Potential Energy and CO_2 Emissions Impacts of Naturally Occurring, Abundant, Geologic Hydrogen

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30th AIM International Workshop

Tsukuba, JAPAN

28 August 2024

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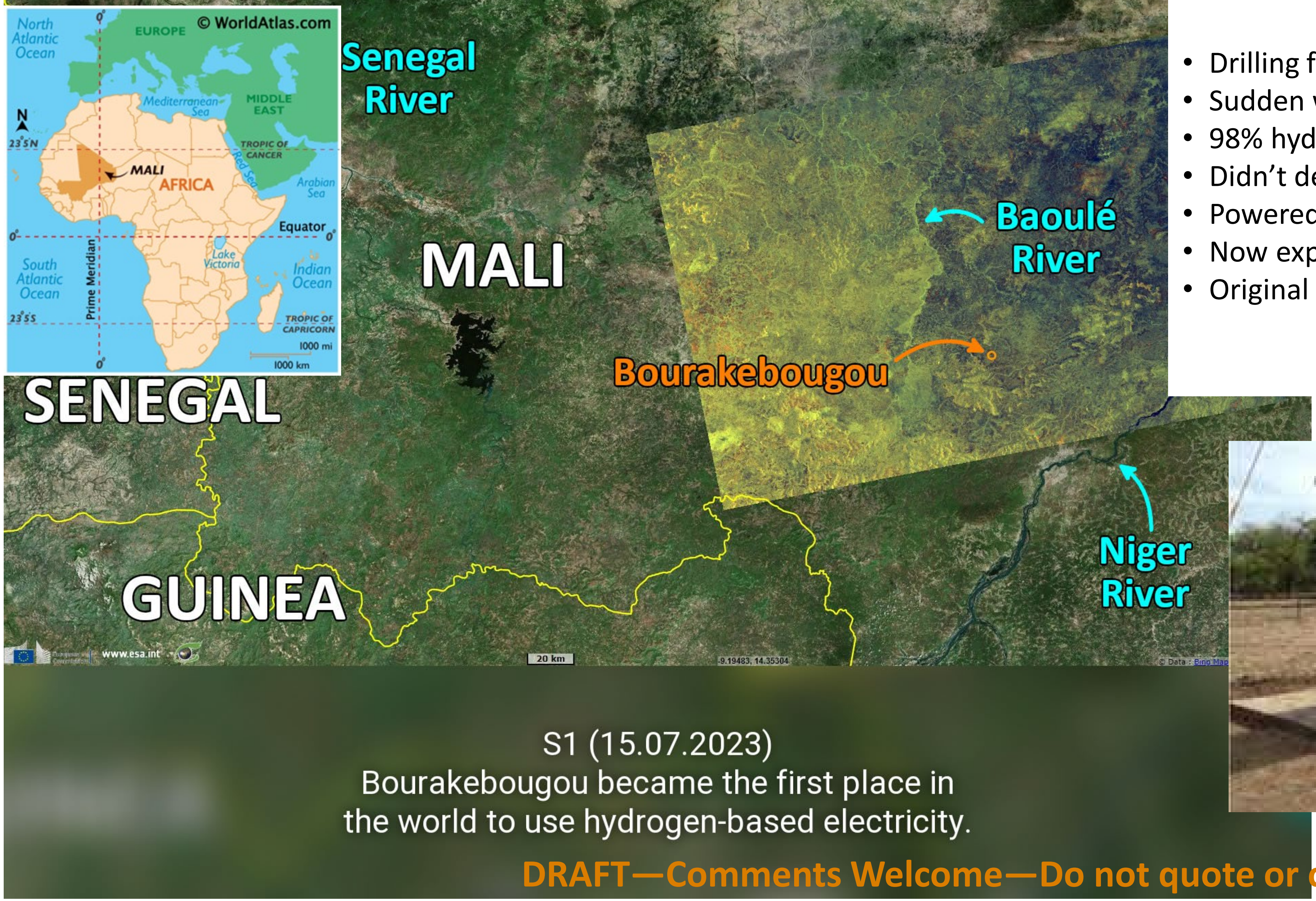
Discovery of Naturally Occurring Geologic Hydrogen



Mali Well

- Drilling for water – 100 m
- Sudden wind from borehole + cigar = explosion
- 98% hydrogen – White/Gold/Natural/Geologic H
- Didn't deplete – renewable
- Powered Village generator for 10+myears
- Now expanding to 130MW generator
- Original generator replaced with fuel cell

