How can the US meet energy demand while keeping emissions down?

Jack Diamond
Joanna Slusarewicz
Priya Niezgoda
Su Chen Teh


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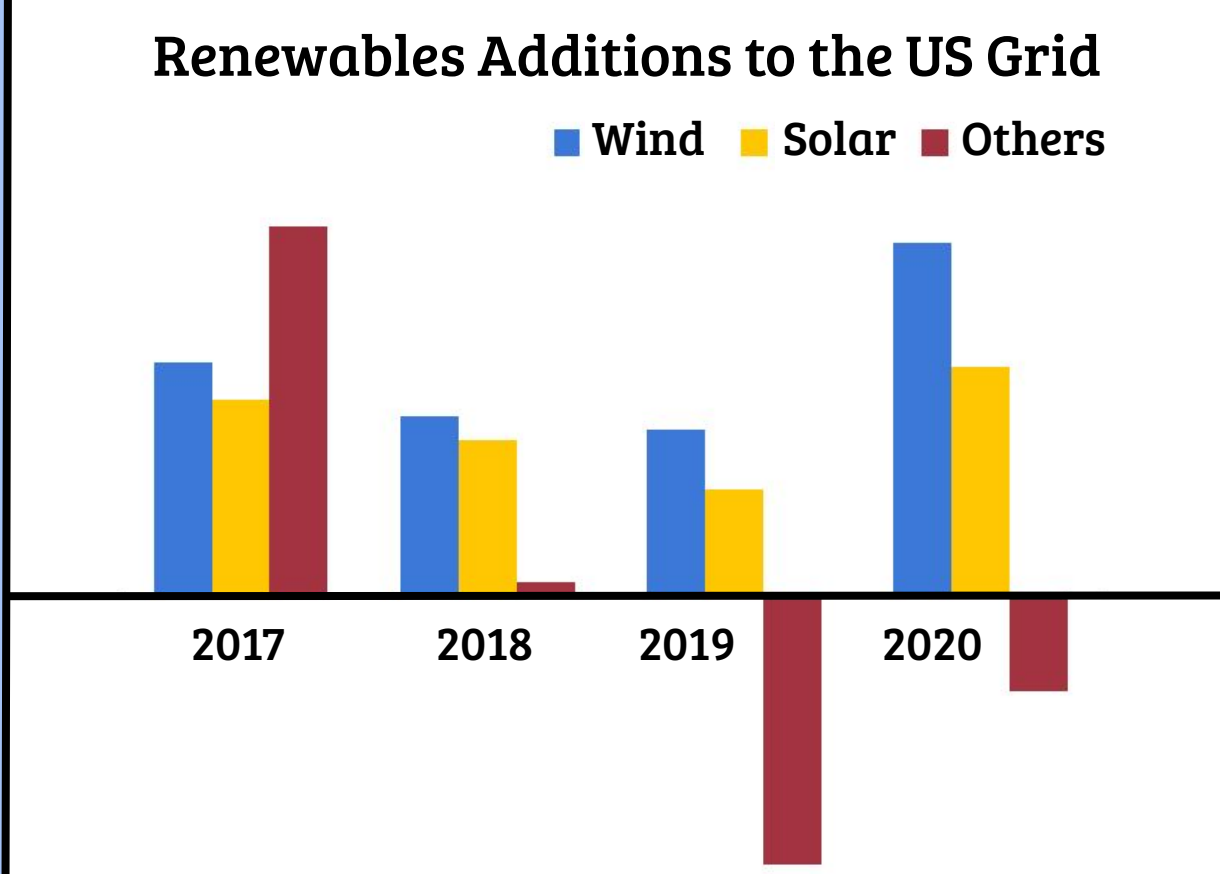
The Popular Solution: Solar and Wind

Short-Term:

