Low carbon energy programme

The Royal Society is carrying out a major policy programme on low carbon energy. This aims to consider how transformational science and technology can help the UK transit to a low carbon future, whilst pursuing an active industrial strategy that creates growth and jobs in the short and medium term. This programme follows the commitments made in Paris at the 2015 United Nations Climate Change Conference.

Drawing on the expertise of Fellows of the Royal Society and the wider scientific community, the programme consists of several short projects each focused on a priority area of low carbon science and technology. A final project will then combine cross-cutting themes to set out a research and innovation vision for the UK's energy system.

The short projects, encompassing workshops and reports, aim to provide a rapid and authoritative synthesis of the current evidence. Policy briefings have been published exploring:


options for producing
low-carbon hydrogen at scale


potential utilisation of
carbon dioxide


geological
carbon storage

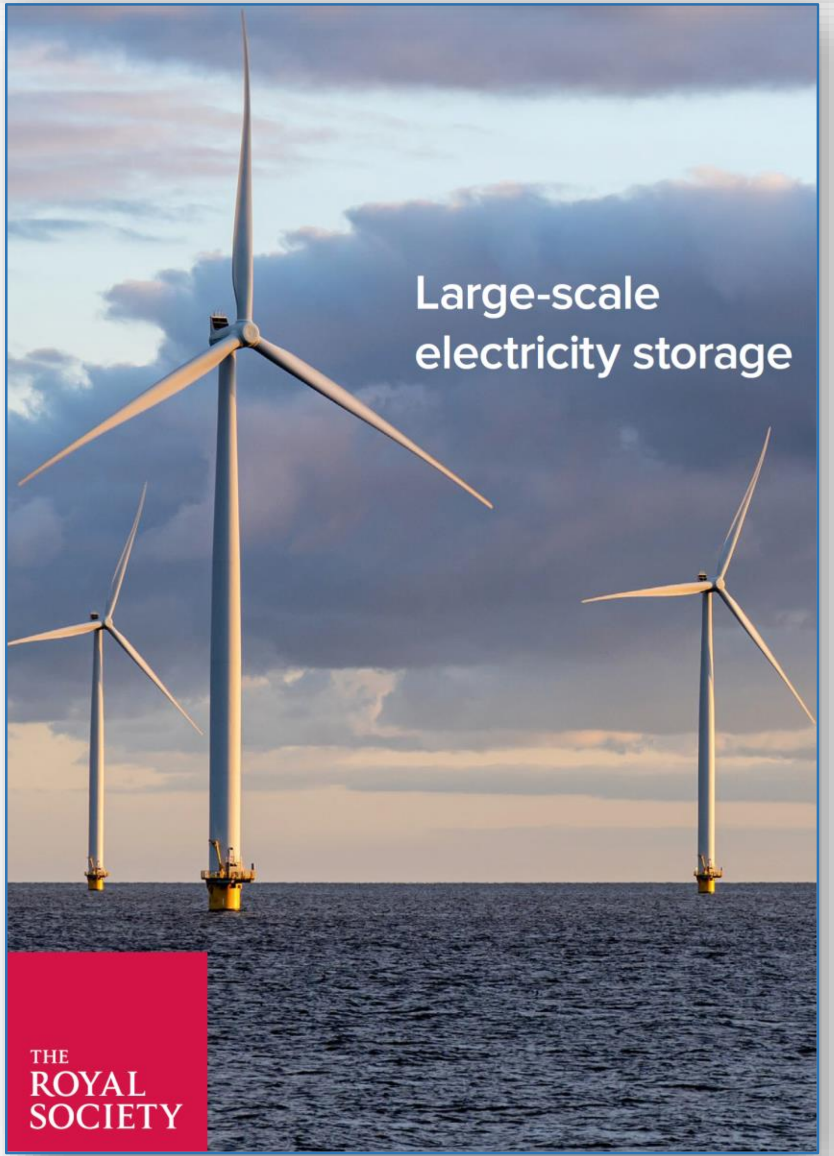

sustainable synthetic carbon-
based fuels for transport


ammonia: zero-carbon fertiliser,
fuel and energy store


nuclear cogeneration
in a low carbon future


net-zero aviation fuels
resources and environment


large-scale electricity
storage for the UK



Executive summary

The UK Government has a stated ambition to decarbonise the electricity system by 2035 and is committed to reaching net zero by 2050. As Great Britain's electricity supply is decarbonised, an increasing fraction will be provided by wind and solar energy because they are the cheapest form of low-carbon generation. Wind and solar supply vary on time scales ranging from seconds to decades. However high the average level of supply might be, there will be times when wind and solar generation is close to zero and periods when there is enough to meet part of but not all demand, as well as times when it exceeds demand.

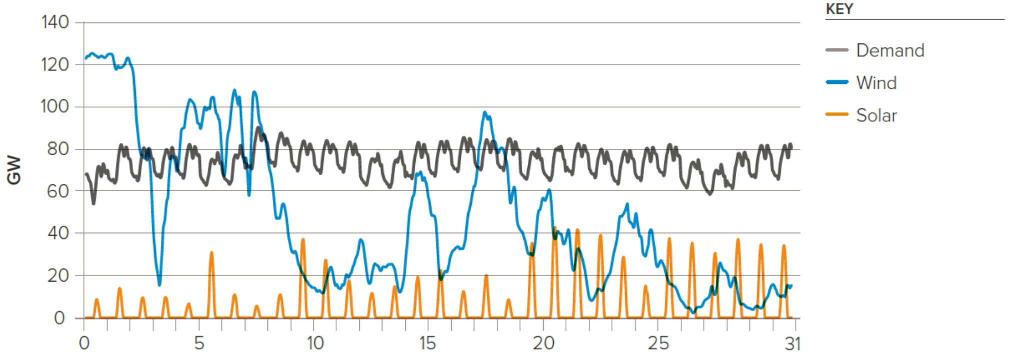
- Wind supply can vary over time scales of decades and tens of TWhs of very long-duration storage will be needed. The scale is over 1000 times that currently provided by pumped hydro in the UK, and far more than could conceivably be provided by conventional batteries.
- Meeting the need for long-duration storage will require very low cost per unit energy stored. In GB, the leading candidate is storage of hydrogen in solution-mined salt caverns, for which GB has a more than adequate potential, albeit not widely distributed. The fall-back option, which would be significantly more expensive, is ammonia.

FIGURE 1

Modelled profiles of wind and solar generation and electricity demand.

Profiles of i) wind and solar electricity generation, based on actual weather data in a typical year (1992) scaled to 570 TWh/year averaged over 37 years (with, for reasons explained in Chapter 2, 80% from wind and 20% from solar) and ii) a model (described in Chapter 2) of possible GB demand of 570 TWh/year in 2050. Flexible supply from other sources and / or imports and / or stored surpluses are required to fill the gap between demand and wind + solar supply.

