Energy

One thing our scientists and spiritualists agree on is that ultimately everything is energy, even stuff we think of as very physical or ethereal, including rocks and our own bodies, beings, thoughts and actions. Most of us think of energy, though, as how we get power to make things happen physically.

Until 150 years ago, that was human and animal labor; gravity; burning stuff for heat, cooking and light; using sun energy to grow things; coiled springs; and wind and water powered pumps, boats and mills. Then, in the 1800s, there was an industrial revolution powered by coal, steam and mechanical invention. Then, revolutions in petroleum, combustion engines and electricity, and developments like geothermal, nuclear, wind, solar, h information and communication technologies, and hydrogen fuel cells.

Our energy industries have empowered all kinds of things we've benefitted from and/or enjoyed: heating and cooling systems, so we don't have to do as much to adapt to the climate; transportation systems that quickly move people and goods all over the Earth; machines that can do all kinds of work; lighting so we can see better; systems that let us and our machines communicate quickly in many ways; wide varieties of entertainments; production of a wide variety of goods; and so many other things.

In recent decades, our smart and hard-working scientific community, the community that brought us these technologies, has come to understand that we are doing great harm with at least some of them. We have radically increased the amount of greenhouse gases introduced into our shared atmosphere with our energy industries, and many other industries. That is causing changes in climates, changes that are already doing harm, and will produce far greater harm, devastating, catastrophic, sickening changes.

This global warming or global climate change problem is an existential threat to humanity, and many other species, which can't do anything about it. In 2018, the U.N. issued a report warning humanity that it has a decade to drastically change actions warming the atmosphere to keep global temperature rise from pre-industrial levels below 1.5° C (2.7° F). "There is no documented historic precedent" for the scale of changes to transportation, energy and other systems required. Or, it's too late.[259] 15,000 scientists from 184 countries called it our last chance to do something about it before catastrophic change is irreversible.[260] The current U.S. administration's analysis estimates about 4°C (7.2°F) of average global temperature increase by 2100 if we do nothing.[261] The sirens are wailing!

These catastrophic changes may include things like:

- Deserts expanding and emerging in places they're not today, making land unusable to us,
- Water sources disappearing, harming agriculture, causing mass migrations and conflicts,
- Arctic ice shelves collapsing into the seas, causing huge sea rises, inundating all coastal cities,
- Forests devastated from insect invasions, diseases and fires, accelerating problems,
- Insurance systems collapsing because of losses from storms, floods, fires and disasters,
- Industries and businesses failing, and economies and political and social systems collapsing,
- Millions of humans and others starving and dying of thirst because of food and water shortages,
- Millions dying in wars fought over water, food and land that is still useful to humans,
- Diseases spreading and killing millions as environmental conditions change, and
- Billions of humans and other life forms perishing prematurely, with 1 million species extinctions.

Human activity is causing these changes. We must change our activities to prevent these outcomes.

Globally, human energy use is responsible for 72% of greenhouse gas emissions. To date, in the world, the U.S.A. is responsible for the most greenhouse gases ever released into our shared atmosphere.[262] The U.S. is therefore responsible for much of this problem. If it is to behave responsibly now, it must change, right now, even more than others. Changes in the energy sector are essential to doing that.

The U.S. uses and produces different types and sources of energy, grouped into general categories, like primary and secondary, renewable and nonrenewable, and fossil fuels. Primary energy sources, where our energy comes from, include fossil fuels (petroleum, natural gas, and coal), nuclear and renewable. Electricity is a secondary energy source generated from primary energy sources, and so is hydrogen.

Energy sources are measured in different units: in the U.S., liquid fuels in barrels or gallons, natural gas in cubic feet, coal in short tons, and electricity in kilowatts (power) and kilowatt-hours (power used). The British thermal unit (Btu), a heat energy measure, is used to compare different kinds of energy. Total U.S. primary energy consumption was 97.7 quadrillion (97,728,000,000,000,000) Btu's, in 2017.

That's like 208 15-gallon (56-liter) tanks of gasoline for each of the 250 million adults in the U.S.,[263] or each of the 250 million U.S. adults driving a 50 mpg (21 km/l) hybrid car 430 miles (692 km) every day,[264] which would consume an entire work day to do. Big numbers. We're consuming a lot of energy.

In 2017, primary energy consumption shares by the 5 primary energy consuming sectors were:

- Electric power—38%
- Transportation—29%
- Industrial—22%
- Residential—6%
- Commercial—5%

The electric power sector generates most of the electricity, and the other 4 sectors consume most of it.

Primary source use varies by sector. For example, transportation uses petroleum for 92% of its energy, but petroleum is only used to make 1% of electricity. In 2017, petroleum, natural gas, and coal, the three major fossil fuels, accounted for 78% of U.S. primary energy production. Total shares were:

- Natural gas—32%
- Petroleum—28%
- Coal—18%
- Renewable energy—13%
- Nuclear—10%[265]

Not Renewable or Sustainable Energy Sources

Non-renewable energy sources have a finite supply, and we can use it all up, so they're not sustainable. They're also not sustainable, because they're causing our climate to warm and change in ways that can be catastrophic, and because they're dangerously poisonous and harming human and other life.

Fossil Fuels

Fossil fuels are various forms of hydrocarbons from plant and animal leftovers buried in the ground, over millions of years. There's a finite supply, and a limit to how much we can extract cost effectively. Fossil fuels are: petroleum oil, natural gas, hydrocarbon gas liquids and coal. Fossil fuels have dominated the U.S. energy mix for 100 years. The mix changes over time.

Petroleum Oil

Crude oil is liquid underground hydrocarbons. On- and off-shore drilling gets it from underground pools. Other techniques get it from small spaces in alluvial rocks, and from tar oil sands near Earth's surface.

It's then sent to refineries for processing, in ships or pipelines, where different parts of the crude oil are separated into various useable petroleum products, like gasoline, diesel fuel, heating oil, jet fuel, waxes, petrochemical materials, lubricating oils and asphalts, and, maybe elsewhere, with other manipulations, plastics and other petrochemical products.[266] Shipping it, processing it and using it are all very polluting.

Some countries have national oil companies operated or overseen by governments. The U.S. and others rely on privately-owned oil companies, primarily motivated to make profits for their owners. OPEC is a organization created by 14 countries, only 6 bordering the Persian Gulf, to negotiate with oil companies on oil production, prices and future rights. Russia and Saudi Arabia are the world's largest oil producers, each producing 13% of global oil, followed by the U.S., with 12% of global production.[267] Oil production generally decreased each year between 1970 and 2008. In 2009, it began to rise again. 2015 and 2017 production were the 2nd and 3rd highest on record.[268] In 2016, the U.S. oil/gas market was $286 billion, the largest in the world, with 24% of the global oil & gas market,[269] with 4% of the global population.[270]

The U.S. produces 15 and consumes 20 million barrels of petroleum per day, so it depends on imports.[271] In 2017, the U.S. consumed 20 million barrels per day (b/d), including 1 million b/d of biofuels, for:

- Transportation—14m b/d—71%
- Industrial—5m b/d—24%
- Residential—0.5m b/d—3%
- Commercial—0.5m b/d—2%
- Electric power—0.1m b/d—1%

In 2017, petroleum products consumed most in the U.S. were (in million barrels per day):

2017 Petroleum Use in U.S.	Million Barrels Per Day	Million Barrels Per Year	Percent	How Many Miles High Those Annual Barrels Would Stack
Finished motor gasoline (including ethanol)	9.327	3,404.4	46.7%	1,799,967
Diesel fuel and heating oil (including biodiesel)	3.932	1,435.2	19.7%	758,815
Hydrocarbon gas liquids (HGL)	2.643	964.7	13.2%	510,058
Kerosene-type jet fuel	1.682	613.9	8.4%	324,600
Still gas	0.690	251.9	3.5%	133,159
Petrochemical feedstocks	0.351	128.1	1.8%	67,738
Asphalt and road oil	0.351	128.1	1.8%	67,738
Residual fuel oil	0.342	124.8	1.7%	66,001
Petroleum coke	0.316	115.3	1.6%	60,983
Miscellaneous products and other liquids2	0.130	47.5	0.7%	25,088
Lubricants	0.121	44.2	0.6%	23,351
Special napthas	0.052	19.0	0.3%	10,035
Aviation gasoline	0.011	4.0	0.1%	2,123
Kerosene	0.005	1.8	0.0%	965
Waxes	0.005	1.8	0.0%	965
Total petroleum products	**19.958**	**7,284.7**	**100.0%**	**3,851,585**
2015 Total World Consumption	**93.000**	**33,945.0**	**100.0%**	**17,947,562**

[272]

That number of 7,285 million annual barrels of petroleum consumed in the U.S. in 2017, stacked on top of each other, would create 16 columns reaching up to the average distance to the moon from Earth.[273]

That number of 33,945 million annual barrels of oil consumed in the world in 2015, stacked on top of each other would create 75 columns reaching up to the average distance to the moon from Earth.[274] That's a lot of petroleum consumed. Petroleum is a third of total world energy consumption.[275]

In 2015, the five largest petroleum-consuming countries with their shares of world consumption were: U.S.-20.5%, China-12.6%, Japan-4.3%, India-4.3%, Russia-3.7%.[276] China has 4 times the U.S. population.

Petroleum exploration, transportation, refining, processing, products and uses have big environmental impacts on lands, waters, air, light, sound and ecosystems. Seismic techniques used to explore for oil under the ocean harms marine life. Used on land, they harm life on land. Drilling a well on land often means clearing lands. Spills pollute lands, waters and air, sometimes in devastating volumes, like the Exxon Valdez in Alaska and Deepwater Horizon spills in the Gulf of Mexico. Rig and refinery burns pollute everything, including night skies with light. Drilling, pumping and transportation noises do harm. Oil spill events increased from 573 in 2012 to 715 in 2015, producing significant environmental harms.[277]

Hydraulic fracturing, fracking, uses huge amounts of water and hazardous chemicals to pull oil from shale and other rock formations, which is linked with earthquakes and harms to water, land and air. Tanker ships burn one of the most polluting fuels in existence, in high volumes, polluting water and air. Drill, refinery, petrochemical and even gas station sites become highly polluted, hazardous waste areas.

Most U.S. oil refineries are located along coasts, at increasing risk for increasing storm events and sea level rise, like Hurricane Harvey flooding Houston, TX with tons of poisonous chemicals. Oil company reactions to ice caps melting is less horror and regret, and more to make plans to go drill the arctics.[278]

Petroleum and petrochemical products themselves are poisonous and cause massive and widespread health problems in their preparation, transportation, use and disposal. Plastics and many petrochemical products create enormous environmental problems, like overwhelming ocean, land and water pollution. Petrochemicals drive global warming and are the largest source of growth in oil use.[279] We gotta stop it!

