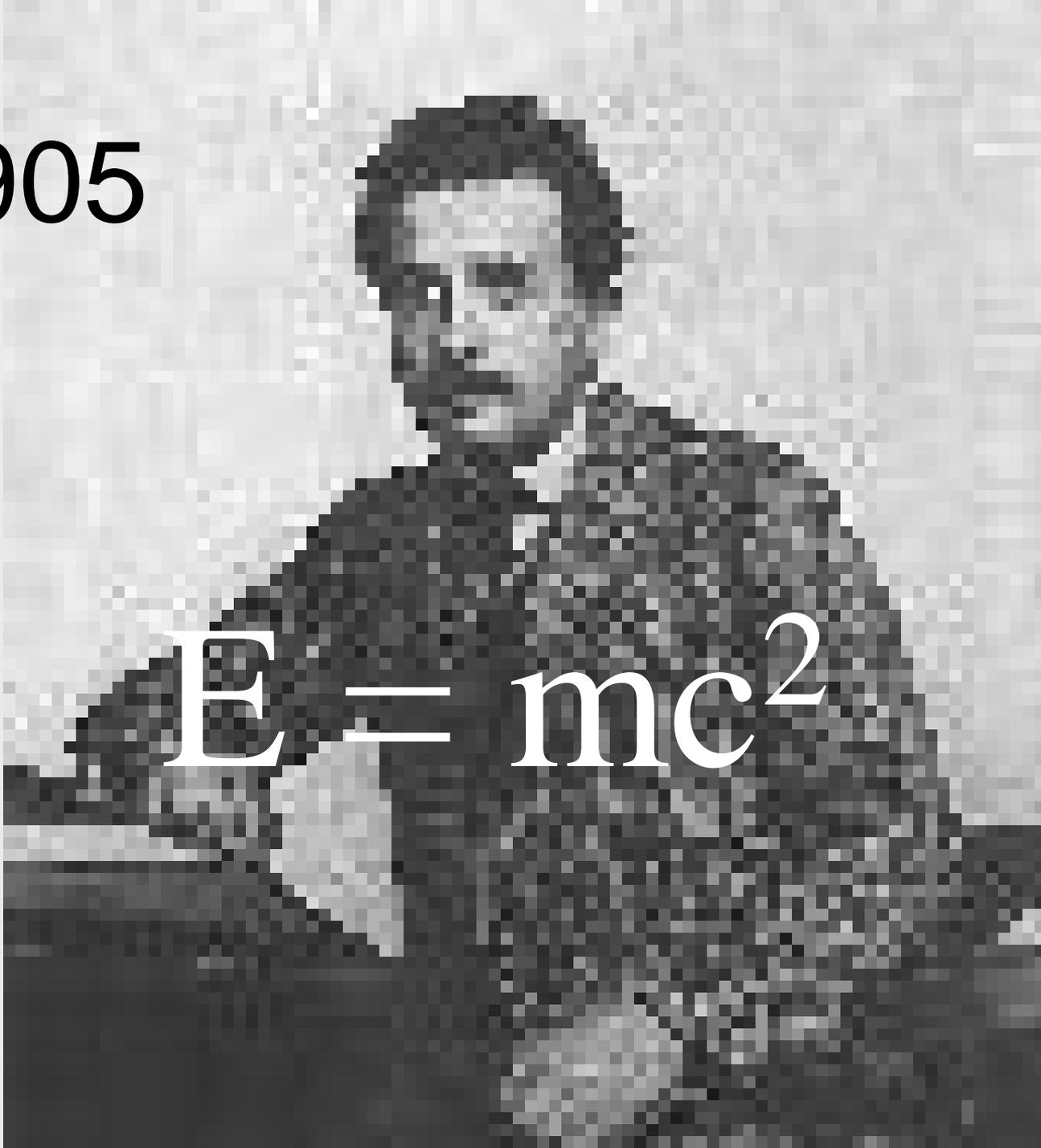


# Terrestrial Energy

Power for the 21<sup>st</sup> Century

1905


$$E = mc^2$$





Matter and  
Energy are  
Interchangeable

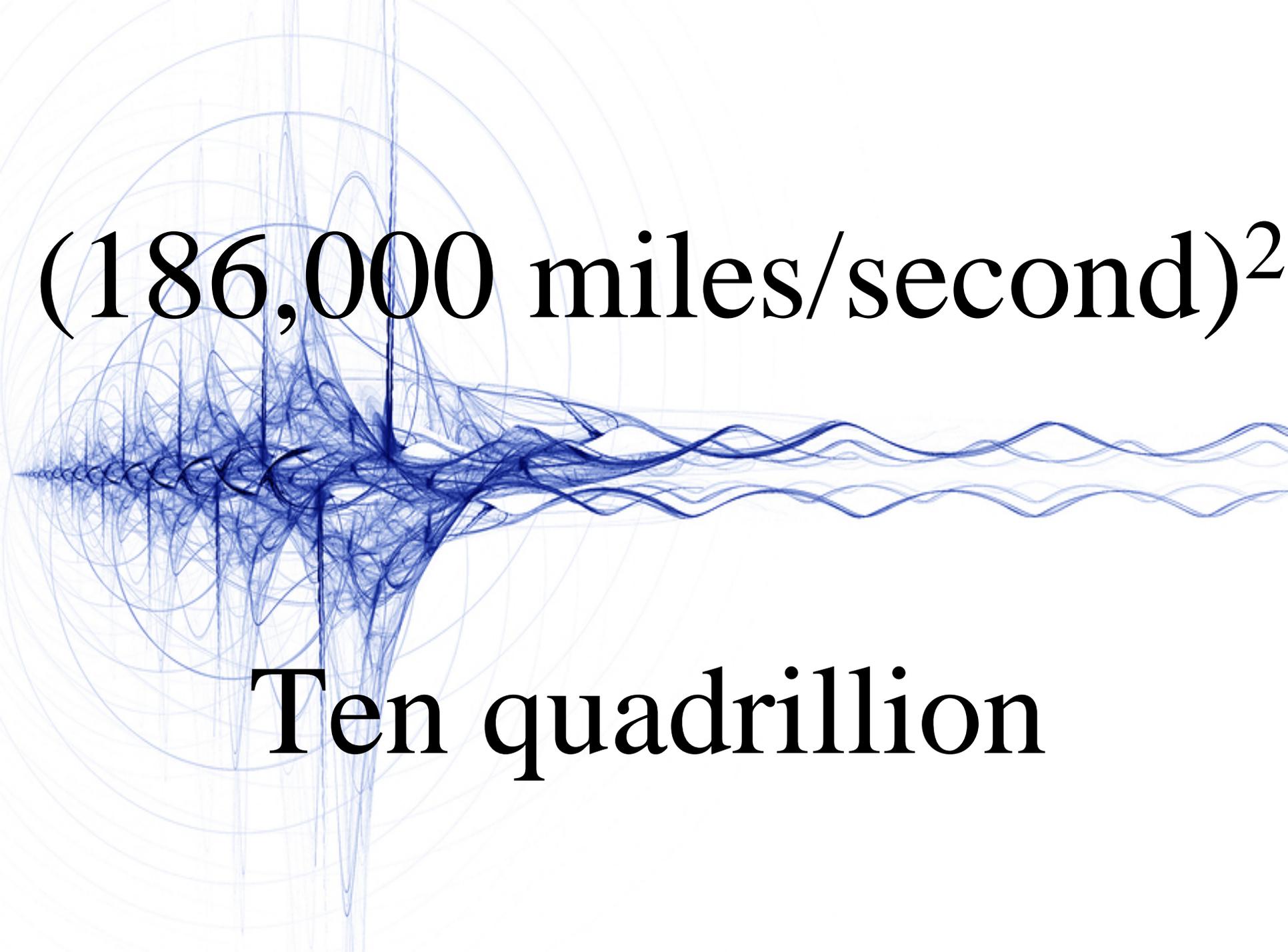
$$E = mc^2$$

$$E = \frac{1}{2} mv^2$$

# Energy Density

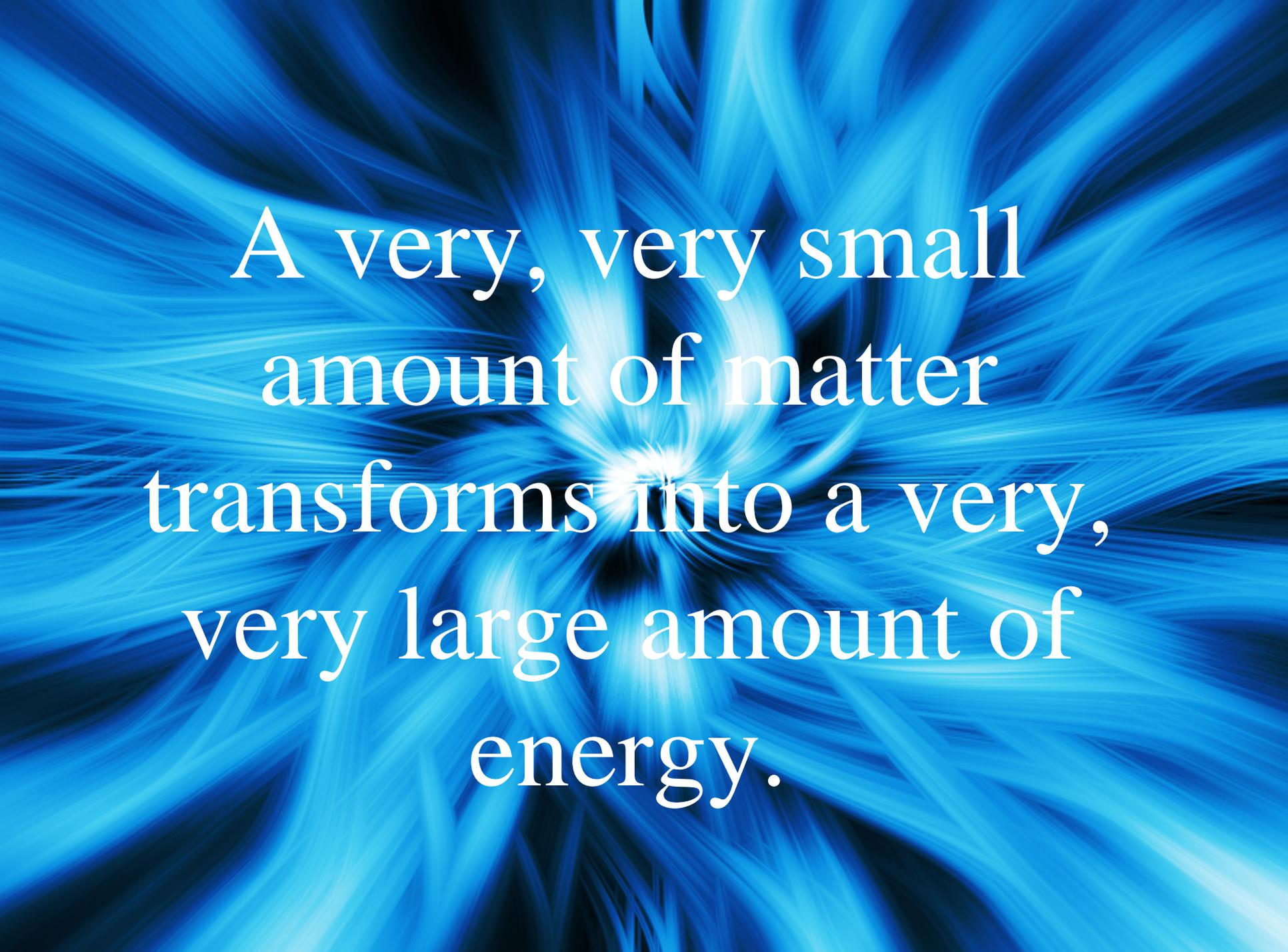
$$E = m C^2$$

$$E = \frac{1}{2} m v^2$$

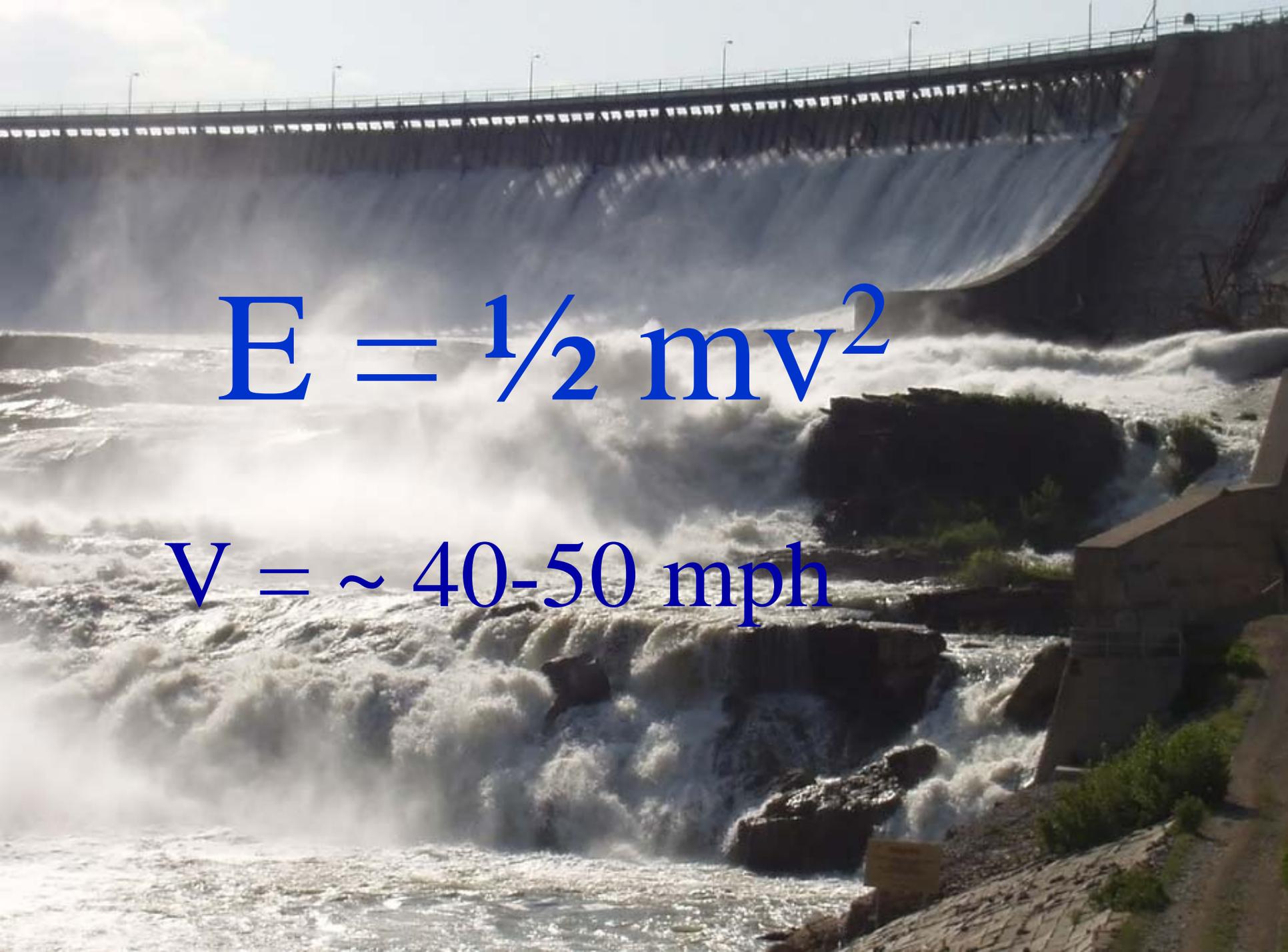


$(186,000 \text{ miles/second})^2$

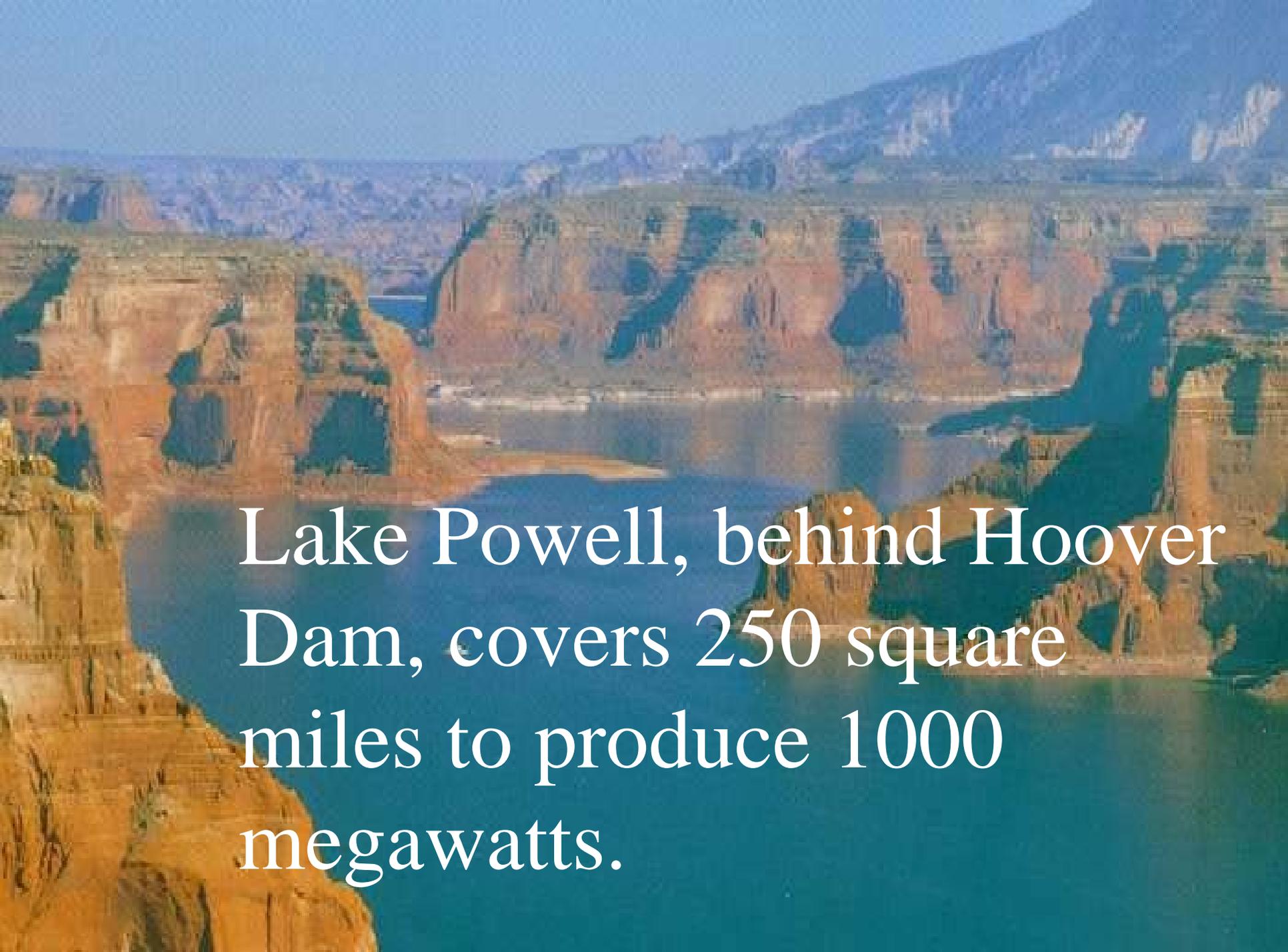
Ten quadrillion



A very, very small  
amount of matter  
transforms into a very,  
very large amount of  
energy.


$$E = \frac{1}{2} mv^2$$

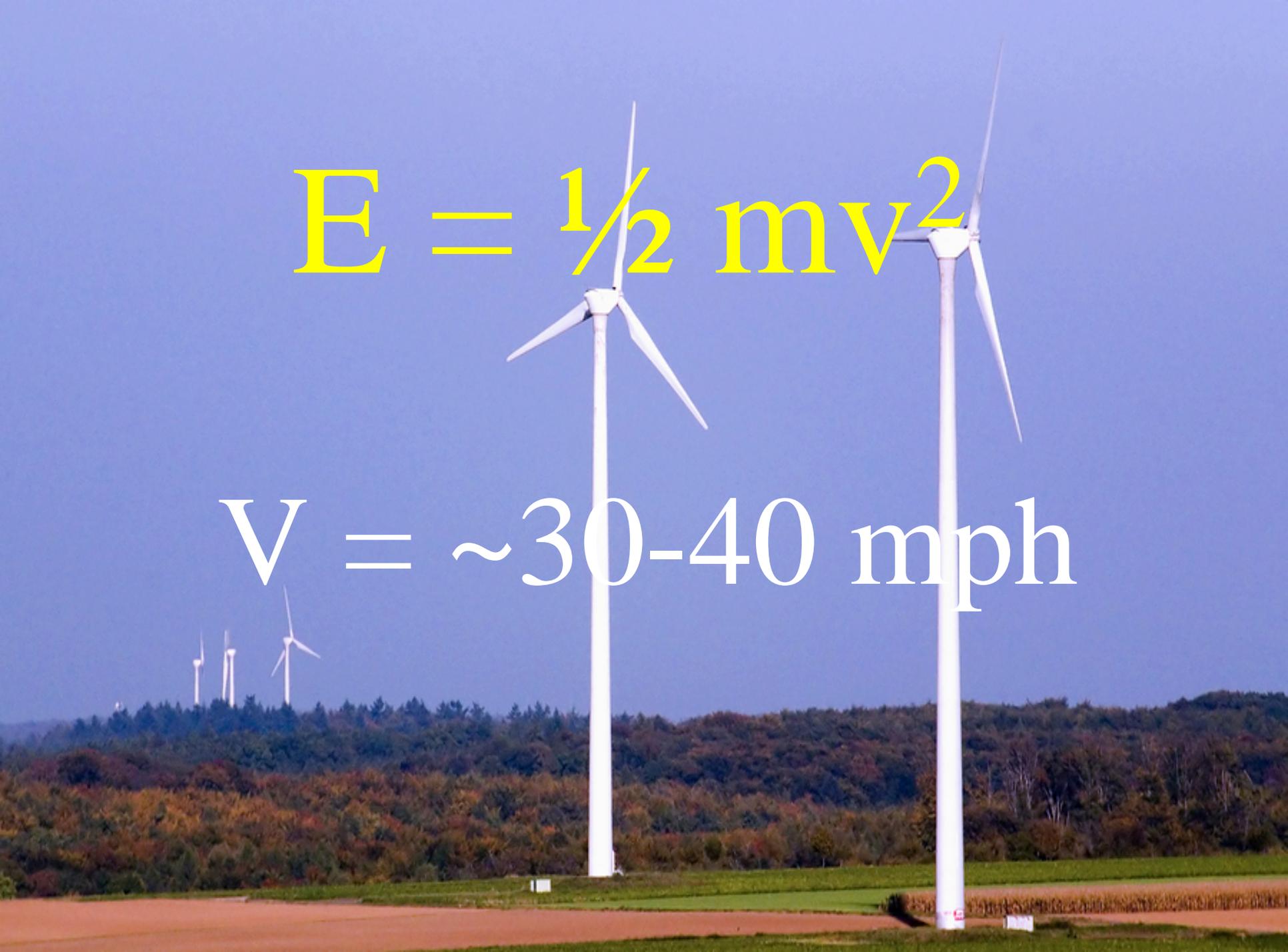
$$V = \sim 40-50 \text{ mph}$$

An aerial photograph of Lake Powell, a large reservoir behind Hoover Dam. The water is a deep blue-green color, filling a deep canyon. The surrounding landscape is rugged and arid, with reddish-brown rock formations and sparse vegetation. The sky is clear and blue. The text is overlaid on the lower half of the image.

Lake Powell, behind Hoover Dam, covers 250 square miles to produce 1000 megawatts.

$$E = \frac{1}{2} mv^2$$

$$V = \sim 30-40 \text{ mph}$$



# Biggest Ever?

125 square  
miles for  
1000 MW



# Tidal and Wave Energy

$$E = \frac{1}{2} mv^2$$

$$V = \sim 5-7 \text{ mph}$$

An aerial photograph of a rugged coastline. The land is covered in green vegetation, with some areas showing reddish-brown soil or erosion. The coastline is characterized by steep cliffs and rocky outcrops. The ocean is a deep blue, with white waves crashing against the shore. The text "1000 mw = Dozens of miles of coastline." is overlaid on the right side of the image in white font.

1000 mw =  
Dozens of  
miles of  
coastline.

$$E = mc^2$$

90 million from Earth

Solar energy hits the earth  
at an average of 400 watts

Solar conversions take place at  
best at ~ 20 percent

One 100-watt light  
bulb per square meter.



# Solar Thermal

A tall, slender solar tower stands in the center of the frame. The tower is a dark, vertical structure with a slightly wider section near the top. In the background, a vast field of heliostats (mirrors) is visible, reflecting sunlight. The sky is a clear, pale blue. The overall scene is a desert landscape under bright sunlight.

