The Economics of CCS

Tunç Durmaz, PhD

April 3, 2020

Presentation plan

What is CCS?

- Methods for capturing CO_2

Why CCS is important?

Economic drivers of CCS - a basic approach

What is CCS?

- CCS is a technology that comprises the separation of CO_2 from industrial- and energy-related activities and the transportation to storage locations such as saline aquifers and depleted oil and gas reservoirs
- Its main goal in this regard is to prevent CO_2 emissions from entering the atmosphere.

- CCS can be used by large stationary point sources such as fossil fuel-fired power plants and emission-intensive industrial facilities.
- The rates of carbon captured can be as high as 85–95%.
- There are three methods for capturing CO_2.
  1. *Post-combustion* carbon capture
  2. *Pre-combustion* carbon capture
  3. *Oxy-fuel combustion process*

Methods for capturing CO_2

- *Post-combustion* carbon capture removes carbon from coal fired power generation or natural gas combined cycles after combustion. Here, CO_2 is separated from the flue gases using a liquid solvent.

Post-combustion carbon capture)

Burning of coal

Post-combustion carbon capture

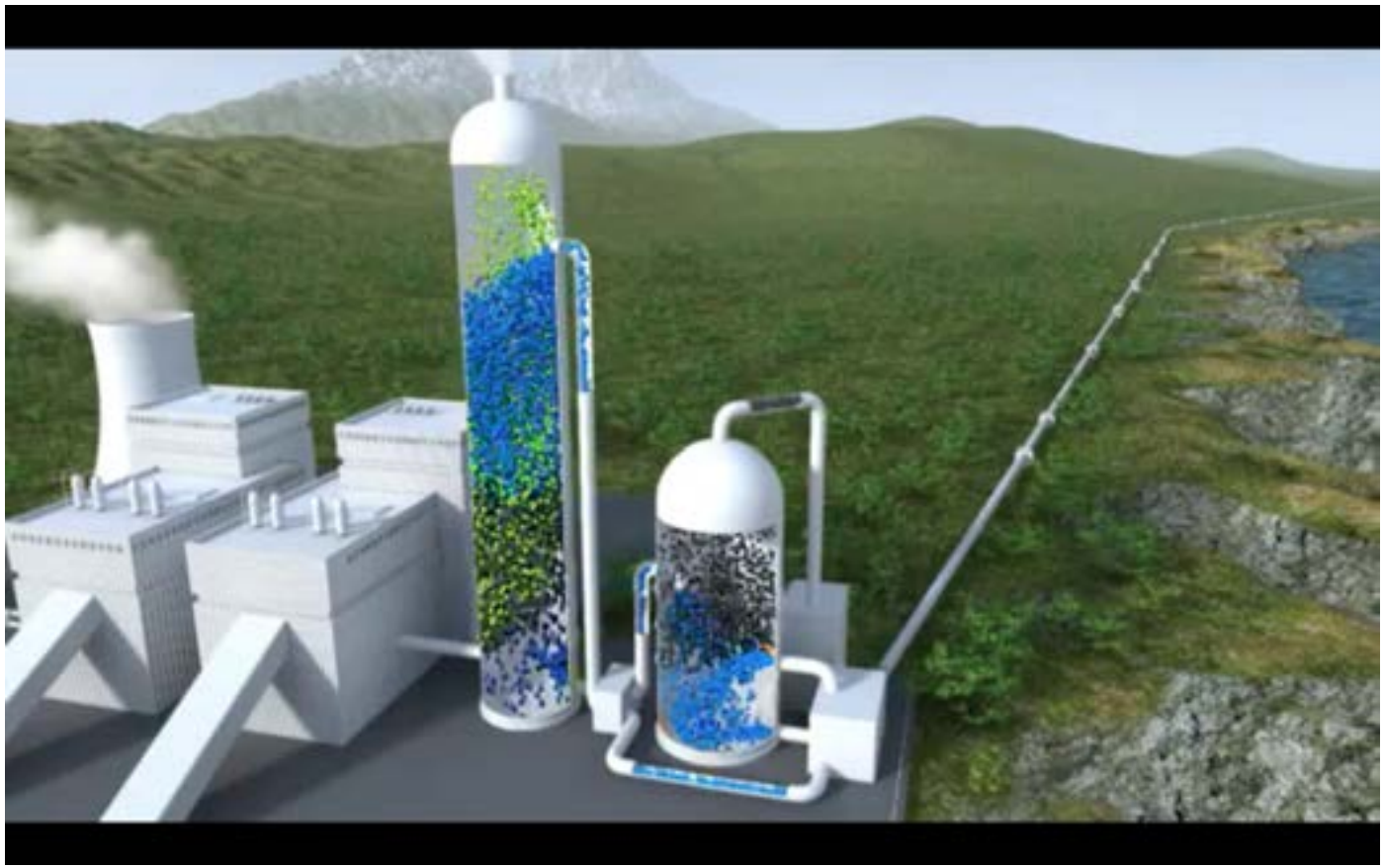
CO_2 emissions upon combustion

Post-combustion carbon capture

Emissions can be eliminated by implementing CCS

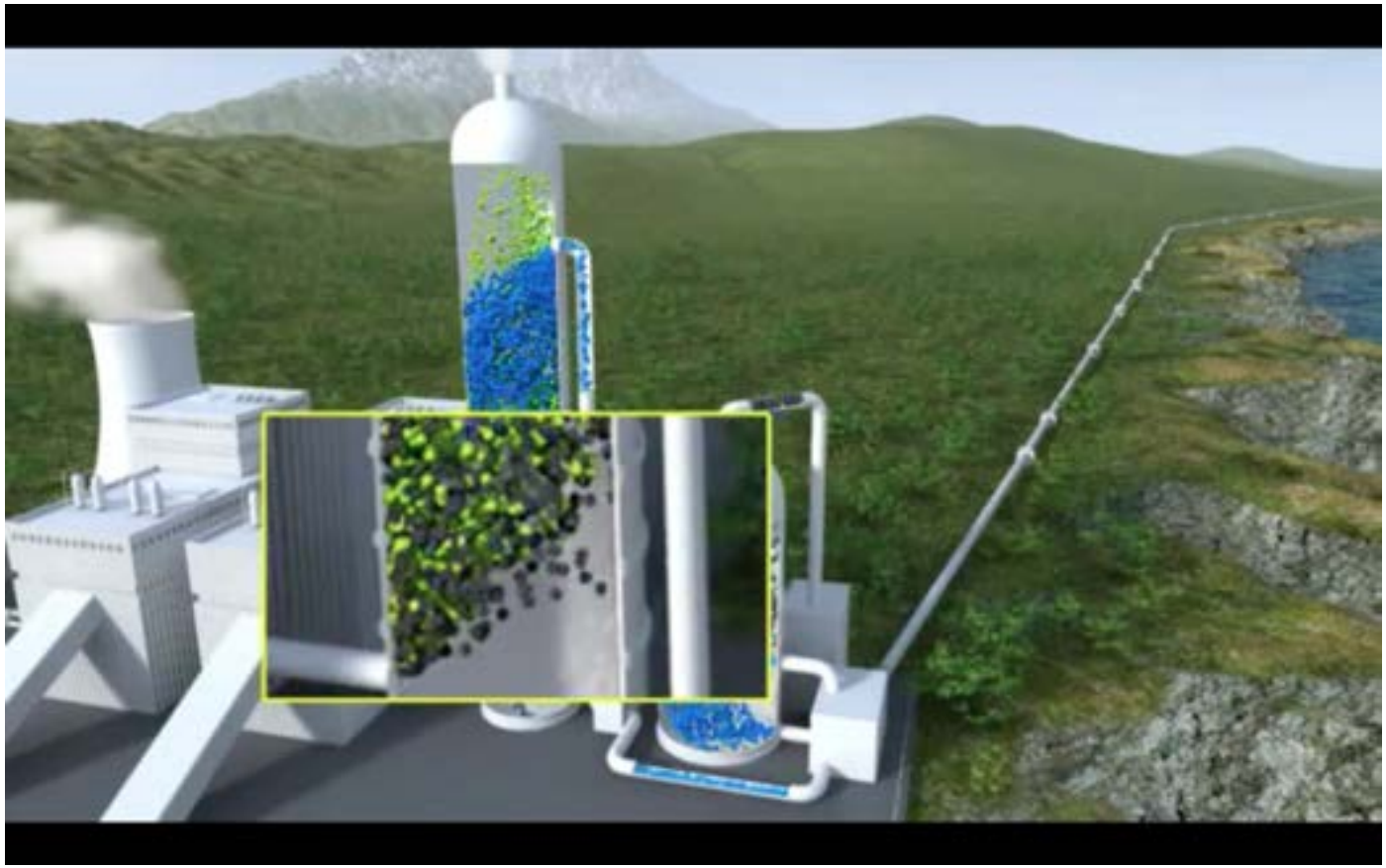
Post-combustion carbon capture

The cleaning system: the flue gas enters the first tank of the CO_2 capture plant.



