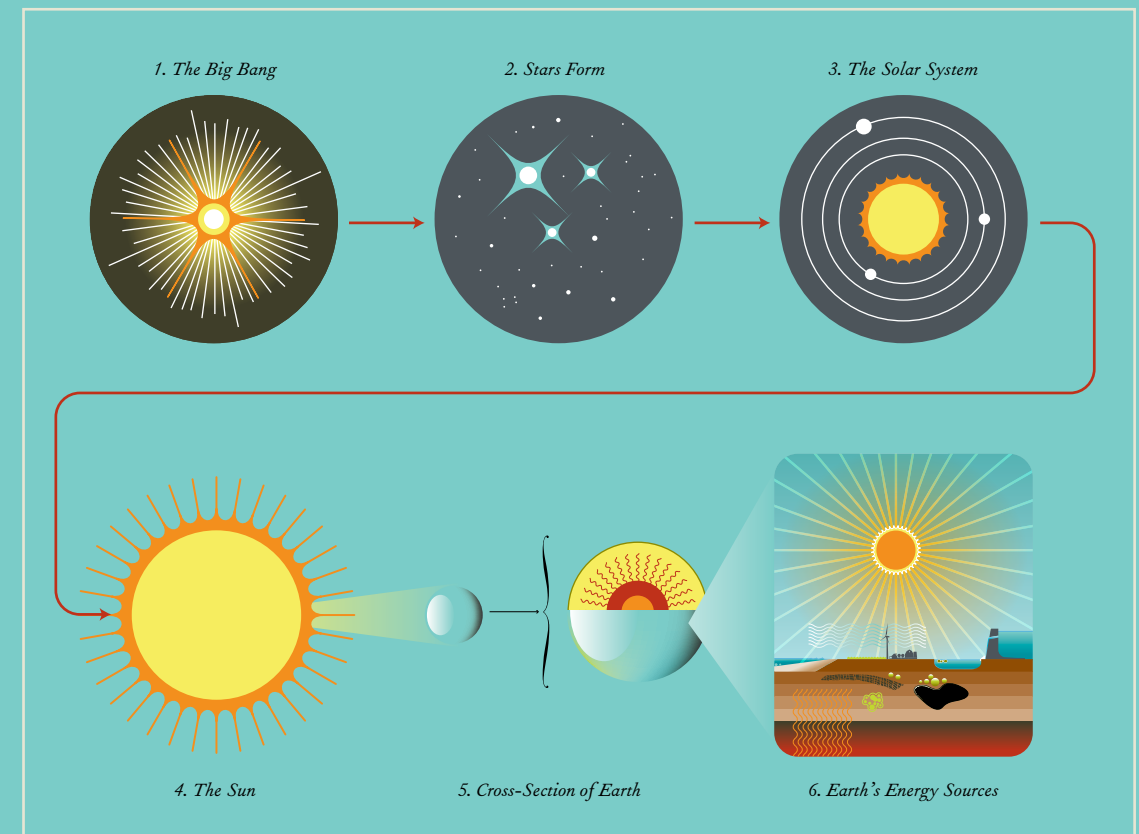


Energy and persistence alter all things.

