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RECCS: ecological, economic, and structural comparison of renewable energy technologies (RE) with carbon capture and storage (CCS) – an integrated approach

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Introduction: Rising oil and gas prices, insecure energy supplies, and increased energy consumption in transition economies like China have led to greater use of coal. This is because coal is the most abundant fossil fuel and many countries possess considerable reserves within their borders (especially China, India, South Africa, and the Unites States). However, the use of coal is connected with the highest specific greenhouse gas (GHG) emissions. In this context, the discussion about carbon capture and sequestration (CCS) has steadily moved up the agenda in many countries as well as globally.
Research objectives: Studies so far conducted in this field have concentrated largely on the technical feasibility of carbon capture and storage. There has not yet been a detailed integrated assessment across all stages of the process of the kind that is today a matter of course as is the case for other new energy technologies. Including CCS in the fossil fuel cycle makes it possible for the first time to conduct a comparison with renewables on equal terms (with respect to climate policy). Such a future oriented assessment, made on the basis of a comprehensive set of criteria, was the object of the RECCS study, answering the following main questions: 1. How do the life cycle assessments (LCA) of these processes look, and how does low-CO2 fossil electricity generation compare with CO2-free options (especially renewables) in this respect? 2. What role can CCS play for climate protection in comparison with other relevant options in the future (systematic comparison on the basis of significant criteria such as cost, window of opportunity, ecological restrictions, etc.)? 3. What role can CCS play at the national and international levels as a possible bridge to a renewable energy system?
Assessment Methodologies Used: The ecological assessment is done via a screening LCA according to ISO 14.040 adopted to possible power plant configurations in the year 2020. Future cost development will follow mass market effects and technology improvements and is modelled using experience curves and corresponding learning rates for both upcoming capture and storage technologies and renewable energy technologies until 2050. Furthermore, scenarios on increasing fossil fuel prices are introduced. The long-term energy systems analysis is done by including CCS technologies into existing sustainable energy scenarios (for Germany) investigating three possible developments: no use of CCS, CCS as a bridge, and CCSMAX from 2020.
Results Obtained: 1. CO2 capture requires additional energy consumption of 20 to 44%, depending on the applied process. Furthermore, only the CO2 emitted directly in the power station can be captured (by 88 to 90% in 2020) – emissions of the upstream and downstream processes increase proportional to fuel consumption. Finally, the discussion to date has also neglected to consider that – according to the Kyoto Protocol – GHG emissions as a whole – and not only CO2 emissions – have to be reduced. Our LCA shows that with a CO2 capture rate of 88%, GHG emissions can only be reduced by 67–78% depending on the fuel and the process. Furthermore, other environmental impacts like photo-oxidant formation, eutrophication, or particle emissions increase because the pollutants causing these impacts can not be captured. 2. Alternatives have already entered the market: On the one hand, the GHG emissions and the cumulative fossil energy demand of electricity generated from solar thermal power or wind power is just 2 to 3% of the corresponding figures for fossil-fuelled CCS plants. On the other hand, the GHG emissions of electricity generated by advanced natural gas fired combined heat and power station technologies are roughly equivalent to those for power stations using CCS. This means that there are fossil technologies commercially available that are already as green as CCS power stations aim to be in 2020. But of course establishing these technologies requires significant structural changes within the overall energy system architecture. 3. From the calculations done, no direct cost advantage for technologies using fossil fuels is recognizable compared to advanced renewable energy technologies. If the capture and storage of CO2 can be demonstrated successfully, electricity generating costs (at power stations) of between 6.5 and 7 ctEUR/kWh can be expected in 2020. In view of the fuel price rises expected in the longer term, a further rise in costs to between 7 ctEUR/kWh (coal) and 8 ctEUR/kWh (natural gas) is probable by 2040. Renewables, which – based on a representative mix – today still involve electricity generating costs of approximately 13 to 14

ctEUR/kWh can also achieve that level of costs by 2020 if their market introduction continues at a similar pace to now. That means, at the time when the first CCS power stations might be coming on stream some individual technologies (e.g. wind offshore, solar thermal power plants) could already be offering cheaper electricity generation costs and would further extend that advantage over the course of time while the price of fossil fuel-based electricity generation might show a continuing increase. 4. Germany is facing the complex challenge of having to replace a large proportion of its power station capacity within the coming fifteen years. As a main element of a climate protection strategy (as assumed by the CCSMAX scenario) CCS runs into structural and capacity limits. The earliest date when CCS technologies are expected to be ready for implementation is 2020, which is too late for the first wave of the necessary power station replacements. It would necessitate extremely rapid growth rates for CCS plant between 2020 and 2050 and speedy establishment of a hydrogen infrastructure. If a vigorous political course of promoting renewables and efficiency improvements is pursued over the next ten to fifteen years, the realisation of energy-saving potentials and the successive expansion of renewables would be able to make a more rapid contribution to climate protection than CCS. In this case the use of CCS technologies is not absolutely necessary for meeting even ambitious climate protection targets. The period until 2020 should be used to thoroughly explore the development and costcutting potentials of CCS technologies and to demonstrate technological feasibility. If that process proves to be successful, CCS would offer the possibility, as described in the BRIDGE scenario, of switching to a climate-friendly path even if it has not proved possible to sustain the ambitious pace of implementation of efficiency potentials and renewables over time. In view of the real interests involved in the field of energy, especially in the global context (where energy saving efforts are counteracted by substantial growth trends), this constellation may well become reality.
Conclusions: Our analysis shows that a future-oriented approach is necessary to assess new technologies depending on several parameters currently not known. Most studies only consider state-of-the-art conditions or – if at all – a situation in 2020, when CCS power plants are expected to run commercially. Our results show that conclusions based only on a year 2020 analysis could lead to wrong and insufficient results and clarify the necessity to think under long term conditions and to analyze the impacts of measures launched today with regard to a long-term time frame.