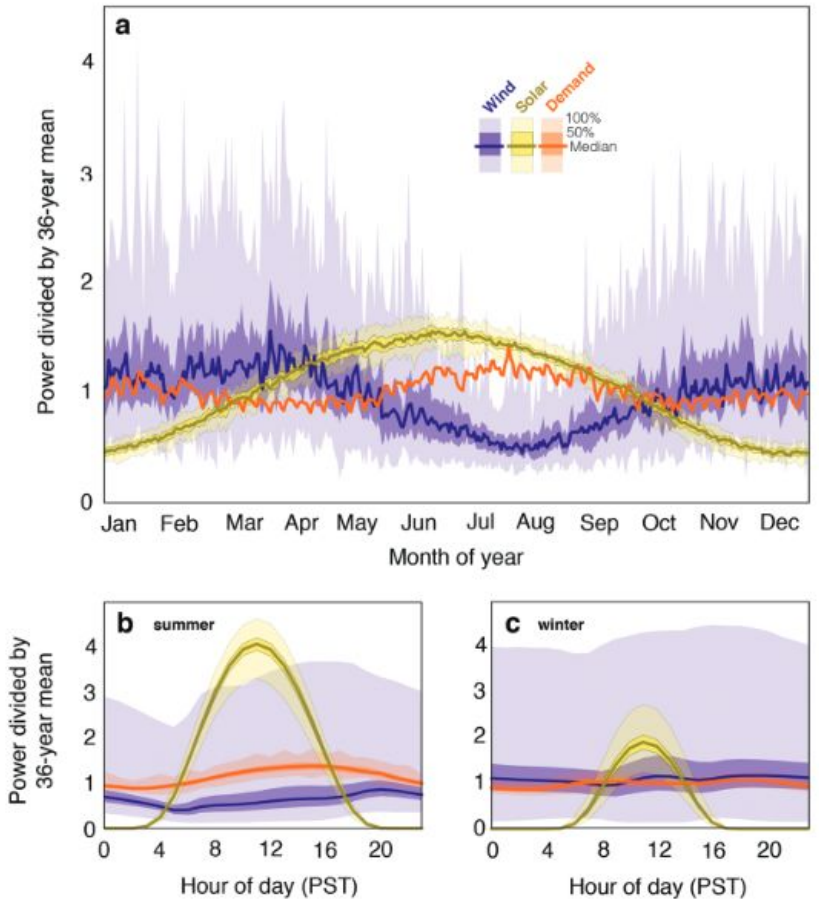
Of clean energy options, wind and solar will win out.



Long-Term:

Without energy storage, we can reliably meet **48%** of US demand.