BENJAMIN FRANKLIN

ENERGY: *A User's Guide*

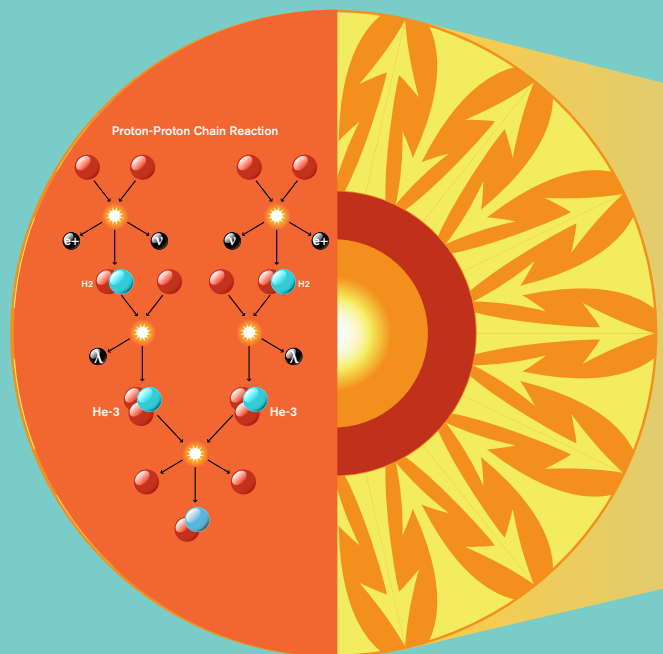
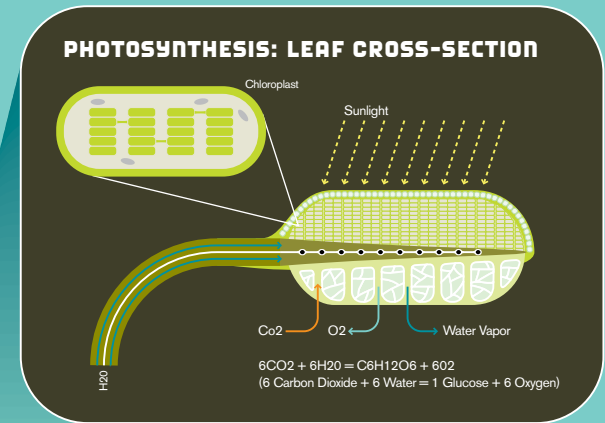
EVERYONE'S TALKING ENERGY THESE DAYS, but who among us—engineers, scientists and brainiacs aside—really understands what, exactly, energy is, where it comes from, how it gets here, and what we gain or lose by our relationship to it? The following few pages provide a visual primer on the science behind 2007's defining issue.



II. WHERE IT COMES FROM

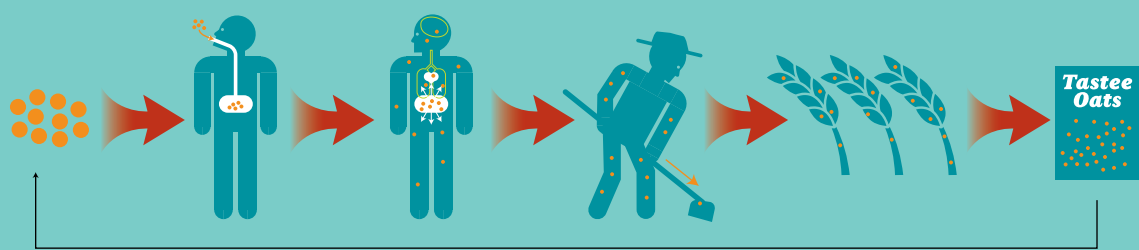
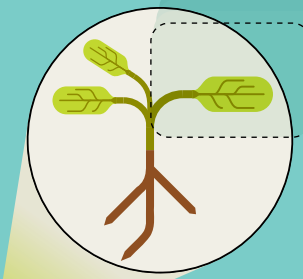
The sun, as we all know, is literally a ball of energy. It is comprised of billions of hydrogen atoms that collide and split into smaller atoms in a constant chain reaction. Inside the sun, 4.4 megatonnes of matter is converted into energy every second, which is 30 trillion times the amount of all energy

consumed on Earth in 2005. Some of the energy created in this process radiates out in the form of radiation and sunlight; but most of the harmful radiation doesn't make it through the atmosphere. If it did, we wouldn't be around to talk about it.