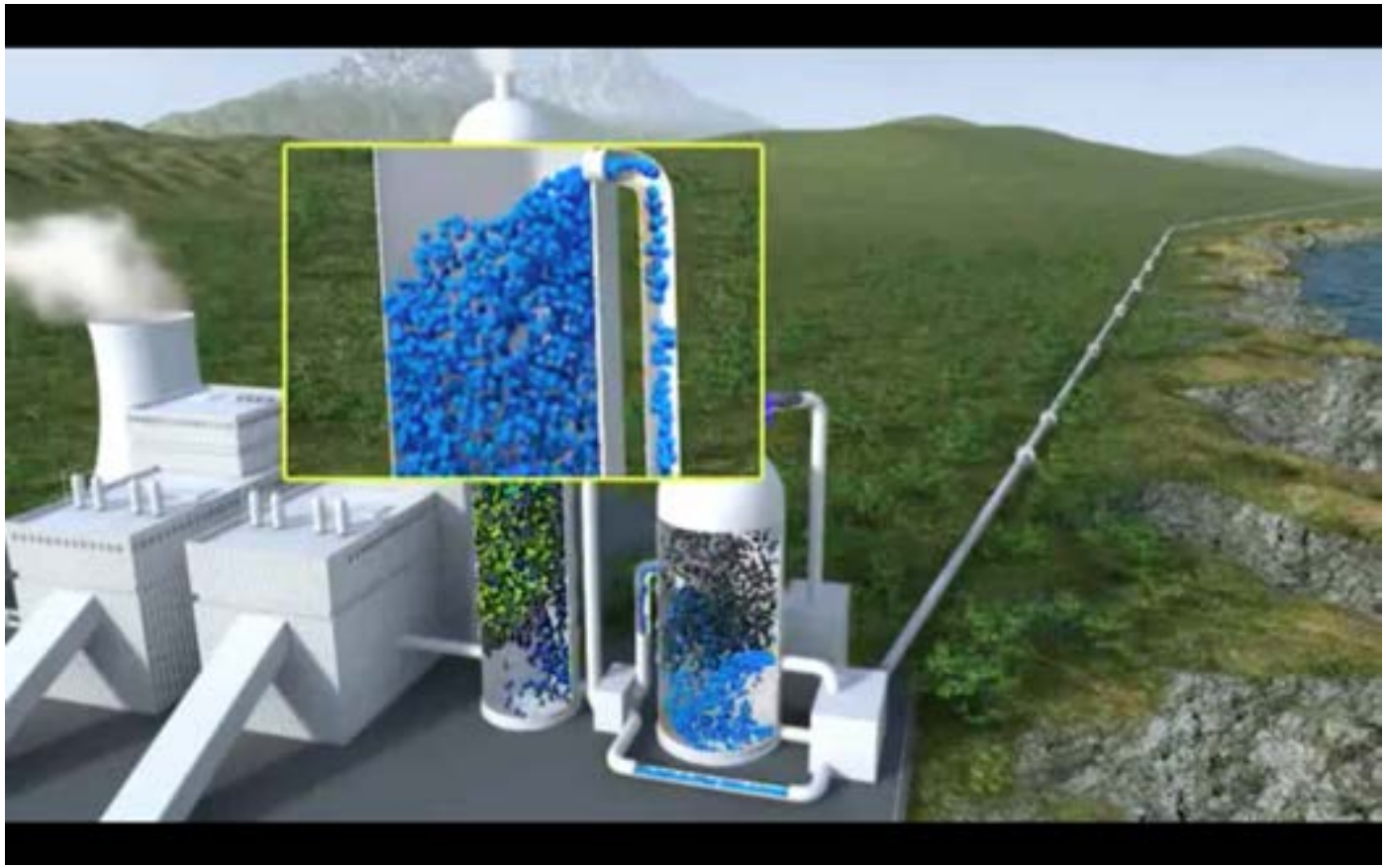
Post-combustion carbon capture

It mainly consists of CO_2 (black particles), nitrogen and water vapor (green particles).