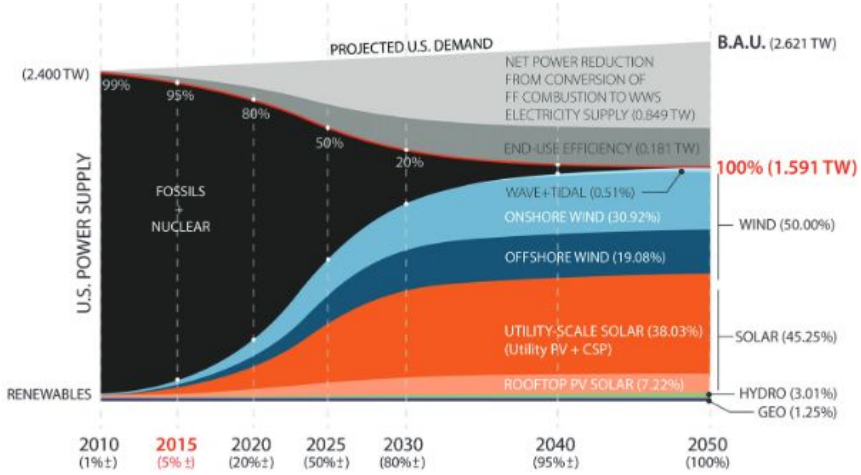
Demand vs. Production over Time



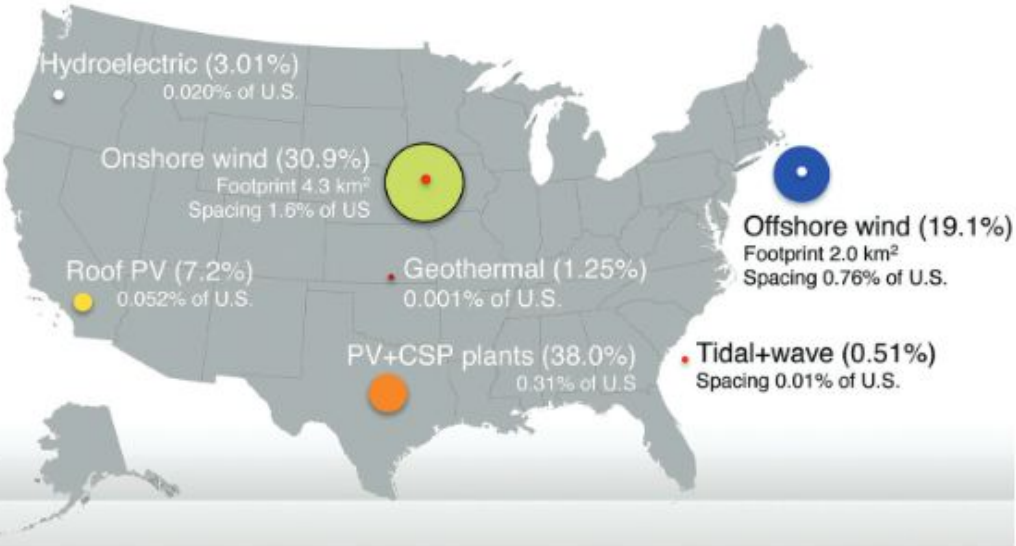
Long-Term:

We can reliably meet 100% of US demand with ~600 GWh of storage.

Grid Mix



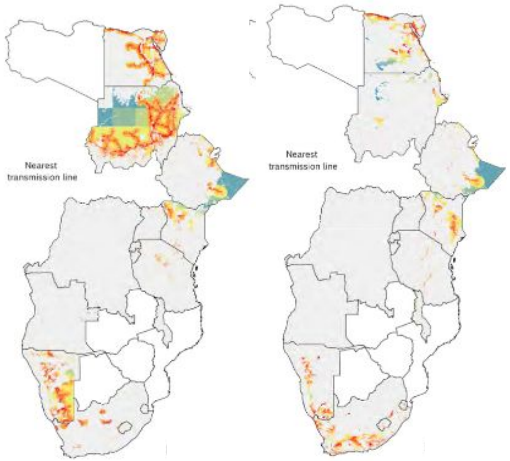
Land Use



Wind and Solar Outside the US:

Sub-Saharan Africa

- Over 600 million people lack access to power
- Over 10,000 GW of solar potential

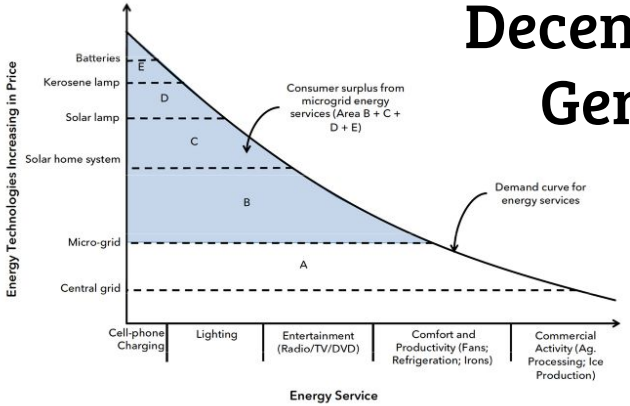


Distance of high-energy solar and wind from nearest transmission.

