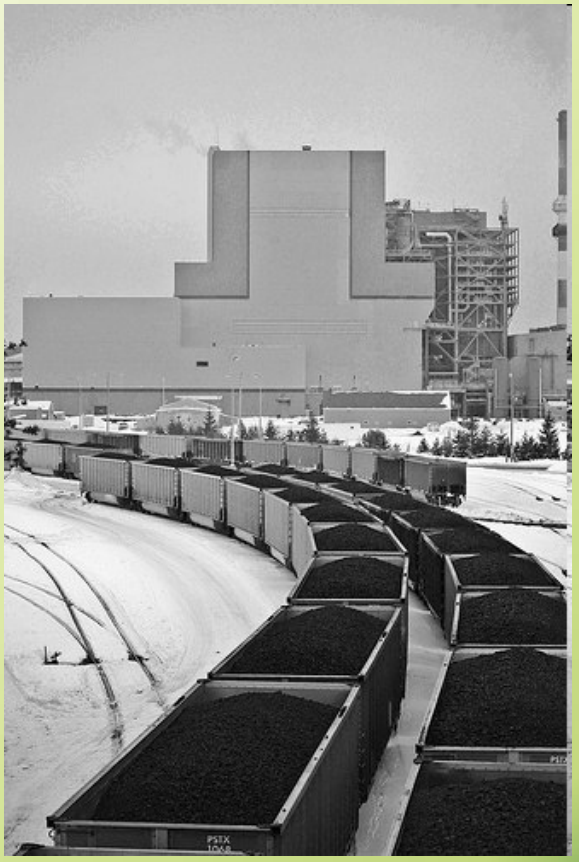
The Future of Energy

Jay Wherley – BrevardBiodiesel.org

- Where do we get Energy from?
- How efficiently do we use it?
- How will this change in the next 20 years?

Today's Fuel

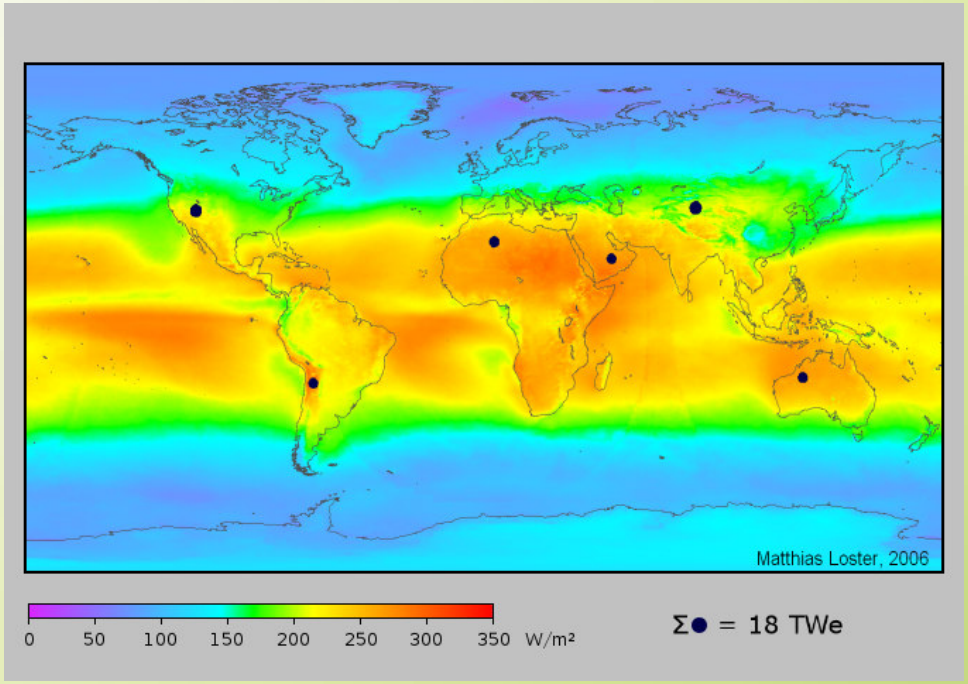
- Almost all of our past, present, and future energy is *already* **Solar** (or is it **Nuclear**)!?!



Photos by: Ian Ransley, Dr. Keats, Wsilver (FLICKR)

How much Energy is available from the Sun? Plenty.

- The Sun provides Earth with as much energy **every hour** as human civilization uses **every year**.



Six Florida sized sites using 8% efficient photovoltaic systems producing electricity of three terawatts each.

Image from www.ez2c.de/ml/solar_land_area/

But we use it Inefficiently…
Gasoline Recipe

INGREDIENTS

90 tons phytoplankton

DIRECTIONS

Collect sedimentation on ocean floor. Press in to very large pie plate. Bake for 10 million years in secret location. Search and locate resulting crude oil. Extract crude oil. Refine crude oil.

SERVE

Produces **1 gallon** gasoline

Photo by: Arria Belli (FLICKR)

How Inefficient is Gasoline?

Plants capture solar energy via photosynthesis at roughly 3% efficiency.
The efficiency of turning that captured energy into gasoline…

- ~ **2%** of phytoplankton mass falls to ocean floor as sedimentation. (Resulting in kerogen)
- ~ **80%** of kerogen becomes fossil fuel; ~ **75**% of that becomes crude oil.
- ~ **3%** of that crude oil is located in reachable reservoirs
- ~ **25%** of reachable crude is recoverable
- Resulting Fuel Synthesis Efficiency of **0.009%**

See: BURNING BURIED SUNSHINE: HUMAN CONSUMPTION OF ANCIENT SOLAR ENERGY by: Dr. Jeffrey Dukes

We're still not done wasting energy with Gasoline…

- A gasoline powered internal combustion engine runs at about 40% efficiency. **60%** of our gasoline energy **is lost** to heat and friction.
- Rube Goldberg might be proud of the methods we currently use to run on "Paleo-Solar Power"!

