PROSPECTS FOR CO_2 CAPTURE, SEQUESTRATION, UTILIZATION, AND NEGATIVE EMISSIONS

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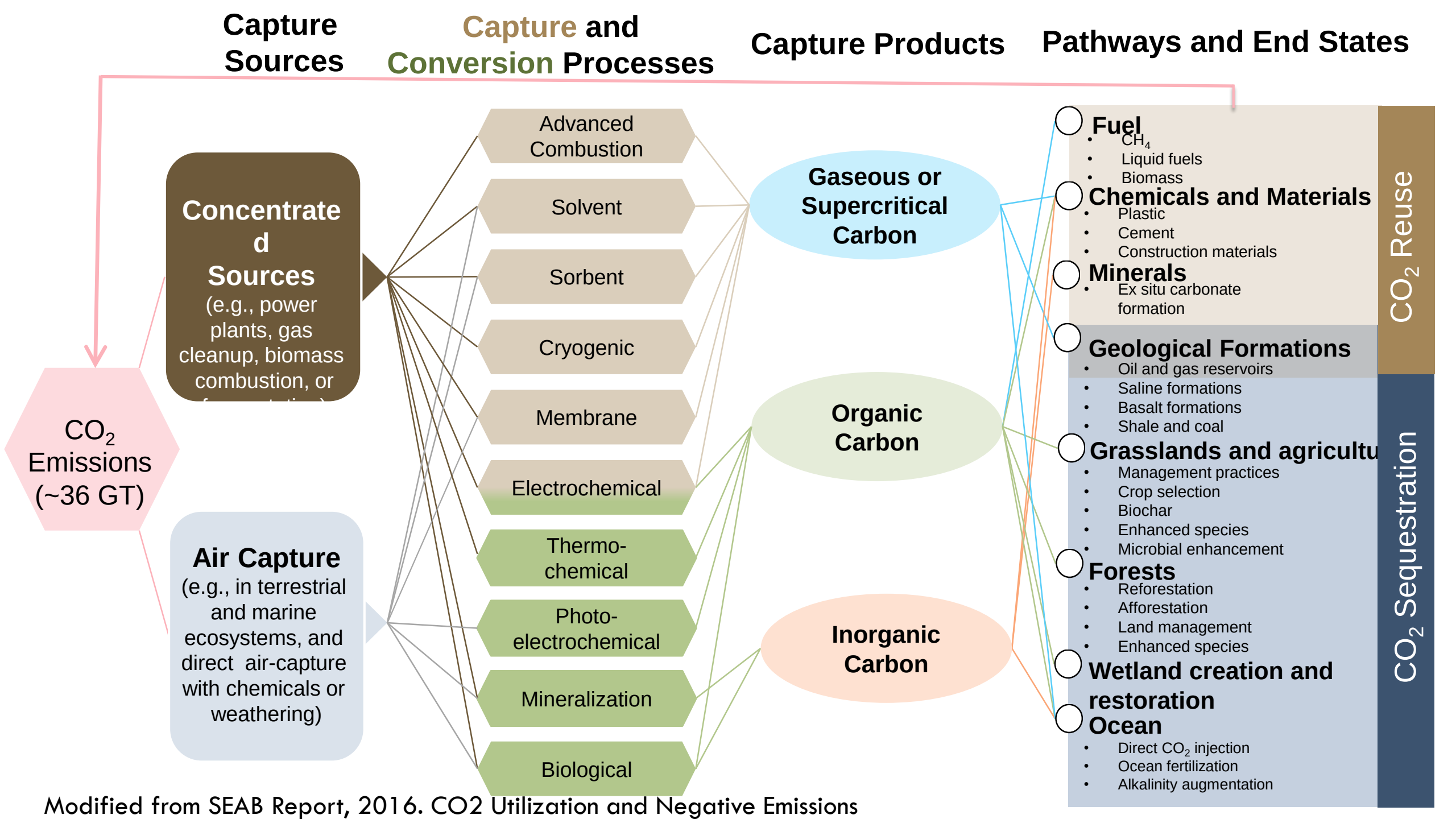
Topics

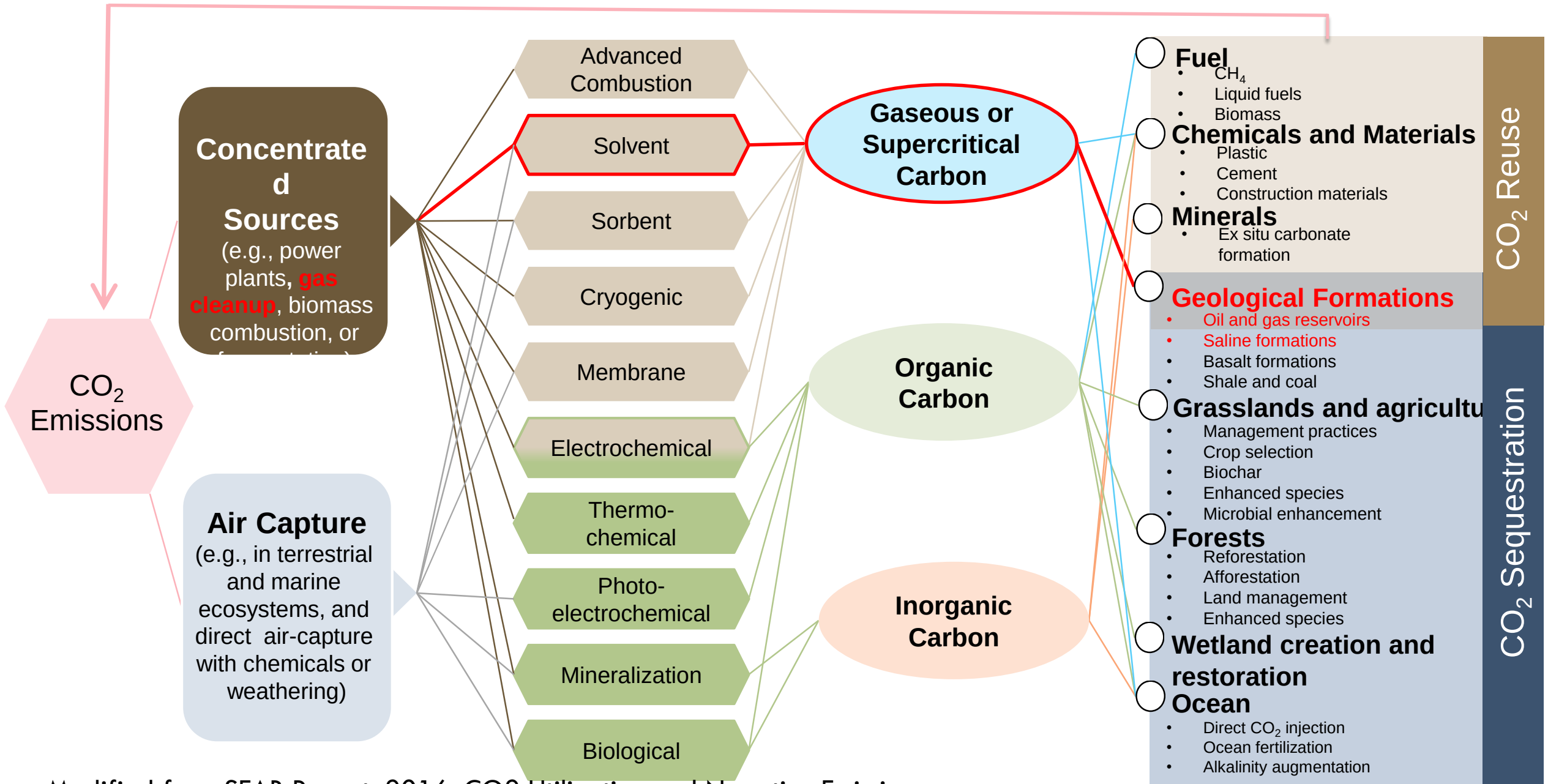
1. Landscape for CO_2 capture, utilization, negative emissions, and sequestration
2. Status of CO_2 sequestration in deep geological formations
3. Conditions for Successful Scale-Up of CCS & Negative Emissions Using BECCS (Bioenergy + CCS)