A) January



B) July

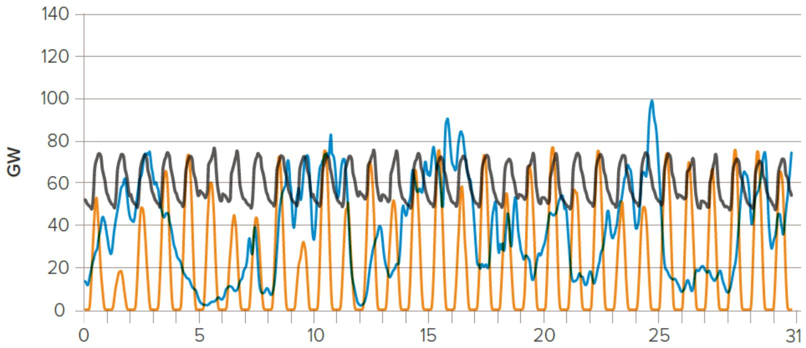
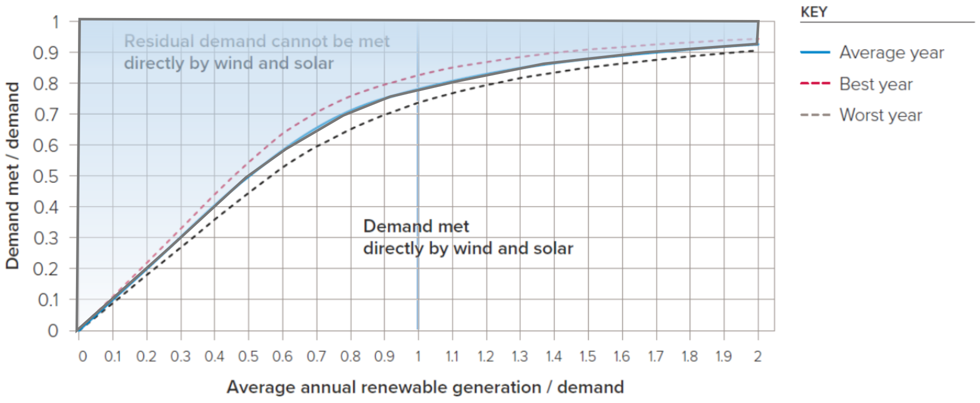
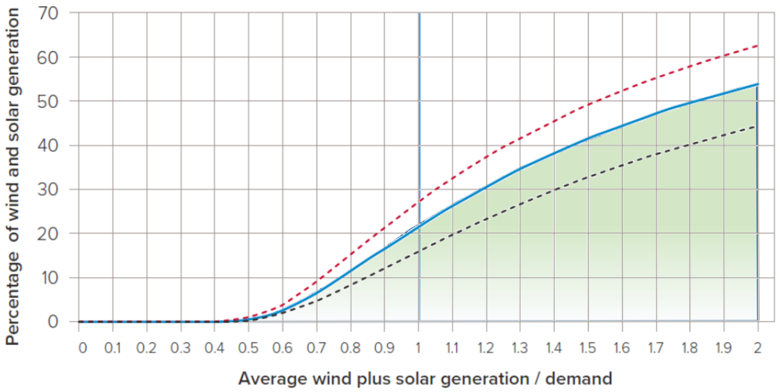


FIGURE 9

A) Fraction of demand that can be met directly by wind and solar in an average year.



B) Percentage of wind and solar generation that cannot be used to meet demand directly, and is therefore available to be stored or used in other ways.



JPhys Energy

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2023 Roadmap on ammonia as a carbon-free fuel

William I F David[1], Gerry D Agnew[2], René Bañares-Alcántara[3], James Barth[4], John Bøgild Hansen[5], Pierre Bréquigny[6], Mara de Joannon[7], Sofia Fürstenberg Stott[8], Conor Fürstenberg Stott[8], Andrea Guati-Rojo[9], Marta Hatzell[10], Douglas R MacFarlane[11], Joshua W Makepeace[12], Epaminondas Mastorakos[13], Fabian Mauss[14], Andrew J Medford[15], Christine Mounaïm-Rousselle[6], Duncan A Nowicki[16], Mark A Picciani[17], Rolf S Postma[18], Kevin H R Rouwenhorst[19], Pino Sabia[7], Nicholas Salmon[20], Alexandr N Simonov[11], Collin Smith[21], Laura Torrente-Murciano[21] and Agustin Valera-Medina[22]

Accepted Manuscript online 7 November 2023 •

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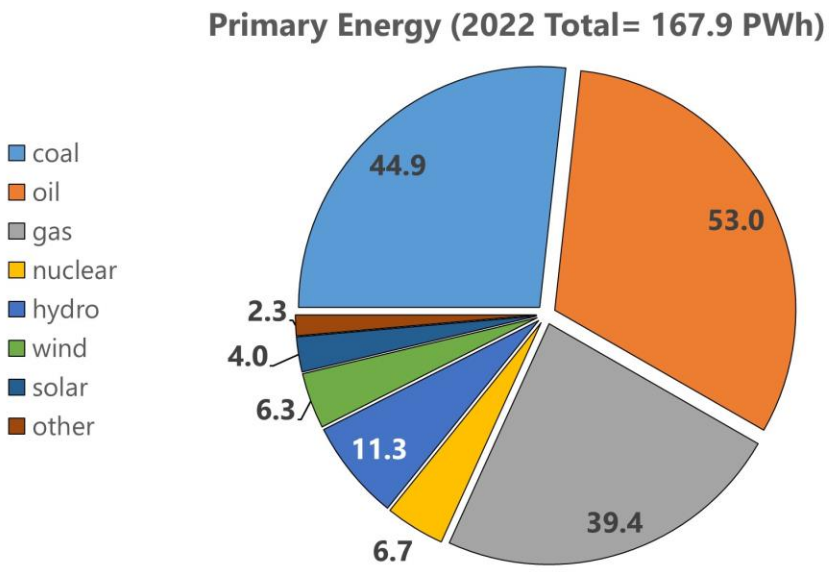

