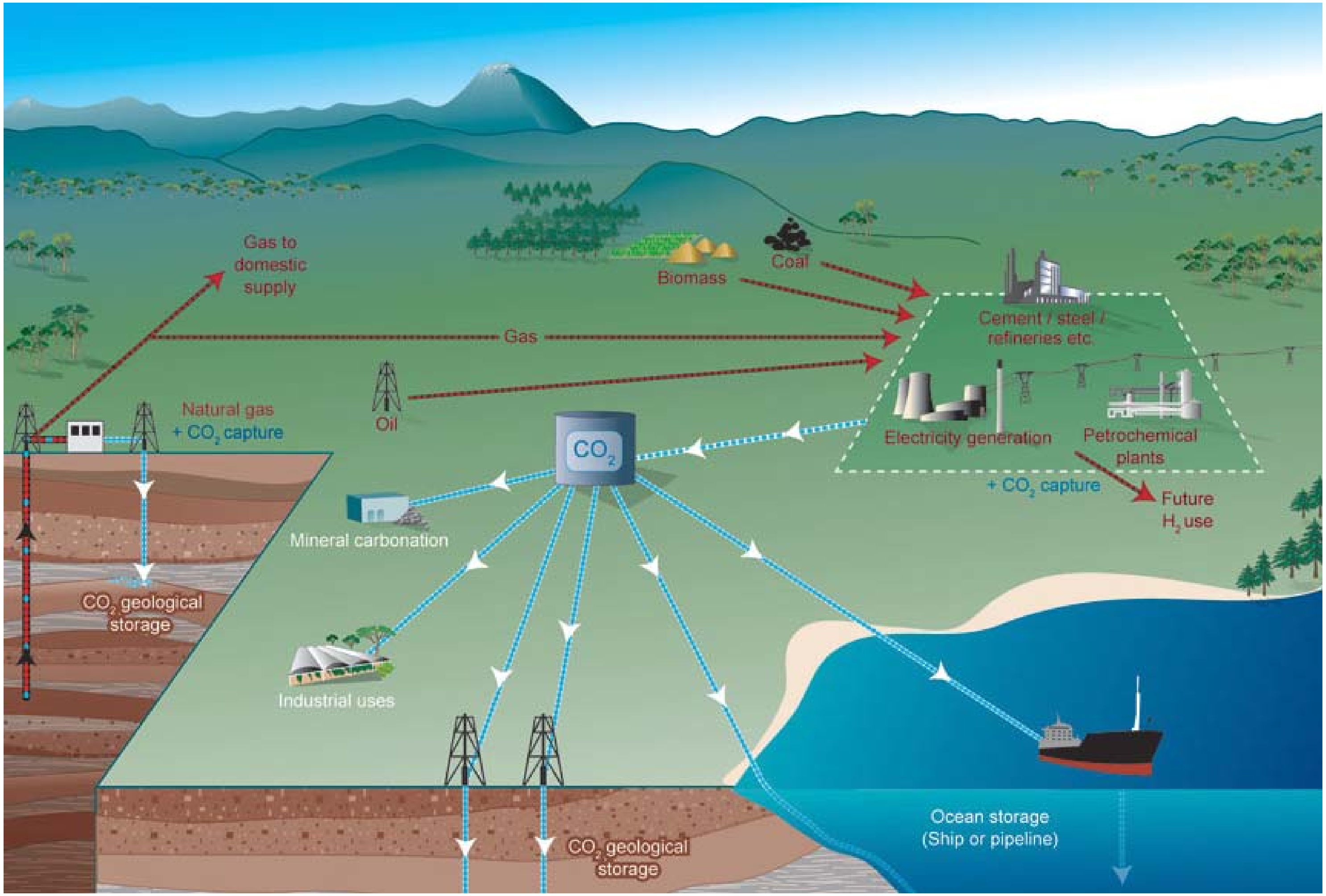
- What is CO_2 capture and storage (CCS) ?
- Role and importance of CCS in mitigating climate change -The rationale for CCS
- Main capture technologies - Maturity of the technologies
- Cost of CO_2 capture
- Conclusions

What is CO_2 capture and storage (CCS) ?