Landscape for CO_2 capture, utilization, sequestration, and negative emissions



Modified from SEAB Report, 2016. CO2 Utilization and Negative Emissions

Carbon Capture and Storage Today



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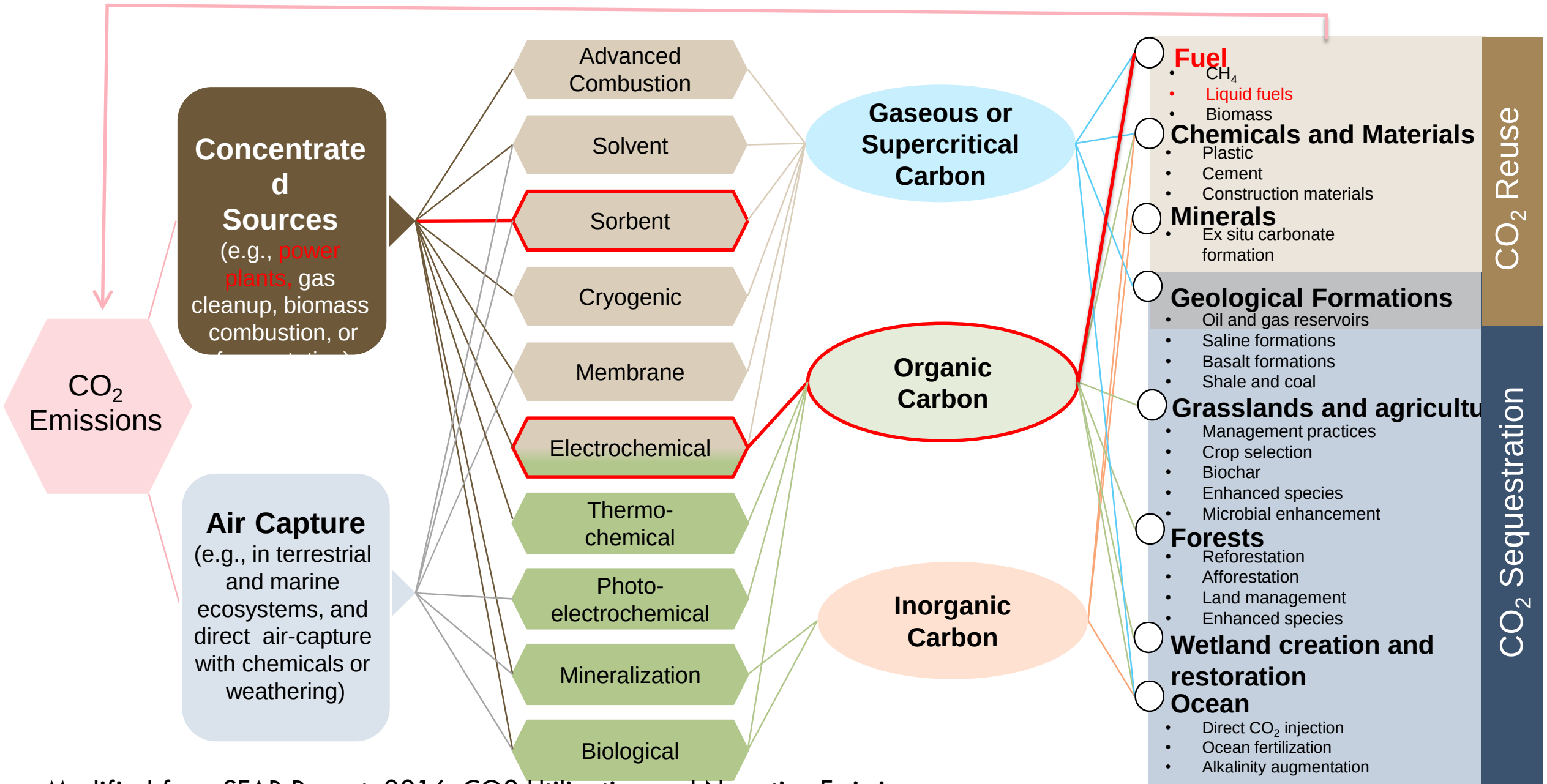
Example of Possible CO_2 Utilization in the Future



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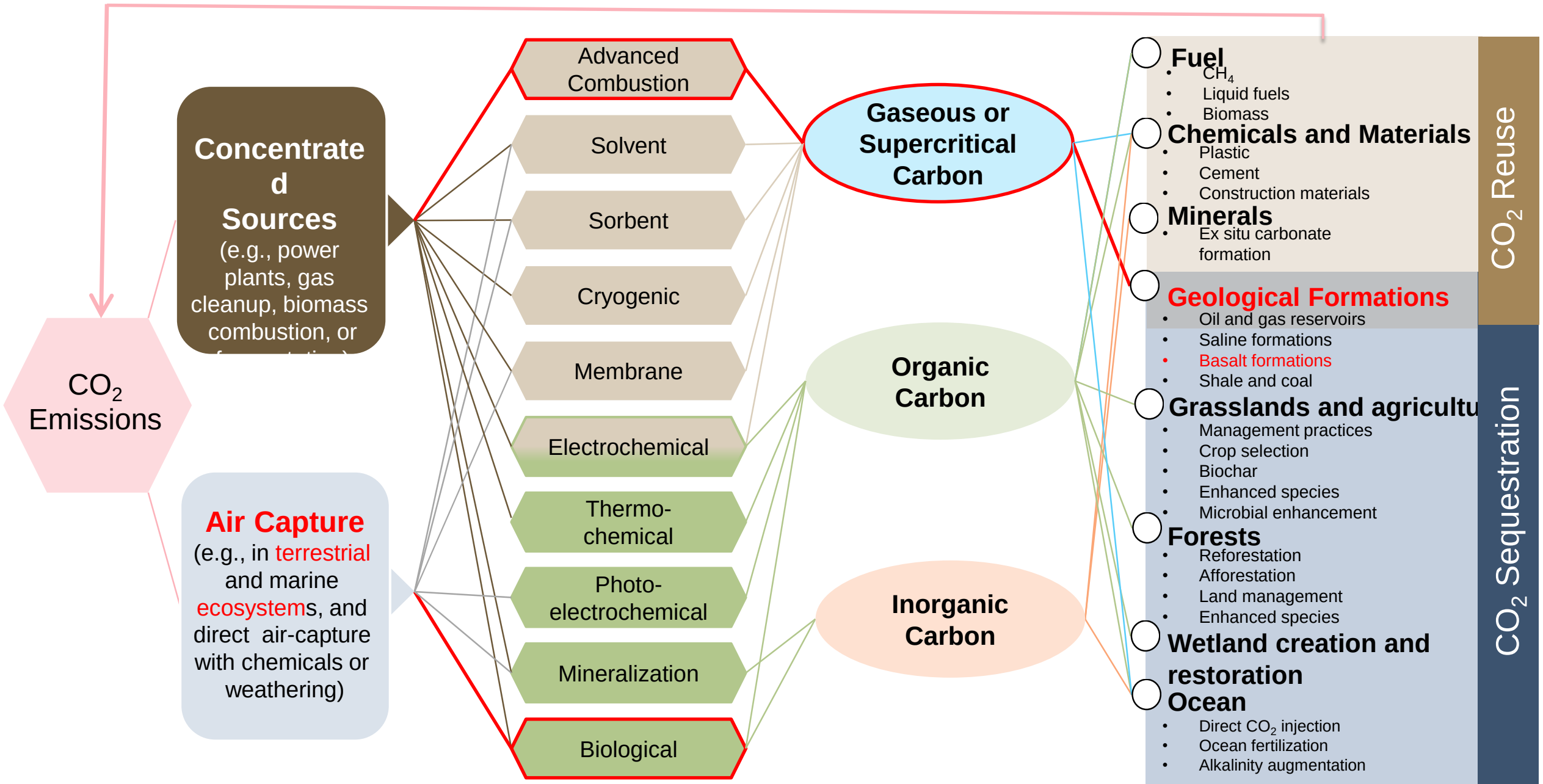
Example of Possible CO_2 Negative Emissions in the Future



