Systems thinking to inform DAC R&D needs

Delivering negative emissions under different conditons

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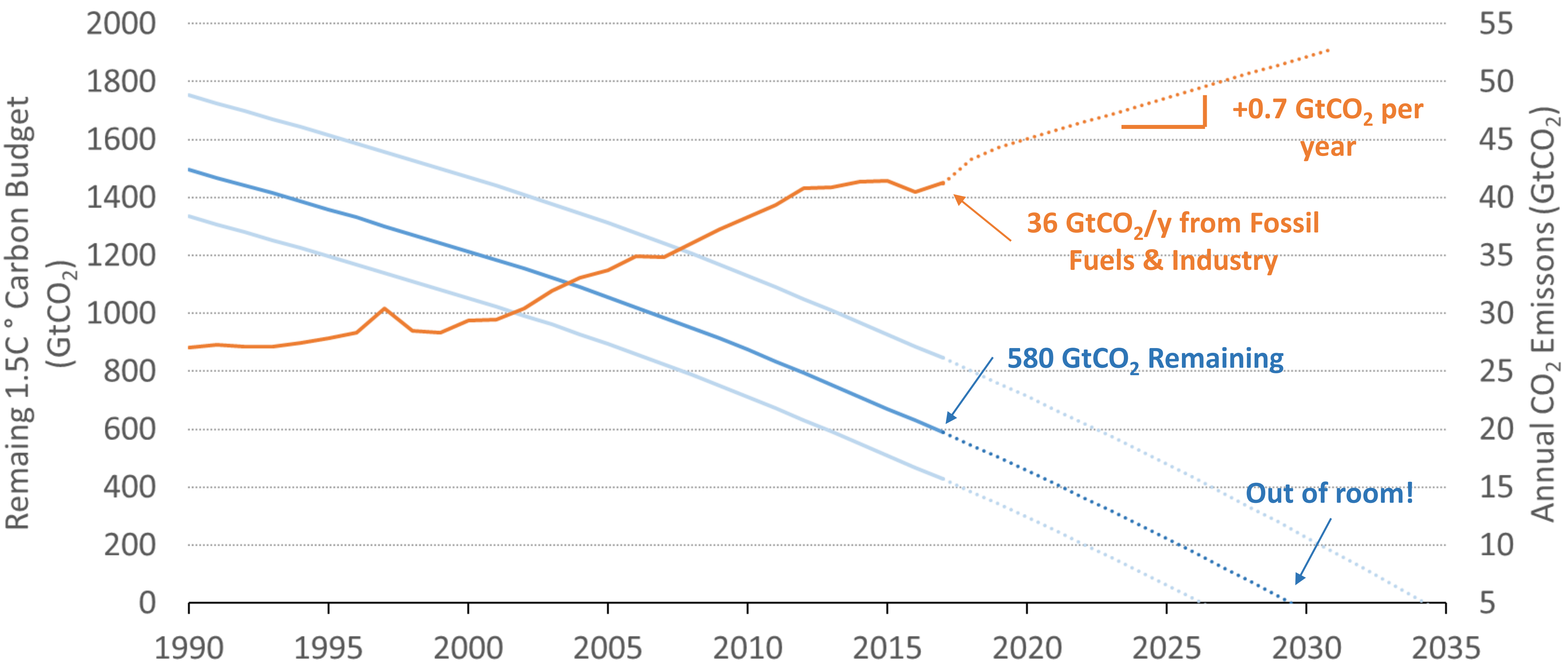
The exigencies of the carbon budget



Carbon budget based on IPCC SR1.5, Table 2.2 (50% TCRE solid blue; 33% and 67% dashed) with historical emissions on Le Quéré et al., 2018. Dotted lines are based on an extension of cumulative emissions trends from 1990 to 2017.