The Birth of White Hydrogen

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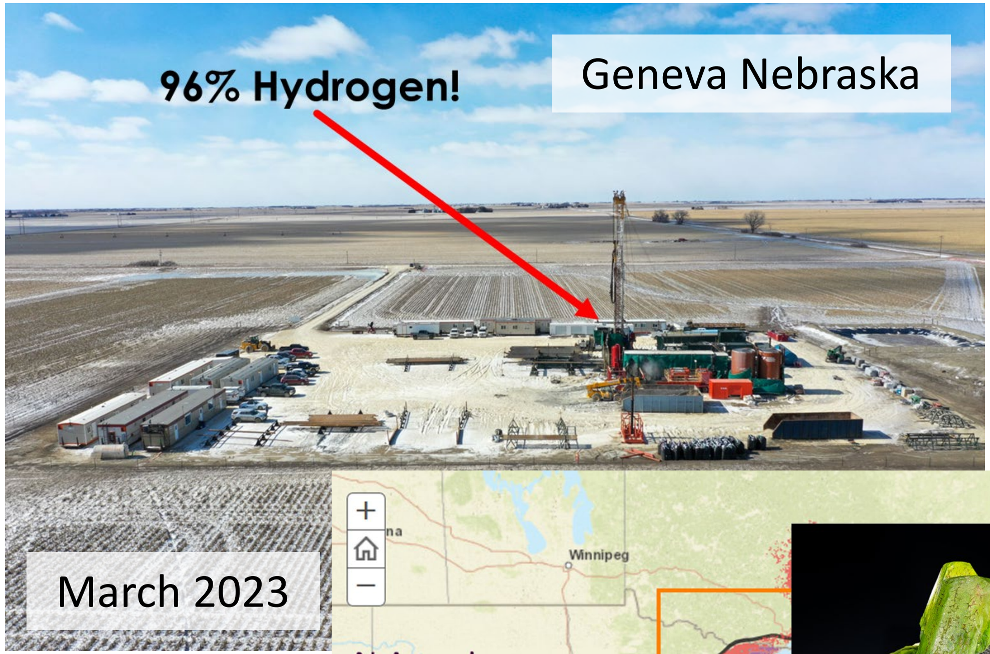
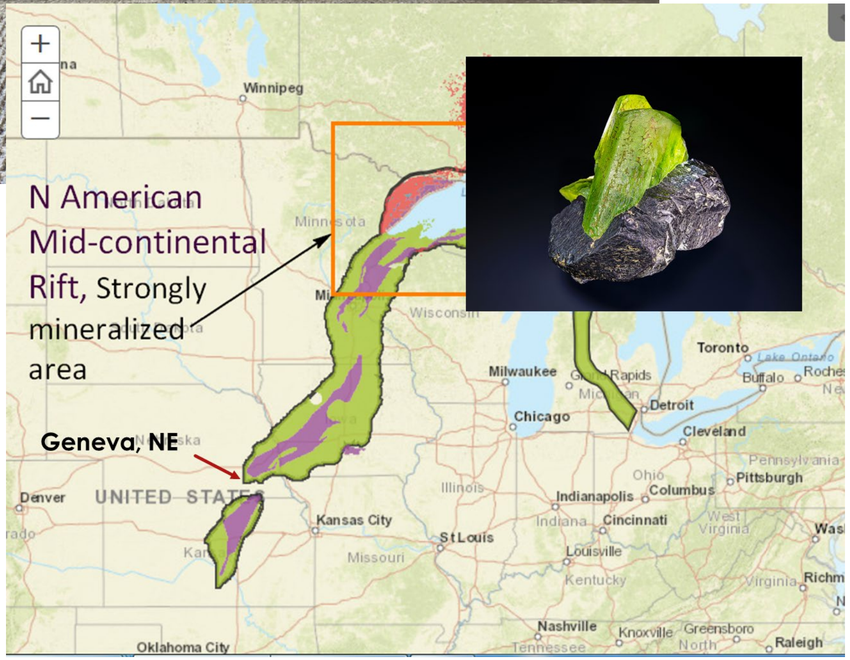
Motivation

- Unlike "green" hydrogen produced using electrolysis, geologic (aka "white" or "gold") hydrogen is potentially abundant, renewable and inexpensive.

- **Our question: What would abundant and inexpensive hydrogen mean for the global energy system and GHG emissions?**





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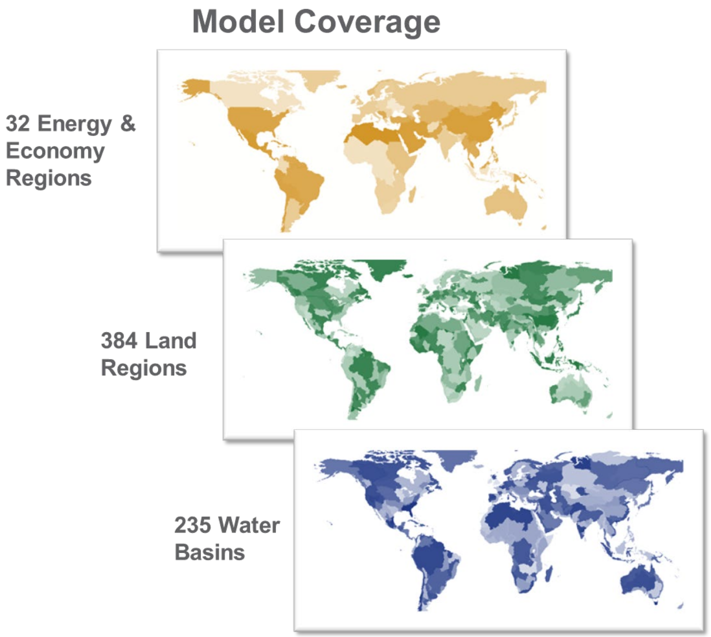
Experimental Design