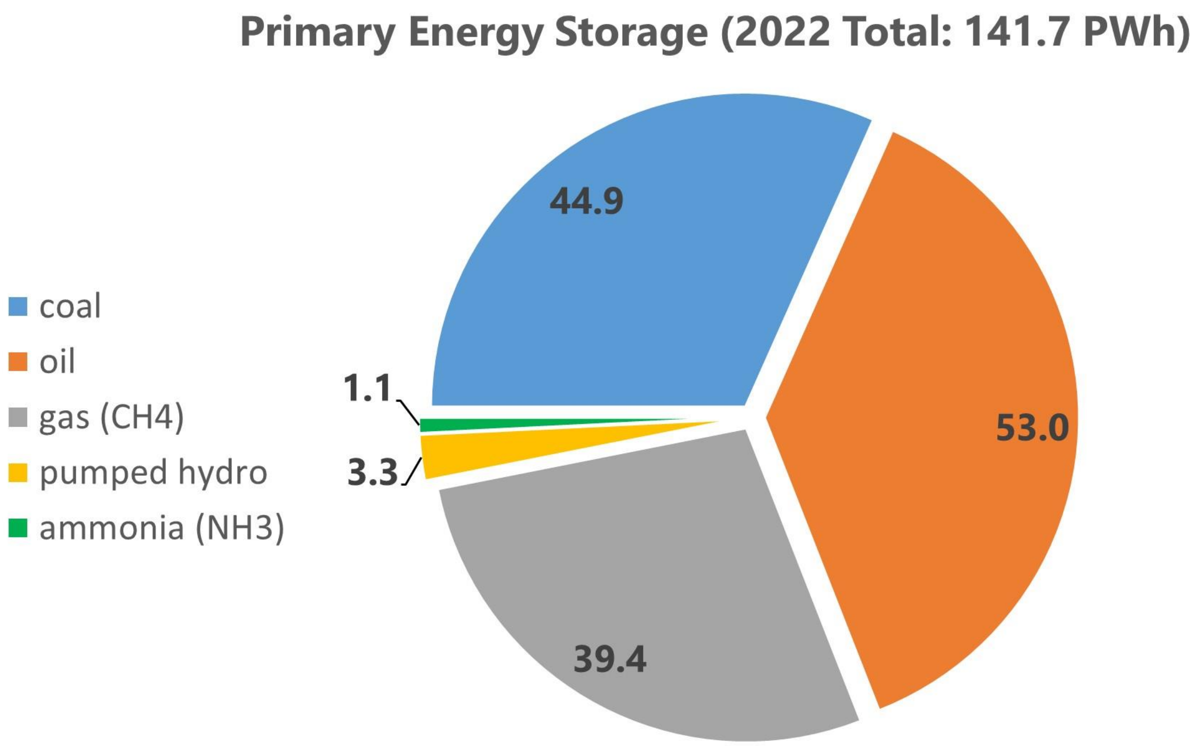

ex www.energyinst.org/statistical-review/resources-and-data-downloads

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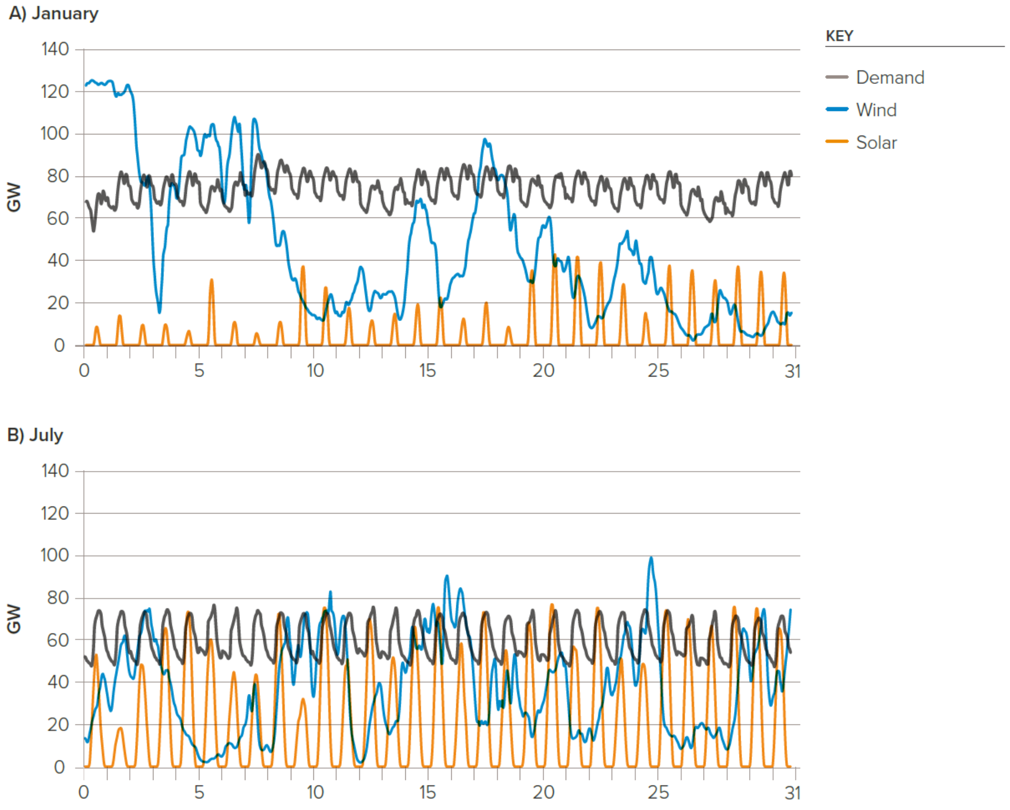


www.energyinst.org/statistical-review

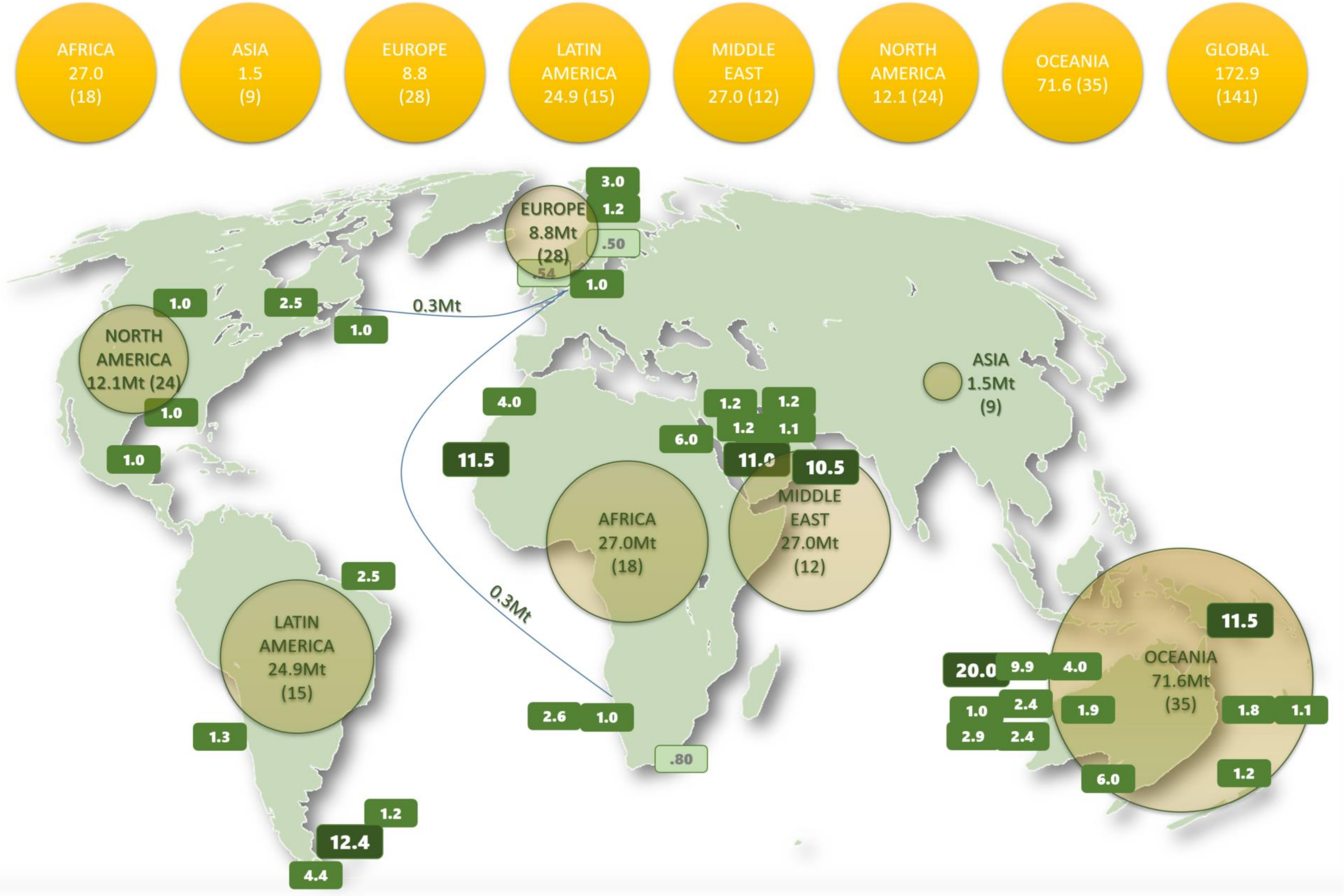
2022 Energy consumption	Total (TWh)	Electricity (TWh)	E/T
Global	167,900	29,200	16%
USA	26,600	4,600	17%
UK	2,000	330	16%

batteries (intraday)

