"Leave the coal in the hole, leave the oil in the soil, leave the tar sand in the land"
Nnimmo Bassey, Friends of the Earth International, 2009

Carbon Capture and Storage – Not a Bridging Technology

1. Abstract

Carbon Capture and Storage (CCS) cannot deliver the reductions in CO_2 emissions that the industry and other proponents have promised. The atmosphere will receive 75–90% of the cumulated emissions from 2010-2049 from industries where CCS could be applied.

It is unlikely that CCS can result in more than 10-25% avoided emissions of the overall emissions from 2010-2050 from the power plants and industries where it can be applied. That is the message in this paper by NOAH Friends of the Earth Denmark.

If the world shall avoid catastrophic climate change then the available global carbon budget[1] is so small that emissions must peak before 2015. From there they must decline rapidly. The overall budget 2010-2049 is assessed to be 926 $GtCO_2$.

Carbon Capture and Storage – CCS - cannot fit in such a scenario because it could not be deployed early enough and because the cumulated emissions consequently will be too large over the next four decades.

Apart from that the technologies in CCS are so energy ineffective that even when CCS is applied the emissions from e.g. a power plant will be too large.

CCS will at best be developed to be commercially by 2020. EU has set aside billions of Euros in funding from its Emissions Trading Scheme towards 12 large scale demonstration projects in the coming years.

[1] The 'carbon budget' is a way to express the amount of CO_2 and other greenhouse gases that the World (or a country) can emit within a certain time frame.

CCS will first of all lock-in the energy supply systems with an outdated type of power generation, namely coal. If CCS-systems are retrofitted to existing power plants they can take turns becoming obsolescent thus prolonging the coal age indefinitely.

Embarking on the extremely expensive CCS-pathway would result in spending not only a huge amount of money on a very limited gain for the climate but more crucially it will spend costly time at a moment in history where the right decisions can not be taken too soon.

2. Main findings

CCS can not be called a bridging technology[2] connecting a black fossil present with a bright green future, nor can it be labelled a technology for *adequate* emissions reductions.

In a *business as usual* scenario with increasing CO2-emissions CCS will result in only **9,72-25,01% avoided emissions from 2010 to 2049** – dependent on factors like rate and speed of deployment of CCS, the size of the energy penalty and the net efficiency in plants with CCS.

In other words: **the atmosphere will receive 75-90% of the cumulative emissions from 2010 to 2049 despite the application of CCS.**

In a scenario with *decreasing* CO2-emissions, CCS will result in an even smaller proportion of avoided emissions, namely **16.63%** (Scenario 4) compared to 25.01% (Scenario 3)

3. Defining the problem

In order to properly assess CCS as a mitigation technology over the next decades it is necessary to include all the facilities that reasonably could be equipped with CCS and to look not only at a snapshot of "one facility" or of one year in the future (e.g. 2030, 2040 or 2050) but the whole film, i.e. the whole period from now and till 2050 for instance. (2050 is not an arbitrary year in this context as it is one of the most crucial milestones in the IPCC reports and most other reports dealing with mitigation of climate change).

Setting 2050 as the far end of the perspective is justifiable if the warnings from recent science is taken serious, e.g. Copenhagen Diagnosis (2009)[3] or Meinshausen et. al. (2009)[4].

<u>The budget approach</u>
It is necessary to look at the CO2-budgets or GHG-budgets, i.e. the atmospheric space available in the future for emitting greenhouse gases.

> **"Latest research shows that there is only a realistic chance of restricting global warming to 2 °C if a limit is set on the total amount of CO_2 emitted globally between now and 2050 (CO_2 global budget)."[5]**

None of the CCS reports has to date given an assessment of how much large scale deployment of CCS would influence the remaining CO2 budgets for the decisive next four decades.

The question for this study is therefore:

<u>How much could a large scale deployment of CCS contribute to the avoiding the release of greenhouse gases to the atmosphere seen in the perspective of the constrained budget?</u>

[2] CCS is actually not one technology, but rather a set of combined technologies. For simplicity it is here labelled as one technology.
[3] The Copenhagen Diagnosis, 2009: Updating the World on Latest Climate Science e.g. Figure 22.
4 Nature, vol. 458, April 2009, e.g. Table 1.
5 WBGU, Solving the climate dilemma: The budget approach. Special Report. Berlin 2009. See figure next page.