We use the GCAM model



- **Dynamic-recursive,** (NOT optimization).
- **Single Unified Code**: Simultaneously resolves **energy**, water, land, and economic markets, and climate systems.
- **Five-year time steps** but can run on one-year time steps.
- **Time horizon is 2100.**
- **Community model** (https://github.com/JGCRI/gcam-core/releases) source code, data, and documentation
- **All emissions:** Greenhouse gases, aerosols and short-lived species.

- **Create a geologic H_2 resource**
  - Universally available
  - At a prescribed cost.
- Initial experiment
  - **$1/kgH2 (2020 US$)**
  - **Current Price $6-8/kgH2 (2020 US$)**

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Experimental Design

- Low CCS: AR6 C1 10th percentile (~2000 MtC in 2050)
- Low Bio: AR6 C1 10th percentile (~64 EJ in 2050)
- Low Nuclear: No new nuclear (2025 forward)
- Geological H_2 supply
  - H_2 central production (subsector and technology)
  - Subsector share-weight (0 in 2020, linearly to 1 in 2030)
  - Supply cost = 1 ($2020/kg)
  - Global unlimited resource
- Electricity sector: H_2 combustion turbines added

Six Scenarios

	Carbon Policy	
Geo. H_2 & Alternative Technology Availability	Reference **SSP2**	Net-zero CO_2 (in 2050)
No Geo. H_2	Geo. H_2 not available + No carbon policy	Geo. H_2 not available + NZ CO_2
Geo. H_2	Geo. H_2 available + No carbon policy	Geo. H_2 available + NZ CO_2
Geo. H_2 + Low CCS, Bio and Nuclear	Geo. H_2 available + No carbon policy + Low CCS, Bio, and Nuclear	Geo. H_2 available + NZ CO_2 + Low CCS, Bio, and Nuclear

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Reference H2 Production and Consumption