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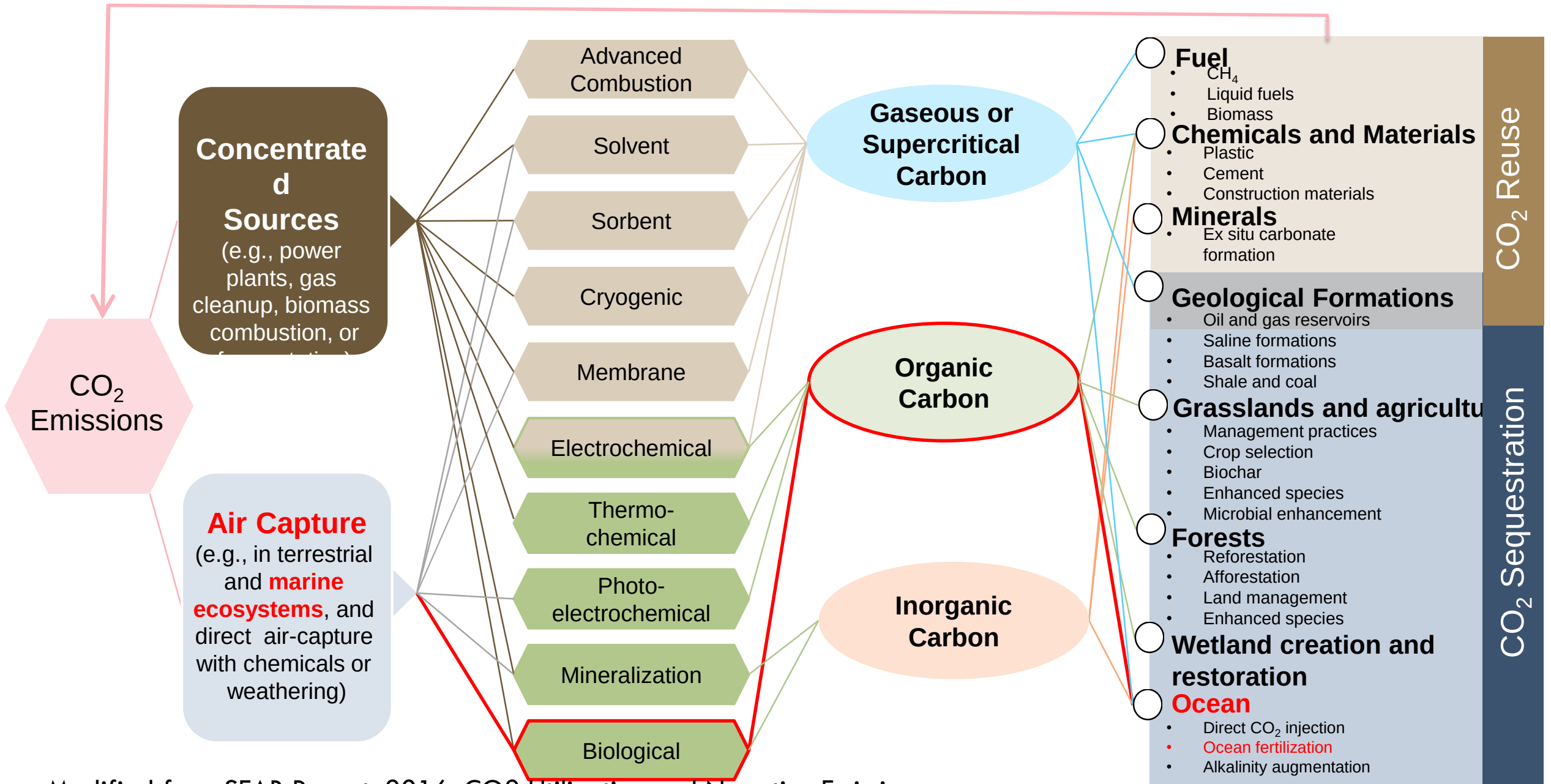
Example of Possible CO_2 Negative Emissions in the Future



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A Rich Landscape of Options, But…

- Key issues affecting feasibility of CCUS and negative emissions
  - Need gigatonne scale solutions (36 GT emissions today from fossil fuels)
  - Energy inputs for capture and conversion are large (~20% to >>100% primary energy content of fuels)
    - Consequently, carbon-free energy is needed for these processes
  - Systems accounting for **environmental and societal impacts** and **life-cycle emissions** of CO_2 management options
  - Permanence of sequestration options
  - Cost
  - Time and resources to scale-up of new solutions

Readiness for CCUS and Negative Emissions at Scale

Here Today

- CO_2 capture from high purity sources
- CO_2 capture from natural gas cleanup
- CO_2-enhanced oil recovery
- CO_2 storage in saline aquifers in sedimentary formations
- Others (e.g. reforestation)?