Natural Gas

Natural gas is gaseous underground hydrocarbons. Its largest component is methane, 30 times more potent than CO2 as a greenhouse gas,[280] the stuff that's in cow farts and decaying garbage in dumps.

It is called: 1) conventional natural gas when it's found in big cracks and spaces between layers of rock; 2) shale, tight or unconventional natural gas when it's found in small spaces in formations of shale, sandstone and other sedimentary rock, and that's often obtained via fracking; 3) associated natural gas when it's found with crude oil deposits; and 4) coalbed methane when it's found in coal deposits.

After being drilled or fracked for, extracted and transported, natural gas is processed, removing ethane, propane, butanes and pentanes, called natural gas plant liquids (NGPL). Chemical odorants are added, because otherwise we can't smell it. It's then distributed in pipelines, tanks, trains, ships and trucks.

In 2017, natural gas production was the 2nd-highest ever, after a record in 2015.[281] Most natural gas consumed in the U.S. is produced in the U.S.[282] 2017 total imports and exports were both 3 trillion cubic feet (Tcf), exports were highest ever. The U.S. began calling natural gas "molecules of U.S. Freedom"![283] Huh? 78% of natural gas exports were by pipeline, 63% to Mexico, the rest to Canada.[284]

Natural gas is mostly distributed through a pipeline network connecting production and storage facilities with consumers through 3 million miles of pipe, enough pipe to go to the moon 12.5 times.[285] In 2017, this pipeworks system delivered 25 trillion cubic feet (Tcf) (700 billion m^3) of gas to 75 million clients.[286] A cube of natural gas with each side 29,240 miles long, twice the diameter of the Earth? Sheesh?!

Osama bin Laden was killed in Pakistan in 2011. In 2019, we're still in Afganisthan.[287] Why? We finish the Tapi pipeline by 2020, creating profits from the world's 4th largest natural gas reserves, supplying a billion people in Pakistan and India.[288] [289] The war/occupation costs are public; profits are private.

In 2017, U.S. total proved natural gas reserves were estimated at 464 Tcf, about 18.5 years' worth at 2017 consumption rates. We guess there is another 1,986 Tcf of unproved technically recoverable natural gas, 80 years' worth.[290] So, we'll burn it all up well within 100 years, the way we're going.

Natural gas is considered a relatively clean-burning fossil fuel, because it produces 117 pounds of CO2 per million British thermal units (MMBtu), compared with more than 200 for coal and 160 for fuel oil. That's still a lot. Some of it leaks from wells, tanks, pipelines, plants and connectors. In 2015, these leaks were the source of 32% of U.S. methane emissions and 4% of all U.S. greenhouse gas emissions.

The same harms oil drilling produces, natural gas drilling produces. Laying pipelines creates problems. Leaking pipelines create huge problems. Production can involve huge volumes of contaminated water that can pollute land and other waters. Natural gas wells and pipelines often have engines that run equipment and compressors, which produce air pollutants and noise. It's a dirty business.

Where natural gas pipelines aren't available to take away associated natural gas from oil wells, it may be reinjected into the ground to keep pressure up for extracting oil, or it may be vented or burned (flared), which produces CO2, carbon monoxide, sulfur dioxide, nitrogen oxides and many other compounds. Flaring is saf<u>er</u> than releasing natural gas into the air, and it has lower overall greenhouse gas emissions, because CO2 is not as strong a greenhouse gas as methane. It is not safe, though.

Natural gas fracking is linked with earthquakes and lots of pollution, particularly water pollution, at the surface, underground and far underground, where poisoned waters are injected as a "solution."[291] Hm.

Hydrocarbon Gas Liquids (HGL)

Hydrocarbon gas liquids (HGLs) are derived from natural gas and crude oil and produced with natural gas at processing plants, and when crude oil is refined into petroleum products.[292] They're used in every end-use sector: residential, commercial, industrial, transportation and electric power, and include:

- **Butanes** - used as a petrochemical and petroleum refinery feedstock for gasoline blends, plastics, synthetic rubber and lighter fuel
- **Ethane and ethylene** - used in power generation, plastics, anti-freeze and detergents
- **Natural gasoline** - used as a petrochemical feedstock for gasoline additives; heavy crude oil diluents, denaturants and solvents
- **Propane** - used as fuel for space heating, water heating, cooking, drying and transportation, and as a petrochemical feedstock for plastics
- **Refinery olefins (ethylene, propylene, normal butylene, and isobutylene)** - used as petrochemical feedstocks for plastics, artificial rubber, paints, solvents and resins

Natural gas plant liquids (NGPL) are hydrocarbon gas liquids (HGL) extracted from natural gas before natural gas is put into pipelines for transmission to consumers. Its production has increased along with natural gas production increases, and reached a record high in 2017. [293]

The U.S. usually produces more HGLs than it uses. It imports some to meet high seasonal demand and serve areas hard to get to with domestic sources. In 2017, it imported 196,000 barrels per day (b/d), 91% from Canada, and exported 1.4 million b/d of HGL.[294] Similar environmental harms are produced by HGL as other petroleum and natural gas products. In other words, HGLs are very harmful.

Coal

Coal is solid underground hydrocarbons. It's classified into 4 main types, depending on its types and amounts of carbon, how old it is, and how much heat energy it makes, which is related to how much pressure and heat acted on it over time (longer and hotter in the ground = longer and hotter burning):

- **Anthracite** – (86–97% carbon), 300+ million years old, generally has the highest heating value. Less than 1% of U.S. coal, it's all mined in Pennsylvania, mostly for use in metals industries.
- **Bituminous coal** – (45–86% carbon), 100-300 million years old, the most abundant in the U.S., 46% of U.S. coal, ¾ from WV, IL, PA, KY and IN, is used to make electricity, iron and steel
- **Subbituminous coal** – (35–45% carbon), >100 million years old, 45% of coal, 89% in WY.
- **Lignite** – (25–35% carbon), <100 million years old, has lowest energy content, had less underground heat and pressure, and is crumbly and moist. 9% of coal, half TX and 43% ND, mostly to generate electricity. An ND facility converts it to synthetic natural gas.[295] Dirty, dirty.

In surface/strip mining, large machines remove topsoil and rock to expose and remove 2/3 of U.S. coal. Sometimes, whole mountaintops are dynamited and moved to get at it. In underground/deep mining, miners ride elevators 100s to 1000s of feet down vertical mine shafts and use large machines to dig out coal from miles of horizontal tunnels, often getting sick from hard and unhealthy working conditions.

Conveyors, trams and trucks move coal around mines, to nearby patrons, or other transportation. Then, trains move 70% of U.S. coal. Barges move it on rivers and lakes, ships on the Great Lakes and oceans. Transportation can cost more than mining. So, some coal-fired electric power plants locate nearby.[296] All that transportation burns energy and creates huge environmental harms.

Coal peaked in 2008, trended down through 2016, and increased again in 2017, with the new President, who supports it. The main reason it has declined is that it is extremely polluting and causes harms.[297] Coal was the source of the black skies, cities and lungs of the industrial revolution and Dickens stories.

In 2017, about 775 million short tons of coal were produced in 24 U.S. states.[298] A modern train coal car carries 120 tons of coal. So, that coal would fill 6,458,000 rail cars, each 50 feet (15.24 meters) long. Hooked together in one train, that train would be 61,000 miles long, 25 times longer than the distance between New York City and Los Angeles. Wow, and that's using less than 10 years ago.

Some coal-burning power plants along the Gulf Coast and Atlantic Ocean find it cheaper to import coal than to get it from U.S. coal-producing regions, so in 2017, the U.S. imported 8 million short tons of coal. In 2017, the U.S. exported about 97 million short tons of coal, about 13% of U.S. coal production to: India-11.8%, South Korea-9.7%, The Netherlands-9.7%, Japan-7.9, Brazil-7.8%, Others-53.1%.[299] The amount of coal the U.S. shipped all over the world in 2017 would fill 3.4 trains as long as the distance from New York City to Los Angeles, and that transportation burns lots of dirty ship oil and creates harms.

Coal at currently producing mines would last 23 years at current consumption rates. All coal anywhere in the U.S. would last about 370 years at current consumption rates, if we can get it all out. In 2015, world proved recoverable reserves of coal were 1.1 trillion short tons. Five countries had 74% of it all: the U.S.-22%, Russia-16%, Australia-14%, China-13%, and India-9%.[300]

93% of coal is used to generate electricity in the U.S.; the rest for making concrete, paper and steel, synthetic fuels (synfuels), or chemicals for other products.[301] All of that is very polluting.

Concrete is the most widely used man-made material, 2nd to water as Earth's most-consumed resource. Cement, its key ingredient, is all over our built areas. It has a massive carbon footprint, as source of 8% of global CO2 emissions. If the cement industry was a country, it would be world's 3rd largest emitter, after China and the U.S., not far behind global agriculture (12%) as a major source of CO2 emissions.[302]

In 2016, 65% of U.S. mined coal came from surface mines (AKA strip mines), the largest in Wyoming. Large areas of the Appalachians in West Virginia and Kentucky have been harmed by mountaintop removal and valley-fill mining, which demolish the tops of mountains and other land with explosives, changing entire landscapes, covering streams in rock and dirt, and polluting air, lands and waters.

Underground mines can collapse, and drain acidic water. Methane gas in mines can explode if not properly vented, and contributes to global warming if it is, as an exceptionally powerful greenhouse gas. In 2015, methane emissions from coal mining and abandoned coal mines were 10% of total U.S. methane emissions, and 1% of total U.S. GHG emissions. Main emissions from coal combustion are:

- **Sulfur dioxide (SO2)**, a source of acid rain that harms forests, lakes and life.[303]
- **Nitrogen oxides (NOx)**, contributors to smog and respiratory illnesses
- **Particulates**, contributors to smog, haze, respiratory illnesses and lung disease
- **Carbon dioxide (CO2)**, the main greenhouse gas produced from fossil fuel burning
- **Mercury and other heavy metals**, tied to neurological and developmental damage in life
- **Fly and bottom ash**, toxic leftovers created when coal is burned at power plants[304]

Coal-fired power plants are the largest source of mercury in the U.S., 48% of mercury emissions in 2015. This mercury falls back to Earth and becomes highly toxic methylmercury, which moves up food chains. Wildlife that eat fish, like loons, bald eagles, otter, mink and marine mammals get mercury poisoning. Many songbird and bat species are threatened from methylmercury exposures. Humans get poisoned.

