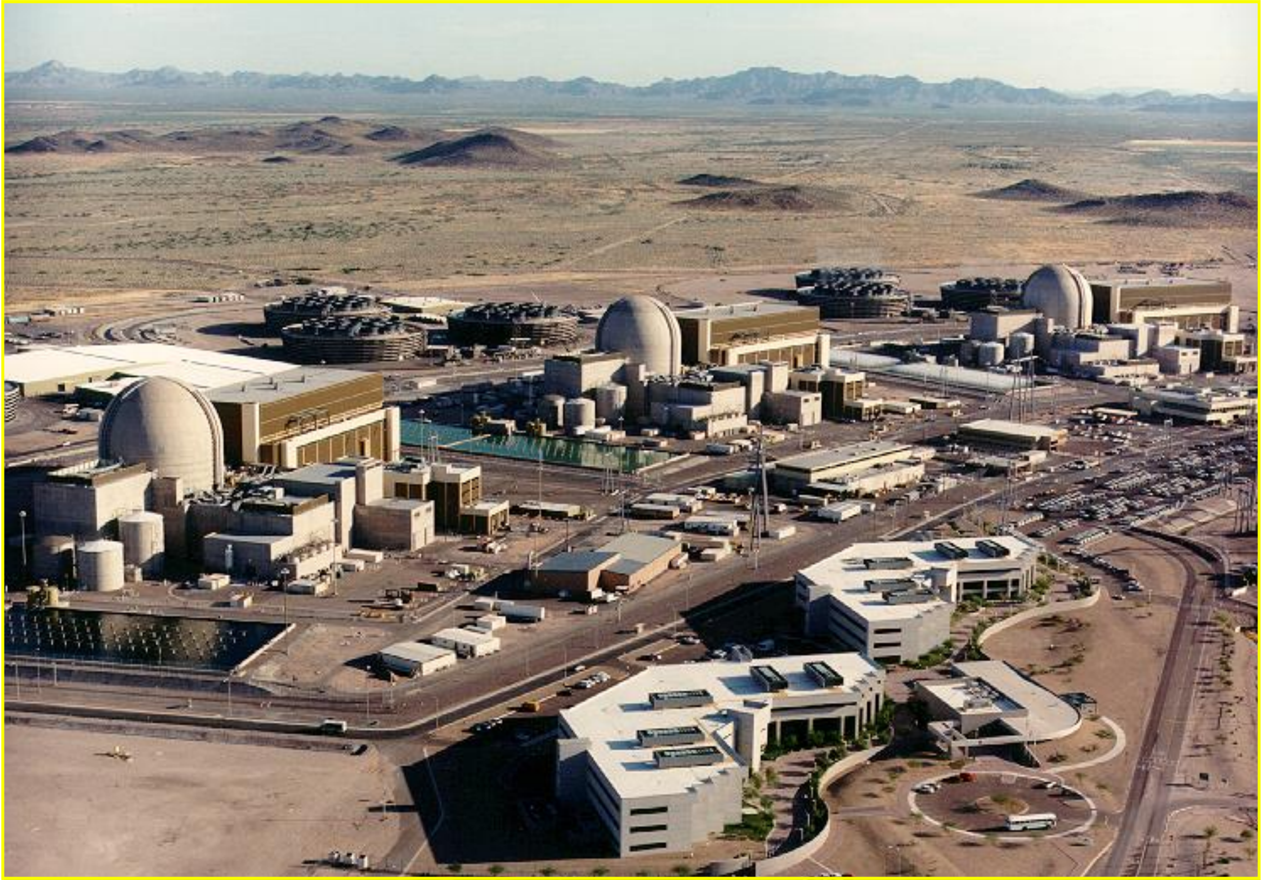
Palo Verde Nuclear Generating Station

Presented by:
Terry Price
Senior Mechanical Engineer
Palo Verde Nuclear Generating Station



