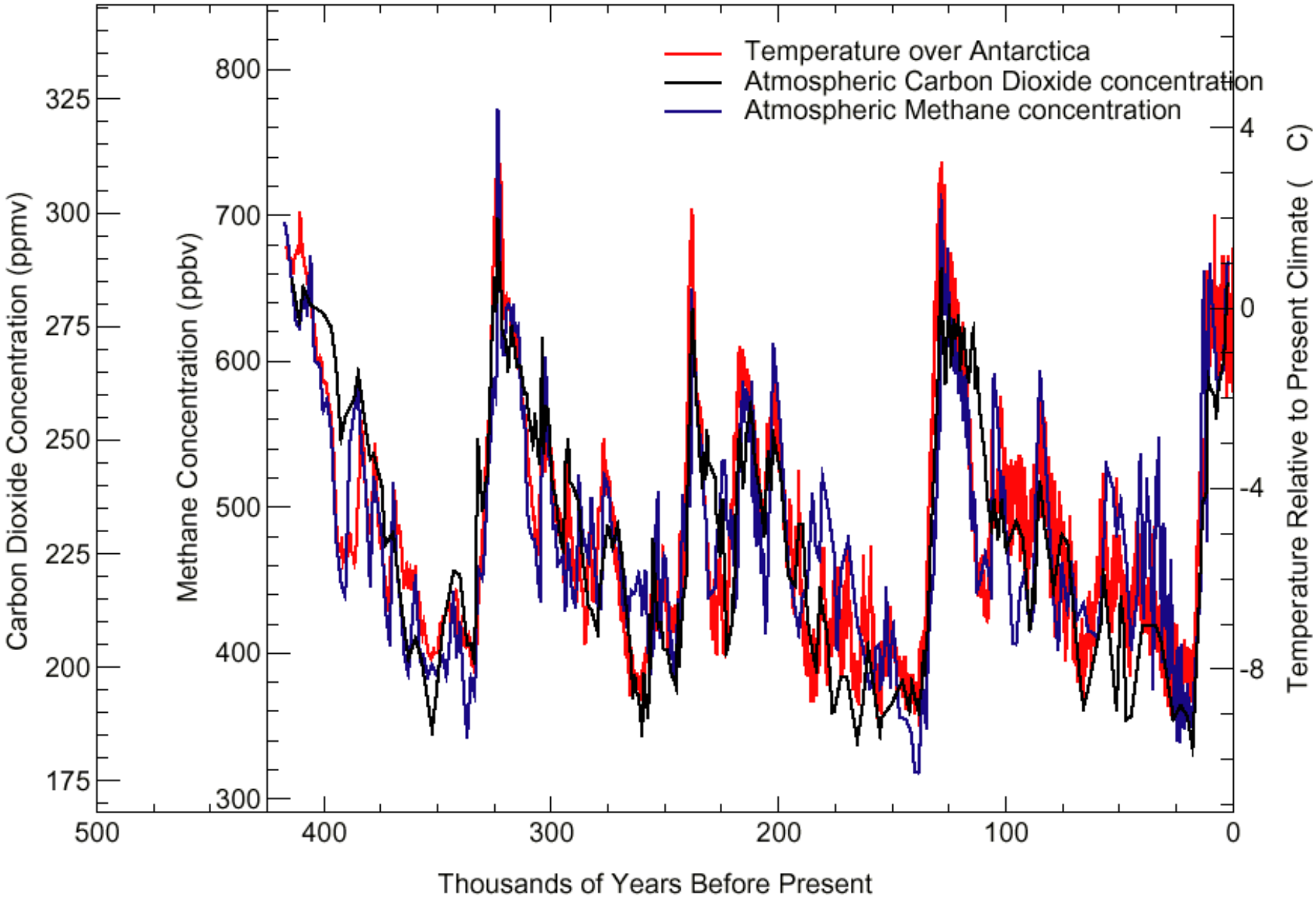
The Architecture

of Energy Systems

What's constant, what changes, where are we going, why hydrogen?