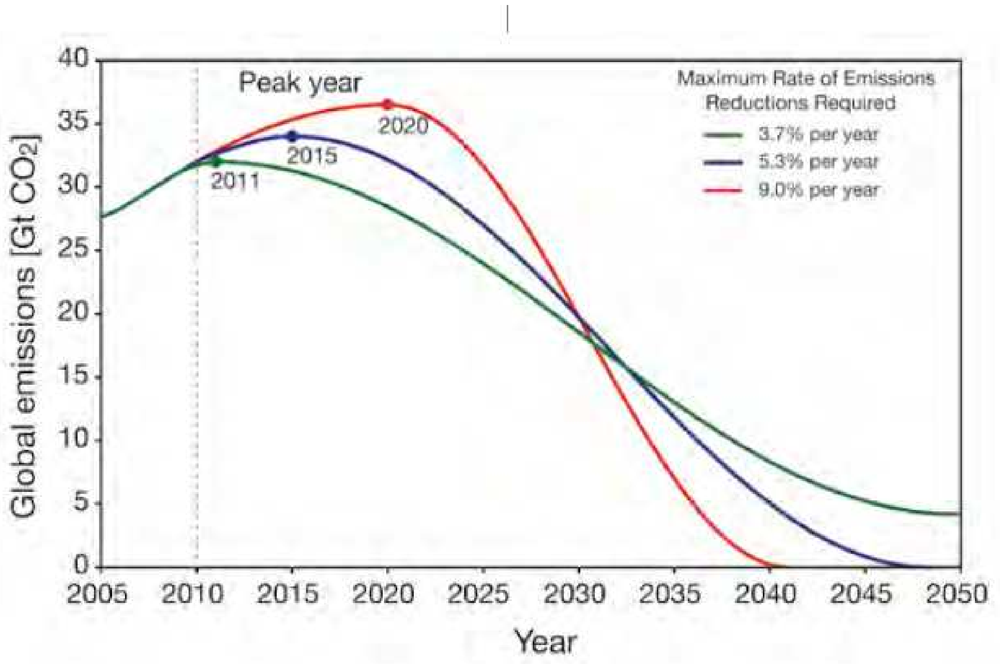

Figure [22]. Examples of global emission pathways where cumulative CO2 emissions equal 750 Gt during the time period 2010-2050 (1 Gt CO2 = 3.67 Gt C). At this level, there is a 67% probability of limiting global warming to a maximum of 2^{o} C. The graph shows that the later the peak in emissions is reached, the steeper their subsequent reduction has to be. The figure shows variants of a global emissions scenario with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, maximum annual reductiona rates of 3.7% (green), 5.3% (blue); or 9.0% (red) would be required (relative to 2008). (Source: German Advisory Council on Global Change; WBGU 2009)

4. How to calculate the avoided emissions system globally and across the system?

The following parameters should be worked into a comprehensive model:

1. The speed and rate of deployment of CCS.[6]
2. The capture efficiency (theoretically often quoted as 85%)
3. The energy penalty[7]
4. The CO2 efficiency[8]
5. The global emissions that might be abated by CCS, i.e. emissions from Large Point Sources.[9]
    a. For simplicity's sake our calculations focus on coal fired Power Plants only.

[6] The rate of deployment of CCS will be defined by factors like research and development, price and availability of raw materials, the general economy and the political regime. (When will the technologies be mature enough to go from demo projects to full scale facilities? How fast can the planning and construction be – in the early stages and later on? How fast can the financing be put in place?)

[7] i.e. the extra fuel required to run the capture process, most often estimated to be 25-40%

[8] A debit and credit balance sheet must be established to account for - on the credit side: the emissions captured and on the debit side the emissions pertaining to: mining, transport of coal, building of CCS plant, building of infrastructure, capture process and compression of CO2, transport and injection, monitoring and leakages

9 "CCS is more than a strategy for "clean coal." CCS technology must also be adopted by biomass and gas power plants; in the fuel transformation and gas processing sectors; and in emissions-intensive industrial sectors like cement, iron and steel, chemicals, and pulp and paper." IEA Technology Roadmaps; Carbon capture and storage (2009)

A comprehensive model must calculate the avoided emissions as the difference between the CO2-emissions generated and the CO2-emissions captured 2010-2049 from all the point sources that are equipped with CCS during the period 2010-2049. The emissions generated must include the emissions pertaining to the energy penalty and the emissions from mining, transport of coal, building of CCS plant, building of infrastructure, the capture process and compression of CO2, transport and injection into the storage and finally monitoring of and leakages from the transport and the storage. In our scenarios we have made a ballpark assessment of these upstream and downstream emissions to be in the territory of 8-9%. It is rather too low than too high.

