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CCS development and gas versus coal competition for power generation

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Background

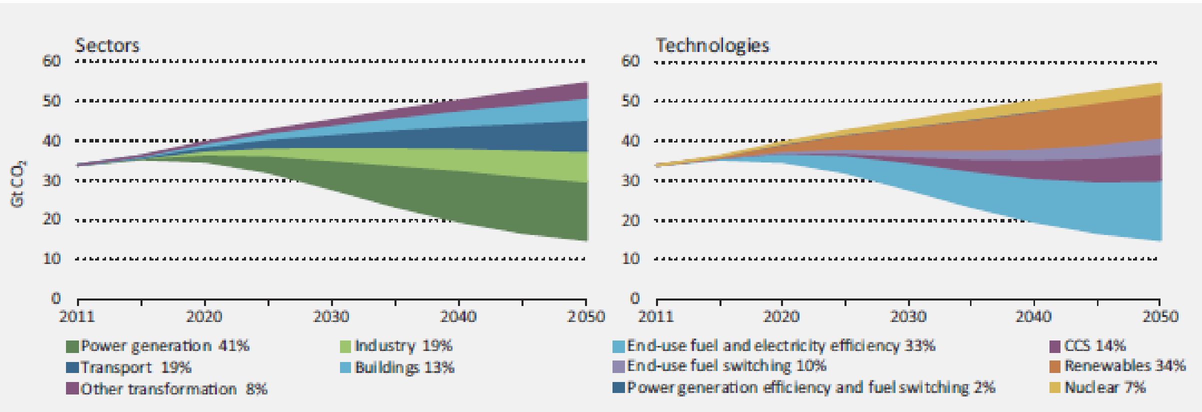
The expected contribution of Carbon Capture and Storage (CCS) to climate change mitigation, challenges, and the issue of CO_2 storage capacity.

IEA and IPCC views on the role of CCS in climate change mitigation.

Both the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) believe that CCS is bound to play a very significant part in the fight against climate change.

According to the IEA, CCS, through the implementation of a few thousand projects around the world, will account for 14% of the cumulative CO_2 emissions reductions needed by 2050 to stay below a 2°C increase in global temperatures. Around 40% of the CO_2 that will be captured and stored will be extracted from emissions from fossil power plants – mostly coal-fired power plants.

Contributions to annual emissions reductions to stay below a 2°C increase in global temperatures



Source IEA Energy Technology Perspectives 2014

The IPCC view is that close to zero greenhouse gas (GHG) emissions will have to be achieved during the second half of this century. For this to happen, CCS would play a key role in a world where fossil energies will still account for a significant share of the energy mix. Currently, most models that result in efficient climate change mitigation require the development of CCS on a very large scale, as well as the development of Bioenergy combined with CCS. It appears that the cost of not developing CCS would be higher than the cost of failing to increase renewable energies or nuclear power production.

For CCS to play a significant role in climate change mitigation, it will have to be developed on a very massive scale and at a very fast pace. For example, the IEA reckons that around 8 $GtCO_2$ must be captured and stored in 2050. This is equivalent to roughly 200 million barrels per day (bpd) of "dense phase" CO_2. A comparison with today's oil output (less than 100 million bpd) provides some insight into the scale of the business that will have to be developed within the very short timeframe of about 35 years.

The quantity of CO_2 that is currently being captured and stored amounts to around 30 $MtCO_2$/year. Projects now under construction represent a total capture and storage quantity of about 15 $MtCO_2$/year (*Source* Global CCS Institute: Global Status of CCS: 2014). In other words, current quantities must increase by two orders of magnitude (from about 45 $MtCO_2$ to about 8,000 Mt CO_2) in the space of 35 years in order to meet the targets for 2050. The Integrated Carbon Capture and Storage Project on the coal-fired Boundary Dam power plant in Saskatchewan (Canada), launched in October 2014, is the world's first commercial-scale power generation CCS project integrated with power generation in general and with coal-fired power generation in particular.

The challenges.

Numerous challenges will need to be overcome in order for CCS to attain such an ambitious growth target.

The energy penalties and costs associated with the capture side of the process are currently very high. For example, implementing a capture unit integrated with a coal-fired power plant increases the energy requirement of power generation by roughly 25%.

We still lack a business model for the storage side of the CCS. What kind of company will store CO_2 emitted by others? What mechanism could be used to ensure an economic return at the appropriate price? There is also work to be done on the regulatory framework, particularly with respect to the sharing of liability and costs over the long term.

Public support is not a given. There are already a few examples of CCS projects that were canceled due to a lack of support. Beyond the usual fear of new technology, reticence relates to the matter of assigning liability in the context of long-term storage.

