

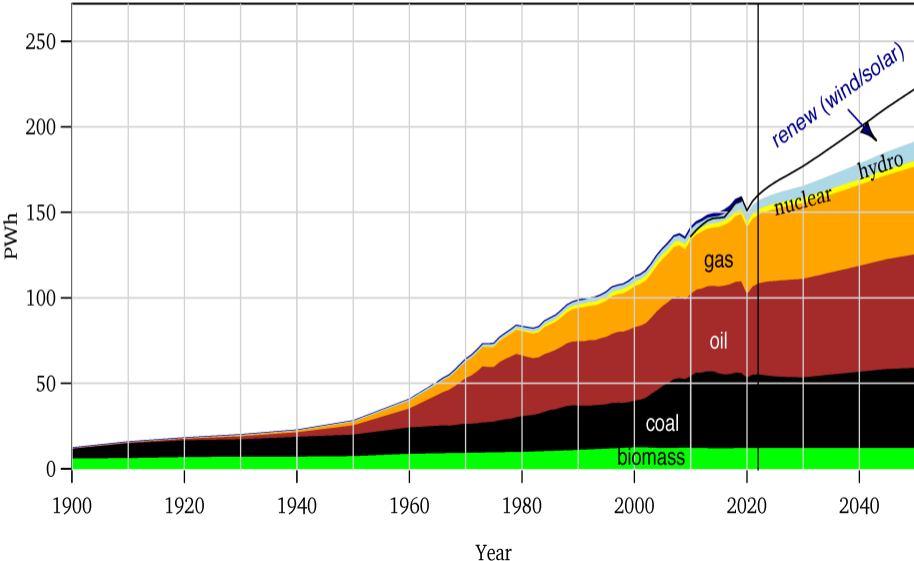
Fossil Fuels & Substitutes

There is a whole ocean of oil under our feet! No one can get at it except for me — Daniel Plainview.

Ivo Welch

2023-02-17

Situation Today



Fossil Fuels

- ▶ Here now and *cheap*.
- ▶ Existing infrastructure:
 - ▶ gas and oil is cheap to ship,
 - ▶ and easy to store.
- ▶ Limited disaster potential:
 - ▶ kills more steadily, not very saliently.
- ▶ Fossil fuels make great heat engines,
 - ▶ but poor electricity and kinetic engines.

Basic Alternative Fuels / Stores

1. Hydrogen
2. Batteries
3. Nuclear

More details in next chapters.

1. Hydrogen

- ▶ Lighter but less dense (lower per m^3)
 - ▶ Best for airplanes and ships far off the grid.
 - ▶ Will need new designs, but not terribly novel.
- ▶ Flammable (better and worse than gasoline).
- ▶ Similar but more corrosive than natgas.
- ▶ **Storable like natgas**

Hydrogen's Deadly Problem

Cost!

Hydrogen's Deadly Problem

- ▶ **Clean** hydrogen costs about **10x** as much as natgas
 - ▶ could come down to **2x** in 30 years?!
- ▶ Who wants to pay “only” twice as much?
 - ▶ Think competitive industries.
 - ▶ Think Expedia airplane trips
 - ▶ Think shipping containers.

Better catalysts? Cheaper electricity inputs?

2. Nuclear Power

- ▶ Clean reliable power

except when plant blows up.

Nuclear Power Safety

- ▶ Safest plants ever built, but *not* safe enough.
 - ▶ 1 core melt-down per 4,000 reactor years.
 - ▶ Unknown problems always creep up.
 - ▶ Disasters can be terrible.
 - ▶ Hard to control human agency problem:
 - ▶ Make 100x profit using 5c screw as \$5 screw.
 - ▶ Who will check later?
 - ▶ Screw changes risk from 1/100m to 1/99.99m.

Nuclear Power Safety

- ▶ How safe is safe enough?
 - ▶ Even overall, could make twice the profit allowing 1-in-3,000 over 1-in-4,000?
 - ▶ What company and manager wouldn't want to outperform others and be promoted?
 - ▶ Inspect (or **falsify** reports)?
 - ▶ Much easier to conquer atom than humans!
 - ▶ Watch HBO **Chernobyl miniseries**.

