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

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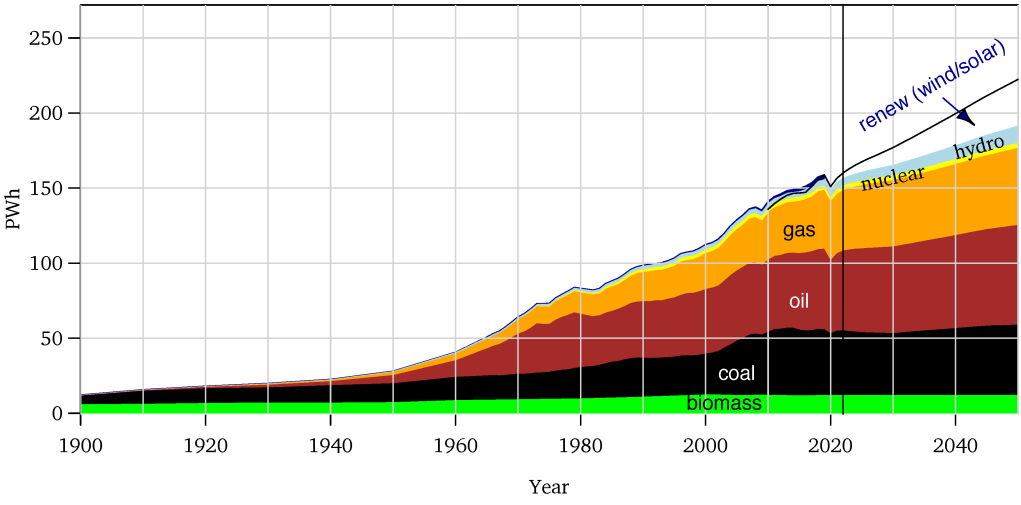
Situation Today



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 ≈ 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.