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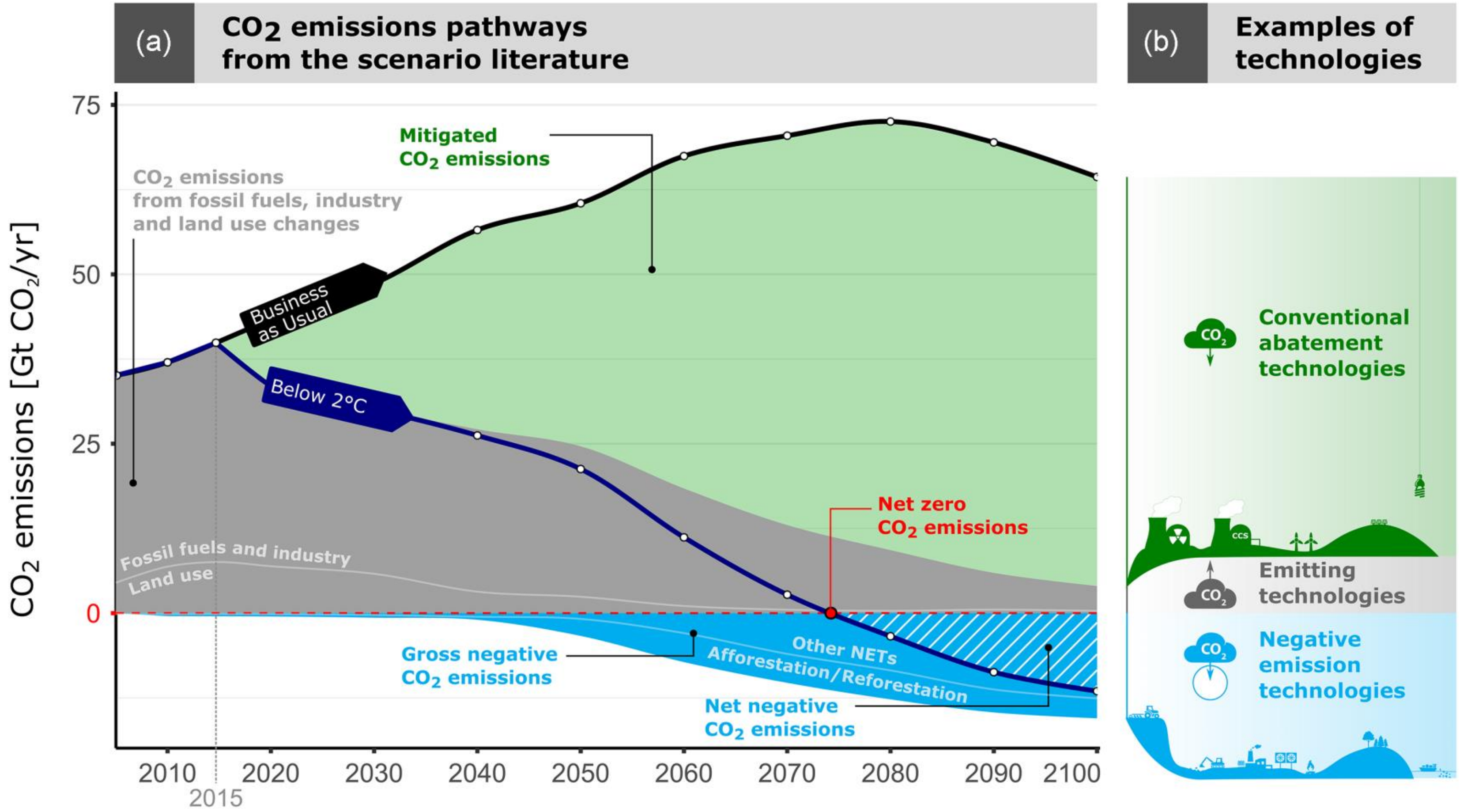
Using the budget to define timelines for action



Fuss et al., 2018

Absent a **nearly immediate peak and rapid decrease in emissions to zero, carbon dioxide removal (CDR) is needed** to meet the carbon budget constraint