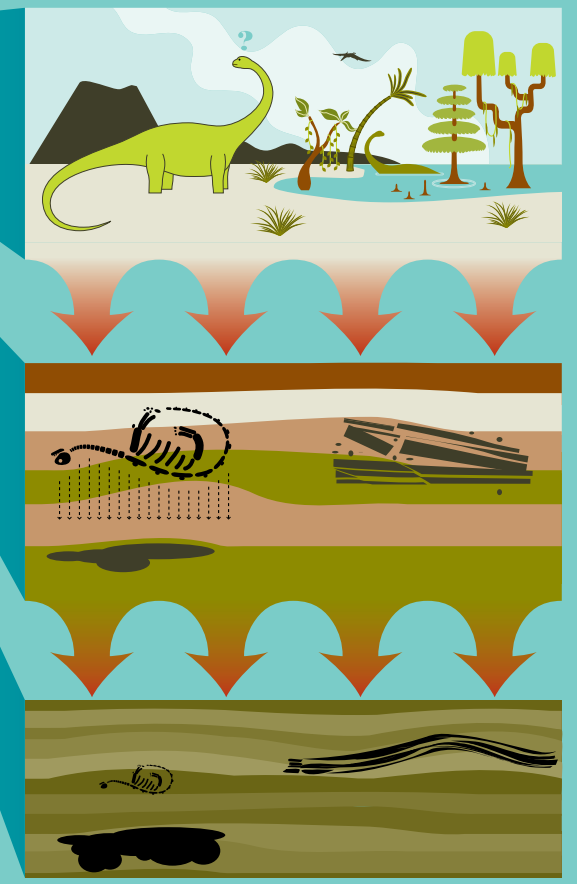
143.2 MILLION KM/
93 MILLION MILES

SOLAR CONSTANT: 170 MW/m²



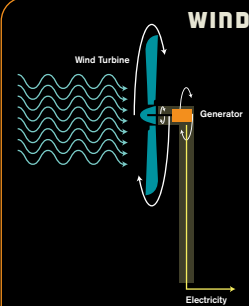
Sunlight streams toward Earth, travelling 93 million miles through space, and upon meeting the leaves of a plant it is converted to chemical energy during photosynthesis, feeding the plant.

The plant feeds an animal, and the plants and animals feed us. When we eat, we are eating energy from the sun that has been made edible. This energy transference allows us to go on living.

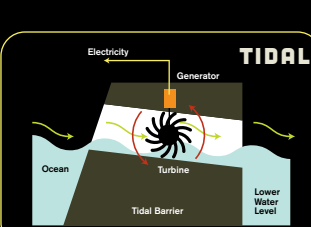
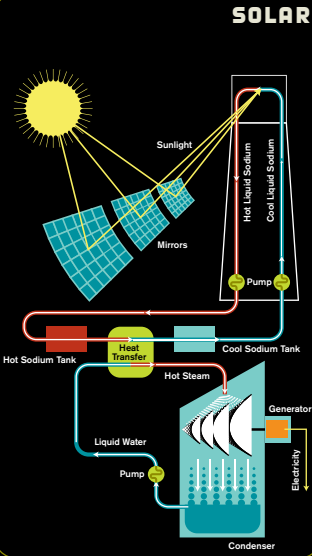


MILLIONS OF YEARS

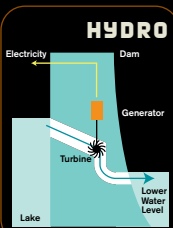
A wind turbine is perhaps the simplest and cleanest way to generate electricity. The turbine is mounted on the outside of the windmill where it picks up wind. A gearbox is used to transfer the mechanical energy directly to a generator. Windmills require only routine maintenance.



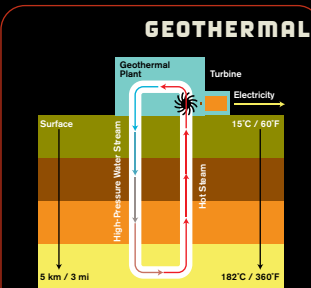
Solar power plants are complicated. There are several different kinds. Shown here is a "Power Tower" like those recently constructed in Spain and South Africa. Sunlight is reflected by mirrors into a concentrated beam, and is directed to heat a transfer fluid such as liquid sodium, which moves heat away from the tower to a boiler where it boils water to drive a turbine. The hot liquid sodium can be stored for later use.