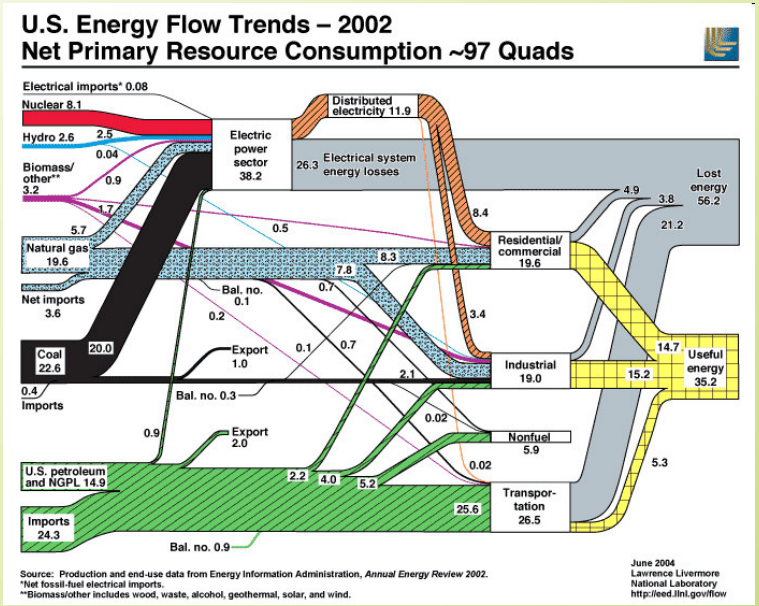
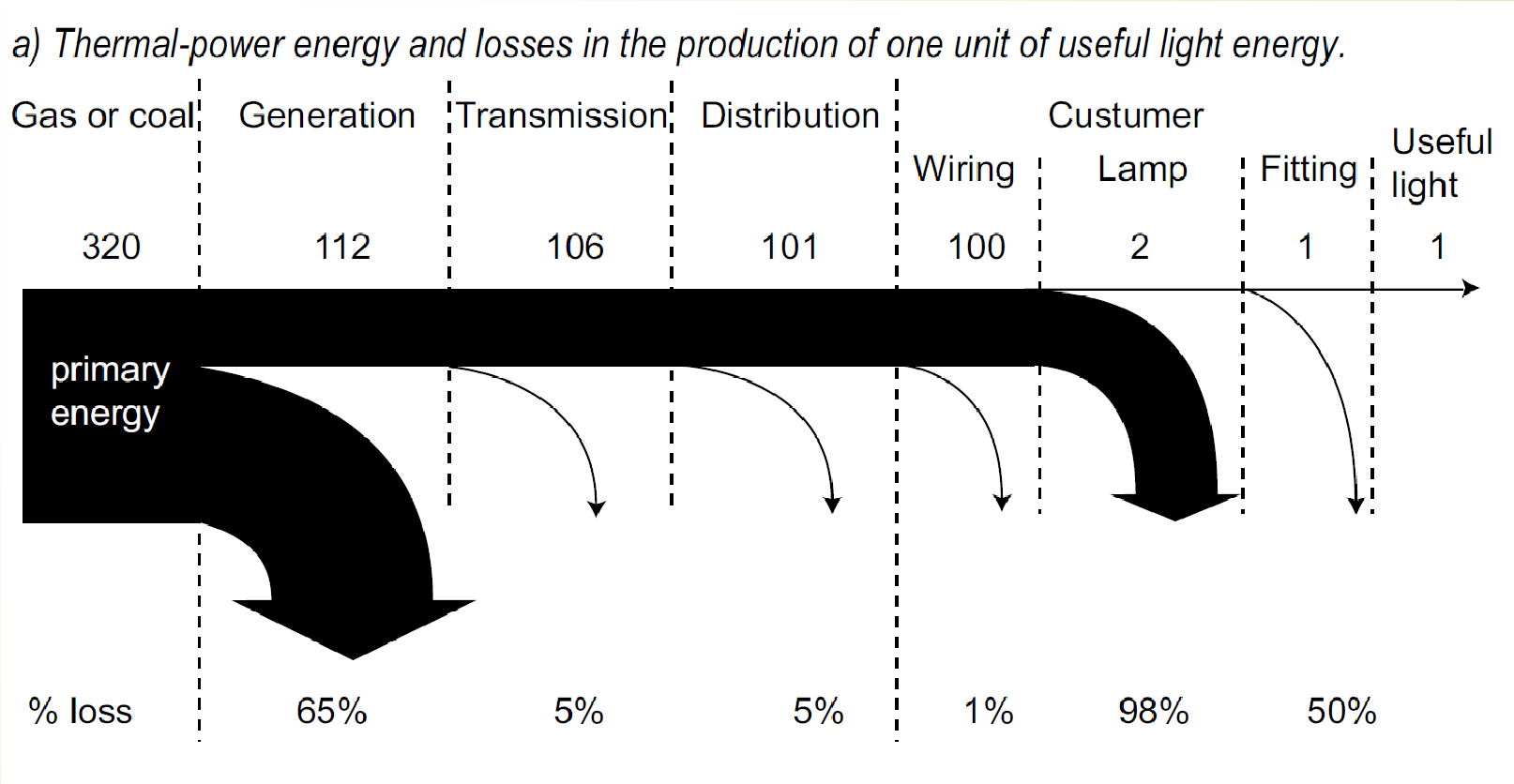


Chart from J. Dukes "BURNING BURIED SUNSHINE: HUMAN CONSUMPTION OFANCIENT SOLAR ENERGY" 2003 Photo by Klobetime (FLICKR)

How efficiently do we light up?



Source Cleland 2005 via IPCC AR4 WG3 Chapter 4

Our “Bank Account” of “Buried Sunshine” – how low is it?

We use Fossil Fuels over 400 times faster than they were deposited.