Credit	**Gt CO2**	**Debit**	**Gt CO2**
Cumulative emissions captured AND stored 2010-2049		Cumulative emissions from all the sources equipped with CCS in the period 2010-2049	
		Cumulative emissions from all the sources NOT equipped with CCS in the period 2010-2049	
		Upstream emissions 2010-2049 from:	
		Mining of coal	
		Transport of coal	
		Building of CCS-plants	
		Building of CCS pipelines	
		Capture process	
		Compression of CO2	
		Transport of fluid CO2	
		Downstream emissions 2010-2199 from:	
		Injection of fluid CO2	
		Monitoring of CO2-storage	
		Leakages	
SUM Credit		**SUM Debit**	
		Difference Debit - Credit	

This difference must then be deducted from the cumulative emissions in a baseline scenario without any CCS. The resulting figure is then the size of the avoided emissions due to CCS.

5. Presenting the results

Assumptions: figures 1 – 3

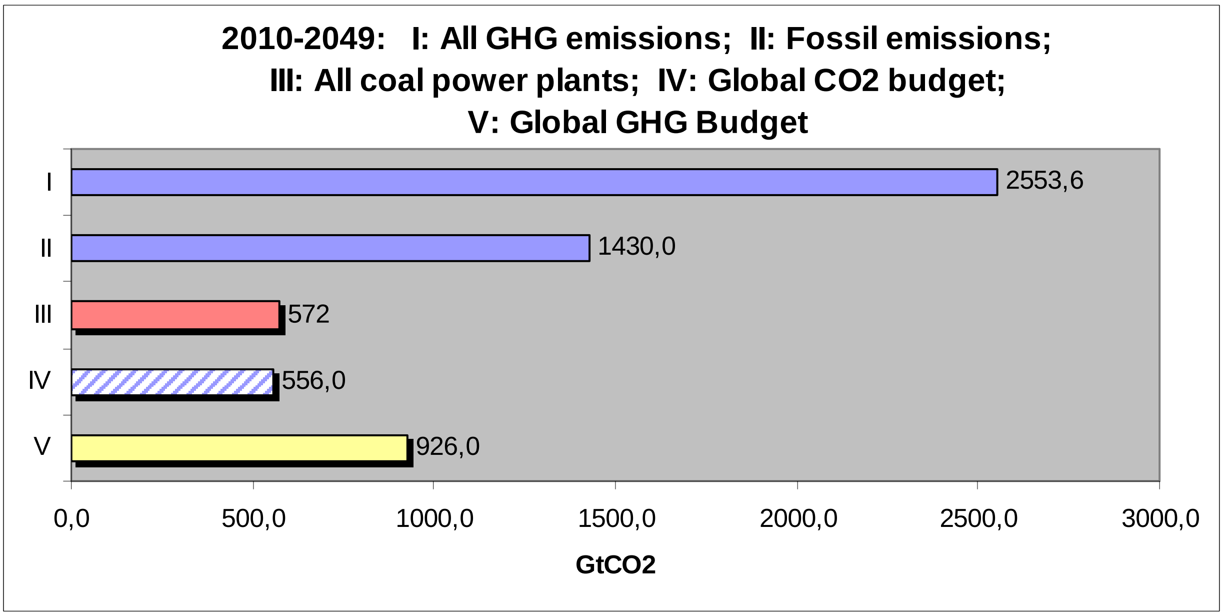

Figure 1
This figure illustrates the assumption in scenarios 1-3 about
I: the cumulative GHG emissions 2010-2049
II: the cumulative CO2-emissions from fossil fuels 2010-2049
III: the cumulative CO2-emissions from coal power plants 2010-2049
IV: the global CO2-budget 2010-2049
V: the global GHG-budget 2010-2049

[The global GHG budget is derived from Meinshausen et al., 2009]