Centralized Generation

vs.

Decentralized Generation

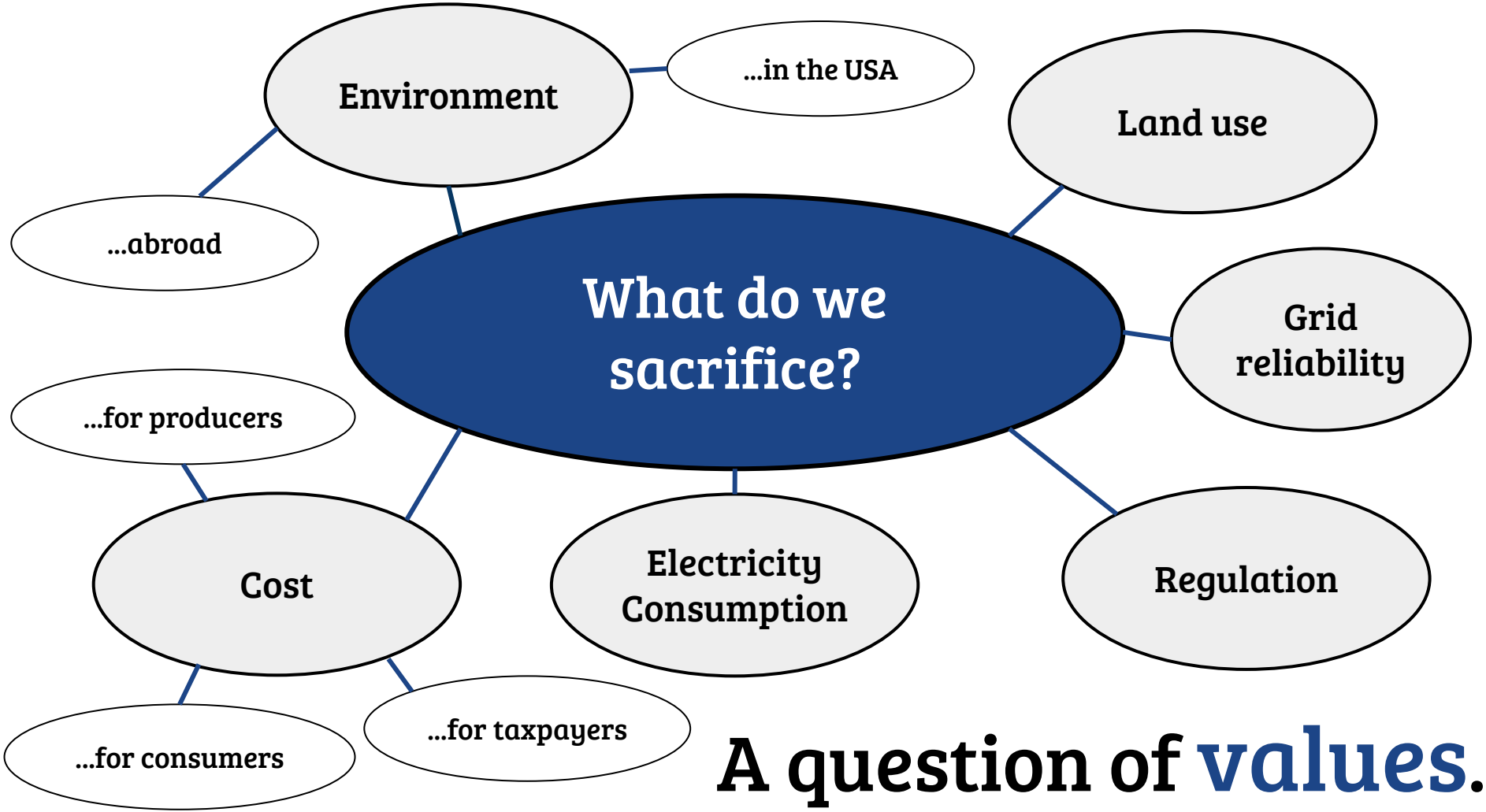


Key point:
It is easier to introduce new technologies than it is to integrate them.