It compromises productivity of economically valuable game fish. Mercury concentrations in fish reach 10-100 million times more than in water; and we eat fish, causing 80% of human methylmercury intake. Drugs can't fix methylmercury toxicity. Now, all fish in U.S. waters have measurable methylmercury. States post fish consumption advisories for waters known to have elevated contaminants. In 2013, mercury advisories were in effect in all 50 states, 1 U.S. territory and 3 tribal territories, 81% of all advisories, more advisories for mercury than for all other contaminants combined.[305]

Coal fly and bottom ash are mostly stored near power plants or put in landfills, kind of like pig feces is put in big ponds at hog farms. Pollution leaches from ash storage and landfills into groundwater, and ruptures and spills of large ash lakes are large environmental problems. Ugly stuff.

The Clean Air and Clean Water Acts, now under attack, require industries to reduce pollutants released into air and water. The coal industry has found some ways to help reduce sulfur and other impurities. Scrubbers can "help reduce" SO2, NOx and particulates, and "help reduce" mercury emissions.[306]

If forced to meet modern pollution standards, though, 98% of currently operating coal power plants would be unprofitable, compared to equivalent natural gas plants. They stay open because of regulations allowing pollution exemptions, and by forcing taxpayers to pick up the climate change bill.[307] Coal combustion creates half of global emissions causing climate change, and health damage caused by coal is estimated at $500 billion (43% of FADS) in the U.S, far more in China.[308] It's a big global problem.

Nuclear

Nuclear energy is in atoms, the building blocks of molecules that make up all gases, liquids and solids. An atom has a nucleus, or core, containing positively charged protons and neutrally charged neutrons, orbited by negatively charged electrons, kind of like a miniature solar system.

Nuclear energy can come from nuclear fusion, when atoms are fused together to make bigger atoms, the energy source in the sun. We can't do that efficiently enough to be commercially viable, yet. Nuclear power plants use nuclear fission, with uranium as fuel. Enormous energy binds the nucleus. Nuclear fission releases that energy. In fission, a neutron smashes into a uranium atom, and splits it, releasing heat and radiation energy, and more neutrons, which strike other atoms, in a "chain reaction." That reaction is managed to make heat, and that heat spins turbines, which generate electricity.

Uranium, a nonrenewable energy source, is about 100 times more common than silver, but U-235, the fuel most used in nuclear fission, because its atoms are more easily split, is rare. Uranium ore is mined in the western U.S.,[309] but, in 2017, U.S. nuclear power reactor companies bought only 7% of uranium in the U.S., 93% from other countries, so we depend on them: Canada-35%, Australia-20%, Russia-18%, Kazakhstan-12%, Uzbekistan-5%, Hungary, Malawi, Namibia, Niger, S. Africa, Ukraine, etc.-10%[310]

U-235 is extracted and processed before it can be used as a fuel.[311] At uranium mills, chemicals process it into yellowcake (U3O8), solid leftover mill tailings are dumped, water is pumped into the ground, and U308 is converted into uranium hexafluoride (UF6) gas. Then, at the only U.S. enrichment facility, it's separated into isotopes U-234, U-235 and U-238, and the U-235 is enriched to 4% to 5% concentrations. That's sealed in canisters, cooled and solidified, and transported to nuclear reactor fuel assembly plants.

There, it's processed into small ceramic fuel pellets, sealed into long metal tubes to form fuel rods, and bundled together to make fuel assemblies. Fuel assemblies are transported by trucks to reactors and stored until needed. They're only mildly radioactive, because most radiation is contained in the tubes. Typically, one-third of a reactor core (40 to 90 fuel assemblies) is used up every 12 to 24 months.

In 2017, 45.5 million pounds (20.6 million Kg) of enriched uranium were loaded into U.S. commercial nuclear power reactors. Big number. 24 tons of enriched uranium fit in 4 to 5 trucks.[312] So, 421,296 truckloads of enriched uranium were transported and used in U.S. nuclear power reactors.[313] Trucks average 75 feet (23m) long. Nose to tail, that would be a train of trucks 6,000 miles (9,500 Km) long,[314] 2.4 times the 2,450-mile (3,950 Km) distance from New York City to Los Angeles. Spent fuel is eventually transported away from power plants, which means those numbers are doubled. 20 million global radioactive uranium transports happen every year.[315] Those produce big CO2 emissions and pollution.

A reactor core is a set of fuel assemblies in a steel pressure vessel. Its moving parts are a small number of control rods inserted to regulate the nuclear fission reaction. Placing the fuel assemblies next to each other and adding water initiates the nuclear reaction. Impressive we've figured this out and can do it!

After use in reactors, fuel assemblies are very radioactive. They're removed and stored in water at reactor sites in spent fuel pools for several years. Fission reaction has stopped, but spent fuel still gives off heat from radioactive decay. Water cools the fuel and blocks radiation release. 1968-2013, 241,468 fuel assemblies were used and stored at 118 U.S. commercial nuclear reactors. After a few years, spent fuel is cool enough to move to outdoor concrete or steel, air-cooled, dry storage containers at plants. The last step is to put it in a permanent underground repository. But there's no such thing in the world.

Of the 31 countries with commercial nuclear power plants in 2015, the U.S. had the most nuclear electricity generation capacity and generated more electricity from nuclear energy than any other. France, #2, got 78% of its electricity generation from nuclear energy, the largest share of any country. 15 countries get at least 20% of their electricity from nuclear power, including Russia and China.[316]

In 2018, 99 reactors operated at 61 power plants in 30 U.S. states. (36 plants have more than 1 reactor.) Average age was 37 years; the oldest is from 1969. 20 reactors at 18 sites are being decommissioned. In 2016, the first new U.S. reactor since 1996 came online, in Tennessee. Two new reactors in Georgia have been approved, the first approved in more than 30 years, and are expected to be online by 2020. In 2017, 18 applications for new reactors were in various stages of review.

Nuclear power has supplied a fifth of U.S. electricity since 1990, even with fewer plants, because of capacity increases and better efficiencies at existing plants. Nuclear electricity generation capacity in the U.S. is estimated to decrease every year through 2050,[317] as more go offline than online. We'll see.

Unlike fossil fuel-fired power plants, nuclear reactors don't directly release air pollution or CO2, but building plants, mining and refining uranium ore, making reactor fuel, and transporting ore and fuel do. Nuclear power plants also have lots of metal and concrete, which take lots of energy to manufacture.

Nuclear reactor accidents can pollute large areas of land, air and water. Despite best efforts, it happens. The 3-Mile Island disaster halted new nuclear plants in the U.S. for 30 years.[318] The Chernobyl accident has irradiated big parts of the U.S.S.R. and Europe.[319] The Fukushima, Japan nuclear disaster may have irradiated the entire northern Pacific Ocean.[320] Fallout and consequences are still happening. We'll see.

Radioactive wastes are giant environmental and health concerns. We try to take care with it, and how it's handled is regulated, but it is very dangerous.[321] Radioactivity is the worst pollution ever devised, making life sick and altering DNA. Uranium tailings contain radium, which decays into radioactive radon. Most is covered with a barrier like clay to prevent radon from escaping, and covered to prevent erosion, but sometimes that fails. When a nuclear reactor stops operating and is decommissioned, the reactor and everything that's radioactive has to disassembled, transported and/or safely stored somewhere. High level nuclear waste, the stuff that comes out of reactors, is truly nightmarishly terrifying.

It goes to 4 storage facilities (in TX, SC, UT or WA), or the Waste Isolation Pilot Project (WIPP), near Carlsbad, N.M., a ditch 100' (30m) wide, 2 miles (3km) long and 33' (10m) deep, with 48 stone markers, etched with warnings in 7 languages, ranging from English to Navajo, and human faces contorted in expressions of horror. It's meant to last 10,000 years, twice as long as the Giza pyramids have survived. But radioactive stuff in a salt mine in this hole will be lethal at least 25 times that long, 250,000 years.[322] (The site was closed for years when the wrong kind of cat litter was used to soak up radioactive waste, and it reacted and exploded, above and below ground.) A long-term plan to bury nuclear waste under Yucca Mountain, NV is stuck, because people there don't want it,[323] and taxpayers pay utilities $1 billion a year in fines, because our government has not yet solved what to do with utility company waste.[324]

The U.S. does not have a permanent disposal and storage facility for its high-level nuclear waste.[325] **And if it did, it would have to manage that 250,000 years to be sure radioactivity is not released.**[326] **How long will the U.S. exist? There are 250,000 tons of nuclear waste, globally, and no solutions.**[327] **Costs to assure safety of nuclear waste are not born by nuclear operators, or there would be no nuclear power, because there would be no business case for nuclear energy. It's far too expensive.**

Renewable and Sustainable Energy Sources

Petroleum, natural gas, HGL, coal and nuclear energy are all non-renewable. They have a finite supply, and we can use it up. We'll use up fossil fuels within 100 years. They are therefore not sustainable. They're also not sustainable, because they cause our climate to warm and change in ways that can be catastrophic to us and other life, and because they are poisonous and are harming human and other life.

Renewable energy comes from sources that are naturally replenishing, but limited at any given time. Replacing non-renewable, unsustainable and dangerously poisonous fossil fuel and nuclear energy with sustainable and non-toxic renewable energy is an important way to reduce global warming, and many enormous health and environmental problems. Major current sources of renewable energy include: Biomass, Hydropower, Geothermal, Wind, and Solar.

Until the mid-1800s, wood was used for almost all human energy needs for heating, cooking and light. Since then, fossil fuels have been our major energy sources. Hydropower and solid biomass were our main renewable energy sources until the 1990s. Since, biofuels, solar and wind energy have increased.

In 2017, renewable energy provided a record high 11% of total U.S. energy consumption, about 11 quadrillion British thermal units (Btu). (11 followed by 15 zeros.) 57% of U.S. renewable energy was consumed by the electric power sector, and 17% of U.S. electricity generation was from renewables.

2000 to 2017, biofuel and other non-hydroelectric renewable energy consumption more than doubled, mostly because of previous government requirements and incentives to use renewable energy.[328] Hydroelectric power production was 2% lower than the 50-year average. Record high production of wind and solar energy helped increase the overall energy production from renewable sources.[329]

Hydropower

Humans have a long history of using the force of stream and river water flows for mechanical energy, like in grain and saw mills. Hydropower was one of the first energy sources used to generate electricity, in 1880, and it's still the largest single U.S. renewable energy source for electricity generation.