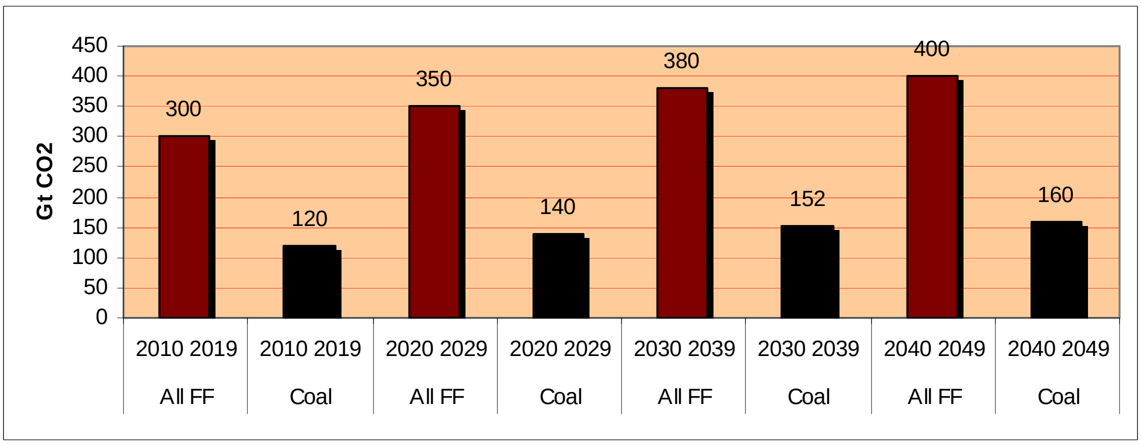

Figure 2
This figure presents the assumptions about the overall CO2-emissions from fossil fuel and coal respectively. They are projected to increase by a moderate 25% from the first till the last decade. This projection is used in the first 3 scenarios.

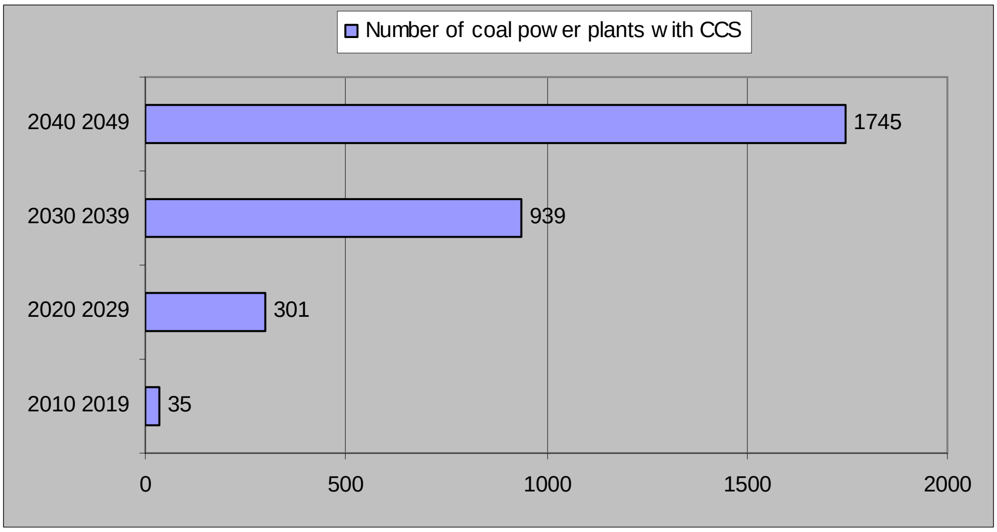

Figure 3
The number of power plants with CCS is projected to increase rapidly through the first two decades, nine-doubling from the first to the second decade, then tripling in the next and finally doubling in the last decade reaching a level of almost one third of all power plants which is a faster deployment than expected in the IEA CCS Roadmap (2009).
Total no. of power plants is assumed to be unchanged at 4942 for simplicity's sake.
(This is admittedly not a realistic assumption, but as it is the proportion of plants with CCS that influences the result it can pass.)

SCENARIOS 1 – 4

In the following Scenarios 1-4 the cumulated emissions 2010-2049 are calculated for

A) a baseline without any CCS,

and then in scenarios with deployment of CCS: cumulated emissions from

B) plants with CCS and

C) plants without CCS;

D) the total of these two,

and then

E) the net amount of captured CO2;

F) the cumulated emissions to the atmosphere

and finally

G) the avoided emissions (A – F).