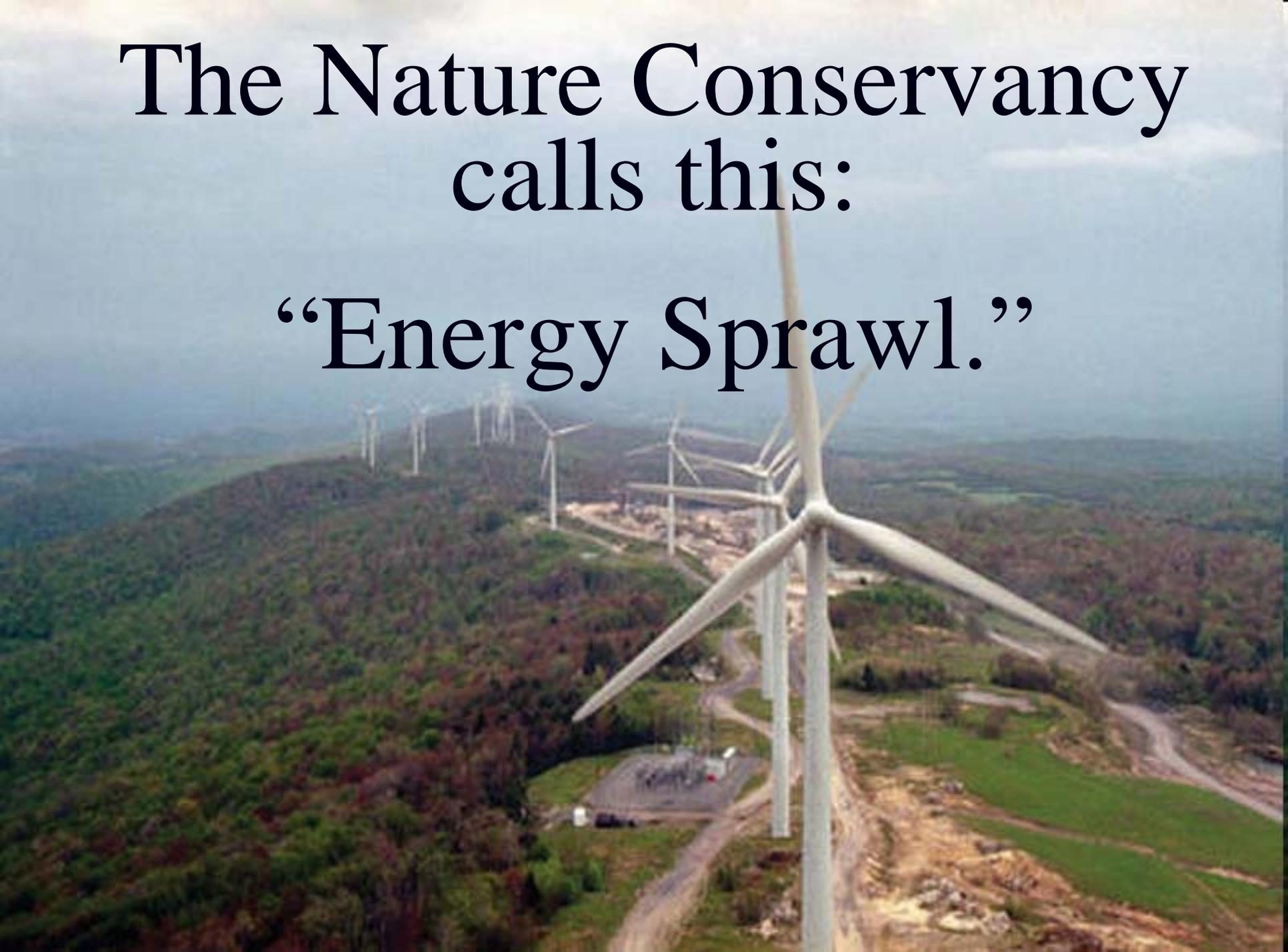
10 Megawatts – 1/5 sq. mile

46,000  
square  
miles of  
western  
desert

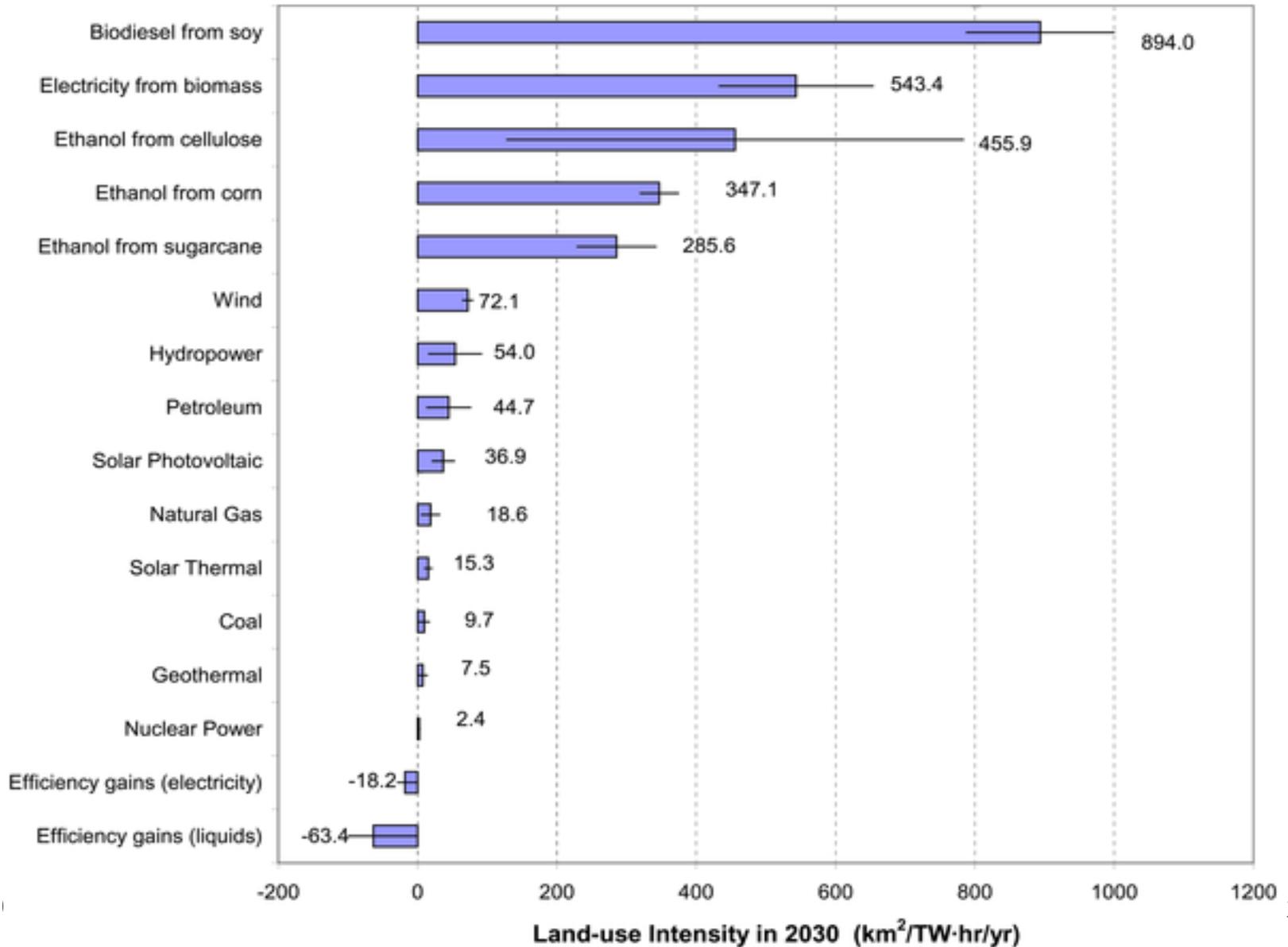


The Nature Conservancy  
calls this:

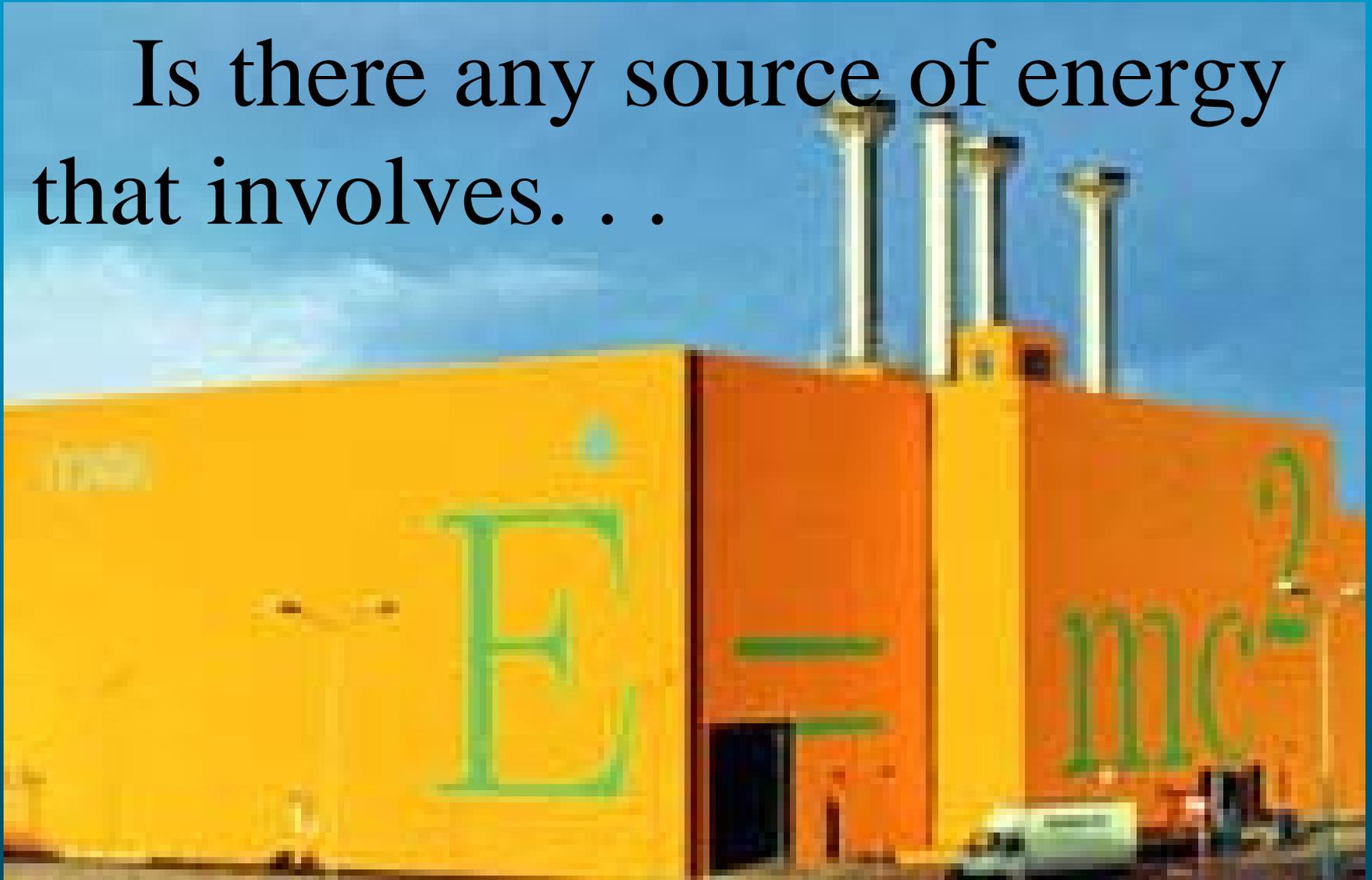
“Energy Sprawl.”



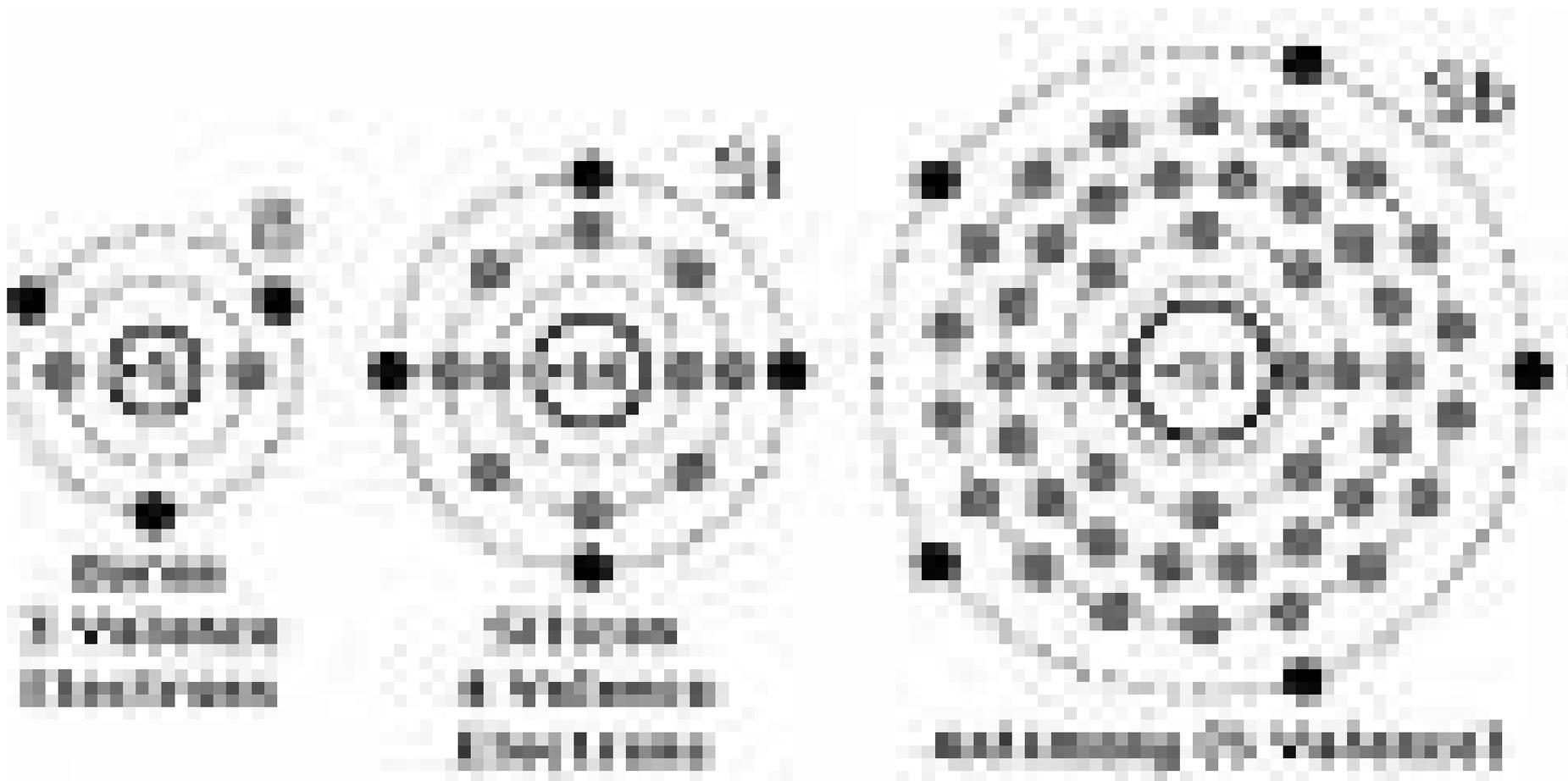
# Energy Density



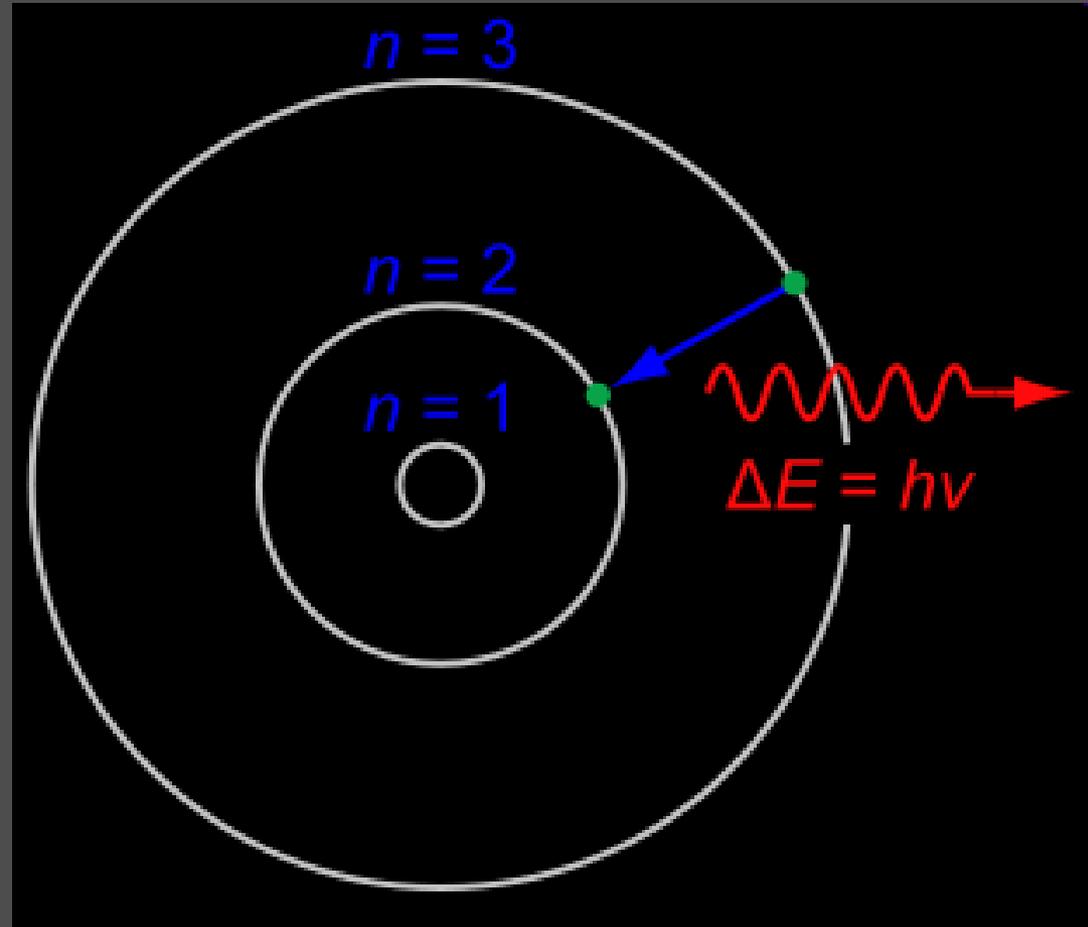
Is there any source of energy  
that involves. . .



# Chemistry

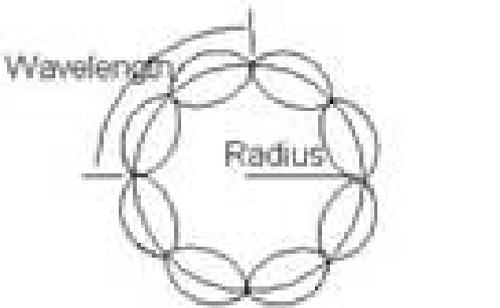


# Quantum Theory

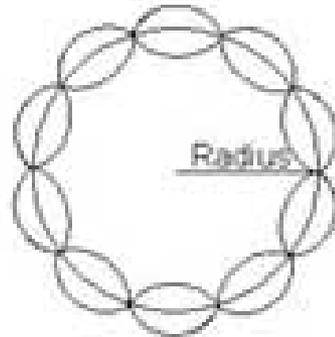


Niels Bohr 1885-1962

# Electrons as Particle/Waves



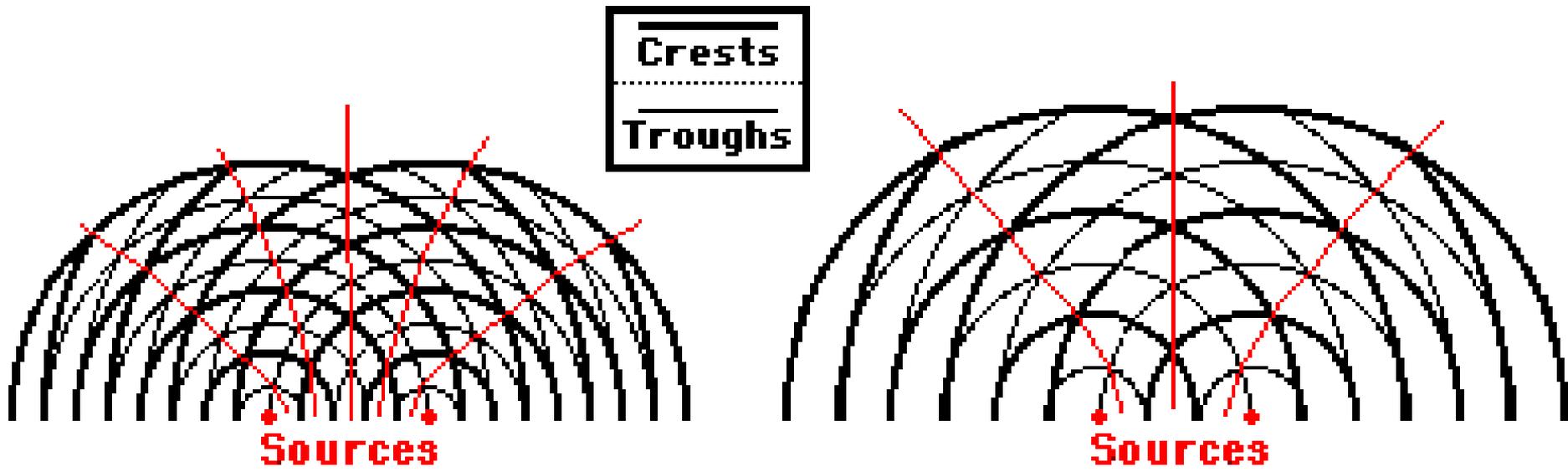
Electron Orbit = Four Wavelengths



Electron Orbit = Five Wavelengths

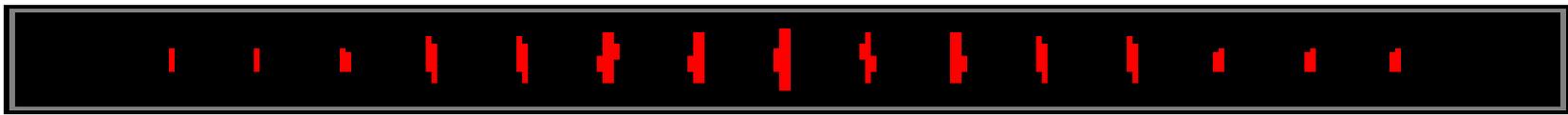


Louis de Broglie  
1892-1987



The proximity of the anti-nodal lines in a two-point source interference pattern is dependent upon the wavelength of the waves.

### Two-Point Source Interference Pattern

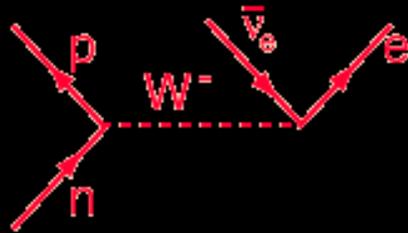


The projection of an interference pattern onto a screen results in an alternating pattern of bright (anti-nodes) and dark (nodes) bands.

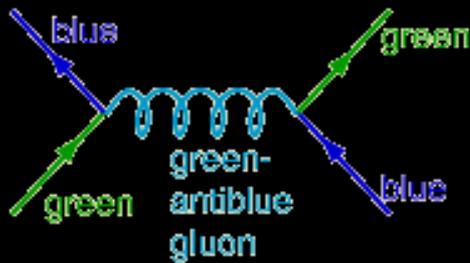
# Matter = Energy



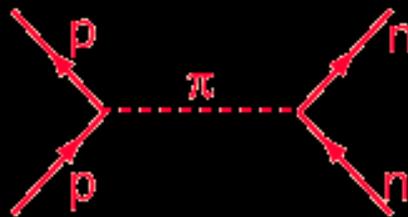
Electromagnetic



Weak

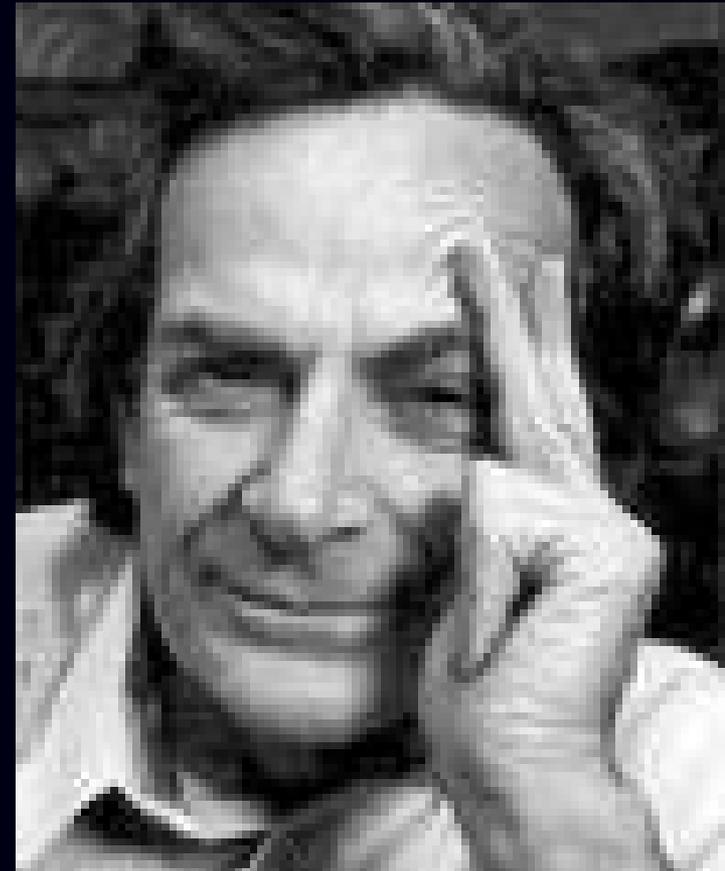


between quarks



between nucleons

Strong Interaction



Richard Feynman 1918-1988

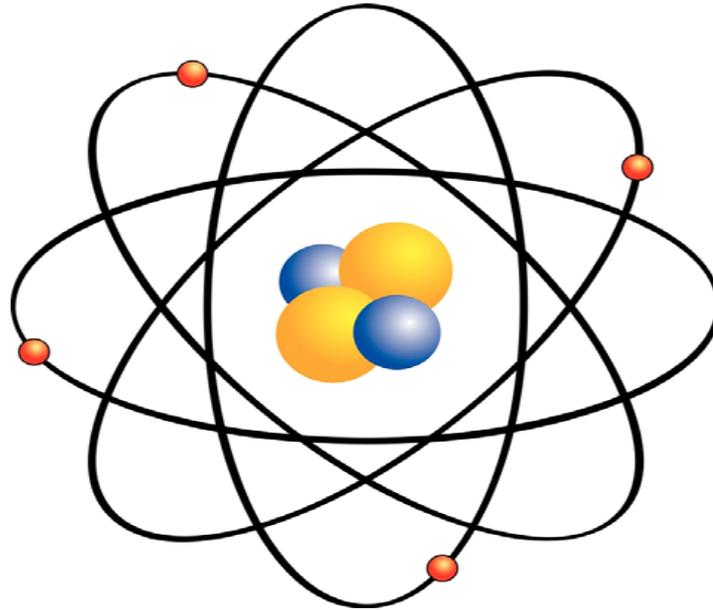
One billionth of the mass.