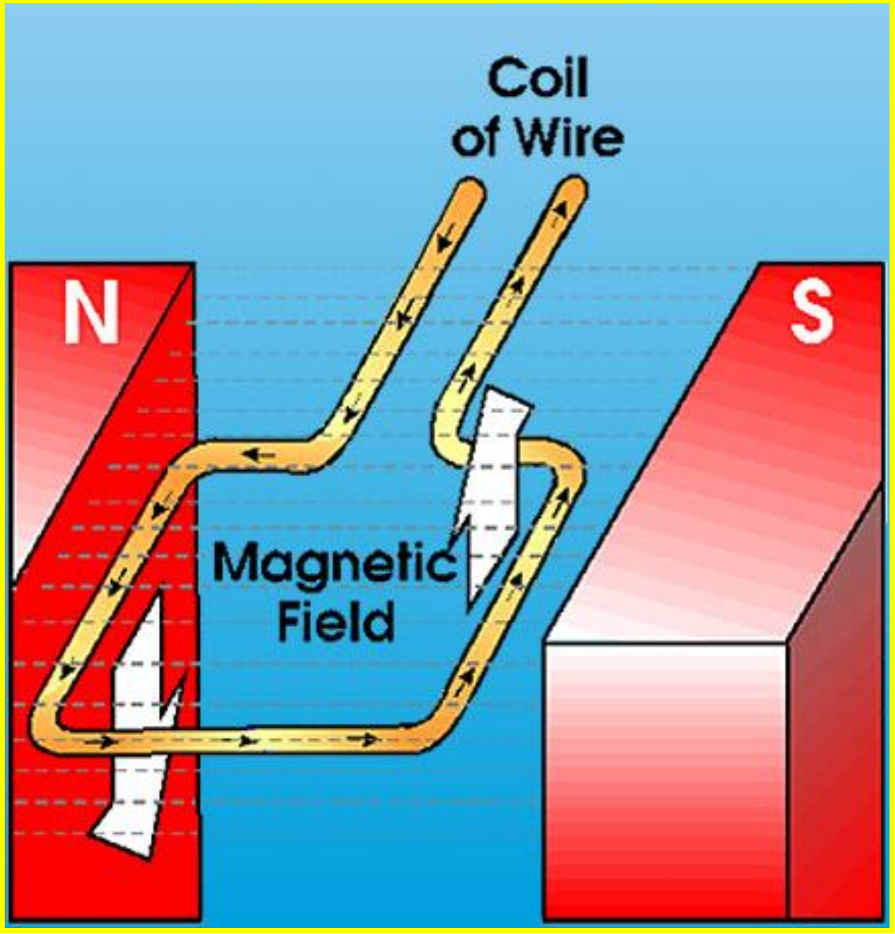
Energy Cornerstone of the Southwest

Terry Price
APS Generation

- Senior Mechanical System Engineer
- 16 years at Palo Verde
- Over 32 years in nuclear power