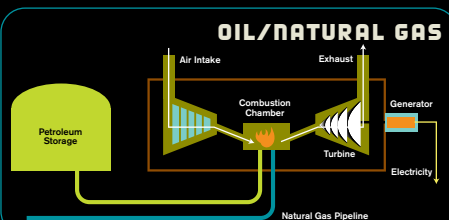
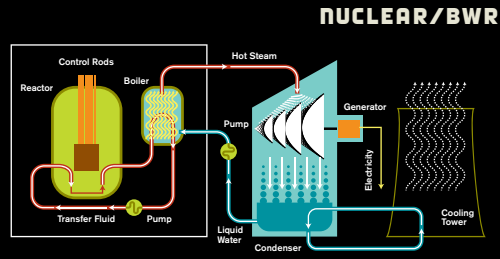
There are several types of tidal power stations. The one illustrated here uses a large, dam-like barrier to absorb crashing waves. Sluices in the barrier allow water to rush in, where it drives a turbine. Water then pours through the other side into a basin at a lower level.



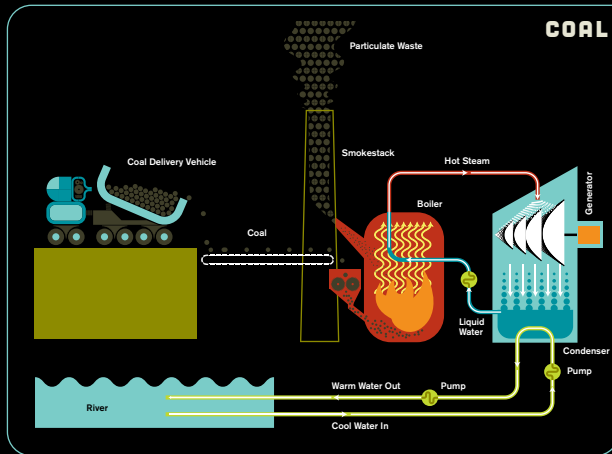
Hydroelectric dams are one of the most widely used and oldest power sources in the world. Water pours through the dam and turns a turbine to produce electricity. Gates are opened or closed to regulate power generation. In pre-modern times, dams harnessed rivers to grind corn or pump water.