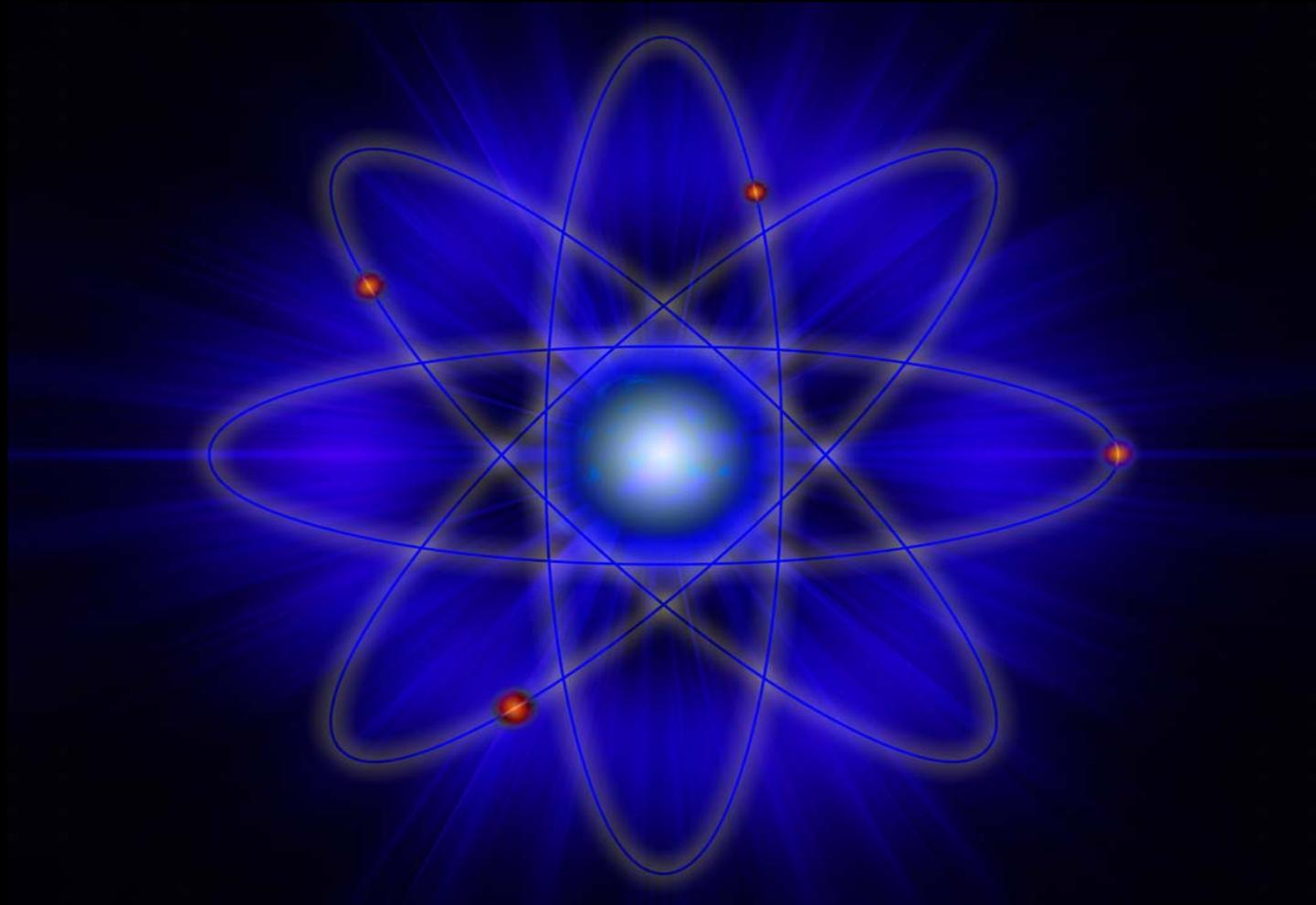
2000 pounds for 30 miles.

Is there any other  
concentration of matter  
in the universe other  
than the electron?

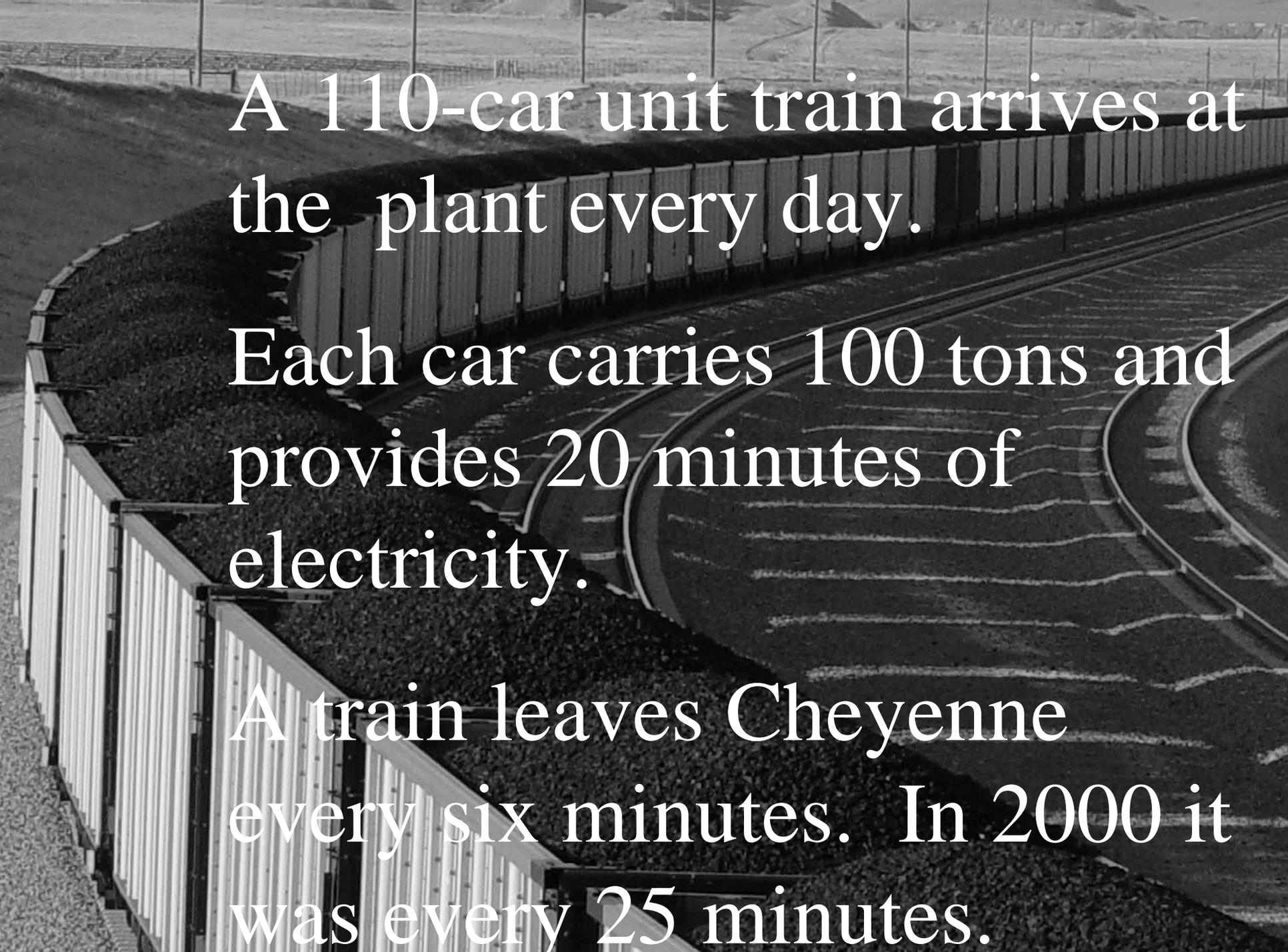
Only  $1/1800^{\text{th}}$  of the mass is in the electrons.



The remainder is in the nucleus.



The energy release from splitting a uranium atom is *2 million eV*.



A 110-car unit train arrives at the plant every day.

Each car carries 100 tons and provides 20 minutes of electricity.

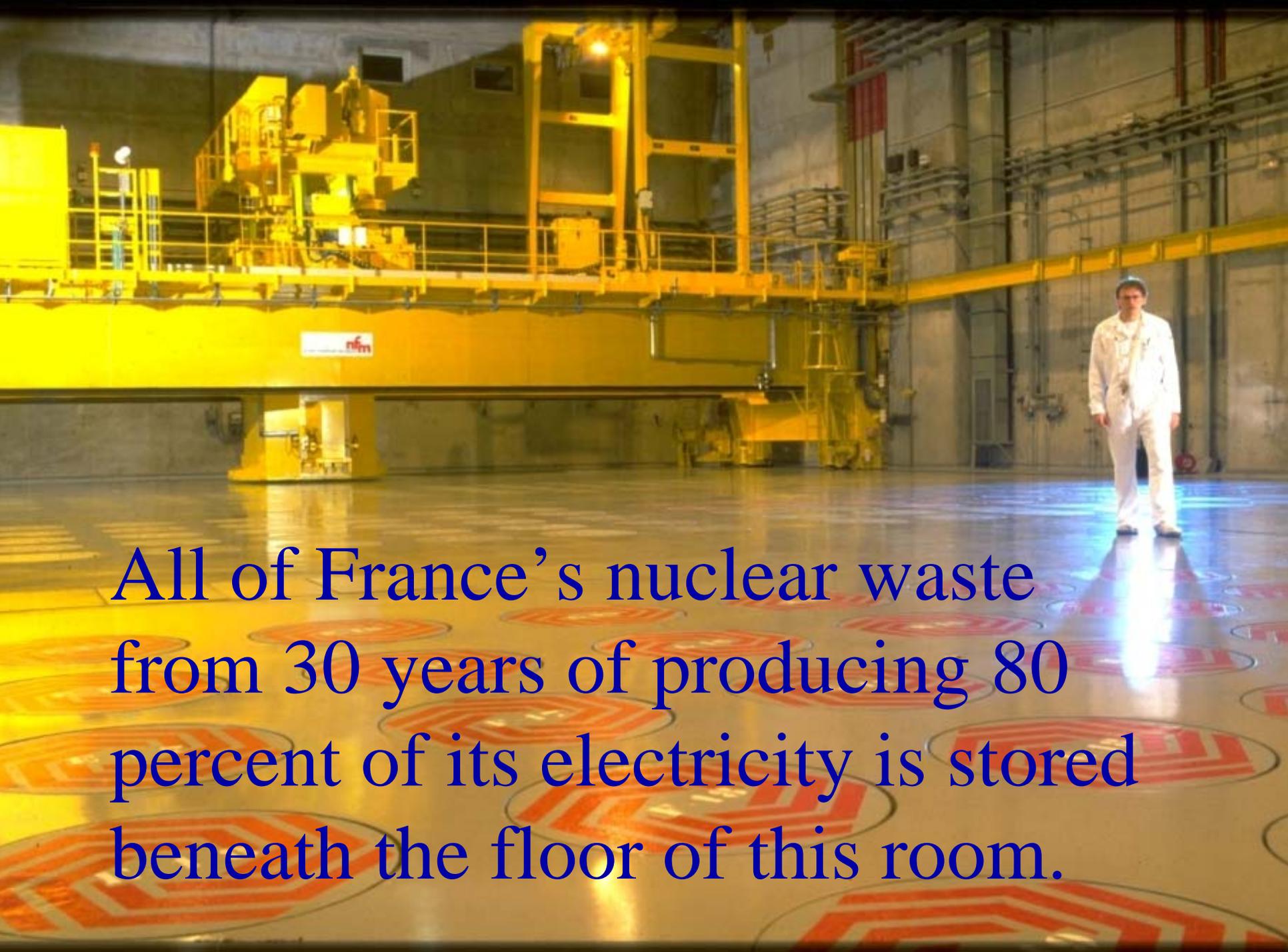
A train leaves Cheyenne every six minutes. In 2000 it was every 25 minutes.

Two years worth of electricity.





Four years' worth of nuclear waste.



All of France's nuclear waste from 30 years of producing 80 percent of its electricity is stored beneath the floor of this room.

It takes 100 years for ideas  
to enter history.

$$E = mc^2$$

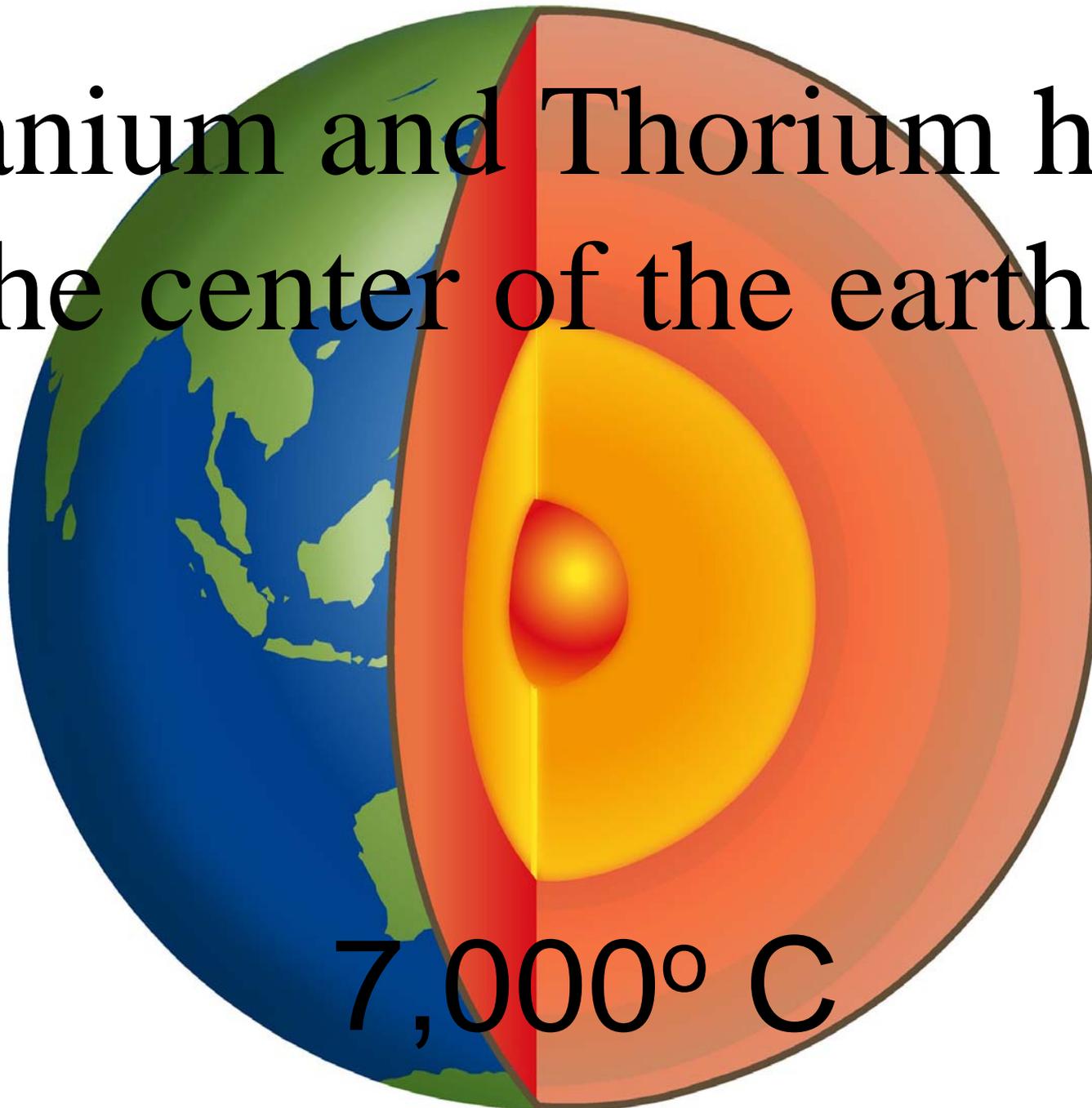
1905 - 2009 – It's time!!







Uranium and Thorium heat  
the center of the earth.



7,000° C

H Hydrogen																	He Helium
Li Lithium	Be Beryllium											B Boron	C Carbon	N Nitrogen	O Oxygen	F Fluorine	Ne Neon
Na Sodium	Mg Magnesium											Al Aluminum	Si Silicon	P Phosphorus	S Sulfur	Cl Chlorine	Ar Argon
K Potassium	Ca Calcium	Sc Scandium	Ti Titanium	V Vanadium	Cr Chromium	Mn Manganese	Fe Iron	Co Cobalt	Ni Nickel	Cu Copper	Zn Zinc	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium	Br Bromine	Kr Krypton
Rb Rubidium	Sr Strontium	Y Yttrium	Zr Zirconium	Nb Niobium	Mo Molybdenum	Tc Technetium	Ru Ruthenium	Rh Rhodium	Pd Palladium	Ag Silver	Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine	Xe Xenon
Cs Cesium	Ba Barium		Hf Hafnium	Ta Tantalum	W Tungsten	Re Rhenium	Os Osmium	Ir Iridium	Pt Platinum	Au Gold	Hg Mercury	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine	Rn Radon
Fr Francium	Ra Radium		Rf Rutherfordium	Db Dubnium	Sg Seaborgium	Bh Bohrium	Hs Hassium	Mt Meitnerium	Ds Darmstadtium	Rg Roentgenium	Uub Ununbium	Uut Ununtrium	Uuq Ununquadium	Uup Ununpentium	Uuh Ununhexium	Uus Ununseptium	Uuo Ununoctium

K  
 Potassium  
19

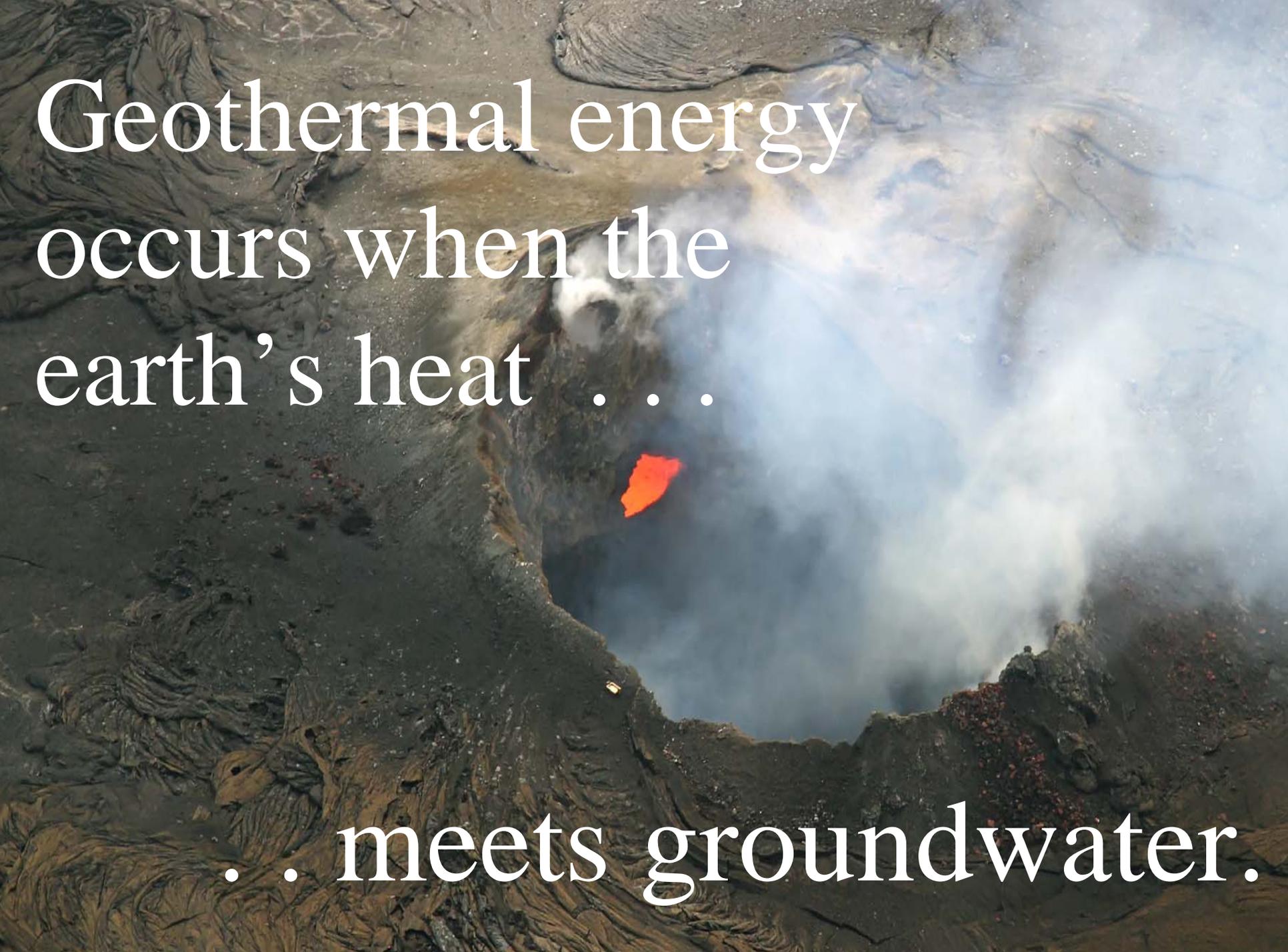
The remainder comes from the radioactive

breakdown of three elements.

La Lanthanum	Ce Cerium	Pr Praseodymium	Nd Neodymium	Pm Promethium	Sm Samarium	Eu Europium	Gd Gadolinium	Tb Terbium	Dy Dysprosium	Ho Holmium	Er Erbium	Tm Thulium	Yb Ytterbium	Lu Lutetium
Ac Actinium	Th Thorium	Pa Protactinium	U Uranium	Np Neptunium	Pu Plutonium	Am Americium	Cm Curium	Bk Berkelium	Cf Californium	Es Einsteinium	Fm Fermium	Md Mendelevium	No Nobelium	Lr Lawrencium

Th  
 Thorium  
90

U  
 Uranium  
92

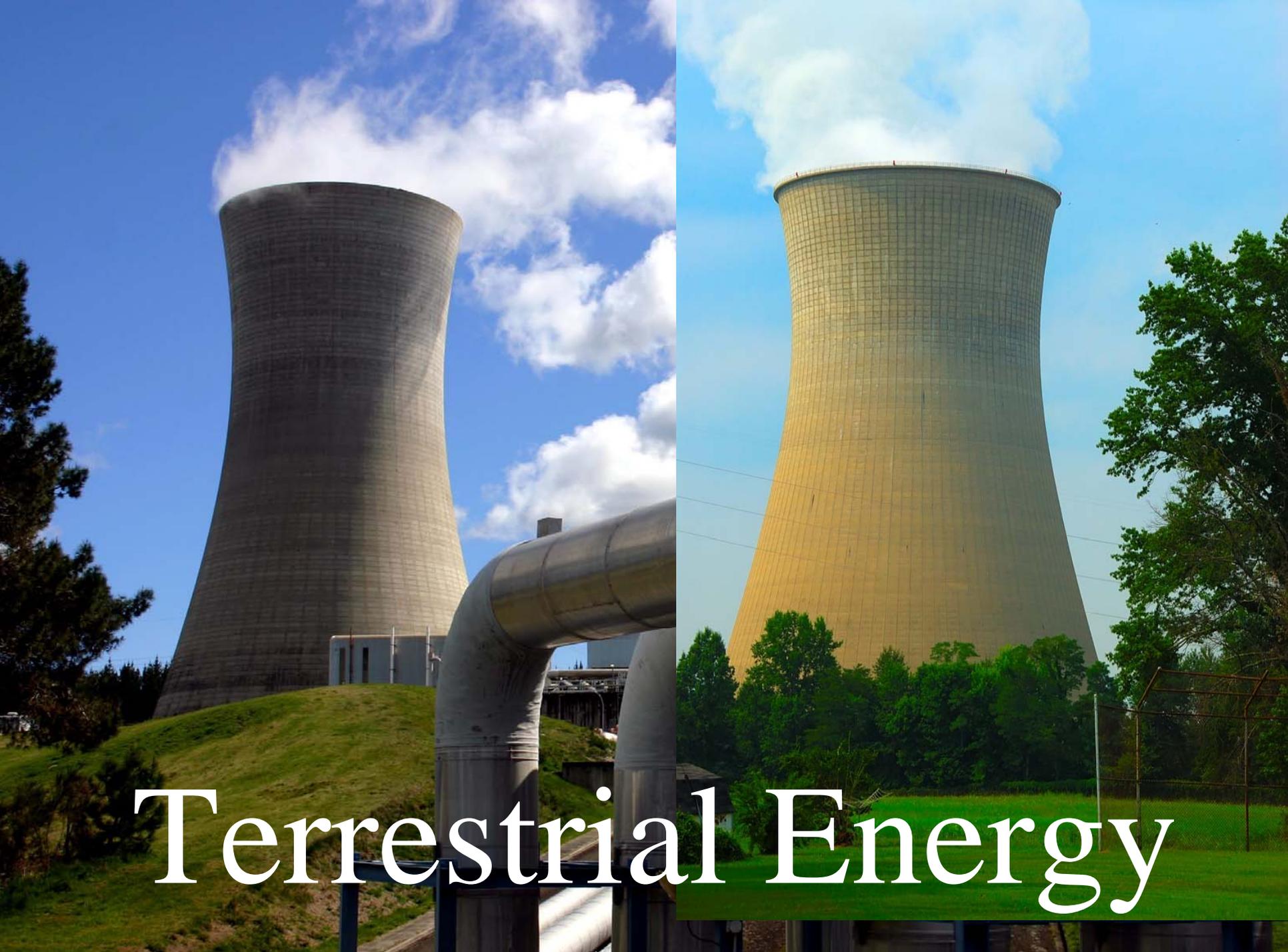
A photograph of a volcanic crater. In the center, a bright orange and red lava flow is visible, surrounded by dark, jagged rock formations. A large, billowing plume of white smoke or steam rises from the crater, filling the right side of the frame. The foreground shows dark, textured volcanic rock.