- Separation of carbon dioxide from flue gases of combustion stationary sources mainly power plants (mostly dilute, 4-15% CO_2 depending on the fuel type) and or process streams (more concentrated up to 100%, e.g. natural gas processing, ammonia, hydrogen and ethylene production, etc.),
- Compression to a suitable pressure (dense gas or liquid)
- Transportation to suitable storage area which is as close as possible to the source
- Storage in a suitable underground storage area or oceans.

See the diagram in the next slide (IPCC, 2005)

Schematic of CCS system



Role and importance of CCS in mitigating climate change -The rationale for CCS (1)

- Over 85 % of energy supply from fossil fuels with more than 20 GT of CO_2 emissions per year
- Stabilizing greenhouse gas concentrations in the atmosphere at 450 ppm by 2050 to keep the temperature increase to below 2 degrees centigrade (IPCC, 2007 and COP16 decision)
- Deep reductions of 50-80% of GHGs is required which can not be achieved through the existing methodologies such as energy conservation/efficiency, renewable energies, etc.
- Fossil fuels will dominate the energy market, in particular the electric power sector
- Industrial development will increase, especially in major developing countries, requiring more fossil energy use (electricity and thermal energy) and more process emissions.
- Transformation to a sustainable energy system with low greenhouse gas emissions is very challenging.

Role and importance of CCS in mitigating climate change -The rationale for CCS (2)

- Worldwide assessments suggest that under a range of stabilization scenarios, the contribution of CCS is anticipated to about 20% of needed emission reductions over the next century compared with the contributions from renewable energy supplies and end-use efficiency gains (IPCC, 2005; IPCC, 2007; IEA 2008).
- While the early focus of CCS has been on reducing emissions from electricity generation from coal and natural gas, it is estimated that by 2050 about 2-3Gt/yr of CO2 from industrial sources will need to be captured and stored (IEA, 2009).
- In the future, CCS may also contribute significantly to emission reductions from the transportation sector via hydrogen production, electrification of vehicles, production of synthetic fuels using captured CO2, or manufacturing of other products such as cement or polymers from captured CO2.

Role and importance of CCS in mitigating climate change -The rationale for CCS (3)

- Carbon capture and storage (CCS) is an important part of the lowest-cost greenhouse gas (GHG) mitigation portfolio.
- Without CCS, overall costs to reduce emissions to 2005 levels by 2050 increase by 70%.
- An ambitious CCS growth path is needed to achieve this GHG mitigation potential, envisioning 100 projects globally by 2020 and over 3 000 projects by 2050).
- This roadmap's level of project development requires an additional investment of over USD 2.5-3 trillion from 2010 to 2050, which is about 6% of the overall investment needed to achieve a 50% reduction in GHG emissions by 2050. OECD governments will need to increase funding for CCS demonstration projects to an average annual level of USD 3.5 to 4 billion (bn) from 2010 to 2020. In addition, mechanisms need to be established to incentivise commercialisation beyond 2020 in the form of mandates, GHG reduction incentives, tax rebates or other financing mechanisms.

Source: Technology Roadmap, CCS, IEA.

Role and importance of CCS in mitigating climate change -The rationale for CCS (4)

- An enormous amount of effort is now devoted to advancing this technology with over 238 active or planned projects. In total, 80 large-scale integrated projects are in various stages of the asset life cycle, nine large-scale projects are operating with two more under construction, and an additional 69 potential projects are at various stages of planning . As of April 2010, this represented $26 B of government investment (GCCSI, 2010).

Role and importance of CCS in mitigating climate change -The rationale for CCS (5)

- Today, four CCS projects capture from 0.5 to 2 Mt/yr of CO_2 from industrial sources and store it in deep geological formations and have been operating for years to a decade or more— demonstrating that, at least on this limited scale, CCS can be safe and effective for reducing emissions. For three of these projects, CO_2 is captured from natural gas cleanup operations while in the fourth, CO_2 is captured from a coal to synthetic natural gas plant.