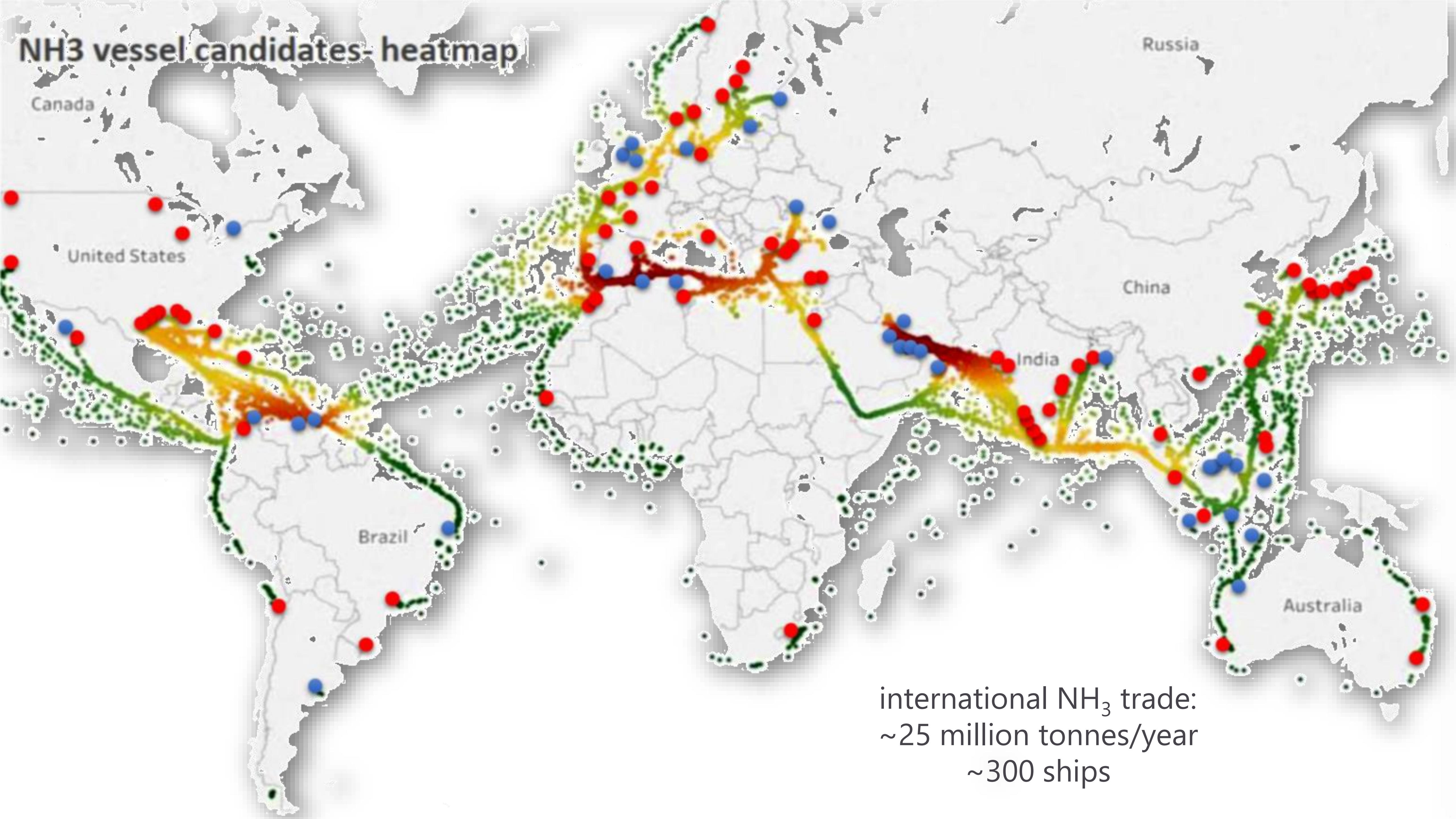
Power	Total (TW)	2050 (TW)	TWh	"cars"
Global	19.0	40	500	1,000M
USA	3.0	6	75	150M
UK	0.23	0.5	6	12M

NH_3 (interseasonal)

2022 Energy consumption	2050 (TWh)	interseasonal (TWh)	NH_3 (Mt)	× 2022 NH_3
Global	350,000	70,000	20,000	× 100
USA	50,000	10,000	3,000	
UK	4,000	2,000	660	



announced 2022 low-carbon ammonia plants project list (courtesy Ammonia Energy Association)



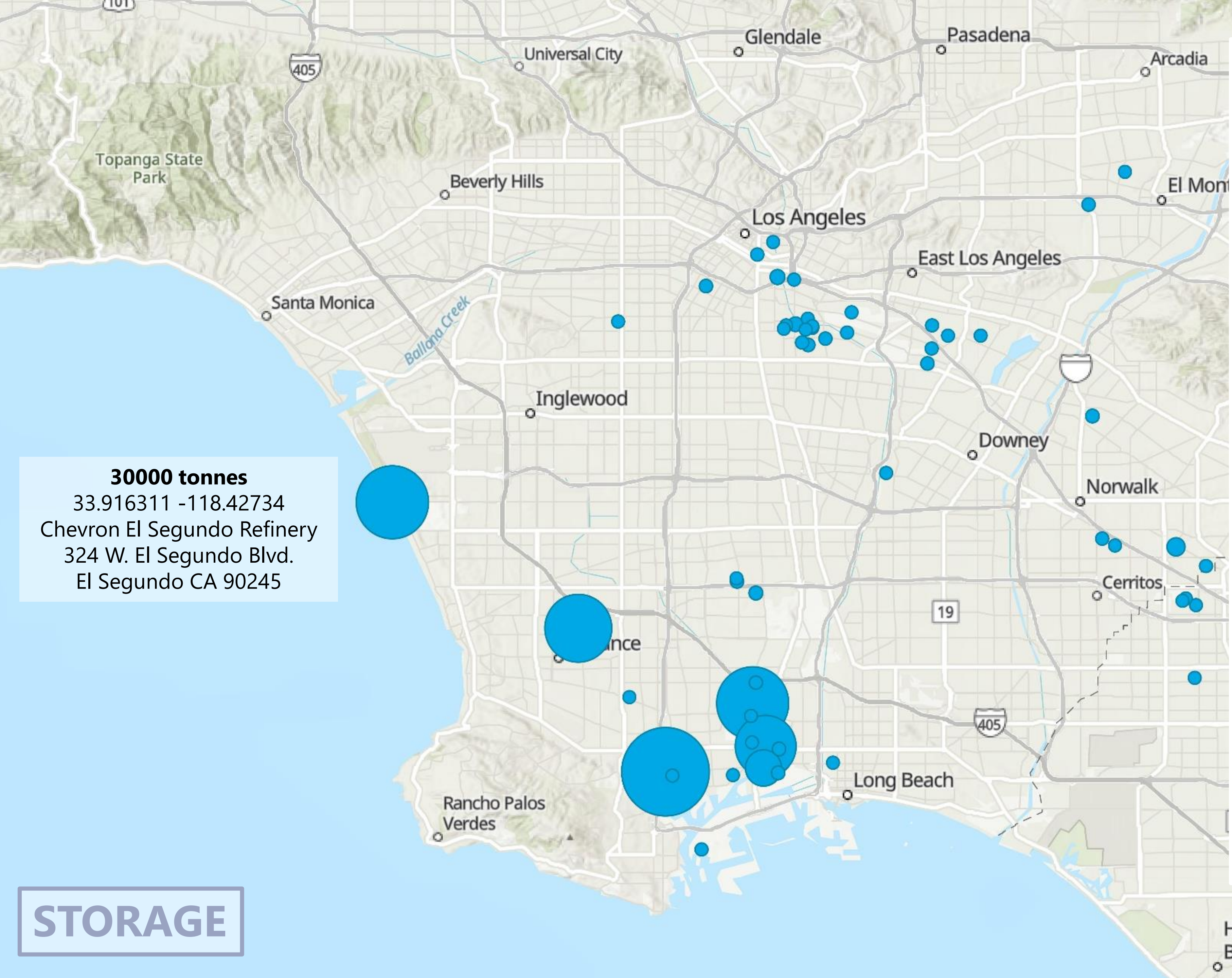
international NH_3 trade:
~25 million tonnes/year
~300 ships