Geothermal energy  
occurs when the  
earth's heat . . .

. . . meets groundwater.



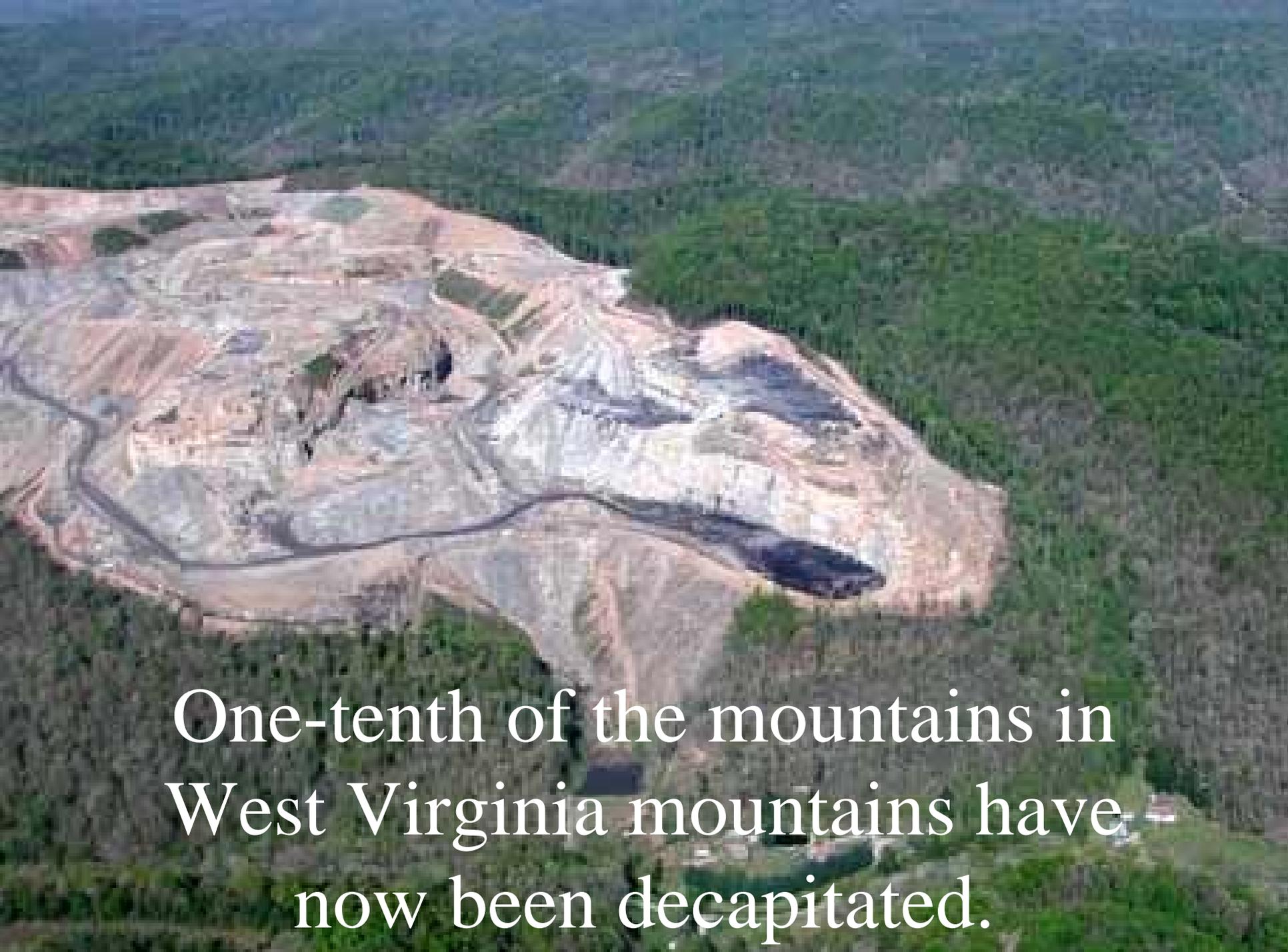
# Geothermal energy - Iceland



# Terrestrial Energy

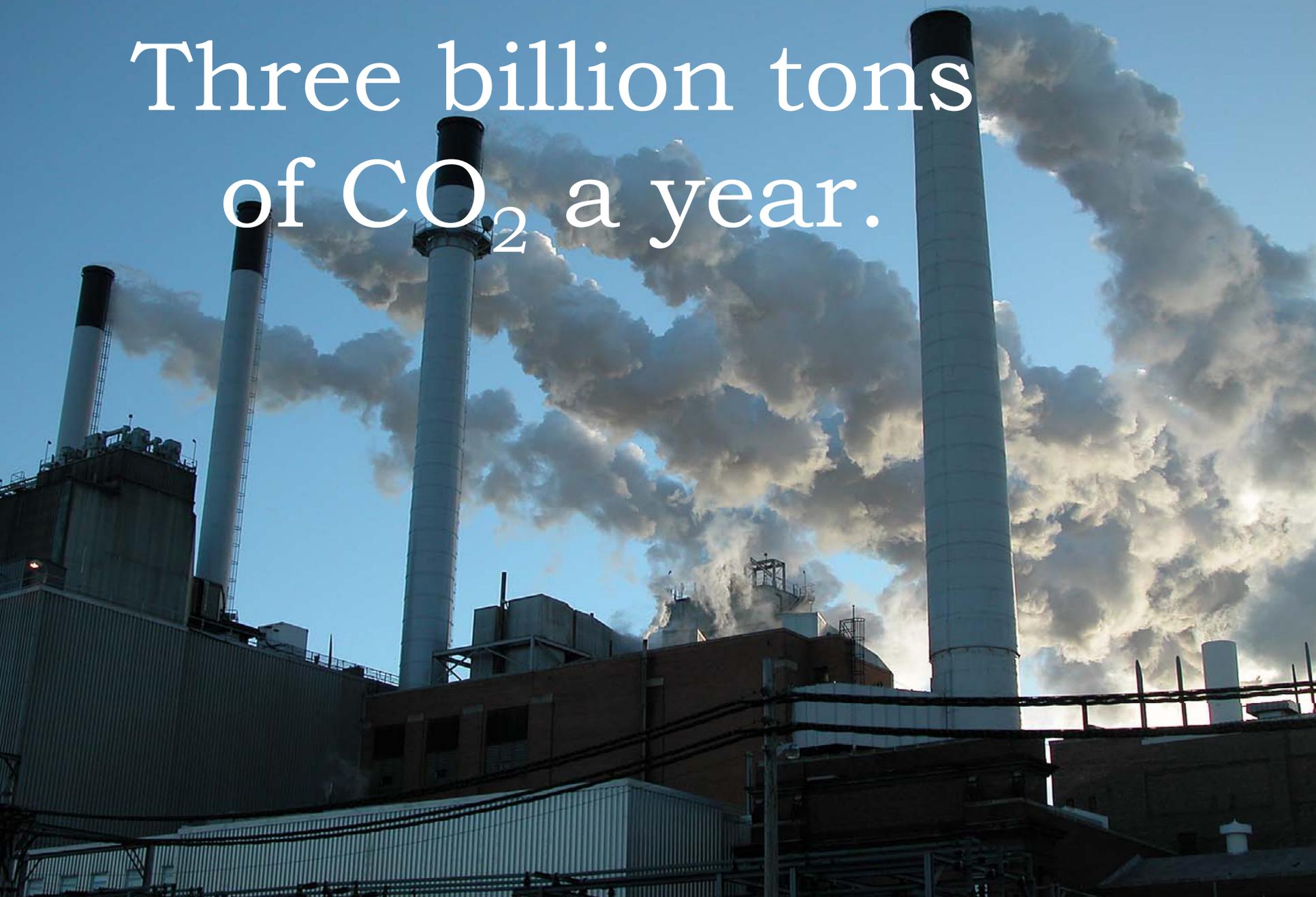
What does this mean  
for energy supplies and  
the environment?

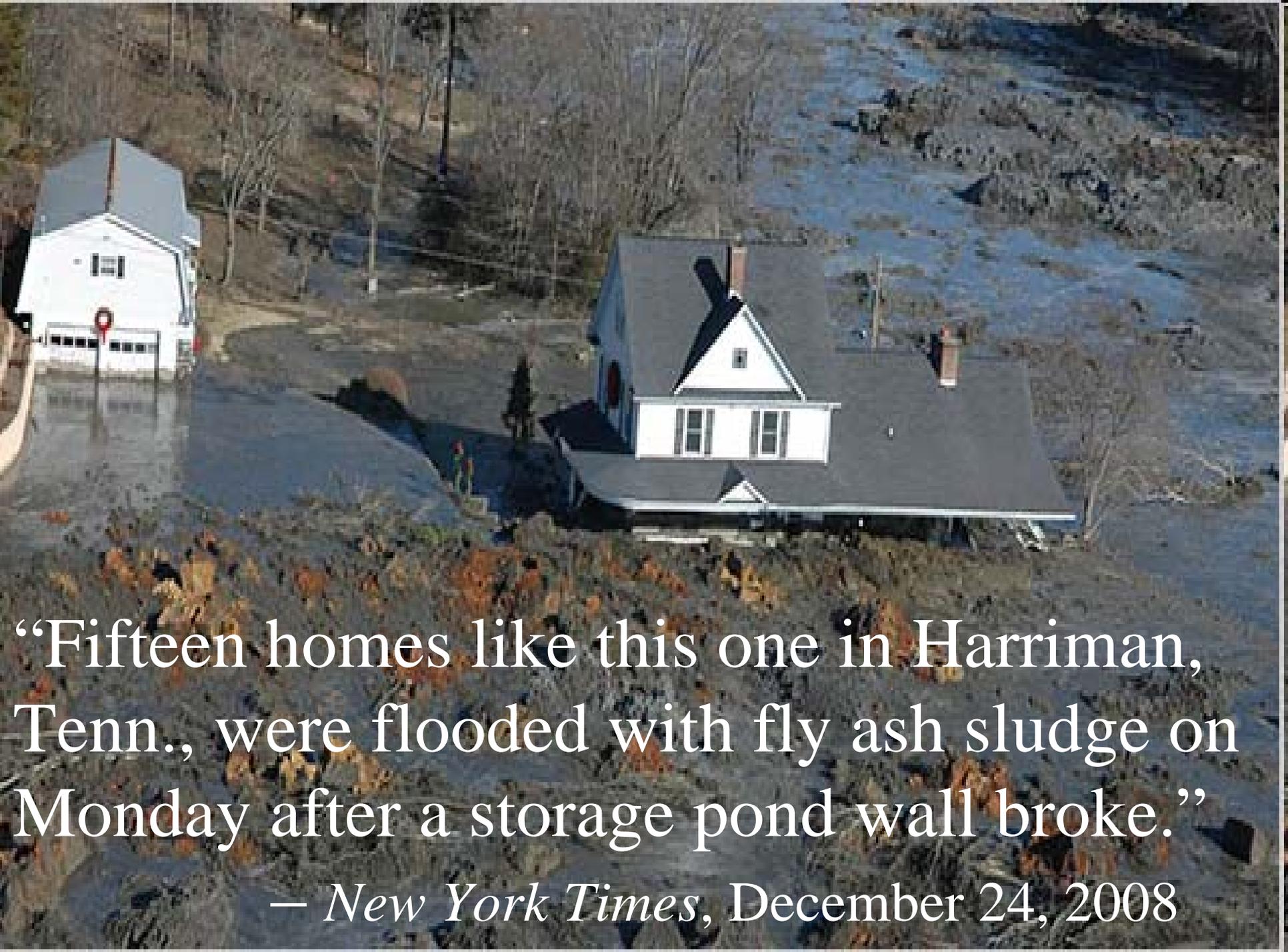




One-tenth of the mountains in West Virginia mountains have now been decapitated.

Three billion tons  
of CO<sub>2</sub> a year.





“Fifteen homes like this one in Harriman, Tenn., were flooded with fly ash sludge on Monday after a storage pond wall broke.”

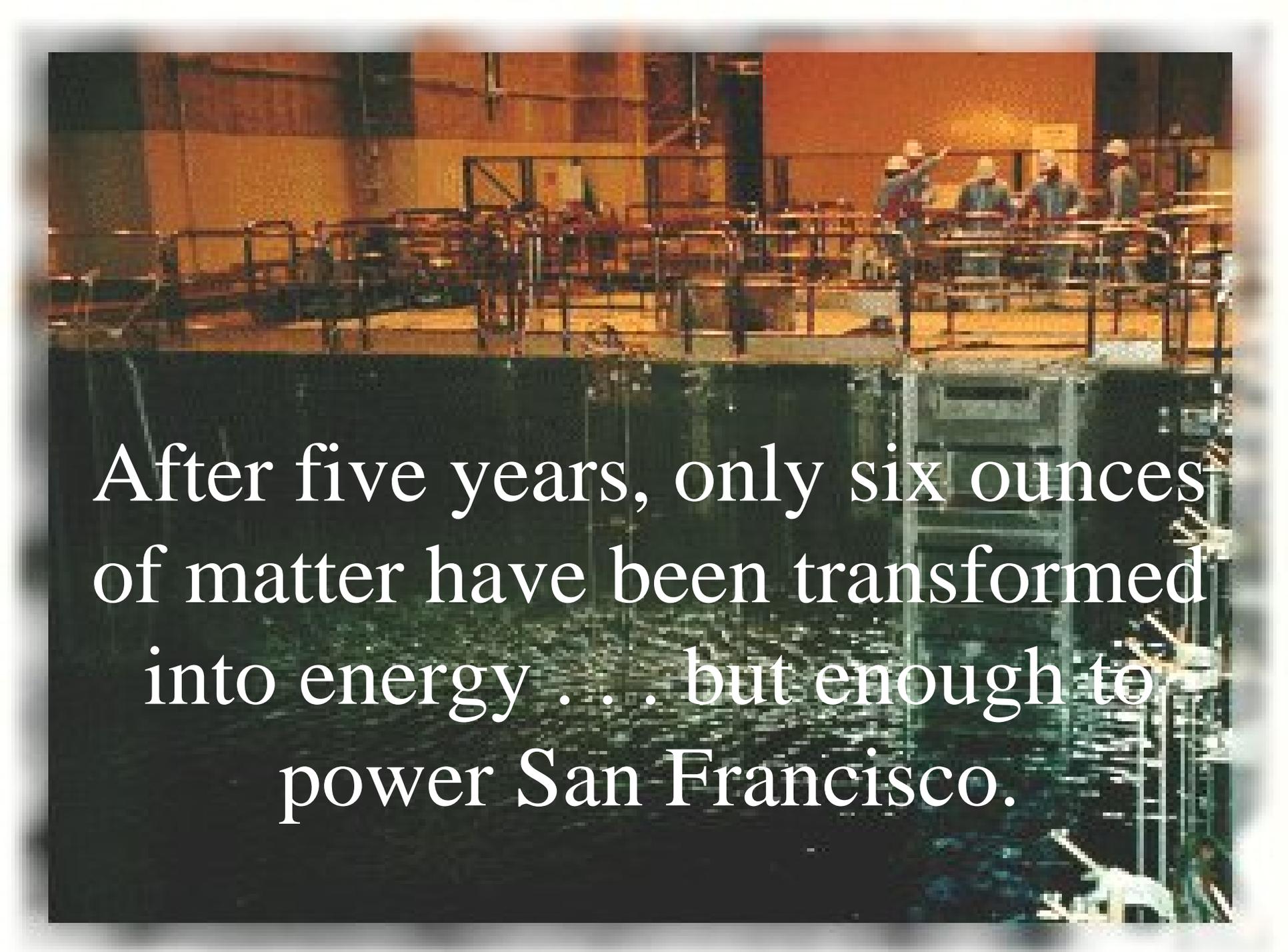
— *New York Times*, December 24, 2008

What happens at a  
nuclear reactor?

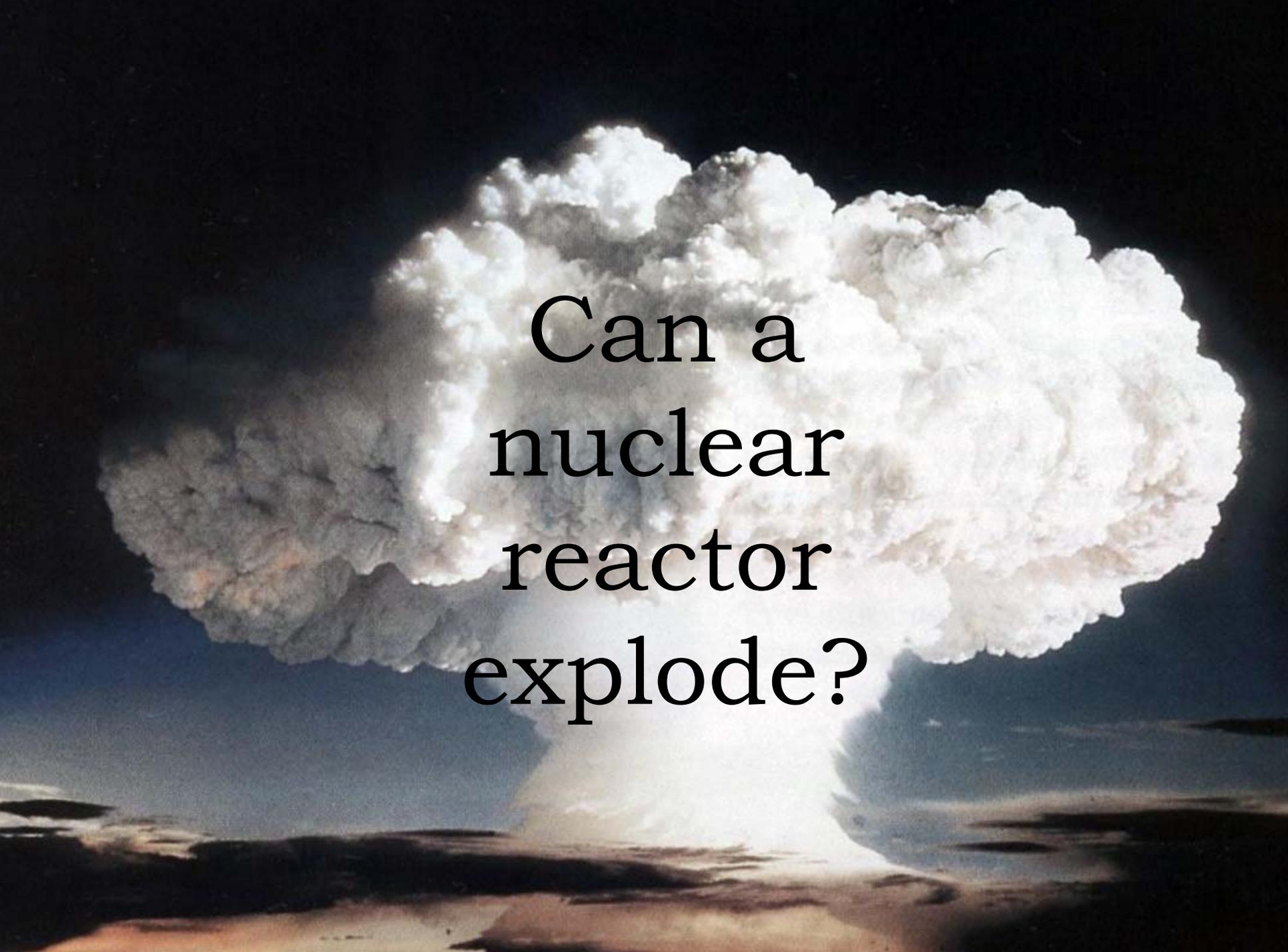


No CO<sub>2</sub> emissions.



A photograph of a nuclear reactor core. The image shows a complex structure of metal walkways and railings. Several workers wearing hard hats and safety gear are visible on the upper levels of the structure. The background is a large, dark, industrial space. The text is overlaid on the lower half of the image.

After five years, only six ounces of matter have been transformed into energy . . . but enough to power San Francisco.

A large, billowing mushroom cloud from a nuclear explosion, with a bright white core and a greyish outer layer, set against a dark sky and a dark, flat landscape below. The cloud is the central focus of the image.

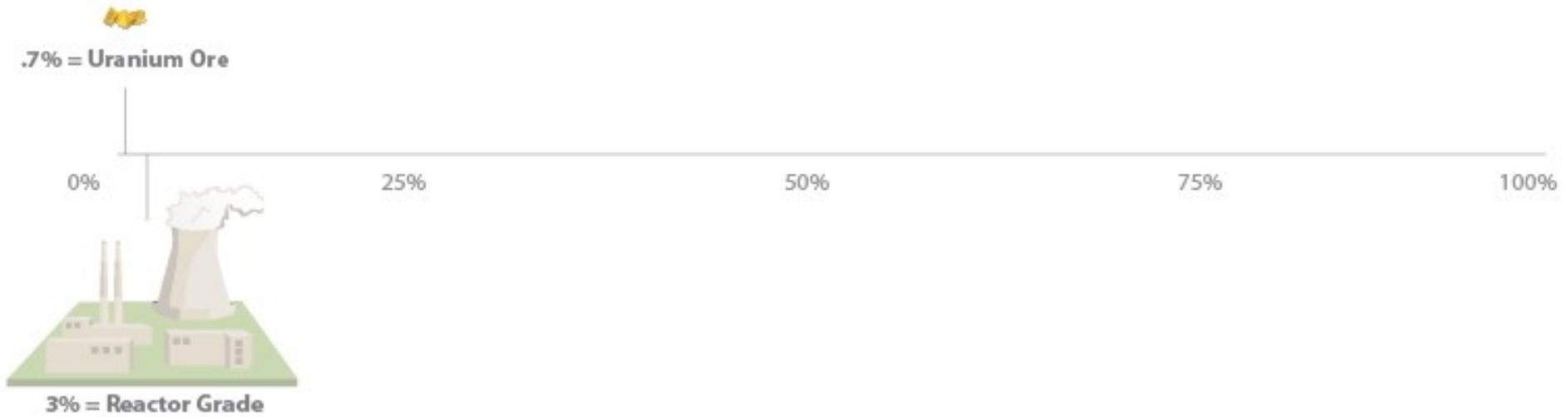
Can a  
nuclear  
reactor  
explode?



