The Green Economy
What Possibly Could Go Wrong?

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Energy – The Staff of Life

WE DEPEND ON ENERGY (FOOD) FOR OUR SURVIVAL.

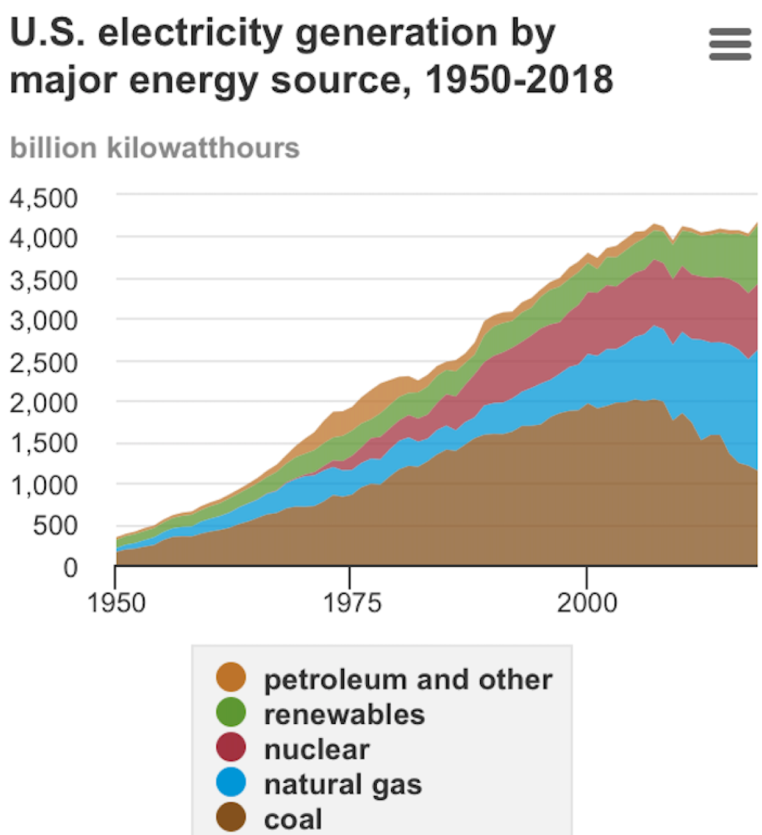
WE DEPEND ON ENERGY IN THE FORM OF ELECTRICITY AND FOSSIL FUELS TO POWER AGRICULTURE, PRODUCTION OF GOODS AND SERVICES, TRANSPORTATION, COMMUNICATIONS, HEATING AND COOLING FOR OUR MODERN ECONOMY.

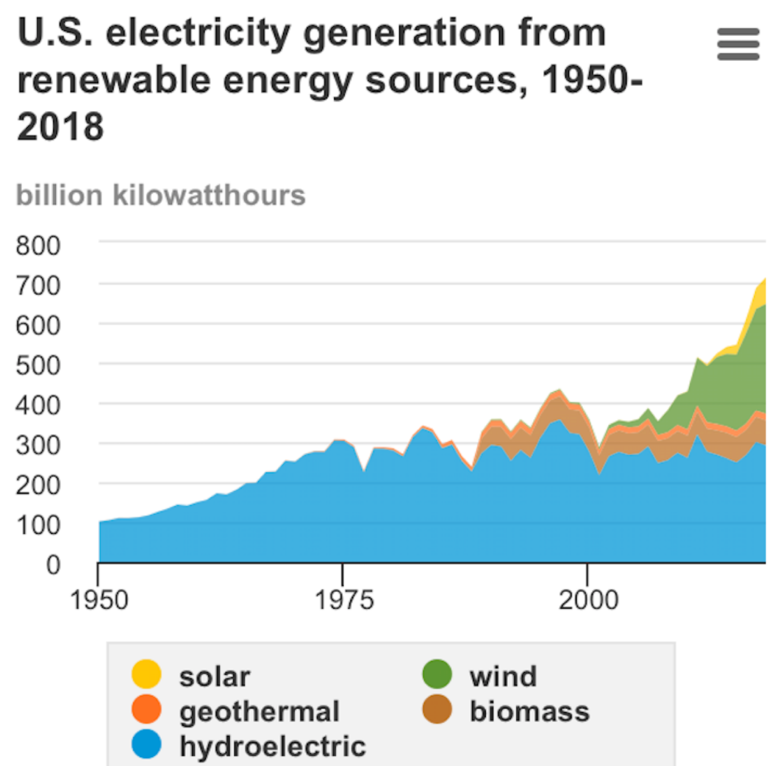
PRINCIPAL SOURCES OF ENERGY INCLUDE COAL, GASOLINE, NATURAL GAS, NUCLEAR, AND “RENEWABLE GREEN ENERGY.”

RENEWABLE GREEN ENERGY INCLUDES, SOLAR, WIND, HYDRO, GEOTHERMAL AND BIOMASS.

The shares of utility-scale electricity generation by major energy sources in 2018 were

35% natural gas	27% coal	19% nuclear	17% renewables (total)	**10%** nonhydroelectric renewables **7%** hydroelectric	1% petroleum and other

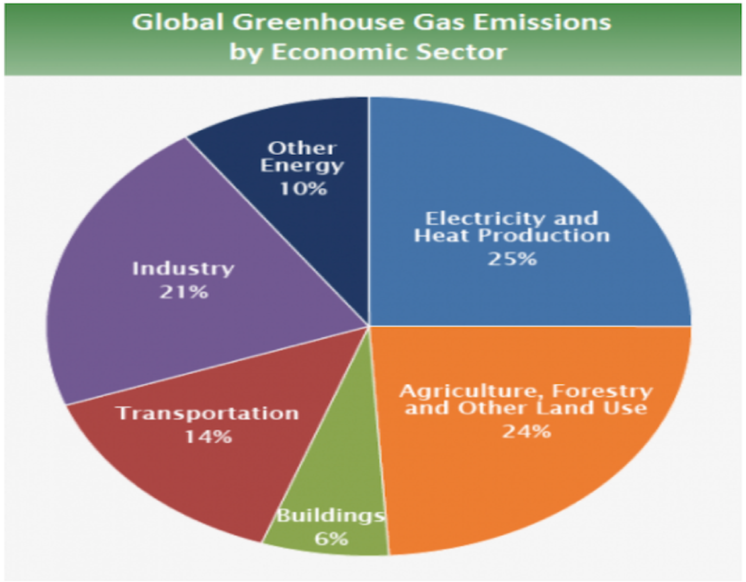




Note: Electricity generation from utility-scale facilities.