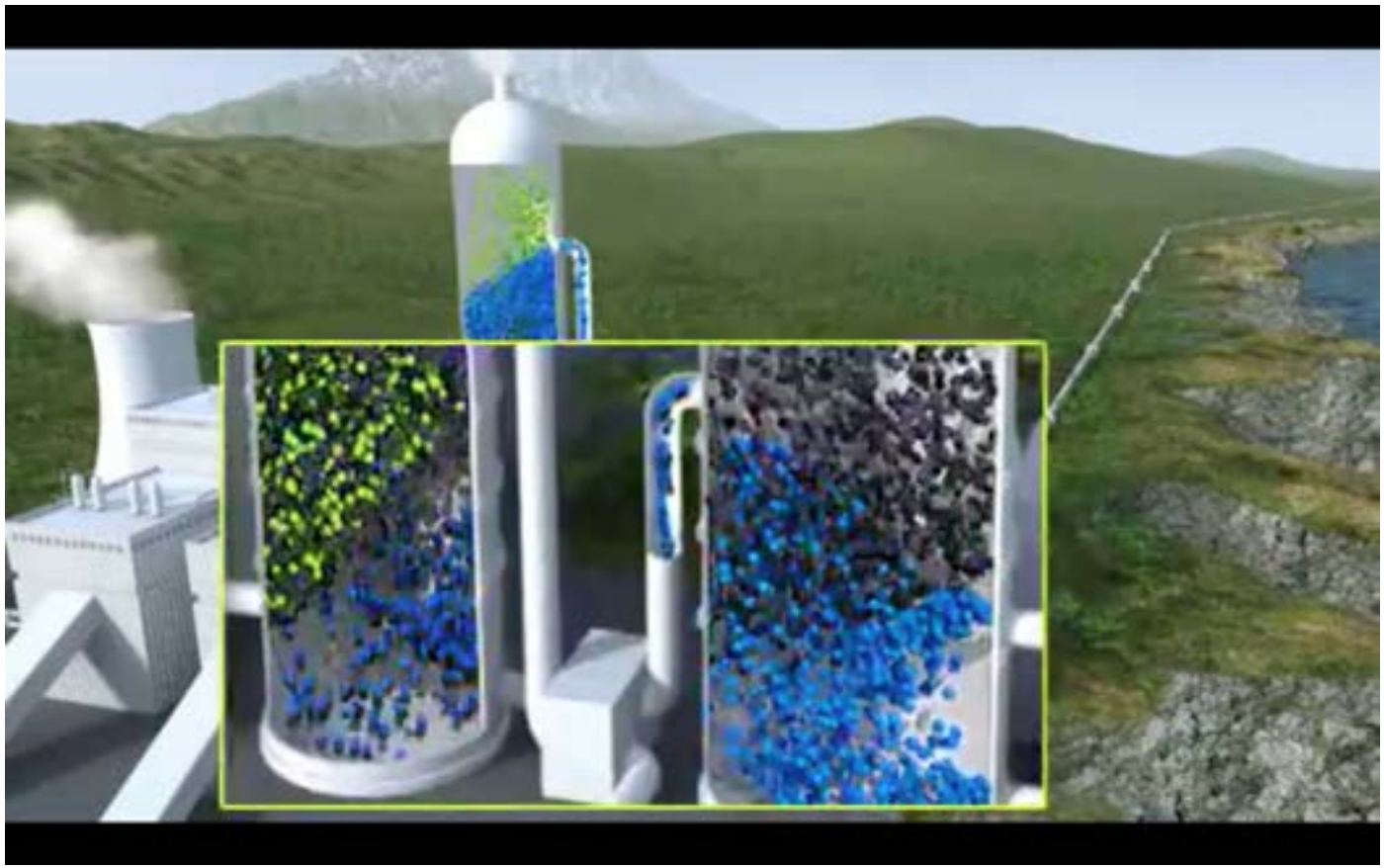
Post-combustion carbon capture

Blue particles entering the top of the capture plan are a chemical –also called solvent– that can react with CO_2



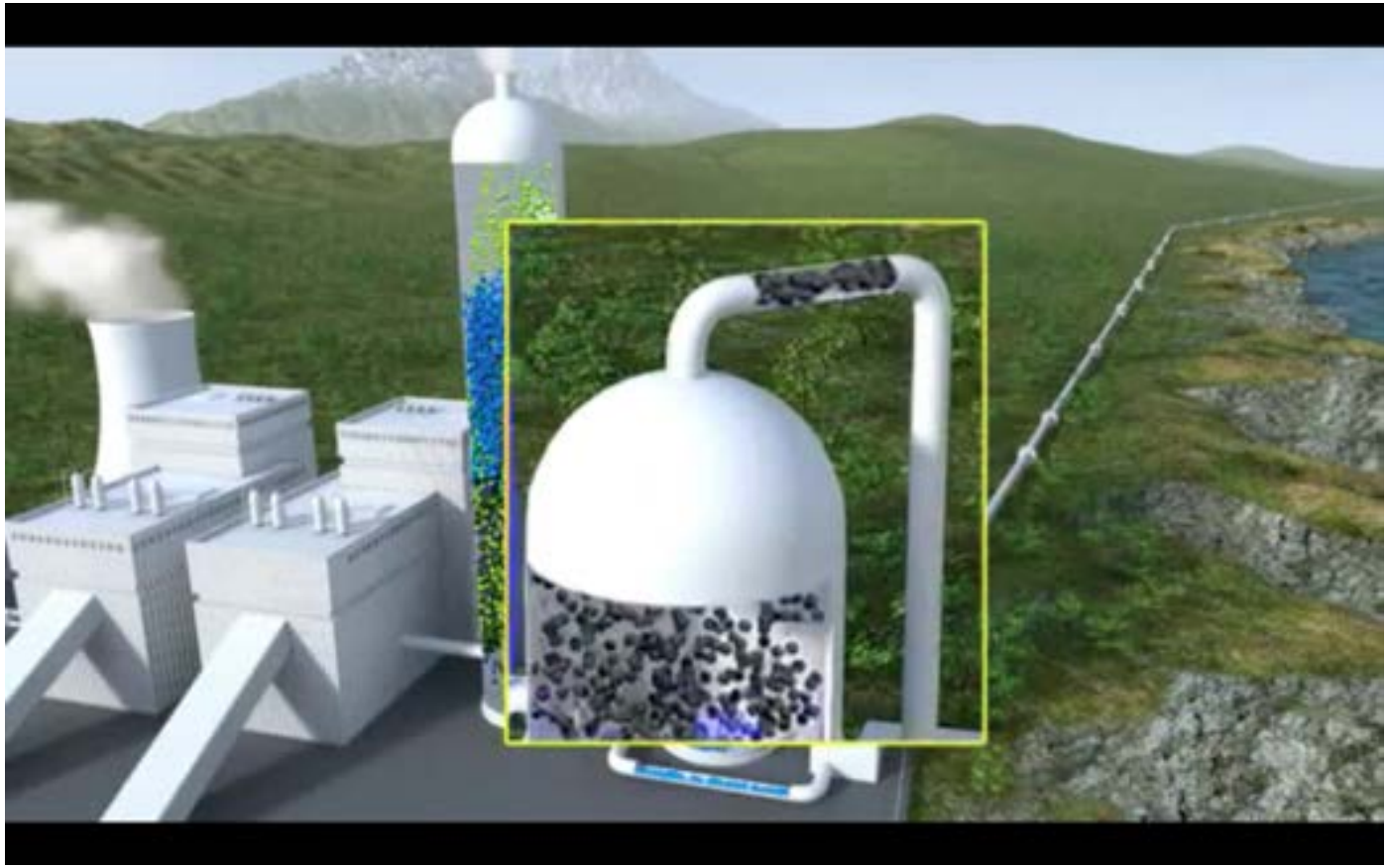
Post-combustion carbon capture

Once the solvent is reacted with CO_2, it leaves the first tank and is pumped in to the second tank