SCENARIO 1

Cumulative emissions to the atmosphere 2010-2049 despite CCS: 90,3% (F)
Cumulative avoided emissions 2010-2049: 9,7% (G)

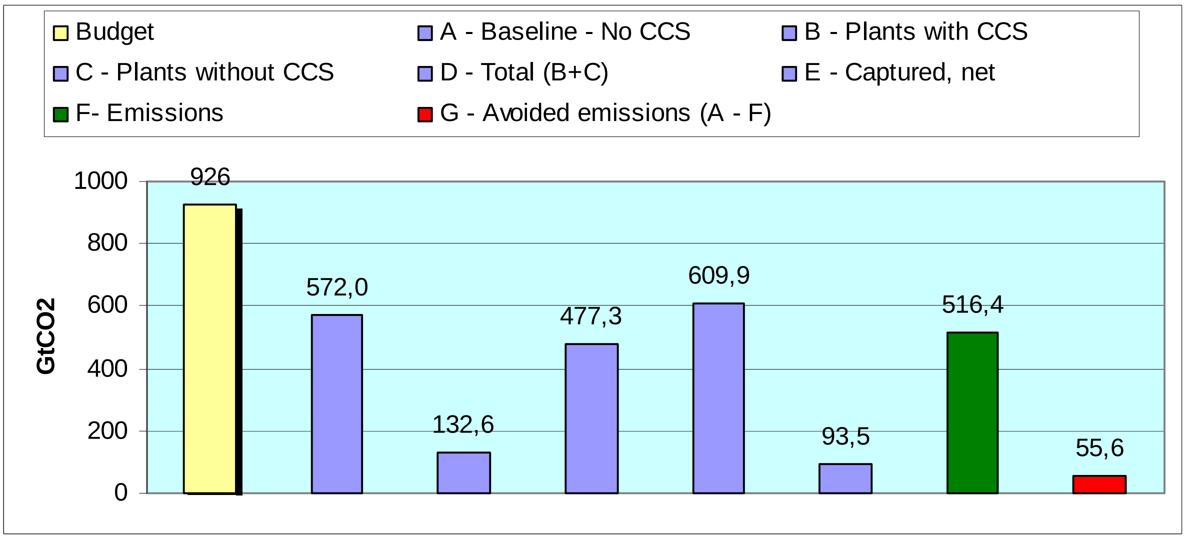

Figure 4
In this first scenario the assumptions are: Emissions as outlined in figure 2, number of point sources with CCS as in figure 3. Energy penalty: 40%. Capture efficiency: 70.6% net.
Deployment of CCS as in figure 3.

SCENARIO 2 – energy penalty reduced

Cumulative emissions to the atmosphere 2010-2049 despite CCS: 88,7% (F)
Cumulative avoided emissions 2010-2049: 11,3% (G)

The change in energy penalty has less influence on the final cumulative emissions to the atmosphere / cumulative avoided emissions than was expected.

The implication of this is that it is the rate and speed of deployment that really matters when it comes to the cumulative emissions whereas the energy penalty of course is significant on the single plant level.