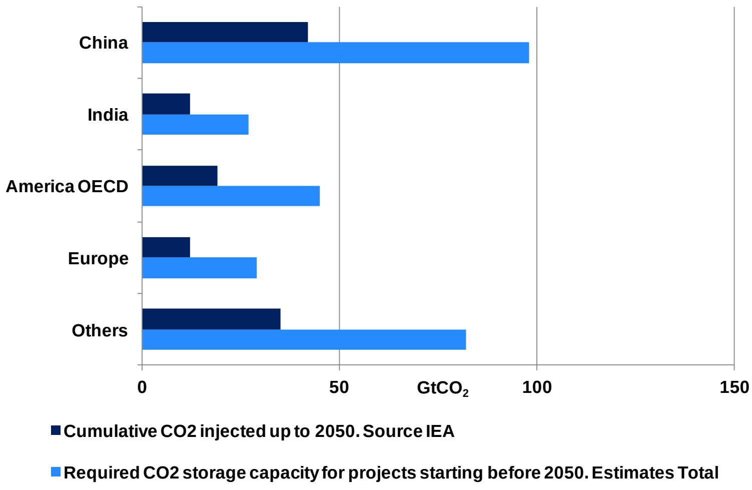
The sheer scale of the anticipated development is an issue: a whole new industry is expected to grow rapidly and on a massive scale. Potential impediments to this growth include the amount of financing it will require and the industry's ability to attract scarce resources (materials, infrastructure, and possibly human resources). Actually, due to its required size, the CCS industry will have to compete hard with the oil and gas industry.

A closer look at a specific issue: worldwide and regional CO_2 storage capacity.

For CCS to develop on the massive scale dictated by climate change imperatives, another aspect must be investigated more closely than is currently the case, namely, whether storage capacity will be available to match this development.

CO_2 storage capacity naturally must be assessed on the global scale. However, the issue must also be considered region by region. Transportation costs must be kept as low as possible. CO_2, as a gas, will be costly to transport, whether by pipeline or by ship. It is therefore essential to determine for each area whether sufficient reservoirs do exist and whether an economically viable correlation between CO_2 emission sources and CO_2 storage sites can be found.

For any project, CO_2 storage capacity will have to be identified well before the start of the operations. The following graph shows the IEA estimate for CO_2 injections to 2050 (in dark blue), along with Total's simplified estimate for the CO_2 storage capacity that must be identified in connection with CCS projects due to come on stream during the period. We introduced some additional simple assumptions concerning storage identification. The key assumption was that any CCS project will need storage capacity equivalent to 50 years of captured CO_2 emissions. Another was that storage capacity will be proven five years before the start of CCS operations.



Due to the CO_2 storage requirements, this graph raises the question of whether there will be enough capacity in all the major emitting areas.

It is widely agreed that deep saline aquifers will store the lion's share of injected CO_2 in the future.

In its 2005 special report on CCS, the IPCC's estimates of worldwide CO_2 storage capacity in deep saline aquifers exhibited a broad uncertainty range (from 1,000 Gt to 10,000 Gt). A review of the history of estimations of CO_2 storage capacity in deep saline aquifers reveals significant variability in estimates made on the scale of any given geological basin or country. These differences are generally not due to the acquisition of new data, but rather to the use of different methodologies. These numbers thus warrant very careful consideration.

In most regional studies, such as atlases, the methodologies applied to assess CO_2 storage capacity are based on the volumetric storage efficiency. These methods ignore the fact that during CO_2 injection, pressure is not evenly distributed in the aquifer. Dynamic modeling studies show that if pressure distribution is not properly taken into account, capacity may be overestimated by a factor of 10 or more. (See for example Thibeau et al, "Using Pressure and Volumetric Approaches to Estimate CO_2 Storage Capacity in Deep Saline Aquifers," in *Energy Procedia 63 (2014)*, presented at GHGT-12 Conference).

Actually, estimates of CO_2 storage capacity at the regional scale should be based primarily on the well-known closed aquifer formula, which has proven to yield more realistic regional CO_2 storage capacity estimates than the more frequently used volumetric storage efficiency methodology.

Some major CO_2-emitting areas of the world might not have sufficient CO_2 storage capacity. In other areas, it might be necessary to implement pressure management, such as water extraction, which could result in potentially significant cost increases.

Due to the foreseeable continuing growth in power generation investments and the fact that some of these assets will still be operational in a few decades, CO_2 emissions, particularly those from power plants, will continue to increase. Progress is thus needed with regard to the methodologies for assessing regional CO_2 storage capacity. This is essential to ensure pertinent decision support for the choice of investments.