	Carbon Policy	
Geo. H_2 & Alternative Technology Availability	Reference	Net-zero CO_2 (in 2050)
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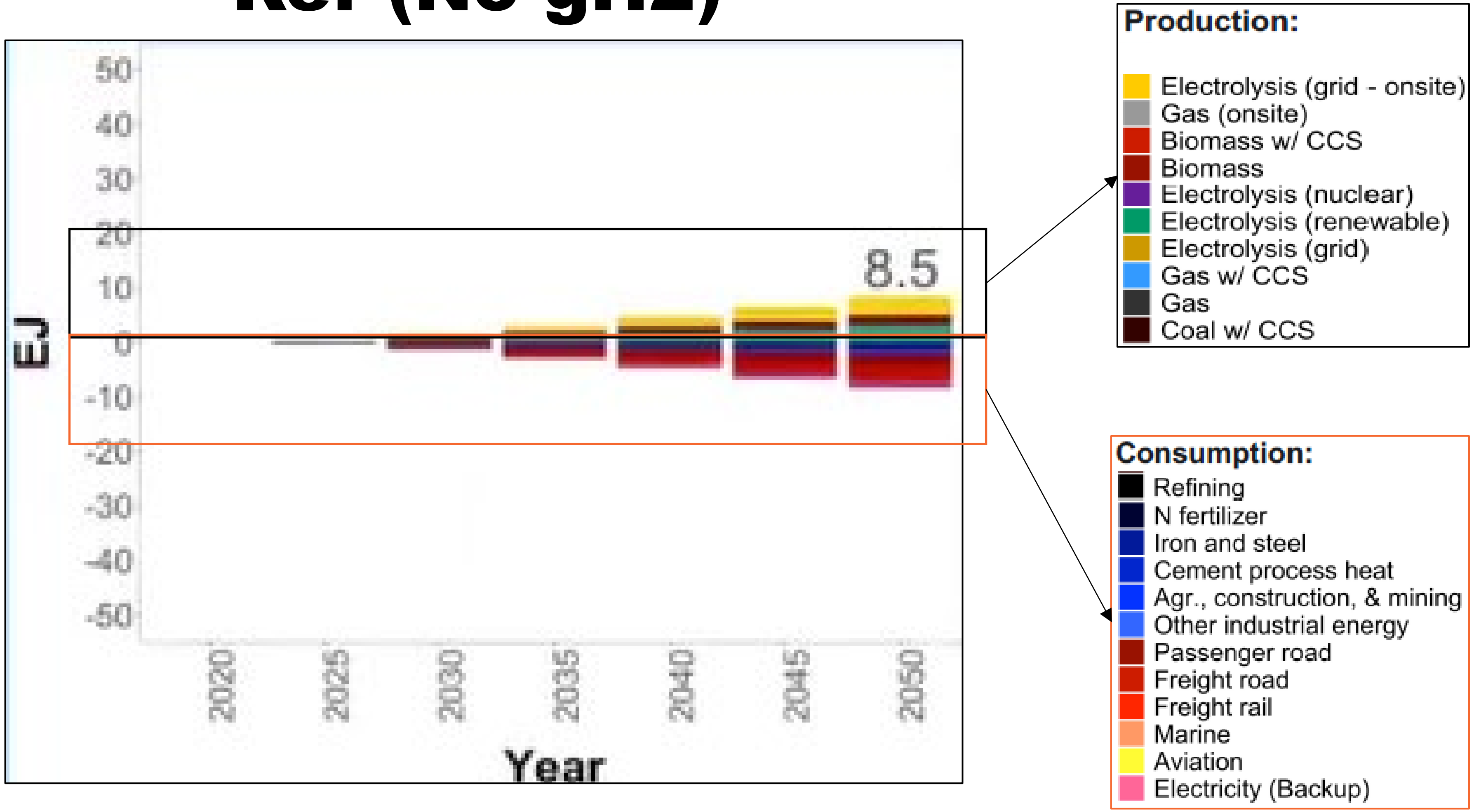
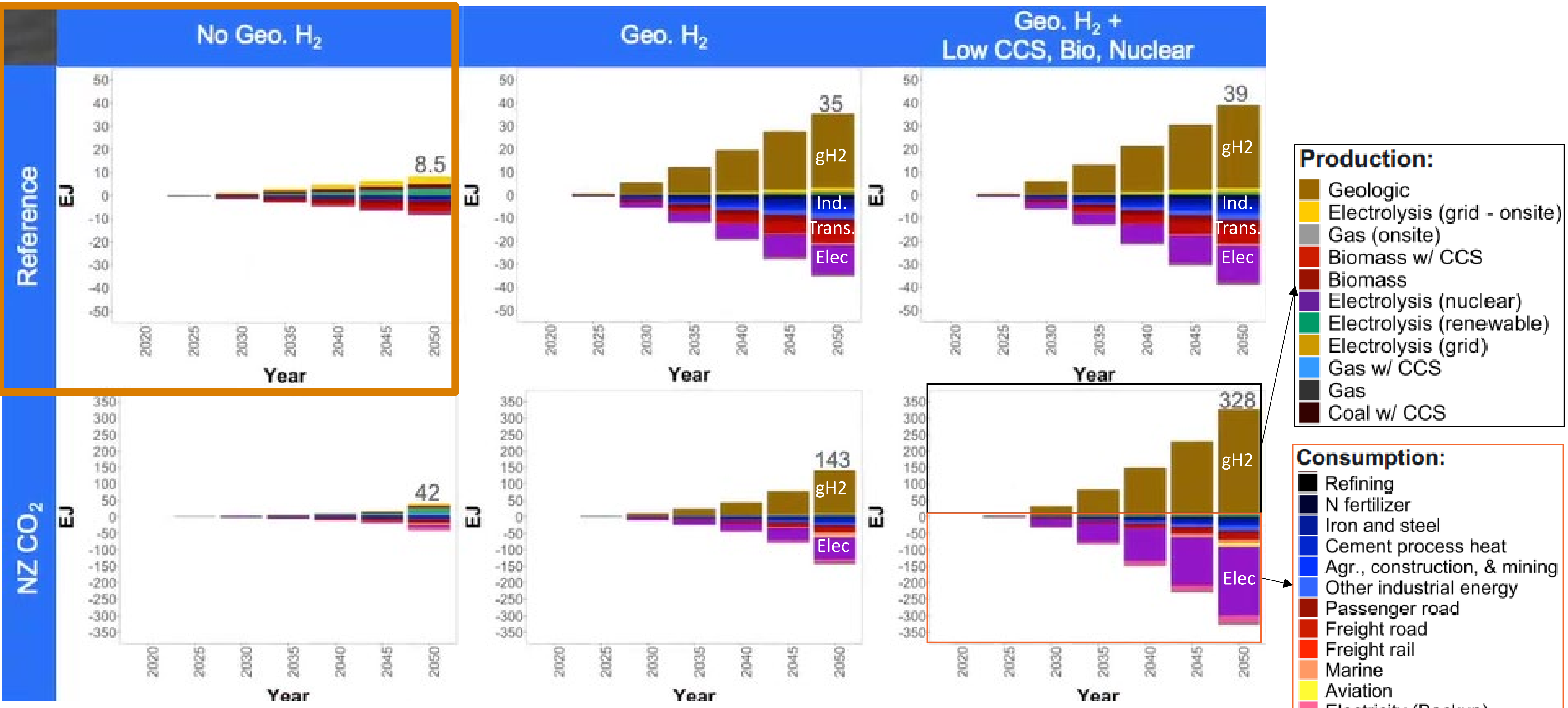
Geo. H_2 + Low CCS, Bio and Nuclear	Geo. H_2 available + No carbon policy + Low CCS, Bio, and Nuclear	Geo. H_2 available + NZ CO_2 + Low CCS, Bio, and Nuclear