In 2017, it provided 7.5% of all U.S. utility-scale electricity generation, and 44% of total utility-scale electricity generation from renewable energy sources. Its share of total U.S. electricity generation has decreased over time, because generation from other sources has increased more.

Understanding the 3-step water cycle is important in understanding hydropower:

- Solar energy heats water on the surface of rivers, lakes and oceans and causes it to evaporate.
- Water vapor condenses into clouds and falls as precipitation.
- That water forms streams and rivers, which flow into oceans and lakes, and the cycle repeats.

Precipitation volume in a drainage system affects how much water there is to make hydropower. Seasonal variations in precipitation and long-term changes in precipitation patterns, such as droughts, have a big impact on hydropower production. So, climate change can threaten hydropower.

Hydroelectric power is made from moving water, so hydroelectric plants are usually by a water source. There, flowing water pushes against and turns turbine blades that spin a generator to make electricity.

Sometimes, the natural flows turn the turbine. Sometimes, water pipes create drop and power. Sometimes, water is stored in reservoirs behind dams and released as needed to make electricity.[330]

Every state has hydropower plants. Most hydroelectricity is from big federal-government-built dams, mostly in the west. In 2017, U.S. hydroelectricity generation capacity was 80,000 megawatts (MW). Biggest 5 states by share of total capacity were: Washington—27%, California—13%, Oregon—11%, New York—6%, and Alabama—4%. In 2017, total U.S. hydroelectricity generation was about 300 billion kilowatt-hours (kWh), 7.5% of all U.S. utility-scale electricity generated.

Only a small percent of U.S. dams produce electricity. Most were built for irrigation and flood control and don't have generators. Those could potentially produce another 12,000 megawatts (MW).[331]

Hydropower doesn't directly emit air pollution, and has 50 to 100 year operating lives, but reservoirs, dams and hydropower operations affect environments. Their concrete involves lots of greenhouse gas. Dams block fish migrations and hurt populations, and fish can be injured or killed in turbines. Low river flows can harm ecosystems, changing water temperatures and chemistry, silt volume, flow and physical characteristics, harming plants and animals. Reservoirs flood natural areas, agricultural lands, homes and/or archeological/historical sites. There are catastrophic flood risks if they fail, and many are old.

Greenhouse gases, like CO2 and methane, can form in reservoirs and be emitted into the atmosphere. Their Greenhouse effects in tropical/temperate regions, including the U.S., may be the same or more than those of CO2 emissions from same amounts of electricity generated with fossil fuels.[332] Bummer.

There are other ways to generate hydropower also. Gravitational pulls of the moon and sun and Earth's rotation cause tides, which can be up to 40 feet (12 meters). More than 1,000 years ago, people in Europe used tidal energy to run grain mills. Tidal energy systems are now used to generate electricity.

One way uses a "barrage" (dam) built across an ocean bay inlet or lagoon that forms a tidal basin. Water moving through barrage openings spin turbines and generators to make electricity. These can change basin water levels, increase turbidity (stuff suspended in water), harm navigation and recreation, and plants and animals in basin estuaries. The U.S. has no tidal power plants. Its best sites are in Alaska.

There are other ways to use tidal energy to make electricity that don't do such harm. Tidal turbines are like wind turbines on the sea floor where there's strong tidal flow. They have to be a lot sturdier and heavier than wind turbines, and they're more expensive to build than wind turbines, but they capture more energy with the same size blades. A demonstration project is coming in New York's East River.

A tidal fence is a similar tidal power system with vertical axis turbines mounted in a fence or row on the sea bed generating electricity. As of the end of 2017, no U.S. tidal fence projects were operating.[333]

Research is happening on how to make electricity with ocean wave energy, created by wind blowing across of open water surfaces in oceans and lakes. Ocean waves carry enormous energy. Theoretically, 2.6 trillion kilowatt-hours, 66% of 2017's U.S. electricity generation, is in waves off U.S. coasts.[334]

Another hopeful area for hydropower generation is ocean thermal energy conversion (OTEC), making energy and desalinating ocean water using temperature differences (thermal gradients) between deep and surface waters. Warm surface water evaporates and drives turbines and generators. Vaporized gas is cooled back into a liquid using cold ocean water from deeper in the ocean, and it has no salt in it.[335] So, it could also provide desalinization services to produce fresh water.

Biomass

Biomass, organic material from plants and animals, is a renewable energy source containing stored energy plants absorb from sun's energy in photosynthesis. When it's burned, its chemical energy is released as heat. It can be burned directly, or converted into liquid bio-fuels or -gas that can be burned.

Wood, paper and wood processing wastes can be burned to heat buildings, produce heat for industry, and generate electricity. Agricultural crops and wastes can be burned as fuel or made into biofuels. Food, yard and wood waste in garbage can be burned to produce electricity, or converted to biogas. Animal manure and human sewage can be converted to biogas and burned as a fuel. [336]

Humans have used wood for cooking, heat and light for at least thousands of years. It was the world's main source of energy until the mid-1800s. It's still an important fuel, especially for cooking and heating in developing countries. In 2017, 2% of U.S. annual energy consumption was from wood/wood waste.

Industry, electric power producers and commercial businesses use most of the wood and wood waste fuel consumed in the U.S. Wood and paper products industries use wood waste to make steam and electricity, which saves them money by reducing amounts of other fuels and electricity they buy.

Wood is used throughout the U.S. for heating, in fireplaces, wood- and pellet-stoves. In 2017, wood energy was 2% of residential energy consumption. In 2015, 12.5 million (11% of) U.S. households used wood as an energy source, mainly for space heating, and for 3.5 million it was the main heating fuel.

Amounts (in trillion BTUs) of U.S. wood/wood waste energy consumed by sector with shares in 2017: Industrial-1,480-69%, Residential-334-16%, Electric power-247-12%, Commercial-84-4%.[337]

Ethanol is a biofuel made with corn and sugar cane fermentation. Biodiesel is a biofuel made from vegetable oils and animal fats that is burned in vehicles, and as heating oil. In 2017, biomass fuels provided about 5% of total primary energy used in the U.S. Of that 5%, 47% was from biofuels (mostly ethanol), 44% from wood and wood-derived biomass, and 10% from municipal waste biomass.[338]

Stuff in municipal solid waste (MSW), or garbage, that burns is used to make energy at waste-to-energy plants and landfills. In 2015, 262 million tons of MSW were generated in the U.S., and: 52.5% was landfilled, 25.8% was recycled, 12.8% was burned with energy recovery, and 8.9% was composted.

In 2016, 71 U.S. plants generated 14 billion kilowatt-hours of electricity burning 30 million tons of MSW. Biomass was 64% of the weight of material burned, which made about 51% of the electricity. The rest of the stuff burned was mainly plastics, which has to be done carefully to avoid releasing dangerous poisons into the environment. Burning garbage reduces volumes in landfills.[339]

Many large landfills also generate electricity by burning methane gas from decomposing biomass. Bacteria decompose organic landfill waste into biogas, 40%-60% methane, and the rest mostly CO_2. Methane is what's in natural gas, and it's a powerful greenhouse gas. Some landfills reduce methane emissions by just burning it. That releases CO_2, but that has less greenhouse gas impact than methane. Others collect biogas, treat it and sell the methane. Some burn the methane gas to generate electricity.

In 2016, 278 billion cubic feet of landfill gas was burned for energy at U.S. landfills to generate about 11.2 billion kilowatt-hours (kWh) of electricity, 0.3% of total U.S. electricity generation.

Some farmers make biogas in "digester" tanks, where they put manure and old bedding from barns. Others cover manure ponds or lagoons to capture biogas. Biogas digesters and manure ponds use the same anaerobic bacteria as landfills. Biogas methane can then be burned to heat buildings and water, and made into fuel to burn, in diesel-engine generators to make electricity for the farm, or in tractors.[340]

Biomass and biofuels from biomass are fossil fuel alternatives. Burning fossil fuels or biomass releases greenhouse gas CO2, but plant sources of the biomass capture nearly the same amount of CO2 through photosynthesis while they are growing, which can make biomass a carbon-neutral energy source.

Using wood, wood pellets and charcoal for heating and cooking can replace fossil fuels and may cause lower CO2 emissions overall, but wood is only sustainable if it's regrown responsibly. Else, it causes deforestation and harm. Wood smoke carries harmful pollutants like carbon monoxide and particulates. Modern wood stoves, pellet stoves and fireplace inserts can reduce particulates from burning wood.

Burning MSW, or garbage, to produce energy means less waste is buried in landfills. On the other hand, burning garbage produces air pollution and releases chemicals and substances in the waste into the air. That can harm life and environments if not managed well. Rules require waste-to-energy producers to use air pollution control devices, like scrubbers. Electricity from burning MSW is considered renewable, because we keep making trash. It can replace electricity from fossil fuels, with net CO2 reductions.

Ash can contain high concentrations of metals from the original waste. Separating waste before burning can reduce the problem. Batteries and florescent light bulbs shouldn't be burned, for example. Some MSW landfills use ash tested safe as a landfill cover layer, or to make concrete blocks and bricks.[341]

Biofuels

Biofuels are transportation fuels like ethanol and biodiesel that are made from biomass materials. They're usually blended with gasoline and diesel petroleum fuels, but they also work on their own. Ethanol and biodiesel burn cleaner and hotter than pure gasoline and diesel fuel, and the more of those we burn, the less crude oil we burn and import from other countries.

Ethanol

Ethanol is an alcohol fuel made from sugars in grains, like corn, sorghum and barley, or other plants, like sugar cane, beets and potatoes. Most is from corn. Other options, like switchgrass, are being explored.

In the 1850s, ethanol was a major fuel for lighting. In the Civil War, a liquor tax on ethanol raised money for the war, but it increased its price so much it could no longer compete with other fuels, like kerosene, so production fell sharply, and production did not begin to recover until that tax was repealed in 1906. In 1908, Henry Ford's Model T ran on a mixture of gasoline and alcohol he called the fuel of the future. 1919-1933, ethanol was banned during Prohibition, because it was considered an alcoholic beverage.