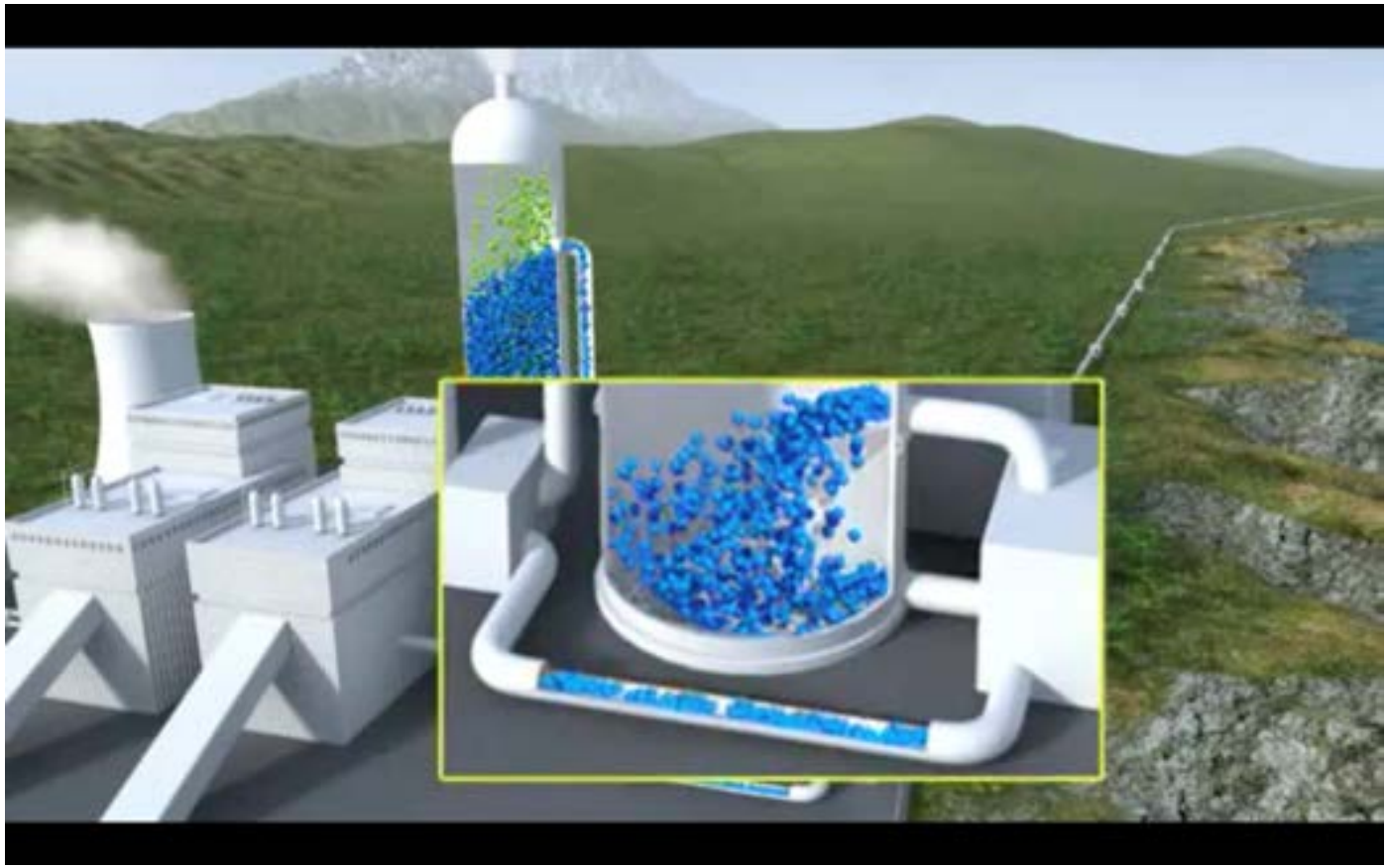
Post-combustion carbon capture

To separate CO_2 from the solvent, the solvent is heated (*requires a lot of energy*).
This process produces a gas stream of CO_2 and...