Constraints on CCS development and competition between coal and gas in the power sector

The constraints on CCS development, particularly the issue of CO_2 storage capacity, affect the competition between coal and gas in the power sector.

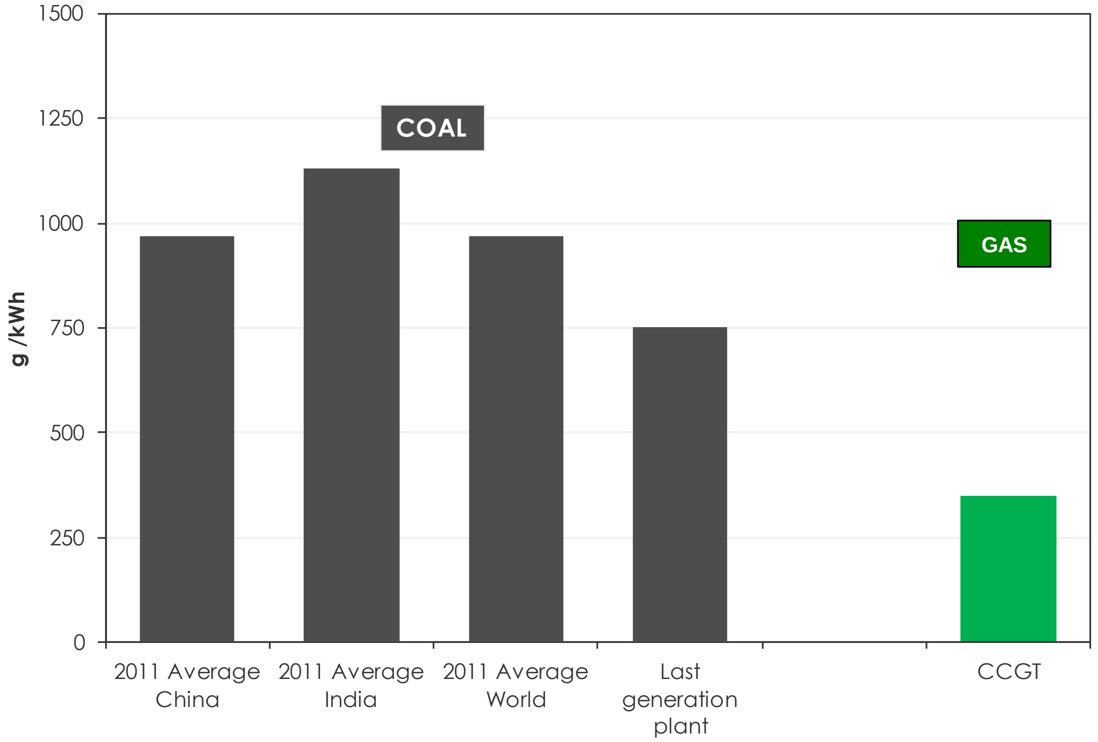
The future of the fossil energy industry will depend on the same factors as the ones that have determined its course since its inception, such as demographics, growth, consumption patterns, energy efficiency, and competition between different types of energy. Two additional factors will combine to play their part: climate change-related constraints and the ability of CCS to contribute to the development of fossil energy within these limitations.

The issue of CO_2 storage capacity in the major CO_2-emitting areas of the world will impact not only the competition between fossil and decarbonized energies, but also that between coal and gas.

The power sector, which accounts for most of the emissions from large emitting sources, and one-third of the total CO_2 emissions due to fossil fuel consumption, is a case in point. If two types of fossil fuel are competing for the same usage (power generation) and are significantly differentiated by their CO_2 emissions (before CCS), the hierarchy between them can be affected by constraints on CCS development.

