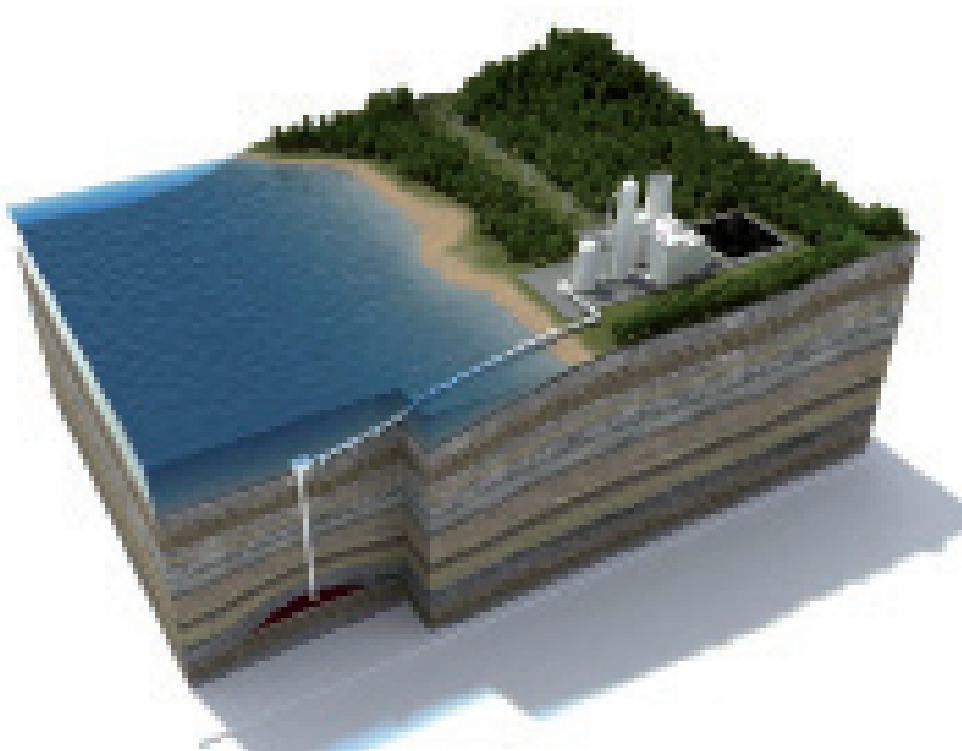


WHY CCS NOW

This publication explains why capture and geological storage of CO₂ is a necessary tool to combat global warming



www.bellona.org/ccs

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The Bellona Foundation is an environmental NGO based in Oslo, Norway, with offices in Brussels, Washington D.C., Murmansk and St. Petersburg.

Founded in 1986 as a direct action protest group, Bellona has become a recognised technology- and solution-oriented environmental organization.



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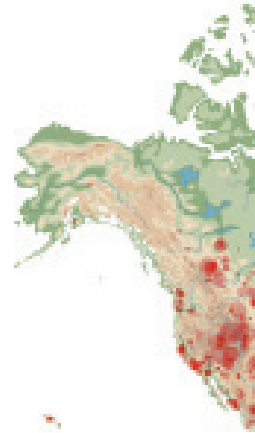
Why CO₂ Capture and Storage (CCS)?

Global warming is already taking place and it is one of the biggest challenges facing mankind. Failing to tackle it could have dramatic consequences such as ^{1,2}:

- More extreme weather events
- Rising sea levels
- Less drinking water
- Spreading of diseases
- Extinction of endangered species
- Migration of climate refugees

To have a reasonable chance of avoiding such consequences, the global average temperature must not increase by more than 2°C above the pre-industrial level. According to the Intergovernmental Panel on Climate Change (IPCC) this requires an overall 50 to 85% reduction of global greenhouse gas (GHG) emissions by 2050 ³. This also means that global emissions must peak in 2015-2020 before falling rapidly to near zero³.

