The role of CCS in the greenhouse gas mitigation portfolio of Kazakhstan

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Introduction

CO_2 capture and storage is a key technology that is proposed to drastically reduce the emissions of greenhouse gasses, more particularly of CO_2, from industrial sources. It has repeatedly been shown that reaching deep reduction targets is at least more expensive (cf. IEA, 2010) , or even technically nearly impossible, when CCS is not considered as part of the energy and industrial portfolio.

Although a few CCS projects are currently in operation, it is much more difficult to implement than many of the renewable technologies. One obstacle is that economic CCS projects are necessary large scale, while renewable projects such as wind or solar can start out small and gradually upscale with time. A second main concern is the economy of such large projects. Although they are likely to be cost competitive, and even more economic than other options, they only become economic because the costs for emitting CO_2 are avoided. In other words, the CO_2 price (in an emission trading scheme) or CO_2 tax should be sufficiently high. The level of such a price or tax indicates the national and worldwide ambition to tackle the climate issue, and it is currently uncertain how far that ambition reaches.

Kazakh Situation

For economies in transition, such as the one in Kazakhstan, it can be questioned whether CCS is a feasible solution. In such countries the amount of money put into investments is already stretched thin, making investments into very large and somewhat uncertain CCS projects even less realistic than in developed economies.

Nevertheless, if a momentary lack of resources prevents the implementation of a solution that in the long run is more economic and from an environmental point of view beneficial for the world as a whole, then international support for realising such projects would not be unrealistic. In order to explore whether CCS is indeed an option that fits those criteria, this option is objectively evaluated against other traditional and renewable technologies.

Methodology

The evaluation of different technologies is done with the PSS III simulator, of which a more circumstantial explanation can be found in Piessens et al. (2012). Briefly put, PSS III is a true economic simulator in the sense that it predicts future investment decisions based on realistic investment schemes (a combination of real options analysis and mean variance optimal portfolio). This series of decisions leads to a balanced energy portfolio that reflects the production costs and uncertainties of the different technologies. It is also capable of simulating projects that consist of individual steps, e.g. for finding the most economic combination of a capture technology, the best transport route and the best suited geologic storage reservoir. PSS III also has unique capabilities of taking into account different uncertainties, making it possible to express outcomes as probabilities and uncertainty ranges.

Two different scenarios are set up for Kazakhstan, which differ only in the assumed CO_2 price in the ETS system. In the 'Global Warming' scenario, it is assumed that climate awareness is low and that therefore relative little impact is created through the ETS system for limiting the amounts of emitted CO_2. This corresponds to prices that on average do not exceed 5€/t, as can be seen in figure 1. In a second scenario is called 'Climate Control' and assumes that the ETS price is higher, up to around 40€/t by 2050, in order to trigger investments in low CO_2 technologies of which those in the energy sector are evaluated.

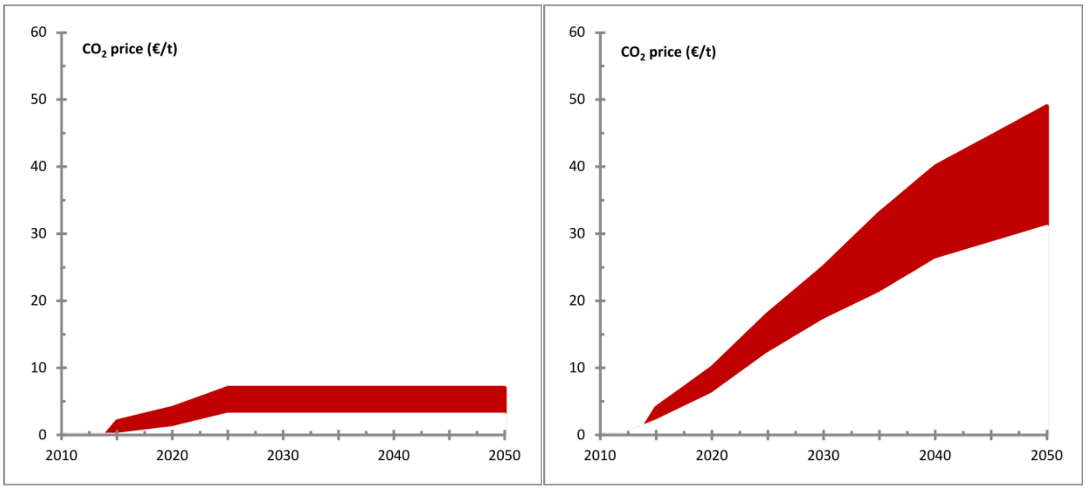

Figure 1: Evolution in the CO_2 price in respectively left and right the Global Warming and the Climate Control scenario. The wide of the band corresponds to the uncertainty range that is taken into account in the simulations.

