Decarbonizing the Energy Market through use of the Subsurface

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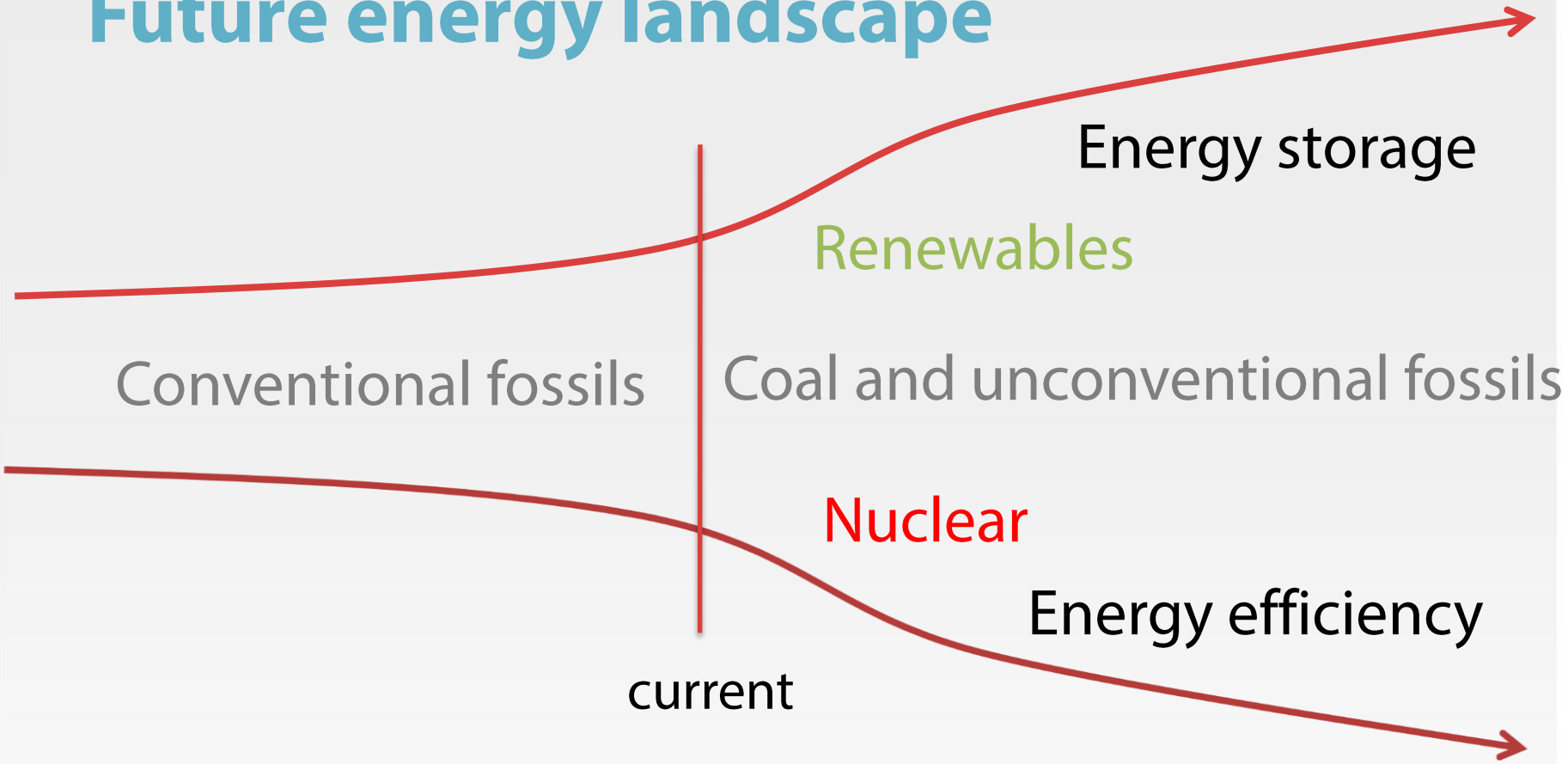
Future energy landscape



University energy education must realize the present state, rapid changes, and future uncertainty in the global energy mix

(Michael A. Celia, Princeton, 2014)