David Sanborn Scott



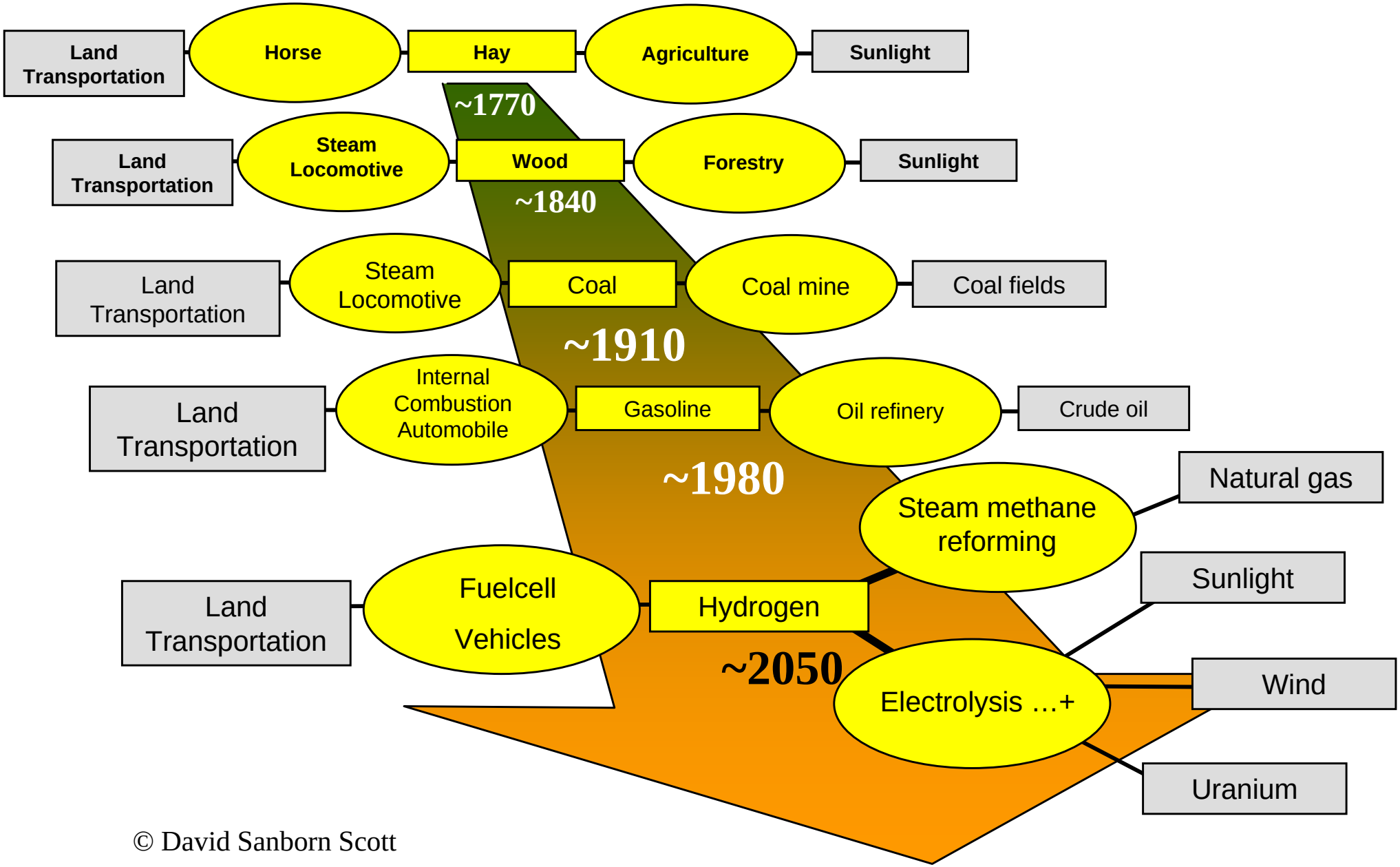
Energy System Chain

What People Want...

| ← What Civilization Creates → |

What Nature Provides

Land Transport: Δt ≅ 70 years



Why Hydrogen?

2nd → Planetary climate security

1. *CO_2* **from fossil fuels is forcing climate destabilization, *which*, if unabated → catastrophic.**
2. **To eliminate *CO_2* emissions requires: *BOTH* non-carbon *sources* & non-carbon *currencies*.**
3. **Many NC *sources* available—or developable. (hydraulic, nuclear fission/fusion?, sunlight, wind…)**
4. **Contrast: Only two Non-C *currencies* can, together, provide complete services: electricity and hydrogen.**
5. **Therefore, anthropogenic *CO_2* only slowed by extensive *H_2* → and only stopped with supremacy of *H_2* among chemical fuels.**

When Hydrogen?

Lest we mislead

1. **When H_2 technologies BETTER**
2. **Equivalent, not good enough.**
3. **Old technologies always "fight back."**
4. **International security**
   & Climate security
   ONLY background drivers.