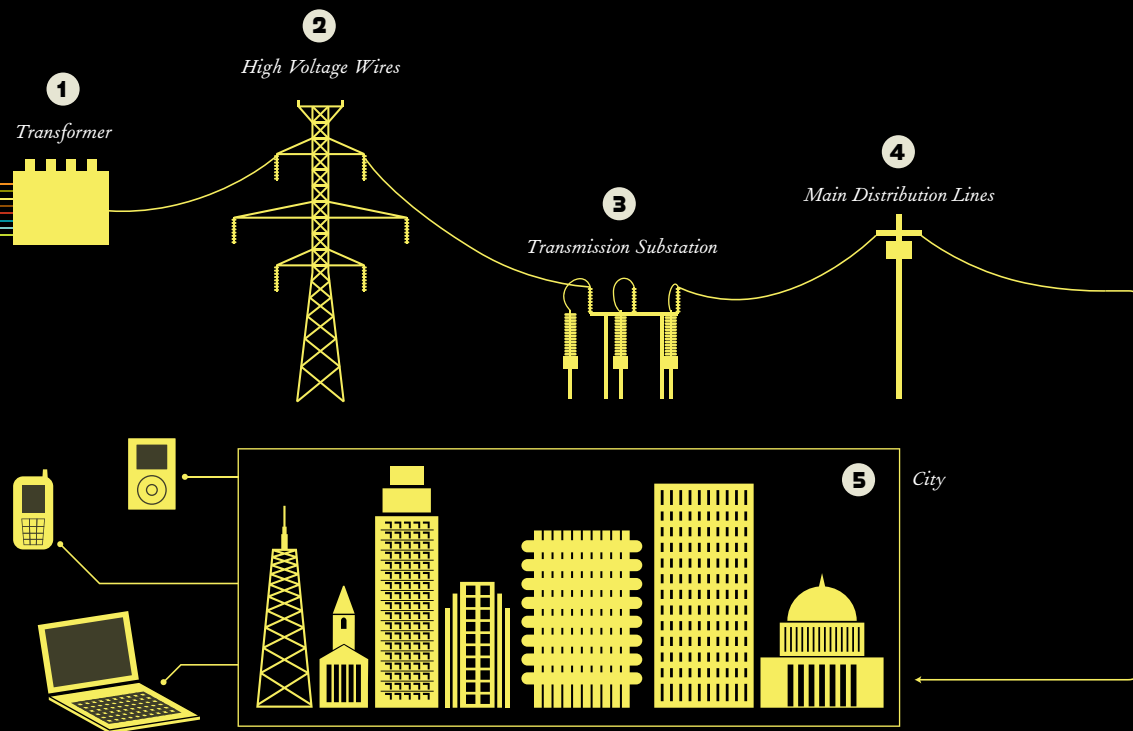
Geothermal power is widely available and squeaky clean. Like nuclear power or coal power, it uses heat to boil water to turn a turbine. The heat comes from a deep borehole over hot rock, using waste heat from the Earth's mantle. Water is pumped into the borehole and then returns to the surface as steam. Geothermal heat supplies abundant, cheap, and clean electricity.



Coal power plants and nuclear power plants both use fuel to drive a steam turbine to supply large base-load power needs. In a common Boiling Water Reactor, a nuclear fuel (Pu-238) undergoing radioactive decay heats a transfer fluid (such as liquid sodium) to move heat out of the reactor to a boiler, where water steam is produced to drive a turbine. Heat is regulated by raising or lowering the control rods. In a coal-burning plant, large amounts of coal is simply dumped onto a conveyor belt, pulverized, and ignited to heat water to drive a turbine. In both plants, water is cooled and recycled back to the plant.