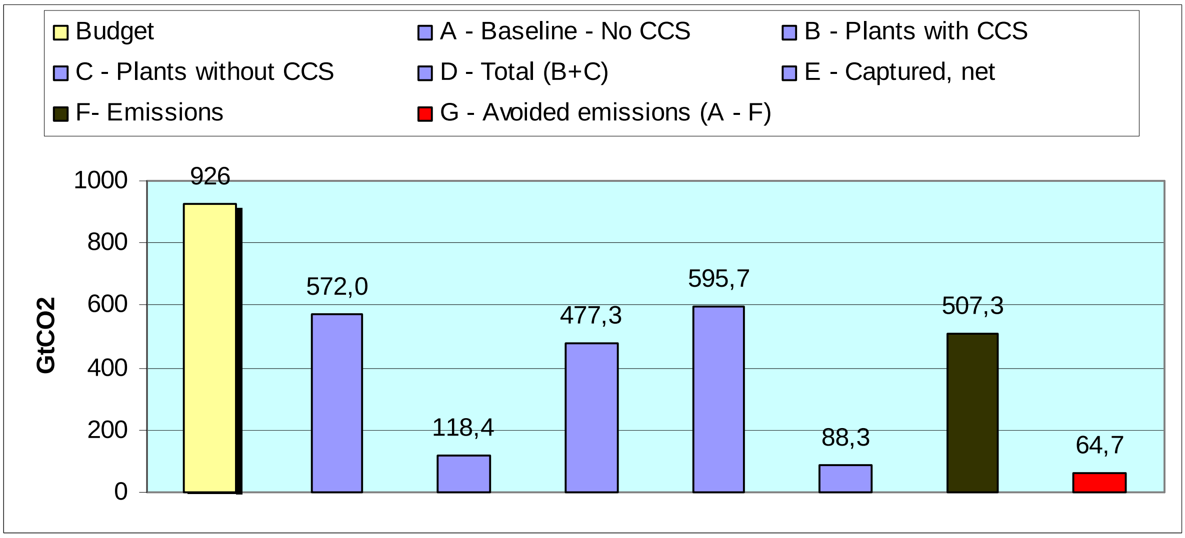

Figure 5
In this Scenario 2 energy penalty is reduced to 25%.
Capture efficiency is 74.6% net (as in Scenario 2, figure 5). Deployment rate of CCS is unchanged.

SCENARIO 3 – faster deployment

Cumulative emissions to the atmosphere 2010-2049 despite CCS: 75.0% (F)
Cumulative avoided emissions 2010-2049: 25.0% (G)

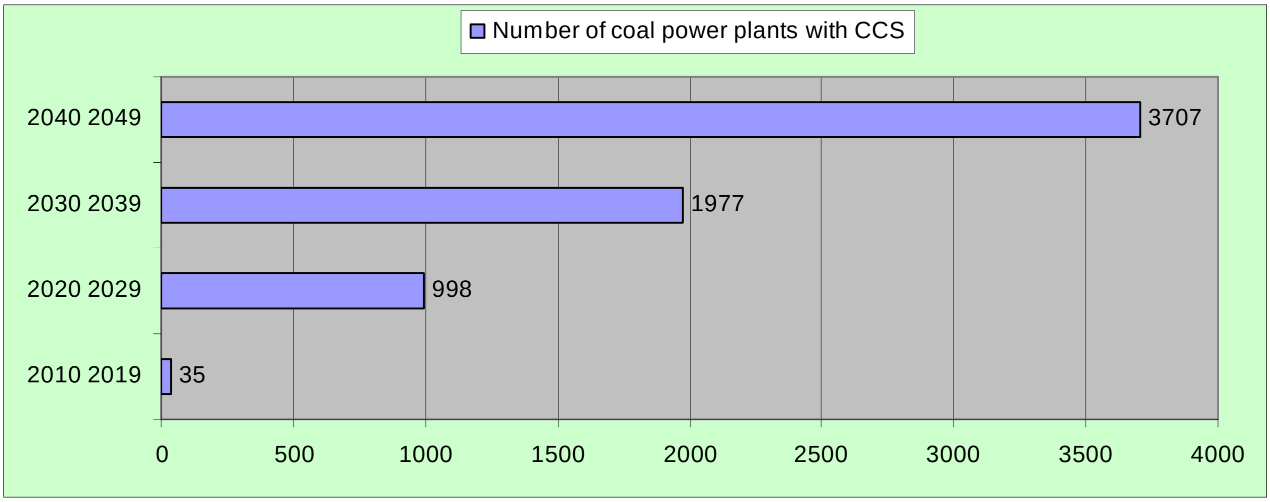

Figure 6
Deployment is projected to increase faster in scenario 3, totalling 75% in average in the last decade.