Use increased in World War II, with oil and other resource scarcities. With the 1970s oil embargoes, rising oil prices and oil import vulnerabilities, it rose again. Since then, its production and use have been encouraged by tax benefits and environmental regulations requiring or incenting cleaner-burning fuels. U.S. government promotes ethanol as a transportation fuel to reduce imports of oil and CO2 emissions. In 2005, it set minimums required for renewable fuel use. In 2007, targets were set to increase to 36 billion gallons annually by 2022. In 2017, U.S. consumption was 14 billion gallons of ethanol fuel.[342] That's about 21,000 Olympic swimming pools worth.[343]

Now, nearly all gasoline sold in the U.S. is about 10% ethanol by volume. Any U.S. gas-powered engine can use it (called E10), but only some engines can burn fuel mixtures with more than 10% ethanol. Flexible-fuel vehicles can use E85, a fuel that is 50%-85% ethanol. U.S. cars and light trucks since 2010 can use E15 (gas with 15% ethanol).[344] Unlike gasoline, pure ethanol is nontoxic and biodegradable. It quickly breaks down into harmless stuff. But, chemical denaturants added to it make fuel ethanol toxic. Ethanol is very flammable.

Biofuels may be carbon-neutral, because, as they grow, plants used to make them (corn and sugarcane for ethanol and soy beans and palm oil trees for biodiesel) may absorb the same amount of CO2 as the biofuel releases when it is produced and burned. Growing plants for biofuels is controversial, though, because land, fertilizers and energy for growing biofuel crops could be used to grow food crops instead. That can cause disruptions in food supplies and agricultural markets.

Ethanol and gasoline-ethanol blends burn cleaner and have higher octane ratings than pure gasoline, but their emissions leaking from fuel tanks and pumps make harmful, ground-level ozone and smog. Biodiesel combustion produces fewer sulfur oxides, less particulate matter, less carbon monoxide, and fewer unburned and other hydrocarbons, but it produces more nitrogen oxide than petroleum diesel.[345]

Biodiesel

Biodiesel is made from vegetable oils, fats, or greases, like French-fry-oil. It works in any diesel engine. It's non-toxic, biodegradable and produces less of most air pollutants than petroleum-based diesel fuel. It is usually sold as a blend of biodiesel and petroleum-diesel. A common blend is B20, 20% biodiesel.[346] In 2017, major sources of U.S. biodiesel by percent were:

- Soybean oil - 52%
- Canola oil - 13%
- Corn oil - 13%
- Recycled used cooking oils and grease - 12%
- Animal fats - 10%
- (Rapeseed, sunflower and palm oils are big sources in other countries.)

Before petroleum diesel fuel became popular, Rudolf Diesel, the inventor of the diesel engine in 1897, experimented with using vegetable oil (biodiesel) as fuel. Until 2001, only small amounts were used in the U.S. Since then, consumption has grown, largely because of the availability of various government incentives and requirements to produce, sell and use biodiesel.[347] Government incentives matter.

Biodiesel is used as heating oil. It's blended with petroleum diesel at 2% (B2), 5% (B5) or 20% (B20), but can be pure (B100). It pollutes less than petro-diesel. Any diesel engine can use 5% (B5) or less blends. To use higher blends, engines must be modified. Gas stations sell biodiesel blends in almost every state.

B2 and B5 are popular in the trucking industry. Biodiesel is sensitive to cold and may need a special type of anti-freeze, but it acts like a detergent additive, loosening and dissolving sediments in tanks, so it improves engine performance. It's a solvent, so B100 can make rubber and other components fail in older vehicles, but biodiesel blends don't have that problem.

Environmental benefits, ease of use, availability, government incentives and U.S. fuel standards have contributed to its increased use. From 2001 through 2017, that went from 10 million to 2 billion gallons (7 billion liters) annually, 3,000 Olympic swimming pools worth.[348] Globally, from 2001-2016, biodiesel consumption grew from 0.3 billion gallons to 9.3 billion gallons (35 billion liters) in at least 56 countries. By billions of gallons and share of world total:

- U.S.A. 2.1 22%
- Brazil 1.0 10%
- France 0.9 10%
- Indonesia 0.8 9%
- Germany 0.7 7%
- <u>All others 3.9 42%</u>
- World total 9.3 100%[349]

Biodiesel is nontoxic and biodegradable. It produces fewer air pollutants, like carbon monoxide, sulfur dioxide, hydrocarbons and particulates, than petroleum diesel. NO_2 emissions may be a little higher. It's carbon-neutral, because growing plants it comes from absorb similar amounts of CO_2 to what it releases when burned. Clearing a forest to grow plants for biodiesel creates more harm than benefit.[350]

Wind

Geothermal wind happens when Earth's surface heats up more in the sun in some places than in others. In the day, air heats up faster over land than water. It rises, heavier cooler air moves in, creating wind. At night, winds reverse because air cools faster over land than water. In the same way, atmospheric winds circling the Earth happen, because lands near the equator are hotter than toward the poles.[351]

In 5,000 BC., people used wind energy to sail boats on the Nile River. By 200 BC, wind-powered water pumps were used in China, and windmills ground grain in Persia and the Middle East. Merchants and Crusaders brought wind technology to Europe. The Dutch drained lakes and marshes with wind pumps. U.S. settlers used windmills to grind grain, pump water and cut wood. Homesteaders and ranchers used windmills to pump ground water. In the late 1800s, small wind-electric generators were widely used.

Some windmills still operate on farms and ranches, mostly pumping water for livestock, but when power lines were built to transmit centralized utility electricity to rural areas in the 1930s, wind pump and small turbine use declined. Small wind turbines for electricity are slowly becoming common again. Today, wind energy generates lots of electricity. Wind pushes against turbine blades, creating lift, like around airplane wings; that turns the blades; which turns a generator that makes electricity. In the 1980s, thousands of wind turbines were installed in California, due to government incentives. 1990 to 2017, the share of U.S. electricity generation from wind grew from less than 1% to 6%. European incentives have led to a big expansion of wind energy use there. China is investing heavily in wind energy and now has the world's largest wind electricity generation capacity.[352]

2000-2017, U.S. electricity from wind has grown from 6 billion kilowatt-hours (kWh) to 254 billion kWh, 6.3% of total U.S. utility-scale electricity generation. That's largely because of efficiency improvements, and government incentives.[353] Efficient electricity generation from wind involves careful placement of wind turbines. Wind speed typically increases with altitude and over open areas without windbreaks. Good wind turbine sites include smooth round hilltops, open plains and water, and mountain gaps that funnel and focus wind. Blow, baby, blow!

In 2017, 40 U.S. states had utility-scale wind power projects. The 5 generating the most electricity were Texas, Oklahoma, Iowa, Kansas and California, which produced about 66% of total U.S. wind electricity. Waters off U.S. coasts have big potential for wind electricity generation. The first offshore wind power project in the U.S. began off the coast of Rhode Island in 2016. Other offshore projects are in planning. Europe has various operating offshore wind energy projects.

In 2015, about 834 billion kilowatt-hours of electricity were generated by wind energy in 116 countries. The top 5 by shares of world total wind electricity generation were: United States—23%, China—22%, Germany—9%, Spain—6%, India—5%.[354]

There are two basic types of wind turbines: horizontal- and vertical-axis. Horizontal-axis turbines have (usually 3) blades like airplane propellers. The largest are 20-stories tall with blades 100 feet (30m) long. Taller turbines with longer blades generate more electricity. Most wind turbines use horizontal-axes. Blades on vertical-axis turbines are attached to the top and the bottom of a vertical rotor, kind of like a big, 2-bladed egg beater. They can be 100 feet tall and 50 feet (15m) wide.

Small wind turbines can power a single home with maybe 10 kilowatts (kW). The biggest wind turbines can produce up to 10,000 kW, and bigger ones are in development. Large turbines are often clustered together to create wind farms that send power to electricity grids.[355]

Wind energy has fewer effects on the environment than most other energy sources. It's a sustainable and renewable energy source. Producing electricity from wind releases no carbon or other pollutants, and it needs no water for cooling. An individual wind turbine has a relatively small physical footprint.

Wind farms have some negative environmental effects. Modern wind turbines can be very big, visually affect the landscape and produce sound pollution. Some types cause bird and bat deaths. Most on land need service roads that impact the environment. They can use rare Earth minerals, and mining them can have negative effects on the environment and on people and societies where they are found. Concrete foundations or other materials used to make wind turbines have carbon footprints.[356]

Geothermal

Geothermal energy, from heat in the Earth, is a renewable energy source, because it's always produced, from slow decay of radioactive particles deep in the Earth's core, a process that happens in all rocks.

Some geothermal energy uses Earth's heat near the surface; some of it requires drilling miles deep. There are 3 main types of geothermal energy systems:

- **Direct use and district heating systems** - hot water from springs or reservoirs near the surface used to bathe, cook and heat. Many think hot, mineral-rich waters have natural healing powers. District heating systems pipe that water directly into buildings for heat. Industrial applications include food dehydration, gold mining and milk pasteurizing.
- **Electricity generation power plants** – use heat and steam for turbines to generate electricity.[357]
- **Geothermal heat pumps** – Air temperatures above ground change during the days and seasons, but Earth temperatures 10 feet (3 meters) below ground are consistently 50-60°F (10-15°C). Geothermal heat pumps move air or water at those temperatures from the ground into buildings to do the bulk of the heating and cooling work, and they are <u>the</u> most energy-efficient, environmentally clean and cost-effective systems for heating and cooling buildings. All kinds of buildings, homes, office buildings, schools and hospitals can use geothermal heat pumps.[358]

Most U.S. geothermal power plants are in the western states and Hawaii, along the Ring of Fire around the Pacific Ocean. California generates the most electricity from geothermal energy. The Geysers in Northern California, the world's largest known dry steam field, has been making electricity since 1960.[359]

The U.S. produces more electricity from geothermal energy than any other country. In 2017, U.S. geothermal power plants produced about 16 billion kilowatt-hours (kWh), or 0.4% of all U.S. utility-scale electricity generation. 7 states had geothermal power plants, with share of U.S. electricity produced: California-73%, Nevada-21%, Utah-3%, Hawaii-2%, Oregon-1%, Idaho-<1%, and New Mexico-<1%.

In 2015, 22 countries generated 76 billion kWh of electricity from geothermal energy. The Philippines was the 2nd-largest producer after the U.S., at 11 billion kWh of electricity, 14% of its total electricity. Kenya had the largest share of its total electricity generation from geothermal energy at about 47%.[360] The environmental effects of geothermal energy depend on where and how it is used or converted. Geothermal heat pumps and direct use applications have almost no negative effects on the environment and can have positive effects by reducing uses of energy that have negative effects on the environment.

Geothermal power plants don't burn fuel to generate electricity, so they emit 97% less acid rain-causing sulfur compounds and 99% less CO2 than fossil fuel power plants of similar size. Most inject steam and water they use back into the Earth, recycling to renew the geothermal resource. Geysers in Yellowstone National Park are well-known examples of geothermal energy.[361] Geothermal and heat pumps, yay!