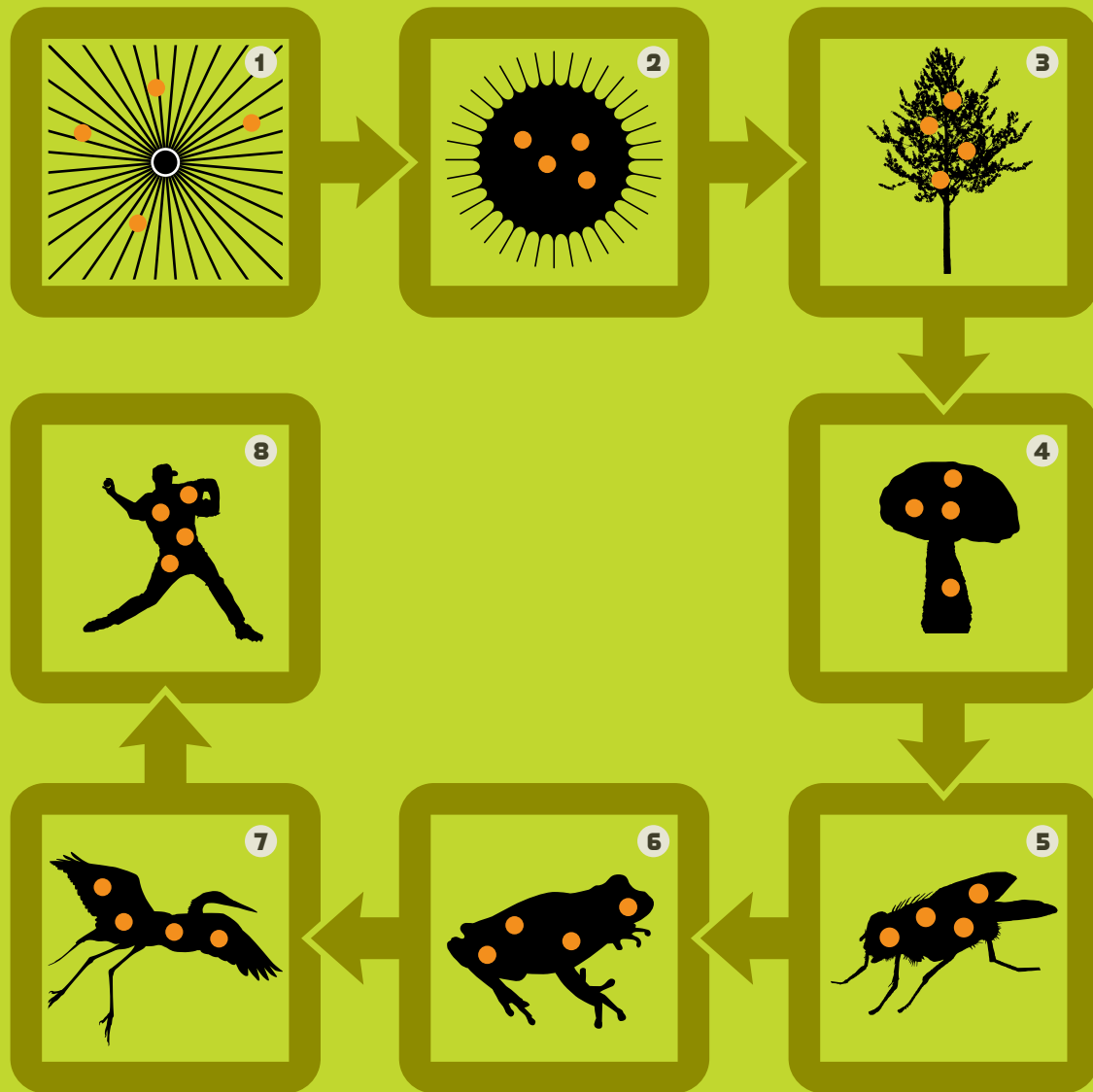
Oil and natural gas plants work in the same manner that a car or jet engine works. Fuel is pumped in one pipe, air is pumped in another, they ignite in a combustion chamber and force the superheated air into an air turbine. Petroleum power is common in oil-rich countries where coal and nuclear fuel do not exist, and natural gas power is common in countries with abundant natural gas, including the United States.



IV. HOW WE USE IT

Electricity allows us to put energy into almost anything with a power cord attached to it. Power plants convert fossil fuels, solar energy, gravity, nuclear materials, or wind into heat or mechanical energy, which is converted to electrical energy.

All fossil fuel power is dirty, and there is no way to remove the pollution. Waste from nuclear power must be carefully disposed of. Large hydroelectric dams can cause great environmental damage. Solar power doesn't work so well at night. Wind power depends on the weather. Tidal power doesn't yet generate enough energy for a large population. A geothermal borehole near Basel once caused an earthquake, but no one was hurt.



V. HOW IT SUSTAINS US

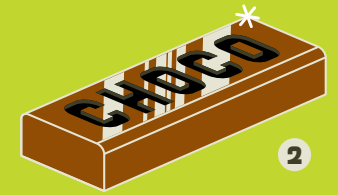
Our most intimate relationship with energy is in the form of food. Every creature that has ever lived long enough to reproduce has had to eat to survive. The sun feeds a tree, which feeds a mushroom, which a fly eats, only to be consumed by a tree

frog, which is in turn eaten by a bird. Every living thing is a survivor of a long ancestral chain of creatures who managed to eat just enough to survive, passing on energy to one another over hundreds of millions of years.



