CLIMATE OVERSHOOT COMMISSION

# Assessing Adaptation, Carbon Dioxide Removal, and Sunlight Reflection Options

In response to a request to illustrate different approaches to assessing options for adaptation, carbon dioxide removal (CDR), and sunlight reflection methods (SRM), this brief identifies assessment criteria and uses estimated values published by the IPCC to show how different adaptation and CDR options compare to one another along key dimensions, and points toward possible prioritization. It does not pursue assessment for SRM, however, for reasons discussed below.

## Adaptation

Because the availability of evidence regarding the effectiveness (or cost-effectiveness) of adaptation options is limited, adaptation researchers and the IPCC have embraced "potential feasibility" as the key criterion for assessment. According to the IPCC,

> feasibility refers to the potential for a mitigation or adaptation option to be implemented. Factors influencing feasibility are context-dependent, temporally dynamic, and may vary between different groups and actors. Feasibility depends on geophysical, environmental-ecological, technological, economic, socio-cultural and institutional factors that enable or constrain the implementation of an option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened (AR6 WGII SPM p. 21).

Potential feasibility is a composite of economic, technological, institutional, sociocultural, geophysical, and environmental feasibilities. Based on qualitative evaluations along these six dimensions, the IPCC has classified adaptation options in terms of low, medium, or high feasibility, with the confidence level associated with each classification characterized similarly as low, medium, or high. Table 1 summarizes this assessment of potential feasibility.

**See table on next page.**

**Table 1: Potential Feasibility of Different Adaptation Options**
Note: Values derived from IPCC AR6 WGII SPM Figure SPM.4(a).

<table>
<tr><th>Adaptation option</th><th>Potential feasibility</th><th>Confidence</th></tr>
<tr><td>Energy reliability</td><td rowspan="4">High</td><td rowspan="3">High</td></tr>
<tr><td>Forest-based adaptation</td></tr>
<tr><td>Resilient power systems</td></tr>
<tr><td>Improve water use efficiency</td><td>Medium</td></tr>
<tr><td>Climate services, including early warning systems</td><td rowspan="15">Medium</td><td rowspan="5">High</td></tr>
<tr><td>Coastal defense and hardening</td></tr>
<tr><td>Disaster risk management</td></tr>
<tr><td>Green infrastructure and ecosystem services</td></tr>
<tr><td>Integrated coastal zone management</td></tr>
<tr><td>Agroforestry</td><td rowspan="10">Medium</td></tr>
<tr><td>Biodiversity management and ecosystem connectivity</td></tr>
<tr><td>Health and health systems adaptation</td></tr>
<tr><td>Human migration</td></tr>
<tr><td>Improved cropland management</td></tr>
<tr><td>Livelihood diversification</td></tr>
<tr><td>Risk spreading and sharing</td></tr>
<tr><td>Social safety nets</td></tr>
<tr><td>Sustainable aquaculture and fisheries</td></tr>
<tr><td>Sustainable land use and urban planning</td></tr>
</table>

| Adaptation option | Potential feasibility | Confidence |
| --- | --- | --- |
| Sustainable urban water management | | |
| Water use efficiency and resource management | | |
| Efficient livestock systems | Low | Medium |
| Planned relocation and resettlement | Low | Low |

A supplementary assessment criterion for adaptation options employed by the IPCC is synergies with mitigation (defined as emissions reductions combined with CDR). Given the Commission's focus on integrating multiple approaches to reducing climate risk, the degree to which adaptation measures amplify emissions cuts and/or CDR is important to strategically addressing climate overshoot. As with potential feasibility, the IPCC has classified adaptation options in terms of low, medium, or high synergies with mitigation, with the confidence level associated with each classification characterized similarly as low, medium, or high. Table 2 summarizes this assessment of synergies with mitigation.