Solar

The ultimate source of most energy sources and fuels we use today is our sun. For our whole history, humans have used its radiation for warmth, light, growing and drying things. We now use direct solar thermal energy to heat water to use in homes, buildings or pools, and heat homes, greenhouses and other buildings; direct solar energy to heat fluids to high temperatures in solar thermal power plants, which are used to generate electricity; and solar photovoltaic systems to convert sunlight into electricity

People use solar thermal energy to directly heat water and air, in passive and active systems.

- **Passive solar space heating** – lets sun shine through windows of a building and warm it inside. U.S. building designs to optimize passive solar heating usually have south-facing windows that let the sun shine in on solar heat-absorbing walls or floors in winter. Natural radiation heats the space, and convection circulates the air. Window overhangs, shades or roof shadow angles block sun from entering the windows during summer to keep the building cool. Very clever.
- **Active solar heating systems** - use a (roof) collector and a fluid that absorbs solar radiation. Fans move air or pumps move heat-holding liquids through collectors and spaces to be heated. Water heating systems usually have a tank for storing solar heated water.[362] Also very clever.

People use solar energy to generate electricity.

Concentrating solar energy technologies use mirrors to reflect and focus sunlight and make heat, to run a turbine and spin a generator to make electricity.[363] They may heat energy storage sources in the day, and use them to make electricity at night or when it's cloudy. They may also be hybrid systems that use other fuels, like natural gas, to supplement sun energy at night or when it's cloudy. Different types are:

- **Linear Fresnel reflector (LFR) Systems** - concentrate sunlight at 30 times normal intensity onto receivers above mirrors designed with the Fresnel lens effect, what's used in lighthouse lenses.
- **Linear Concentrating Systems** - collect solar energy using long, rectangular, U-shaped mirrors that can focus sunlight 30-100 times its normal intensity, and achieve 750°F (400°C).
- **Solar Power Towers** - use large fields of flat, sun-tracking mirrors called heliostats to reflect and focus sunlight up to 1,500 times normal onto a receiver on the top of a tower.
- **Solar Dish/Engine Systems** - use a big mirrored disk, like a very large satellite dish, to focus light and achieve temperatures higher than 1,380°F (750°C).[364]

Solar photovoltaic (PV) devices, or solar cell systems convert sunlight into electricity via small PV cells that can power calculators, watches and other small electronic devices. Arrangements of many solar cells in PV panels, and arrangements of multiple PV panels in PV arrays, can power an entire house. Large arrays in PV power plants can cover many acres and produce electricity for thousands of homes.

Sunlight has photons, particles of light carrying energy. PV cells are made of semiconductor material. When photons hit a PV cell, they reflect off of it, pass through it, or are absorbed by that material. When semiconductor materials absorb enough solar energy, electrons are released from their atoms, migrate to the cell surface and become electrical current.

The efficiency with which PV cells convert sunlight to electricity varies by semiconductor material type and PV cell technology, currently between 5% and 15%, which people are working to improve. Efficiencies are improved when PV cells and panels directly face the sun, so they absorb more light. Some systems track the sun as it moves and adjust panels to always face it to improve efficiency.

PV cells generate direct current (DC) electricity, which can charge batteries or power things that use DC, or inverters can be used to convert the electricity to alternating current (AC), what we mostly use.

Some advantages of PV systems are:

- PV systems can supply electricity to an electric power grid, or to off-grid locations,
- PV arrays can be installed quickly and can be any size,
- The environmental impact of operating PV systems is minimal, especially if on buildings, and
- They don't produce air pollutants or CO2.

Solar energy systems also have some constraints:

- The amount of sunlight varies, depending on location, time of day, season of the year and weather conditions, and that affects how much electricity can be generated and when, and
- Large surface areas are needed to absorb or collect enough energy.[365]

In 2017, 50 billion kilowatt hours (kWh) of electricity were generated at utility-scale PV power plants. Another 24 billion kWh were generated by small-scale grid-connected PV systems.[366]

The solar energy Earth receives each day is way, way, many, many times more than people consume. Covering 4% of the world's deserts with photovoltaics could supply the whole world's electricity use.

Solar energy systems and power plants don't produce air or water pollution, or greenhouse gases. Their net effects on the environment are positive if they replace or reduce use of other energy sources with more harmful effects on the environment. However, some toxic materials and chemicals are used to make PV cells, some solar thermal systems use hazardous fluids to transfer heat, and these materials could be harmful to the environment. U.S. environmental laws regulate their use and disposal.

As with any power plant, large solar power plants can affect the environment near their locations. Clearing land for construction of the power plant placement may have long-term effects on habitats and native plants and animals. Some solar power plants may use water to clean solar concentrators and collectors or for cooling turbine generators. That can affect ecosystems. The beam of concentrated sunlight a solar power tower produces can kill birds and insects that fly into the beam.[367] However, altogether, solar energy is extremely clean and renewable, and anybody can do it, right now.

Hydrogen

Hydrogen is the simplest element, with only one proton, and also the most plentiful gas in the universe. Stars like our sun are mostly hydrogen. The sun is basically a giant ball of hydrogen and helium gases. Hydrogen occurs naturally on Earth in compound form with other elements in liquids, gases and solids. For example, hydrogen combines with oxygen to make water (H2O). Earth has lots of water.

Hydrogen has the highest energy content of any of our fuels by weight (3 times more than gasoline), but the lowest energy content by volume (4 times less than gasoline). Hydrogen can be made by separating it from various sources, including water, fossil fuels or biomass, and used as a source of energy or fuel.

It takes more energy to produce hydrogen, by separating it from other element molecules, than it provides when it's converted to useful energy. However, it's a good energy source/fuel, because it has high energy content per unit of weight, which is why it's used as a rocket fuel and in fuel cells to make electricity on spacecraft. It's not widely used now, but it has great potential for the future.[368]

The two most common methods for producing hydrogen are:

- **Steam reforming** - currently the least expensive way to make hydrogen, and how most is commercially produced in the U.S., is used in industries to separate hydrogen atoms from carbon atoms in methane (CH4), but the steam reforming process results in CO2 emissions.
- **Electrolysis** - splits hydrogen from water using electricity. Its only emissions are hydrogen and oxygen, and electricity used in electrolysis can come from renewable sources like hydro, wind or solar energy, with fixed costs, so the electricity is free once the energy investment is paid off. This is an extremely green and promising way to produce energy for transportation! Yay!

Research is underway to find other ways to make hydrogen, like using microbes that use light to make hydrogen, and converting biomass into liquids and separating the hydrogen.[369]

Almost all the hydrogen consumed in the U.S. is used by industry for refining petroleum, treating metals, making fertilizer and processing foods. Rocket fuel is the main use of hydrogen for energy, so far, and NASA is the largest user of hydrogen as a fuel and one of the first to use fuel cells, on spacecraft.

Hydrogen fuel cells make electricity by uniting hydrogen and oxygen atoms, and its waste is H2O, water. They're 2 to 3 times more efficient than internal combustion engines running on gasoline. Different types serve a range of applications. Small ones power cell phones, laptop computers and military stuff. Big ones can provide emergency electricity in buildings, or power in remote areas not on electric grids.

A major focus of fuel cell R&D is on hydrogen as an alternative transportation fuel, because it can be produced in the U.S., it can produce zero-emission electric vehicles, and it is so very high efficiency. Several vehicle manufacturers have begun making light-duty hydrogen fuel cell electric vehicles available in select U.S. areas and regions, like in California, where there is access to hydrogen fueling stations.

Most hydrogen-fueled vehicles are cars and transit buses with electric motors powered by fuel cells. Few burn hydrogen directly. High fuel cell costs and limited availability of hydrogen fueling stations have so far limited the number of hydrogen-fueled vehicles. People won't buy them if refueling stations aren't easily available, and companies won't build refueling stations if they don't have customers. Catch-22. In 2018, only 60 hydrogen vehicle refueling stations were operating, 40 of them public use, nearly all in California, where there has been government support for developing the technologies.[370]

Electricity

Electricity is the flow of electrons, electrical power, as part of nature, and a widely used form of energy. We make use of it by converting it from energy from primary sources, like coal, nuclear, wind and solar, rather than harvesting it from natural lightning storms, like Ben Franklin and Dr. Frankenstein did.

We haven't used electricity long. 150 years ago, candles, fires, whale oil and kerosene made our light; iceboxes kept food cold; and wood- or coal-burning stoves made heat. In the late 1800s, Nikola Tesla devised generation, transmission and use of alternating current (AC) electricity, making it efficient to send electricity long distances, bringing it into homes and factories. Like air and water, now we take it for granted, using it for many things, every day, like lighting, heating, cooling, and powering devices.[371]

How it works

Atoms are building blocks of the universe. Everything's made of them: stars, plants, animals, people. The nucleus of proton and neutron particles bound with strong energy is at its center. Electron particles orbit the nucleus, at fixed distances, like planets around the sun. Atoms are almost all empty space.

A proton has a positive (+) charge; and an electron has a negative charge (-); and the charges are equal. Atoms are in balance when they have equal numbers of protons and electrons. Opposite charges attract; and same charges repel. How many protons an atom has defines what atom, or element, it is. An element is a substance of one kind of atom. The Periodic Table of Elements shows elements by atomic numbers, the number of protons they have. Every atom of hydrogen (H) has one proton. Carbon (C) has six. Neutrons have no charge, and their numbers can vary.

Electrons usually stay fixed distances from an atom's nucleus, in its shells, or fixed orbits. The closest shell to the nucleus can hold 2 electrons. The next shell can hold up to 8. Outer shells can hold more. Atoms with lots of protons can have up to 7 shells with electrons in them. Electrons in shells closest to the nucleus are most attracted to its protons. Electrons in outermost shells, less so. Applying a force can free them, or make them jump from one atom to another. These moving electrons are electricity. Lightning is electricity, electrons jumping from one cloud to another, or jumping from cloud to ground. The shock of touching something after walking across a carpet is an electron stream flow.[372]

Electrons going around a nucleus create a magnetic field. In most things, they spin in random directions, and those forces cancel each other. In magnetic material, electrons spin in the same direction, and the magnetic forces do not cancel each other, creating magnetic force between its north and south poles. As with protons and electrons, plus/north/positive attracts negative/south in magnets.

