Assessing the potential of photoelectrochemical carbon removal as negative emission technology

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Anthropogenic emission rates are reduced too slowly

→ Almost all climate models assume negative emissions, where energy is invested to sequester atmospheric CO$_2$, starting from 2030

Type of technology and costs still very speculative

Most considered technologies are based on natural photosynthesis. Sequestration of CO₂ itself mainly relies on (safe) mineral trapping [2].

Natural Photosynthesis

- Scalable!
- Long-term storage feasible
  - *Energetic* efficiency ca. 2-3% [1]
  - Large areas [2,3]:
    - 10 Mio. km$^2$ for dedicated crops

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Efficiency as the bottleneck!

\[\text{Area (10}^6 \text{ km}^2\) for -10 Gt per yr.\]

\[\text{Crop BECCS, CDR, Forest BECCS/AR}\]

Artificial Photosynthesis

- (Photo)electrochemical CO$_2$ reduction
- PV-coupled to dark electrolysis or
  - Integrated systems
  - Challenges of PV & electrocatalysis
  - For hydrogen, with 19% energetic efficiency about 10x more efficient than its natural counterpart [1]
  - Negative-emissions-hydrogen [2]

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Suitable bandgap combinations, efficient catalysis

Model using detailed balance, $\eta(j)$ from catalysis \[2\]

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STF $\sim \frac{j \Delta G}{P}$

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Limits about 10-20× of (achieved) nat. photosynthesis

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Electrochemical production of solid carbon demonstrated [2]

Organic construction materials?

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→ **Solar-To-Carbon** efficiency as benchmark for evaluation

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**Summary & Outlook**

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Thanks for your attention!

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