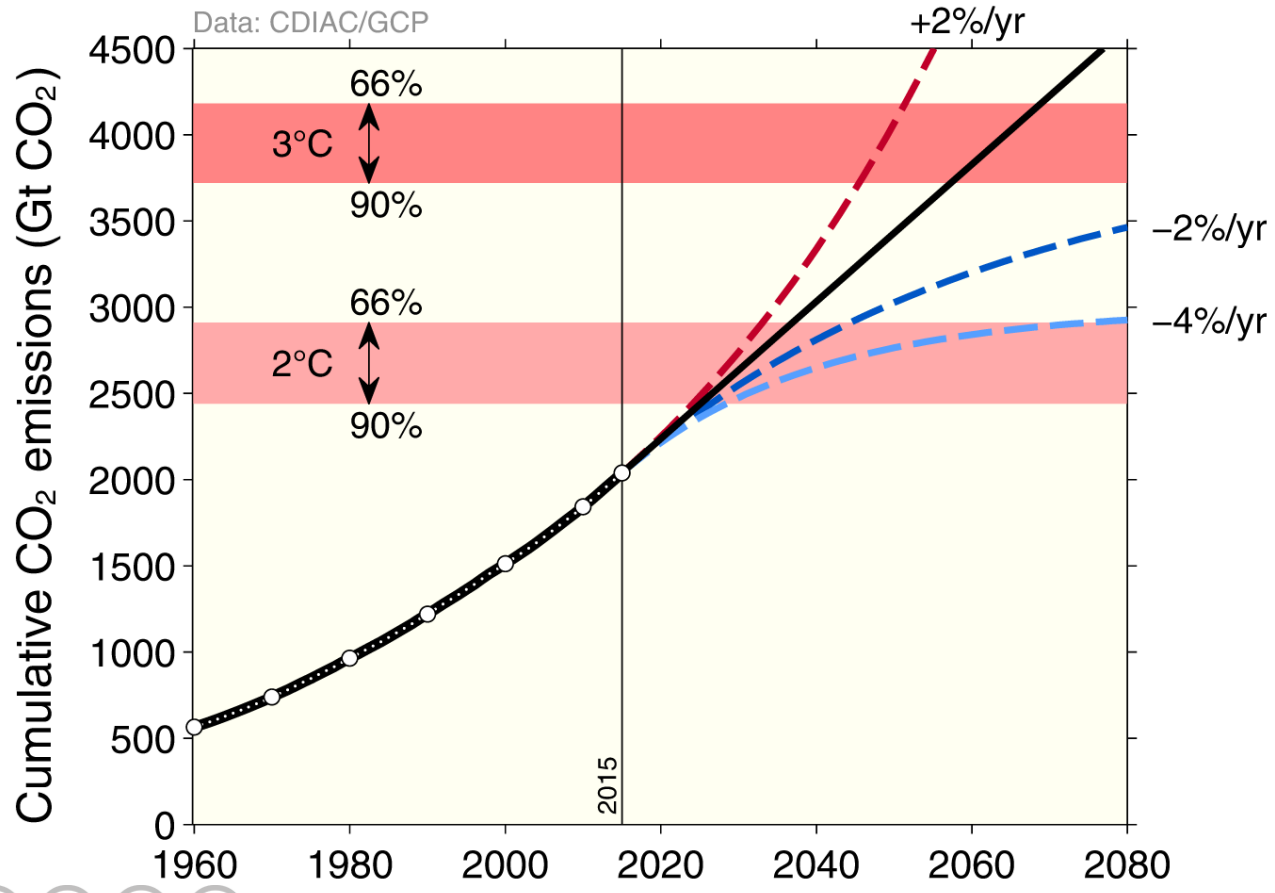
Coming Soon

- CO_2 capture from coal and natural gas power plants
- Co-optimized CO_2 + storage
- Bioenergy + CCS for negative emissions

On the Horizon

- Direct air capture
- Electrocatalysis of CO_2 for CO production
- Advanced energy conversions for CO_2 capture
- Sequestration as minerals in basalt
- Soil carbon enhancement
- Many others

About 4% per Year Reductions in Emissions Will be Needed to Limit Warming to 2º C



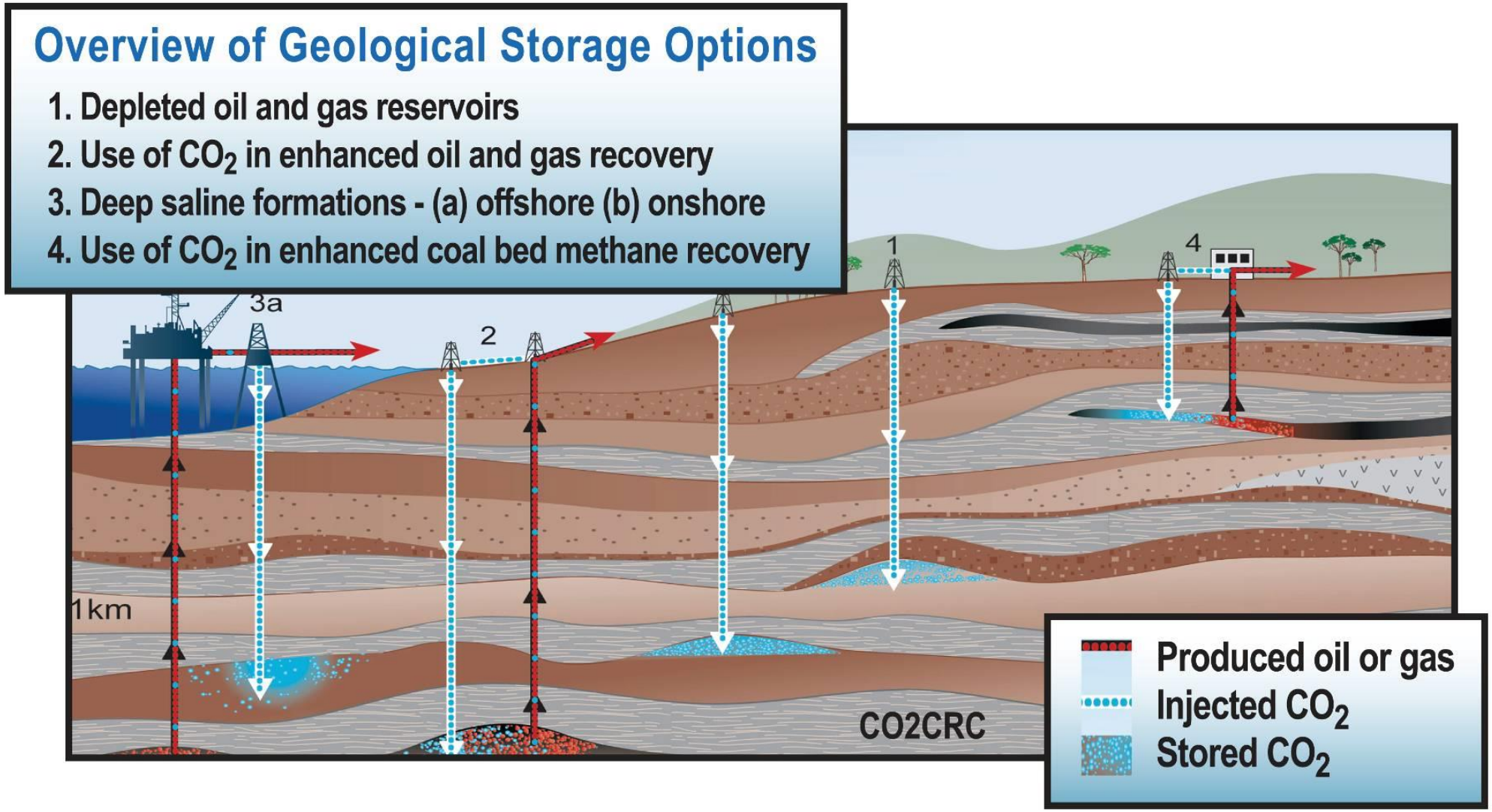
- Don't have time to wait
- Scale-up needs to begin happening now
- Carbon capture from concentrated emission sources with geological sequestration is the only option available at scale today