Role and importance of CCS in mitigating climate change -The rationale for CCS (6)

- Relevant experience from nearly 40 years of CO_2 enhanced oil recovery also show that CO_2 can safely be injected underground. While most of the CO_2 used for EOR is from natural CO_2 reservoirs, a small fraction is produced from industrial sources such as natural gas cleanup, hydrogen production and ammonia production.
- A 5 to 10-fold scale-up in the size of individual projects would be needed to capture and store emissions from a large coal-fired power plant.
- A thousand-fold scale-up in CCS would be needed to achieve a contribution to emissions reductions on the order of 20% over the next century (GCCSI, 2010).

Main capture technologies - Maturity of the technologies

CO_2 capture technologies have long been used by industry to remove CO_2 from gas streams where it is not wanted, or to separate CO_2 as a product gas. There are currently three primary methods for CO_2 capture:

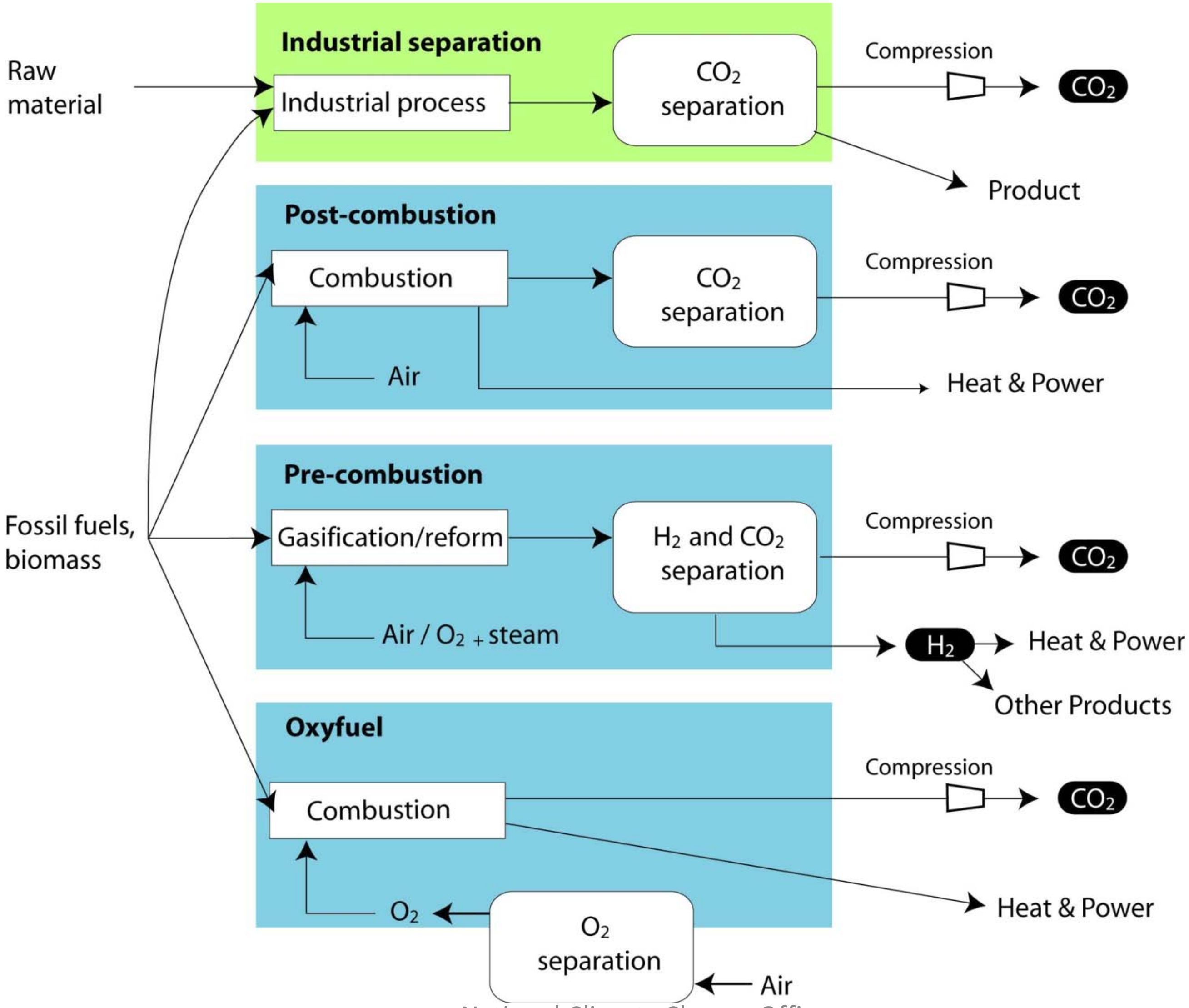
• Post-combustion capture where CO_2 is scrubbed out of flue gases by a physical or chemical solvent , or separated by adsorbents or membranes. Solvent scrubbing is a well established technology.