Global Emissions by Economic Sector

Global greenhouse gas emissions can also be broken down by the economic activities that lead to their production.[1]



Source: IPCC (2014); EXIT based on global emissions from 2010. Details about the sources included in these estimates can be found in the *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. EXIT

- **Electricity and Heat Production** (25% of 2010 global greenhouse gas emissions): The burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions.
- **Industry** (21% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from industry primarily involve fossil fuels burned on site at facilities for energy. This sector also includes emissions from chemical, metallurgical, and mineral transformation processes not associated with energy consumption and emissions from waste management activities. (Note: Emissions from industrial electricity use are excluded and are instead covered in the Electricity and Heat Production sector.)
- **Agriculture, Forestry, and Other Land Use** (24% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector come mostly from agriculture (cultivation of crops and livestock) and deforestation. This estimate does not include the CO_2 that ecosystems remove from the atmosphere by sequestering carbon in biomass, dead organic matter, and soils, which offset approximately 20% of emissions from this sector.[2]
- **Transportation** (14% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector primarily involve fossil fuels burned for road, rail, air, and marine transportation. Almost all (95%) of the world's transportation energy comes from petroleum-based fuels, largely gasoline and diesel.
- **Buildings** (6% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector arise from onsite energy generation and burning fuels for heat in buildings or cooking in homes. (Note: Emissions from electricity use in buildings are excluded and are instead covered in the Electricity and Heat Production sector.)
- **Other Energy** (10% of 2010 global greenhouse gas emissions): This source of greenhouse gas emissions refers to all emissions from the Energy sector which are not directly associated with

US primary energy consumption by source and sector (2017)[17]

Supply sources	Percent of source	Demand sectors	Percent of sector
Petroleum **36.2%**	72% Transportation 23% Industrial 5% Residential and commercial 1% Electric power	**Transportation** **28.1%**	92% Petroleum 3% Natural gas 5% Renewable energy
Natural gas **28.0%**	3% Transportation 35% Industrial 28% Residential and commercial 34% Electric power	**Industrial** **21.9%**	38% Petroleum 45% Natural gas 5% Coal 12% Renewable energy
Coal **13.9%**	9% Industrial <1% Residential and commercial 91% Electric power	**Residential and commercial** **10.4%**	16% Petroleum 76% Natural gas <1% Coal 8% Renewable energy
Renewable energy **11.0%**	13% Transportation 23% Industrial 7% Residential and commercial 57% Electric power	**Electric power** **37.2%**	1% Petroleum 26% Natural gas 34% Coal 17% Renewable energy 23% Nuclear electric power
Nuclear electric power **8.4%**	100% Electric power		

Note: Sum of components may not equal 100% due to independent rounding.

Climate Change
Global Warming

Wind and solar generate green houses gases in construction, installation, and maintenance.

Fossil fuels generate green house gases in all phases including combustion. When hydrocarbons burn they produce carbon dioxide and water. Coal is almost 100% carbon. Methane combustion is 55% hydrogen.

Nuclear produces CO2 in construction and a slight amount in operation.

All sources of energy produce carbon dioxide (CO2) in construction and operation. Some produce methane CH4.

But burning fossil fuels such as coal, liquid fuels, and natural gas produce carbon dioxide when burned and methane on use and extraction.

These fossil fuels are hydrocarbons. When burned they produce carbon dioxide and water.

Coal produces the most CO2 per energy unit produced natural gas the least.

Increasing Levels of CO2 in the Atmosphere

GLOBAL WARMING HAS BEEN LINKED WITH INCREASING LEVELS OF ATMOSPHERIC CO2.

THE CO2 LEVEL IN 1900 (THE BEGINNING OF THE INDUSTRIAL REVOLUTION) WAS 300 PPM (PARTS PER MILLION). THE CURRENT LEVEL IS 407 PPM.