Global Carbon Project

- The red shaded areas are the chance of exceeding different temperatures above
- pre-industrial levels using the cumulative emissions concept
- Source: Jackson et al 2015b; Global Carbon Budget 2015

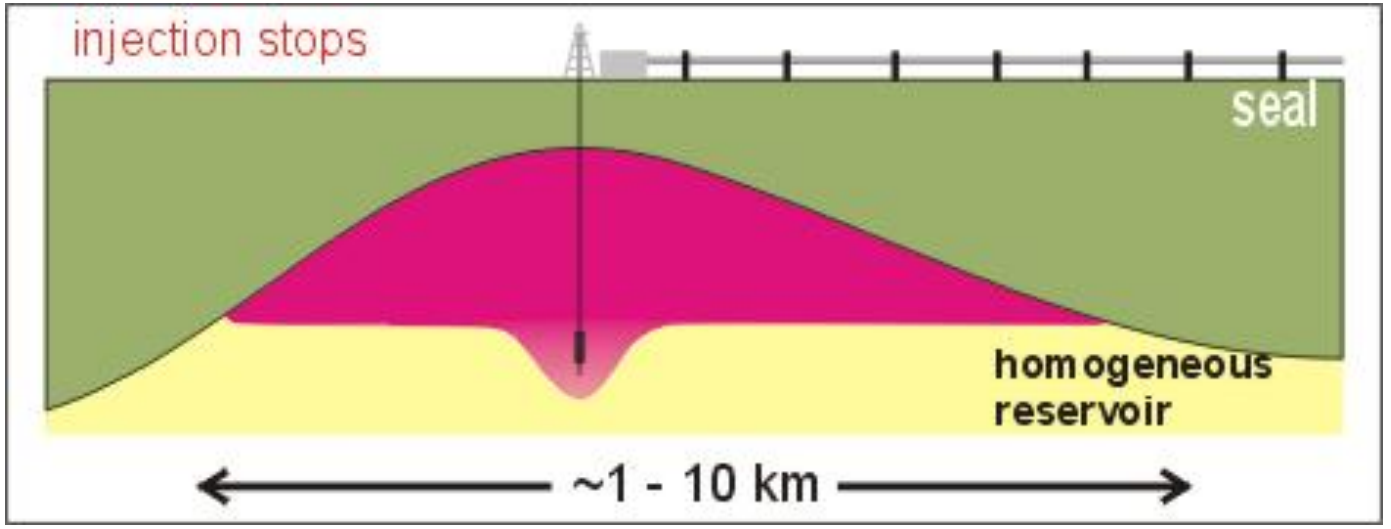
Status of CO_2 sequestration in deep geological formations

Options for Geological Storage



Basic Concept of Geological Storage of CO_2

- Injected at depths of 1 km or deeper into rocks with tiny pore spaces
- Primary trapping
  - Beneath seals of low permeability rocks



Courtesy of John Bradshaw

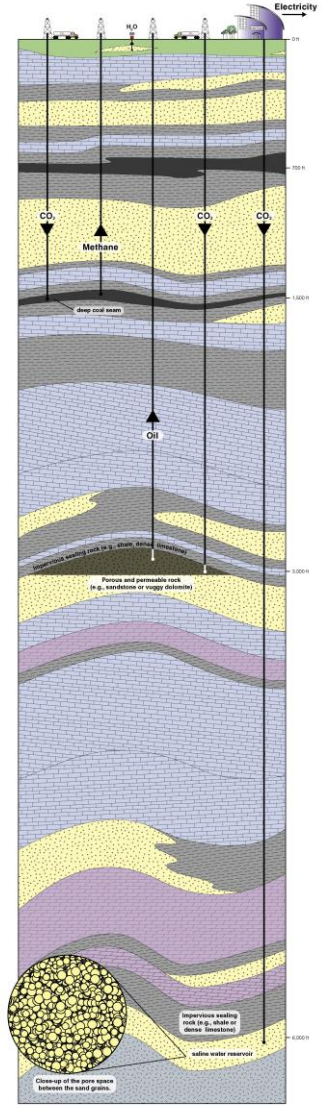
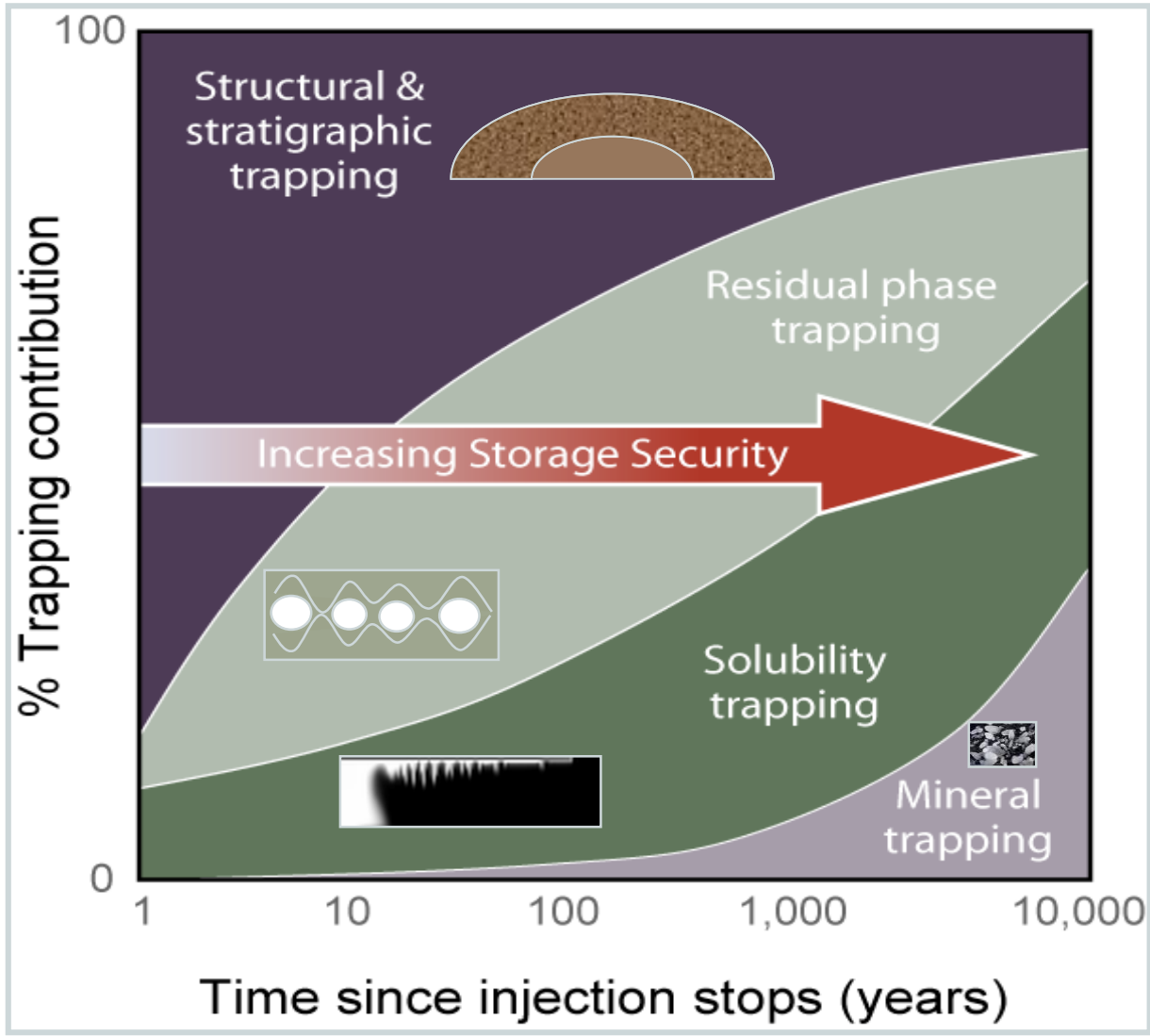