Post-combustion carbon capture

...a liquid stream of pure solvent

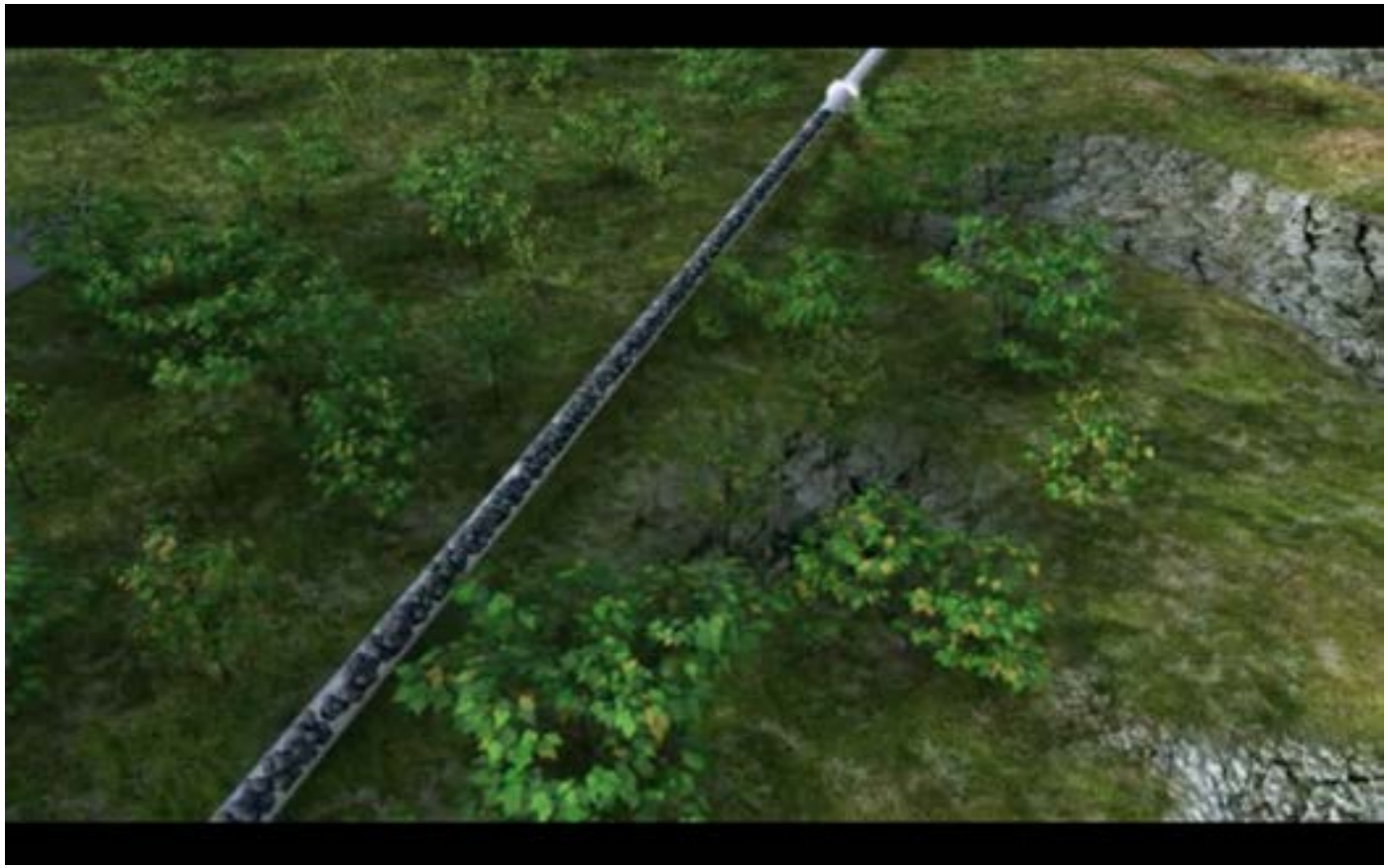


Post-combustion carbon capture

Pure CO_2 leaves the top of the tank...