Hydrogen-Electricity Age
CURRENCY Synergies

- H_2 (can be) stored in enormous quantities, electricity cannot.
- Electricity moves energy without material, H_2 cannot.
- H_2 is chemical/material feedstock, electricity is not.
- Electricity can process & store information, H_2 cannot.
- H_2 wins for long-distance transport (Earth)

Hydrogen Age
CURRENCY Similarities

Both

- **H_2 and electricity can be manufactured from *any source***
- **H_2 and electricity can be *interchangeably converted***
- **H_2 and electricity are *renewable***

Now to the Deep Future

Hydrogen Age

to look @ three middle links

- **Service Technologies**

  Focus: → Transportation

- **Currencies**

  Distribution/Delivery Infrastructures

- **Transformer Technologies**

  Reliables and Whimsicals

Energy System Chain

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Service Technologies

Zoom to: Free-range transportation

Hydrogen will fuel:

- **All free-range vehicles**
  1. **Air: Heat engines dominate, except fuelcells for APUs**
  2. **Surface: Fuelcell powertrains dominate**

Service Technologies

Focus: Free-range transportation

Onboard storage: LH_2 dominates.

- Liquefaction efficiency → will be *much* improved.
- Synergies: Between "cold" and "chemical" exergy. (e.g.: aircraft, & fuelcell vehicles)
- Constant ratio: thermomech./chemical exergy.
- Lightest (by far) → essential for flight
- Enhanced Cryogen Exergy Recovery Systems

Currencies (*hydrogen & electricity*) Distribution and Delivery

Continental delivery: gaseous H_2 pipelines,

- **Some using old electricity right-of-ways.**
- **Inherent energy storage → gaseous compressibility**

LH_2 not used for trunk lines

- **Capital cost & incompressibility are show-stoppers.**

Urban distribution: → gaseous H_2 pipelines

- **Fuelcells provide dc electricity for residence & office (feeding dc appliances)**

Remote and rural distribution:

- **Some small-capacity dc electricity grids.**

Transformers *(source to currency)*

RELIABLES

- **Nuclear fission: dominates (swing H_2 ←~→ e)**
- **Nuclear fusion: perhaps? (H_2 dedicated)**
- **Hydraulic: minor & if non-intrusive (swing H_2 ←~→ e)**
- **Coal and oil: illegal or irrelevant for fuel. (High-value-added role → e.g. medicines, materials, lubricants, foods?)**
- **Some natural gas (H_2 via SMR): When sequestering available**