Large-scale wind and solar may work better outside the US.

Short term: wind and solar succeed. But long term...

What do we sacrifice?

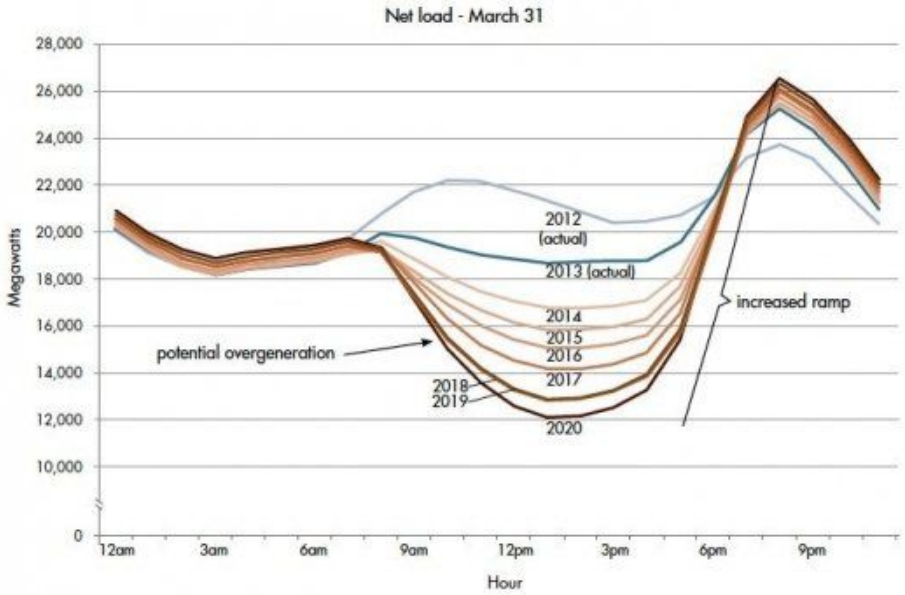


A question of values.

Drawbacks of Battery Storage

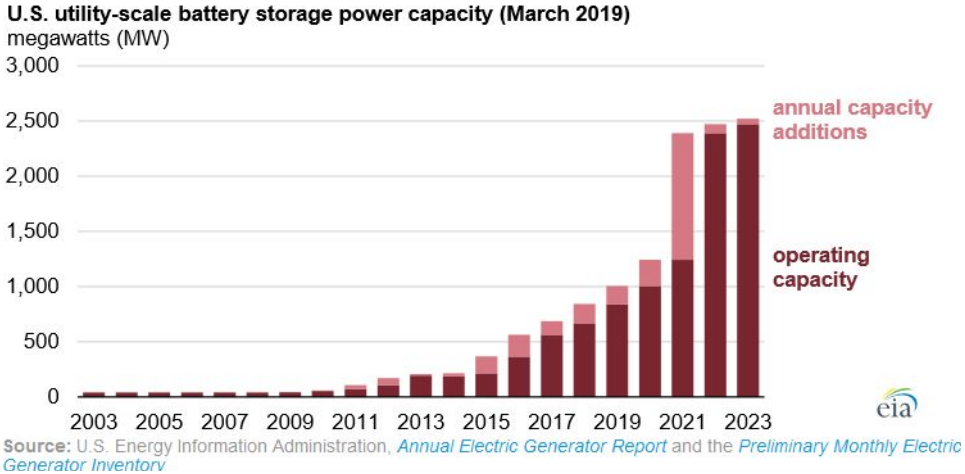
Battery Storage

- Difficult to find projections
- Renewables will have a greater role in the share of total energy production
- Resulting duck curve is still an issue