THE UNTHINKABLE

© THE LOS ANGELES TIMES - 1979

# Percent of U-235



## Percent of U-235 Content



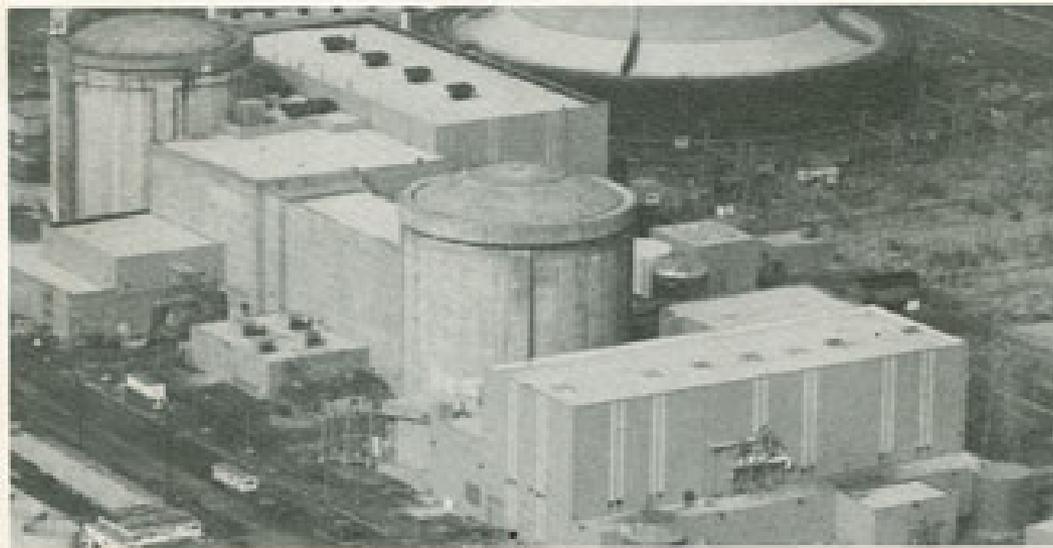
---

*Report Of*  
*The President's Commission On*

---

# THE ACCIDENT AT THREE MILE ISLAND

---



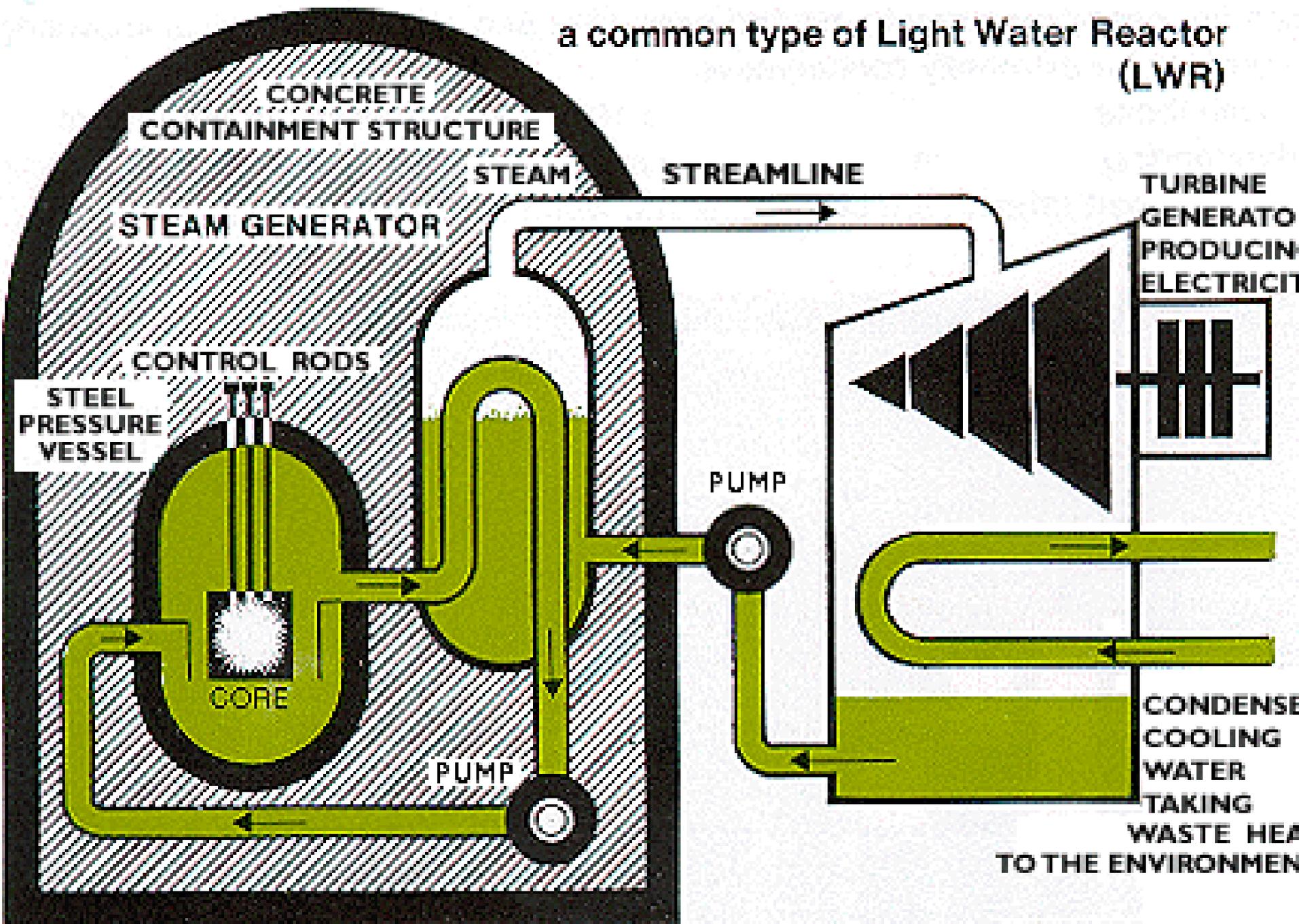
---

*The Need For Change:*  
*The Legacy Of TMI*

---

# Pressurized water reactor —

a common type of Light Water Reactor (LWR)





BELARUS

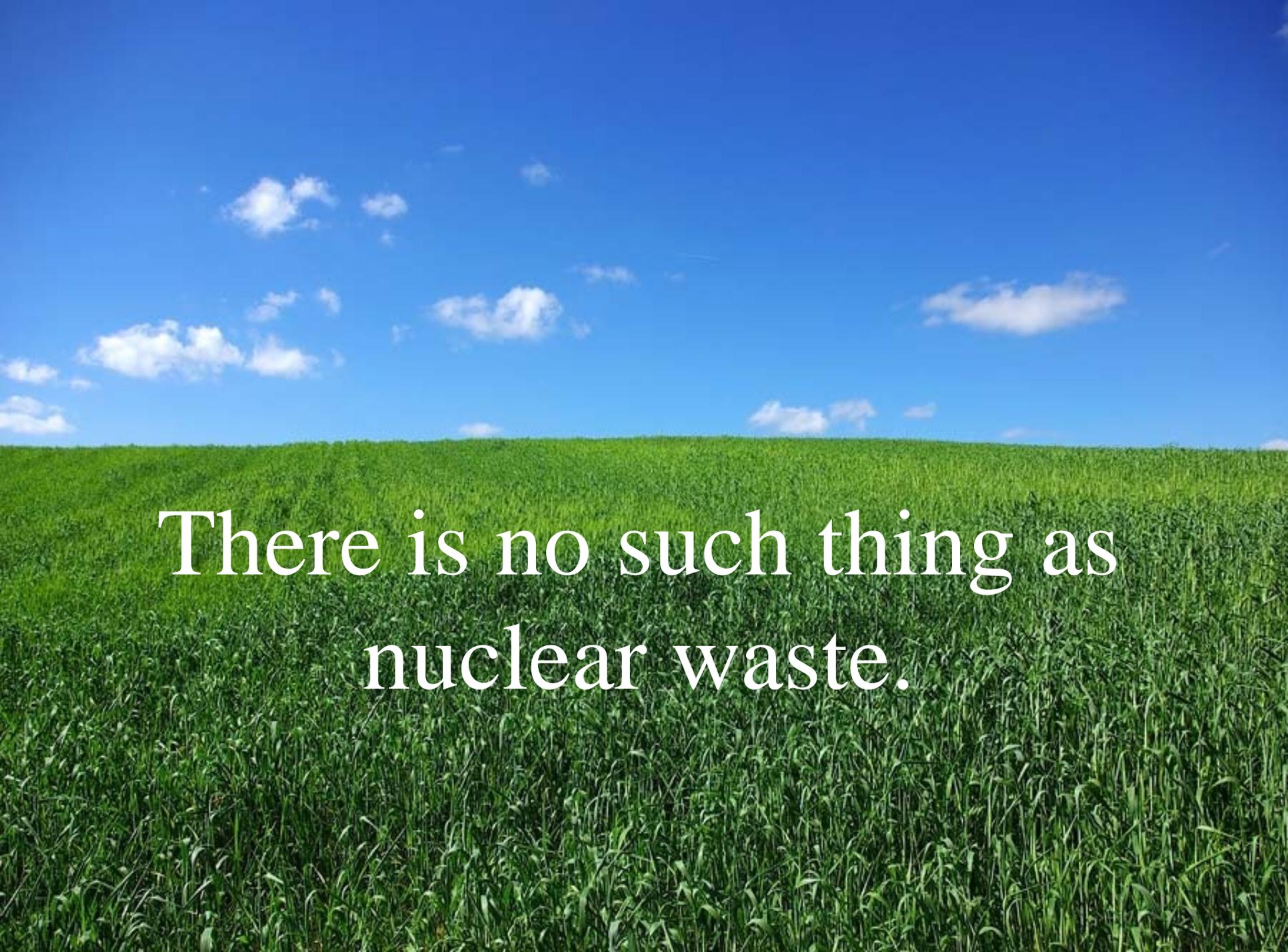
WOLVES LAND

UKRAINE

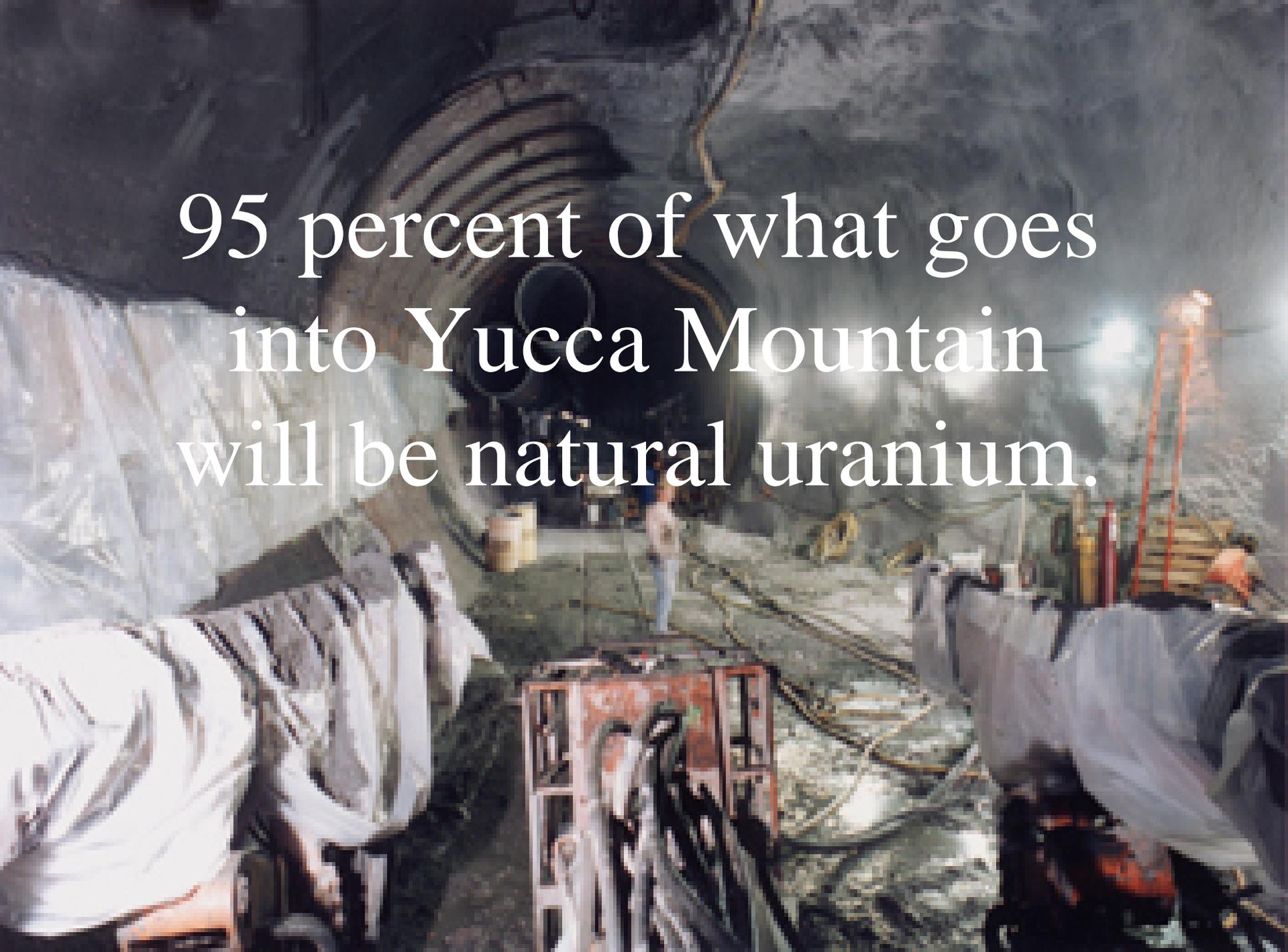
RUSSIA



“What are we  
going to do  
with the  
waste?”

A wide-angle photograph of a lush green field, likely corn, stretching to the horizon under a clear blue sky with scattered white clouds. The text is centered in the middle of the image.

There is no such thing as  
nuclear waste.

A photograph of a large underground tunnel under construction. The tunnel is dimly lit, with bright lights illuminating the work area. In the foreground, there are large pieces of machinery and equipment covered with white plastic sheeting. In the background, a person is visible standing near a large circular opening or tunnel entrance. The overall scene depicts a busy underground construction site.

95 percent of what goes  
into Yucca Mountain  
will be natural uranium.

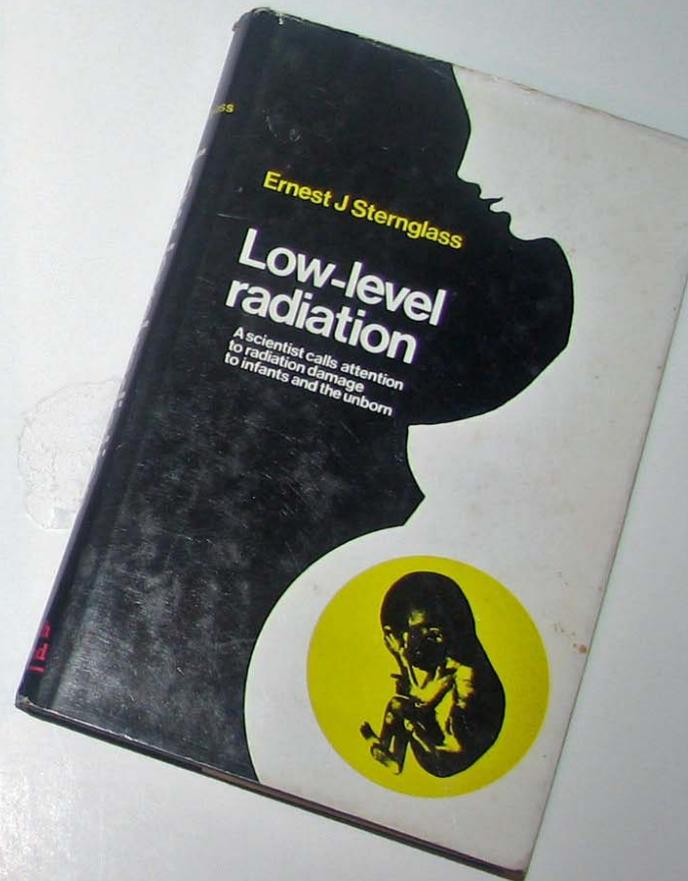
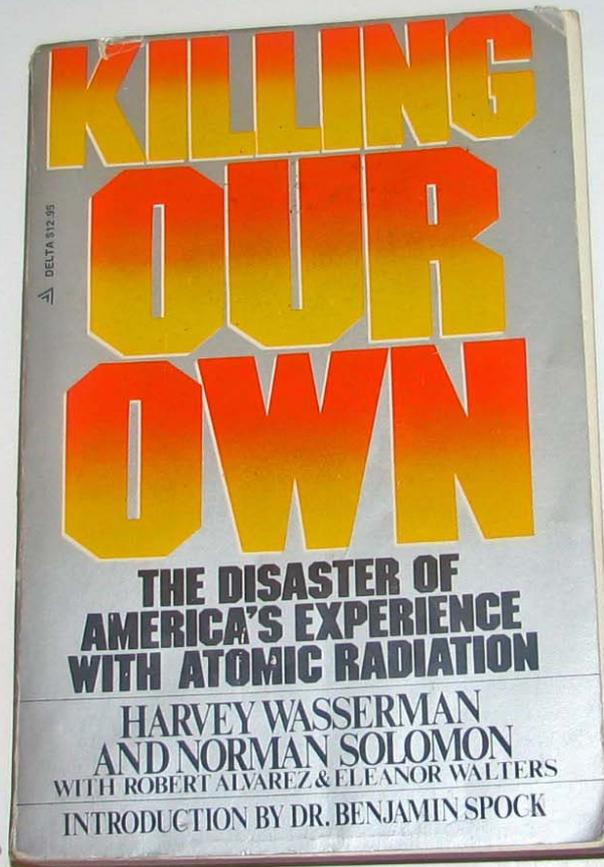
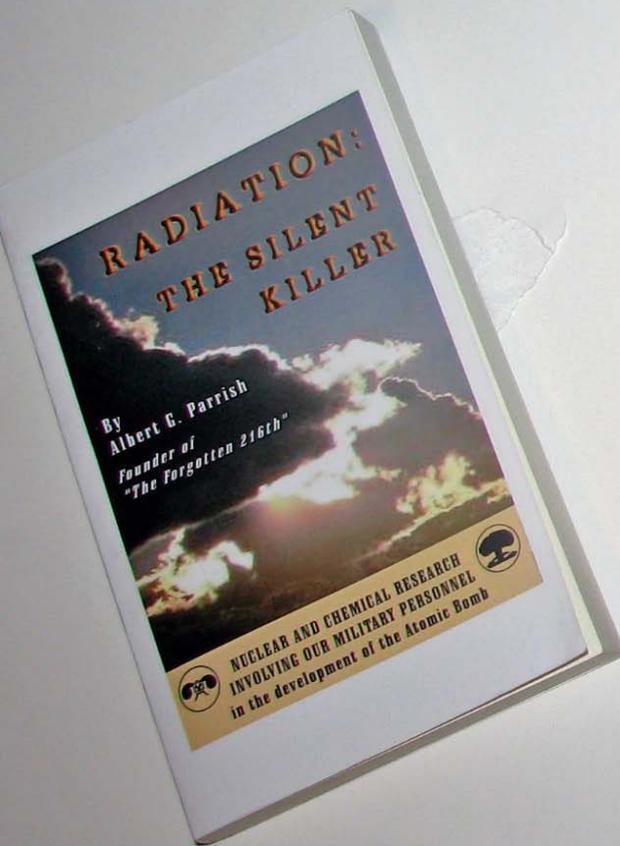
# Hippies versus Nazis