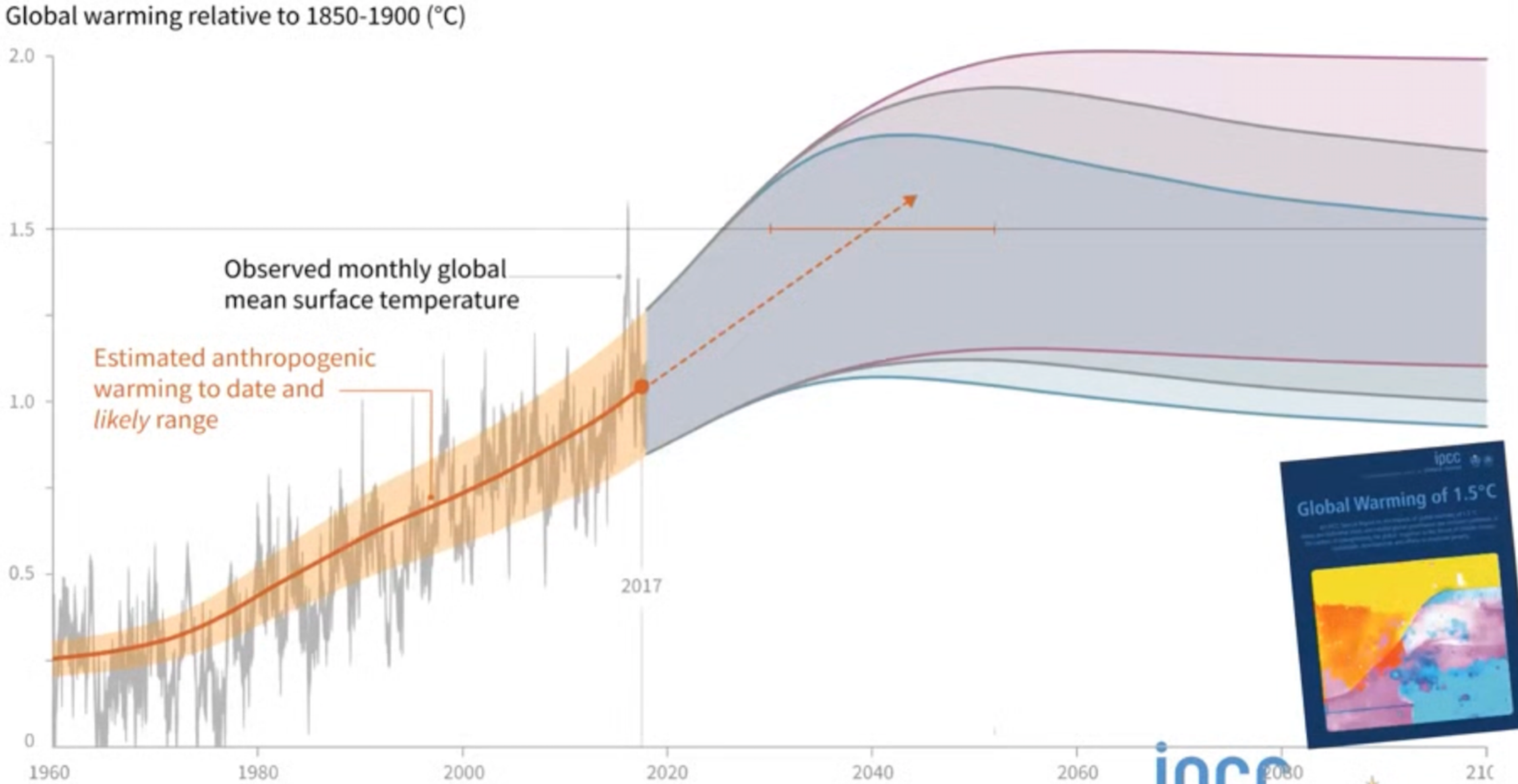
407 PPM IS 407/1,000,000 = .041%.

SO CO2 IS A “TRACE GAS” IN THE ATMOSPHERE YET IT IS BELIEVED TO HAVE A POWERFUL EFFECT ON CLIMATE CHANGE.

METHANE (CH4) ALSO IS A GLOBAL WARMING GAS

Human-induced global warming has passed 1°C, and likely to reach 1.5°C in 15-20 years at the current rate of increase

a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



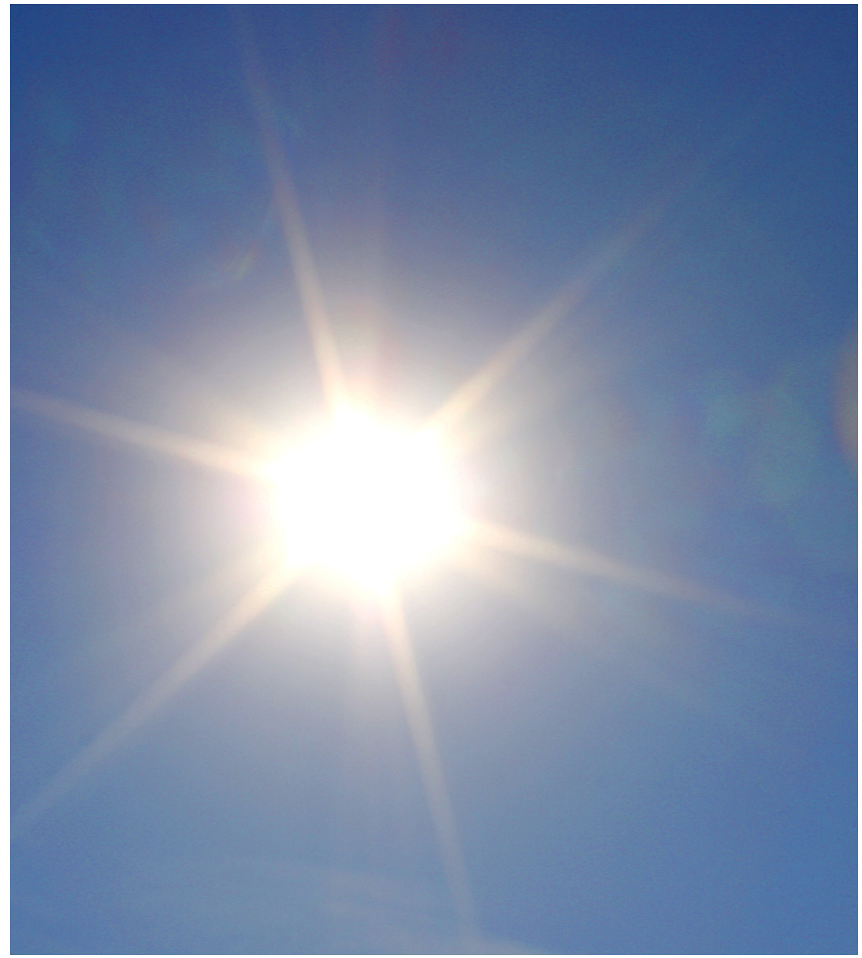
ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Dispatchable vs. Intermittent Power