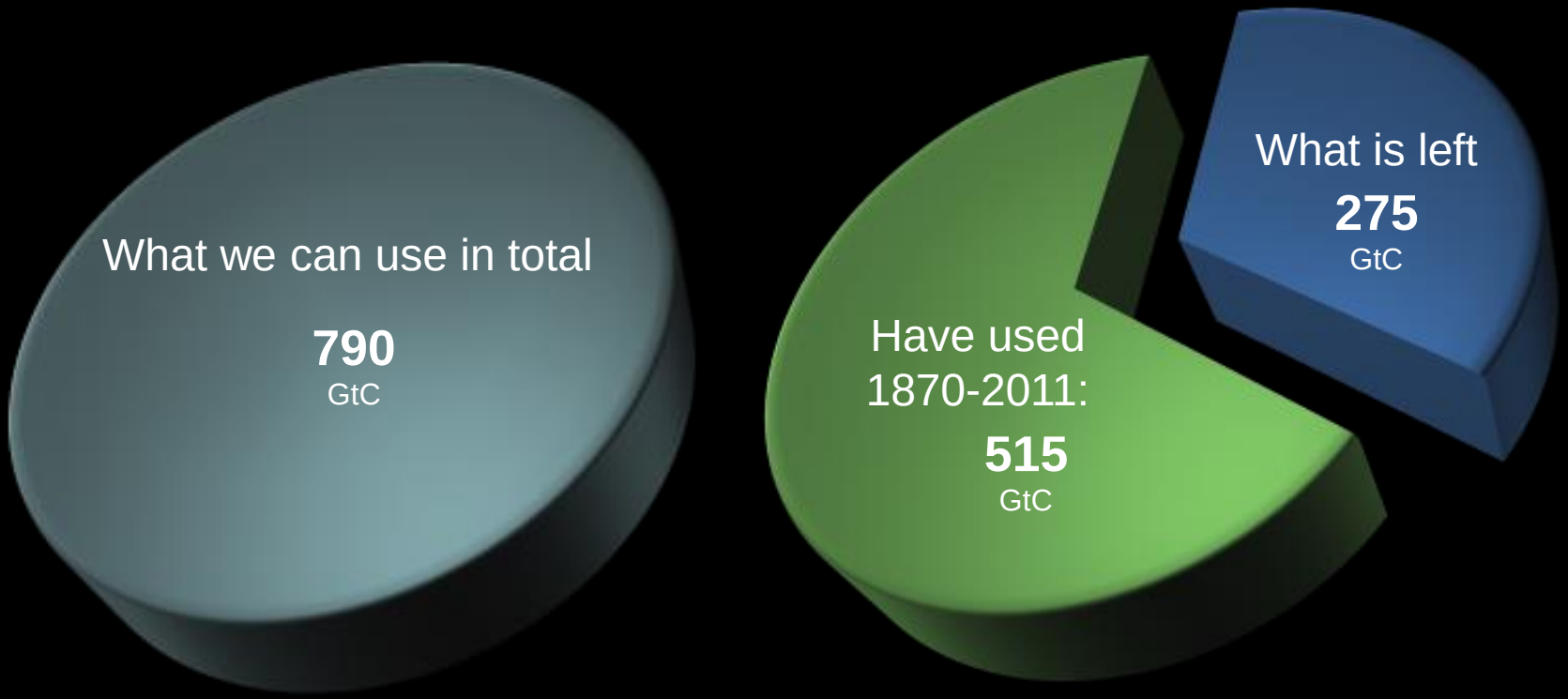
Bjerknes Centre
for Climate Research

Bjerknes Centre for Climate Research

"The aim of the Bjerknes Centre is to understand and quantify the climate system for the benefit of society"

UNIVERSITY OF BERGEN
uniResearch
NERSC Nansen Center, Bergen
HAVFORSKNINGSINSTITUTTET INSTITUTE OF MARINE RESEARCH