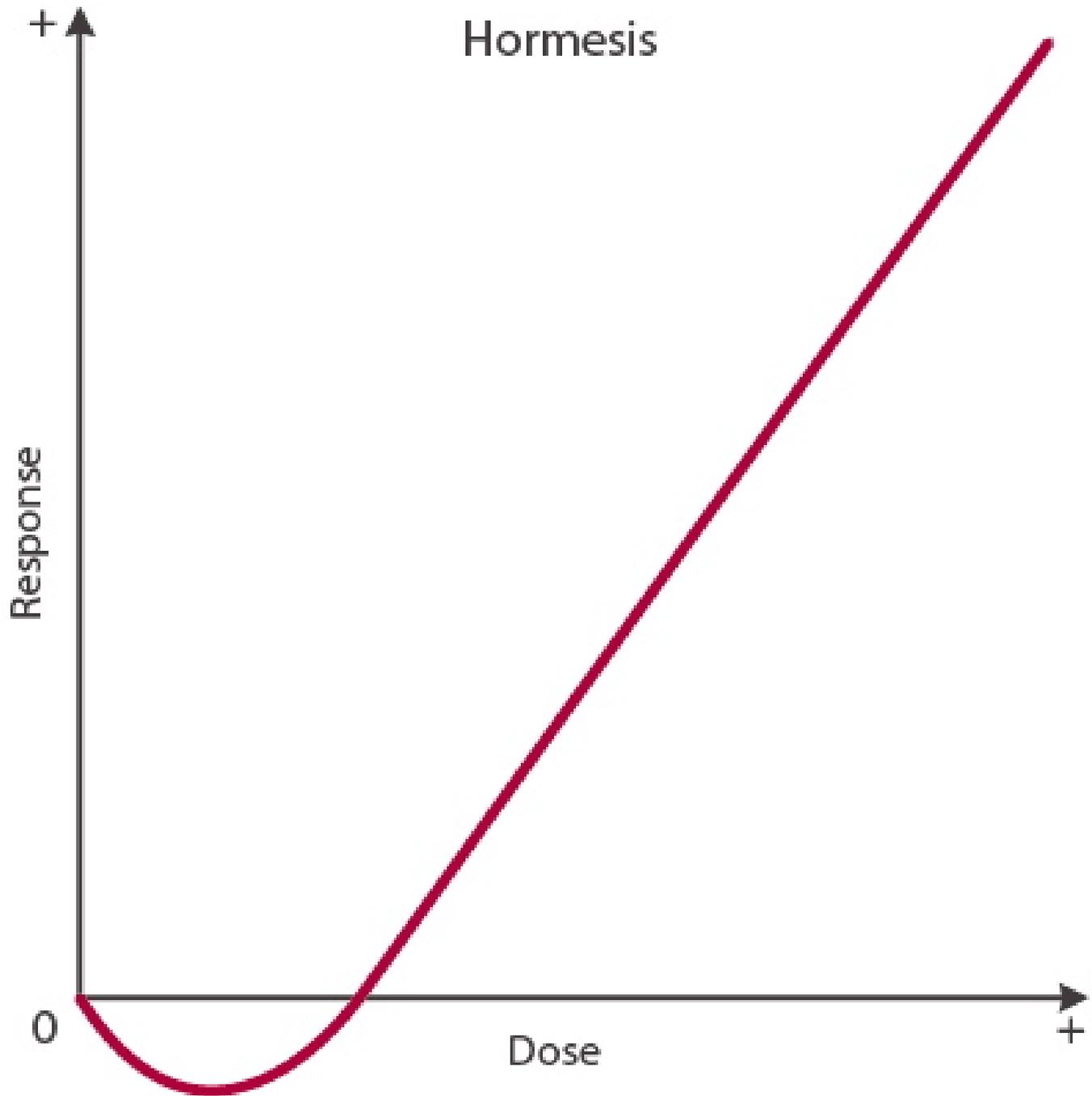












# “Is Chronic Radiation an Effective Prophylaxis Against Cancer?”

W.L. Chen, et al. Journal of American Physicians and Surgeons, Spring 2004

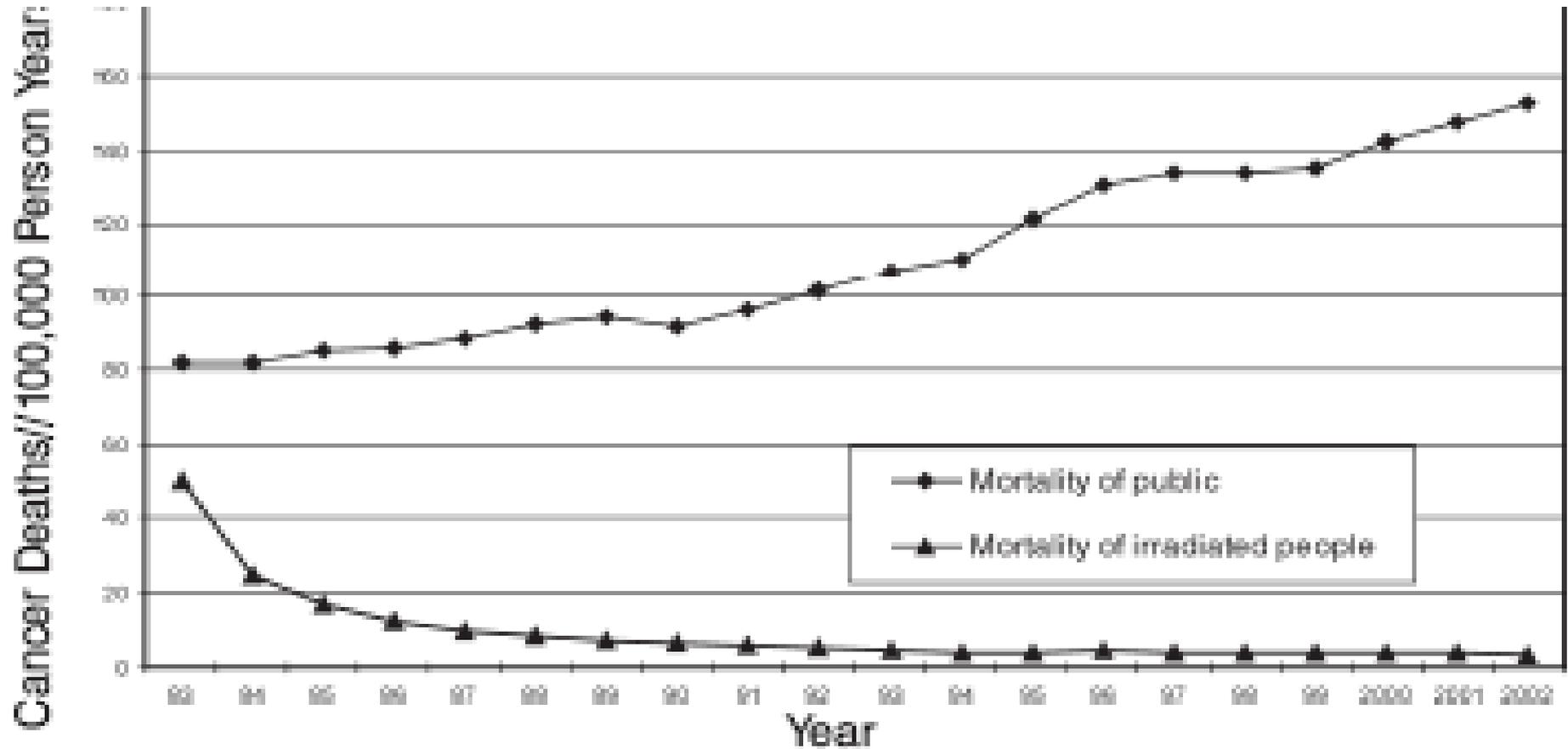
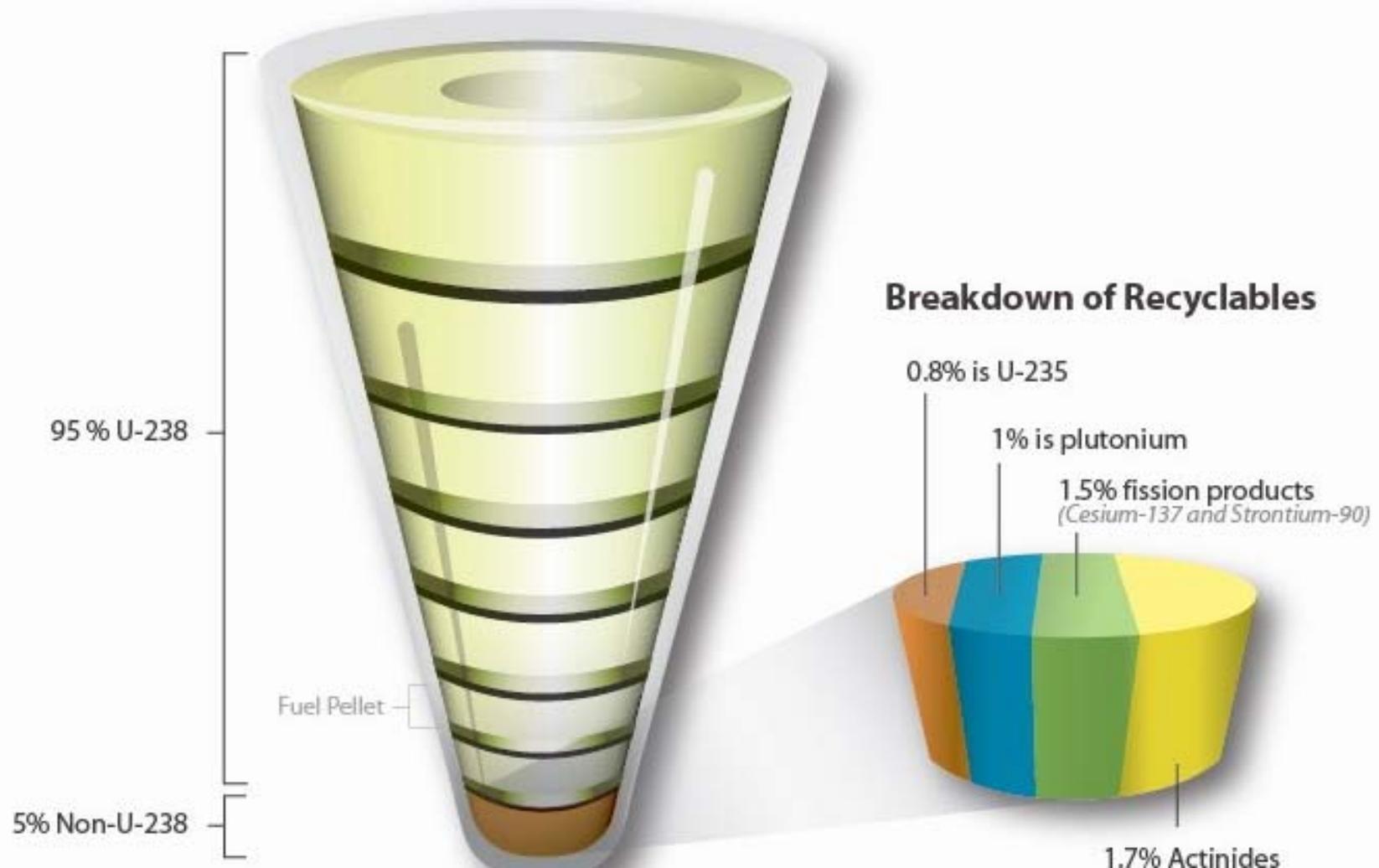


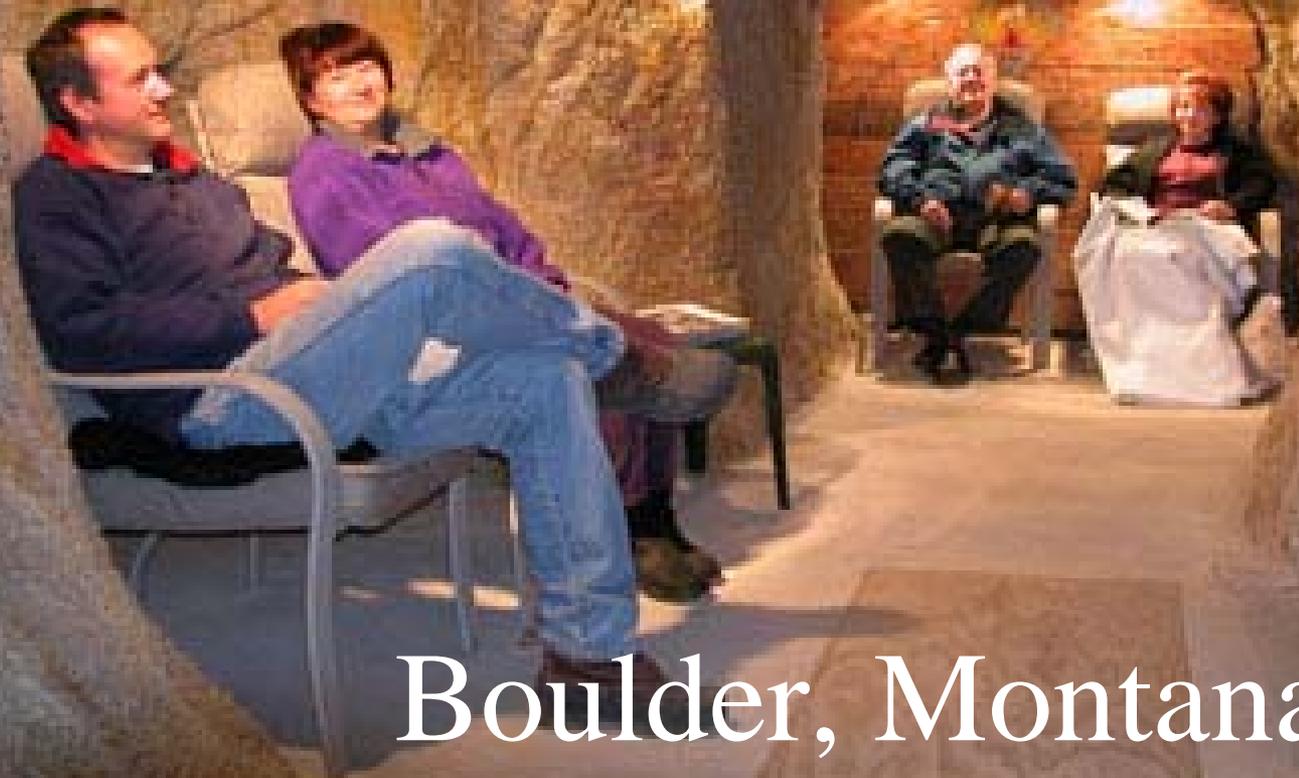
Figure 1. Cancer Mortality of the General Population and of the Exposed Population

# Reprocessing reduces nuclear waste by 97 percent.

Spent Fuel Rod



# Free Enterprise Radon Health Mine



Boulder, Montana

What are the  
problems  
with  
nuclear?



Centrifuges must run for more than a year to get bomb-grade material.

~~This document contains information relating to the National Defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sec. 793 and 794, and the transmission or revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

SECRET  
21.

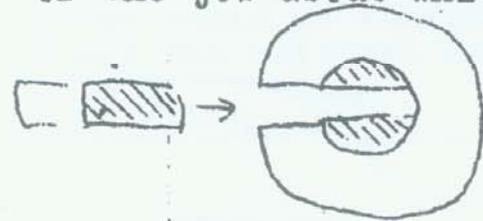
~~SECRET  
LIMITED~~

concentration of impurities in 25 may be  $10^4$  times that in 49 for the same background, which is not at all difficult of attainment.

To summarize: 49 will be extremely difficult to work with from the stand-point of neutron background whereas 25 without U tamper will be not very difficult.

20. Shooting

We now consider briefly the problem of the actual mechanics of shooting so that the pieces are brought together with a relative velocity of the order of  $10^5$  cm/sec or more. This is the part of the job about which we know least at present.



One way is to use a sphere and shoot into it a cylindrical plug made of some active material and some tamper, as in the sketch. This avoids fancy shapes and gives the

most favorable shape, for shooting; to the projected piece whose mass would be of the order of 100 lbs.

The highest muzzle velocity available in U. S. Army guns is one whose bore is 4.7 inches and whose barrel is 21 feet long. This gives a 50 lb. projectile a muzzle velocity of 3150 ft/sec. The gun weighs 5 tons. It appears that the ratio of projectile mass to gun mass is about constant for different guns so a 100 lb. projectile would require a gun weighing about 10 tons.

The weight of the gun varies very roughly as the cube of the muzzle velocity hence there is a high premium on using lower velocities of fire.

~~SECRET  
LIMITED~~  
Persons receiving this report are to be restricted to the information contained herein and are not to disseminate it to other persons without the express authorization of the same laboratory.



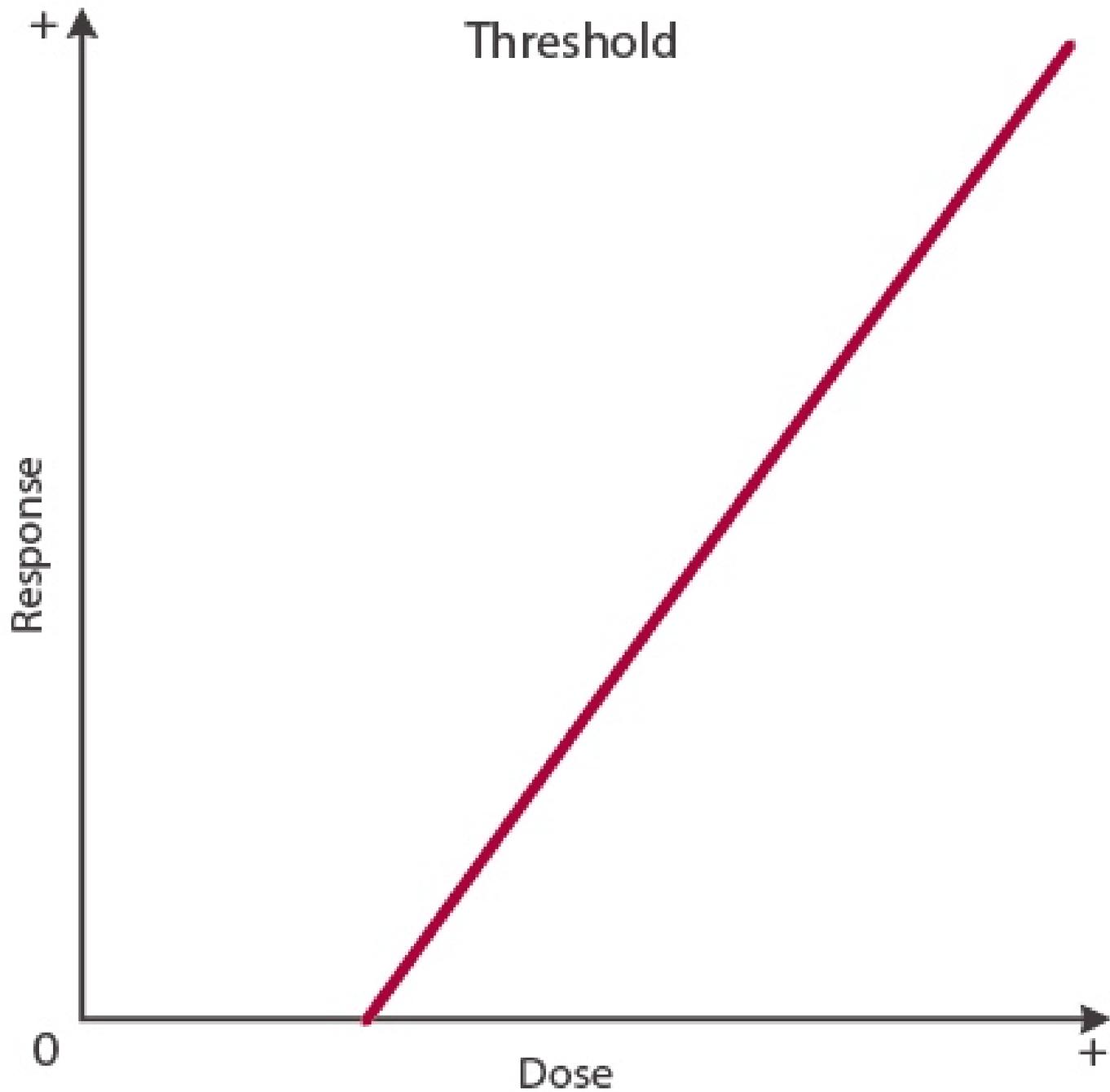




Radiation

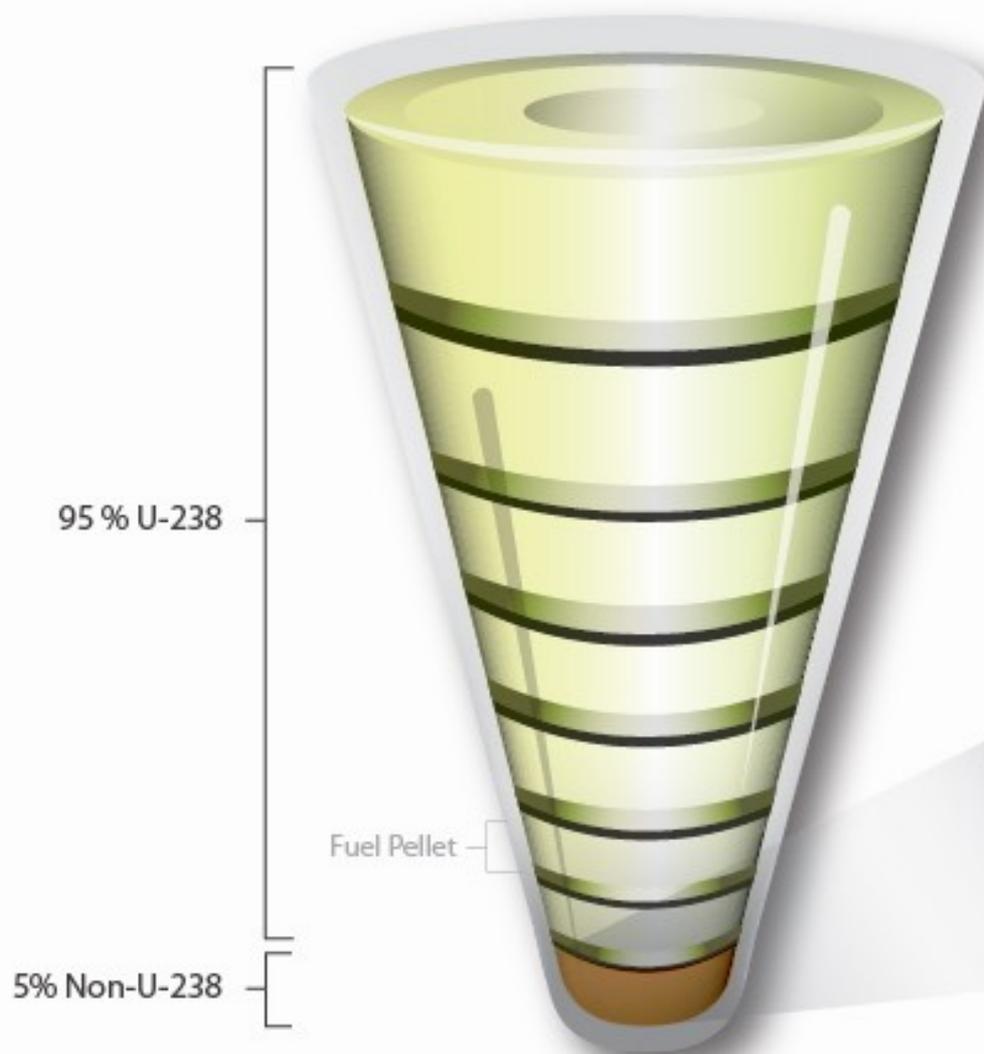
(not invented in  
1946)



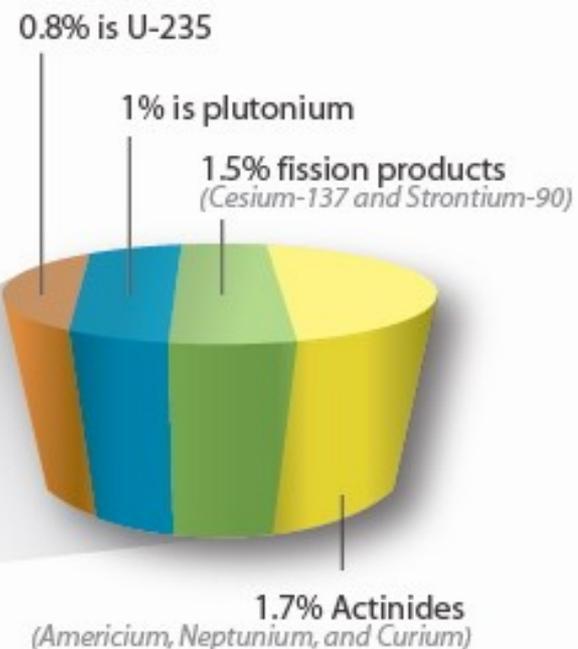


“What are we  
going to do  
with the  
waste?”

## Spent Fuel Rod

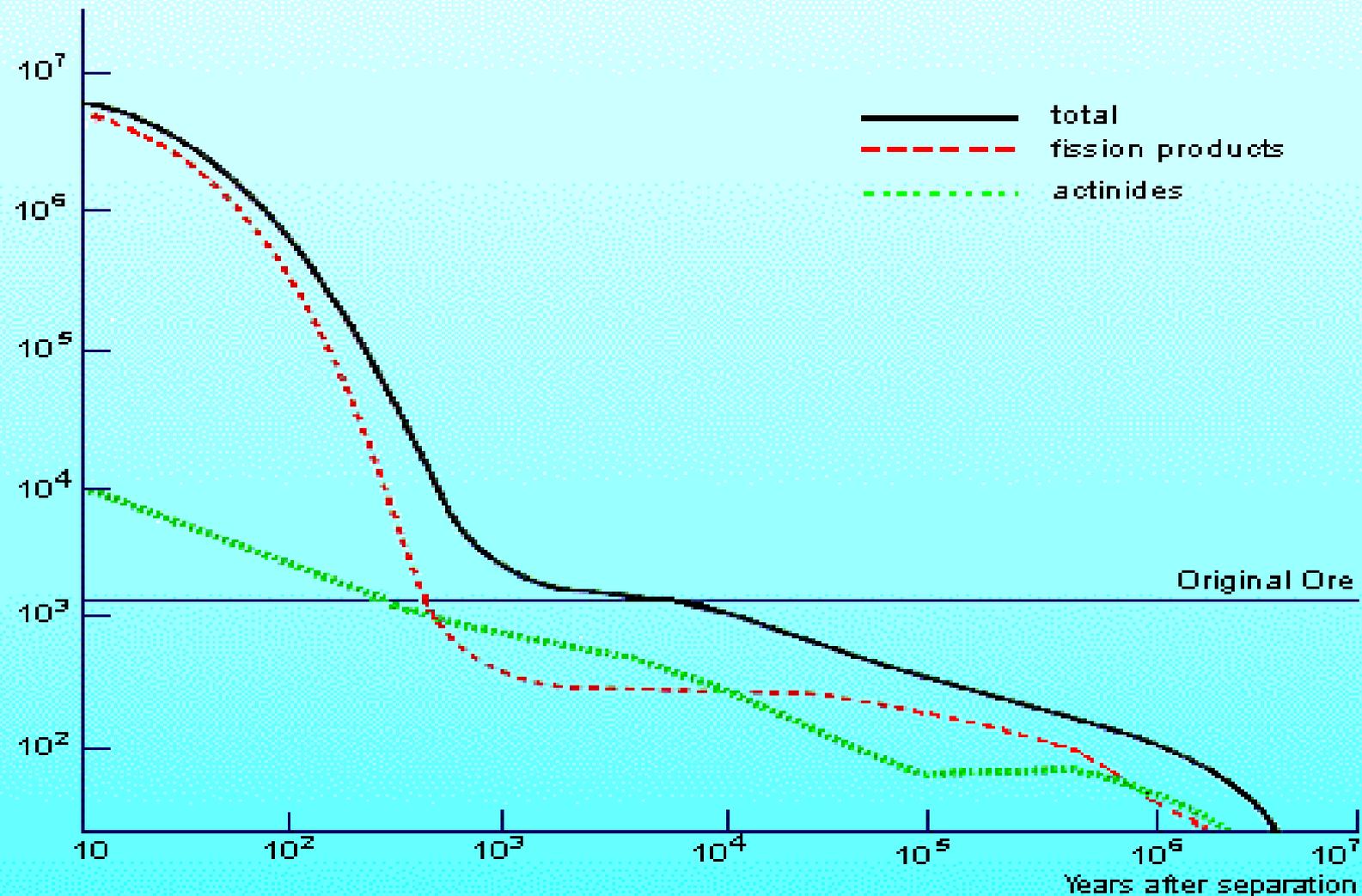


## Breakdown of Recyclables



# Decay in radioactivity of high-level waste from reprocessing one tonne of spent PWR fuel

Radioactivity (GBq)



Gbq =  $10^9$  becquerel

The straight line shows the radioactivity of the corresponding amount of uranium ore.

NB both scales are logarithmic.

Source: OECD NEA 1996, *Radioactive Waste Management in Perspective*.



# Nuclear France:

*materials and sites*

---

MARY BYRD DAVIS

# Hippies versus Nazis



**BIG COAL**

“ . . . whatever coal’s environmental problems are, at least coal plants are not going to melt down into some radioactive nightmare or increase the risk that some Middle Eastern terrorist will get his hands on a few ounces of uranium.”

**Jeff Goodell**



Nuclear's biggest supporter.

# Reactors Prone to Long Closings, Study Finds

By MATTHEW L. WALD

WASHINGTON, Sept. 17 — An analysis of nuclear reactors by a safety group has found that they are prone to costly, lengthy shutdowns for safety problems regardless of their age or the experience of their managers. The finding could have implications for companies considering building new reactors.

The analysis, by David Lochbaum, a nuclear engineer at the Union of Concerned Scientists, counted 51 times that a reactor had been closed for a year or more. Thirty-six of those shutdowns were to restore an adequate level of safety by fixing flaws in equipment, procedures or training; 11 were to replace major components required for operations and safety; and 4 were for damage recovery. In all, of the 130 power reactors ever licensed, 41, were closed for at least a year. Ten were closed twice.

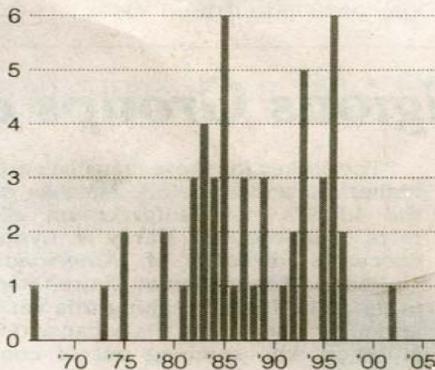
Mr. Lochbaum said the most common reason for a shutdown was for an "attitude adjustment" for workers and managers, so they would be more attuned to safety. He said he was surprised by some of his findings, which are scheduled to be released Monday. "I expected that the first plant off an assembly line would have been challenged, or troubled, but that there was a learning curve, and the fourth or fifth or sixth plant for a company would have avoided these problems," he said. "But it wasn't the case."

But a vice president of the industry's trade association, Marvin Fertell of the Nuclear Energy Institute, said that the industry had, in fact, learned from its errors, and that only experienced operators would build new plants. And at the Nuclear Regulatory Commission, Stuart A. Richards, deputy director of the division of inspection, said his agency had improved its inspections, to focus on "risk-significant areas," and was now able to find problems more promptly.

Extended shutdowns would be a bigger problem for future plants be-

## Reactors on Ice

Number of nuclear reactors shut down for more than a year, plotted by the year the shutdown began.



Source: Union of Concerned Scientists

The New York Times

shutdown.

"This is the wrong way to do business, from a safety standpoint and an economic standpoint," he said in a telephone interview.

Mr. Fertell, of the industry trade group, agreed.