• Pre-combustion capture where a gasification process is followed by separation with solvents, membranes, etc., leaving hydrogen fuel gas. Pre-combustion CO_2 capture from an integrated gasification combined cycle (IGCC) power plant has yet to be demonstrated; however, elements of the pre-combustion capture technology have already been proven in other industrial processes (IPCC, 2005; Henderson et al., 2009).

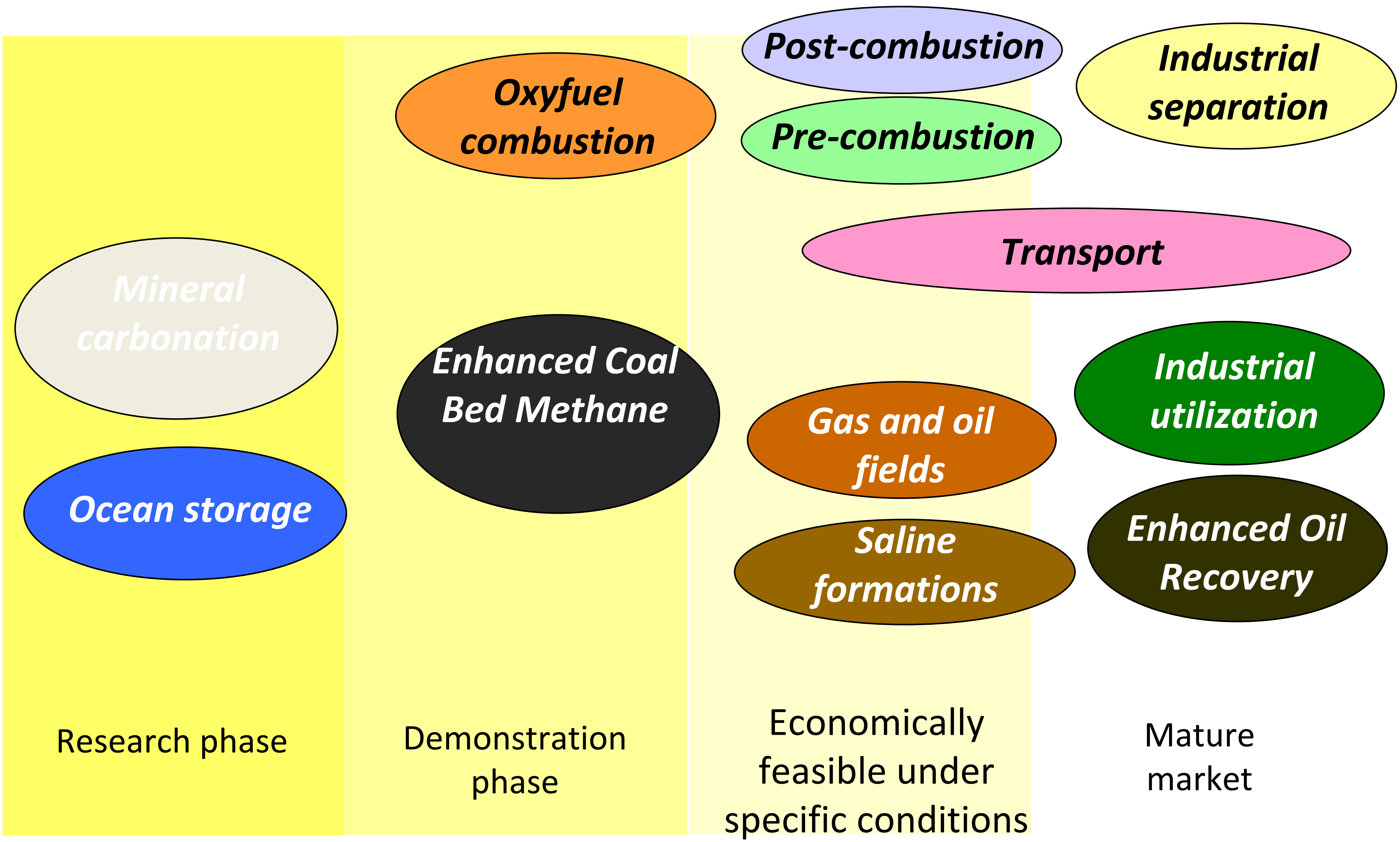
• Oxy-fuel combustion involves combusting fuel with pure oxygen or in recycled flue gas enriched with oxygen to produce a CO_2-rich gas.