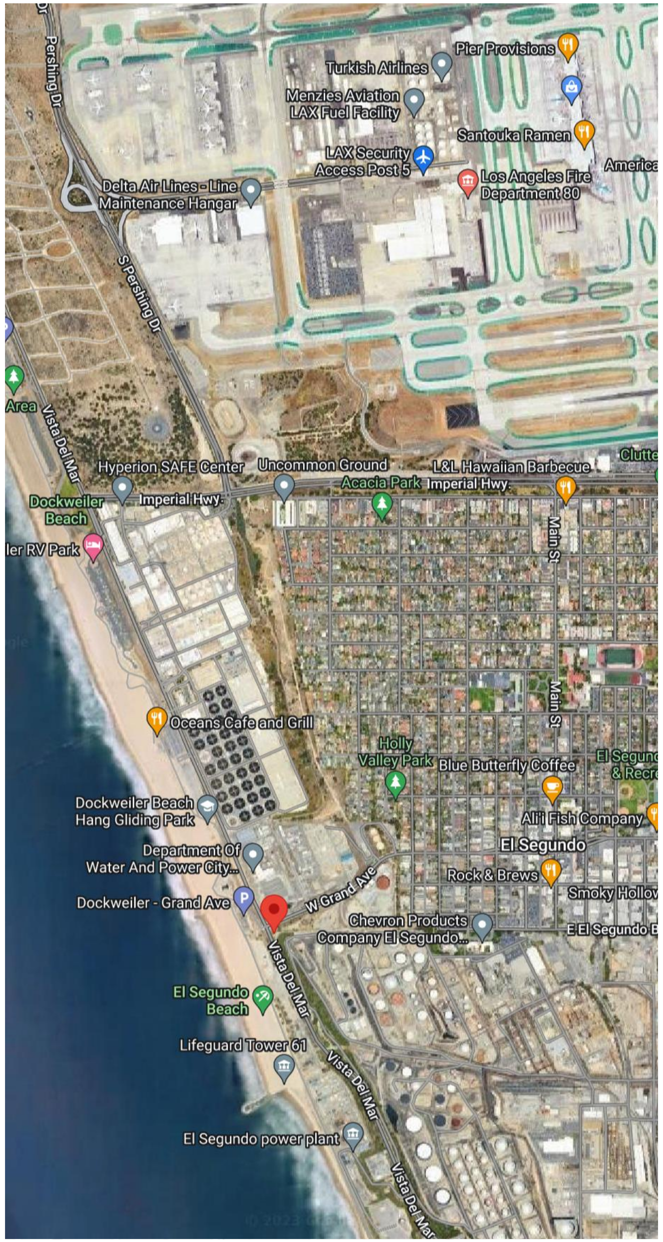
Alternative Fuels Insight

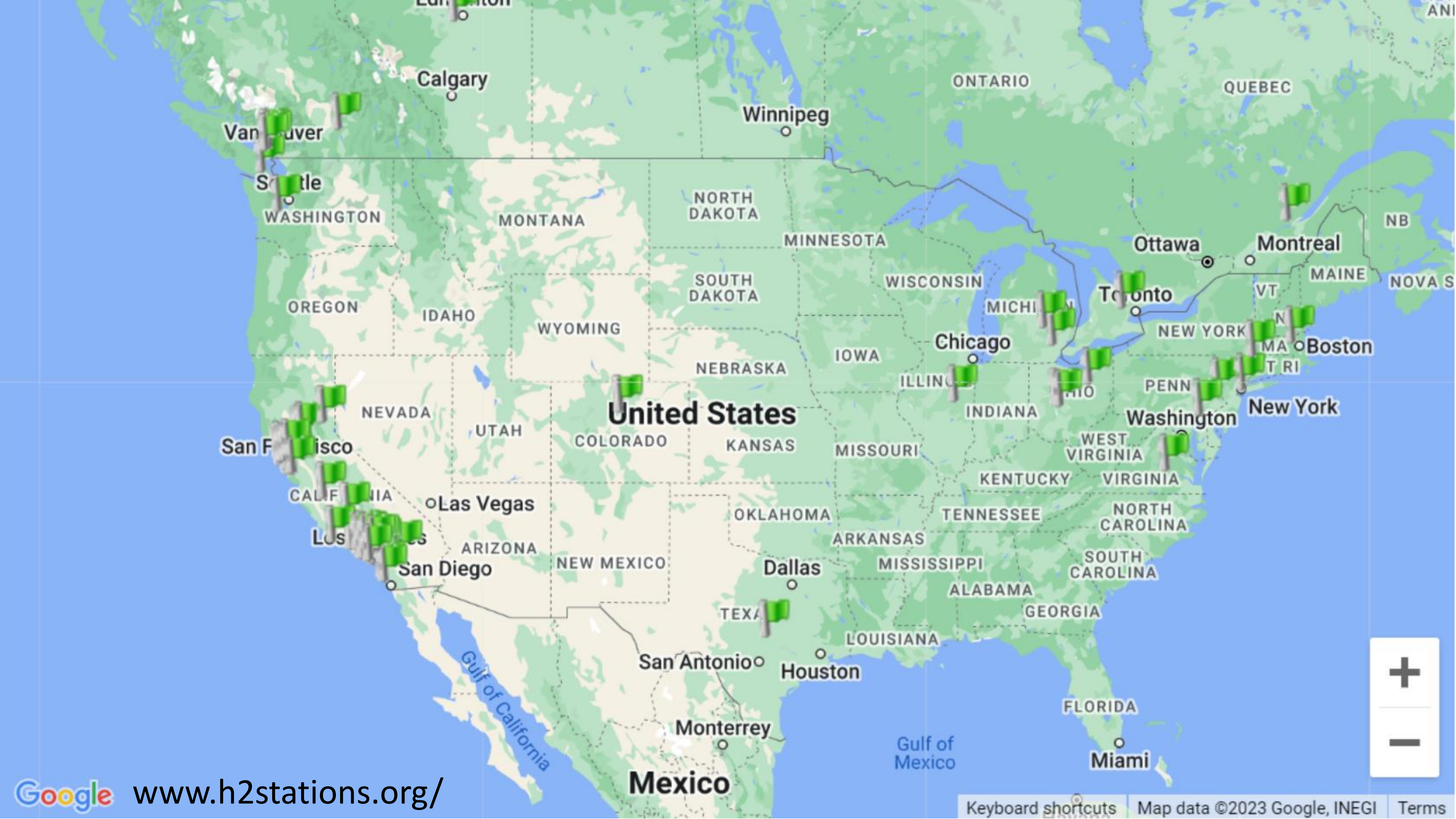
afi.dnv.com/Map

STORAGE

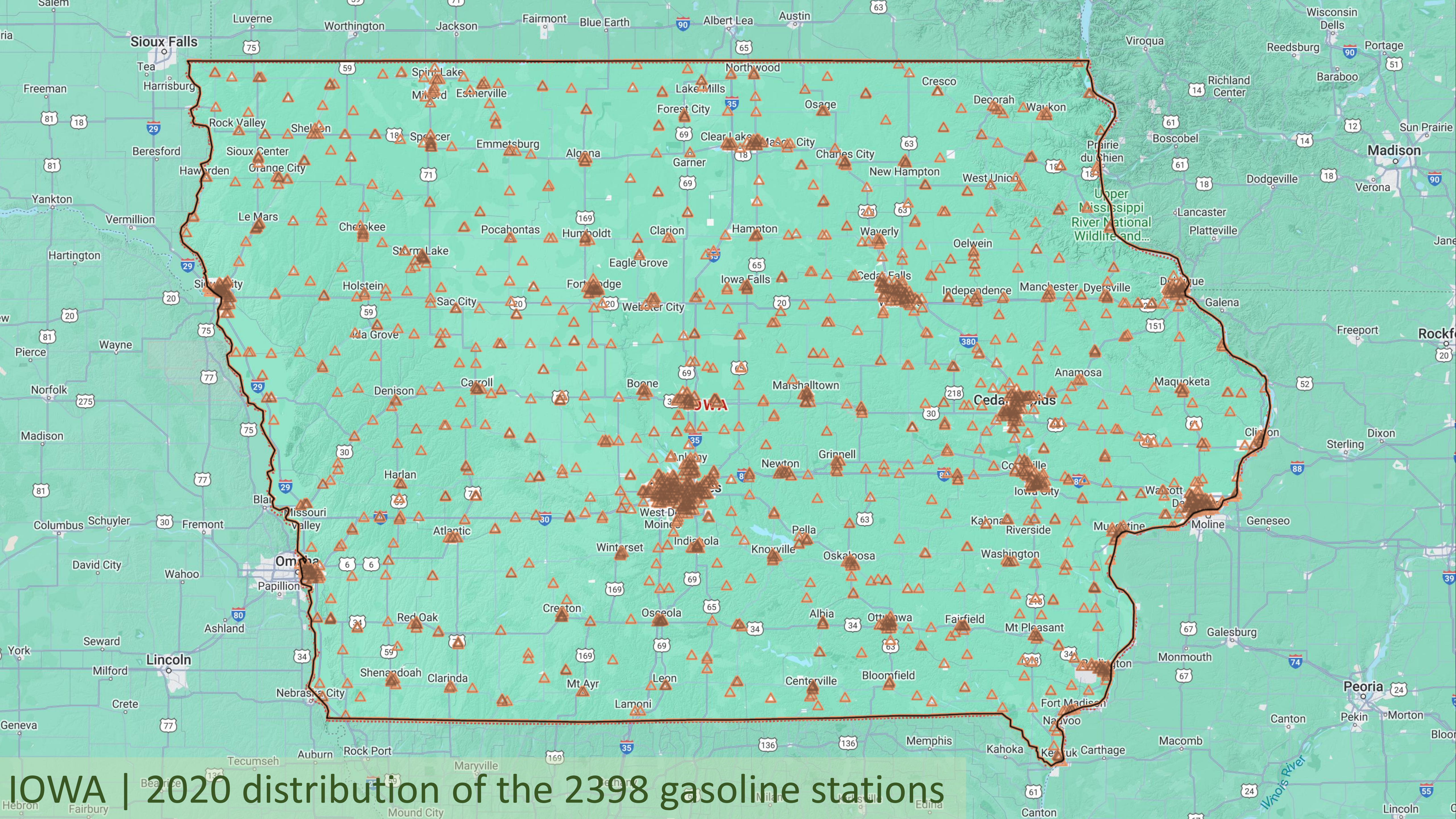
30000 tonnes
33.916311 -118.42734
Chevron El Segundo Refinery
324 W. El Segundo Blvd.
El Segundo CA 90245