The only reactor currently in an extended shutdown is the Tennessee Valley Authority's Browns Ferry Unit 1, in Alabama. It last ran in 1985. The shutdown of more than a year that ended most recently was at Davis-Besse, near Toledo, Ohio, where workers found that an acid used in

**Persistent safety problems are found at nuclear plants of every age.**

the plant, boron, had corroded a 70-

gineers later found that crucial pumps that used water for lubrication were prone to break down because of debris in the water. Discovery of decades-old design problems is common during lengthy shutdowns.

While Mr. Lochbaum, a longtime adversary of the nuclear industry, is often critical of the companies that operate reactors, he said regulators were the problem in this area. The rules require reactors to have Corrective Action Programs to keep track of physical and procedural problems, and each lengthy shutdown is an indication that the program itself is flawed, he said. Regulators monitor the physical condition of reactors, he said, but are not good at observing the quality of the corrective programs. For example, the commission gave high marks to the program at Davis-Besse less than a year before inspectors found that operators had let acid eat through six inches of steel, bringing the plant close to a catastrophic rupture.

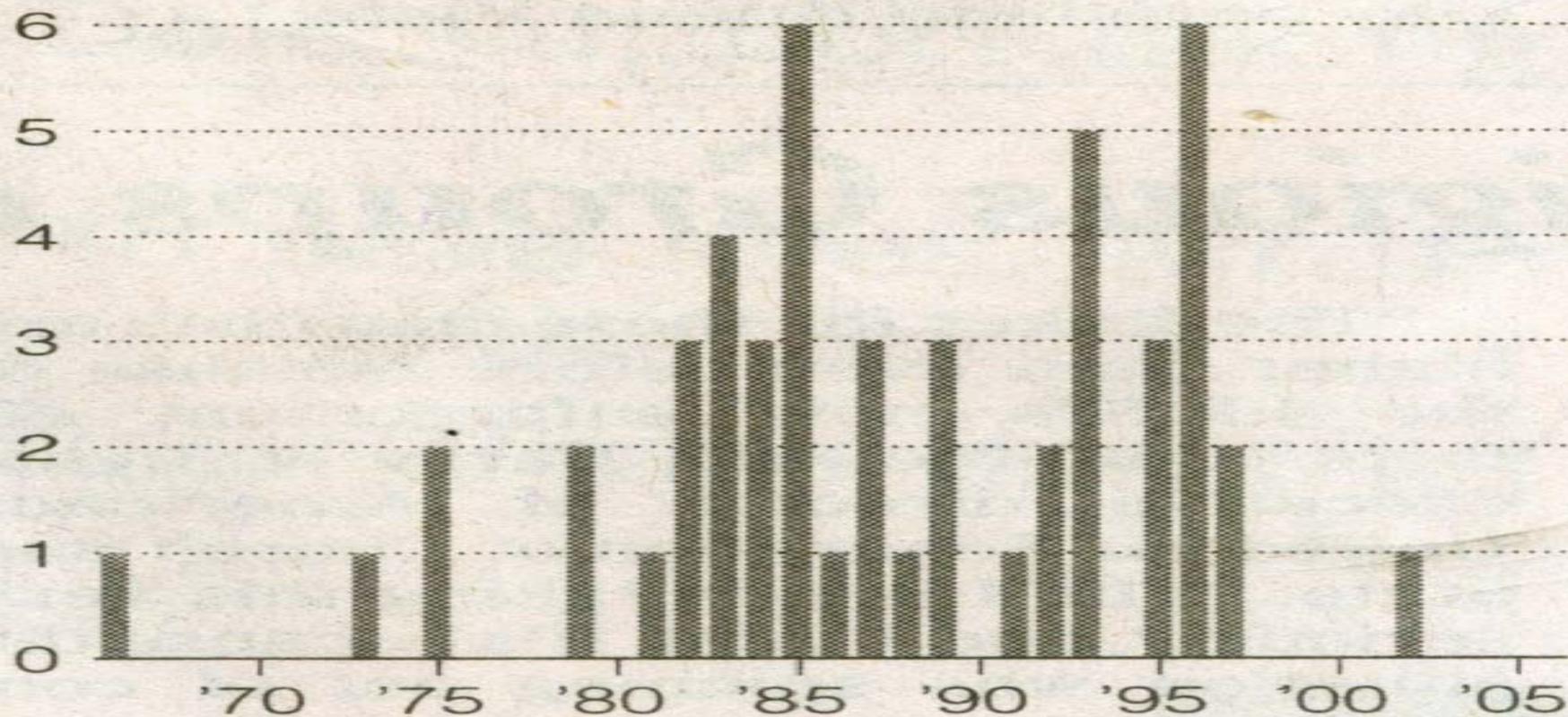
Mr. Richards said he had not seen the report but acknowledged errors by the commission in handling the Davis-Besse case. But he said N.R.C. inspections had been improved using a new process, of which the Corrective Action Program itself was a major component. And, he said, the commission had previously penalized reactors for accumulations of minor violations, adding them up to count for a major problem; now it focuses only on major problems.

Mr. Lochbaum said that after a reactor was shut down for one reason, other problems were often discovered. In an extended shutdown at the Crystal River plant, in Florida, workers found design defects even though the plant had been running for nearly 20 years. He said the problems included that, in an emergency, the pumps would not have worked as intended and piping would have exposed workers and the public to radiation.

"Did the plant's owner bring in

# Reactors on Ice

Number of nuclear reactors shut down for more than a year, plotted by the year the shutdown began.



Source: Union of Concerned Scientists



*Entergy*®

THE POWER OF PEOPLE™



**Duke  
Energy**®



Progress Energy

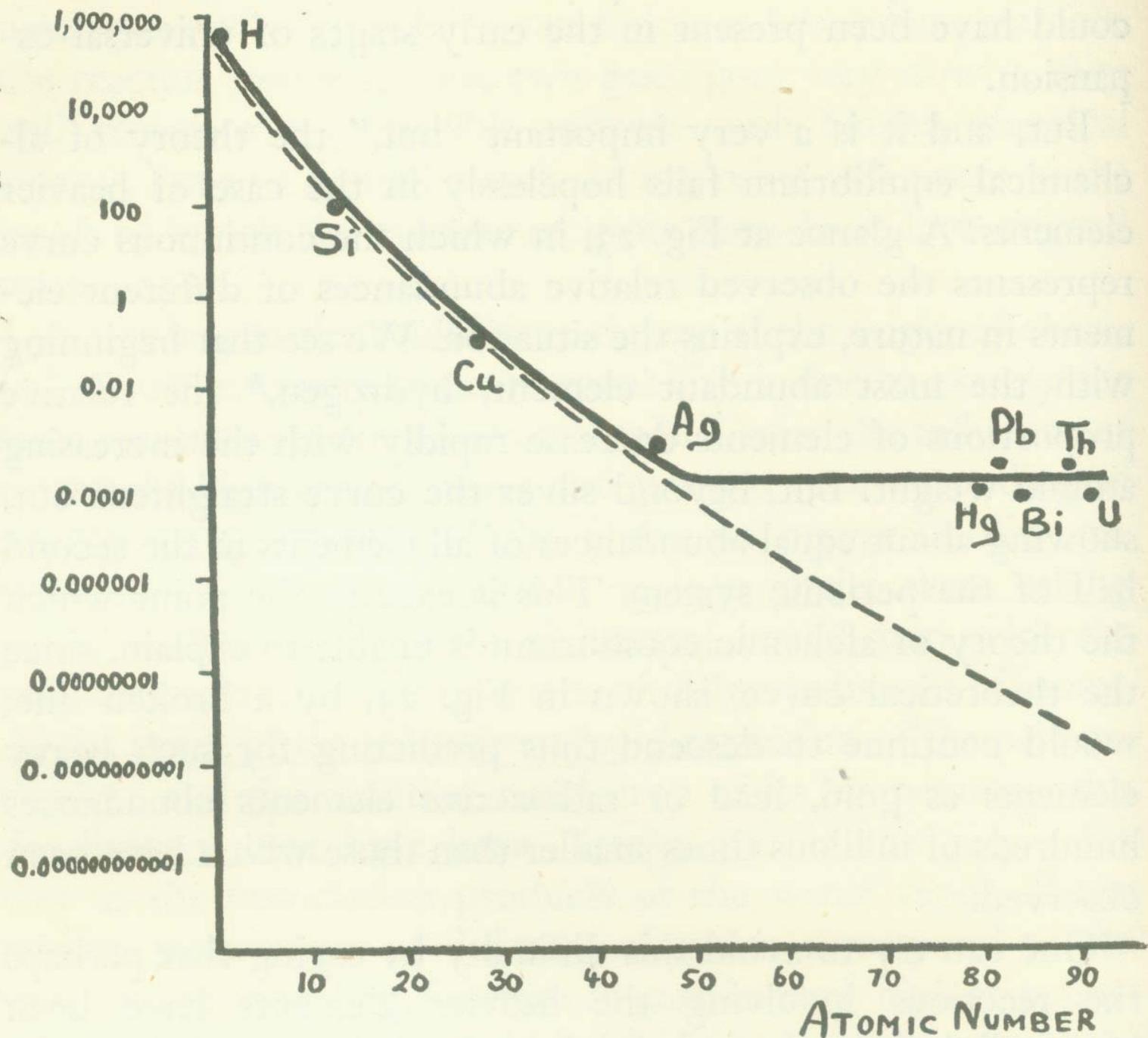


**Dominion**®  
It all starts here.®

**Exelon**®

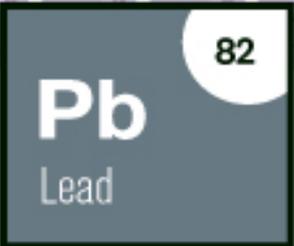
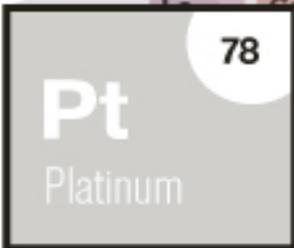
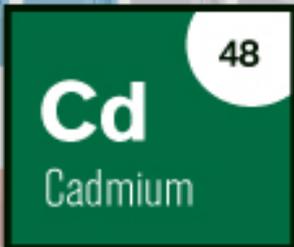
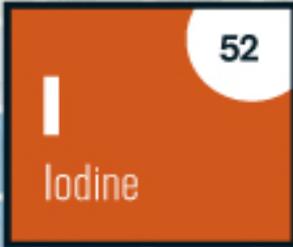
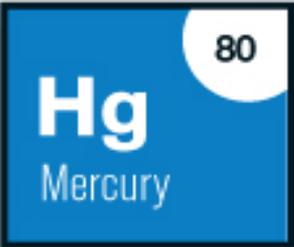
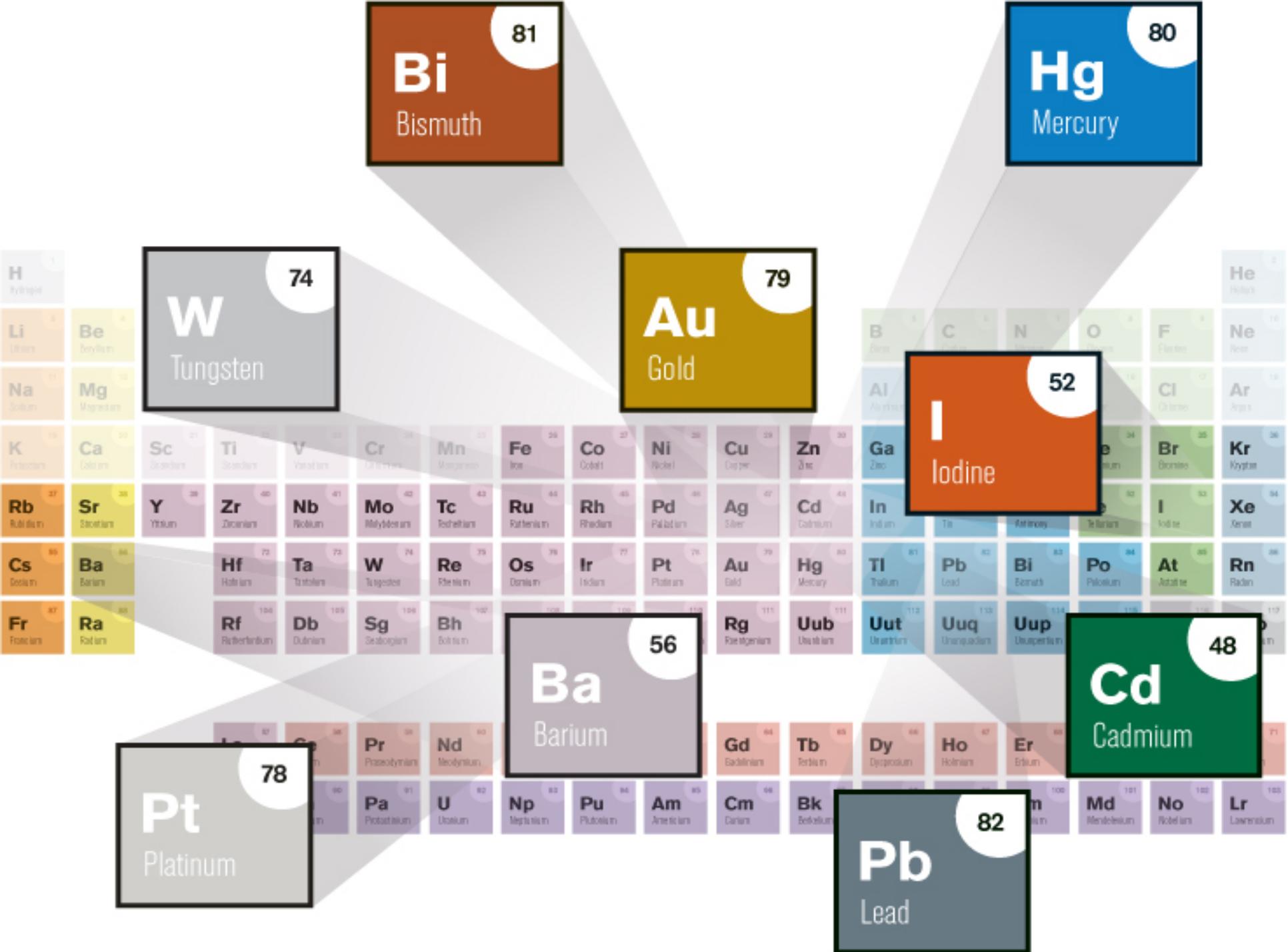
**Where does all this  
energy come from?**

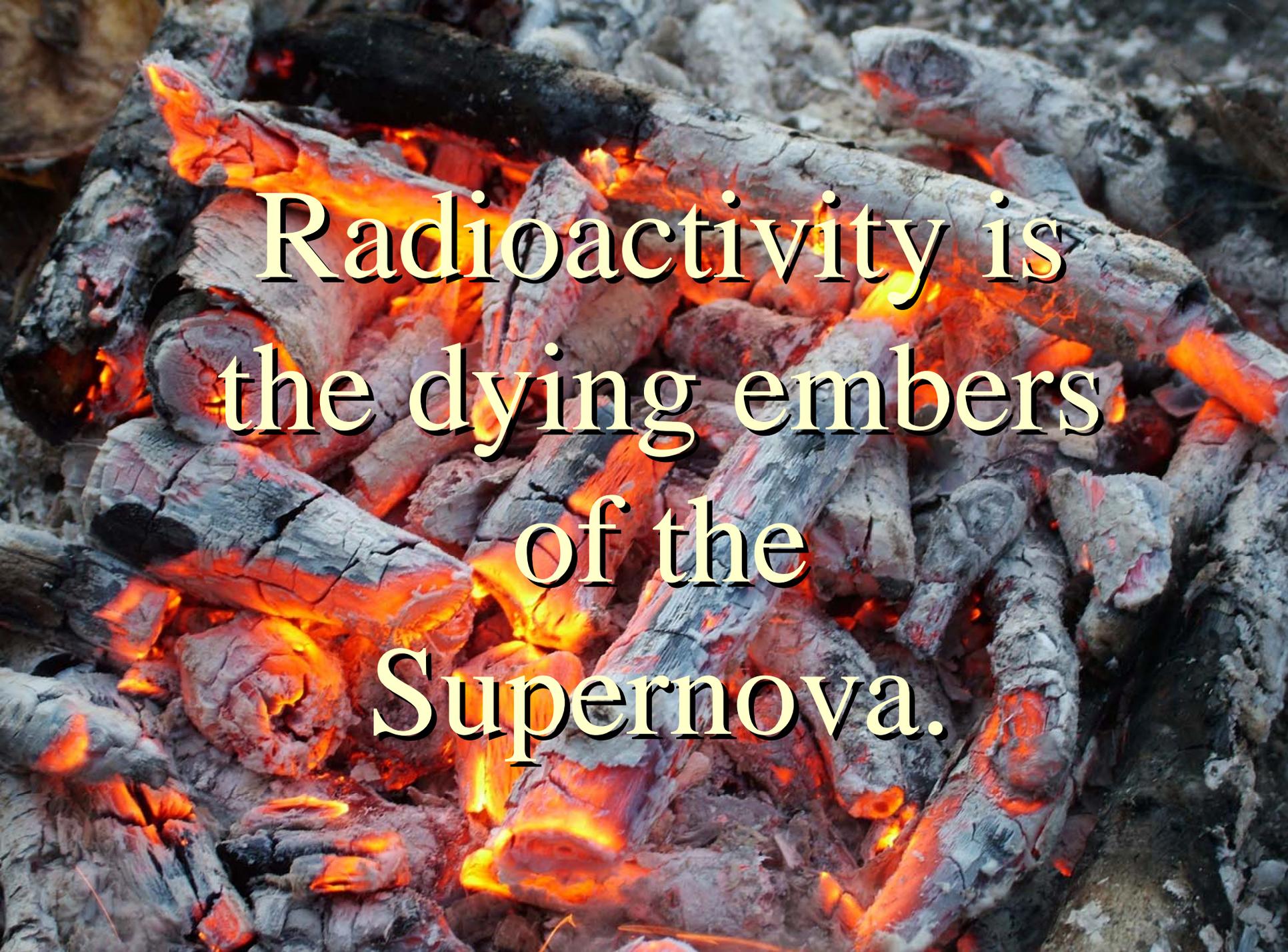




# Supernova!

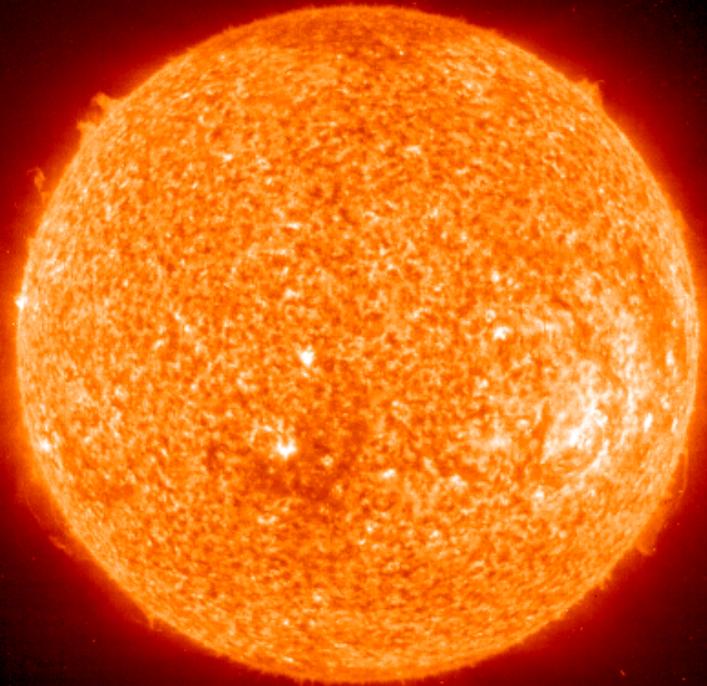
The seeds of our solar system.





Radioactivity is  
the dying embers  
of the  
Supernova.

# The Marriage of Heaven and Earth



9/30/2009 Energy for the 21<sup>st</sup> Century.



•

Following slides are  
excess

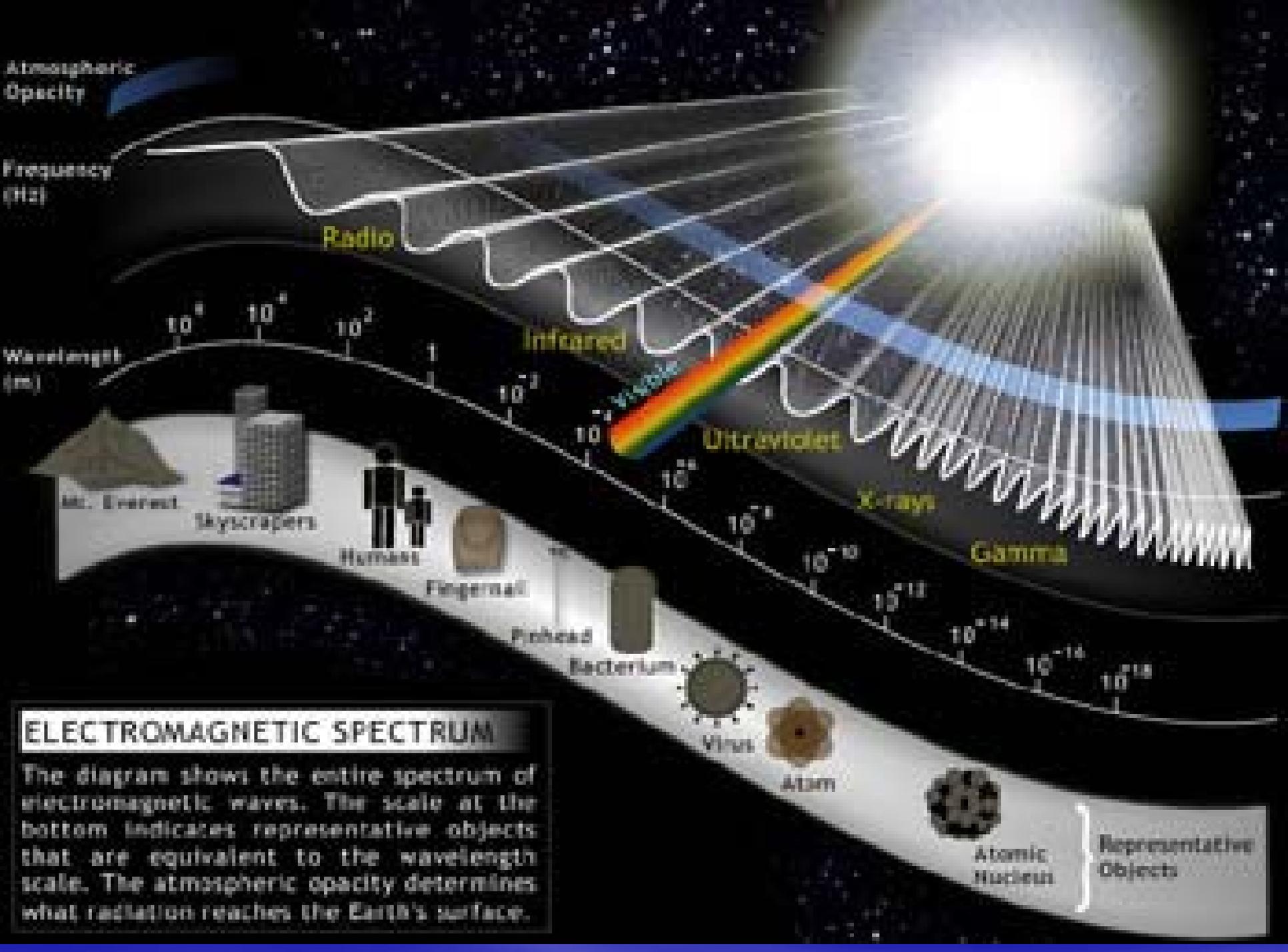












## ELECTROMAGNETIC SPECTRUM

The diagram shows the entire spectrum of electromagnetic waves. The scale at the bottom indicates representative objects that are equivalent to the wavelength scale. The atmospheric opacity determines what radiation reaches the Earth's surface.