Achieving a 85% cut in global GHG emissions by 2050 is possible, but requires a tremendous effort to transform society into a low carbon emitting economy. Indeed, it can only happen using a portfolio of solutions. Although enhanced energy efficiency together with a greater share of renewables in energy production are the two main strategies to slow global warming, their potential to achieve the needed GHG emission reductions within such a short timeframe is limited. The required emission reduction targets can only be obtained using CO₂ Capture

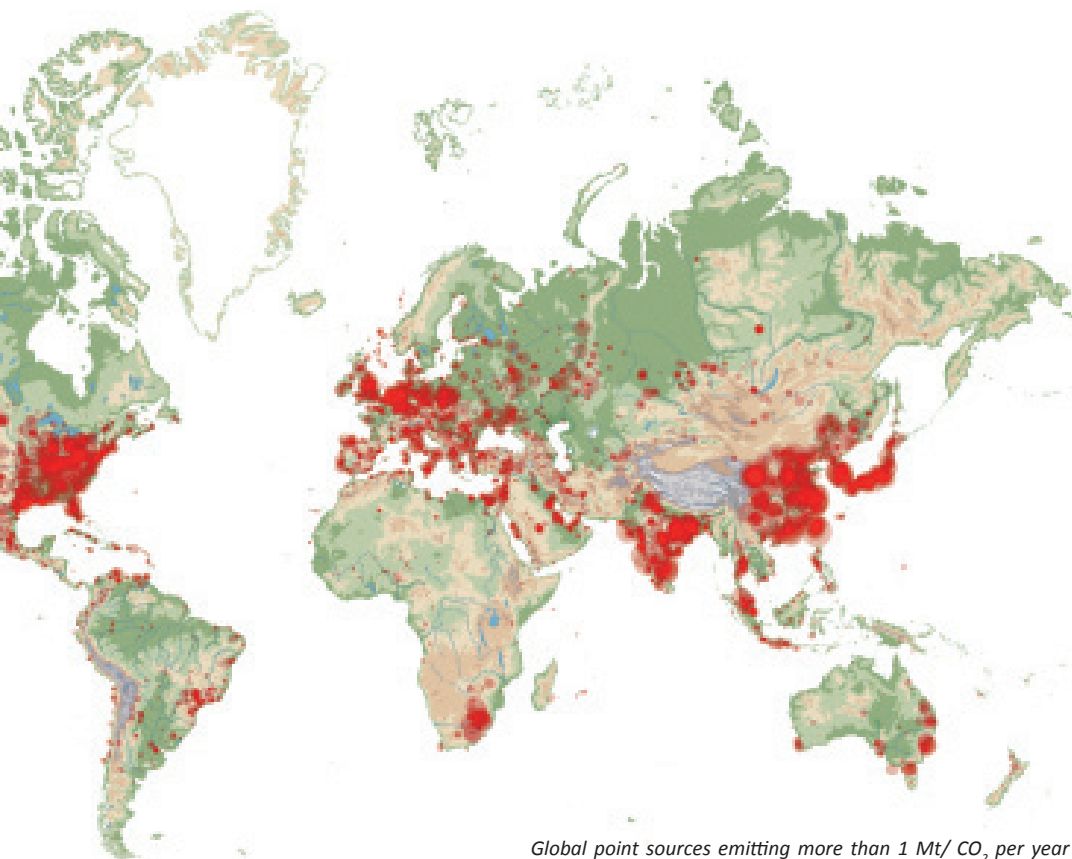


CCS is not a goal in itself, it is a bridge to a truly sustainable energy chain.

and Storage (CCS) as an additional strategy. By 2050, CCS has the potential to cut global CO₂ emissions by 1/3⁴.

Eventually, we will need to become “carbon negative” by removing CO₂ from the atmosphere and putting it back underground.

CCS is the critical and additional solution that enables us to eliminate emissions in a world that will contain 9 billion people by mid-century.



Global point sources emitting more than 1 Mt/ CO₂ per year are shown in red

In order to limit global warming, atmospheric CO₂ concentrations should not exceed 350 parts per million (ppm)⁵. We are already at 385 ppm, and increasing by 2 ppm per year.