Safety Considerations

- ▶ Human Operations Error:
 - ▶ we need nuclear plants where operator can no longer even intentionally blow up the plant,
 - ▶ no matter how hard they try.

Better Than Fossil Fuels?

- ▶ Fossil fuels kill hundreds of thousands
 - ▶ every year, but not with big bangs,
 - ▶ and scary radioactivity.
- ▶ Since 1960, nuclear has killed \approx 100,
 - ▶ almost all in Chernobyl.
 - ▶ Devastation in Fukujima is from Tsunami, not from nuclear plant core meltdown!
 - ▶ Radiation is not as bad as public imagines it.
 - ▶ It truly depends on dose.

Nuclear Power Regulation

The Regulator's Problem:

- ▶ Companies that want to go to 1 in 3,000,
- ▶ and know more than the regulators.
- ▶ What does a bureaucrat get for:
 - ▶ Type-I error?
 - ▶ Type-II error?

wanna become famous? only one way...

Innovation And Improvement

Nuclear Regulatory Commission, 1975:

- ▶ Need better regulation.
- ▶ More regulation is not better regulation.
- ▶ No new designs both completed and built
- ▶ Some slightly better designs were finished.
 - ▶ Better safety features than older designs.
- ▶ About to change (Terapower Wyoming)

- ▶ FOAK costs, experience, etc.

Nuclear *Fusion* Plants

- ▶ Completely different physics.
- ▶ Power source of the sun, infinite supply.
- ▶ *Don't drink the Cool Aid.*

- ▶ Ironically, ***economically*** just like fission:
 - ▶ very high fixed costs,
 - ▶ very low marginal costs,
 - ▶ near infinite supply of fuel.
- ▶ Except
 - ▶ fusion plants cannot blow up, more like flame very difficult to sustain.
 - ▶ less radioactivity at end of life (EOL)

No panacea, but good to research.

Eol Nuclear Waste Problem?

- ▶ Spent Fuel-Rod Disposal
 - ▶ but could be reused 1,000x more in breeder reactors, which no one wants to license,
 - ▶ and government has guaranteed disposal.
- ▶ PS: **Fossil Fuels have same problem,**
 - ▶ but public does not seem to care as much;
 - ▶ much stronger lobby for fossil fuels!
 - ▶ Perfunctory: Feds collect nominal amounts.

Biggest Nuclear Problem

- ▶ Huge Fixed Cost: Think ***\$20b/plant.***
 - ▶ plus maybe cost overruns.
- ▶ Think 10 years to build.
- ▶ Could be obsolete at opening,
 - ▶ while suffering new regs along the way,
 - ▶ or be so unpopular as not to be licensed.

- ▶ Who wants to gamble their retirement funds?

3. Batteries

- ▶ Very low energy density.
 - ▶ Think 5% of fossil fuels.
- ▶ Never useful for heat.
 - ▶ Make heat first and store heat!
- ▶ Battery capacity on grid is tiny.
 - ▶ Think 10 minutes of storage.
 - ▶ Even hydro storage is much more.
 - ▶ Only useful for niche applications sofar.

Today's Lithium Batteries

- ▶ Best and dominant technology
- ▶ Very lightweight (great for cars)
- ▶ Highly explosive when exposed to humidity.

We will cover batteries in the next chapter.

Cool Aid: Green Tech

- ▶ Even technologies working in the lab usually fail to work in the real world.
 - ▶ Think 1 in 10 will ultimately make it.
- ▶ Fortunately, civilization has 20 draws.
- ▶ R&D investment is large and risky,
 - ▶ also because another stealth green company could solve problem even better.
- ▶ Better to research, develop, or deploy now?

Cool Aid: Fossil Fuels

- ▶ FUD. Attack critics.
- ▶ Huge lobbying engine and political power.
- ▶ Fossil fuels have enjoyed huge subsidies.