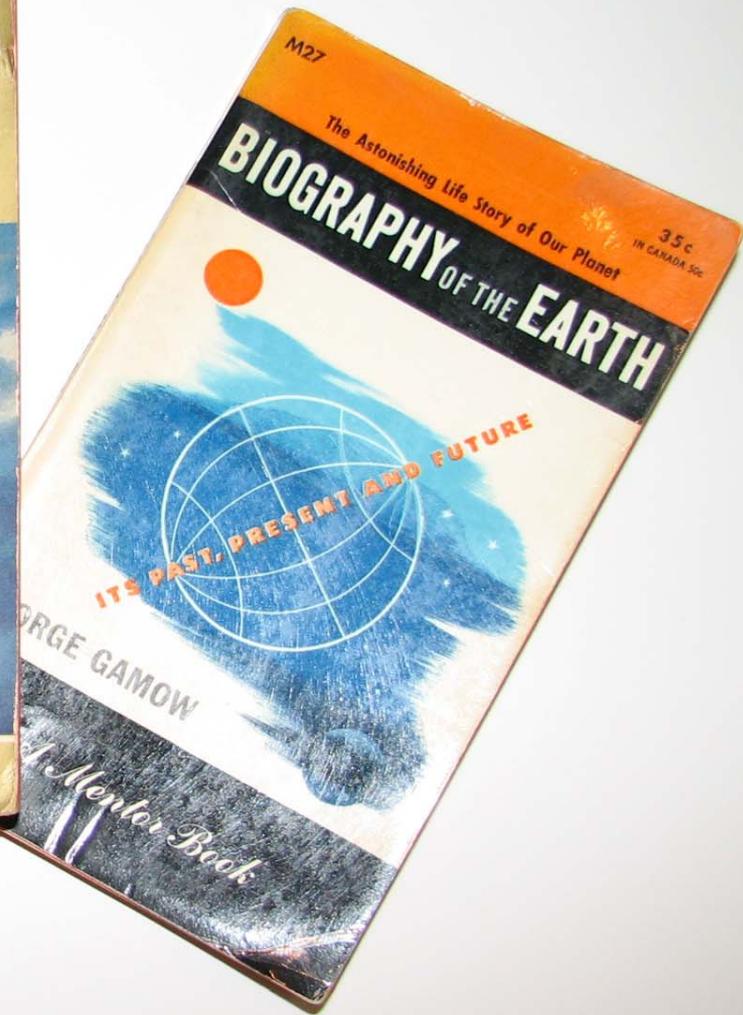
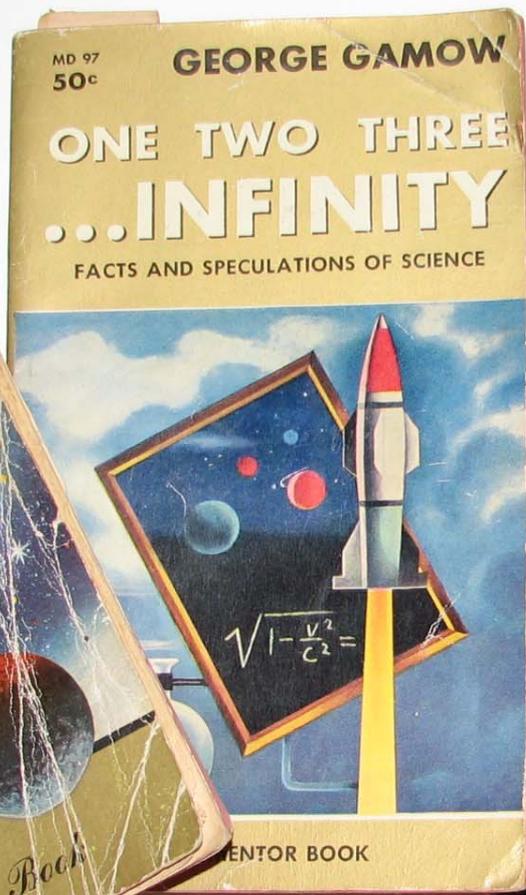
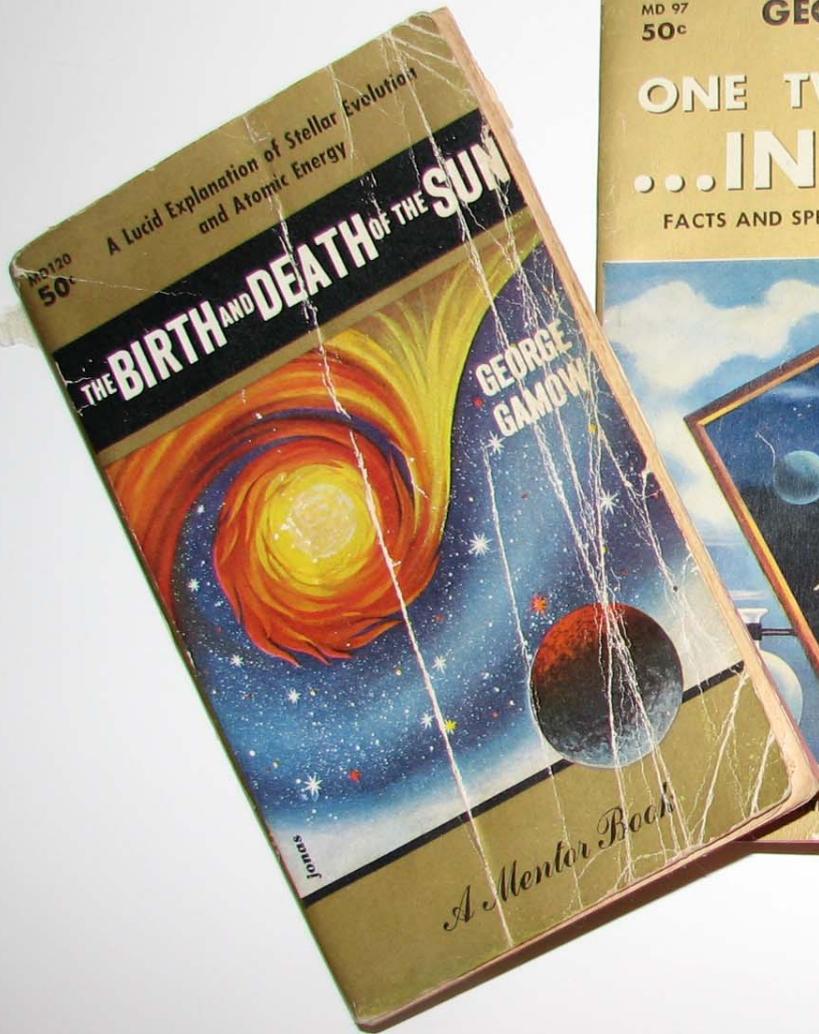
Representative Objects

$$E = mc^2$$

$$E = \frac{1}{2} mv^2$$

# George Gamow, 1904-1968





THE THEORY OF THE SUN

which, held by the gravitational attraction of the central body, were forced to revolve around the Sun in the form of separate planets.

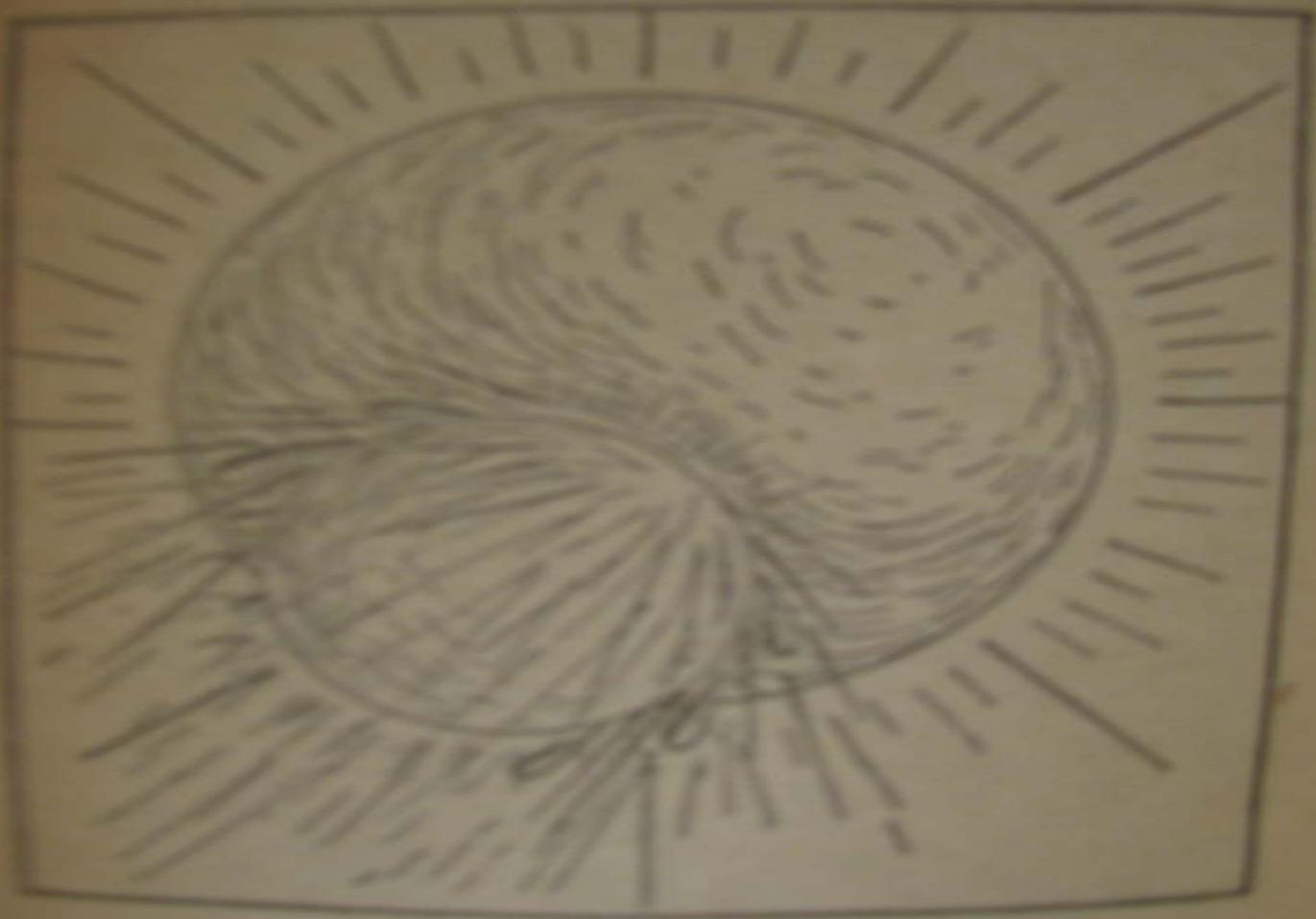


Diagram 2  
The relation between the Sun and a passing star (after Kelvin).  
This would explain in a satisfactory manner why all the planets of our system are in the same plane.



Room temperature  $\sim 1/40^{\text{th}}$  electron-volt

Photon  $\sim 1.77\text{-}3.10$  electron-volts

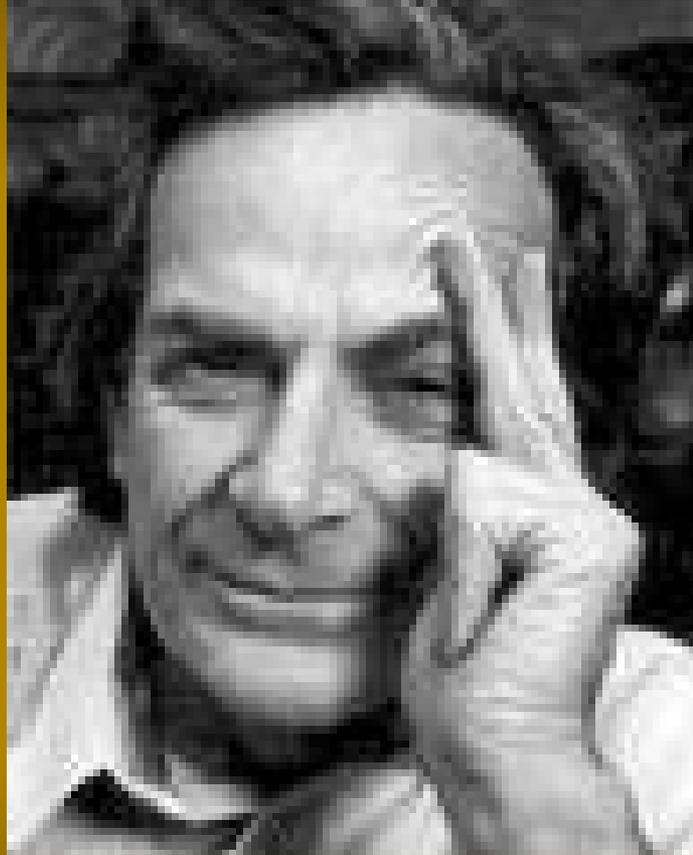
Chemical bonds  $\sim 1$  electron-volt





When matter is  
completely  
transformed into  
energy it becomes . . .

# Richard Feynman - 1918 - 1988



“There’s Plenty of Room at the Bottom.”

50 mph = 74 feet/sec

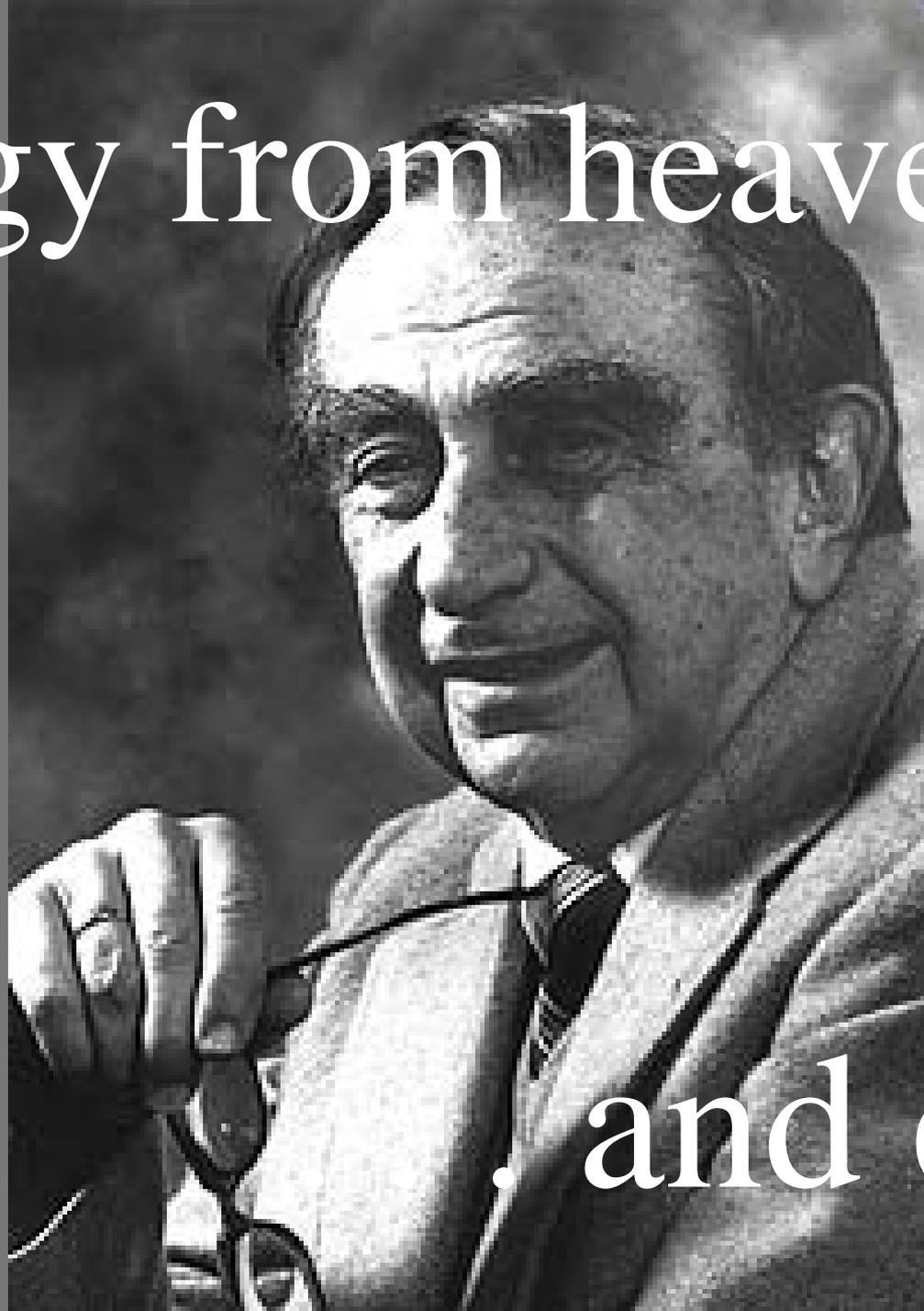
$5.4 \times 10^3$  feet/sec<sup>2</sup>

186,000 miles/sec

$9.8 \times 10^{17}$  feet/sec<sup>2</sup>

Factor of 180 quintillion

Energy from heaven . . .



. and earth.



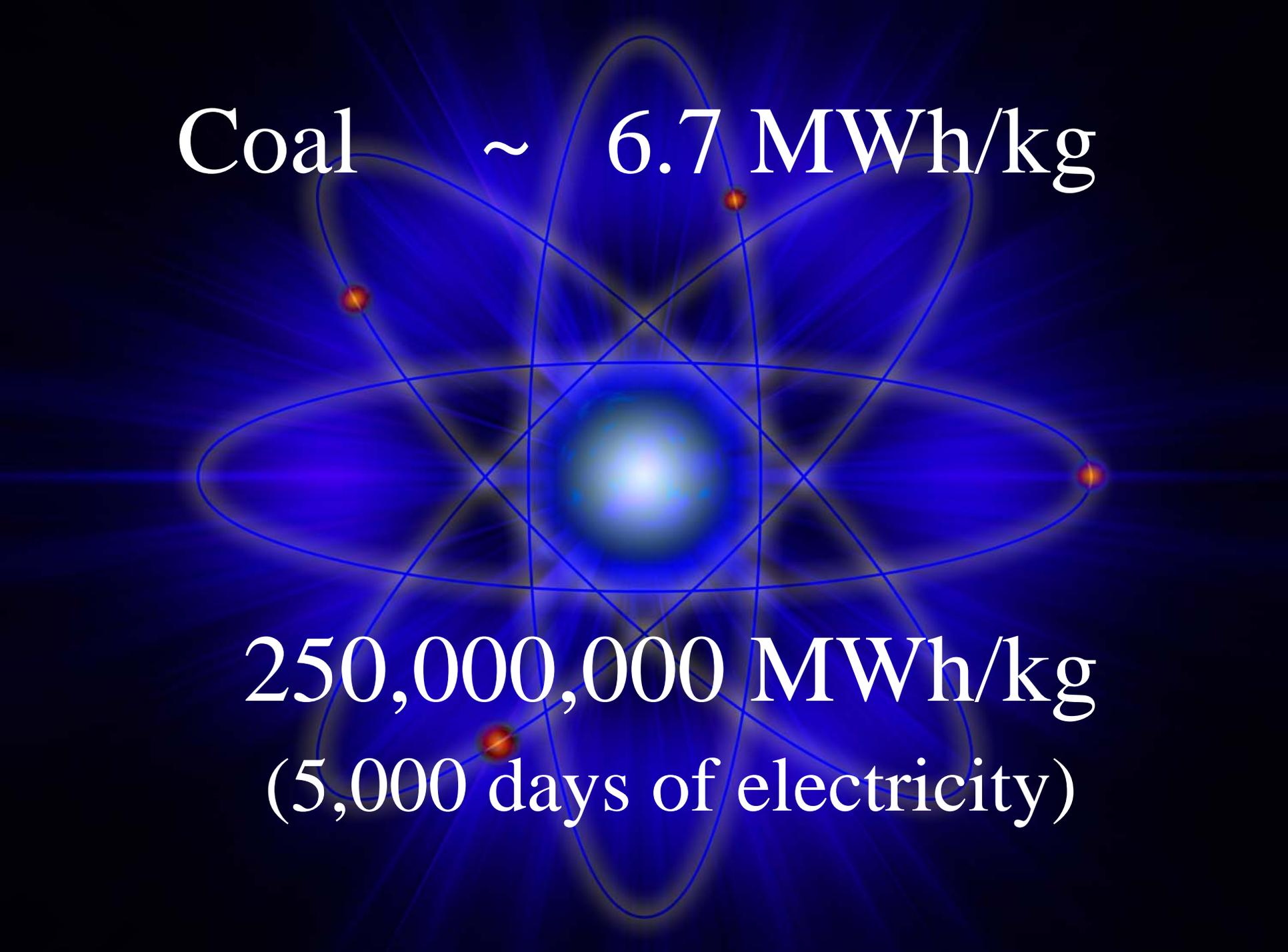
A close-up photograph of a lit matchstick. The matchstick is positioned vertically, with its head at the bottom and the flame extending upwards and to the left. The flame is bright orange and yellow, with a textured, diamond-patterned surface on the matchstick head. The background is solid black, making the fire stand out prominently.

*A World Lit  
Only By Fire . .*

Things have changed . . .

. since the industrial revolution.





Coal ~ 6.7 MWh/kg

250,000,000 MWh/kg  
(5,000 days of electricity)

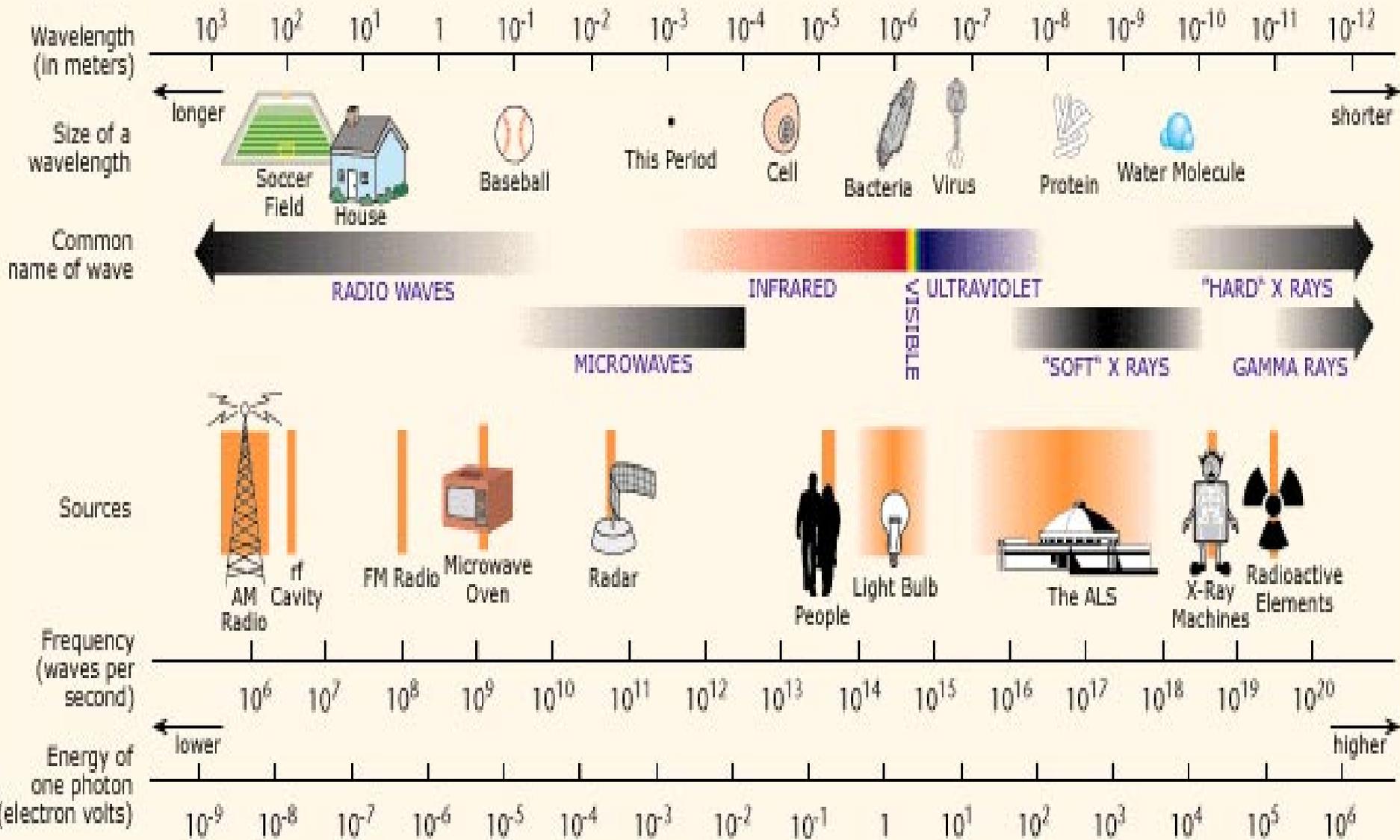
One carbon bond = 1 eV

One photon ~ 1-2 eV

One uranium atom =

200,000,000 eV

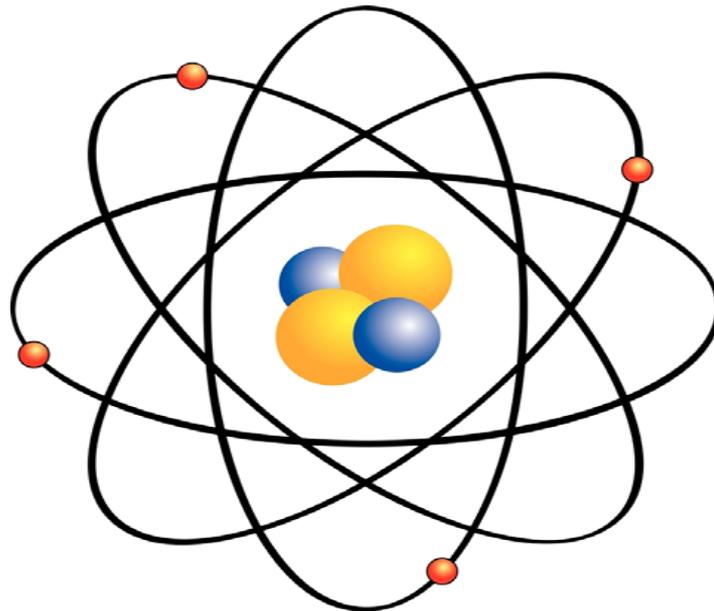
# THE ELECTROMAGNETIC SPECTRUM





First tamed  
700,000 years ago.

Only 1/1800<sup>th</sup> of the mass is in the electrons.



Mass of electron -  $9.109 \times 10^{-31}$  kg

Mass of proton -  $1.673 \times 10^{-27}$  kg

9/30/2009 Mass of neutron -  $1.675 \times 10^{-27}$  kg

$E = mc^2$

\_\_\_\_\_