¹ The Intergovernmental Panel on Climate Change (IPCC), 2007. In: Climate Change 2007: Impacts, Adaptation and Vulnerability, Summary for Policymakers

² Stern, N., 2006. Stern Review: The Economics of Climate

³ The IPCC Fourth Assessment Reports, Intergovernmental Panel on Climate Change (IPCC), 2007

⁴ "How to Combat Global Warming", Stangeland, A. et al., 2008, Bellona Report

⁵ For different global climate policies models (emission scenarios) see <http://adamproject.info>

80-90% of global energy production is based
on fossil fuels

2/3 of the global population requires greater access
to energy in order to raise their standard of living

Global energy demand is projected to increase
by 40% by 2030¹

Global CO₂ emissions from the energy sector

- have increased by 38% from 1990 to 2007
- are projected to increase by 65% from 1990
to 2020 and by 92% from 1990 to 2030¹

Fossil fuels remain the dominant source
of primary energy worldwide.

They account for more than 3/4 of the overall increase
in energy use between 2007 and 2030^{1, 3}

China opens a new large coal-fired power plant each week

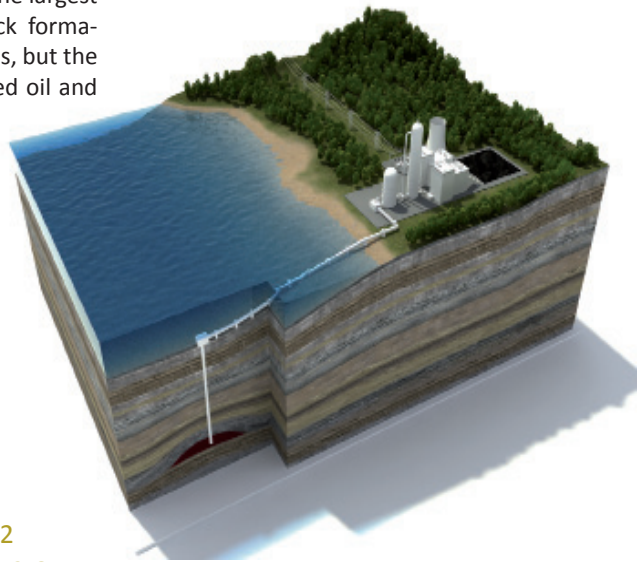
What is CCS?

The greatest source of CO₂ emissions is coal power plants. The emissions from these plants are not only CO₂, but also harmless steam and nitrogen. CCS is a technology whereby CO₂ is separated from these components. After the CO₂ is captured it can be transported by ship or via a pipeline to deep underground storage locations where it is injected into porous rock formations and isolated from the atmosphere.

Storage of CO₂ takes place deeper than 800 m underground, in special geological formations. The storage sites with the largest storage potential are porous rock formations with saline water in it's pores, but the CO₂ can also be stored in depleted oil and

gas fields.

The purpose of CCS is to stop CO₂ emissions from large point sources without closing down the industrial sites.



CCS stands for CO₂ Capture and Storage and consists in capturing emitted CO₂ and storing it underground

Closing the carbon loop: putting CO₂ back where it came from

Fossil fuels like coal, gas and oil are excavated or pumped up from natural underground storage sites and converted into energy in large power plants.

Capturing the CO₂ emissions from these plants and storing it underground again, returns the carbon to where it originally came from.

The CO₂ is stored underground by imitating trapping mechanisms used by nature to store CO₂, gas and oil for millions of years.



Illustration by Statoil



Environmentally sound CCS

Capture plants for CO₂ must be adopted at all new fossil fuel power plants and CO₂ emitting industrial plants like steel, cement, processing and even biomass plants.

