The Role of Direct Air Capture in the Evolving 21st Century Energy System

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Growing carbon dioxide emissions are the main cause of climate change. Decades of procrastination have put the world on a trajectory that will overshoot the climate targets agreed to by the international community. The uncontrolled dumping of excess carbon dioxide into the atmosphere will have to stop, and the carbon excess will have to be removed from the environment. The scale of the necessary drawdown is far beyond the scope of capture by photosynthetic processes and storage in natural sinks. Direct capture of carbon dioxide from ambient air offers a scalable solution to this waste management problem.

Eliminating all carbon dioxide emissions from the energy sector and cleaning up prior emissions is a gargantuan task that will drive massive changes in the world's energy infrastructure. The rapid drop in the price of renewable energy further accelerates this process. Even though the intermittency of renewable energy poses a formidable challenge, renewable energy is pushing into the market displacing fossil energy as the most affordable resource. Incumbent technologies, hampered by concerns over climate change, will have a difficult time to compete.

Yet, displacing oil and gas for long-term storage and transportation, especially aviation, will be difficult. However, production of synthetic fuels and substitutes for petrochemical from renewable energy will make abandoning carbonaceous fuels and materials unnecessary. Here, direct air capture provides a scalable solution for closing the carbon cycle, eliminating fossil carbon extraction, while retaining much of the current energy infrastructure.

By collecting carbon for disposal and recycling, direct air capture becomes a critical technology in completing the energy transition that is already on its way. To avert a climate disaster, the energy transition will have to happen fast. It also must be executed flawlessly, because even a short and regional breakdown in energy services could have catastrophic consequences.

Advances in direct air capture enable a complete transition to renewable energy without abandoning existing energy infrastructures and combine this transition with the necessary massive drawdown of excess carbon in the environment. We will discuss the technologic and economic requirements, consider possible pathways and highlight gaps in our current understanding. In summary, we argue that photovoltaic electricity should not be shoe-horned into the existing electricity grid but be fed into a large and diverse supply chain, that provides grid electricity, charges batteries for short term storage, produces a variety of fuels and chemicals, produces synthetic hydrocarbon storage to iron out variability in resource availability on timescales ranging from weeks to decades and lastly powers the drawdown of excess carbon from the environment. The least developed aspect of this vision is direct air capture technology. It appears within reach, but it will need a global development effort to succeed.