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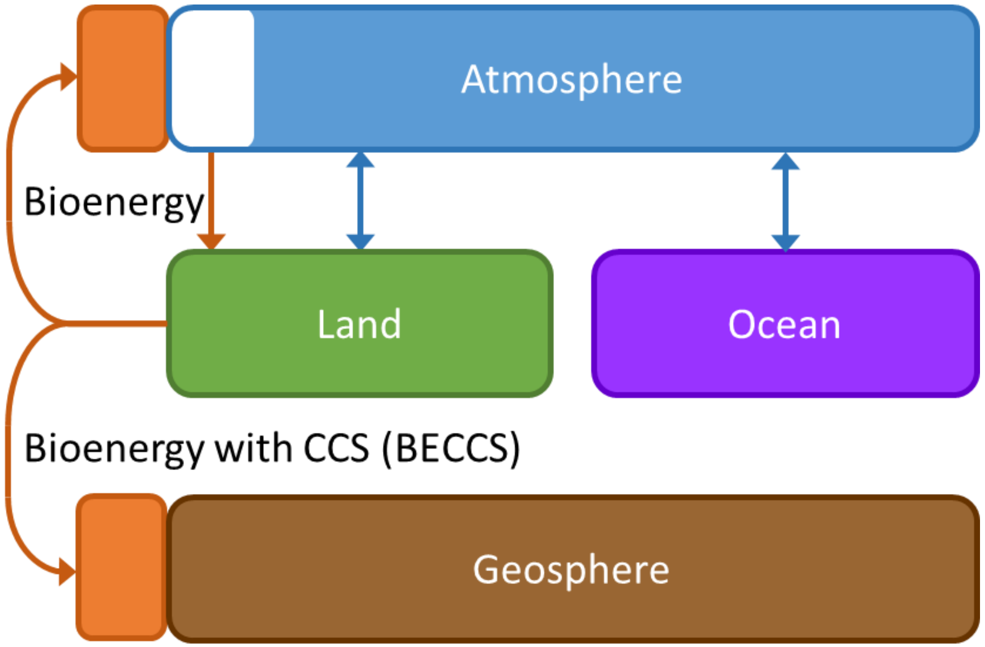
Three *necessary* characteristics for negative emissions technologies



Smith et al., 2016

1. Remove CO_2 from the atmosphere (or ocean)
2. Sequester this CO_2 permanently (or nearly), and
3. Result in the emission of less CO_2 (and other greenhouse gases) than removed

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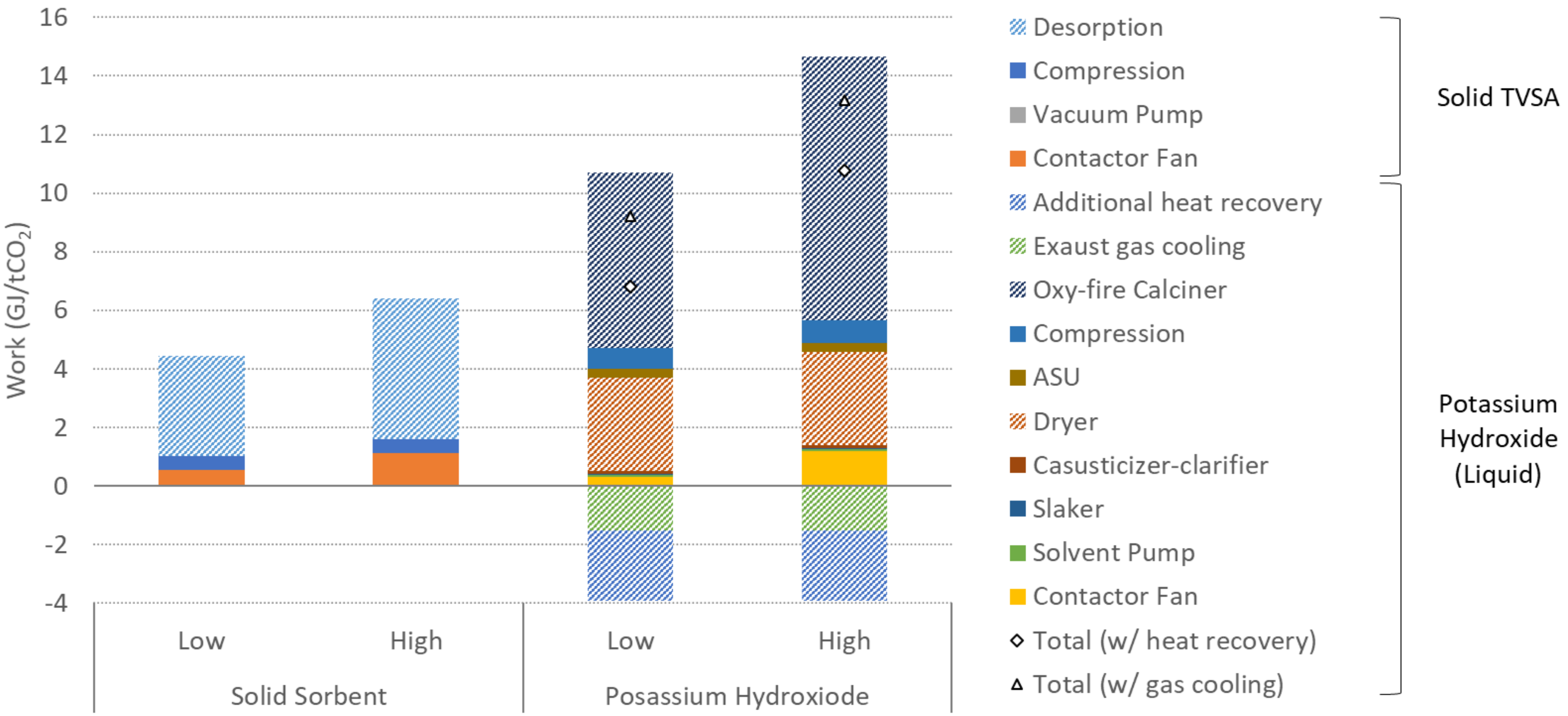
DAC needs heat and electricity in varying proportions