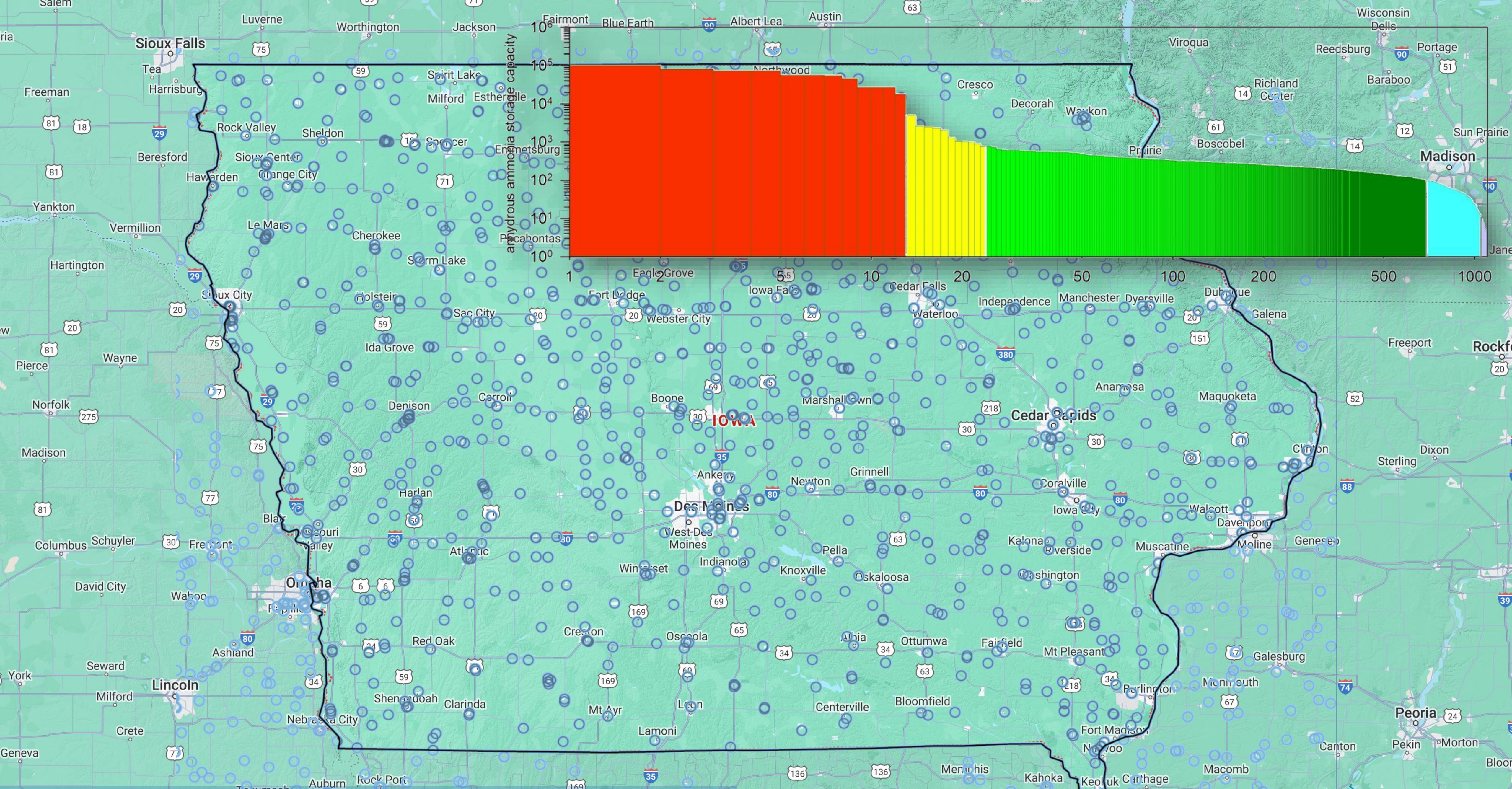




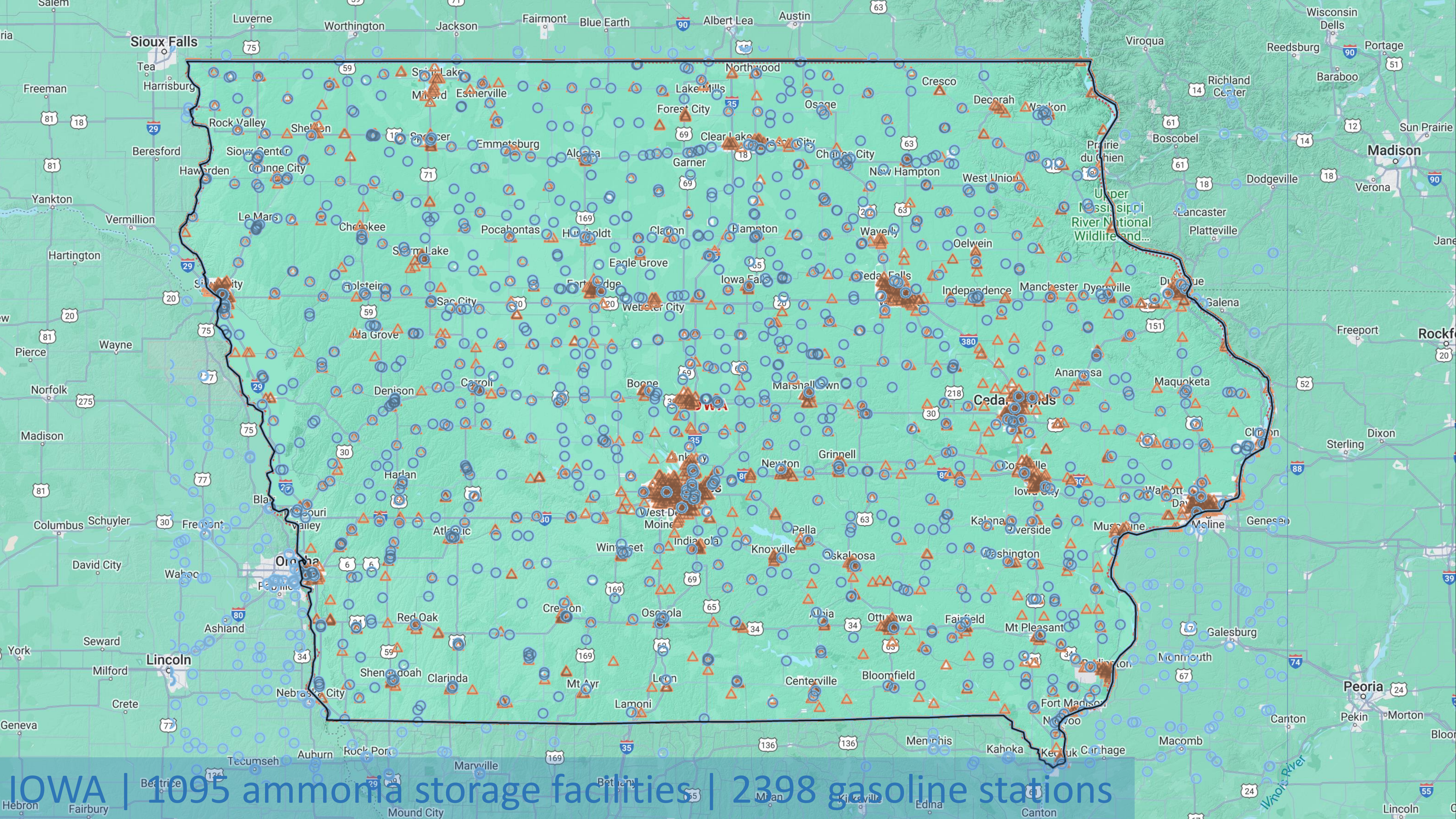
www.h2stations.org/



IOWA | 2020 distribution of the 2398 gasoline stations



IOWA | 1095 ammonia storage facilities



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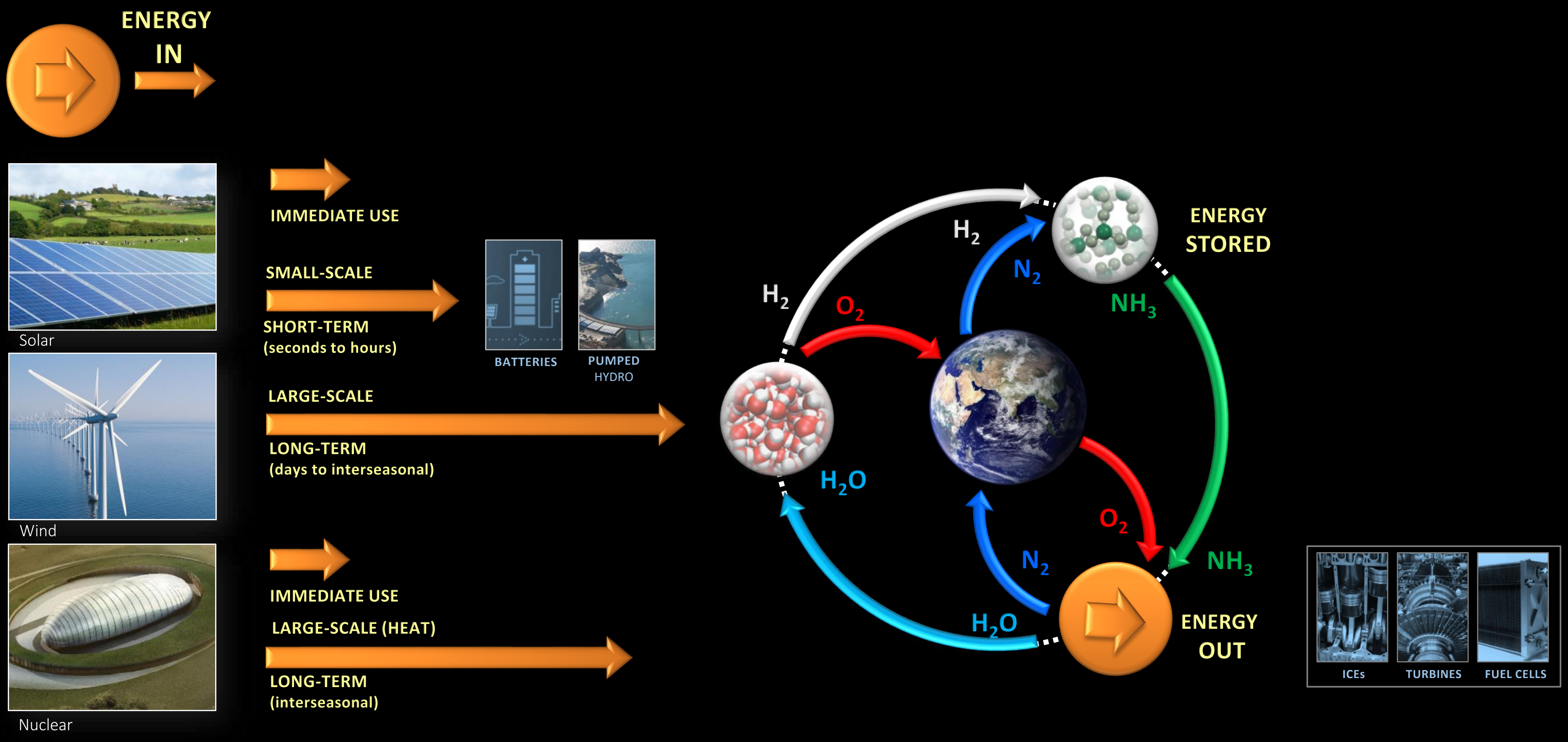
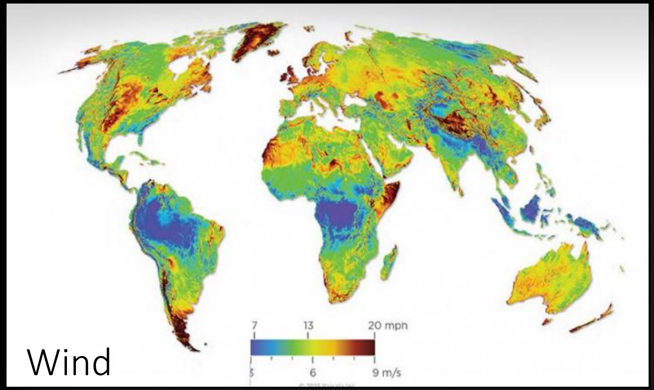