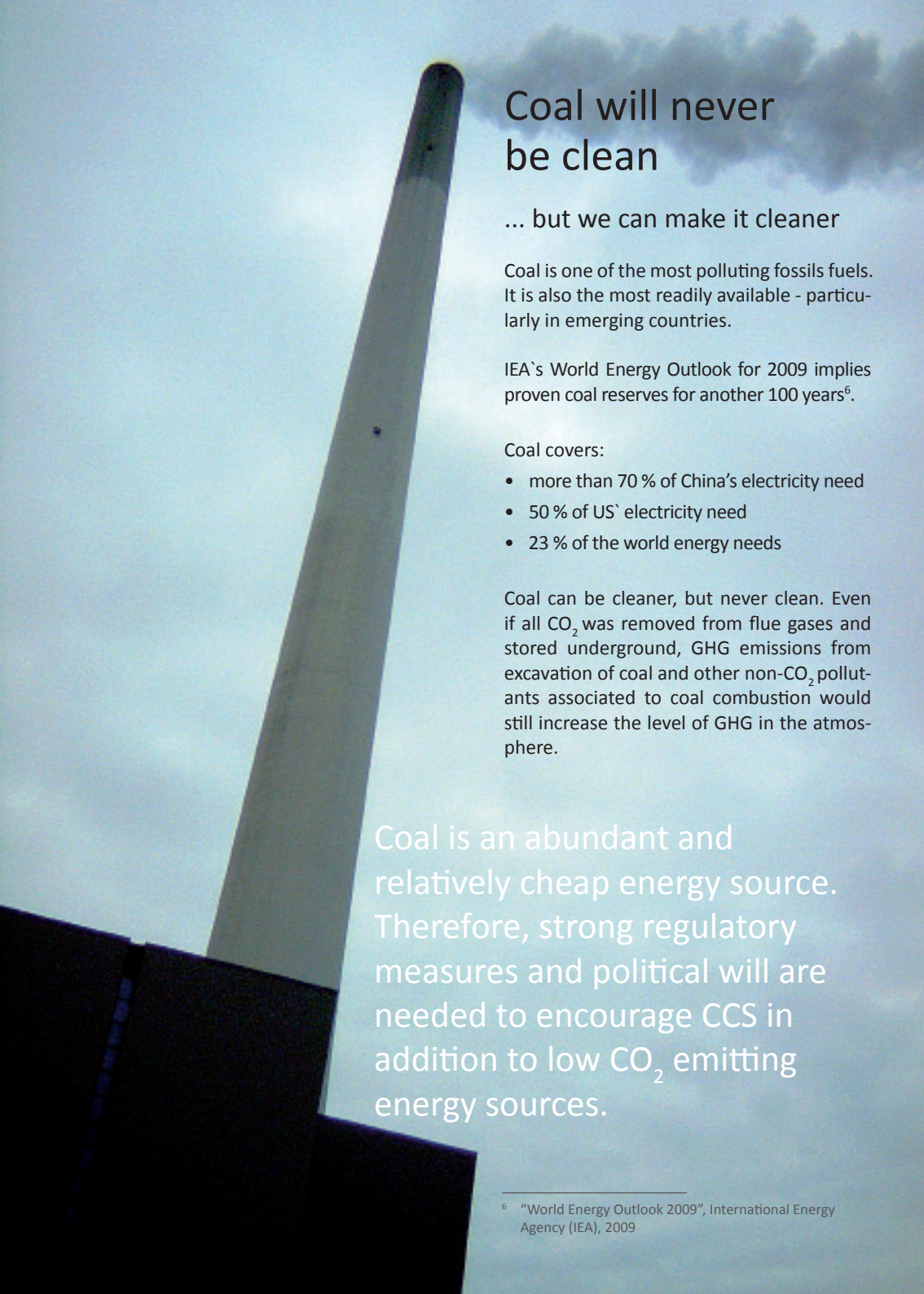
The extraction of oil from tar sand produces vast levels of GHG because the process is technically challenging and energy intensive. The huge amount of energy required to strip heavy oil from the sand and

upgrade it to usable petroleum products, mostly comes from burning natural gas. In this way tar sand uses the least CO₂ emitting fossil fuel (natural gas) whilst contributes significantly to global warming.

In order to reduce GHG by 85% in time for 2050 as recommended by the Intergovernmental Panel on Climate Change (IPCC), the extraction of oil from tar sand is not a viable option, with or without CCS.