Ref (No gH2)



H2 Production and Consumption



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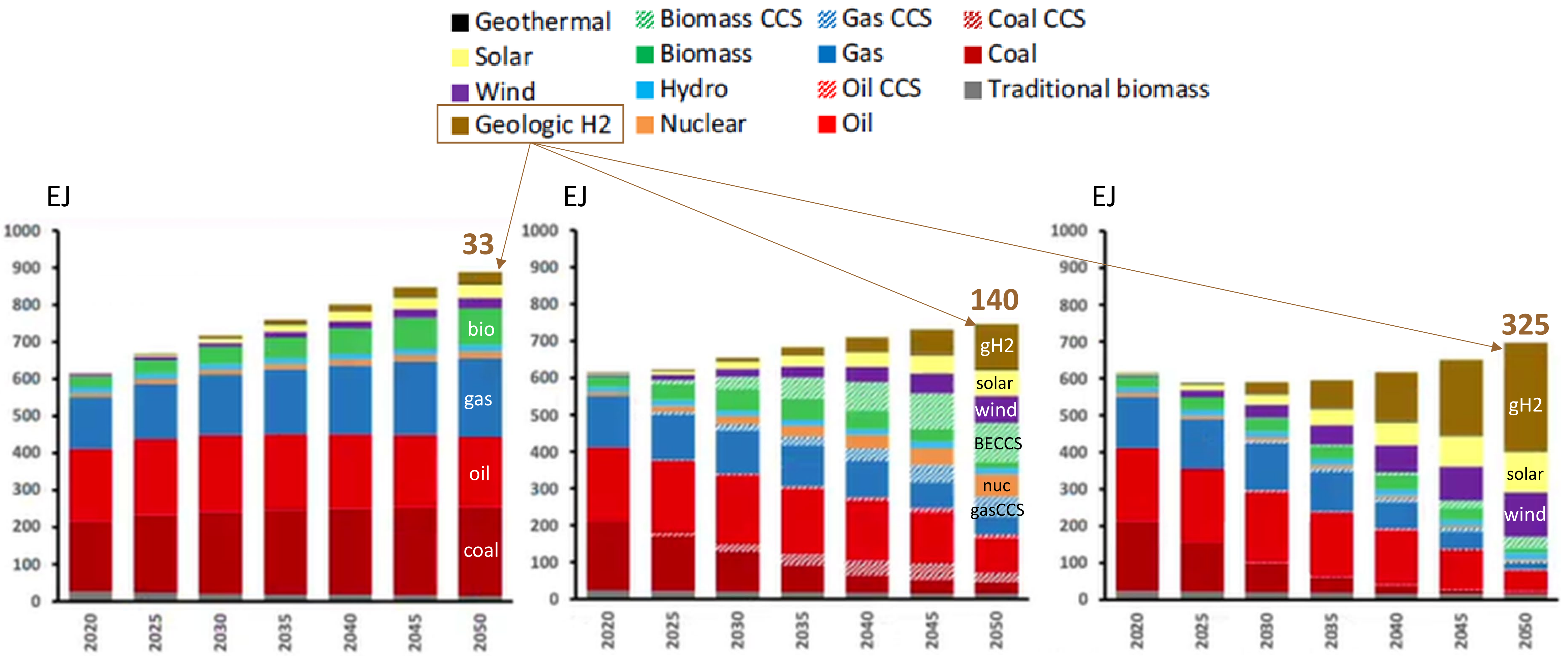
Global Primary Energy Production (EJ)