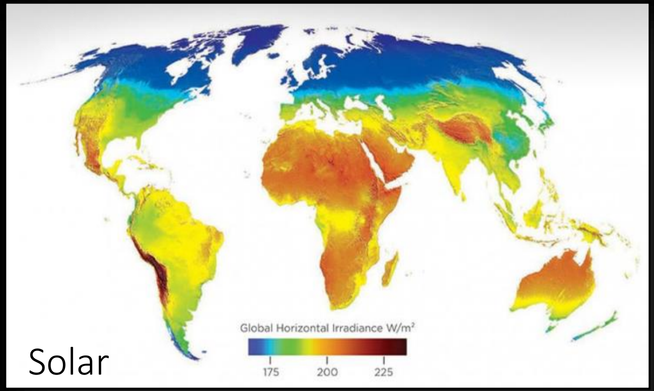
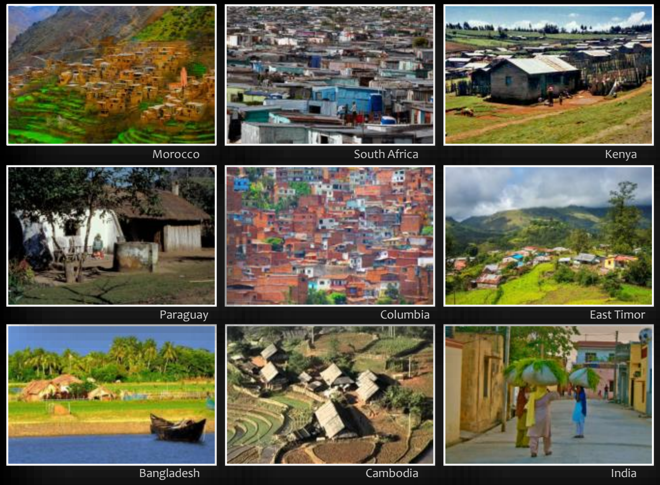


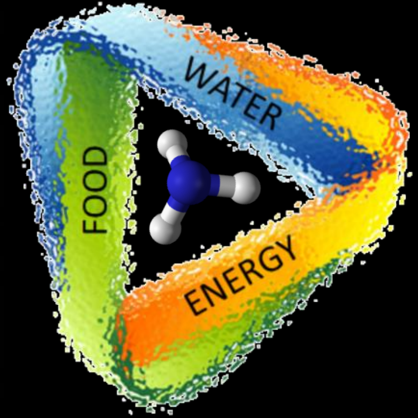
ENERGY IN
Solar
Wind
Nuclear
IMMEDIATE USE
SMALL-SCALE
SHORT-TERM
(seconds to hours)
BATTERIES
PUMPED HYDRO
LARGE-SCALE
LONG-TERM
(days to interseasonal)
IMMEDIATE USE
LARGE-SCALE (HEAT)
LONG-TERM
(interseasonal)