Magnetism is used to make electricity. Moving magnetic fields move electrons. Conducting materials, like copper, which has 29 protons, have loosely held electrons in their outer shells. Moving a coil of conducting wire around a magnet moves electrons in the wire and creates an electrical current.[373]

Electrochemical batteries make electricity with 2 different metals in an electrolyte chemical substance. One end of the battery has one metal, and the other end has the other. Chemical reactions between metals and the electrolyte free more electrons in one metal than the other. It gets a positive charge; the other a negative charge. Connect a conducting wire from one end of the battery to the other, and electrons flow through it to balance the electrical charge, from positive to negative. Electricity flows similarly in generated electrical systems, from generator, through wires, back to source, or ground.

Electrical devices can be connected into wires like that to do something. An incandescent light bulb connected to an electric wire creates light as electrons flow across its filament and heat it up. Electricity needs a complete path, or "closed" electrical circuit, for electrons to move. A switch, or on-off button, on electric devices closes/turns-on or opens/turns-off an electrical circuit in the device, letting electrons flow through it. Switching on a light closes a circuit, letting electrons flow: 1) from the electricity source, 2) through one electric wire, 3) the bulb filament, 4) another wire, and 5) back to the electricity source. An incandescent light bulb burns out when the tiny wire inside the bulb breaks, which breaks the circuit.

To send electricity long distances, a transformer device increases the voltage for fatter transmission power wires, because that's more efficient. Later, transformers also reduce or step-down voltages for transport on local distribution networks. Lower voltage electricity is safer for users.[374] Electricity is lost as it flows down wires. Long wire runs lead to larger losses, as in long runs from generators to users.

Power consumption is measured in Watts, or in kilowatts (1kW = 1,000 Watts). Electricity generation is usually measured in megawatts (1MW = 1,000kW) and gigawatts (1GW = 1,000 MW = 1 billion Watts). A Watt-hour (Wh) is a Watt of energy supplied to and taken from an electric circuit for an hour, usually presented in kilowatt-hours (kWh) on bills. A kWh is one kilowatt generated/consumed for an hour. A 60-Watt (0.06 kW) light bulb used 5 hours, consumes (60*5) 300 Wh, or 0.3 kWh, of electrical energy. Utilities measure customer electricity consumption with meters, usually on the outside of a property.[375]

Most electricity generators use the relationship between magnetism and electricity to convert kinetic energy into electrical energy with some kind of turbine. They generally take a primary source of energy (fossil fuels, nuclear reactions or renewable sources) and use it to spin a series of insulated wire coils, which are surrounded by a magnetic field. That frees electrons in the conducting materials of the wires, which flow along the wires, and are then concentrated and connected to whatever will use them.

In turbine generators, moving fluids (water, steam, air or combusted gases) push blades mounted on a shaft, causing them to rotate. That shaft connects to and rotates the generator's electromagnetic shaft. Most large electric power plants in the U.S. have steam turbines. The energy or power comes from geothermal heat, steam, combustion, water or wind. That energy is converted and carried as electricity.

Combined-heat-and-power (CHP) plants, sometimes called co-generators, use leftover heat used for steam or combustion turbines for other purposes, like space heating or powering industrial processes. Some take unused heat or combustion gases from one turbine, like a gas turbine, and use it to generate more electricity in another turbine, like a steam turbine, which increases efficiency.

Electricity generators that don't use turbines include solar PV cells, which convert sunlight directly into electricity, and fuel cells, which convert fuels like hydrogen into electricity through a chemical process. In 2017, shares of total U.S. utility-scale electricity generation by major types were:

- Steam turbines–64%
- Combustion turbines–21%
- Hydroelectric turbines–7%
- Wind turbines–6%
- Solar PV systems–1%
- Combustion engines–<1%[376]

The U.S. uses many different primary energy sources and technologies to generate electricity, and that mix changes over time. In 2017, the 3 major categories and sources of energy for electricity generation were fossil fuels (petroleum, natural gas and coal), nuclear and renewable energy:

- Fossil Fuels (63%)
  - Natural gas (32%)
  - Coal (30%)
  - Petroleum (< 1%)
- Nuclear energy (20%)
- Renewable energy (17%)
  - Hydropower (7%)
  - Wind (6%)
  - Biomass (2%)
  - Solar (1%);
  - Geothermal (<1%)[377]

Some individuals and organizations produce their own power and electricity. Most rely on centralized electric utility systems to produce and provide their electricity. In those, electricity from power plants moves through complex systems of power lines, substations and transformers, called grids, connecting electricity producers and consumers. Grids are interconnected for scale, reliability, efficiency and commercial reasons. Utilities bring wires and electricity to the edge of a customer's property, where a meter measures how much electricity is used, and responsibility is passed off to the customer.

Some disagree whether this combined electricity system, the Public Switched Telephone Network or the public Internet is the largest and most complex physical creation of humanity. The whole U.S. electricity grid has hundreds of thousands of miles of high-voltage power lines, and millions of miles of low-voltage power lines, with substations and distribution transformers, that connect thousands of power plants to hundreds of millions of electricity customers, each with internal wiring and systems, all over the country. There would be no telephone network or Internet without reliable electricity. The telephone network and Internet are interconnected globally. The power grid is not. More devices are on the Internet.

Grid stability requires electricity supply to always meet electricity demand, so appropriate numbers of electrons are flowing at any given time, which needs coordination between many entities operating different grid components. The U.S. grid has 3 large, coordinated and interconnected systems. One's in the east, one's in the west, and one's in Texas. East and west grids are connected with Canada.

Utilities figured out how to send electronic data over the same wire networks that distribute electricity. That enables "smart grid" technologies, like "smart meters," so meter readers don't have to walk to each user location every month to read the meter, which eliminated lots of jobs and cost. It enables all kinds of sensors and data collection that make it possible to manage networks more efficiently, and it enables "smart devices" consumers can use to better understand and manage how we use electricity.

Origins of electricity consumers purchase vary. Some electric utilities generate all the electricity they sell using just their own power plants. Others purchase electricity directly from other producers, or from wholesale markets organized by regional transmission reliability organizations. Different kinds of organizations produce and distribute electricity, including: not-for-profit municipal electric utilities; electric cooperatives owned by their members; private for-profit electric utilities owned by stockholders (AKA investor-owned utilities); and federally owned power authorities. Local electric utilities operate distribution systems that connect consumers with the grid, regardless of the source of the electricity.

Construction of electricity infrastructure in the U.S. began in the early 1900s. Now, some of the older, existing transmission and distribution lines have reached the end of their useful lives and need to be replaced or upgraded. New power lines are also needed to maintain the electrical system's overall reliability, outside and inside buildings, and to provide links to new renewable energy generation, like wind and solar power, which are often located far from where electricity demand is concentrated.

Several other challenges exist for improving grid infrastructure, including:

- Siting new transmission lines (getting route approvals and land rights),
- Figuring out revenue and cost sharing across different network providers and operators,
- Figuring it all out in regulatory environments,
- Protecting the grid from physical and cyber attacks,[378] and
- Managing variable electricity loads from distributed solar and wind at homes and workplaces.[379]

How Much We Use

In 2017, U.S. electricity consumption was 3.82 trillion kilowatt-hours (kWh). 96% came from utilities. 4% was generated by consumers. Consumption by sector was:

- Residential - 1.38 trillion kWh - 37.4%
- Commercial - 1.35 trillion kWh - 36.6%
- Industrial - 0.95 trillion kWh - 25.7%
- Transportation - 0.01 trillion kWh - 0.2%

A modern light-emitting diode (LED) lightbulb that provides 800 lumens and uses 10 watts is comparable to a 60-watt incandescent bulb,[380] bright enough to read by. In 2017 in the U.S., we used electricity equivalent to burning 382 billion of those 24x7, or 1,528 of them 24 hours a day for each U.S. adult.[381] Meanwhile, 1 in 8 people in the world has no access to electricity.[382] We use a lot of electricity.

In 2017, residential sector uses of electricity by percent of use were:

- Cooling/air conditioning - 15.4%
- Water heating - 9.5%
- Lighting - 9.4%
- Refrigeration - 7.2%
- Space heating - 6.2%
- Televisions and electronics - 5.9%
- Clothes dryers - 4.1%
- Cooking - 2.3%
- Heating equipment fans and pumps - 2.2%
- Computers and related equipment - 2.2%
- Dishwashers - 2.0%
- Freezers - 1.6%
- Clothes washers (w/o water heating) - 0.5%
- Other miscellaneous uses, mostly small appliances - 31.3%

2017 commercial (retail, office, education, institutional, public and government) electricity use was:

- Refrigeration - 14.0%
- Ventilation - 11.2%
- Lighting - 10.6%
- Space cooling - 10.6%
- Office equipment - 7.8%
- Computers and related equipment - 7.5%
- Space heating - 2.6%
- Cooking - 1.8%
- Water heating - 0.6
- Other miscellaneous uses - 33.3%

2014 major uses of electricity by the industrial sector were:

- Machine drives (motors) - 48.2%
- Process heating and boiler use - 14.4%
- Facility HVAC - 9.5%
- Process cooling and refrigeration - 7.3%
- Electrochemical processes - 6.8%
- Lighting - 6.5%
- Other miscellaneous uses - 7.3%

U.S. electricity consumption declined in only 3 years between 1950 and 2007. It declined in 6 from 2007 to 2017, the most (about 4%) in 2009. Some of that was Great Recession industrial sector decreases, but there were also efficiency gains from standards and regulations, and more efficient insulation, appliances and lighting. 2017 to 2050, total U.S. electricity use is expected to grow less than 1% a year.

OECD member countries consumed 45% of the world's electricity supply in 2015. It will be 37% in 2050. The largest increases in electricity consumption are expected in the developing world.[383] Rising incomes and 1.7 billion more people will increase global energy demand more than a quarter by 2040.[384]

Environmental Impacts

Environmental impacts from production of energy have been addressed in production sections above. Other environmental impacts relate to long distance transmission lines, local distribution lines, and transformers and substation infrastructure for carrying electricity from power plants to customers. Transmission towers and power lines alter lands and disturb environments, animals, people and plants. There are unknown health and well-being impacts from exposure to magnetic fields around them. There are increasing incidents of power lines being credited with starting fires and creating other hazards when they are damaged by storms, mismanagement or abuse, an issue that is increasing as this infrastructure gets older and as climate change creates more fire vulnerabilities.