The 2˚ C target and carbon budget



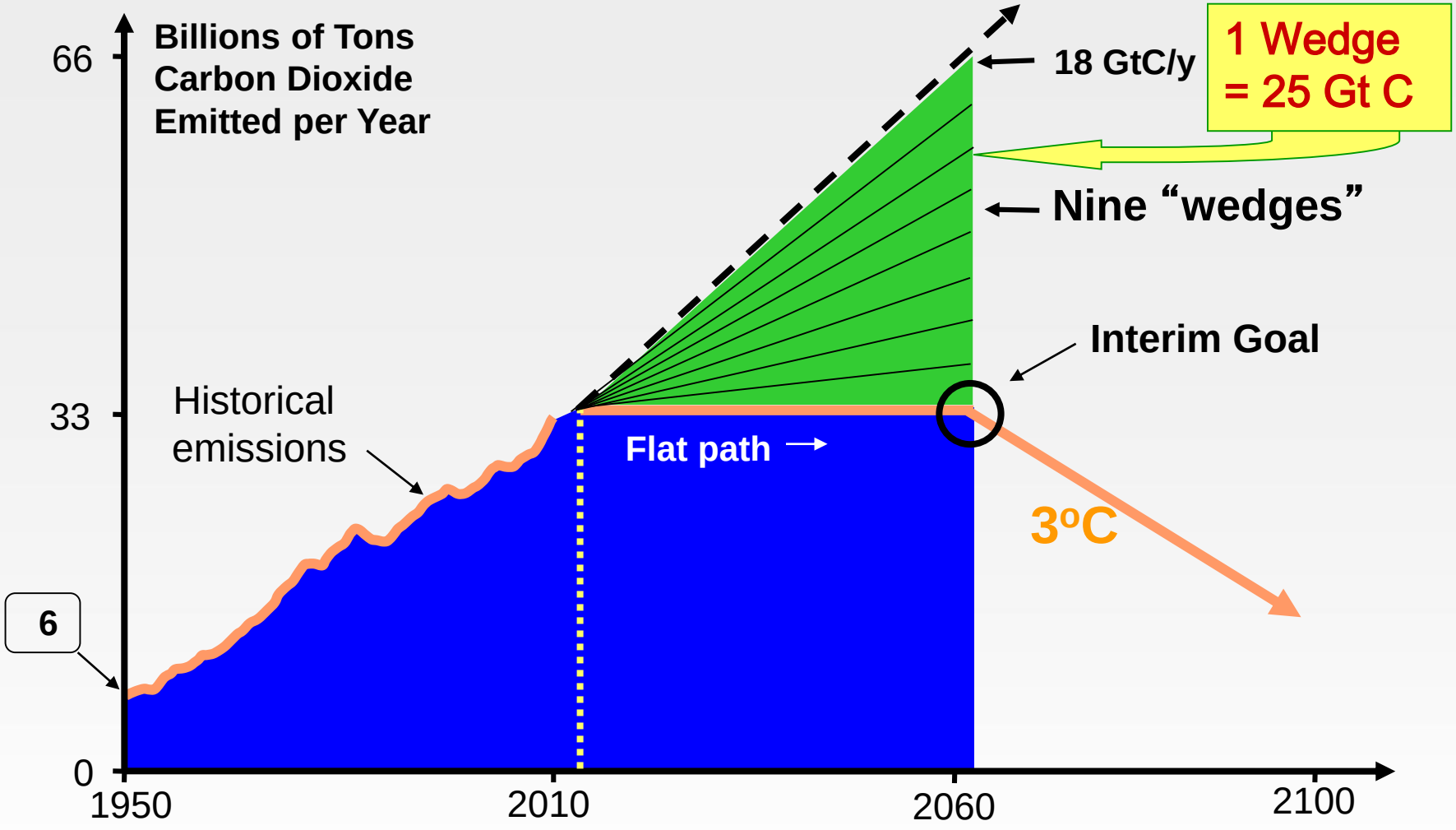
2/3 of our carbon budget already used

80% of all known oil, gas, coal resources must stay in ground

(Unless large-scale carbon capture and storage)

IPCC AR5 WGI SPM

Stabilization Wedges



(Updated (by Socolow) From: Pacala and Socolow, *Science*, 2004)

Carbon (Capture &) Storage:

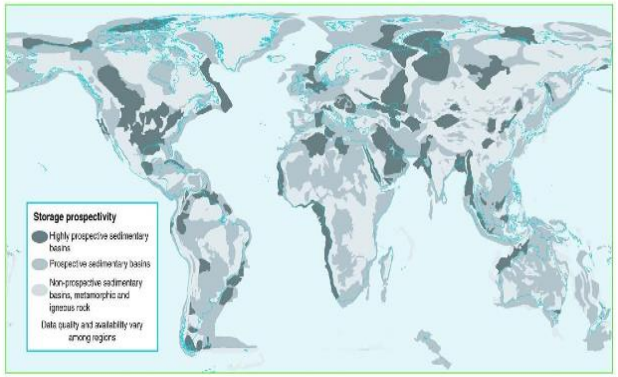
CCS today:

Pretty good for demonstration but not good enough for climate change

- Largest CCS at Sleipner platform in the North Sea (0.85 Mt CO2/yr)
- 10 Sleipners every month to achieve 25 GtC by 2060 (one wedge)

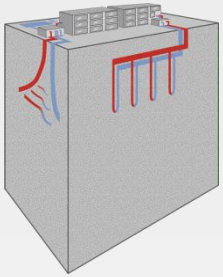
CCS future:

- Use **existing infrastructure and expertise**.
- Exploit **global capacity** in deep saline aquifers
- **Maximize storage security and reduce leakage risk** to:
  - Keep out of atmosphere
  - Account for CO2 credits
  - Protect natural resources



Geothermal Energy (subsurface heat extraction):

Environment-friendly heating, cooling and electricity generation worldwide



Shallow geothermal energy

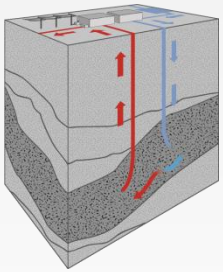
Heating and cooling for buildings, roads and industry

Potential:

Development of sustainable cities (smart thermal grids)

Challenges:

Local interaction between boreholes



Deep geothermal energy

Vast majority of production based on hydrothermal resources

Potential:

By 2050 (IEA):

- 3.5 % annual global electricity production (0.3 % today)
- 3.9 % of energy for heating (0.2 % today)`

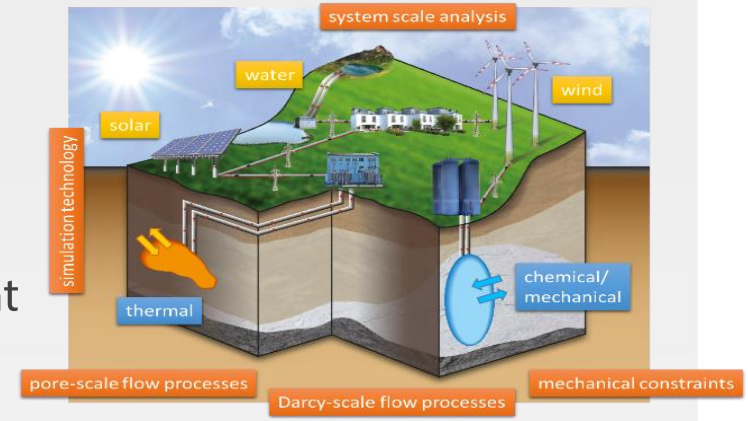
Challenges:

Induced seismicity, cost reduction

Subsurface Energy Storage

- **Importance:**
  - Energy storage is the key enabling technology for unlocking the potential of intermittent renewable energy

- **Potential:**
  - Synthetic gas can be stored directly with current knowledge and technology
  - Combined thermo-mechanical storage has potential for 80% storage efficiency with global scalability



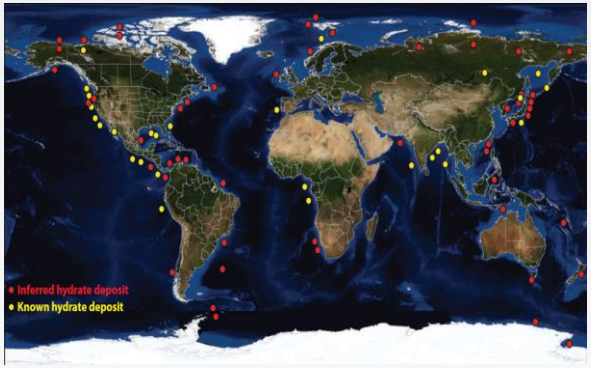
- **Key research challenges:**
  - Physics of high-rate compressible flows in permeable media
  - Thermal weakening and fracture of porous rocks
  - Efficient numerical methods for coupled hydro-thermo-mechanical processes
  - Optimizing engineered systems

CO_2 Storage in Underground Hydrate Reservoirs with Associated Spontaneous Natural Gas Production:

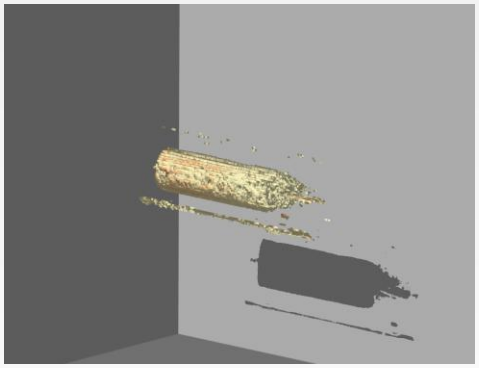
Objectives:

Simultaneous CO_2 sequestration and spontaneous gas production through laboratory and numerical verification when hydrate is exposed to CO_2

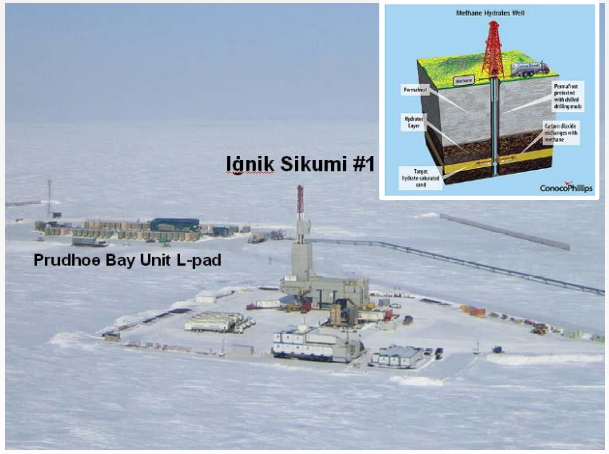
Methane hydrate reservoirs



Laboratory Verification of CO_2/CH_4 Exchange Through MRI imaging



Methane production by CO_2 injection in Alaska field test 2012



- **Less than 10 years from idea to field pilot**
- **UiB patent in 150 countries world wide**
- **CO_2 EOR ongoing with confirmed field trials**

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