1

An active adult male human needs between 2500 and 2800 food Calories each day. A very active adult male human (like a baseball player) might need up to 3000 kcal. Converting this to joules to make our calculations easier, 3000 kcal is equivalent to 12,550,000 J. Picking up a baseball takes 1 joule. Throwing a baseball takes 50 joules. Therefore, a total of 51 joules are needed for each throw of the ball.

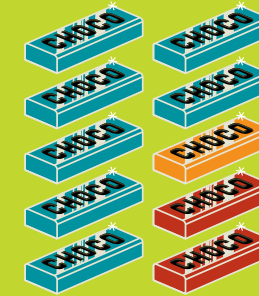


2

A 60-gram chocolate bar represents about 300 kcal (1,255,000 j) of potential food energy.

It will take 10 chocolate bars to supply the daily energy needed by the active baseball player. While this is in no way a healthy diet, it serves to easily show both the high caloric value of a candy bar and the food needs of a highly active person. If you ate ten candy bars you might feel quite sick afterward.

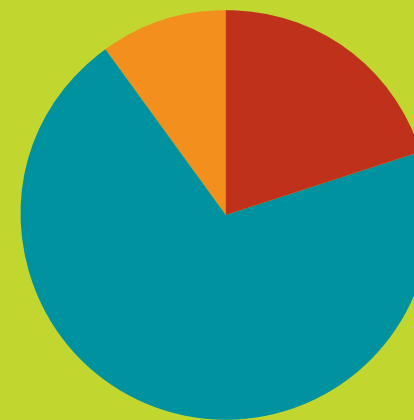
3



Thus, the daily food intake would allow for 246,708 pitches if the pitcher were simply a ball-throwing machine. Since only 20% of food energy is available for mechanical work, the maximum number of throws in ten candy bars is 49,215. Any more than this and the body would use any stored fat, and then muscles, to keep pitching.

4

Exceed 49,215 throws and there may be trouble.