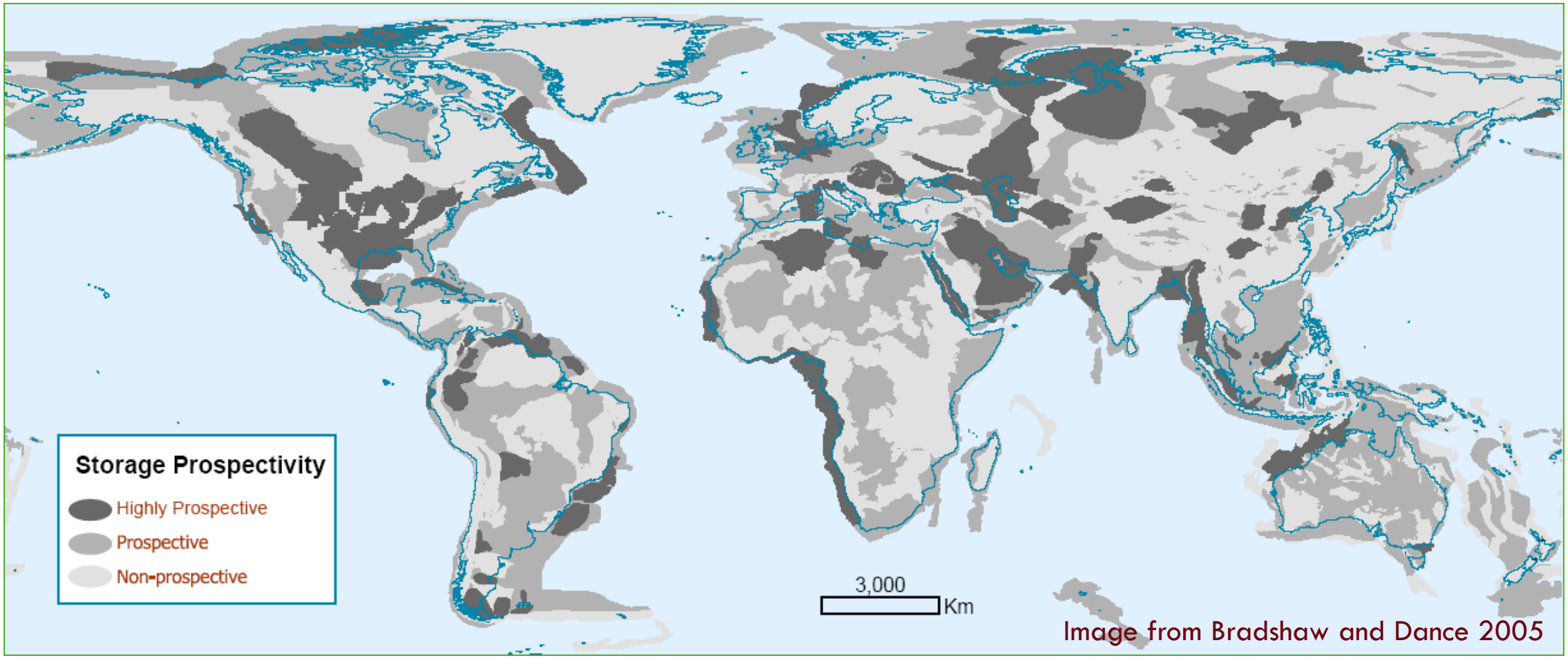
Image courtesy of ISGS and MGSC

Secondary Trapping Mechanisms Increase Storage Security Over Time

- Solubility trapping
  - CO_2 dissolves in water
- Residual gas trapping
  - CO_2 is trapped by capillary forces
- Mineral trapping
  - CO_2 is converted to minerals
- Adsorption trapping
  - CO_2 adsorbs insoluble organic mater in shale and coal