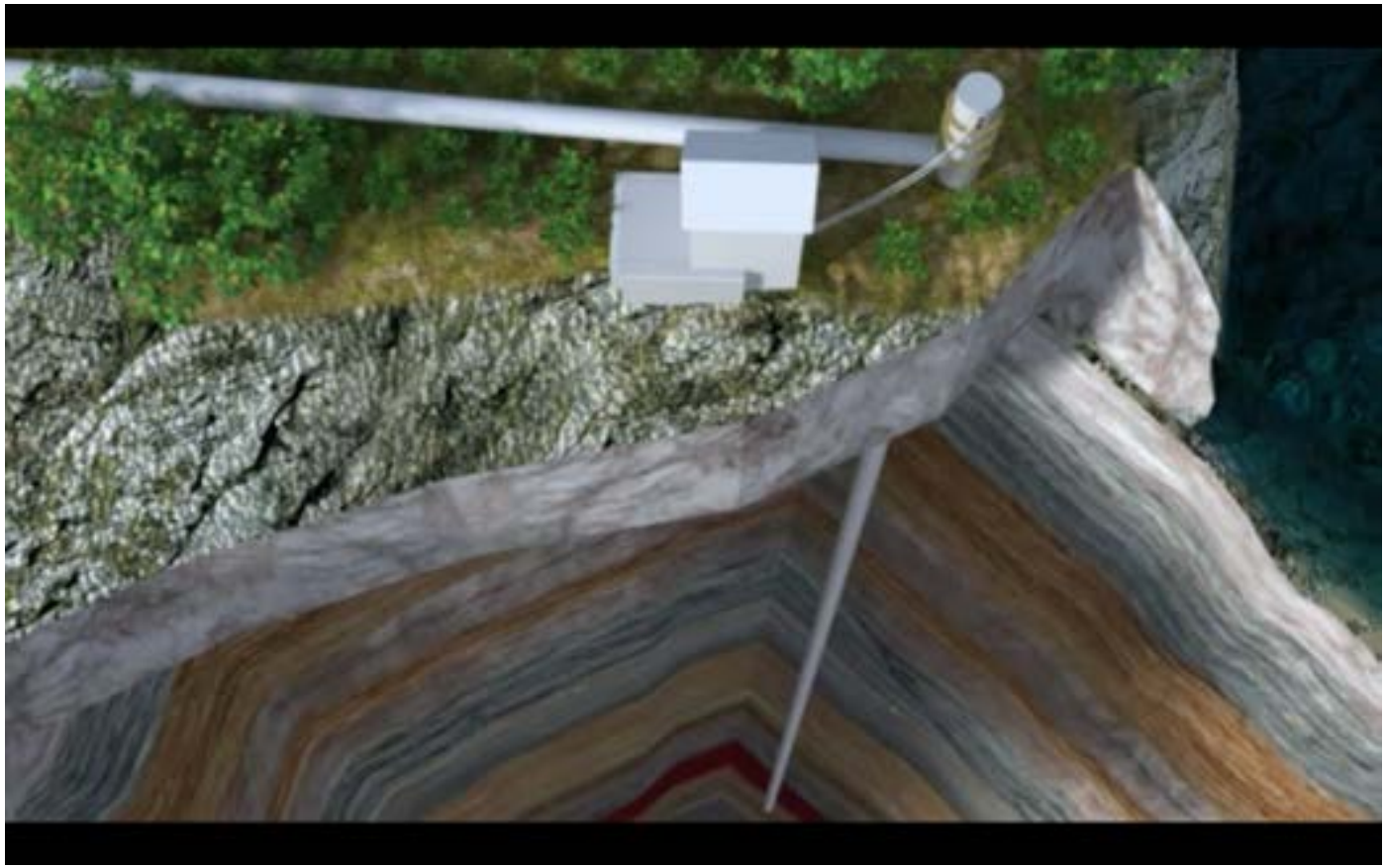
Post-combustion carbon capture

...is compressed and transported, ...



Post-combustion carbon capture

...and injected to convenient storage locations such as porous rock formations.



Methods for capturing CO_2

- In *pre-combustion* carbon capture, fuel is pretreated and converted into a mix of CO_2 and hydrogen. The hydrogen is then separated from the carbon before being burned to produce electricity.
- In the *oxy-fuel combustion process*, the fuel is burned using oxygen rather than air. The result is a flue stream of CO_2 and water vapour. Because no nitrogen is present, CO_2 can be easily removed

Cost estimates for CO_2 avoided:

- Post-combustion CO_2 capture from coal-fired power generation using amines (58 USD_{2010}/tCO_2)
- Pre-combustion CO_2 capture from integrated gasification combined cycles (43 USD_{2010}/tCO_2)
- Oxy-combustion CO_2 capture from pulverized coal power generation (52 USD_{2010}/tCO_2)
- Post-combustion CO_2 capture from natural gas combined cycles (80 USD_{2010}/tCO_2)

Why CCS is important?

Greenhouse effect (GE)

- Earth's surface would be below the freezing point of water if it was not for the GE
  - GE is a process by which the solar energy that reaches the Earth's surface is radiated back and partially absorbed by the atmosphere, making the atmosphere and hence the earth's surface warmer (IPCC, 2007; Freund, 2013).
- GE originate from greenhouse gases (GHGs).
  - CO_2 is the primary GHG emitted through human activities
  - It has hundreds of years of atmospheric lifetime.
  - Thus, adding more of CO_2 to the atmosphere intensifies the GE and warms the Earth's climate.

- More than half of the observed increase in global average surface temperature caused by the anthropogenic increase in GHG concentrations (IPCC).
- Rising global temperatures, which change the Earth's climate, has already started to take its toll
  - retreat of glaciers
  - increased surface melting of the Greenland ice sheet
  - global mean sea level rise
  - extreme weather events such as higher incidences of heat waves / destructive storms / changes to rainfall patterns.
- Unless GHG emissions decrease substantially, there will be further warming, long-lasting changes in all components of the climate system, and severe, pervasive and irreversible impacts for people and ecosystems (IPCC, 2014).

- Yet, the share of fossil fuels within the world energy supply is relatively unchanged over the past 40 years.
- These fuels still supply over 80% of all primary energy needs and will remain the dominant source of energy for the decades to come (IEA, 2013).
- Current trend in CO_2 emissions from fossil fuel combustion. Source: IEA (2014).