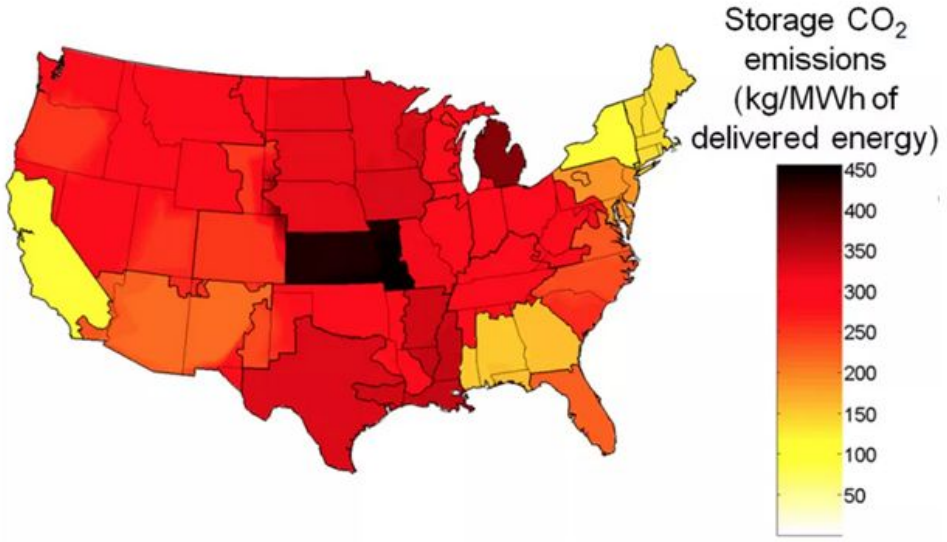
Lithium-Ion Battery Projections

- Lead-acid → Nickel-cadmium → Nickel metal hydride → lithium-ion
- Energy dense, high power capacity
- “exponential technology”
- Near future projections that capacity will increase
- Current mineral (cobalt) and safety constraints



- Could flatten duck curve, stabilize energy grid
- “the deployment of energy storage increases emissions almost everywhere **in the US today**” (Hittinger and Azevedo)
  - 1.) energy sources for storage more carbon intensive when discharged
  - 2.) only 40%-90% efficient
  - 3.) Disposal
  - 4.) Outsourcing pollution
- “storage in the US today has CO2 emissions of 104-407 kilograms per MWh of delivered energy”
- Renewables could work, but not prolific

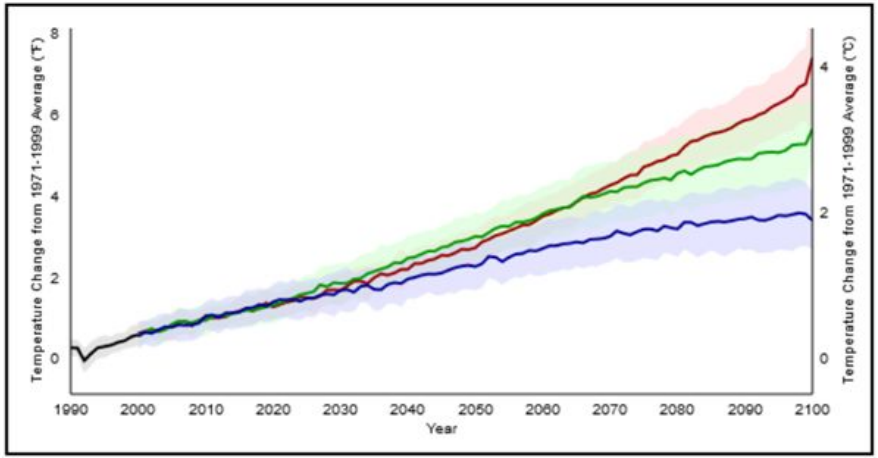
Batteries Increase Emissions



Lesson: never store energy in Kansas. | Hittinger & Azevedo 2017

- Without battery storage or without a large supply of renewable energy, emissions will increase
- Policies that can prevent emissions increase
- Need to consider other ways to reduce carbon emissions