Ref + gH2

NZ + gH2

NZ + gH2 + Lim CCS, Bio, NoNewNuc

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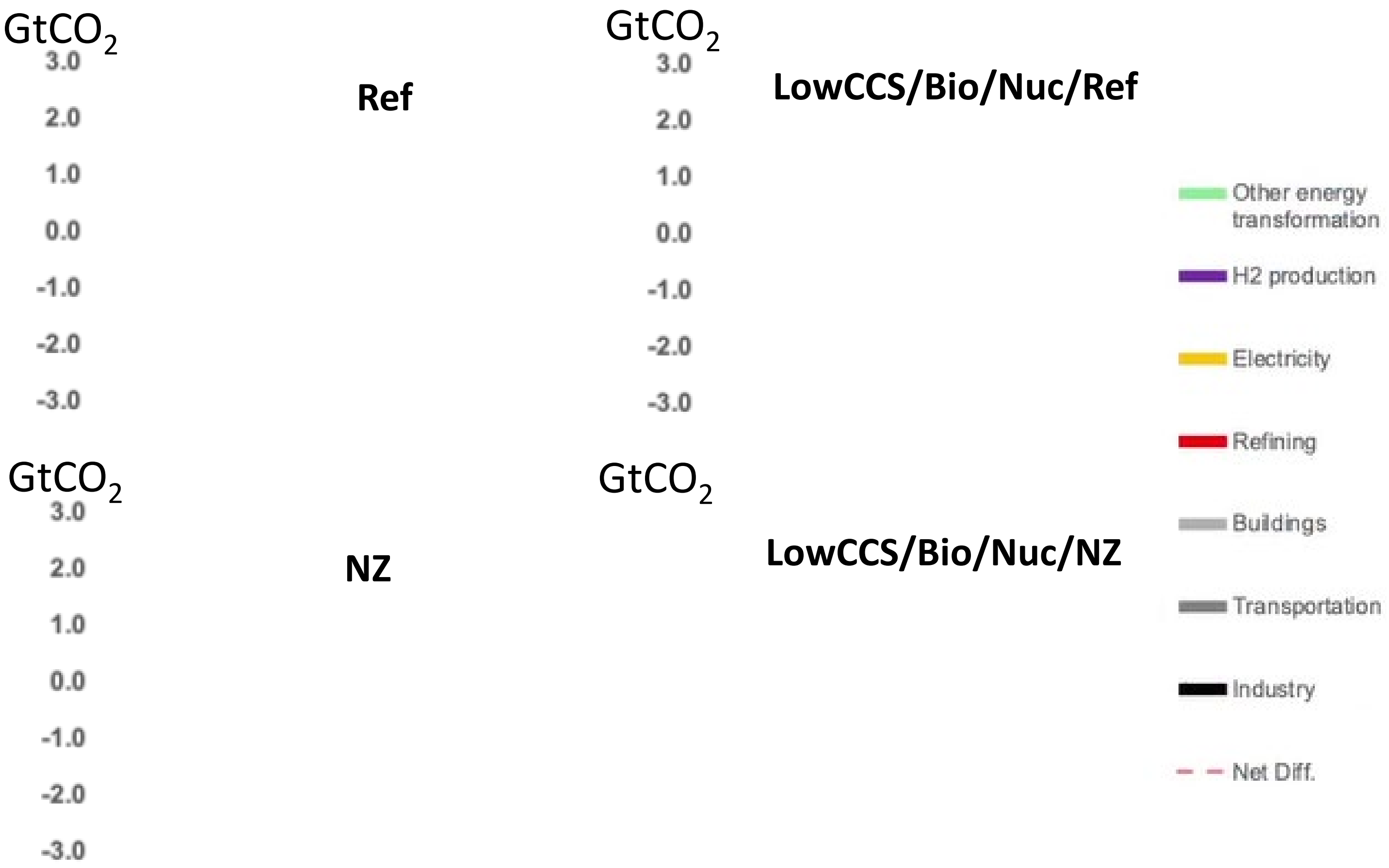
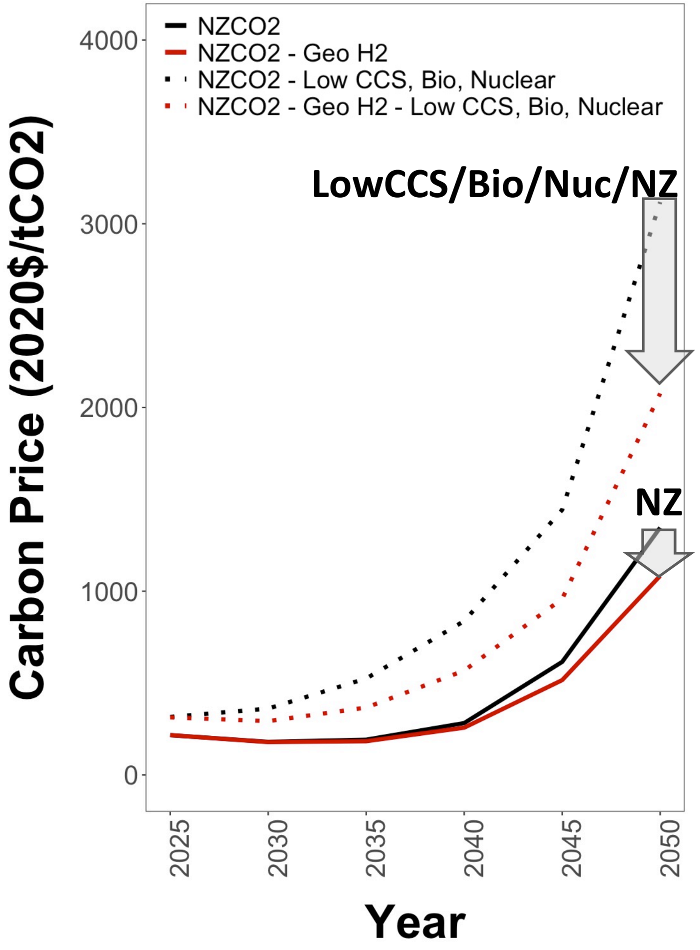
Global GHG Emissions and Carbon Price