Electricity

How Electricity Is Created

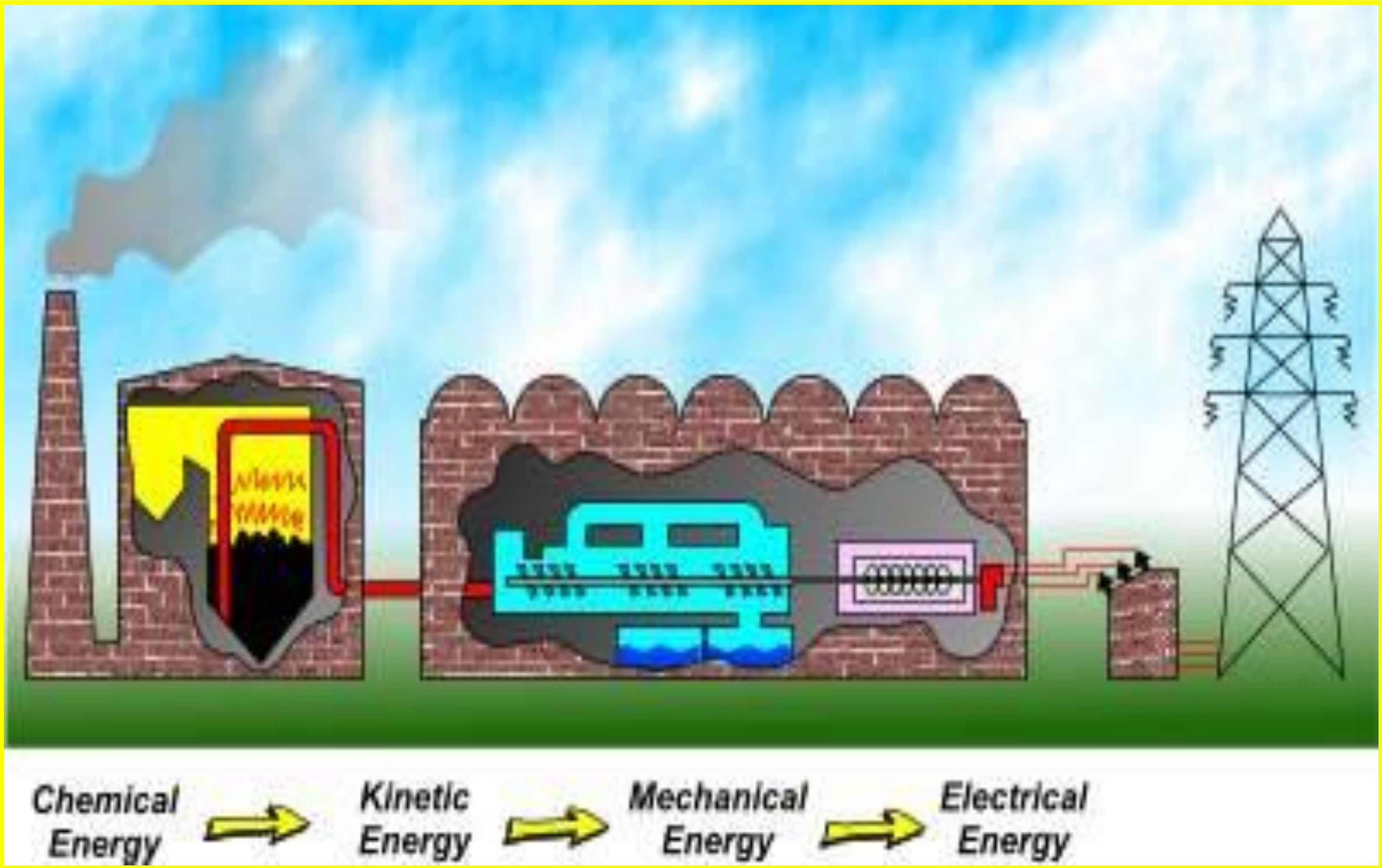


- **Three things to make electricity.**
- **Magnet (a magnetic field)**
- **Wire (an electrical conductor)**
- **Motion between the two.**