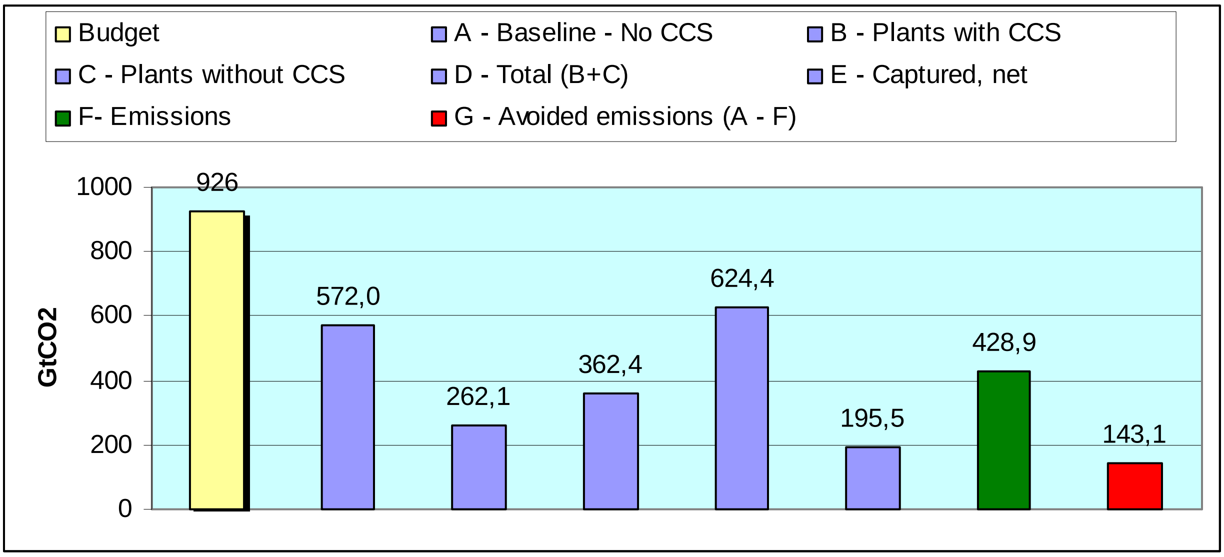

Figure 7
In this Scenario 3 Energy penalty is 25%. Capture efficiency is 74.6% net. (as in Scenario 2, figure 5)
Deployment rate of CCS is increased. (Figure 6)

SCENARIO 4 – Decreasing fossil emissions

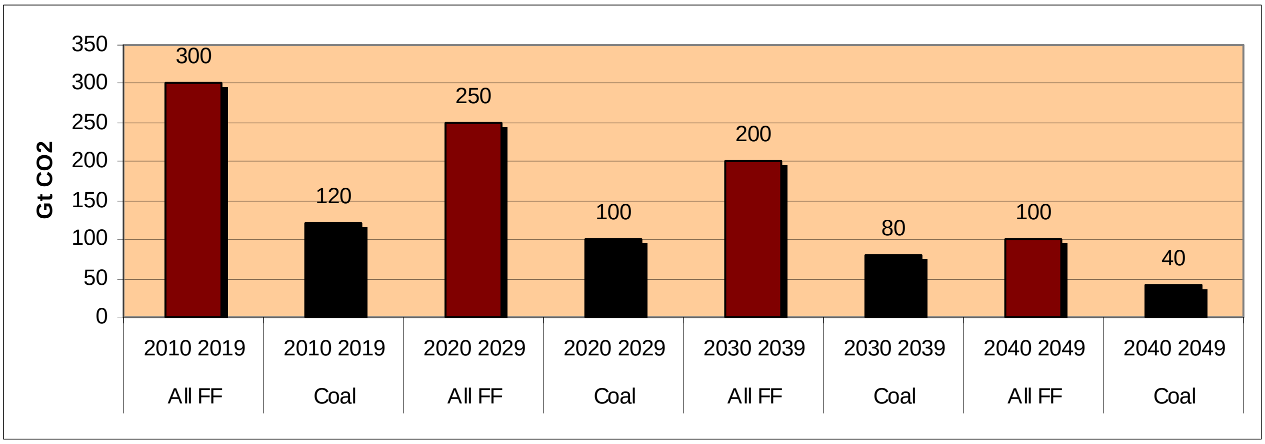

Figure 9
In Scenario 4 the assumption changes from a moderate increase in 2010-2049 emissions to a substantial decrease in emissions. It is very often stated that CCS will be only one of the instruments to mitigate emissions – so here is allowed for a development in energy efficiency plus large scale deployment of renewables substituting a considerable part of fossil fuelled plants.

All other assumptions as in Scenario 3, the very aggressive deployment of CCS (75% in 2040-2049)

The result is a decrease in the percentage of avoided emissions to 16.63% exactly due to the fact that emissions are decreasing while CCS-share is increasing.