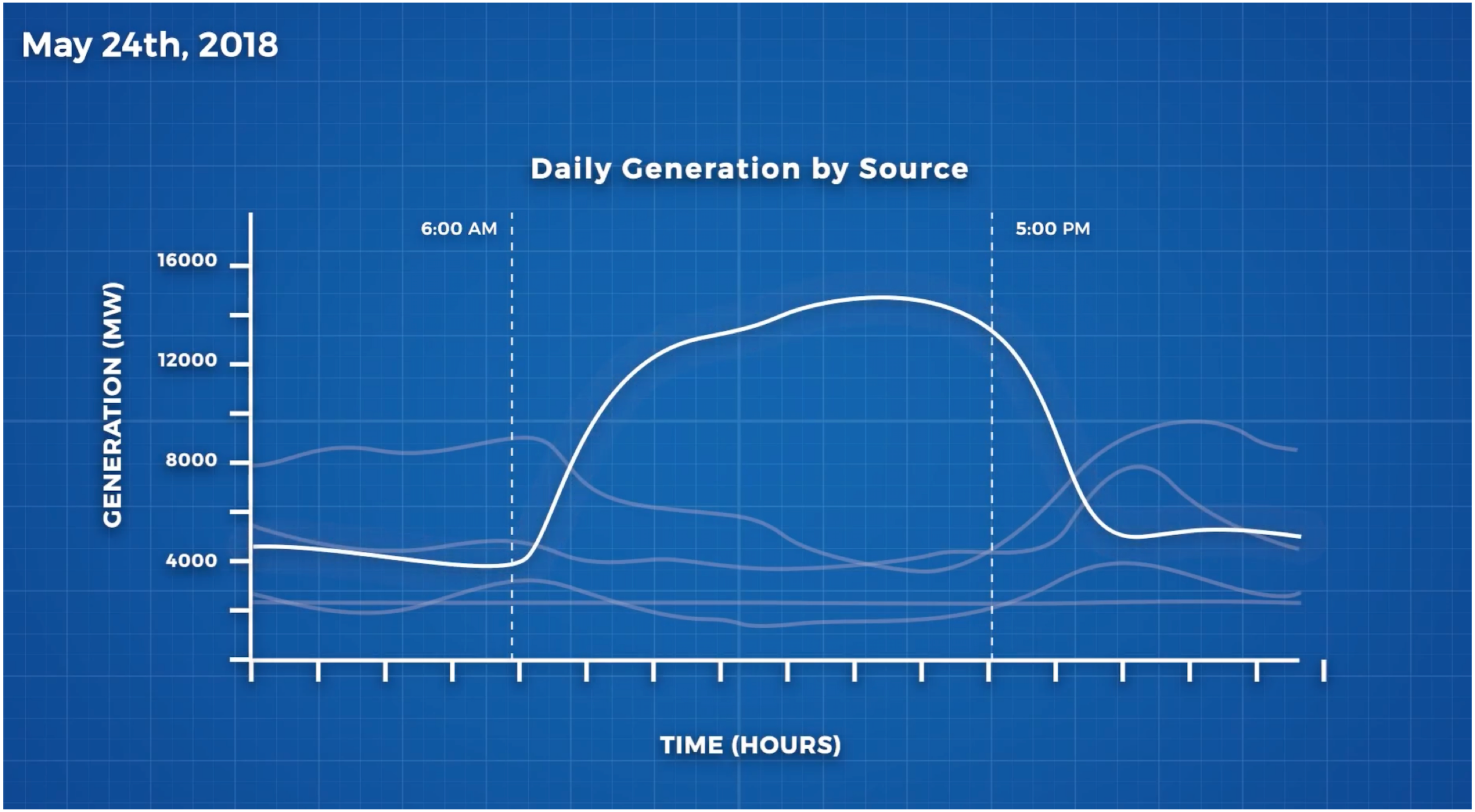
- When we flip the switch we demand power now!
- The power we depend on is called dispatchable power.
- Solar and wind power are dependent on the vagaries of nature. So they must be backed up primarily by natural gas turbines, hydro (where available) or energy storage.
- Solar and wind power save burning fossil fuels but fossil fuel generators are still required. (Running fossil fuel generators in the backup mode is inefficient).
- As we shall see batteries are short term backup (1-3 hours) at best. Many long term energy storage proposals have been advanced the most practical being pumped storage.
- But pumped storage is dependent on favorable geography.