- ▶ Think half-truths and non-sense:
 - ▶ mix liberally,
 - ▶ repeat often.

If it's a lie, then we fight on that lie — Slim.

A lie ain't a side of a story. It's just a lie — Gus.

Attack Vectors

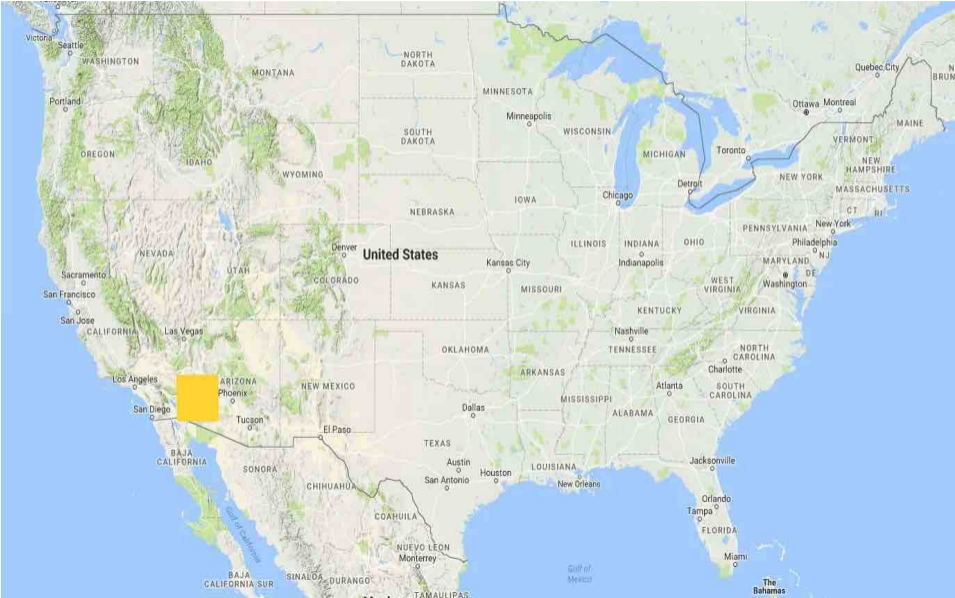
- ▶ Blacken green alternatives
- ▶ Point out unimaginably large numbers
 - ▶ Of course it's big—including the problem.
 - ▶ Ignorant public is easy target.

(PS: also true for green proponents.)

Space Requirements

- ▶ Green Tech requires too much space:
 - ▶ Size of Massachusetts!
- ▶ Yes and no.
 - ▶ Space is not a constraint, except inside cities.
 - ▶ Think instead *size of land for agriculture*.
 - ▶ need only <5% thereof *and* elsewhere.

Space Needs For Solar



Dig, Recycle, Etc.

- ▶ WSJ OpEd: *Get ready digging.*
- ▶ Of course yes, but so do fossil fuels:
 - ▶ Real(istic) EOL consequences of fossil fuels have been terrible!
 - ▶ So are the ongoing local health effects.
- ▶ Worst comes to worst, landfill wind turbines.
- ▶ *But* critique is cosmically good
 - ▶ better designs with recycling in mind.

Tire Mountains, 1970s



Limited Clean Materials

- ▶ Cobalt, Lithium are in short supply.
- ▶ ***Yes and No.***
- ▶ **Cosmic *Nonsense*:**
 - ▶ Just cheapest and best first solutions.
 - ▶ Chemistries will be much better and cheaper in 30 years.

Unfair Government Subsidies

- ▶ Clean energy is indeed getting subsidies,
- ▶ but not nearly as much as fossil fuels have gotten over the decades.
 - ▶ (and this does not even consider the pollution externalities, which we should add in, because we have not charged them for it.)

Conclusion

- ▶ Fossil fuels are not easy to replace,
- ▶ but they are *not* irreplaceable.

Technology alternatives to be explained next.