Change in CO_2 Emissions Due to Geologic H2 Availability



Change in CO_2 Price when gH2 Becomes Available



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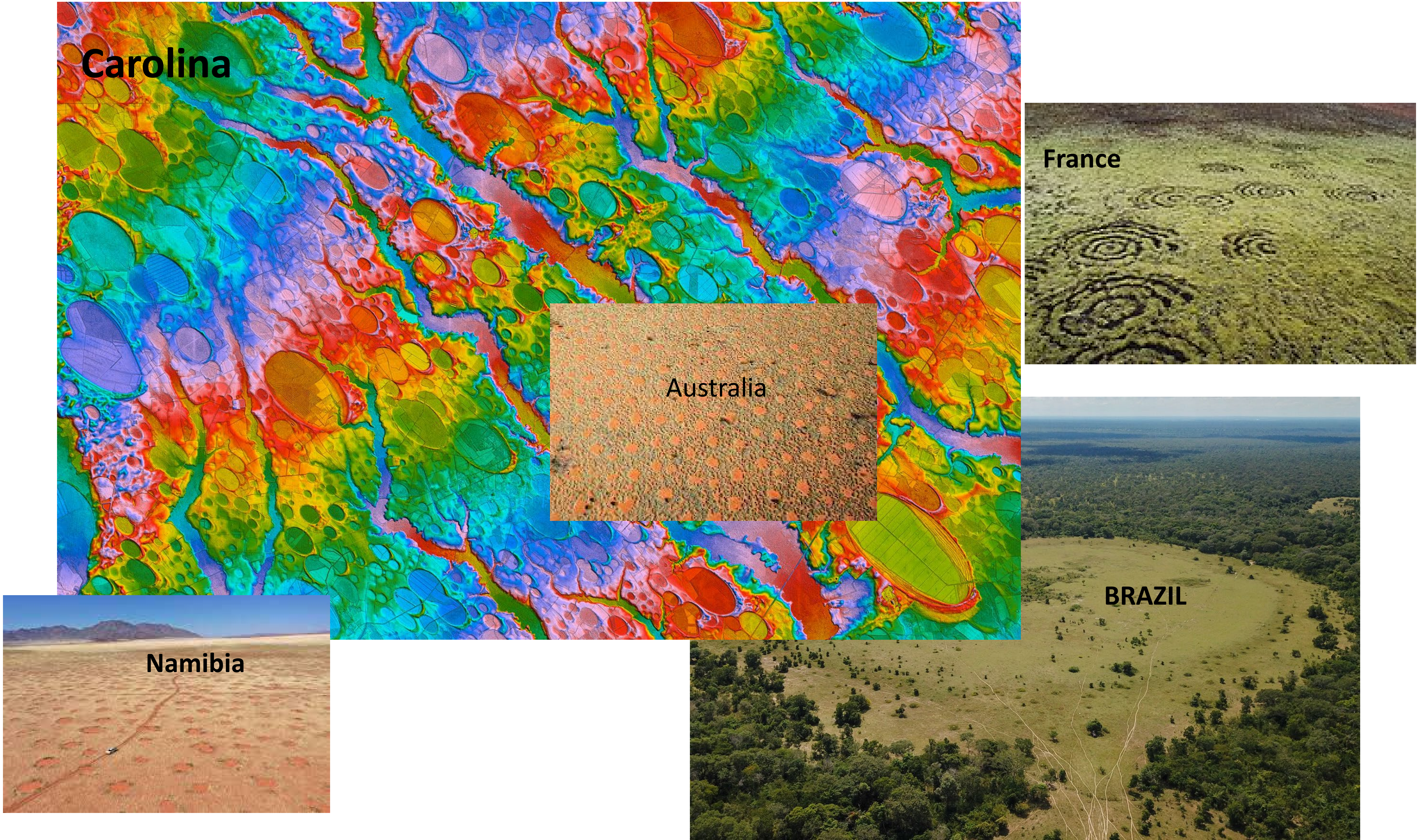
Some Initial Findings