Cumulative emissions to the atmosphere 2010-2049 despite CCS: 83.4% (F)
Cumulative avoided emissions 2010-2049: 16.6% (G)

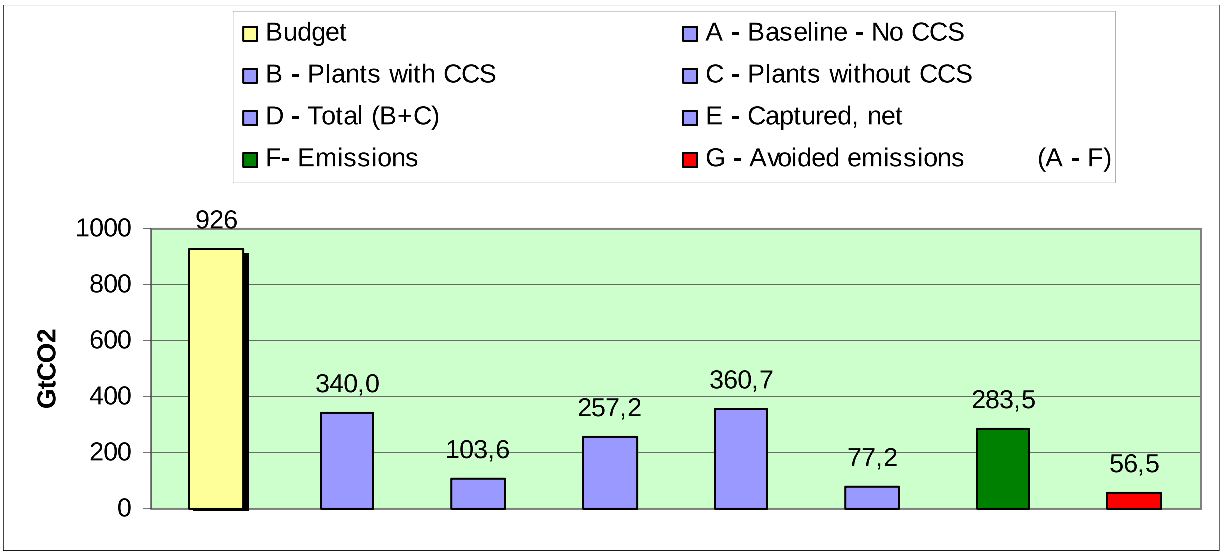

Figure 9
In this **Scenario 4** the assumptions are: Decreasing emissions 2010-49. Energy penalty 25%. Capture efficiency: 74.6% net. Deployment rate of CCS is as in Scenario 3. (Figure 7)

6. Challenging the CCS-lobby

Is it the role for a small environmental NGO with very limited resources to establish the possible value of CCS as a mitigation tool? Most would probably deny this.

It is very hard to understand why the calculations put forward in this paper – however lacking in precision they may be – have not been made by IEA, the International Energy Agency that has produced a large number of reports about CCS over the years.

The IPCC Special Report from 2005 – the only special report from IPCC devoted to a single technology – has not considered this very simple question either despite it should be as important as the chapters on the different technological options, the storage possibilities and the economic implications of a venture into a CCS-future.

The governments that are asked to bring financing towards the R&D and also take over the liabilities once storage in a site is finished could reasonably ask the question: what is the effect?

The Climate and Energy Package of the EU includes financing part of 12 demonstration projects and the EU has also issued a special CCS directive. But EU has not asked the question either: how much can CCS possibly contribute to avoiding emissions over the critical next four decades.

The intention of this paper is therefore to challenge the CCS-lobby – and others - to come forward and give their own estimates.

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NOAH's websites on CCS
http://ccs-info.org [In English]
http://ccs-info.dk [In Danish]

The ccs-info sites cover a whole range of issues such as: timing, environmental impacts, climate effects, economy, financing, liability, energy scenarios, CDM/JI.

Appendix

- CCS will not only mean a prolongation but even an increase in the use of coal of 25-40%, which in itself is linked up with serious social, health and environmental impacts.
- CCS applied world wide would require a transport infrastructure (pipe lines and ships) much larger than the present transport infrastructure for all commodities, which would drain the steel market severely and undoubtedly drive up the price of steel.
- CCS will require much more water per produced kWh, thus competing over a vital resource already in great demand. This especially disqualifies CCS as a technology to be applied at inland facilities in countries like China, India and US.
- CCS will require large scale public co-financing. There is no way it could be commercially viable to introduce CCS without this.
- The long time liability concerning the storage is an issue that is not solved. In the EU-directive it is suggested that the private operators can transfer the liability to the governments as soon as a storage site is sealed and closed.
- CCS will not work well together with an energy supply system with a large share of renewables since the costs of CCS would mean that the plants will be set to deliver base load at full steam, thus not cooperating well with the oscillating renewables like wind and solar.
- Last but not least: as CCS competes with renewables for R&D resources and capital, CCS will in itself prevent a rapid development of sustainable energy supply systems for an energy efficient future with reduced energy demands.