

Beyond Electrification

..and all the pieces matter — Lester Freamon.

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Hydrogen: Differences

- ▶ Three times as heavy as fossil fuels.
- ▶ One-quarter as dense as fossil fuels.

- ▶ → Need to design new airplanes
 - ▶ Airbus is on it.

- ▶ Transportable like natgas,
 - ▶ but more corrosive.

Hydrogen: Production Cost

Cost, \$ per MWh:

- ▶ Natgas Benchmark: **\$20**

Hydrogen, \$ per MWh:

- ▶ Brown (From NatGas): \$27
- ▶ Blue (With Capture): \$85
- ▶ Green (From Electrolysis): \$130

Green Hydrogen Future?

- ▶ In 30 Years: \$30/MWh (?)
 - ▶ Natgas only a little cheaper?
 - ▶ or maybe not even? Maybe catalyst breakthroughs?!
- ▶ Competitive against natgas?!
 - ▶ May depend on location, too.
 - ▶ hydrogen needs no special natgas reservoirs.

Green Hydrogen Future?

Speculating on hydrogen is speculating on:

1. Intermittent energy becomes nearly free.
 - ▶ Facilitates cheap hydrogen.
2. Energy storage remains expensive.
 - ▶ Batteries can't do most jobs better.

Green Hydrogen Future?

- ▶ Competitive against batteries?
 - ▶ Cheaper solar electricity will also reduce cost of battery-stored electricity.
 - ▶ Ionic bonds absorb and release energy easier than chemical covalent bonds.
 - ▶ Batteries' fixed cost may not scale easily,
 - ▶ but batteries are *in front of the cost curve*.
 - ▶ Wires are limited transport technology.
 - ▶ Hydrogen from Saudi to Europe?!

Hydrogen: Likely Future Uses

- ▶ Transportation, off-grid:
 - ▶ Almost surely ships and planes.
 - ▶ Maybe trucks, but we can disagree.
- ▶ Hydrogen for seasonal energy storage:
 - ▶ Unlikely for a long time.
 - ▶ Speculates on lack of progress in batteries.

H already also used for fertilizer production.

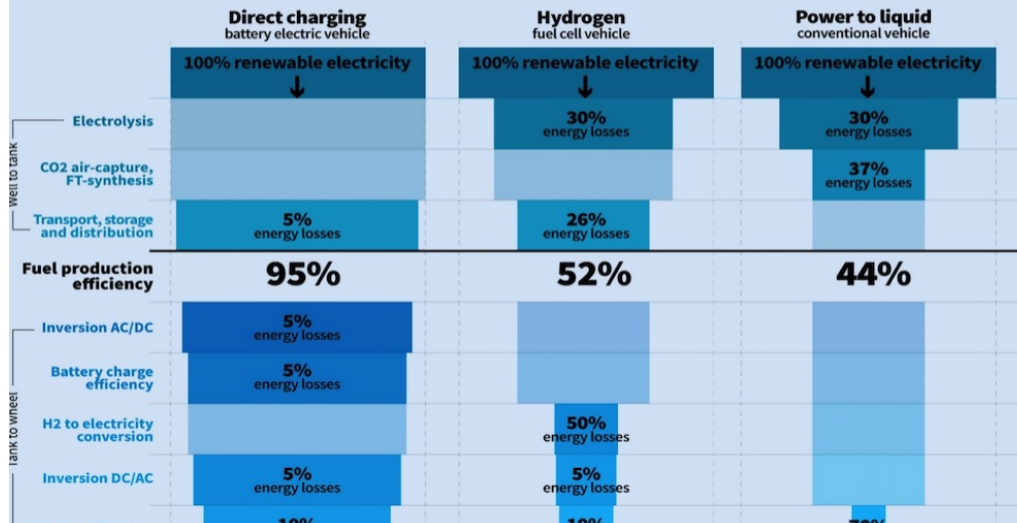
Hydrogen: Less Likely Futures

- ▶ Any uses suitably satisfied with *limited* battery capacity:
 - ▶ Batteries will likely always be more efficient.
 - ▶ Think less resistance both in and out;
 - ▶ Cheap solar energy reduces cost, too.
 - ▶ Batteries will recharge within minutes.
 - ▶ Batteries will improve greatly, too.

What do you think? Near-grid transportation?

Hydrogen: Bad Idea, Cars

Cars: Battery electric most efficient by far



Hydrogen's Kinetic Problem

Assume that hydrolysis is free and we have already have the input energy here.

- ▶ Efficiency of hydrogen for kinetic power:
 - ▶ 40% with a fuel cell *first* making electricity;
 - ▶ 30% with a piston combustion heat engine.
- ▶ Efficiency of battery: 75%.

Hydrogen: Stupid Ideas, Heat

- ▶ Use electricity first to make hydrogen, then burn it to make heat.
- ▶ Instead, just make heat with electricity.
 - ▶ Think **electric arc furnace**.
- ▶ → Avoids hydrogen roundtrip.

Would you make hydrogen to immediately burn it??

Green Hydrogen Future?

- ▶ Invest??

Where can hydrogen replace natgas?

Where can hydrogen replace batteries?

Green hydrogen for storage, transportation, etc., may not happen for decades, if ever.

Industrial, Steel, Cement

- ▶ Tough to replace fossil fuels for heat.
- ▶ Fossil fuels are one-trick ponies,
 - ▶ ... and this is their trick!
- ▶ Industrial heat will probably be the last bastion of fossil fuels.
 - ▶ Also, this discussion has omitted important issues on steel, cement, etc.

Agriculture

- ▶ Most models identify agricultural yields as primary cost of CC?!
 - ▶ Seems pessimistic,
 - ▶ like early clean-tech forecasts.
 - ▶ Boffins are decoding life now.
 - ▶ There is a lot we may be able to do.
 - ▶ But it's *not* certain.