For more recent information on technology, see CCS Roadmap, IEA

Capture of CO2 (Source: IPCC 2005)



Maturity of CCS technology (Source: IPCC, 2005)

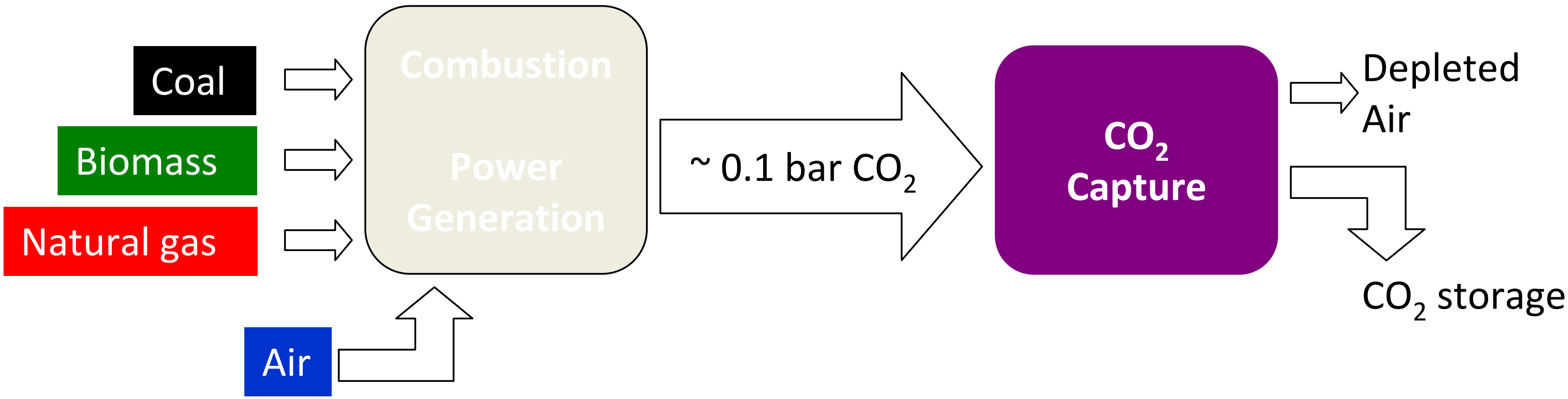


Improvements in capture technology

Efficiency loss and CO_2 capture costs can be reduced by:

- Use more concentrated streams
- Make CO_2 available at higher pressures to reduce compression costs
- Use improved and novel solvents or sorbents with low regeneration energy requirement and high stability
- Use improved membranes

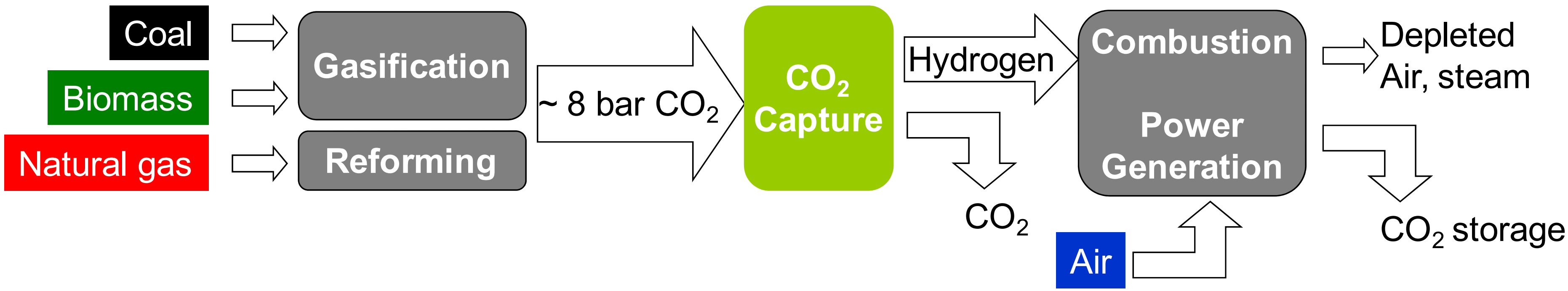
Post-combustion CO_2 capture (advantages (+) and disadvantages (-)