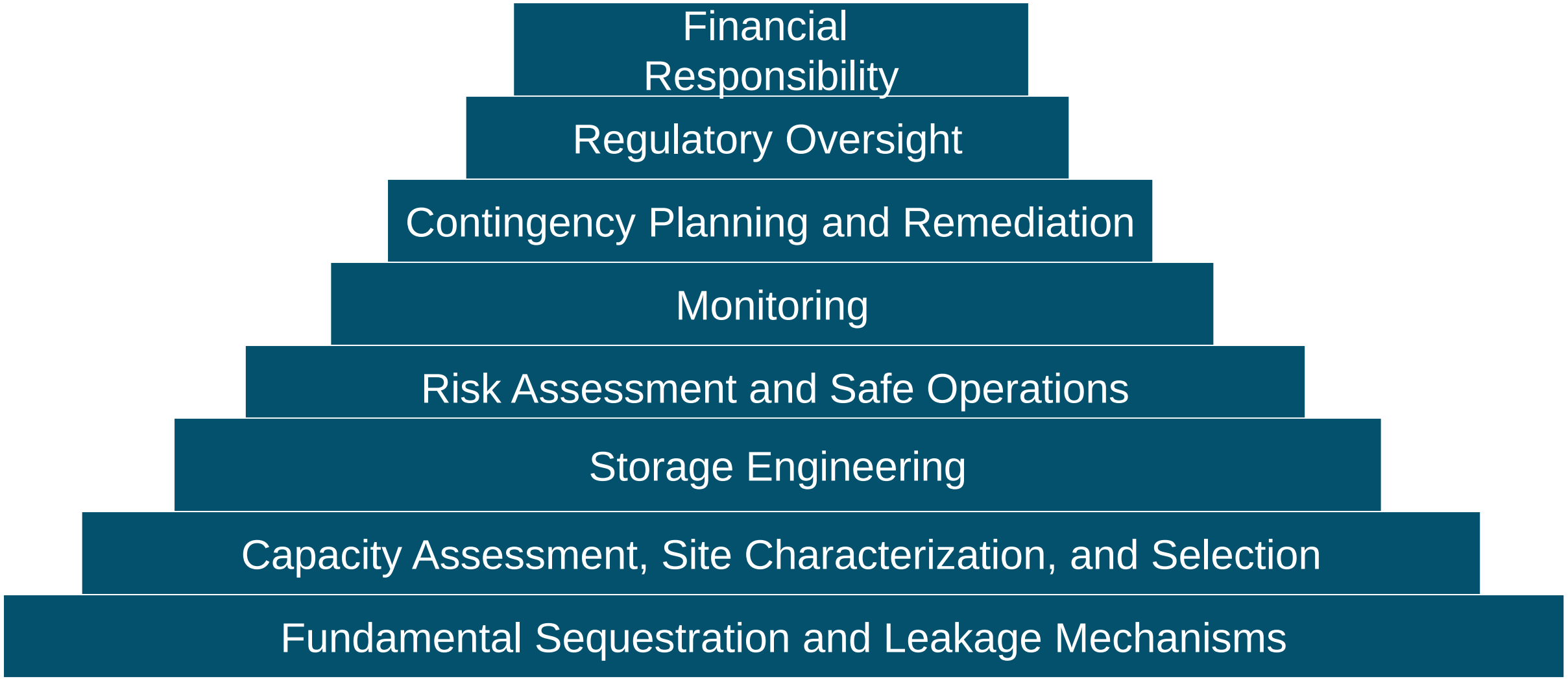


Prospectivity for Storage Around the World

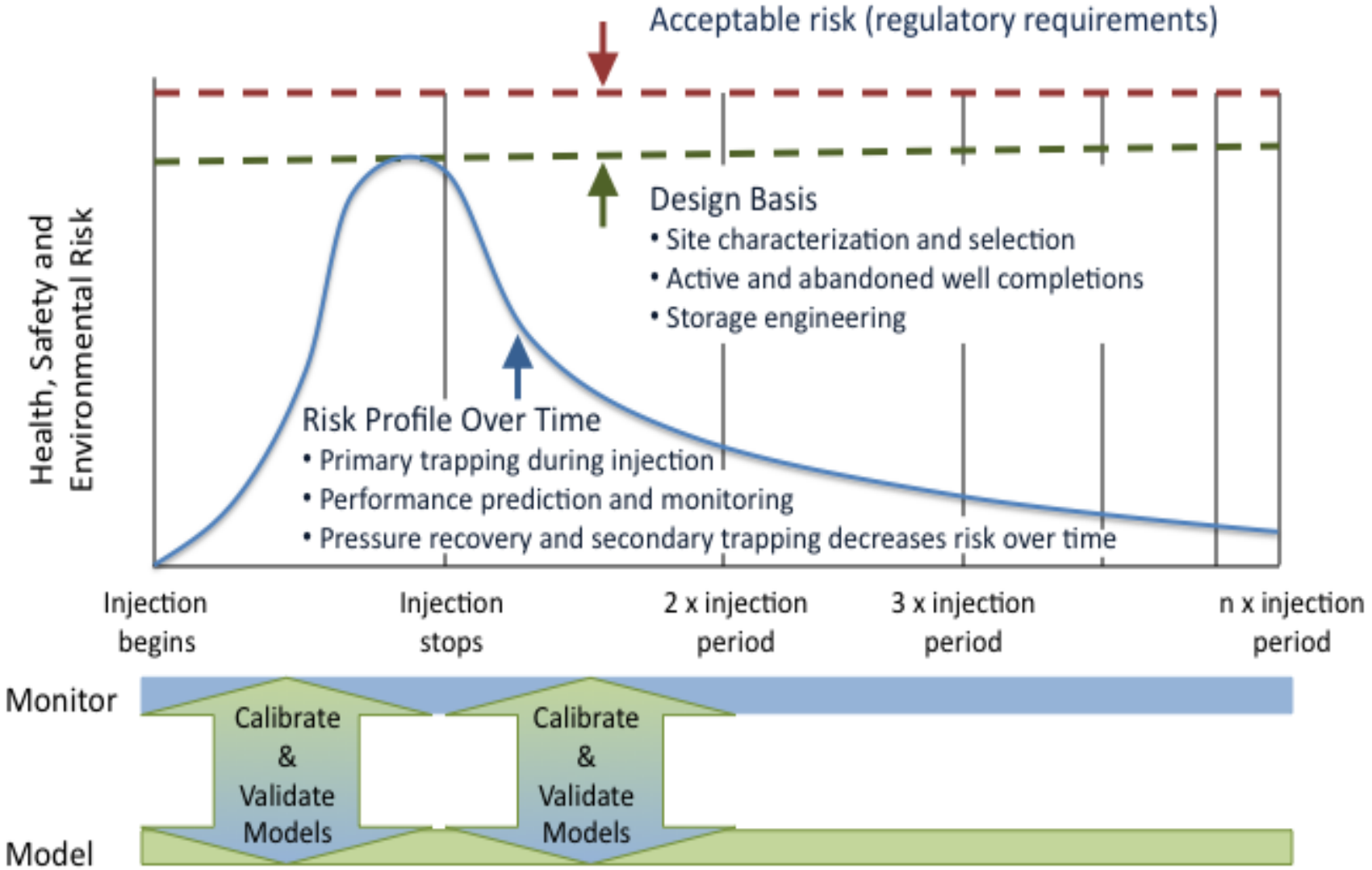


~5,000 to 25,000 GT of sequestration capacity: DeConnick and Benson, 2014.

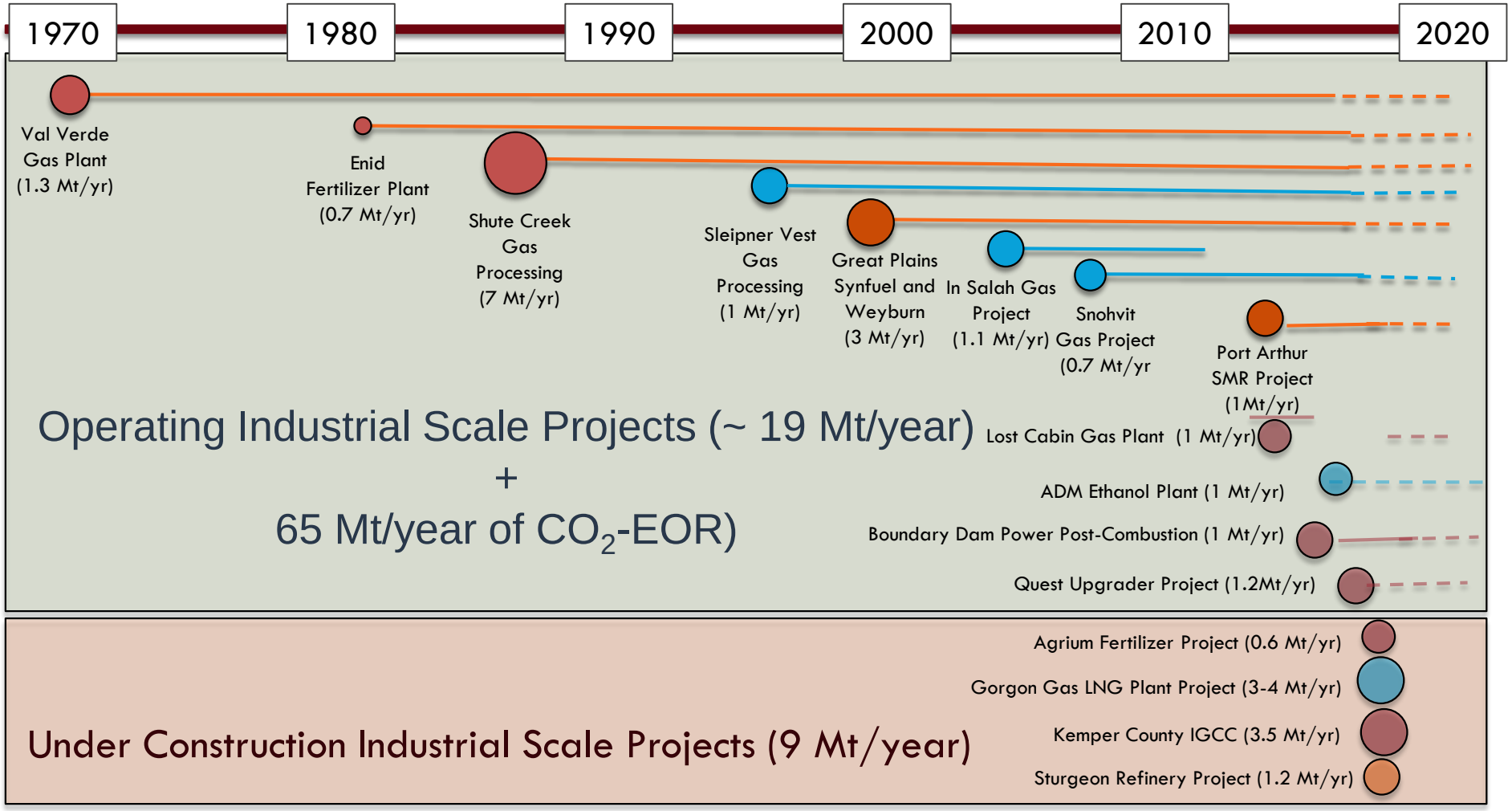
CO_2 Storage Safety and Security Pyramid