Environmentally sound CCS means;

- Safe CCS ensuring storage security, monitoring and risk assessments
- CCS with low energy penalty
- CCS with a satisfactory Life Cycle Analysis taking into account the total CCS value chain
- CCS not diverting funding from renewables
- CCS that does not prolong the use of fossil energy in the long term
- CCS on all CO₂ emitting industry facilities
- CCS that bridges the gap between today and a future based on renewable energy
- CCS as a tool to remove CO₂ from the atmosphere (going Carbon Negative)



Coal will never be clean

... but we can make it cleaner

Coal is one of the most polluting fossil fuels. It is also the most readily available - particularly in emerging countries.

IEA's World Energy Outlook for 2009 implies proven coal reserves for another 100 years⁶.

Coal covers:

- more than 70 % of China's electricity need
- 50 % of US' electricity need
- 23 % of the world energy needs

Coal can be cleaner, but never clean. Even if all CO₂ was removed from flue gases and stored underground, GHG emissions from excavation of coal and other non-CO₂ pollutants associated to coal combustion would still increase the level of GHG in the atmosphere.

Coal is an abundant and relatively cheap energy source. Therefore, strong regulatory measures and political will are needed to encourage CCS in addition to low CO₂ emitting energy sources.

⁶ "World Energy Outlook 2009", International Energy Agency (IEA), 2009

A Carbon Negative Future

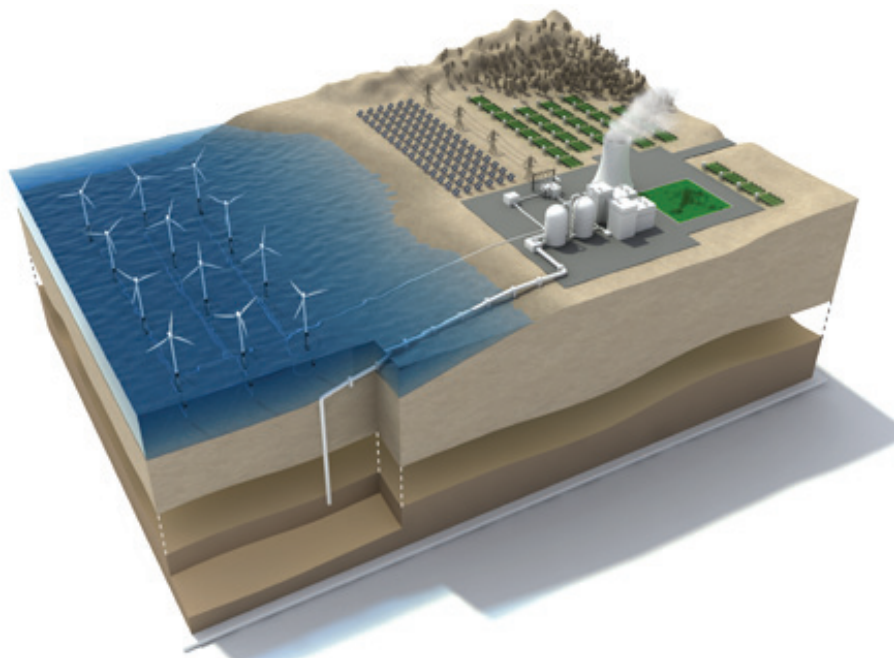
CCS has even a greater potential in terms of emission cuts when combined with biomass. It can serve to achieve a carbon negative value chain that actually remove CO_2 from the atmosphere.

Indeed, in a pure biomass power plant with CCS the CO_2 is captured twice, first during the life of the growing plant and again when CO_2 is captured from the flue gas. This is how we can achieve a carbon negative energy production.

Substituting fossil fuels and feedstocks in transportation, heating, industry, and power generation with biomass will provide for carbon neutral solutions.

For this approach to be sustainable it is vital that the production of the biomass does not displace food production or natural forests.

At present dedicated biomass plants have lower efficiencies than coal power plants, but cofiring biomass with coal increases the efficiency of using biomass for energy production.