Power lines can be put underground for better aesthetics and safety, but it's expensive, so rare.[385]

This system has inefficiencies. For example, in electricity production only 65% of the primary energy becomes electricity in power generation; 35% is lost. High voltage transmission lines sagging, buzzing and popping is the sound of them losing energy; they lose 2-6% along the way. Distribution lines lose 4% of their energy along the way. Lines within buildings lose energy. Together, that's 44% of the energy that is lost, in translation and transportation, from the source to its users.[386] Users waste large amounts. Overall, across all U.S. sectors and sources, it's estimated that we waste two-thirds of our energy.[387]

Infrastructure Challenges

Parts of the U.S. electricity grid were installed before 1900. Most transmission and distribution lines were built in the 1950s and 60s, with 50-year life expectancies, not engineered to meet current demand, or severe weather. 640,000 miles (1 million km) of transmission lines in the lower 48 states' power grid are at full capacity, many operating far beyond designs, enough wire to go to the moon 2.6 times.[388] Congestion affects distribution, reliability and costs, restricting power delivery. Often, a line can't be taken out of service for maintenance because that overloads other interconnected lines.

In 2015, 3,571 electricity outages were reported, with an average duration of 49 minutes. 2003 to 2012, outages and aging infrastructure are estimated to have cost the U.S. economy an annual average of $18 to $33 billion (2-3% of FADS), adjusted for inflation. The cumulative transmission grid investment gap from 2016 to 2025 is estimated at $177 billion (15% of FADS).[389] This stuff is failing and costing us.

There are 5.5 million miles (8.8 million km) of local distribution power lines in the U.S.,[390] enough wire to go to the moon 23 times.[391] Much of that's old and in need of replacement. There is a huge amount of electrical wiring inside buildings that will need to be replaced at some point, also. There are 1,500 miles of electric wires in the Willis Tower building in Chicago alone.[392] Many of our power plants, substations, transformers, and other electricity network components are old and will also soon need replacement.

The undepreciated value of the U.S. electricity network is estimated at $1.5 to $2 trillion. Replacement value of that network is estimated at almost $5 trillion,[393] a fourth of U.S. GDP. Very roughly, $5 trillion in replacement value less $2 trillion in undepreciated current value is about $3 trillion (260% of FADS) to replace stuff in the electricity network that's beyond its useful life, not counting what's inside buildings. If we need to spend that kind of money anyway, does it make more sense to just replace what we have, or to invest in new infrastructure, to create cleaner and more efficient energy solutions?

Subsidies

Subsidies are complex in action. Conceptually, they're pretty simple. They are incentives to encourage something to happen that wouldn't otherwise, like paying somebody to do something others wouldn't, or to help it happen quicker, like nudging supplies down cost curves so they become affordable faster. Subsidies can be direct money to producers, consumers or others, or indirect support mechanisms, like tax benefits, good loan terms, rebates, price controls, trade restrictions, access to low-cost services or resources, preferential regulations, and not imposing external costs.

Developing our energy system has involved lots of subsidies. Eliminating many energy subsidies is now widely seen as one of the most effective ways to reduce carbon emissions. The International Energy Agency and OECD agree. In 2016, G7 nations set a deadline to end most fossil fuel subsidies by 2025.[394] Globally in 2017, oil & gas companies had revenues of $2 trillion,[395] and had long been profitable.[396] Governments give oil and gas firms at least $775 billion to $1 trillion annually in subsidies.[397] Crazy.

A 2016 IMF study estimated global fossil fuel subsidies were $5.3 trillion in 2015, 6.5% of global GDP, ($10 million per minute).[398] Elimination of subsidies would have reduced 2013 global carbon emissions 21% and fossil fuel air pollution deaths 55%, while raising revenue 4% and social welfare by 2.2% of global GDP. It's debated, because it counts as subsidies "externalities," costs caused by fossil fuels not borne by oil companies, like impacts of pollution and health problems.[399] Or, fairly charging them costs?

In the U.S., we spend $20 billion (1.7% of FADS) a year in direct subsidies to huge, profitable oil and gas companies. That's also controversial. It's like wanting people to quit smoking, because it's making them sick and costing us a lot in healthcare, and our solution is to give tobacco companies a bunch of money, so they can get richer or make packs of smokes cheaper.[400] Does that make sense?

"More than 70% of the $2 trillion required in the world's energy supply investment each year, across all domains, either comes from state-directed entities or responds to a full or partial revenue guarantee established by regulation. Frameworks put in place by the public authorities also shape the pace of energy efficiency improvement and of technology innovation. Government policies and preferences will play a crucial role in shaping where we go from here."[401] We need government leadership in this.

In the 2015-16 election cycle, oil, gas and coal companies spent $354 million in campaign contributions and lobbying and got $29.4 billion in U.S. subsidies during those years, an 8,200% return on investment. 88% of those gifts went to legislators from one party, and 97% of those oppose taxing carbon pollution. The current administration is working hard to support the coal industry.[402] That's corruption.

If we are going to subsidize energy, common sense says to do it to create the world we want to live in, not because we are kowtowing to those with power. Incent efficient, clean energy sources and carriers. Dis-incent fossil fuel and nuclear energy, because they are creating harm in our world that we want to correct as quickly as possible, now that we are aware of it. Thank you, but bye fossil fuels and nuclear!

Need for Change in Energy Production and Consumption

Whew, that's a headful of stuff. So, what have we learned?

- We are warming our global climate with our actions, mostly burning fossil fuels; and those fossil fuels are poisoning us and most life on Earth.
- That problem is very urgent. We have about a decade to radically change, or it is too late and we're likely going to have to deal with scary catastrophic changes and challenges.
- The U.S. has the most responsibility for this, because it's created more of it than others.
- Most of our energy now is from non-renewable, unsustainable fossil fuel and nuclear sources.
- We're going to run out of fossil fuels in 50 to 100 years anyway,[403] so we'll have to quit that habit anyway. We might just as well go ahead and start working on that now.
- Pollution from nuclear energy lasts 250,000 years; there's 250,000 tons of it globally, already; we don't have anywhere to put it; taxpayers pay utilities $1 billion a year because we don't; and if we consider how much it will cost to assure it's safe that long, it's definitely not affordable.
- Hydropower is a great source of clean sustainable energy. We don't have to dam rivers to get it, which may cause as much harm in methane production as we prevent from not burning oil. There are many ways we can secure hydropower energy without creating environmental harms.
- Biomass energy and fuels have less environmental impacts than fossil fuels, if we grow biomass sustainably, rather than whacking down forests for it, and burn our wastes for energy.
- Wind is a very sustainable and affordable energy source, at both large and small scales.
- Geothermal has far more possibilities than we have taken advantage of so far for producing energy and reducing energy needs. Heat pumps moderating building temperatures by tapping constant temperatures under the ground are a cheap and effective no-brainer.
- All of our energy sources except geothermal and nuclear are ultimately from the sun. There are many ways we can use its energy renewably and sustainably, including better building designs to take advantage of passive solar energy to heat buildings, solar water heating, big solar heating solutions for producing electricity, and both small and large solar PV solutions.
- Our electricity grid infrastructure is enormous; much is old and needs lots of updating anyway. This is a great time to consider making it much better, rather than just replacing what is, as it is.
- Electric cars reduce emissions from the vehicles themselves, but if the electricity they use is not produced sustainably and cleanly they still have huge environmental impacts.
- Hydrogen is a super promising energy source. Hydrogen fuel cell vehicles can be more efficient than vehicles using combustion engines. They emit clean water as waste. Fuel cells can be used for all kinds of other purposes also. We just need to produce the hydrogen cleanly, efficiently and affordably and make it widely available, which we can do with affordable renewable energy.

Gross corruption allows oil, gas, coal and nuclear energy to appear much cheaper than they really are. They don't take into consideration their external costs to the environment or others. Their prices would be far higher if their costs fairly included costs for:

- healthcare to address health problems they create for millions of lifeforms on Earth,
- many decades of taxpayer subsidies,
- wars and clandestine operations for securing fossil fuels, in money, lives, property and suffering,

- loss of property from rising sea levels,
- storing nuclear waste and making sure it is safe for hundreds of thousands of years,
- loss of clean water, air and land to support life,
- roads, bridges and highways for vehicles,
- cleaning up their spills, fracking harms and environmental disasters,
- harm done by corruption of government,
- lost public benefit from alternative public systems, which oil and automobile industries killed,
- productivity lost by people stuck in traffic, rather than in those alternative public systems,
- forcing pipelines over the public, sovereign Indian nations and impacted property owners,
- current and future losses of clean surface waters and aquifers harmed by spills, and
- the social costs to people who lose their lands, waters, ways of life and livelihoods to them.

Those are some of the ways non-renewable energy special interests have corrupted the game, government and public, with many decades of multi-billion-dollar propaganda and influence buying.

The U.S. put a man on the moon and made all of this existing energy system happen. It can produce most of its energy through renewable clean technologies. It simply takes the will to do so. Taxing oil, gas, coal and nuclear companies to recover costs they create for the public but avoid themselves, and ending taxpayer subsidies, would alter perceived economics of energy, in favor of renewable solutions.

Investing in renewable technologies and their deployment would quickly create innovations and drive costs lower, in addition to creating many thousands of good jobs. However, the indoctrinated public does not adequately fight for those changes; oil, gas, coal and nuclear industry opposition is too entrenched and powerful to overcome; and government is too corrupt, so far.

The U.S. is addicted to cheap energy, even if it only seems cheap, and its dominant ways of producing energy are producing great harm everywhere, which we are largely willfully ignoring. That's broken. People, environments and other forms of life are being badly harmed by existing energy solutions, and it's going to get a lot worse. Enormous changes are needed in how we produce and consume energy, and those changes affect all. We have to get on this in a big way, right now. That's common sense?

It feels bad to know we're harming our climate and Earth's varied and beautiful life, including ourselves, by our behaviors and actions around energy production and use, because we innately want to serve life. It's embarrassing to realize how much energy we use and waste, much of it without conscious intention. It feels unnecessary and undesirable to keep doing things these ways, especially when we can see obvious and proven alternatives that are more promising than what we are doing now. Let's change!

Without waiting for anybody, as much as possible, with our individual choices: Consume less energy! Try to get off of fossil fuels now! Make our lives and homes more efficient, so we waste less energy! Property owners, get a loan and install clean energy now, with the same monthly payment, so it costs no more to use clean electrons than dirty electrons now, and creates independence from grid problems! Renters, convince your landlords to do that! Business owners, you too. It's an absolute no-brainer.

Vote and advocate for clean and renewable energy and getting off of fossil fuel and nuclear energy! Bike, run and walk! Insulate! Don't do any sort of business with nonrenewable energy businesses, and tell them why! Get rid of combustion engines now! Promote hydrogen and fuel cell technologies! Share info and ideas with each other! Use heat pumps! Write letters, even if you think it don't matter!

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