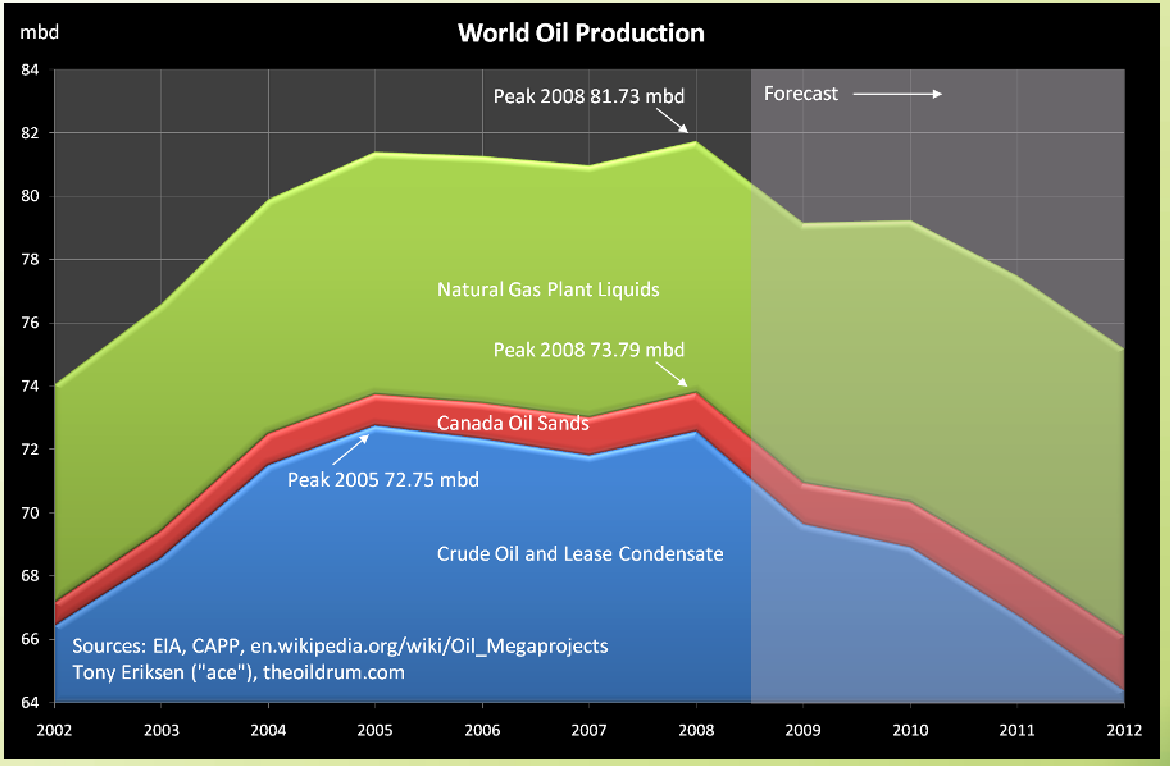


Image from TheOilDrum.com

What options do we have to today's fossil fuels?

- Already in production use:

  Wind Solar Photovoltaic Solar Thermal
  Nuclear Fission 1st generation Biofuels/Biomass
  Hydropower Geothermal

- Yet to be proven at wide production levels:

  2nd generation Biofuels/Biomass Nuclear Fusion
  "Clean" Coal Advanced Solar (Kite, Satellite)
  Tidal Power Wave Power

Wind Power

Currently producing 1.5% of worldwide electricity.

+ Relatively cheap at 4-6 cents per kWh (in US) and dropping
+ Abundant Resource
- Intermittency
- Bat interaction

Image by Squacco (FLICKR)

Solar Photovoltaic

Currently producing 0.1% of worldwide electricity.

+ Very Abundant Resource
- Intermittency
- Still relatively expensive

Image by US DOE WAPA Ft. Collins

Solar Thermal

+ Very Abundant Resource
+ Very low CO2 emissions (production/construction)
+ Fits infrastructure
- Land use
- Water use in some cases

Images NREL

Nuclear (fission)

+ Low CO2 emissions (production & construction)
+ Fits infrastructure
+ High capacity factor
- Waste/Proliferation
- Water use
- Ore supply ~200 years (non breeder type use)

Image DOE Idaho

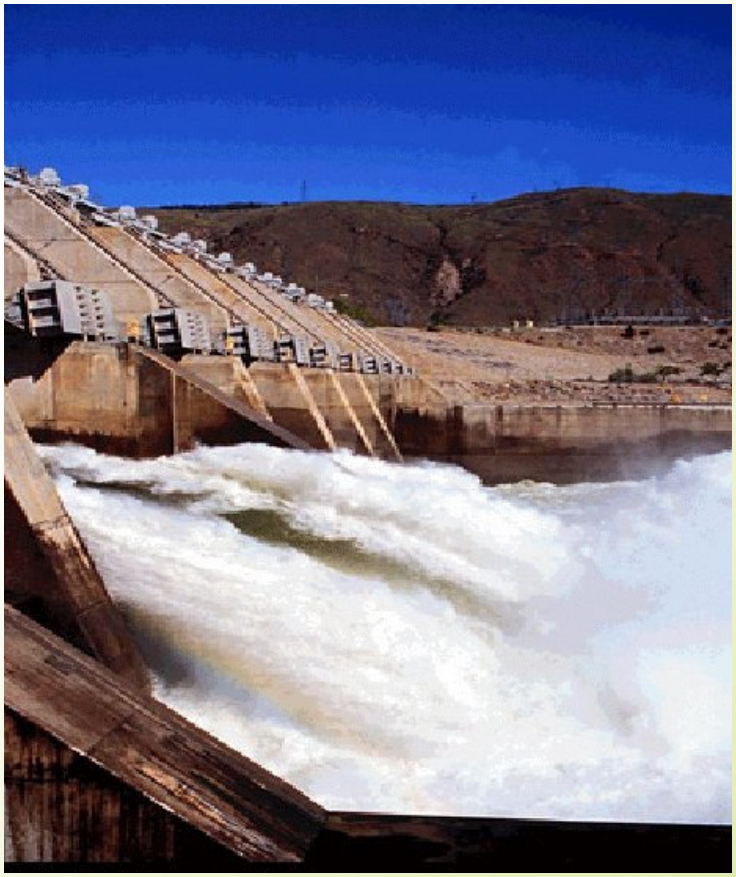
1st Gen Biofuels

0.5% of US Electrical Generation is from Biomass – largest in South Bay FL (140 MW)

Wide variety of feedstocks have varying pros/cons.

Bagasse Image Rufino Uribe via WIKIPEDIA, Biodiesel Image skidrd (FLICKR)

Hydropower



17% of worlds electricity production.

+ Low CO2 emissions (Construction)
+ “Peaking” Power
- Environmental Impacts
- Water use

Image NOAA

Geothermal

0.3% of worlds electricity production.