“By combining technology for CCS with the use of biomass, future energy production can remove CO₂ from the atmosphere. The latest observations of climate change tell us that carbon negative is not only an interesting idea, but a necessity if we are to avoid crossing dangerous climatic tipping points”.

Frederic Hauge
President of the Bellona Foundation 2009



CO₂ storage

Injecting CO₂ underground will in fact return the CO₂ to where it came from.

CO₂ is stored using the same trapping mechanisms as nature has been using to store CO₂, gas and oil for millions of years. The CO₂ is stored in deep saline aquifers or abandoned oil and gas fields, - more than 800 m underground, both onshore and offshore.

The world's petroleum and chemical industries have decades of experience of transporting and storing CO₂ safely.

Suitable geological formations for CO₂ storage are found in layers of porous rock which have space available for the CO₂ similar to the way a sponge has space available for water.

A suitable CO₂ storage reservoir needs⁸:

- A layer of porous rock at the correct depth to hold the CO₂ (anywhere from 800 m to 5,000 m deep)
- Sufficient storage capacity
- An impermeable layer of “cap” rock to seal the porous layer of rock underneath

Existing CO₂ storage sites

CCS in deep saline aquifers is implemented full-scale at the Sleipner gas field in Norway. Since 1996 about 1 Mt of CO₂ per year has been stored in a saline aquifer underneath the gas field. Other storage sites are In-Salah in Algeria, Otway in Australia, Lacq in France, Salt Creek in the USA and Weyburn in Canada (see illustration).

Evidence provided by leading European geological and research organizations from over 13 years of experience with CO₂ storage at the Sleipner site show no sign of leakage⁷. Monitoring of the field provides insight into the geometrical distribution of the injected CO₂ and verifies safe injection.



Existing CCS projects

Trapping CO₂

The injected CO₂ will be trapped by geochemical processes.

The CO₂ storage risks are related to leakage from the storage formation. These risks could include hazards for humans, ecosystems and groundwater.

Observations and analysis of current CO₂ storage sites indicate that the probability of leakage⁷ in an appropriately selected and well managed site is nearly absent². The risk of leakage also decrease over time due to pressure equalization and trapping mechanisms⁸.

During the injection period the pressure may increase in the zone of injection. This is considered as the period of highest leakage risk. After injection has stopped, the risk of leakage decreases. Leakage can occur through undetected faults, fractures or through wells. Leakage routes can be identified by simulation of the subsurface and by characterization of the reservoir prior to injection.

Monitoring

Monitoring is like the speed meter in your car. It tells you whether you are driving within the speed limits considered as safe. Your safety while driving is influenced by the design and maintenance of the car itself, road conditions, how fast you drive and whether you use your seat belt.

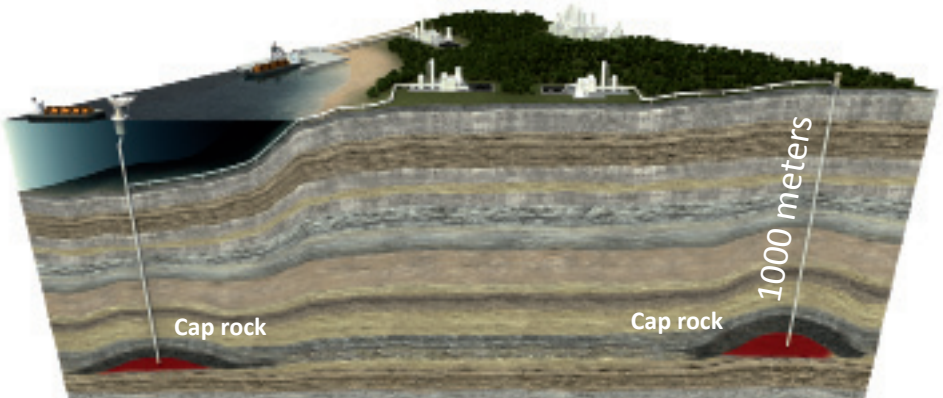
In the same manner the behaviour of CO₂ underground is influenced by similar factors and we can use monitoring techniques to overlook the injection procedure.