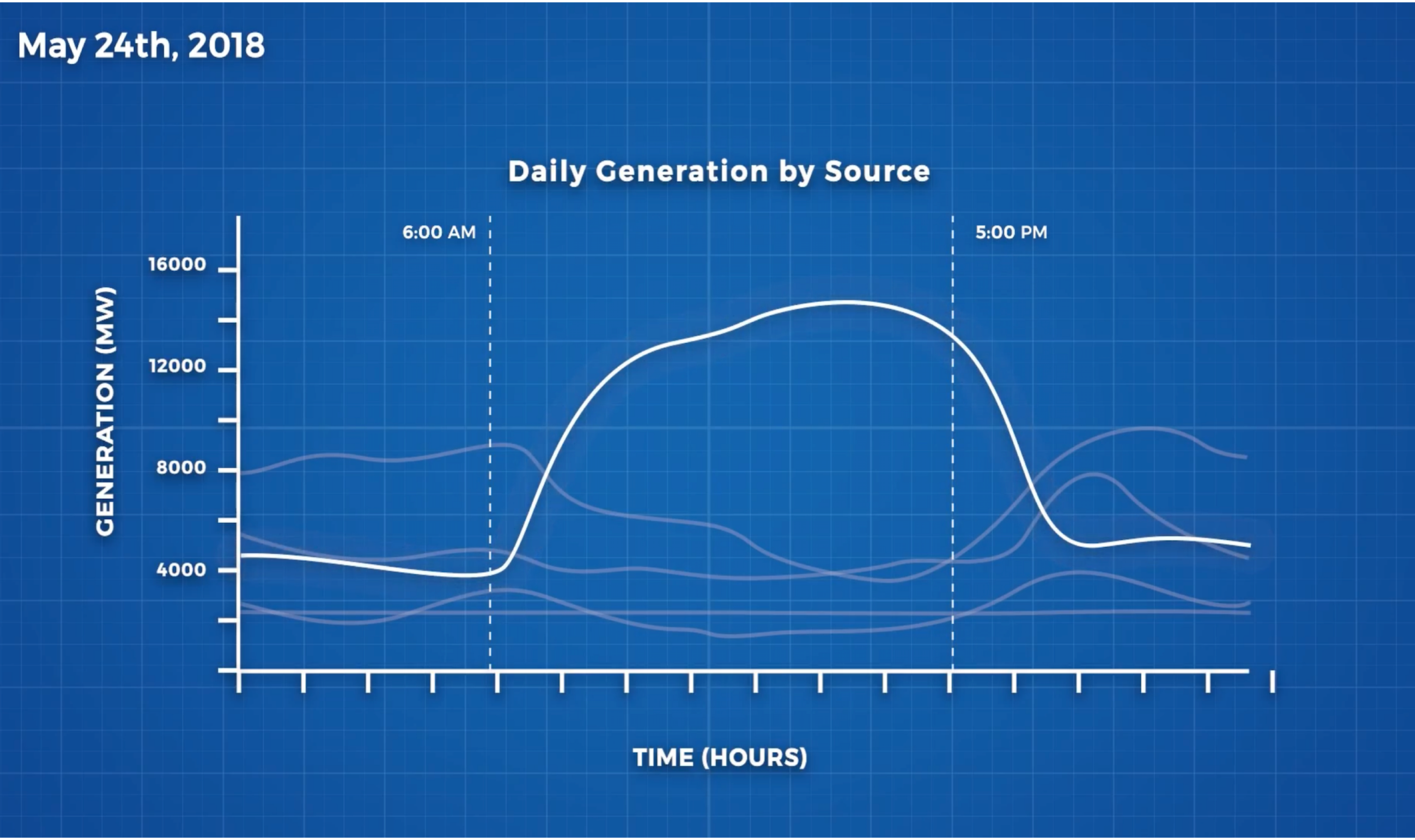
Capacity Factors -- Solar

- Solar panels work only when the sun shines. Even in ideal desert conditions that's about 8 hours per 24 hour day.
- In fact solar panels have a capacity factor of about 22% which means they provide full-time equivalent power of 22% x 24 hours = 5.28 hours of full-time electricity every 24 hours.
- So a 1000 MW solar array provides only .22 x 1,000 = 220 MWh of intermittent electricity.
- While the deserts in the US southwest are ideal locations blowing sand poses difficult challenges.
- Remote desert locations require the construction of costing high voltage transmission.



Solar Generation by Time of Day





May 24th, 2018
Daily Generation by Source
6:00 AM
5:00 PM
16000
12000
8000
4000
GENERATION (MW)
TIME (HOURS)

Capacity Factors - Wind

- Capacity factors for wind are dependent on the location. On land factors range from 20-35%.
- Winds at sea are stronger and more consistent. But the cost of at-sea construction and maintenance is much higher and the power must be sent to land via undersea cables.
- Nevertheless wind power is an important source of renewable power in northern Europe and the UK.
- However wind power is intermittent. Too little or too much wind means no electricity is generated. Power output depends on wind velocity.
- Wind turbines requires a lot of space. If placed too close they interfere with each other so efficiencies drop.

UK Offshore 2.8 GW Wind Farm

Power Density

- Power density refers to the amount of energy (BTU’s or MWh) per weight, volume or area.
- For example gasoline has 100x the power density of lithium ion batteries used in your phone and in Tesla cars (and proposed energy storage projects).
- A 1,000 MW nuclear plan occupies 1 sq. mile. The equivalent solar plant would occupy 71 sq. miles!
- The equivalent wind farm would need 360 sq. miles but the land could have multiple uses.
- To power the US energy needs in 2050 with ”renewables” would require wind farms covering an area the size of Texas for wind and much of the desert southwest for solar. (A bit of fantasy without energy storage or fossil fuel backup).

Battery Storage

The largest battery storage facility is Hornsdale built by Tesla able to store 129 MWh. The US consumes about 11.4 billion MWh per day.

If the US were to electrify ALL of its energy needs we would require 30 billion MWh/day by 2050.

Between 1/3 and 50% of daily usage would need to be backed up by batteries to (mostly) assure on-demand power. That would amount to 77 million Hornsdale sized facilities! What would be the cost?

Add to this the need for thousands of miles of new AC and DC transmission.

What Possibly Could Go Wrong?

- Reject alternatives to renewable energy (solar & wind). No nuclear.
- Persue policies that are (violently) rejected by the public.
- Refuse to develop and utilize Plan B options because “they make it too easy to continue burning fossil fuels”.
- Not use economic incentives and policies such as investment tax credits and carbon tax.
- Not use the creativity and allocation of the marketplace to develop new technological alternatives and adopt the more efficient means of reducing carbon emissions.
- Politicize the problem and solutions. Pass meaningless “commitments.”
- Centralize government control of the economy in order to “save the planet.”

Prospective Solutions

IMPROVE EFFICIENCIES: TRANSPORTATION, BUILDINGS HEATING AND COOLING, MANUFACTURING AND ENERGY DISTRIBUTION. ✈️ 🚔 🏢

INVESTMENT TAX CREDITS TO ENCOURAGE INVESTMENTS IN ENERGY EFFICIENCY.

TIME OF DAY/DEMAND ELECTRICITY PRICING.

CARBON PRICING.

CARBON CAPTURE.

NUCLEAR POWER: MODULAR FISSION U235 REACTORS.

NUCLEAR POWER: THORIUM REACTORS.

NUCLEAR POWER: FUSION POWER.

Thorium Reactor

LIQUID FLUORIDE THORIUM REACTORS – LFTR

THORIUM VERY ABUNDANT. THERE IS ENOUGH THORIUM TO POWER THE EARTH'S NEEDS FOR 1,000 YEARS.

NUCLEAR MATERIALS NOT BOMB-GRADE.

LITTLE NUCLEAR WASTE. CAN BURN NUCLEAR WASTE FROM CURRENT NUCLEAR PLANTS.

THORIUM REACTORS CAN BE "WALK AWAY" SAFE.

MORE RESEARCH AND DEVELOPMENT IS NEEDED.