+ Baseline and “Peaking” Power
- Environmental Impacts
- Can be some greenhouse gas releases

Image Julie Donnelly-Nolan , USGS The Geysers near the city of Santa Rosa in northern California

Comparing choices…
1) Capacity Factor

- Capacity Factor – the ratio of actual electrical power generated over a period to the full "nameplate" capacity.

Photovoltaic	10-20%
Solar Thermal	13-25% (no storage)
Wind	21-42%
Geothermal	73%
Hydro	42%
Wave	21-25%
Tidal	20-35%
Nuclear	81%
Coal	65-85%

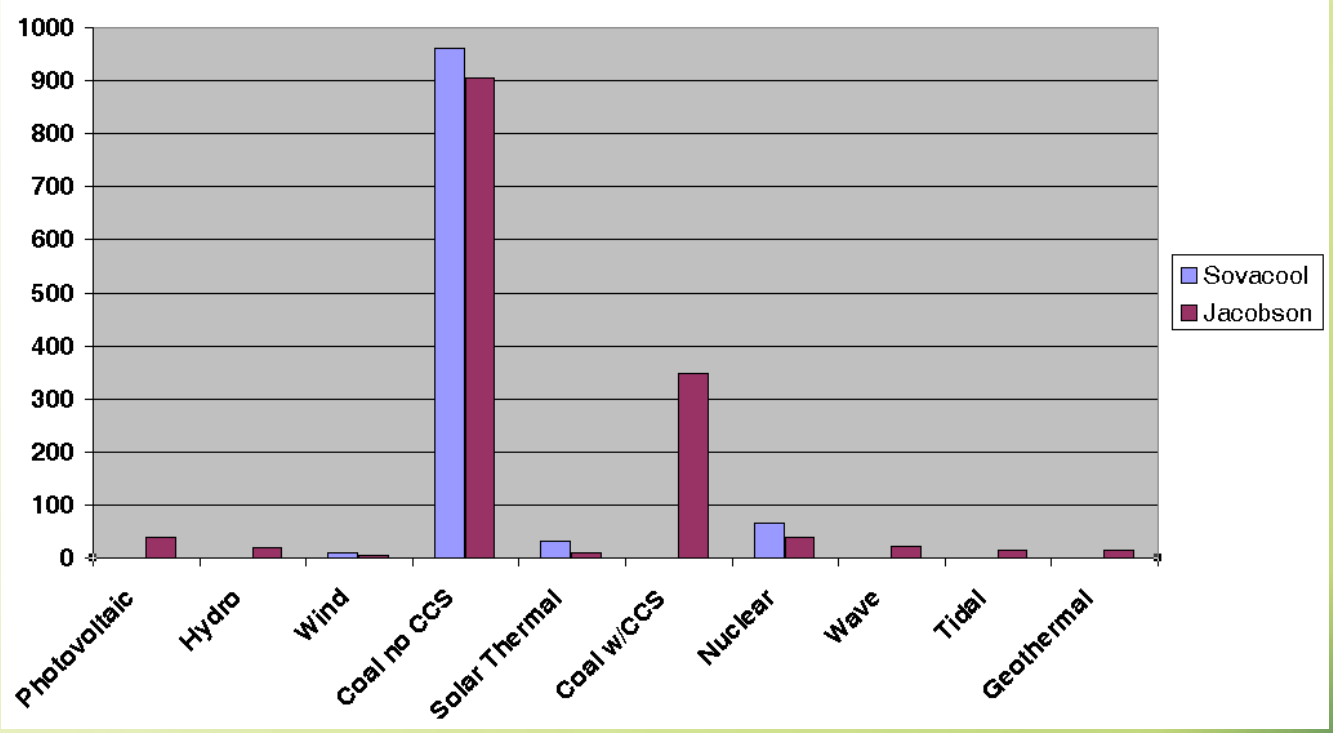
Jacobson "Review of solutions to global warming, air pollution, and energy security" Energy & Environmental Science

Comparing choices…
2) Greenhouse Gas Emissions

- gCO_2e/kWh – Greenhouse gas effect over fuel lifecycle to produce same amount of power.

  CH_4 ~25x

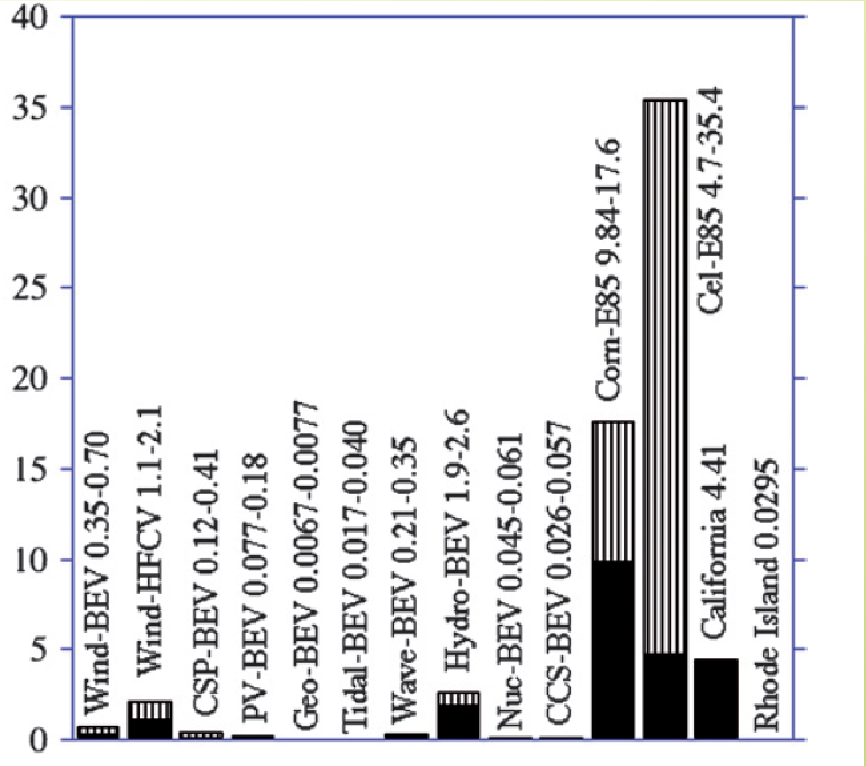
  N_2O ~298x



Green numbers per Sovacool, Gray numbers per Jacobson

Comparing Choices…
3) Land Use

- What percent of US land would be required to power all our vehicles from various energy choices?