Transformers *(source to currency)*

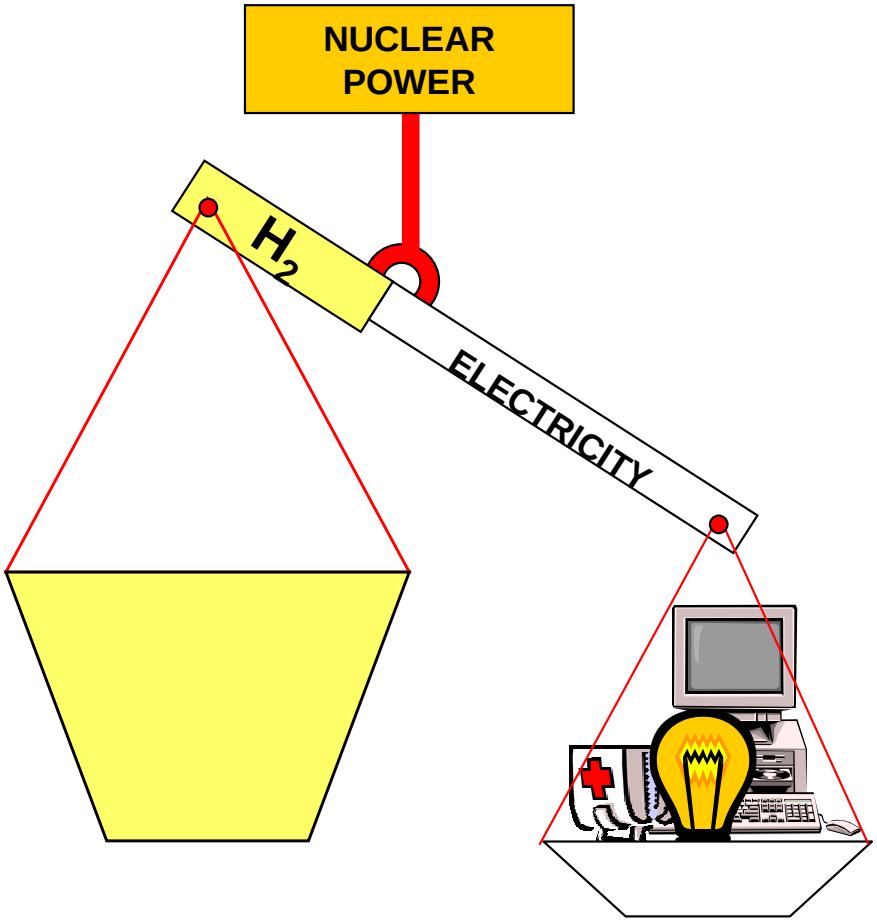
WHIMSICALS

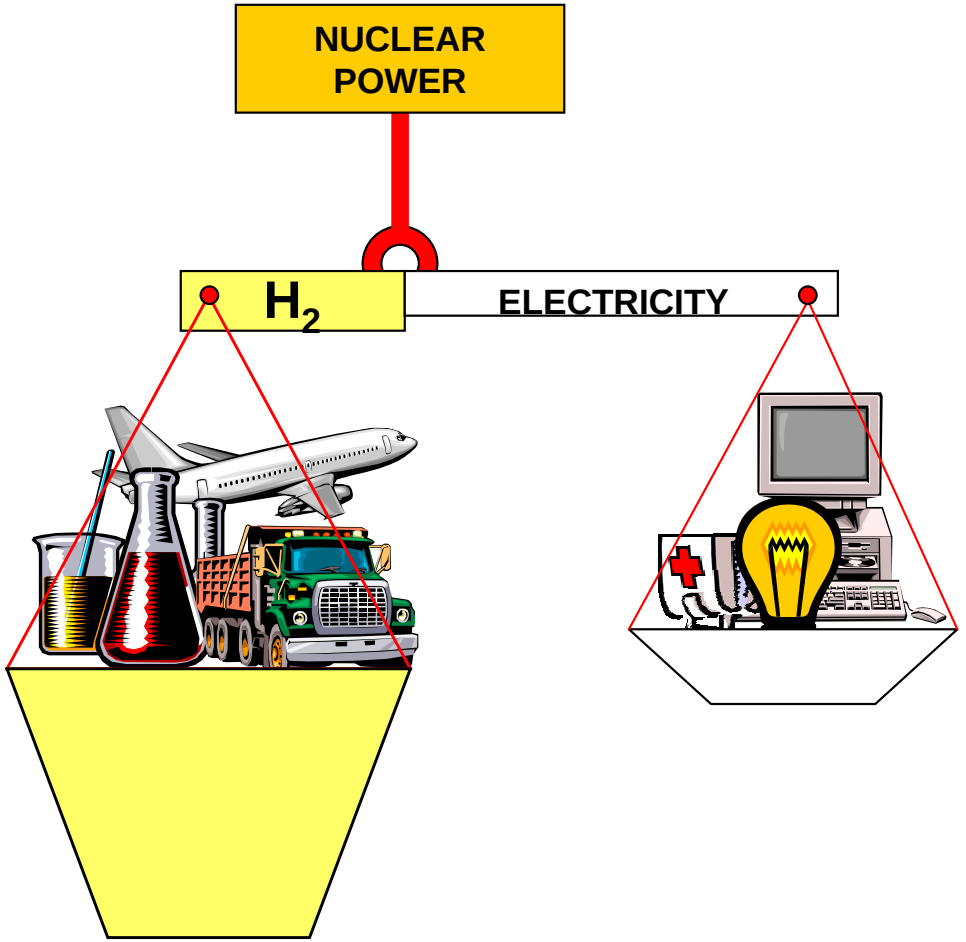
Intermittent renewables ~> wind, sun, tidal, etc.

- **Harvesting rate must be << replenishing rate**
- **Capped by large area requirements.**
- **Capped by intrusion on other renewables (forests, fish, water,wildlife)**
- **Requires storage or spinning reserves.**
- **HELPED: compressible gaseous H_2 pipelines**
  (Nuke-derived H_2 → whimsical gate opener)

Nuclear Power Services

Today and Tomorrow





CONCLUSION

- The needs are critical.
- The fundamental ideas, simple.
- The lack of understanding, stupefying.
- The dithering, scary.
- The promise, brilliant.