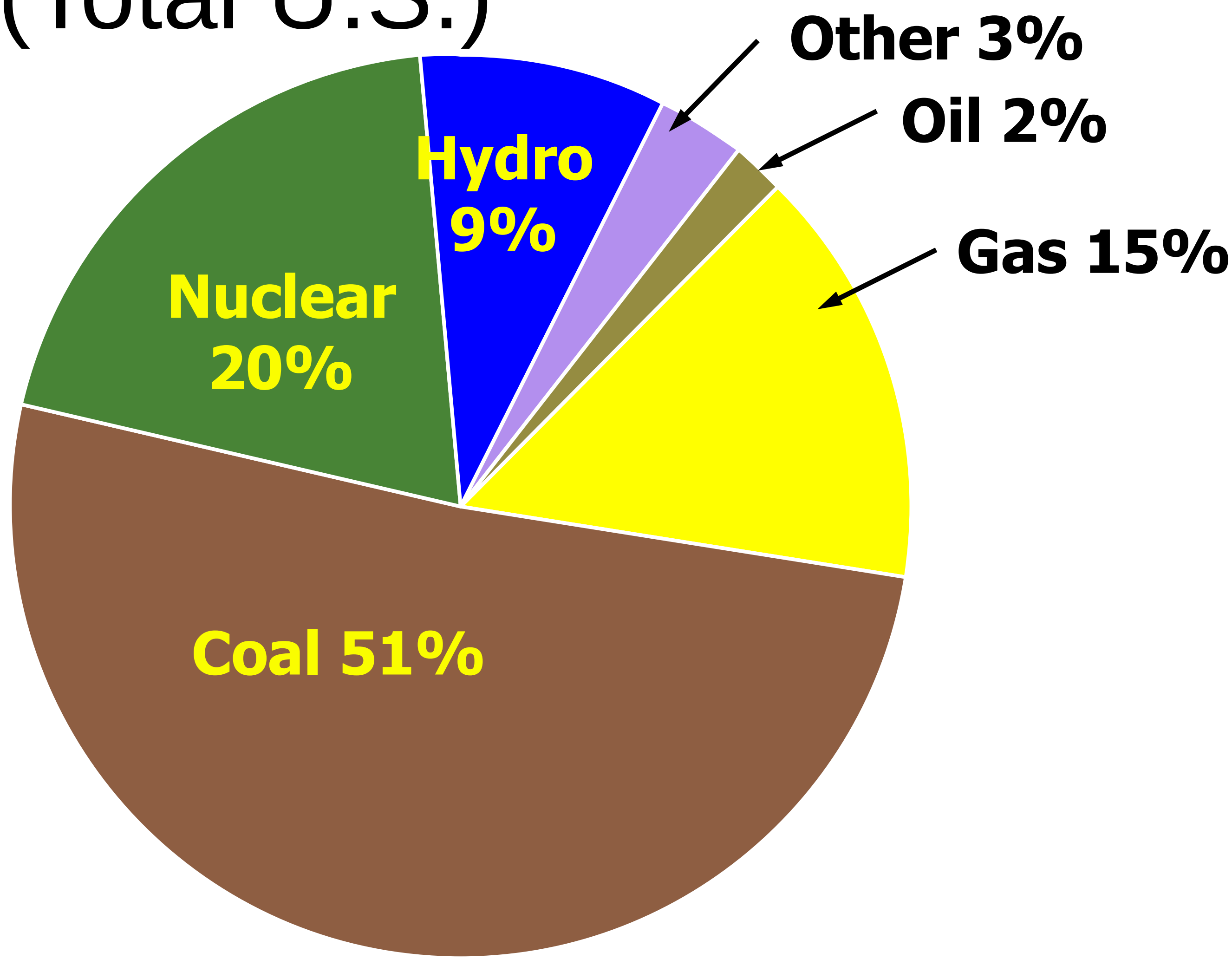
How Electricity Is Created

- Transmission lines carry electricity from power plants to switchyards.
- Use high voltage -- less current losses.
- Western States connected via the grid (WSCC.)

How Electricity Is Created



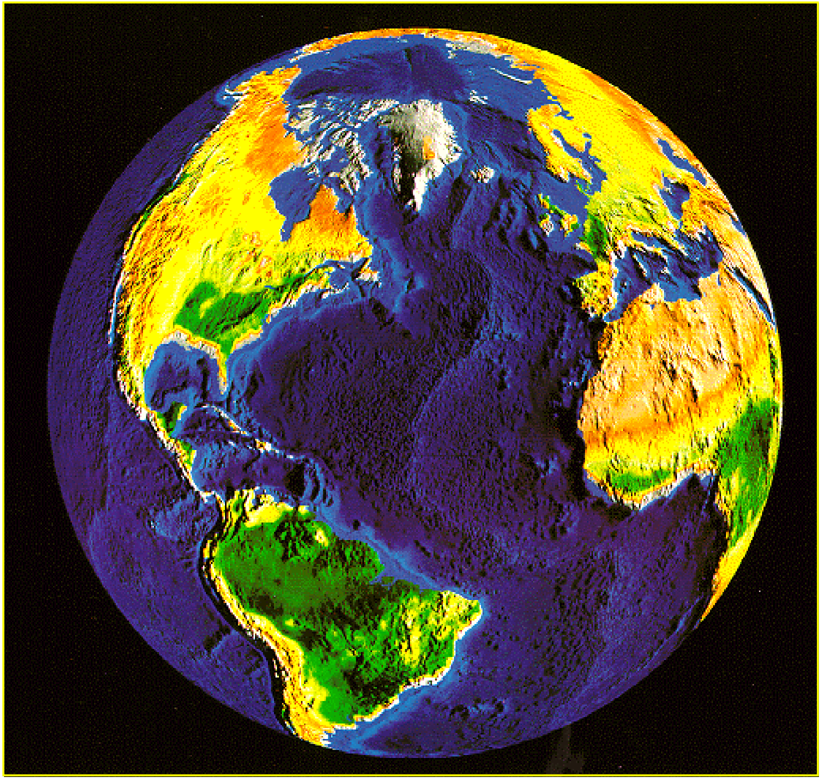
What Generates Electricity (Total U.S.)