In total 22 technologies can potentially be chosen during the simulated investment decisions. All technologies are assumed to be state-of-the-art according to EU standards, and comprise standard coal and natural gas based power plants, as well as those using biomass. Each of these options has a corresponding CCS equivalent. Also concentrated solar, photovoltaic and wind energy are included. Not included in this simulation are hydropower and nuclear power installations. Not the whole territory of Kazakhstan is included in this simulation, and construction of power installation or CO_2 storage sites are limited to those shown in figure 2.

Energy demand is assumed to increase with 2% per year in response to economic expansion. The simulator further takes in to account fuels costs, several GIS based datasets for calculating pipeline construction costs (fig. 2), etc. The current simulation is based on preliminary geological information drawn from general geological maps, which nevertheless show that the vast subsurface of Kazakhstan likely contains several opportunities for storing CO_2.

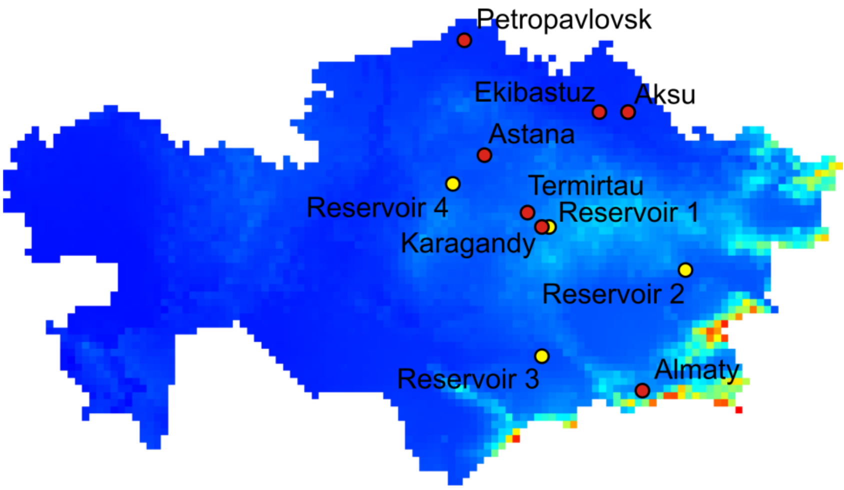

Figure 2: The map of Kazakhstan with for illustration colours according to topographic elevation (being one of the layers taken into account when constructing pipelines for CO_2 transport). Power production units can be constructed on the red locations, while geological storage of CO_2 is possible on the yellow locations.

The current energy infrastructure in Kazakhstan is largely aged, but is nevertheless expected to be decommissioned relatively gently with the last of the currently existing power stations going off line around 2040. The current power stations are not suited to be retrofitted to allow CCS, and this option is therefore not taken into account during simulation. The increasing demand for energy and fading out of existing capacity is compensated for by building new capacity.

Simulation 1: Irresponsive energy portfolio

The choice of the 40 €/t ETS cost was based on experience, supported by literature references, that this price level is sufficient to trigger CCS projects in a European context, as well as some renewable technologies that are price competitive with CCS. 40 €/t is also considered as approximately the highest emission cost that realistically can be implemented in a developing economy.

Instead of the expected portfolio, PSS III predicts for Kazakhstan an almost complete dependence for power production on coal, both for the Global Warming and the Climate Control scenario (fig. 3). The reason for this somewhat unexpected result is that rather inefficient coal technologies are chosen as the most economic ones, which are only economic when the price of coal is low. This is the case in Kazakhstan where the price of coal is assumed to remain about 3 times lower than in Europe.

The large effect of a relatively simple scenario parameter on the nation wide choice of energy technologies clearly illustrates the importance of reliable techno-economic simulators for analysing and predicting complex economic wide interactions.

The somewhat surprising conclusion for Kazakhstan is that even given a significant attempt to mitigate the emission of CO_2, the influence on economic decisions that shape the future energy portfolio is extremely limited. Coal will remain the main source for power, and renewable energy (mainly wind) will play only a marginal role. It is even true that not even the most efficient coal power technologies will be used, because the investment in more efficient plants is not required as long as the coal price remains low. Based on our preliminary findings, the Climate Control scenario will not be successful.