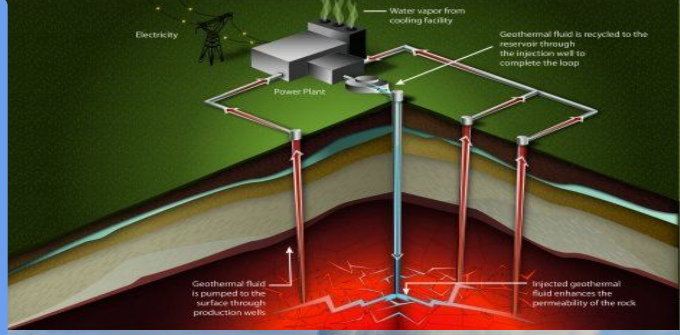
More Immediate Action is Needed

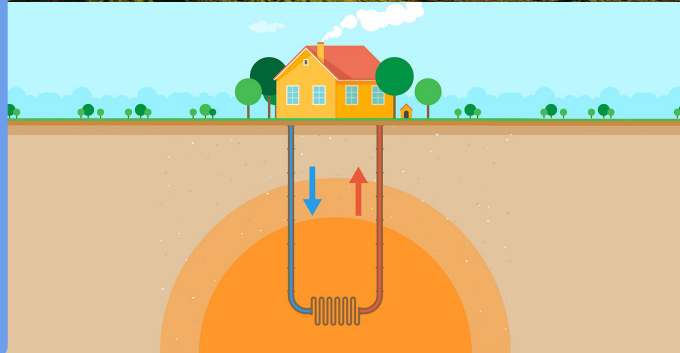


Alternative Energy Solutions

Geothermal

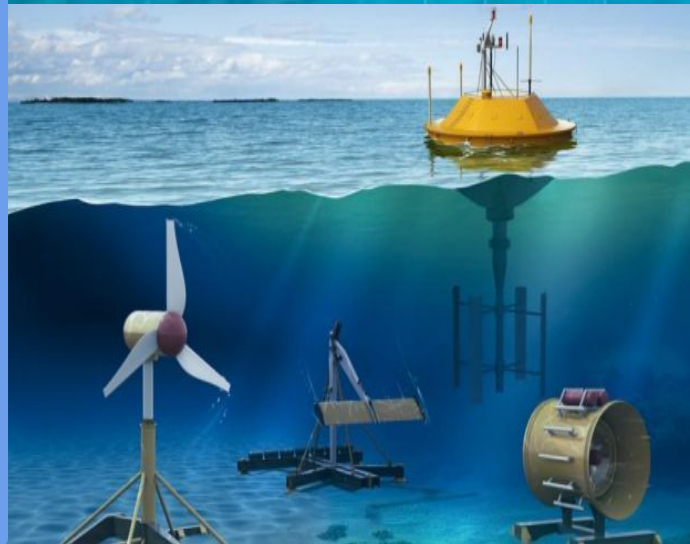
- Baseload energy source
- Potential to be accessible across the country
- Geothermal plants take up less space
- LCOE ranges from 0.05- 0.13 dollars per kWh





Wave and Tidal

- Continuous predictable energy
- Extreme potential
- Still has a long way to go
- LCOE of 0.197 dollars per kWh