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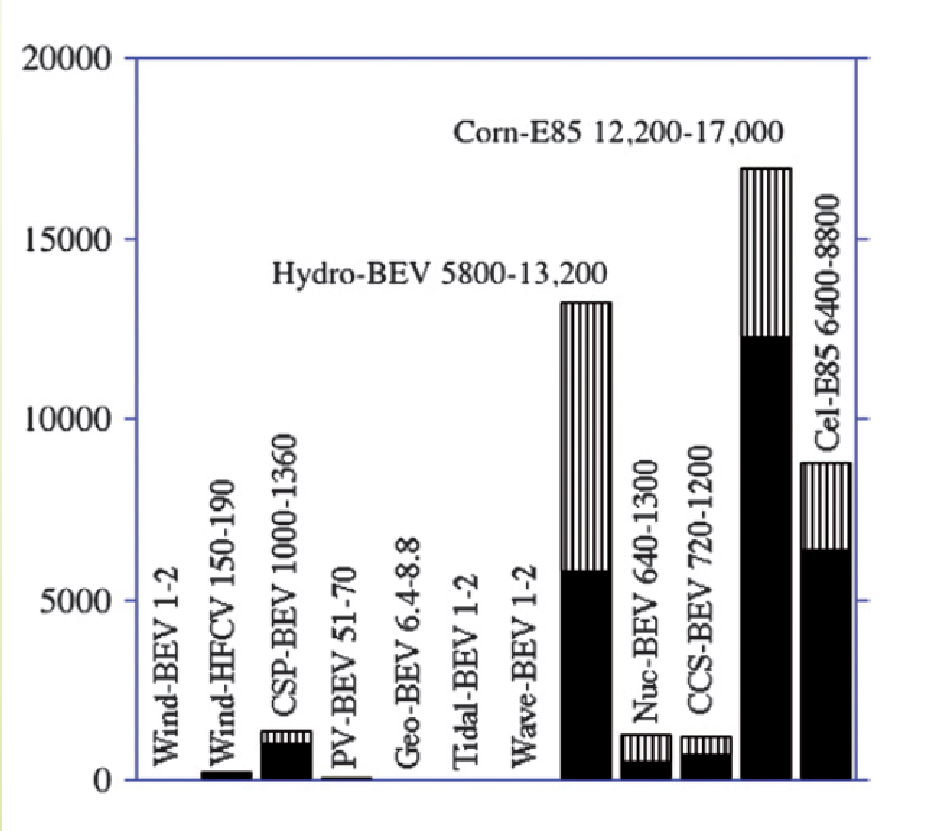
Comparing Choices…
4) Water Use

- How much water would be used when powering all U.S. vehicles from various energy choices?



(Ggal/year)

Jacobson "Review of solutions to global warming, air pollution, and energy security" Energy & Environmental Science

So…how do today's options compare?

1. Wind
2. Concentrated Solar
3. Geothermal
4. Tidal
5. Photovoltaic
6. Wave
7. Hydro
8. Coal w/CCS
9. Nuclear
10. Ethanol

That answer will depend on how you weight the importance of various factors.

Mark Z. Jacobson, *Professor of Civil and Environmental Engineering and Director of the Atmosphere/Energy Program at Stanford University*, ranks them this way…

Table 4 Ranking (from 1–12, with 1 being the best) over individual categories and among all categories of each energy technology combination when used to power all US onroad vehicles. The ranking of each technology for each category is then multiplied by its weight (second column) to obtain a weighted-average ranking, which is analogous to a score from 1–12. The numerical order of the overall rank is then given (bottom row). The weights sum up to 100%

	Weight (%)	Wind-BEV	Wind-HFCV	PV-BEV	CSP-BEV	Geo-BEV	Hydro-BEV	Wave-BEV	Tidal-BEV	Nuc-BEV	CCS-BEV	Corn-E85	Cel-E85
[a]Resourceabundance	10	2	3	1	4	7	10	6	5	9	8	11	12
[b]CO_2e emissions	22	1	3	5	2	4	8	7	6	9	10	12	11
[c]Mortality	22	1	3	5	2	4	8	7	6	10	9	11	12
[d]Footprint	12	1	2	8	9	5	10	4	3	6	7	11	12
[e]Spacing	3	8	9	5	6	2	10	7	1	4	3	11	12
[f]Water consumption	10	1	6	5	9	4	11	1	1	7	7	12	10
[g]Effects on wildlife	6	1	3	5	2	4	8	7	6	9	10	11	12
[h]Thermal pollution	1	1	2	4	8	3	7	6	5	12	11	10	9
[i]Water chemical pollution/ radioactive waste	3	1	3	5	2	4	8	7	6	10	9	12	11
[j]Energy supply disruption	3	3	4	2	6	7	11	5	1	12	8	9	9
[k]Normal operating reliability	8	10	1	10	5	6	2	10	9	7	8	3	3
Weighted average		2.09	3.22	5.26	4.28	4.60	8.40	6.11	4.97	8.50	8.47	10.6	10.7
Overall rank		1	2	6	3	4	8	7	5	9-tie	9-tie	11	12

[a] Based on Table 1, Fig. 5, and discussion in Section 11. [b] Based on Fig. 2. [c] Based on Fig. 4. [d] Based on Fig. 5. [e] Based on Fig. 6, except that tidal was placed ahead of geothermal since the spacing area on the sea floor is not so relevant (although footprint area is). [f] Based on Fig. 7. [g] Based primarily on footprint area, air pollution emissions, and collision risk, as described in Section 8. [h] Based on discussion of thermal pollution in Section 8. [i] Based on the discussion of chemical pollution and radioactive waste in Section 8. [j] Based on discussion in Section 9. [k] Based on discussion in Section 10.

Future – Solar Power from Space?