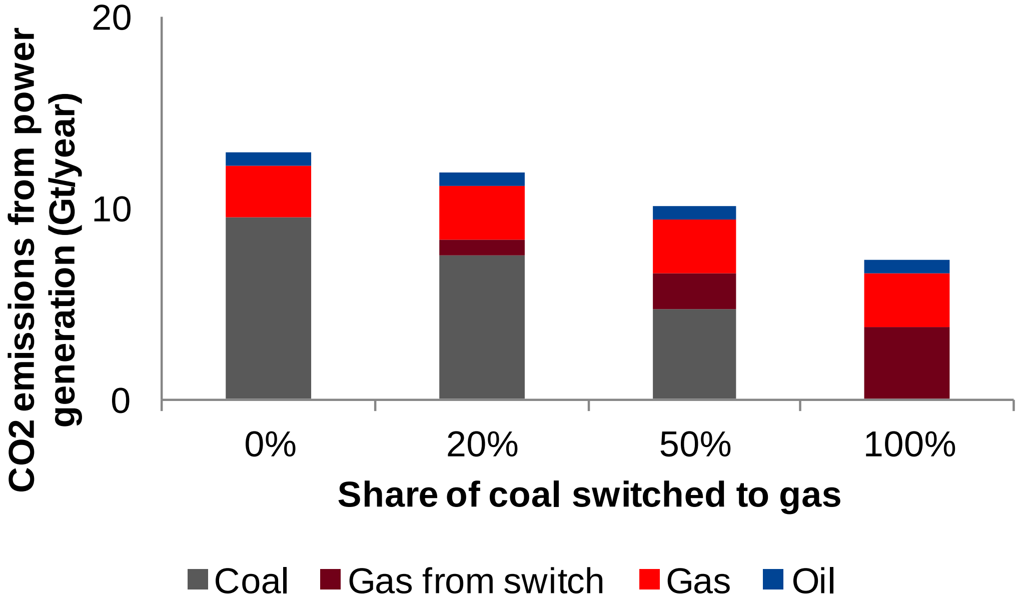
Gas offers the advantage of much lower CO_2 emissions than coal for a given power output: the total theoretical impact of merely switching ALL coal-fired plants to gas for power generation is of the same order of magnitude as the theoretical impact of the CCS development expected by IEA in 2050.

The CO_2 emissions (in g per kWh generated) are around twice as high in a latest-generation coal-fired power plant as in a state-of-the-art combined cycle gas turbine (CCGT). The ratio will be higher if the coal-fired plant is average rather than latest-generation. This comparison assumes that there are no fugitive GHG emissions during the process of producing, treating and transporting either coal or gas. In the case of state-of-the-art industrial practices, that hypothesis may influence the degree of difference between the two types of fossil fuel, yet will not change the fact that gas-fired power production emits much less GHG than coal-fired generation.



Source IEA CO_2 emission from fuel combustion 2013, Total estimates

CO_2 emissions from coal-fired power generation total around 9 Gt/year (*Source* IEA report: emissions from fuel combustion (2013 Edition)). Due to the lower CO_2 emission factor (g/kWh) for a combined cycle gas turbine as compared to a modern or average coal-fired power plant, replacing all coal-fired power plants with CCGT would theoretically reduce CO_2 emissions by around 5 Gt/year. Although merely theoretical, this figure is of the same order as IEA estimates for the development of CCS by 2050 (around 8 Gt/year).



Source IEA, Total estimates

Of course, this theoretical reduction in CO_2 emissions generally will not be fully achieved because hurdles such as access to gas, gas prices, discovery and development of new gas reserves, or energy security will negatively impact the reduction potential.

<u>When CO_2 storage capacity is constrained, switching from coal- to gas-fired power generation with CCS installed on gas will achieve a higher net CO_2 emissions reduction than installing CCS on coal.</u>

Let us take a look at three scenarios, for clarification. The figure below is a simplified view of cumulative gross and net CO_2 emissions for a power generation unit during its lifetime. We consider three different cases concerning CO_2 storage capacity: no CO_2 storage capacity, CO_2 storage capacity equivalent to half the gross CO_2 emissions during the lifetime of the plant, which is assumed to be a state-of-the-art coal-fired power plant, and CO_2 storage capacity equivalent to the gross CO_2 emissions during the lifetime of the same plant. The net emissions are estimated for each of these cases and for two different options with CCS. In one, the plant continues to burn coal. In the other, the coal-fired plant is replaced by a gas-fired plant. The outcomes are compared to the case where the plant is not converted to gas and CCS is not installed.

When CO_2 storage capacity is nil (Case 1), installing CCS is not applicable for either coal or gas. In this case, switching from coal to gas will achieve an emission reduction equivalent to around half the gross CO_2 emissions from coal, assuming that the emission factor for gas is half of the emission factor for coal.

