Looking for massive carbon capture

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Afforestation for carbon sequestration in arid land is challenging due to the lack of sufficient water. A new study investigates the environmental and economic potential of such an approach enabled by desalination plants driven by renewable electricity

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“*It’ll be harder than we thought to get the carbon out*”, this is the provoking but quite telling title of a manuscript[1] from V. Smil, a prominent energy scientist and one of the most critic voices on current measures for transitioning to a carbon-free society. Differently stated, our efforts towards decarbonization has put us face to face with the reality of facts and data: In the last decades, we only witnessed marginal and geographically localized reduction of manmade greenhouse contribution, as opposed to a detrimental increase of gas emission worldwide[2]. We thus have to accept that decarbonizing human activities is sector specific with the hardest challenges still laying in front of us[3]. If tackling CO_2 sources is complex, we have to try with sinks. In their insightful writing in *Nature Sustainability*, Caldera and Breyer[4] investigate the role of trees in unforested areas for removing CO_2 from the atmosphere.

The above research builds upon a previous study[5], where the global potential for forest restoration had been determined along with the corresponding possible amount of carbon that might be captured. However, in the new study, the researchers have taken a step further and identify both restoration and bare land that would be suitable for afforestation provided that enough fresh water can be reliably secured for irrigation, even in arid or semi-arid areas by means of seawater desalination. The core idea behind this approach is grounded on two main assumptions: i) massive access to a sufficiently low-cost renewable electricity (mainly photo-voltaic and wind) to be used to drive reverse osmosis desalination, namely a technology with a high energy efficiency and maturity to date; ii) leaving behind the common commercial concept of tree plantation and chop down after a decade or so with release of the captured CO_2 into the environment.

After selecting a mix of eight different trees that can more suitably withstand arid climates, the researchers were able to carry out their analysis leading to a quantitative estimate of the cumulative amount of CO_2 that can be sequestrated over a long time period of 70 years, starting from 2030. The required energy and cost associated to such carbon sequestration are thus estimated during the entire analysis period by means of a widely used computational framework, referred to as LUT Energy System Transition Model (LUT-ESTM)[6].

Following a subdivision of the world into nine geographical zones as implemented in the LUT-ESTM framework, the main outcome of the study suggests a total potential in the order of 730 $GtCO_2$ during the 70 years’ time period, with the Middle East and North Africa (MENA) and Sub-Saharan Africa having the highest (131 $GtCO_2$) and second highest (87 $GtCO_2$) share, respectively. To put numbers into perspective, the computed total sequestered CO_2 is the amount of global emissions in almost 20 years at a constant rate of the annual record realized in 2021 (i.e. around 37 $GtCO_2$)[7]. Authors found that the total cost, comprising energy, desalination, irrigation and land systems, is region specific and would start on average around 410 €/tCO_2 with an asymptotic tendency to less than a quarter of such value after 30 years. The interesting and striking aspects of such an analysis are related to the total energy shares. As expected, a large majority of the requested energy shall be devoted to fresh water production. However, a slightly less obvious conclusion is that nearly half of the total energy demand (on average) is requested for water pumping from the nearest coastline to internal zones. Interestingly, the latter observation may possibly open doors for further cost reduction, should technologies for localized fresh water production (e.g. atmospheric water generation) become more efficient and mature.

Among the key points of the study from Caldera and Breyer, it is worth stressing the quantitative investigation on the timeframe and conditions under which afforestation enabled by renewable electricity driven desalination becomes economically sustainable, as compared to alternative carbon direct removal approaches, such as direct air capture systems or bioenergy and carbon capture storage. While such an important first step has been taken, we recognize that we are dealing with and extremely multifaceted issue, whose technical and economic viability – through very important – is only one aspect to be considered. In their analysis, the Authors neglected all possible additional beneficial effects that successful afforestation can bring such as mitigation of desertification, soil erosion and floods. Clearly, the latter advantageous *side effects*, in addition to the likely increase in the local rainfall due to the tree canopy cover, can help in reducing further the water needs and the associated cost. This also demonstrates that in such studies there are disparate phenomena that are non-linearly *entangled* thus calling for deeper analyses to better quantify such effects.