Agricultural Emissions

- ▶ About 20% of global GHG today.
- ▶ Methane is especially bad:
 - ▶ Lots of methane From rice and cattle.
 - ▶ Richer people like beef and milk, so their consumption will increase.
- ▶ Farmers also overuse nitrogen.
 - ▶ Unrealistic: tax fertilizers more.

Agriculture

- ▶ Farmers are *not* stupid!
 - ▶ They tend to be conservative,
 - ▶ and they are politically very powerful.
- ▶ Farming is
 - ▶ Result of millennia of improvements.
 - ▶ Large and decentralized.
 - ▶ Cut-throat business.
- ▶ ~~Appeal to social or ecological conscience.~~

Ag Progress I

- ▶ Ag should be able to improve:
 - ▶ Ag will need *many* different solutions,
 - ▶ e.g., *Asparagopsis*, flooding, tilling, etc.
 - ▶ Technology is progressing, too:
 - ▶ GMO and CRISPR/Cas9 are promising,
 - ▶ especially for poor country crops.
- ▶ Cut-throat business favors efficiency
 - ▶ if more efficient to pollute...

(conflict-of-interest disclosure)

Ag Progress Ii

- ▶ Stupid environmentalism can cause big unnecessary environmental problems.
- ▶ Humanity cannot go back to nature!
- ▶ Boffins can *reduce* ecological problems!
 - ▶ Chemicals are necessary to feed humanity, but created many environmental problems.
 - ▶ Biotech now can be on side of environmentalism.

Ag Progress Ii

- ▶ Newer better foods need consumer acceptance.
 - ▶ Do *not* bless non-sense food labels.
 - ▶ ‘Natural foods’, my
 - ▶ Can natural foods use pesticides?
 - ▶ Cyanide is natural, too
 - ▶ Is genetic modification intrinsically bad?
 - ▶ What do you think you are eating today?
 - ▶ How do you think you arose?

Disclaimer

- ▶ Good reasons to oppose many farm practices:
 - ▶ Such as inhumane animal farming.
 - ▶ But please don't oppose better crops.
- ▶ Good reasons to be careful, too:
 - ▶ New technologies may have risks.
 - ▶ *Very unlikely.* (Make boffins eat!)
 - ▶ External application of chemicals more likely more harmful to people and environment.

Personally, I pay extra for humanely farmed animals, but I have no illusions that this will change the world.

More Earth Solutions

- ▶ Food waste
- ▶ Landfills

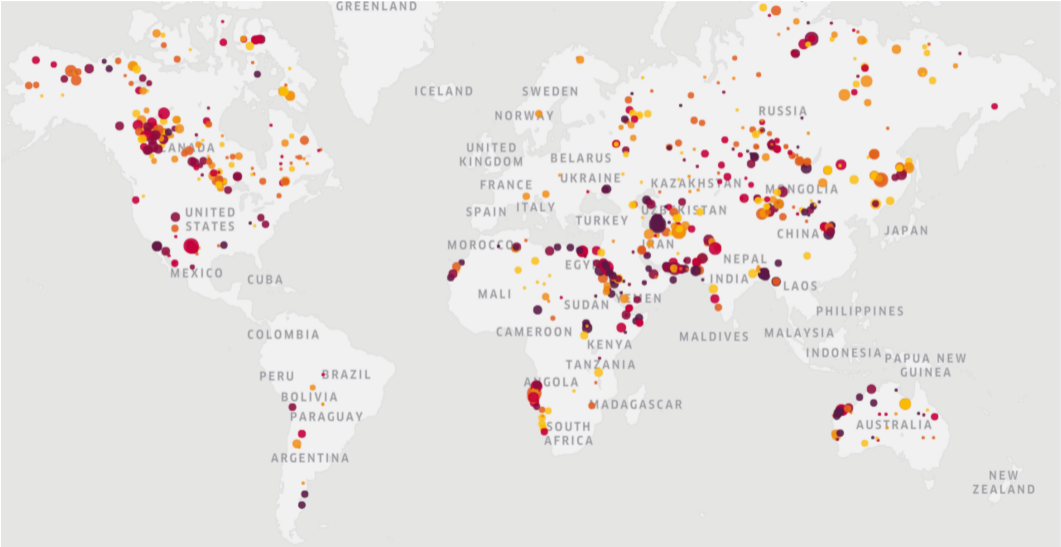
USA Specific

- ▶ Cut stupid ethanol subsidies immediately.
- ▶ Each gallon of ethanol uses more than a gallon of diesel.

Methane

- ▶ Not just USA or OECD problem.
- ▶ Often from oil&gas operations
 - ▶ standard o&g mode is don't cap, sell off.
 - ▶ end-of-life deposits are ridiculously low.
 - ▶ Needs stronger penalties, incl. at EOL.
 - ▶ reach-back liability?
 - ▶ Needs constant measuring of emissions.
 - ▶ easy satellite detection!
 - ▶ Needs resistance to lobbying,
 - ▶ hardest to manage, given reality.

Global Methane Emissions



Yet Others

Lots of mundane stuff. For example:

- ▶ Improve insulation:
 - ▶ incentives, guarantees, financing.
- ▶ Thermal energy storage.
- ▶ Heat pumps:
 - ▶ 400% efficiency!

Conclusion

- ▶ Energy from fossil fuels is the world's biggest pollution issue.
 - ▶ Don't be too bullish on hydrogen,
 - ▶ but hydrogen will likely play a role.
- ▶ Many other GHG emissions need clean solutions, too.
- ▶ Humanity can tackle agricultural & food emissions better.