**See table on next page.**

**Table 2: Synergies with Mitigation of Different Adaptation Options**

Note: Values derived from IPCC AR6 WGII SPM Figure SPM.4(a).
The symbol "/" refers to insufficient evidence.

| Adaptation option | Synergies with mitigation | Confidence |
|---|---|---|
| Agroforestry | High | High |
| Biodiversity management and ecosystem connectivity | | |
| Energy reliability | | |
| Forest-based adaptation | | |
| Improved cropland management | | |
| Disaster risk management | | Medium |
| Green infrastructure and ecosystem services | | |
| Health and health systems adaptation | | |
| Livelihood diversification | | |
| Resilient power systems | | |
| Sustainable land use and urban planning | | Low |
| Efficient livestock systems | Medium | Medium |
| Sustainable aquaculture and fisheries | | |
| Water use efficiency and resource management | | |
| Human migration | Low | Low |
| Improve water use efficiency | | |
| Integrated coastal zone management | | |
| Planned relocation and resettlement | | |
| Risk spreading and sharing | | |

<table>
<tr><th>Adaptation option</th><th>Synergies with mitigation</th><th>Confidence</th></tr>
<tr><td>Social safety nets</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Sustainable urban water management</td></tr>
<tr><td>Climate services, including early warning systems</td><td rowspan="2">/</td><td rowspan="2">/</td></tr>
<tr><td>Coastal defense and hardening</td></tr>
</table>

## CDR

CDR options may be assessed using multiple criteria. Technology readiness level (TRL) is a criterion that estimates technological maturity on a scale from 1 to 9, with 1 being the least developed and 9 the most developed. Table 3 summarizes TRLs for different CDR options.

**Table 3: TRLs of Different CDR Options**

Note: Values derived from IPCC AR6 WGIII Table TS.7.

| CDR option | Technology readiness level |
|---|---|
| Afforestation/ Reforestation | 8-9 |
| Agroforestry | |
| Improved forest management | |
| Peatland and coastal wetland restoration | |
| Soil Carbon Sequestration in croplands and grasslands | |
| Biochar | 6-7 |
| DACCS | 6 |
| BECCS | 5-6 |
| Enhanced weathering | 3-4 |
| "Blue carbon" in coastal wetlands | 2-3 |
| Ocean alkalinity enhancement | 1-2 |
| Ocean fertilization | |

Cost, in terms of US dollars per metric ton of carbon dioxide ($CO_2$) removed, is another criterion. Table 4 summarizes available cost range estimates for different CDR options.

**Table 4: Costs of Using Different CDR Options**

Note: Values derived from IPCC AR6 WGIII Table TS.7. Order based on cost range midpoints. Insufficient data available for agroforestry, blue carbon, improved forest management, and peatland and coastal wetland restoration.

| CDR option | Cost (USC/t$CO_2$) |
| --- | --- |
| Soil Carbon Sequestration in croplands and grasslands | 45-100 |
| Afforestation/ Reforestation | 0-240 |
| Enhanced weathering | 50-200 |
| Ocean alkalinity enhancement | 40-260 |
| Biochar | 10-345 |
| DACCS | 100-300 |
| BECCS | 15-400 |
| Ocean fertilization | 50-500 |
| Agroforestry | - |
| "Blue carbon" in coastal wetlands | - |
| Improved forest management | - |
| Peatland and coastal wetland restoration | - |

Removal potential, or the number of gigatonnes of $CO_2$ any option is estimated to be capable of removing from the atmosphere every year, is another CDR assessment criterion. Table 5 summarizes estimated ranges of annual removal potentials for different CDR options.

**Table 5: Removal Potentials of Different CDR Options**

Note: Values derived from IPCC AR6 WGIII Table TS.7. Order based on range midpoints.

| CDR option | Removal Potential ($GtCO_2$/yr) |
|---|---|
| Ocean alkalinity enhancement | 1-100 |
| DACCS | 5-40 |
| BECCS | 0.5-11 |
| Afforestation/ Reforestation | 0.5-10 |
| Soil Carbon Sequestration in croplands and grasslands | 0.6-9.3 |
| Agroforestry | 0.3-9.4 |
| Biochar | 0.3-6.6 |
| Enhanced weathering | 2-4 |
| Ocean fertilization | 1-3 |
| Peatland and coastal wetland restoration | 0.5-2.1 |
| Improved forest management | 0.1-2.1 |
| "Blue carbon" in coastal wetlands | < 1 |

A fourth criterion is storage timescale, or the period over which carbon removed from the atmosphere using different CDR options is estimated to be secure. Timescales include decades to centuries, centuries to millennia, 10,000-100,000 years, and potentially permanent. Table 6 summarizes estimated storage timescales for different CDR options.