- **Abundant naturally occurring geologic H2 could increase expected H2 deployment.**
  - It tends to expand deployment in power generation, transport and industry.
  - It reduces reference scenario CO_2 emissions—atmospheric chemistry interactions need to be explored.
- **Geologic H_2 plays a markedly different role in a net zero CO_2 emission scenario than in a no-new-climate-policy scenario.**
  - Abundant naturally occurring geologic H2 lowers the cost of meeting NZ goals.
  - When bioenergy, CCS, and nuclear power deployments are limited approximately 40% of the global energy system depends on geologic hydrogen.
- **Future Work:**
  - Explore alternative costs values and availability
  - Couple to HECTOR to assess climate change impacts

DISCUSSION


Carolina
France
Australia
BRAZIL
Namibia


NC
Study Area
North Carolina
Raleigh
Rocky Mount
Greenville
Goldsboro
Fayetteville
Arthur Road Bay
Jones Lake bay
Wilmington
Albemarle Sound
Roanoke Island
Jones Lake bay
Smith bay
Elizabethtown
10 km
Arthur Road Bay
N
100 km
Google earth
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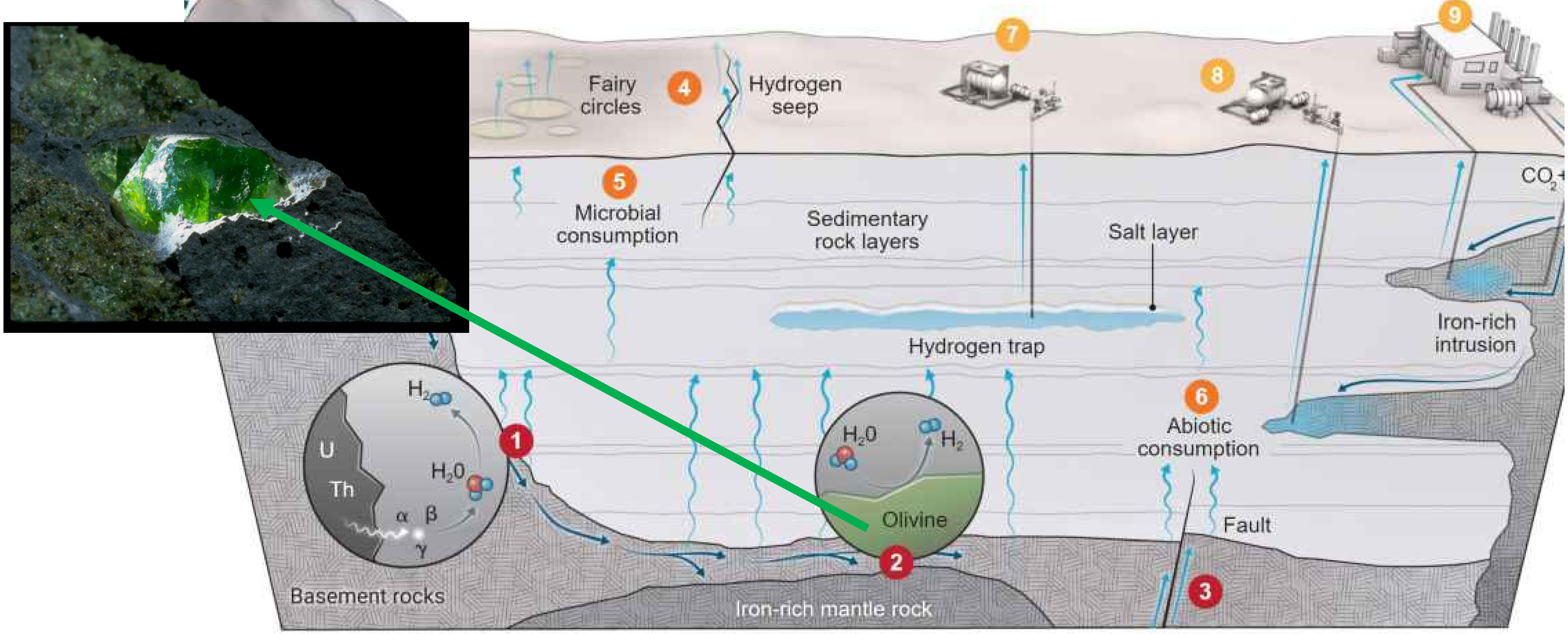
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat

Fig. 2 Subsoil H_2 concentration measurements at Arthur Road Bay and Arthur Road Sandpit (*lower image*). *Dashed lines* outline the bays. *Upper image* is a LiDAR image showing the relief of the lower image. Profile lines follow ditches (*dark lines* in the lower photograph). Date of measurements 14 March 2012. LiDAR image is from the site cintos.org



The reaction responsible for hydrogen production:

$$\mathbf{2(Fe^{2+}O) + H_2O \rightarrow (Fe^{3+})_2O_3 + H_2}$$

In essence, the lower oxidation state of iron in the minerals olivine and orthopyroxene serves as a reducing agent that converts water to hydrogen. In the process, the iron is oxidized to the higher oxidation and turns into the mineral serpentine.

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