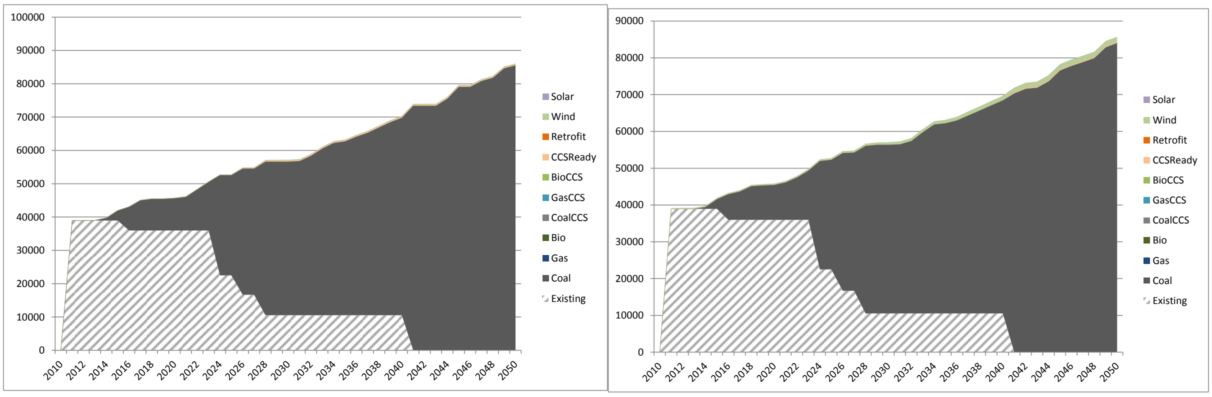

Figure 3: The energy portfolio predicted by PSS III for left the Global Warming and right the Climate Control scenario. In both cases the total portfolio is dominated by coal technologies (grey part). Only wind energy (lime green) plays a marginal role in the Climate Control scenario. Production (vertical axis) in GWh/y.

Simulation 2: Slow responding energy portfolio

Having determined that setting a carbon price alone is insufficient to realise a significant decarbonisation of the power sector, a second simulation was performed in which also performance requirements were set for the different technologies. Basically, power production from coal was still allowed, but only using the most efficient super critical power technology. This assumes that a policy is in place that not only sets a price on the emission of CO_2 (5 or up to 40 €/t depending on the scenario), but also implements rules preventing the construction of the less efficient coal based power plants that dominated the first simulation results.

In this simulation round, the energy portfolio in the Global Warming scenario exists mainly of classical coal fired power, and CCS ready coal fired power. The latter technology represents an only marginally more expensive investment cost, but does allow to reconvert to CCS operational (at an additional cost) if the CO_2 ETS cost were to rise in the future. However unlikely this may be in this scenario, the (very small) additional investment cost is on average still balanced favourably against future flexibility. In none of the cases, however, is a retrofit actually implemented.

In the Climate Control version of this simulation, the coal portfolio is clearly even more balanced towards CCS ready, of which part is effectively retrofitted to become CCS active after 2040. Power from wind is gradually growing over time. Natural gas based power is also visible in the portfolio, but may be a random occurrence since the results of scenario 2 are preliminary and based on too little Monte Carlo iterations to be fully reliable.

In spite of the preliminary nature of the scenario 2 results, the effect of the technological constraints are clear and result in a mitigation of the CO_2 emissions from the power sector due to the introduction of renewable energy (wind) and CCS (relatively fast growing after 2040).