H_2
H_2
O_2
N_2
ENERGY STORED
NH_3
H_2O
O_2
N_2
NH_3
H_2O
ENERGY OUT
ICEs
TURBINES
FUEL CELLS





DEMOCRATISING ENERGY AND POWER

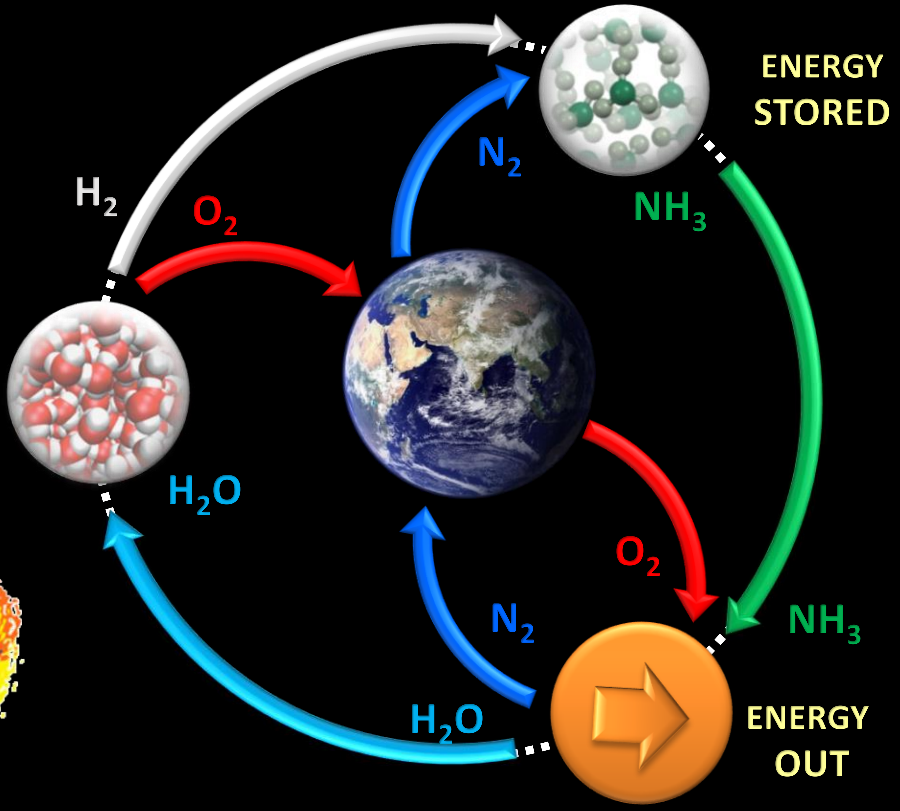




THE WATER-AMMONIA CYCLE

$$6H_2O + 2N_2 \longleftrightarrow 4H_3N + 3O_2$$

H_3N (air hydride 1) $\longleftrightarrow$ H_2O (air hydride 2)



A MOST VIRTUOUS CIRCLE