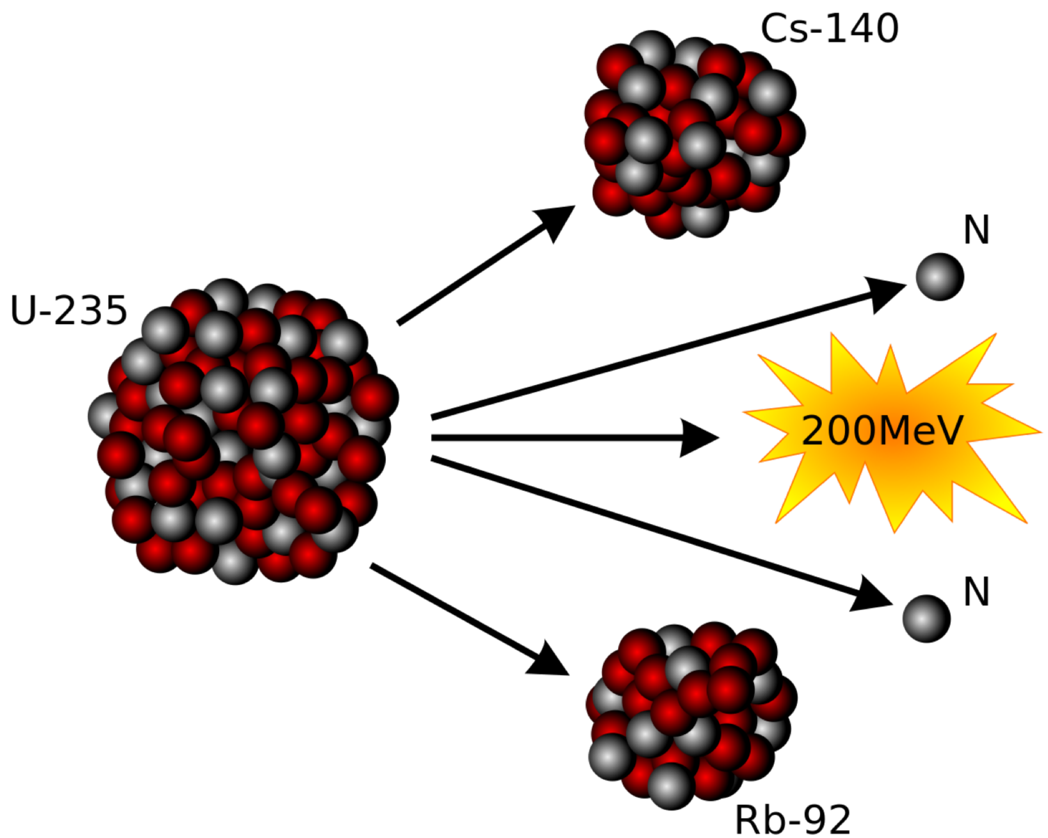
NUCLEAR REACTORS HAVE A VERY HIGH ENERGY DENSITY.

Energy Density of Uranium

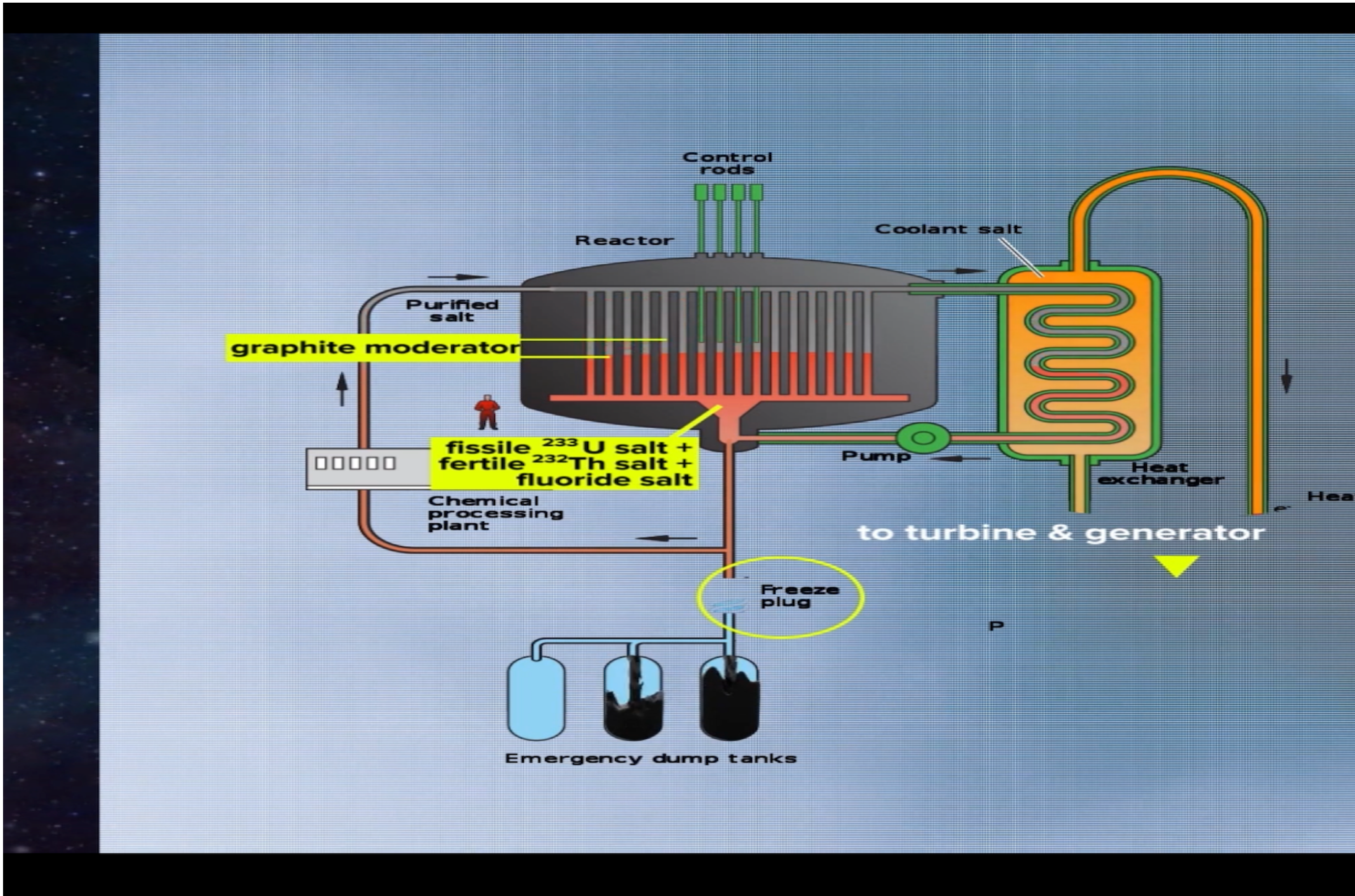
The fission of one gram of uranium produces the equivalent energy of 3 tons of coal or about 600 gallons of fuel oil which produces about ¼ ton of CO2.