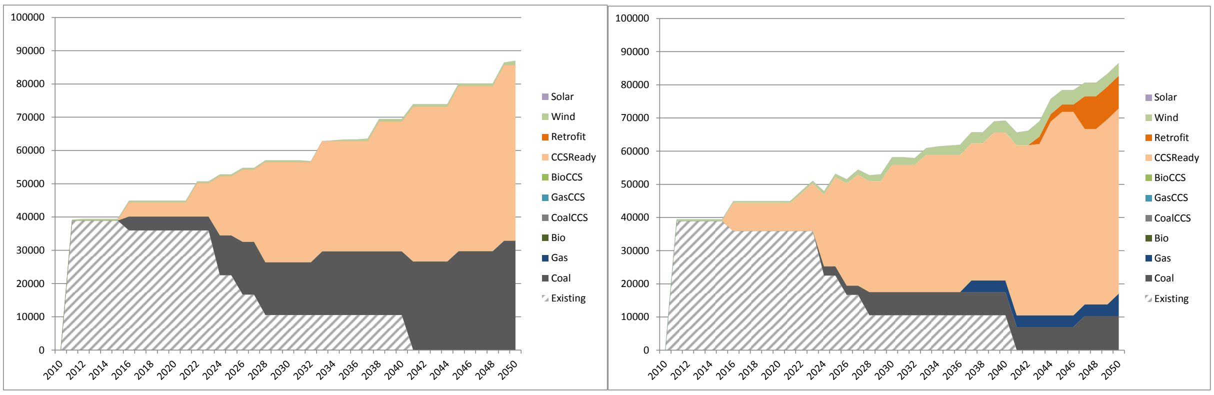

Figure 4: The energy portfolio predicted by PSS III for left the Global Warming and right the Climate Control scenario, now with control on the energy technologies (most efficient coal technologies only). This results in a clear difference between the Global Warming and the Climate Control scenario, because in the latter the cost of emitting CO_2 is important enough to effect the energy portfolio. Production (vertical axis) in GWh/y.

Marginal emission abatement cost curve

In figure 5 a marginal emission abatement cost curve (MACC) presents the results of the PSS III simulator for both scenarios regarding the 2050 portfolio. The marginal cost curve represents the additional cost of an extra ton CO_2 emissions avoided for each emission abatement technology selected by the PSS III simulator. The cost and effects of the abatement is measured against the current coal based power production. The selection of an emission abatement technology depends on the CO_2 price. Figure 5A demonstrates that regarding the climate control scenario, only wind energy is selected for CO_2 emission reduction. If the CO_2 price is higher than €22/ton, wind energy will be adopted. Figure 5B shows that the MACC increases with increasing quantities of avoided emissions. Technologies that reduce emissions at a relatively low cost are adopted first (gas and wind). If tougher regulations are set, CCS retrofit technologies that reduce emissions further but that require higher costs are adopted as well.

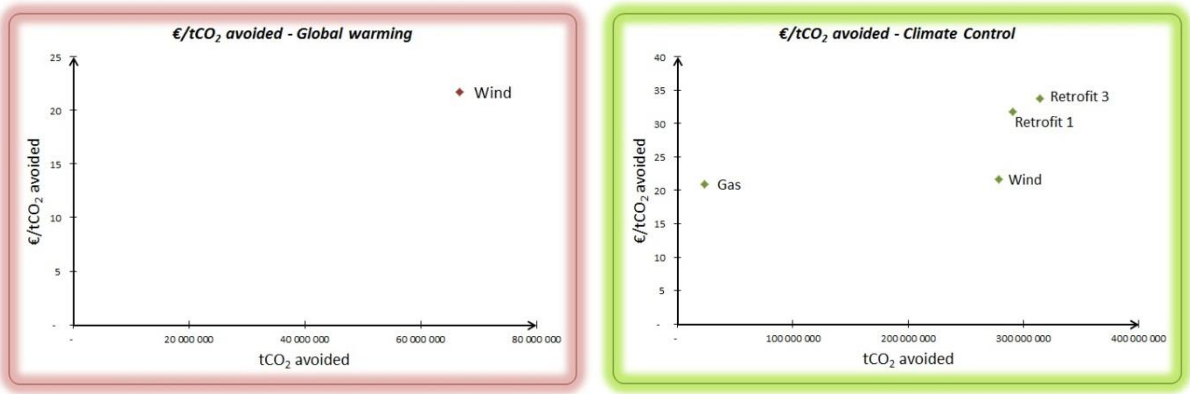

Figure 5: Marginal emission abatement curve for the Global Warming and Climate Control scenario.

Discussion and conclusions

The outcome of scenario 1 is quite different from a European situation, with which the modellers have most experience, and was therefore somewhat unexpected. Scenario 1 shows that an ETS cost up to around 40€/t of emitted CO_2 is insufficient to change the investment decisions in the energy sector. Due to the low price of coal, it remains economic to opt for relatively less efficient power plants. Scenario 2 assumes additional policy measures that restrict the coal based power options to only the most efficient ones. Coal does remain the base of the power sector, but in combination with an ETS system, renewable energy (wind) and also CCS become increasingly more important with time.

The MACC visualizes the trade-off between the cost of CO_2 emission reduction and CO_2 emissions avoided and shows how the introduction of an ETS system can affect energy investment decisions. However, the MACC represents all technologies at a single average cost level. In reality, the emission abatement costs will vary by installation specifications and location. Besides the reduction of GHG emission, also local air quality is improved when CO_2 emission abatement technologies are adopted. The transition from coal based energy production to renewable energy production can lead to SO_X, PM and NO_X emissions reduction. These benefits are not included in the calculation.

The MACC should be considered as one element within the decision making process to support environmental policy. It illustrates the trade-off between emission abatement and the abatement cost and serves as a tool that encourages various stakeholders to engage in the debate of climate change mitigation.

Acknowledgments

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