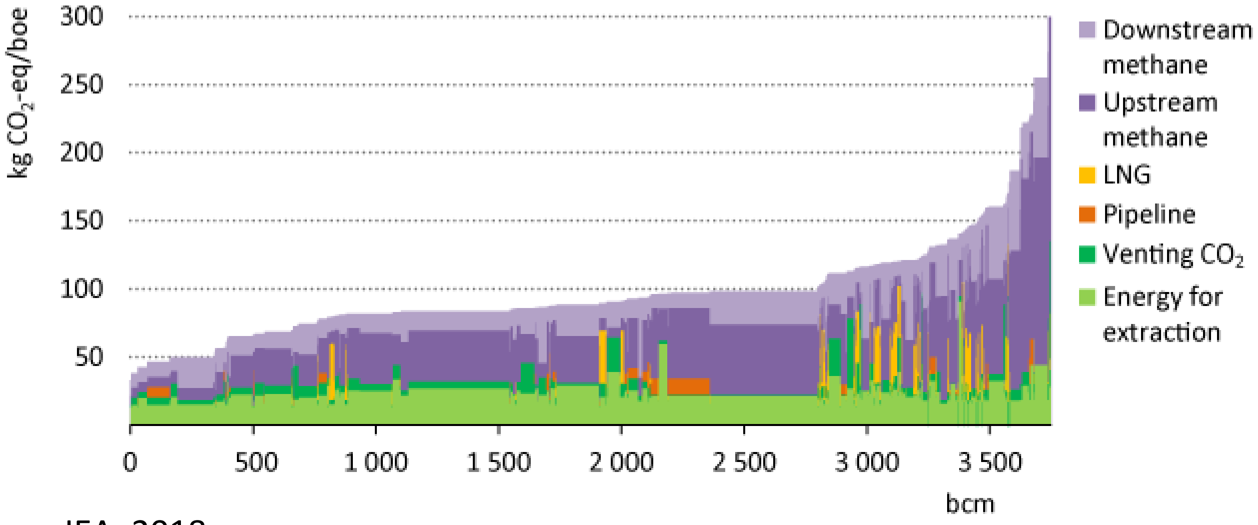
Data from NAS, 2018; Compression & conditioning (130 kWh/tCO_2) added

Environmental impacts of energy supply varies widely

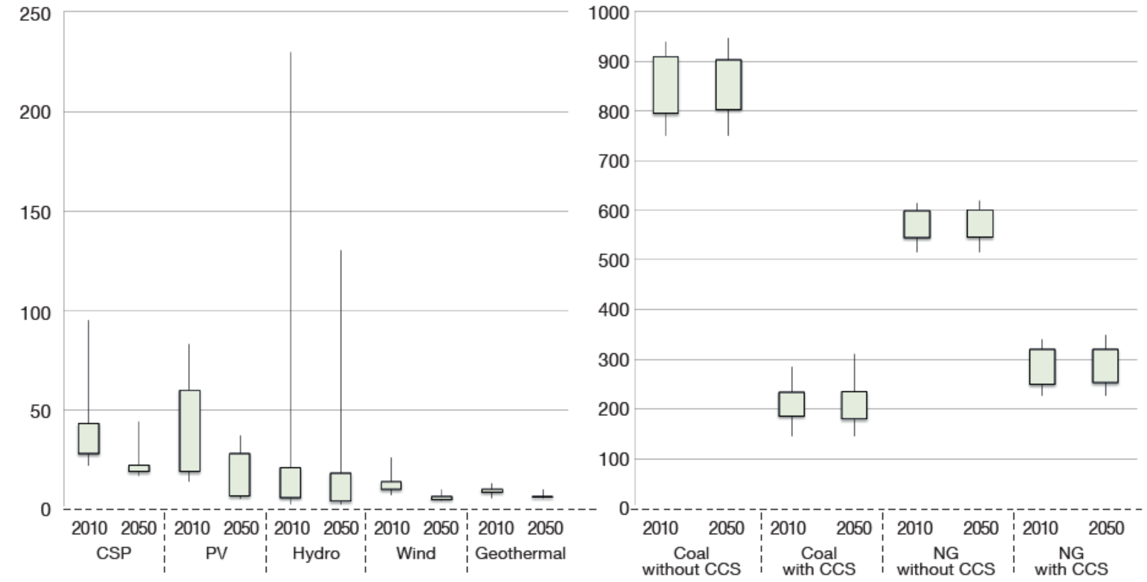
Upstream Natural Gas: 9 – 35 gCO2-eq/MJ (50 – 200 kgCO2-eq/boe)