- \+ 'Standard' power plant
- \+ Retrofit to existing power plants is possible
- \- High efficiency penalty
- \- Not yet proven on large scale in power plant
- \- Solvent losses and environmental pollution

Sources: Energy Research Center of the Netherlands (ECN)

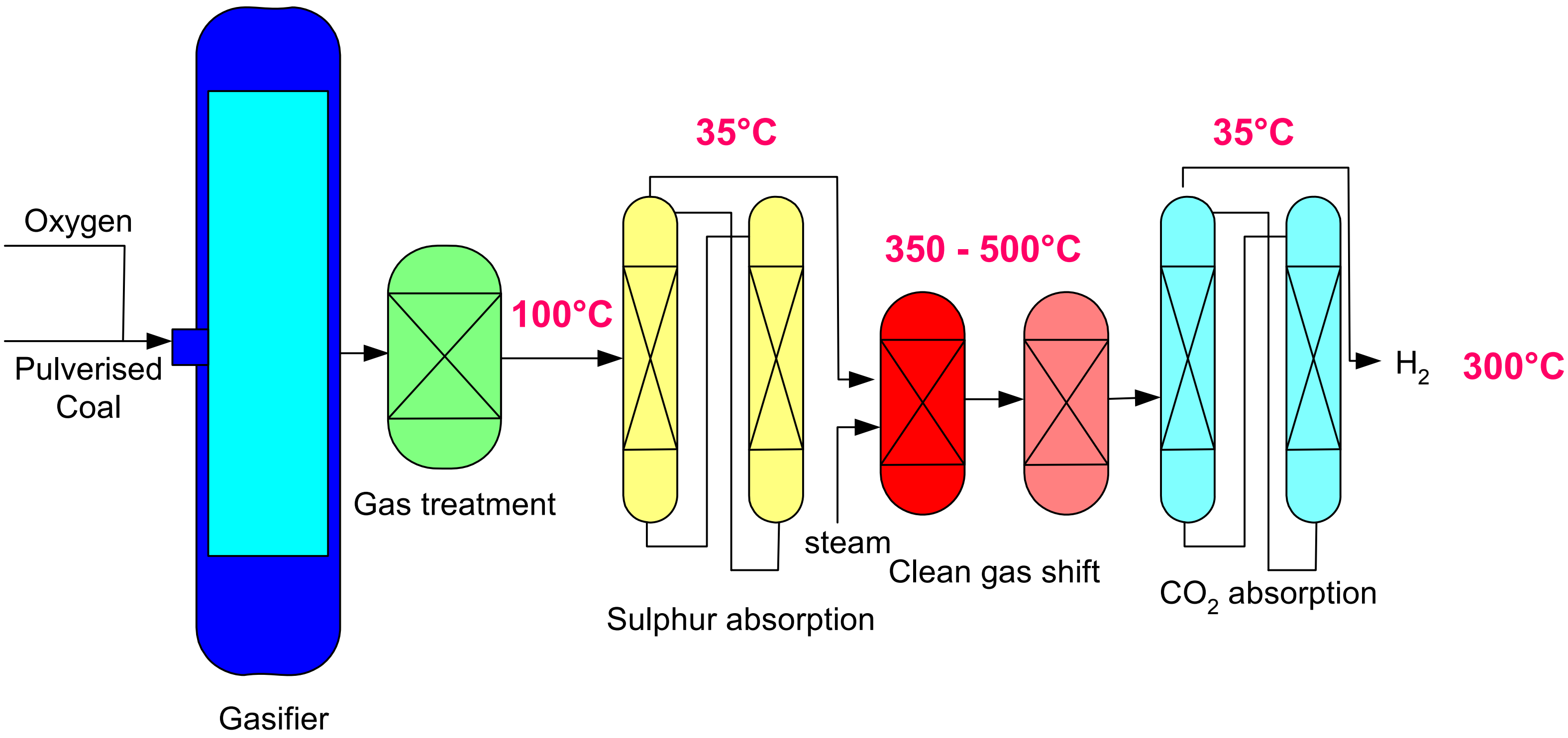
Pre-combustion CO2 capture
Advantages (+) and disadvantages (-)