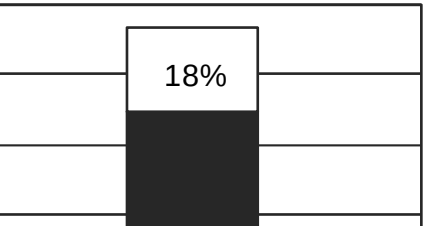
COMBUSTION *Highlights* (2014 Edition)

resulting from the oxi-
ring combustion domi-

about three quarters of
ions for Annex I coun-
al emissions. This per-
ountry, due to diverse

comes from worldwide
ment. Global total pri-
more than doubled be-
relying on fossil fuels

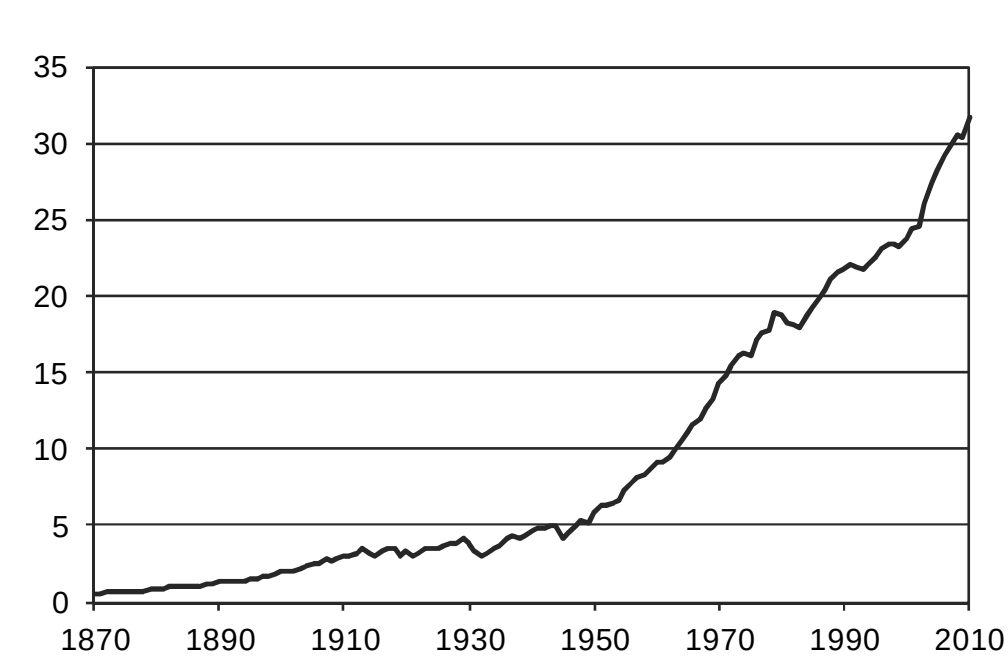
y energy supply*



the share of fossil fuels within the world energy supply is relatively unchanged over the past 41 years. In 2012, fossil sources accounted for 82% of the global TPES.

^{3} 1 mtoe

Figure 3. Trend in CO_2 emissions from fossil fuel combustion



Source: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge

- Current trend of the CO_2 emissions and the dominant role that fossil fuels maintain can prove disastrous for future generations unless.
- Given that fossil fuels will continue to supply a major share of energy needs, CCS appears to be the only technology that can substantially reduce CO_2 emissions.

Important role envisioned for CCS

- Several international and intergovernmental agencies, including IEA, IPCC, EIA, envision an important role for CCS and recommend its use in order to achieve the environmental goals.
- To bring down GHG emissions to 50% of their 2005 level by 2050, IEA (2008) shows that about 20% of the reductions should come from CCS activities.

- IEA Energy Technology Perspectives (2012)
  - Under the 2DS, CCS contributes one-sixth of CO_2 emission reductions required in 2050, and 14% of the cumulative emissions reductions between 2015 and 2050 (compared to 6DS)

- Yet, the progress in CCS is slow and far below than what is required to limit the global temperature rise to 2°C (IEA, 2013).
- The technology still absent in a number of key industrial sectors (iron, steel, cement...)
- Even though CCS is a key (carbon intensive) technology,
  - what can be the reason for these technologies not to have had an international breakthrough?

Economic drivers of CCS - a basic approach

Bibliography

Freund, P. (2013). Anthropogenic climate change and the role of CO_2 capture and storage (CCS). In Gluyas, J. and Mathias, S., editors, *Geological Storage of Carbon Dioxide (CO_2)*, chapter 1. Woodhead Publishing, Oxford.

IEA (2008). Energy Technology Perspectives 2008 - Scenarios and Strategies to 2050. Technical report, International Energy Agency.

IEA (2013). Technology Roadmap: Carbon Capture and Storage. Technical report, International Energy Agency.

IEA (2014). CO_2 Emissions from Fuel Combustion - Highlights. Technical report, International Energy Agency.

IPCC (2007). *Climate Change 2007: Mitigation*. Fisher, B.S., N. Nakicenovic, K. Alfsen, J. Corfee Morlot, F. de la Chesnaye, J.-Ch. Hourcade, K. Jiang, M. Kainuma, E. La Rovere, A. Matysek, A. Rana, K. Riahi, R. Richels, S. Rose, D. van Vuuren, R. Warren, 2007: Issues related to mitigation in the long term context, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the

Inter-governmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Technical report, IPCC.