Combustion Natural Gas: 56 gCO2-eq/MJ

Lifecycle Natural Gas: 65 - 91 gCO2-eq/MJ



IEA, 2018



CSP: concentrating solar power; PV: photovoltaic.

UNEP, 2016; Hertwich et al., 2015

US NERC Sub-regions: 215 – 585 $kgCO_2/MWh$

Canadian Provinces: 1.3 – 750 $kgCO_2/MWh$

European Countries: 4 – 228 $kgCO_2/MWh$

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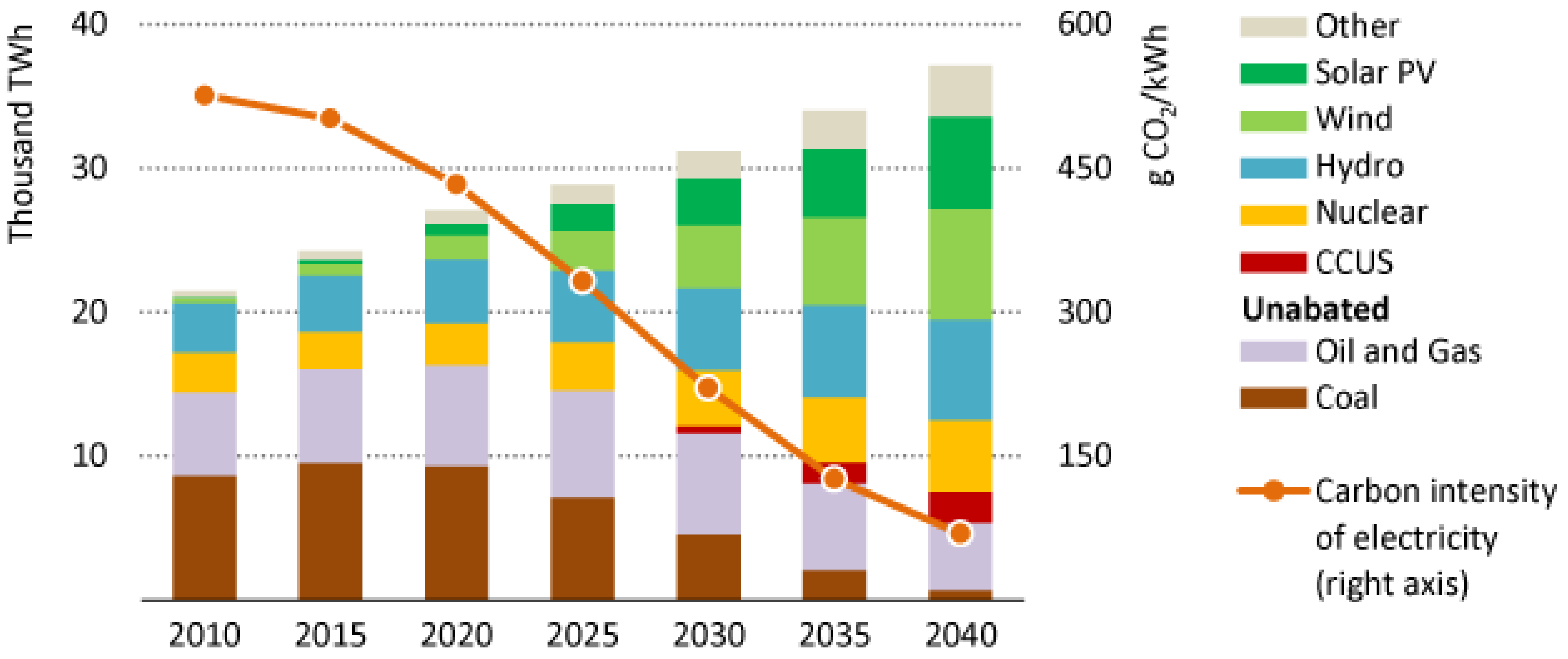
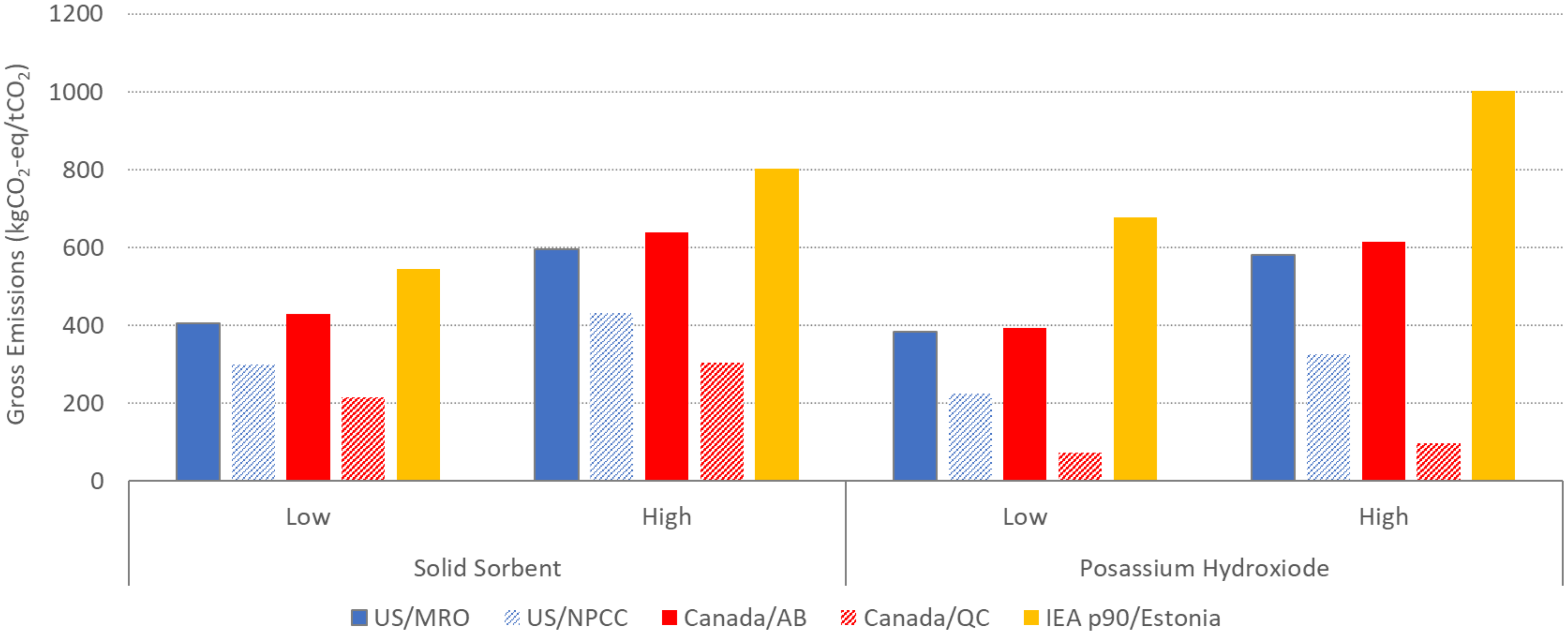
Carbon intensity of energy declines in stabilization scenarios



IEA, 2018 (WEO SDS)

Implications for system negative emissions



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Translating to a research agenda

Low-carbon heat. Current DAC systems require ~70-80% of their energy input in terms of heat. What fuel makes most sense from a lifecycle perspective? How could this heat provided (at the needed temperature) in a system?

Horses for courses. The availability of fuels will influence DAC system economics. Can DAC systems be designed to minimize life cycle emissions with advantaged fuels in mind? Can they be coupled to resources to improve economics and reduction efficiency?

Integration of DAC into capture. At gigaton-scales, industrial CCS and DAC would probably co-exist and infrastructure may be built around industrial CCS. Can extraction and capture be synergistically combined?

Integration of DAC into use. For storage, relatively high CO_2 concentrations are needed for economics and to manage storage capacity. For utilization, CO_2 is not the end product. How can DAC be better integrated into conversions?

Upstream and non-GHG impacts. Direct water use, hazardous sorbent degradation products, and upstream sorbent synthesis impacts will be significant at gigaton-scale. These must be minimised in technology assessment.

Questions?

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