- \+ Lower efficiency penalty
- \+ Exists at large scale hydrogen production
- \+ Different products possible
- \- Coal gasifier is needed
- \- Many process steps

Sources: Energy Research Center of the Netherlands (ECN)

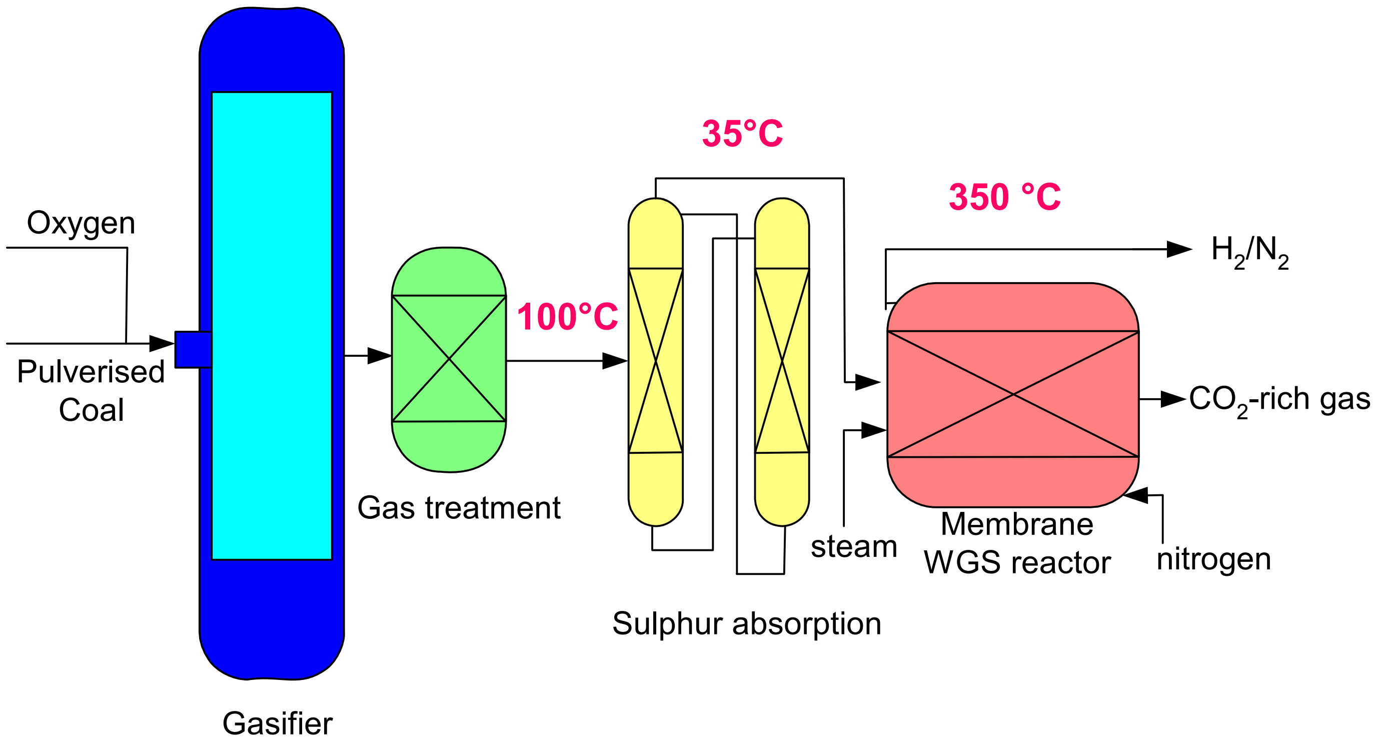
Conventional CO_2 scrubbing



- Multiple process steps
- Hydrogen-rich gas is at low temperature before gas turbine