We can not directly observe what is going on kilometers below the Earth's surface. So specialists address this reality by creating

computer models that seek to visualize what cannot be seen. These models present us with expected behaviours of CO₂ underground. The modelled behaviour is subsequently compared to observations made in the injection wells and by surveillance equipment (seismic, gravity, electromagnetic or satellite data).

The monitoring aims to detect potential leakages before they reach the surface.

And even if there was a 1 percent leakage over thousands and millions of years, it is still better than the alternative, - which today is "100 percent" leakage into the air.



⁷ Best Practice manual, Holloway S., Chadwick A., Lindeberg E., Czernichowski-Lauriol I. and Arts R. (eds.), 2004, Saline Aquifer CO₂ Storage Project (SACS), 53 pp.

⁸ "Carbon Dioxide Capture and Storage", The Intergovernmental Panel on Climate Change (IPCC), 2005. Cambridge University.

Cost of CCS

CCS is expensive and energy intensive. It is repeatedly stated that adding CCS to existing coal plants can lead to an increase in electricity prices, while at the same time reducing plant efficiency. Therefore clear incentives are needed for utility companies to invest in CCS.

This can be done, on the one hand, through the use of regulatory tools that make power and industrial plants without CCS less attractive (e.g. through carbon cap and trade schemes, carbon taxes or straight regulatory bans on conventional plants without CCS).

On the other hand, incentives such as public subsidies must also be provided. This has been done in Australia, US and Europe to co-finance large-scale CCS demonstration projects.

A strong regulatory incentive reduces the need for subsidies. It is no coincidence that one of the most advanced CCS projects, in Bakersfield, California, is being built in a US state where conventional coal-fired power plants have effectively been banned by putting a limit on the amount of CO₂ that can be emitted per kilowatt-hour electricity produced (a CO₂ Emission Performance Standard).

A McKinsey/Vattenfall report (2008)⁹ estimated a global CCS potential of 3.6 Gt/year (0.4 Gt/year in Europe). In their reference case CCS costs at new coal power installations could come down to around 30-45 € per tonne of CO₂ abated in 2030 - which is in line with expected carbon prices in that period. Early demonstration projects will typically have a significantly higher cost - 60-90 € per tonne.

Bellona will not endorse public funding of CCS that comes at the expense of public funding for renewable energy or energy efficiency.

Fortunately, there is no evidence that this is happening. Instead, when public funding for research and development of one energy source increases, public funding for other energy sources also tends to increase¹⁰.

Funding must now increase at a phenomenal pace to make the low-carbon technological revolution come true. It will not be “either or” but “everything at once”.

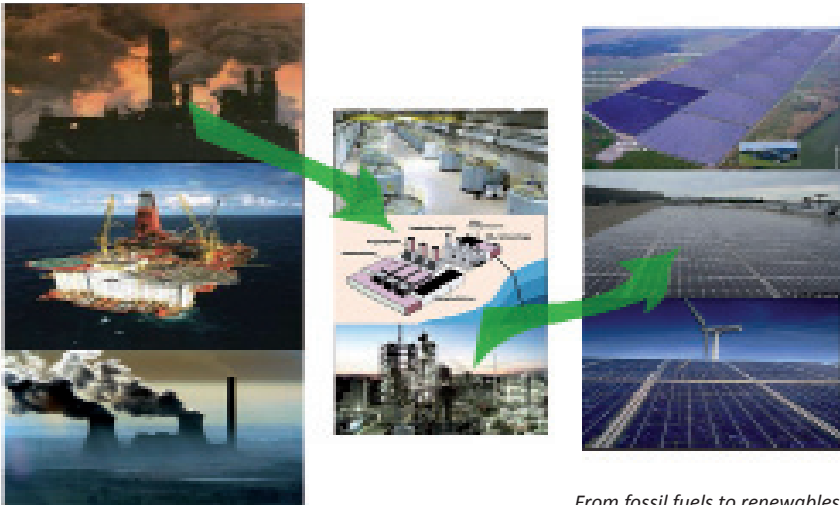
⁹ Carbon Capture & Storage: Assessing the Economics, 2008, McKinsey&Company

¹⁰ IEA (International Energy Agency) 2006 database over public R&D funding for energy

Regulation and liability

Financing and investments in CCS should reflect the amount of time that we expect to use CCS. Industry is not going to take the risk of investing in CCS unless the distribution of responsibilities and liabilities is clarified.