There are 453.6 grams in a pound.

So 1 pound of fissile uranium is energy equivalent to 272,160 gallons of fuel oil weighing almost 2 million pounds.



Liquid Thorium Reactor Cycle



So What's Our Plan B Geoengineering?

Plan A is to reduce carbon emissions through renewable energy and nuclear power.

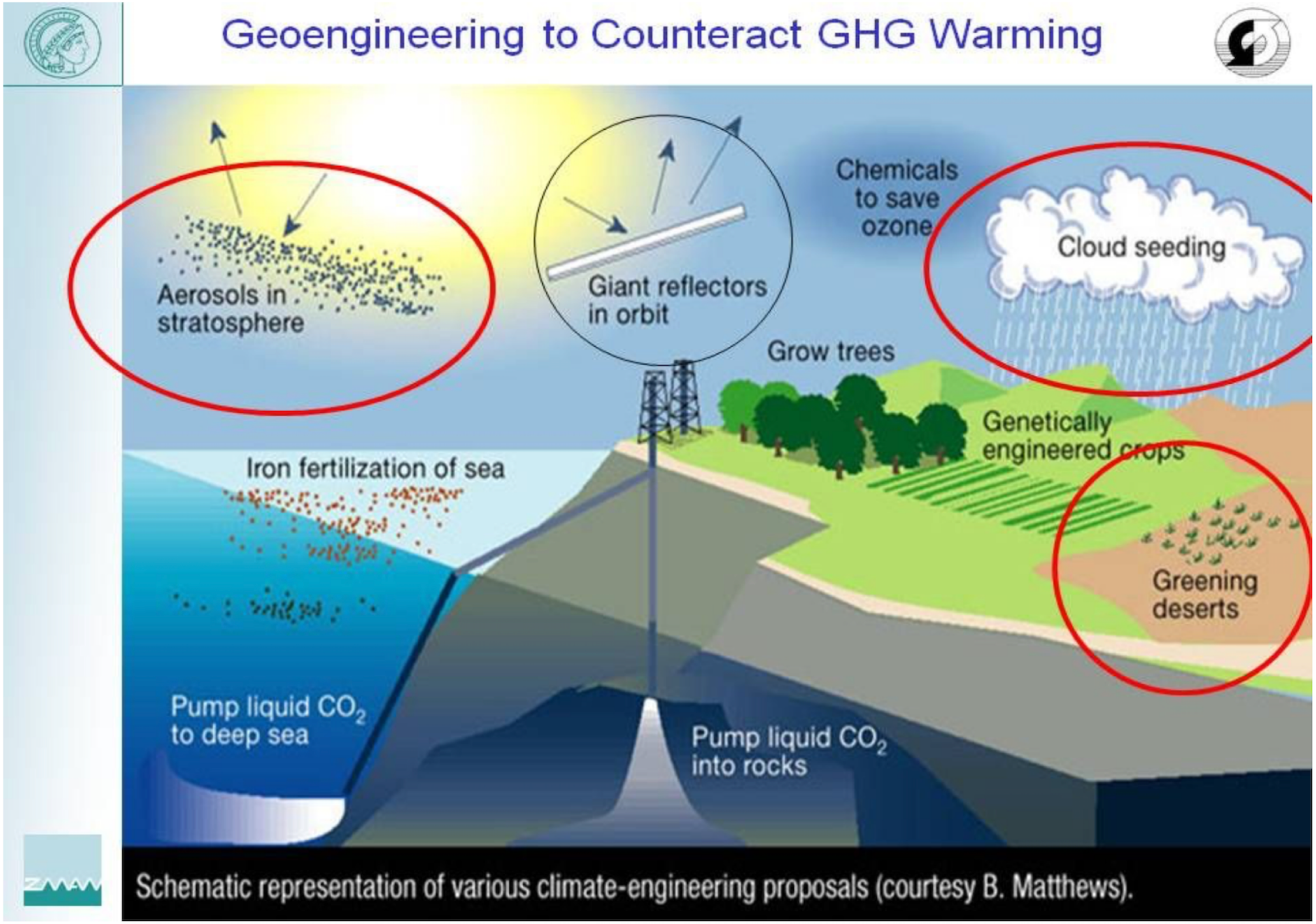
That requires world cooperation. Much of future CO_2 emissions will come from Asia – China and India. Counties will realize only a fraction of the benefit from CO_2 mitigation.

Plan B includes: (1) direct CO_2 capture from the atmosphere or burning fossil fuels, (2) afforestation/agriculture, (3) ocean fertilization, (4) enhanced weathering, (5) BECCS, (6) biochar and (7) solar radiation management.

Would research on Plan B reduce the incentives to reduce fossil fuel emissions?

Solar Radiation Management

By JustMEinT Musings | Published December 5, 2011 | Full size is 960 × 720 pixels



