Statement Regarding the Technical Assessment "Direct Air Capture of CO_2 with Chemicals" of the American Physical Society

Climeworks LLC, Zurich, 18 May 2011

The American Physical Society (APS) has released a technical assessment stating that based on an analyzed "benchmark system", CO_2 capture from air (air capture) will cost at least US$ 600 per ton CO_2 avoided and would therefore "play a very limited role in a coherent CO_2 mitigation strategy for many decades".

Climeworks LLC is commercializing a novel air capture technology, which has been developed at the Professorship of Renewable Energy Carriers at ETH Zurich. It has much greater potential and is fundamentally different than the reference system for the APS assessment. Climeworks therefore does not consider the results of the APS study to be applicable to its developed technology. In contrary, the APS report further underlines the novelty of the Climeworks technology.

First, the targeted mid- to long-term application for Climeworks' air capture technology is the production of renewable liquid hydrocarbon fuels to store and transport renewable energy using existing infrastructure. Several research groups (including groups of ETH Zurich and PSI) and companies are currently developing liquid transportation fuel production processes powered by renewable energy. All of these processes require a source of CO_2 which should not compete with food production. The carbon material cycle for fuel production can therefore only be closed if the CO_2 is captured directly from the air. Only then one can claim the production of CO_2-neutral liquid hydrocarbon fuels.

In this respect, a comparison between air capture and flue gas capture is not meaningful, since unlike air capture, CO_2 capture from flue gases (derived from the combustion of fossil fuels) will obviously not close the material cycle. This important argument for capturing CO_2 directly from atmospheric air has been completely ignored in the APS report.

For other applications, in particular for the sequestration of CO_2 in geological formations, air capture and flue gas capture need not be considered as mutually exclusive alternatives. Under equal conditions (same location, energy, labor and investment costs, etc.), capturing 1 ton of CO_2 out of a flue gas stream will be somewhat cheaper than capturing it out of ambient air. However, air capture is not as hard as it may seem. Thermodynamics reveal that, while the CO_2 concentration differs by a factor of about 300 between flue gas and air, the minimum energy required to extract pure CO_2 differs only by a factor of about 3[1].

Therefore, in many situations the drawbacks imposed by the high dilution of CO_2 in the air can be compensated or overcompensated by the unique advantages of air capture. Most importantly, air capture systems can be strategically located next to the place of further CO_2 processing, eliminating transportation needs. Although transportations is in principle relatively cheap for large quantities (< US$ 10 per ton for 200km pipeline transportation), installation of large pipeline networks through populated or impassable areas poses high obstacles[2].

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[1] Lackner, K.S., *Capture of carbon dioxide from ambient air.* European Physical Journal-Special Topics, 2009. **176**: p. 93-106.

[2] *Carbon Capture & Storage: Assessing the Economics*, McKinsey Climate Change Initiative, September 22, 2008

The APS report states that in order to capture the CO_2 emissions of a 1GW coal power plant from the air, an absorber structure of 30 km length would be required. For a future, optimized Climeworks system, this hypothetical structure would translate into an area requirement of about 50 to 300 hectare (depending on the local conditions and wind exposure), which seems indeed large. However, it needs to be compared to a high-pressure CO_2 pipeline of typically several 100 or even 1000 km length required to connect a power plant equipped with a flue gas capture system to a suitable CO_2 sequestration site or a backbone pipeline. Also, the area required for an air capture system coupled solar-powered synthetic fuel production plant is significantly smaller than the area required for providing the solar energy for fuel production (about 1000 ha for a 1 GW plant). This shows that the first-glance inspection of the geometric dimensions of air capture systems can result in misleading perceptions.

In a first phase, Climeworks expects to capture CO_2 from air at competitive costs for niche markets of technical CO_2, such as greenhouse fertilization. To achieve this, the upper cost limit is about 3 times lower than that predicted by the APS report. This is plausible for three main reasons.

- The "benchmark system" used in the report is based on concepts that are more than five years old and which were developed in the first days of air capture research. No-one active in the field of air capture would consider using this system today because of its low performance.
- The Climeworks technology is based on a novel, highly efficient sorbent material that was developed at ETH Zurich and Empa during the last 2 years, which was not known to the APS committee. Such a development is actually explicitly stated in the APS report as one potential means to significantly reduce the costs of air capture. Climeworks' sorbent material achieves similar CO_2 loadings in an air capture process as the state of the art sorbent materials achieve for CO_2 capture from flue gases.
- As opposed to the reference system analyzed in the report, the Climeworks system requires more than 95% of its energy input in the form of cheap, low-temperature heat.

In the mid to long term, significant cost reductions of at least a factor of two are expected for the Climeworks technology. This is deemed reasonable since air capture and especially the Climeworks concept is a very new technological field with a lot of room remaining for optimization. This is in strong contrast to flue gas capture which has been investigated on an industrial scale for many decades and has seen very significant funding. Total worldwide investment into air capture to date has been less than about US$ 20 million, spread over several projects.

In summary, we can demonstrate that the conclusions of the APS report regarding costs of air capture do not apply for the Climeworks technology. We further illustrate that air capture is the only path to provide a source of CO_2 for a sustainable and CO_2-neutral production of renewable liquid hydrocarbon fuels.

For a further description please refer also to: http://www.climeworks.com/why-air-capture.html