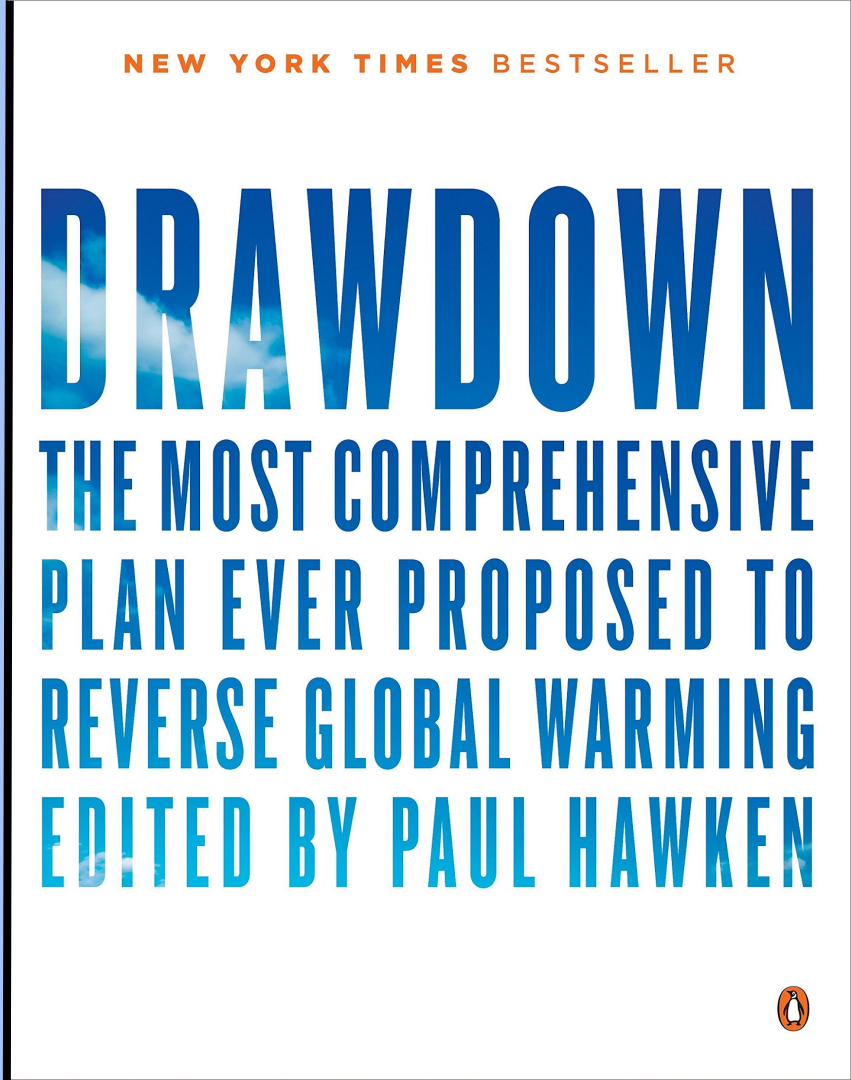
Methane Digesters (Large)

- Methane Digesters reduce methane emissions, create energy in the process
- Could help bring clean power to rural areas
- Typically around 1.2 millions to build

What Does This All Mean?

Project Drawdown

- Started by Paul Hawken and Amanda Joy Ravenhill
- Includes only technologically viable, existing solutions
- Compiled by team of over 200 scholars, scientists, policymakers, business leaders, and activists
- Each solution's carbon impact, total and net cost to society, and total lifetime savings were modeled through 2050



Top 10 Solutions

Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	Refrigerant Management	Materials	89.74	N/A	$-902.77
2	Wind Turbines (Onshore)	Electricity Generation	84.60	$1,225.37	$7,425.00
3	Reduced Food Waste	Food	70.53	N/A	N/A
4	Plant-Rich Diet	Food	66.11	N/A	N/A
5	Tropical Forests	Land Use	61.23	N/A	N/A
6	Educating Girls	Women and Girls	51.48	N/A	N/A
7	Family Planning	Women and Girls	51.48	N/A	N/A
8	Solar Farms	Electricity Generation	36.90	$-80.60	$5,023.84
9	Silvopasture	Food	31.19	$41.59	$699.37
10	Rooftop Solar	Electricity Generation	24.60	$453.14	$3,457.63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