**Table 6: Storage Timescales of Different CDR Options**

Note: Values derived from IPCC AR6 WGIII Table TS.7.

| CDR option | Storage Timescale |
|---|---|
| BECCS | potentially permanent |
| DACCS | |
| Enhanced weathering | 10 to 100 thousand years |
| Ocean alkalinity enhancement | |
| Ocean fertilization | 100s to 1000s years |
| Afforestation/ Reforestation | |
| Agroforestry | |
| Biochar | |
| "Blue carbon" in coastal wetlands | |
| Improved forest management | |
| Peatland and coastal wetland restoration | |
| Soil Carbon Sequestration in croplands and grasslands | |

A final criterion is risk. Risk assessments of different CDR options are largely subjective. Importantly, risks generally increase with the scale of deployment. Table 7 presents CDR options organized according to high, medium, and low levels of risk based on observations from key contributions to the literature (e.g., Fuss et al. 2018).

**Table 7: Risk Levels of Different CDR Options**

Note: Values represent best estimates of current scientific consensus.

| **CDR option** | **Risk** |
|---|---|
| BECCS | High |
| Ocean fertilization | |
| Afforestation/ Reforestation | Medium |
| DACCS | |
| Enhanced weathering | |
| Ocean alkalinity enhancement | |
| Soil Carbon Sequestration in croplands and grasslands | |
| Agroforestry | Low |
| Biochar | |
| "Blue carbon" in coastal wetlands | |
| Improved forest management | |
| Peatland and coastal wetland restoration | |

Thus, assessing CDR options can be based on at least five criteria: TRL, cost, removal potential, storage timescale, and risk. Other assessment criteria are conceivable, for example, co-benefits or measurability, but these have not been systematically explored in the literature. In terms of prioritizing criteria, fundamental concerns about effectiveness and removal integrity suggest that storage timescale–permanence–should rank higher than other dimensions: ultimately, CDR can only succeed if stored $CO_2$ is reliably secured.

## SRM

At present, SRM options are very difficult to assess due to the limited research that has been conducted to date; the extremely limited research conducted on SRM options other than SAI and MCB effectively restricts consideration to these two methods. One obvious criterion is maximum cooling (negative radiative forcing) potential. SAI appears capable of substantially offsetting global warming, but MCB may be limited in this regard (MacMartin, Ricke, and Keith 2018).

Another seemingly obvious assessment criterion for SRM is risk. Indeed, both SAI and MCB pose significant risks. The magnitude of these risks, however, depends fundamentally on the way in which either option might be implemented. SRM does not present a binary choice–to use it or not to use it–but instead a choice among many possible deployment schemes, including no deployment at all. In general, risks scale with the intervention's magnitude, duration, and rate at which it is ramped up and phased down.

In addition, risks also depend on what other climate policies are pursued simultaneously with SRM and their success. For example, the risk of a termination shock (following abrupt and sustained termination of a high magnitude of SRM) depends critically both on the nature of the SRM intervention undertaken, and on whether and how emissions reductions and/or CDR affect atmospheric greenhouse gas concentrations while the intervention is ongoing. If the SRM intervention were large, and greenhouse gas concentrations grew over the course of deployment, then the risk posed by termination shock could be very high. If, on the other hand, the SRM intervention were moderate and greenhouse gas concentrations declined during deployment, the risk posed by termination shock may be small.

Thus, the level of risk characterizing either SAI or MCB is ultimately a function of the specific deployment scheme under consideration, and the ambition and effectiveness of complementary policy approaches. In the absence of information about both the specific deployment scheme being contemplated and the policies that would accompany it (ideally in the context of an integrated strategy), it is not possible to provide meaningful risk assessments of SRM.

## References

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