- Mile wide mirrors in geosynchronous orbit focus solar energy into microwave beam to earth of 1-5 GW steady power. $$$$$$

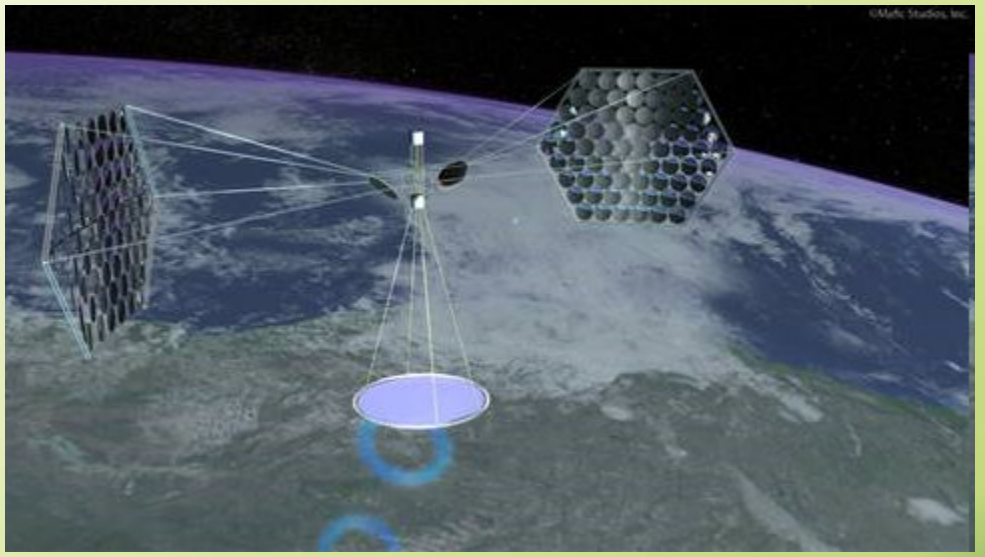


Image: Mafic Studios Inc.

Future – High Altitude Kites?

- 747 sized wing producing 6 MW robotically flying at 2000 ft

Image: Makani Power via TED

Future – Nuclear Fusion?

National Ignition Facility – focusing 192 lasers on a pea sized capsule containing deuterium and tritium fuel to heat it to 180 million degrees Fahrenheit inducing nuclear fusion.

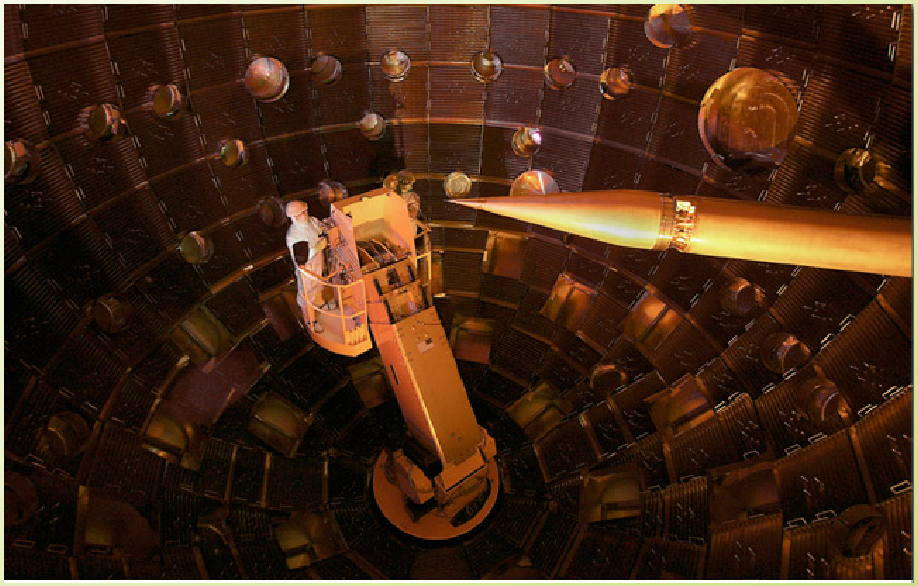


Image: NIF

Future – “Clean” Coal?

- Today coal powered generation produces 45% of the world’s electricity and 40% of the carbon emissions.
- Sequestration only economical if carbon emission has a cost (Carbon Tax or Cap/Trade).
- No proven method to capture and sequester CO2 at scale.
- Coal won’t last forever - ~200 years at current rate – but…
- Efficiency goes down, thus required coal inputs go up.

Image: NIF

Future – 2nd Generation Biofuels?

- Algae – potentially high yield. (Place next to Coal plant to inject CO2?)
- Cellulosic ethanol from agricultural waste
- Florida “Farm to Fuel” program – 500 tons of citrus waste per year – convert to ethanol?

PetroAlgae:Algae R&D site Fellsmere FL

Image: PetroAlgae

Future – Wave and Tidal?

- A handful of each of these types of systems are in place using various technologies.
- Tidal power systems under consideration near Cook Inlet Alaska producing 3-6 GW.

SeaGen tidal rotors, Belfast, before installation in Strangford Lough.

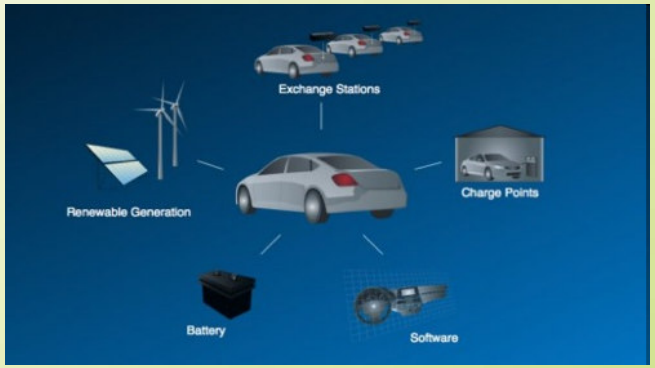
Pelamis machine installed at the Agucadoura Wave Park off Portugal

Images: Fundy, S. Portland (WIKIPEDIA)

What **might** one Future look like?