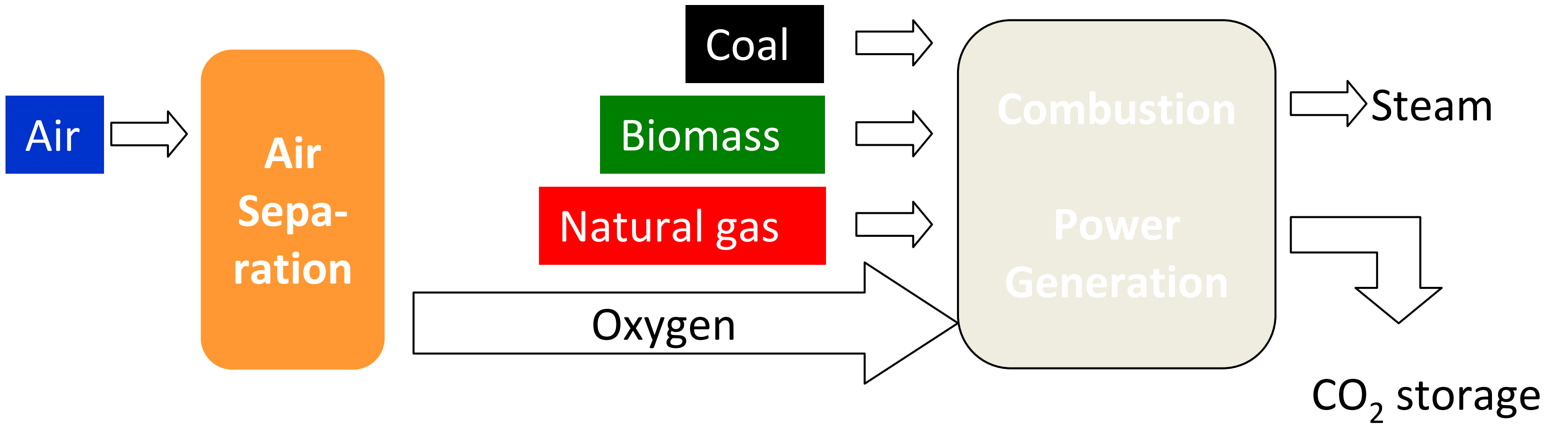
Source: The Energy Research Center of the Netherlands (ECN)

Membrane water gas shift reactor



Energy Research Center of the Netherlands ((ECN)

Oxyfuel CO_2 capture
Advantages (+) and disadvantages (-)



- \+ Air separation is a proven technology
- \+ Large potential for improvement
- \- Air separation is expensive
- \- Burning coal or gas in pure oxygen requires new technology

Source: Energy Research Center of the Netherlands

CO_2 Capture Cost (1)

- Costs vary widely depending on many factors such as CO_2 concentration in the process stream, its pressure and temperature, impurities, separation method, size and age of the plant, scale of operation, plant location and technology, retrofit or new plants, etc.
- There are numerous reports documenting current and future estimates for the cost of capture for power generation and industrial emission sources (e.g. IPCC, 2005; DOE, 2010; MIT, 2007; Al-Juaried and Whitmore, 2009).
- Costs of capture for the nth-of-a-kind plant range from about 30 to $100/tonne of CO_2 avoided and first-of-a-kind plants are expected to cost significantly more with estimates in the range of $100 to $150/t$CO_2$ avoided. Estimates vary widely, in part because they use a variety of different assumptions about baseline technology, capture technology, discount rates, material and labor inflation and regional indices.

CO_2 Capture Cost (2)

Detailed cost estimates are available in the recent publication by GCCSI (The Global Status of CCS: 2010) which includes the scope of works carried out at international level, the purpose of cost estimate, industrial sectors surveyed and the relative uncertainty across cost studies.

Conclusions

- CO_2 capture technology is available for both power sector and industrial processes.
- Different technologies are at different stages of development and maturity.
- Presently, the most developed CO_2 capture technology is post-combustion capture using amines solvents.
- Great potential for future deployment of CO_2 capture technologies.
- High cost and efficiency penalty are major challenges.

Thanks for your attention