Negative emissions in long-term climate scenarios
1. Why are we talking about negative emissions all?
### 2. Proposed negative emission technologies

#### Natural

**Forestry / Agriculture**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afforestation/Reforestation</td>
<td>Tree growth takes up CO₂ from the atmosphere</td>
</tr>
<tr>
<td>Biochar</td>
<td>Partly burnt biomass is added to soil absorbing additional CO₂</td>
</tr>
<tr>
<td>Soil carbon sequestration</td>
<td>Land management changes increase the soil carbon content, resulting in a net removal of CO₂ from the atmosphere</td>
</tr>
<tr>
<td>Other land-use/Wetlands</td>
<td>Restoration or construction of high carbon density, anaerobic ecosystems</td>
</tr>
</tbody>
</table>

#### Combined

<table>
<thead>
<tr>
<th>Technology</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Bioenergy with Carbon Capture and Storage (BECCS)</td>
<td>Plants turn CO₂ into biomass that fuels energy systems; CO₂ from conversion is stored underground.</td>
</tr>
</tbody>
</table>

#### Technological

**Energy / Industry**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Accelerated Weathering</td>
<td>Natural minerals react with CO₂ and bind them in new minerals.</td>
</tr>
<tr>
<td>Direct Air Capture</td>
<td>CO₂ is removed from ambient air and stored underground.</td>
</tr>
<tr>
<td>Ocean Alkalinity Enhancement</td>
<td>Alkaline materials are added to the ocean to enhance atmospheric drawdown and negate acidification</td>
</tr>
<tr>
<td>CO₂ to durable carbon</td>
<td>CO₂ is removed from the atmosphere and bound in long-lived materials</td>
</tr>
</tbody>
</table>
3. Net emissions per sector in a German scenario

- GHG emission reduction potential differs significantly between different sectors
- Almost CO₂ neutral, most net emissions are from non-CO₂ gases
- More than half of remaining emissions from agriculture
4. Emissions and sinks in national and regional scenarios

Gross CO2, non CO2 emissions & sinks in (almost) neutral year 2050, indexed to gross GHG emissions of the historic year of reference*

- Energy industries incl. fugitive emissions
- Industry incl. process emissions
- Buildings
- Transport incl. international air and maritime
- Waste**
- Agriculture***
- LULUCF (Sink)
- BECCS

* For Nordic, gross CO2 emissions only. The historic reference year is respectively: 2010 (CS 95, Nordic), 2015 (nW 2017).
** For Nordic, included in energy industries.
*** For Nordic, included in industry.
5. Bio-energy with carbon capture and storage (BECCS)

- **Needs large bioenergy potentials**
  - Either: Sparsely populated countries (e.g. Scandinavia)
  - Or: Large bioenergy imports

- **Strongly interacts with other assumptions in the energy system**
  - BECCS is stationary technology → not useful if bioenergy is allocated mainly in the transport sector
  - Can lower the pressure for renewable energy and energy efficiency
6. LULUCF sinks

- More than simply planting trees
  - Afforestation and reforestation
  - Protection and improvement of soils

- Strongly interacts with agriculture strategy
  - Reduced animal numbers $\rightarrow$ new areas available
  - Agricultural soil can become a carbon sink by changing the agricultural practice

- LULUCF sinks are very important in holistic approaches (i.e. modeling more than just the energy sector)
7. Conclusion

-General setup and perimeter of modeling strongly determines the choice of negative emission options

- Many scenarios use only one negative emission option
- No result of (cost) optimisation: *Choice between different negative emission options commonly determined by preferences of modelers and/or country-specifics*
- BECCS is often the only negative emission technology in energy-only approaches

-Different priorities of negative emission options

- Either: equal to other measures (renewables, energy efficiency…)
- Or: measure of last resort → avoid the last few percentage points of GHG reduction