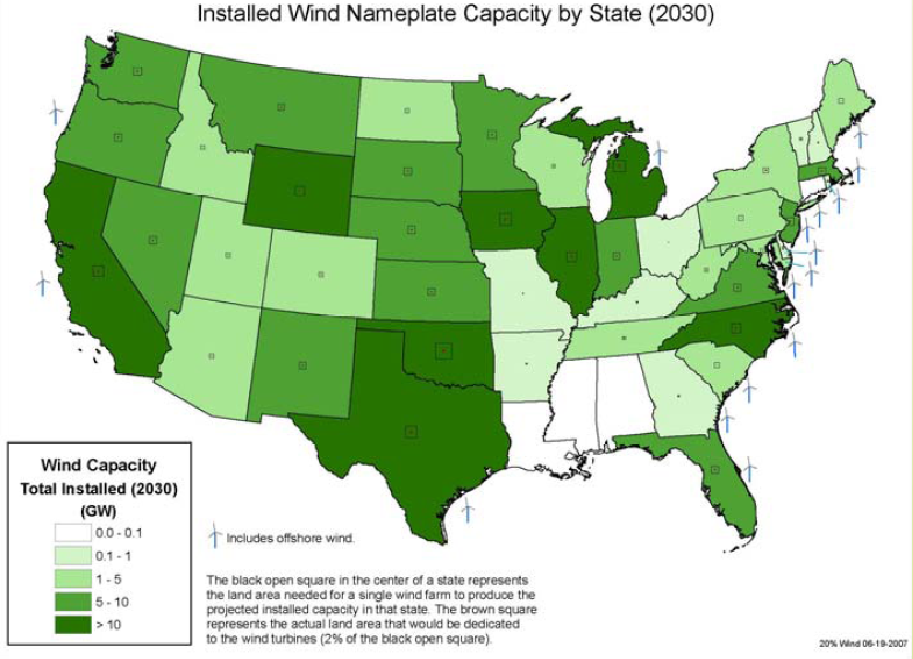
Let's take peek at the United States 20 years down the road….