On the other hand, key challenges should be also highlighted. First, one assumption for the CO_2 sequestration cost to decrease is based on the expected decrease of renewable electricity in the coming decades. In the future, it might be useful to consistently contextualize massive renewable electricity deployment within critical limitations associated with the use of relatively scarce materials[8] as well as with the disposal and recyclability issues of waste renewable energy technologies[9]. Furthermore, a substantial increase of the installed desalination plants inevitably poses additional environmental challenges (and opportunities in material recovery) for sustainable management of the concentrated brine.

Owing to their inspiring results, Caldera and Breyer have the merit to draw the attention of both scientists and politicians on the possible crucial role that renewable energy based desalination technology[10] could play for addressing the current pressing climate targets.

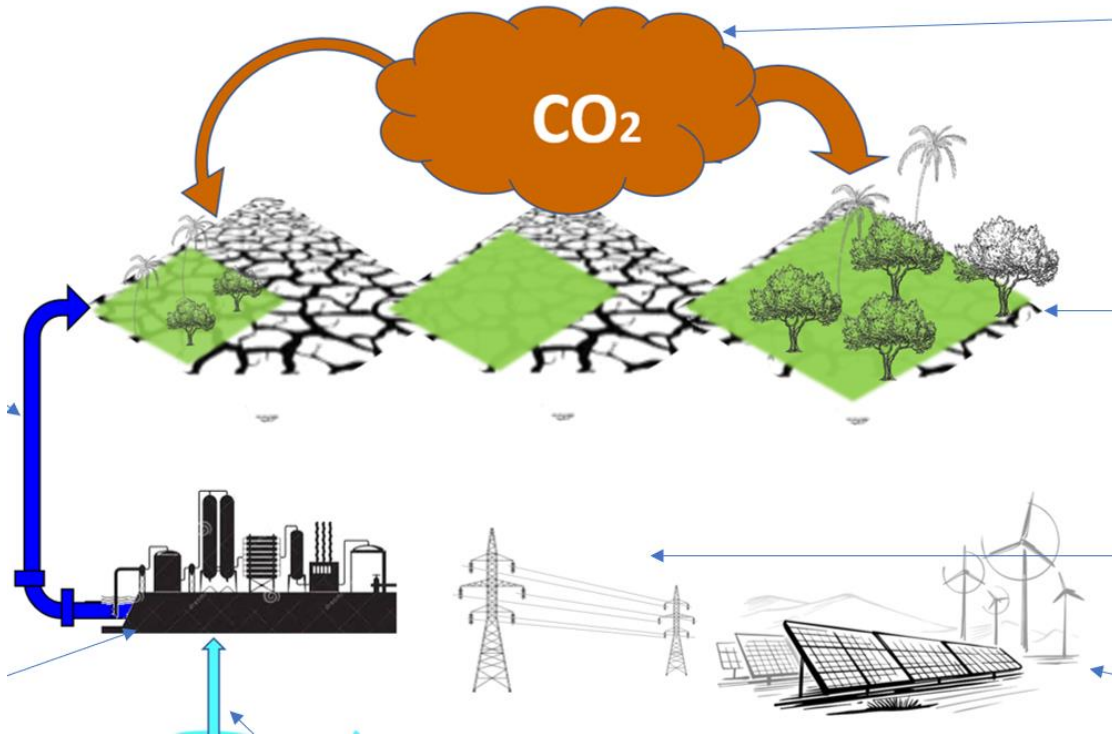

Figure Caption

Water desalination driven by renewable electricity used to provide with the adequate fresh water amount for the afforestation of arid lands, thus contributing to CO_2 capture over long time periods.

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Competing interests

The author declares no competing interests.