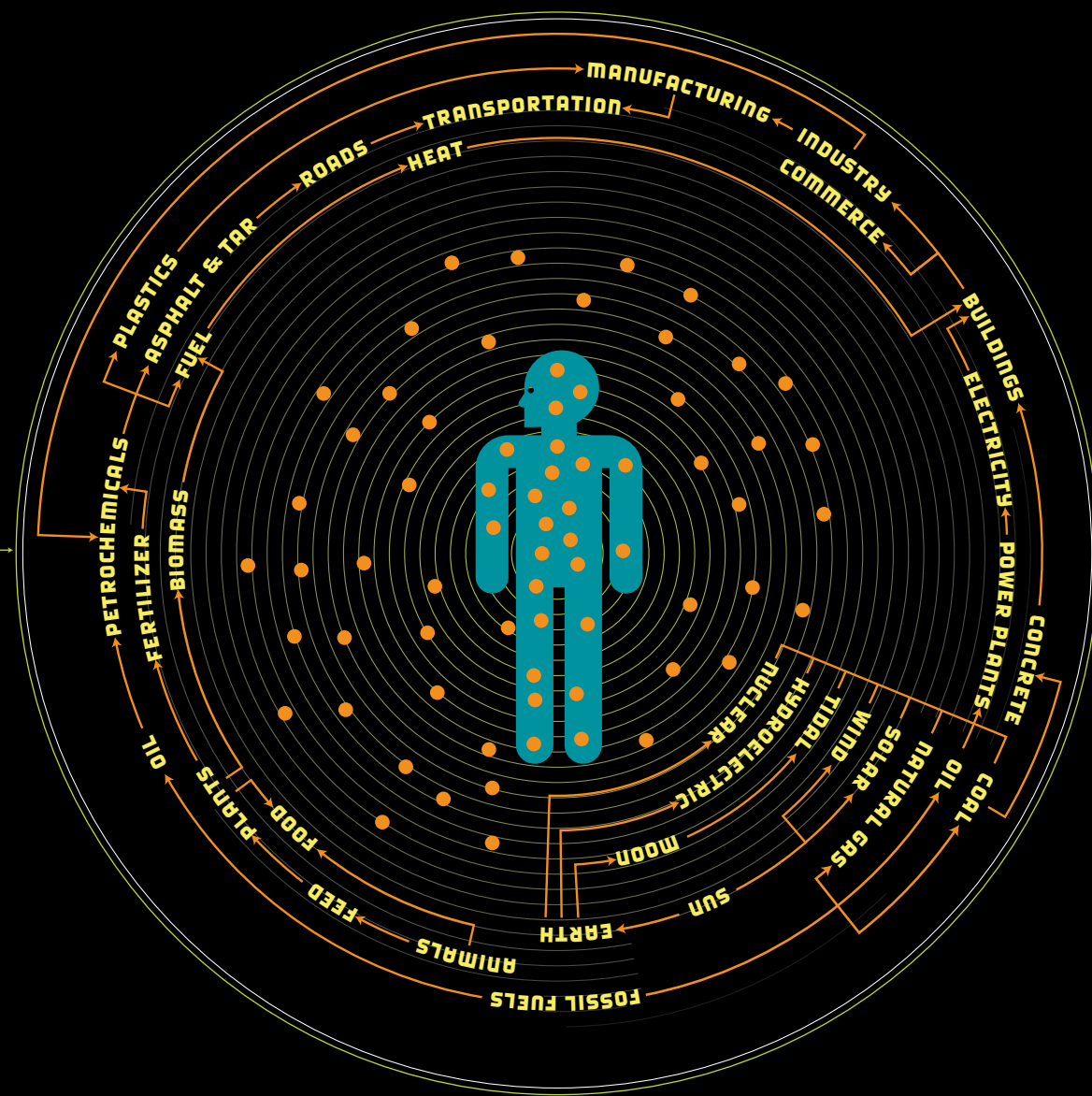
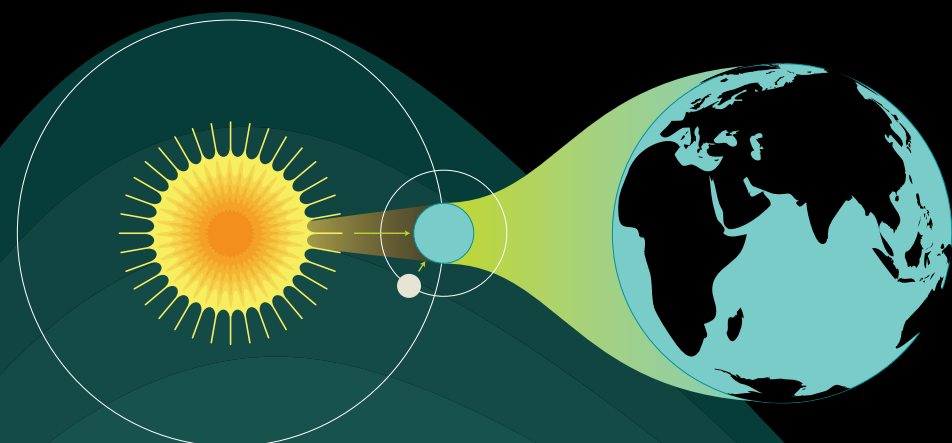


WHERE FOOD ENERGY GOES

- 10%: USED TO CONSUME, DIGEST, AND ABSORB FOOD
- 20%: CONVERTED TO MECHANICAL ENERGY
- 70%: CONSUMED TO SUPPORT BASIC LIFE FUNCTIONS

VI. ENERGY IS EVERLASTING

In all cases, energy creates movement, is transferred to another thing, and the process repeats. Thus it is said that energy can be neither created nor destroyed, just moved here or there.



The U.S. Department of Defense completes the largest solar power installation in the nation, a 15 MW photovoltaic array at Nellis Air Force Base in Nevada.