Preparation and adaption of required regulations and liabilities must be prioritized by local governments in order to meet the CCS deployment timeline for demonstration and full-scale CCS plants.



From fossil fuels to renewables

The lower estimate by the UN IPCC of safe storage capacity is about 1,700 Gt, while annual CO₂ emissions globally are about 30 Gt.

Bellona has estimated that 25 Gt of CO₂ can be captured and stored within the EU by 2050. The wide implementation of CCS can reduce CO₂ emissions by 54% in the EU and 33% globally by 2050 compared to emission levels today¹¹.

¹¹ "A model for the CO₂ capture potential", Stangeland, A., 2007, In: international journal of greenhouse gas control n1

The way forward

As world leaders gather at the United Nations Climate Change Conference in Copenhagen they need to develop a global policy framework that features:

- 1 A pledge to reduce emissions by 85 % by 2050, and a plan for how to achieve it. This essentially means setting a global cap on emissions and a schedule for tightening it.
- 2 A radical increase in public funding for developing and demonstrating new climate-friendly technologies like CCS. While the necessary technologies already exist, substantial efforts are needed to reduce costs and speed their implementation at large scale.
- 3 A change in market conditions to make it financially attractive to protect the climate. In essence, it means giving climate-friendly technologies an advantage by putting a price on emissions and making the polluter pay.



CCS and the UNFCCC negotiations

An ambitious Copenhagen agreement would do what Kyoto failed to do: address all the main emitters of GHG, outline a global program for emissions cuts, create financing plans for poorer countries to adapt to climate change, and finally, fund the additional costs of reducing emission growth rates in developing countries.

In the summer of 2008, G8 leaders - heads of state of the world's largest industrialized countries, made a commitment to limit global temperature increase to 2°C. Achieving this level of emission cuts will call for a tremendous effort, as it requires a full transformation into a zero emissions economy. This will only occur if we use a portfolio of solutions: an unprecedented focus on energy efficiency, massive deployment of a wide range of renewable energy technologies and accelerated deployment of CCS worldwide.

CCS is the new tool for combating global warming that was not available when the Kyoto Protocol was negotiated and signed in 1997. Today, utility companies, policy-makers, researchers, NGOs and the public at large are realizing that CCS can play a vital role in achieving the reductions in GHG emissions necessary to avoid dangerous global warming.

How can a new global climate treaty help speed up the deployment of CCS?

- There must be an incentive for developed countries (so-called Annex I countries) to help finance CCS projects in developing countries (non-Annex I countries). This can be done through a carbon credit mechanism whereby non-Annex I countries sell credits to Annex I countries for the verified avoidance of CO₂ emissions through CCS
- CCS credits will require a set of minimum international requirements to ensure CO₂ storage is safe and permanent
- The CCS demonstration projects now being built in Australia, North America, Europe and the Middle East, and financed in part by public money, should contribute to the speedy deployment of CCS also in other parts of the world. Governments subsidizing domestic CCS projects could pledge, under a global climate treaty, to require recipients to commit to specific roll-out roadmaps for their technologies, including differentiated pricing between developed and developing countries. In case of non-compliance by subsidy recipients, claw-back clauses for the subsidies or compulsory licensing of patents would be applied

The technological solutions already exist; the challenge is to make the policy framework and industrial decision-making process more efficient.

WHAT DO YOU WANT TO KNOW ?

Is underground CO₂ storage safe ?

What are the different opinions on CCS ?

Are there any projects close to where I live ?

Can CCS be made mandatory ?

FIND THE ANSWER AT BELLONA.ORG/CCS

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