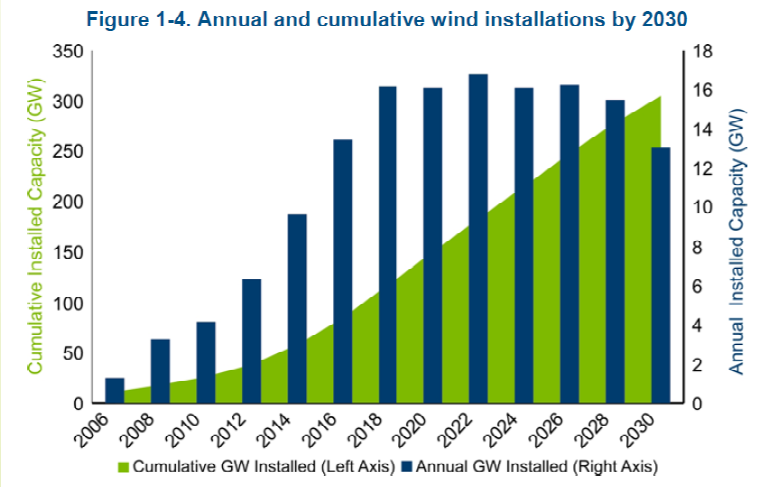
The year 2030…

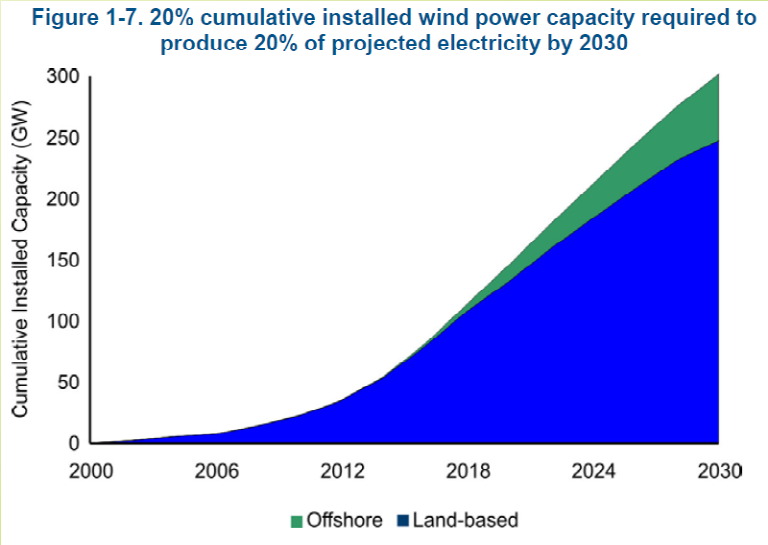


2030 vision - Wind

By 2030 … 20% of US electricity from Wind Power…







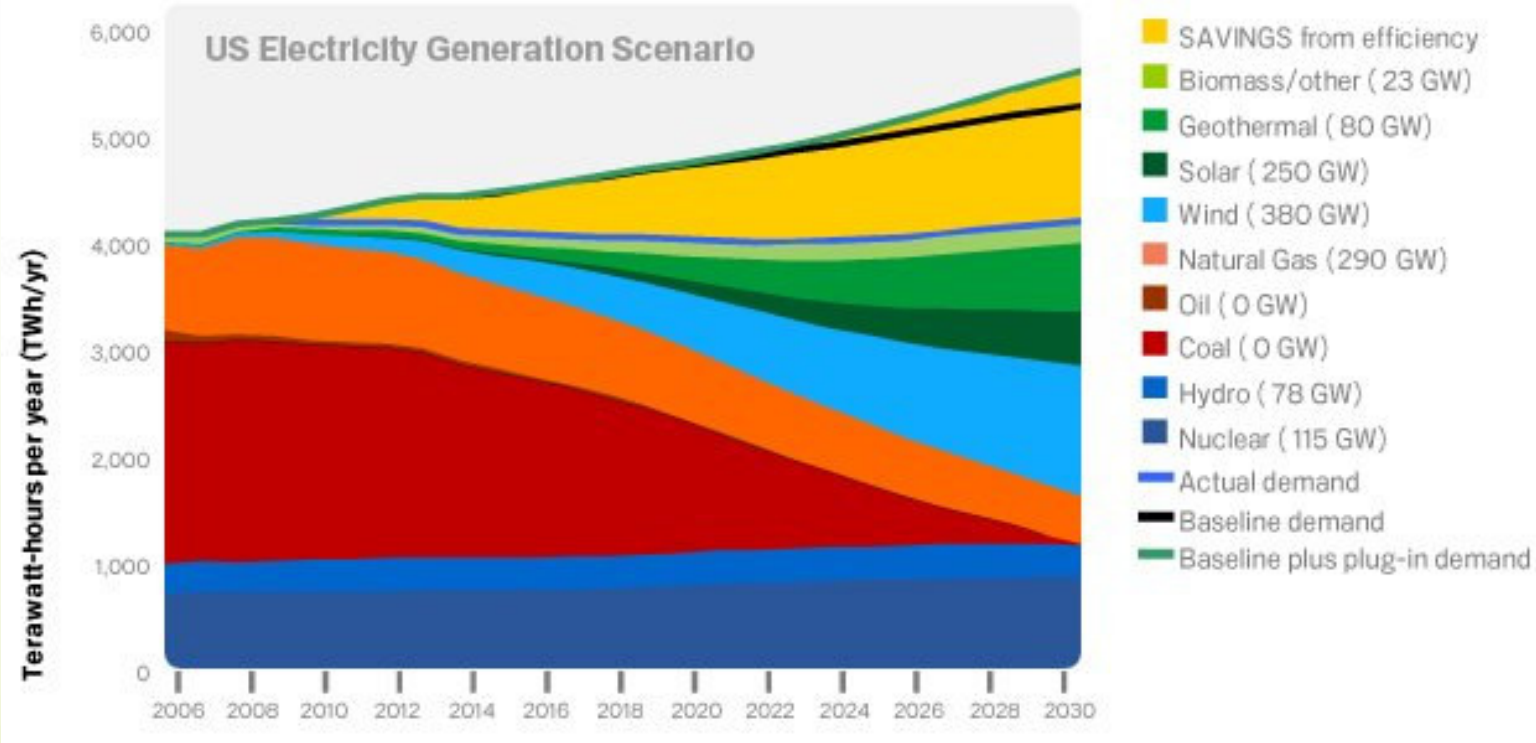
Images: DOE

2030 vision - Efficiency

- “Smart Grid”, “Green Building” techniques and other efficiency improvements, some driven by regulation/incentive lead to flat demand for electricity - rather than “business-as-usual” growth of 1% per year

2030 vision – other power

Geothermal increases to cover 15% of electrical generation. Concentrated Solar and Rooftop solar PV also used.

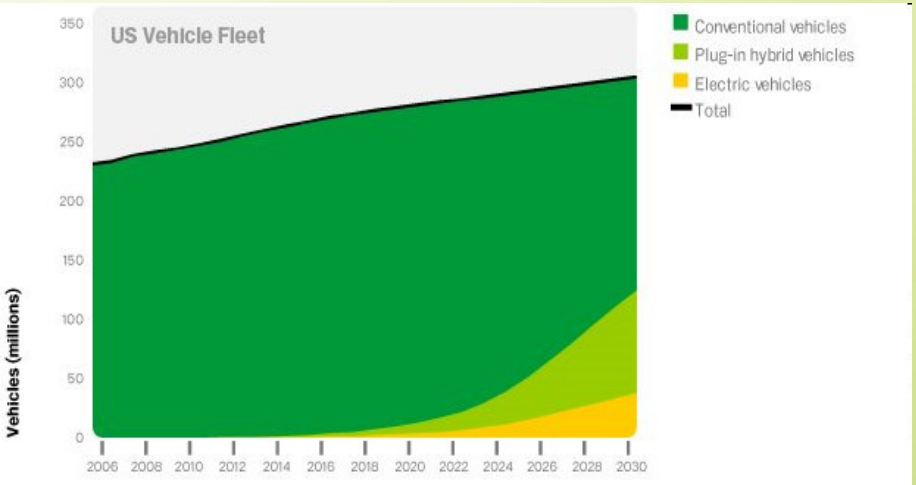


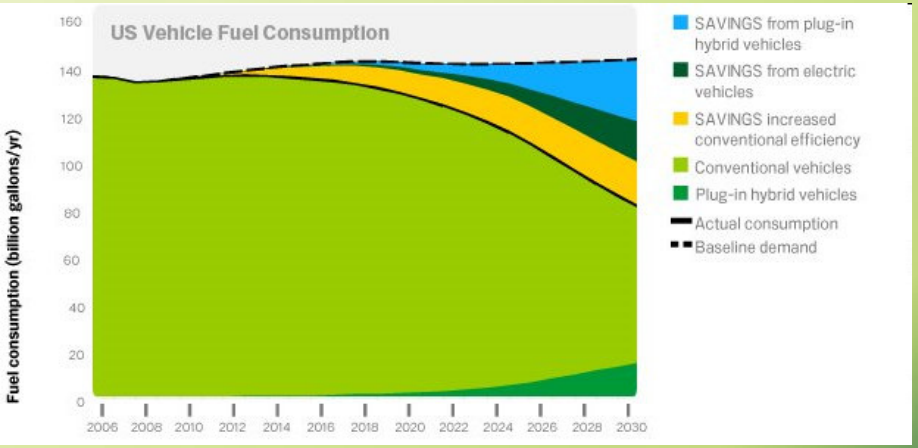
Images: Google Clean Energy 2030

2030 vision - Vehicles

Plug-in vehicle sales climb to 3 million/year in 2020 and 16 million/year in 2030.

“Charge-spots” become common





Images: Google Clean Energy 2030

Resulting in…

- 23 million new jobs in new energy and efficiency sectors (offsetting the 14 million jobs going away in fossil fuel areas)
- Positive net savings vs. investment by 2014 increasing to $50 billion / year in 2025. Cost $4 trillion, savings $5 trillion = net $1 trillion benefit.
- Reduction of CO_2 emissions by 41% versus today. (Shooting for IPCC 80% reduction by 2050).

Could that change really happen in only 20 years?

- 20 years ago – **“web pages” did not exist**.
- Ford made 10,000 cars in 1908 – and over a million cars per year 20 years later.
- The U.S. went from 1% to 20% electrical generation via Nuclear power in 20 years (1970-1990)

The Future of Energy is…

Bright.