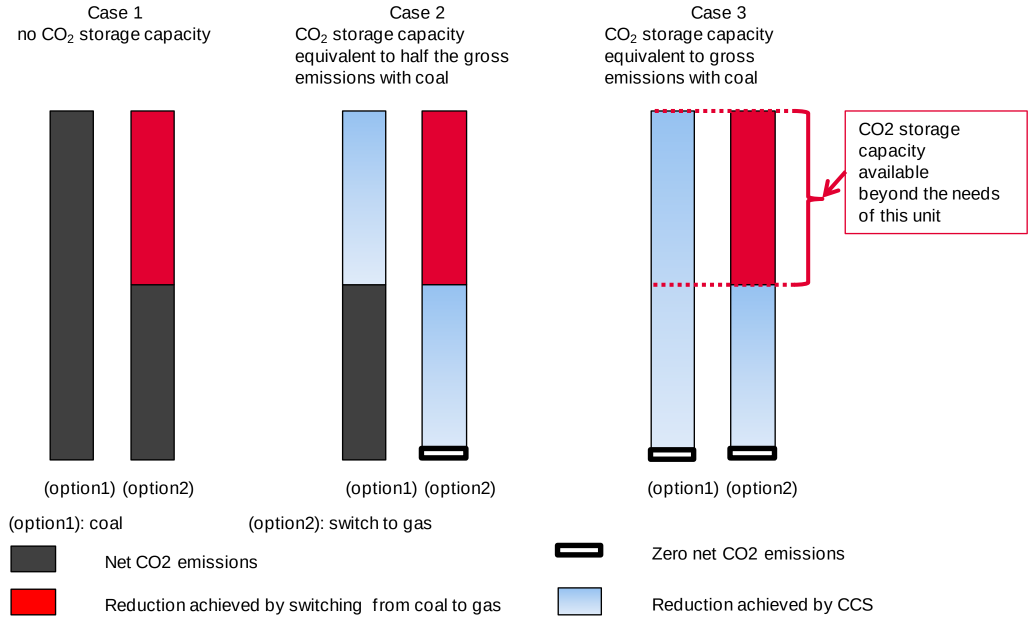
In the intermediate situation where CO_2 storage capacity is equivalent to half the gross CO_2 emissions from coal, implementing CCS on coal will offset half of the CO_2 emissions (Case 2). Thus, only half of the plant's power output can be said to result in zero net CO_2 emissions. In the case of switching from coal to gas and installing CCS on gas, and still assuming that the emission factor of gas is around half that of coal, then the plant's entire power output will be offset by CCS and can thus be said to result in zero net CO_2 emissions. Twice as much power generation will be decarbonized (practically zero net emissions) by switching to gas-plus-CCS as compared to coal-plus-CCS.

In both cases (no CO_2 storage capacity and half the gross CO_2 storage capacity during the plant lifetime), switching from coal to gas will achieve a greater CO_2 emissions reduction than the reduction achieved by coal-fired power generation with CCS (where applicable): the additional reduction will be equivalent to half the gross CO_2 emissions from coal.

Switching to gas and installing CCS on gas is a winning strategy as compared to installing CCS on coal when CO_2 storage capacity is constrained.

When CO_2 storage capacity matches the gross CO_2 emissions over the lifetime of the plant unit (Case 3), implementing CCS on coal would achieve zero net emissions. The same result can be achieved by switching from coal to gas and installing CCS on gas. The difference with this latter option is that there would still be CO_2 storage capacity available after 50 years, given the lower emissions of gas-fired power generation, whereas failing to switch away from coal would result in full use of the storage capacity initially identified.

CO2 EMISSIONS REDUCTION IN CASE OF INSUFFICIENT STORAGE CAPACITY



In addition, even before the region's available CO_2 storage capacity is filled, the gas case will require less transport infrastructure capacity and a slower pace of expansion than the coal case: less capacity because of the difference in CO_2 emission factors; a slower pace of expansion because it will take more time to fill the first and best storage sites in the gas case than in the coal case, for the same reasons. This issue has potential significance as large distances between CO_2 sources and sinks can have a material impact on the economics of CCS.

Conclusions

CCS is expected to contribute very significantly to climate change mitigation.

In some major CO_2-emitting areas, there are uncertainties concerning the adequacy of CO_2 storage capacity with respect to the anticipated very large needs for CCS.

The merits of a strategy based on switching from coal to gas are potentially very significant. This is particularly true in areas where CO_2 storage capacity is limited compared to CO_2 emissions, or where there are significant unknowns concerning this capacity.

In view of the above, developing and implementing sound methodologies for assessing regional CO_2 storage capacity when data are scarce or when it is not yet practical to use detailed flow models is essential to evaluate the decarbonization potential of a CCS strategy in the context of coal- or gas-fired power generation.

It is still essential to maximize the impact of CCS development. Work on storage capacity is one side of the issue, but research on breakthrough technologies to significantly decrease the extra costs and energy penalty of capture is also imperative.The significant potential benefits, in terms of climate change, of switching from coal to gas clearly warrant devoting greater efforts to promote/study CCS on gas.