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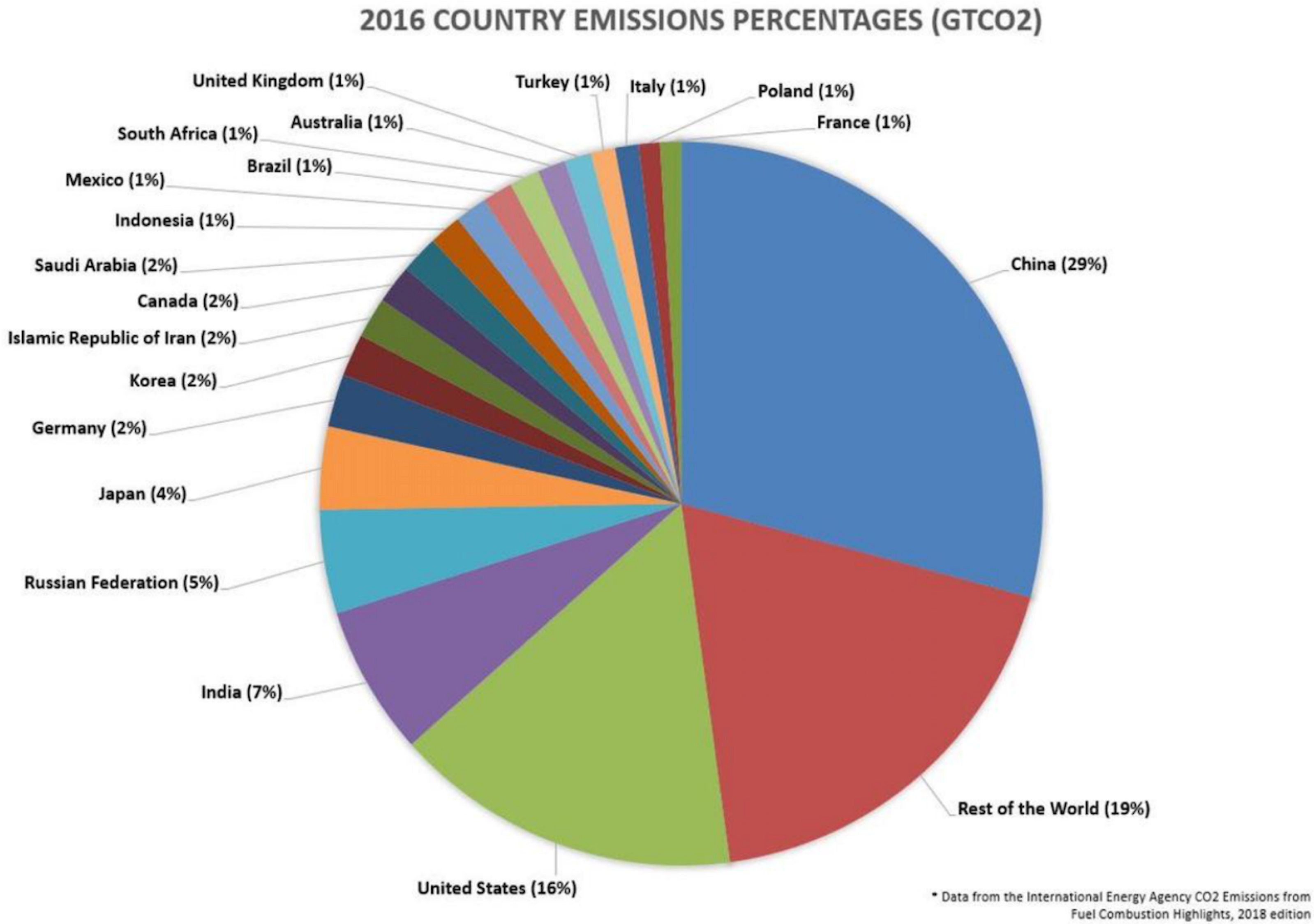
Some Take-Aways

The energy/global warming problem involves very complex technical, engineering and economic problems.

The potential hazards of Global Warming: Sea level rise, increased global temperatures, crop damage etc. are likely but of unknown timing and extent.

While the US has a high per capita emission of CO_2 we account for 16% of global emissions. So we would realize only that fraction of benefits from reducing emissions.

This is the classical externality problem in economics. Why make a costly effect to receive 16% of the benefits?


2016 COUNTRY EMISSIONS PERCENTAGES (GTCO2)
United Kingdom (1%)
Turkey (1%)
Italy (1%)
Poland (1%)
France (1%)
Australia (1%)
South Africa (1%)
Brazil (1%)
Mexico (1%)
Indonesia (1%)
Saudi Arabia (2%)
Canada (2%)
Islamic Republic of Iran (2%)
Korea (2%)
Germany (2%)
Japan (4%)
Russian Federation (5%)
India (7%)
United States (16%)
China (29%)
Rest of the World (19%)
* Data from the International Energy Agency CO2 Emissions from Fuel Combustion Highlights, 2018 edition

Jamie Osborn, 24, charity press officer from Norwich

What Possibly Could Go Wrong

(The Law of Unintended Consequences)

- Pursue renewable energy (wind & solar) exclusively. No nuclear.
- Make politically-driven decisions. Many past decision “50%.”
- Produce unstable electric grid and high prices. Public reaction undermines efforts at decarbonization.
- Act too slowly or too quickly. Commit to wrong solutions.
- Inconsistent policies. Political “warfare.”
- Refuse Plan B options because “they make it too easy to continue burning fossil fuels.”
- Failure to support broadly-based Research & Development.
- Fail to use the creativity of the marketplace to put into service efficient techno-economic alternatives.
- Central control of the economy out of “necessity to save the planet.”
- Serious damage to US economy resulting from imprudent economic policies.

The Paris Accord and CO2 As Plant Food

(Some Controversial Opinions)

- According to Dr. Bjorn Lomborg Paris commitments would cost $1 trillion/yr. With inefficient implementation $2 trillion yr.
- Implementing all Paris promises would reduce world temperature by .05 degrees C by 2100.
- Continuing commitments would decreases world temps by .17 degrees C. by 2100.
- US commitments would reduce world temps by .031 degrees C.

- Dr. Craig D. Idso on CO2 and plant growth.
- Plant productivity is enhanced by increases in atmospheric CO2.
- Herbaceous plants increase productivity by about 1/3 with 300 ppm CO2 increase.
- Woody plants respond at 50% improvement.
- Enhanced water use efficiency.
- Satellite images show increased agricultural and forest productivity.

Sources & Opinions

- The opinions expressed in this presentations are mine alone. Given the controversial and politicized nature of the subject, no doubt many will take exception to my "facts" and thoughts. The purpose of this presentation is to stimulate discussion and awareness.
- I am most concerned with the oversimplification of VERY complex geo-natural, social, engineering and economic systems. Many of the proposed "solutions" are impractical, if not absurd. Politicians and activists, however well meaning, too often are part of the problem.

I have used a great many sources too numerous to list. Note to my students "Google it." (That's what I did).

Vaclav Smil is the world expert in Power Density and Energy Transitions. (Even Bill Gates is a devotee!)

His books include (Among so many):

Power Density: MIT Press 2015.

Energy Transitions 2$^{nd:}$ Praeger 2017.

Growth: MIT Press 2019 (A Bill Gates recommendation).

The Economist "The Climate Issue" September 21, 2019.

Climate Change The Facts 2017: Edit. Jennifer Marohasy, Institute of Public Affairs.