Environmental Risks of CCS Appear Manageable, but Regulations are Needed.



CCS Continues to Expand Worldwide

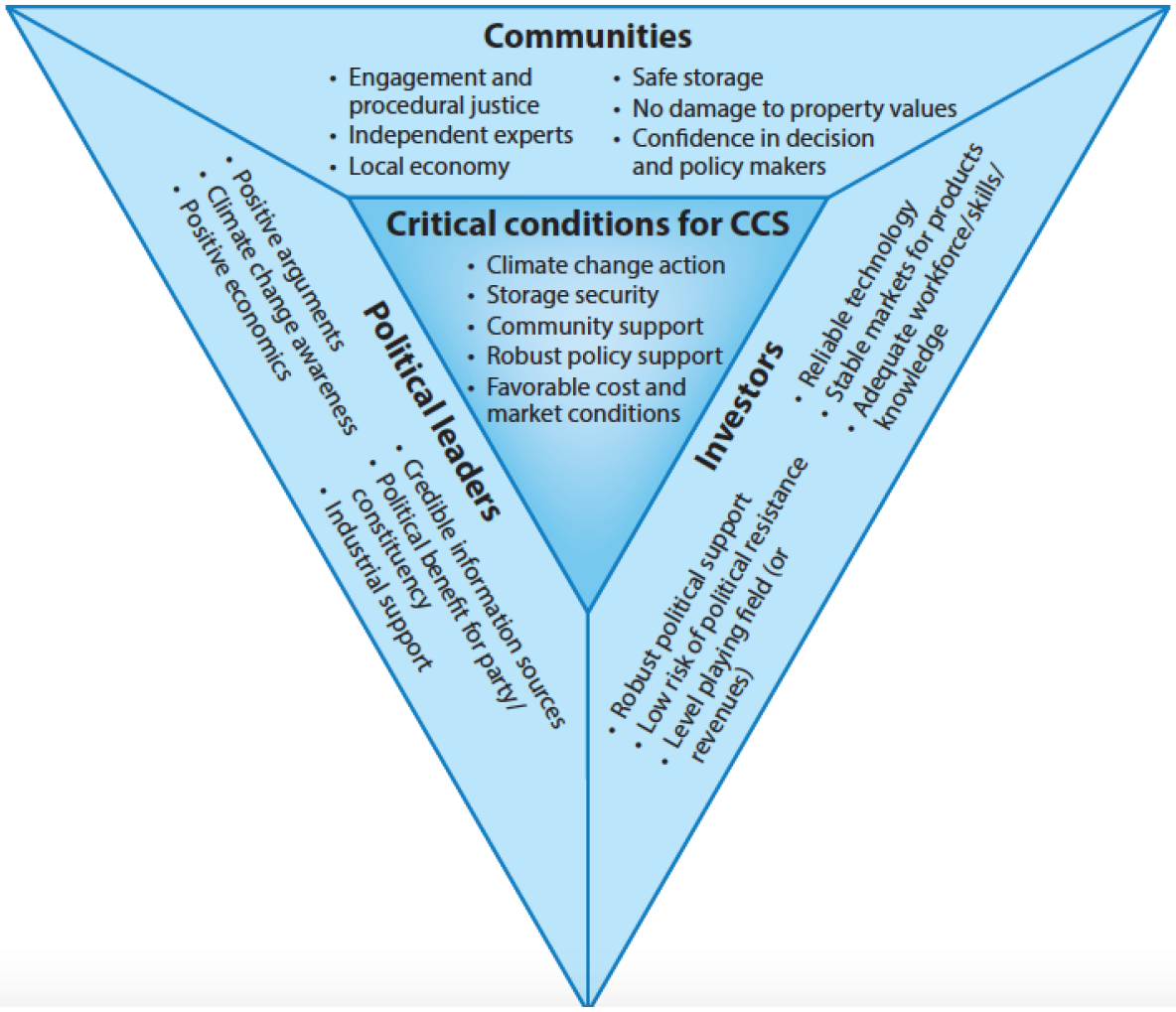


Updated from DeConninck and Benson, 2014. Annual Reviews in Energy and Environment.

Twenty Years of Progress

Financial Responsibility	Insurance policies are available for CO_2 storage projects. Long term liability approaches have been developed in some countries.
Regulatory Oversight	Government regulations for CO_2 storage have been developed in the U.S., Europe, Canada, and Australia.
Contingency Planning and Remediation	Developed methods for contingency planning and remediation of leakage from wells and fault zones.
Monitoring	Development and demonstration of many methods for monitoring CO_2 leakage and tracking plume migration.
Risk Assessment and Safe Operations	Experience from 13 industrial scale and over 20 pilot scale projects show risks are well understood and manageable.
Storage Engineering	Identification of the need for and strategies for to manage pressure buildup to mitigate risks of induced seismicity and leakage.
Site Characterization and Assessment	Globally harmonized capacity assessment showing 5,000 to 25,000 GT sequestration capacity .
Fundamental Storage and Leakage Mechanisms	Understanding, quantification and time-scales for secondary trapping processes show these can play an important role in mitigating risks.

Conditions for Successful Scale-Up of CCS & Negative Emissions Using BECCS



- Cost reductions for CO_2 capture
- Strong support for climate action
- Confidence about secure carbon sequestration
- A price on carbon > \$30/tonne CO_2
- Prioritization of emissions reductions using an economy-wide strategy
- Constructive engagement of communities at sequestration sites

DeConninck and Benson, 2014. Annual Reviews in Energy and Environment.