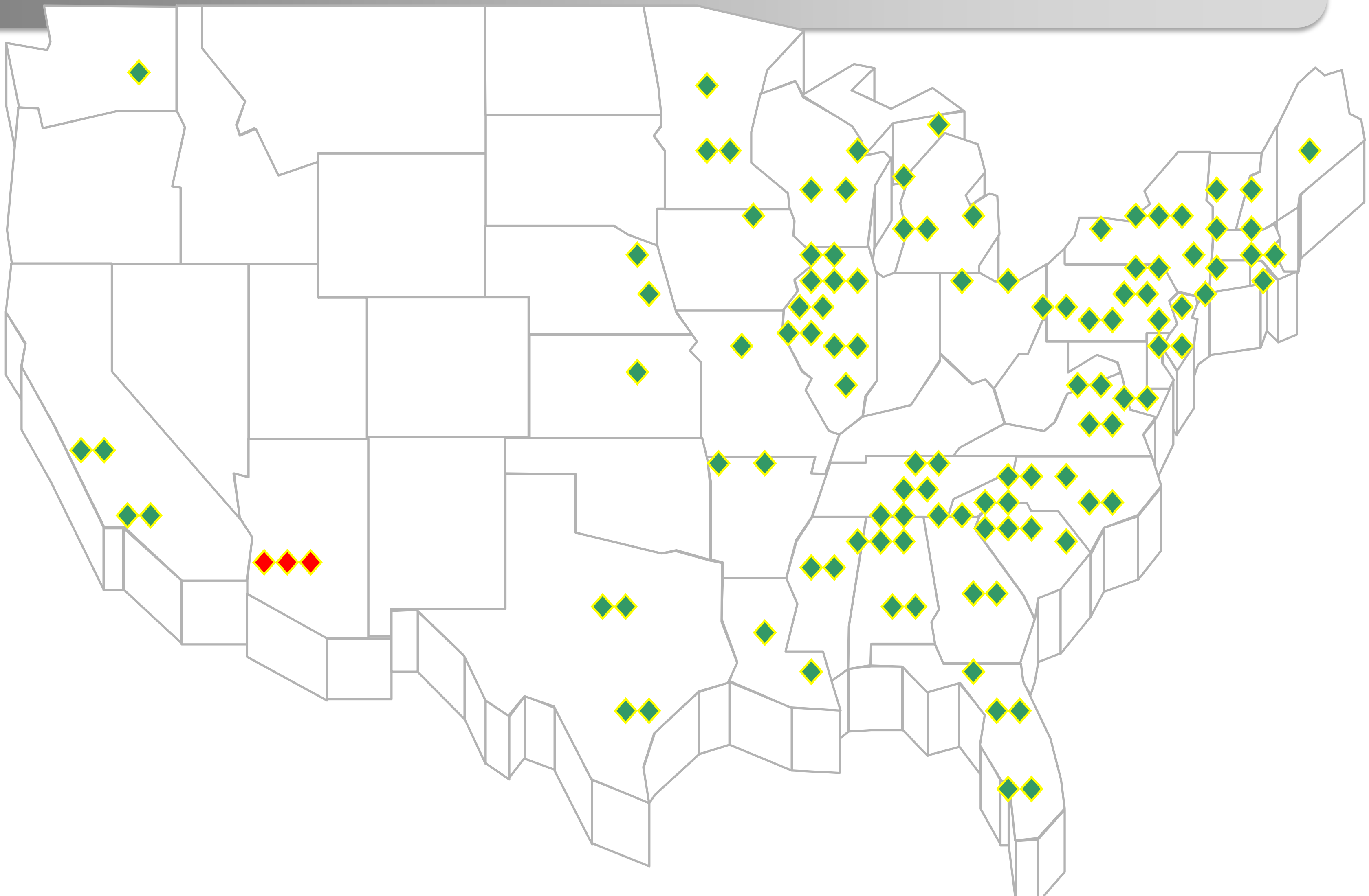
Source: RDI

Did You Know?

- There are 104 nuclear power plants in the U.S.
  - About 20% of U.S. electricity
  - CO_2 Emissions reduced more than 133 million tons a year
- Currently 444 plants throughout the world.



Nuclear Power Plants in the U.S.



Palo Verde’s Role

Palo Verde's Role

Largest power producer in the U.S., producing more electricity than any other power plant of any type!

Palo Verde's Role

- The total electricity produced by a plant depends on two things:
  - The size, or nameplate rating, of the plant.
  - How long during the year the plant can run at full capacity -- the **Capacity Factor**.
- So, to equal the power produced by Palo Verde in a year . . .

Key Facts About Palo Verde

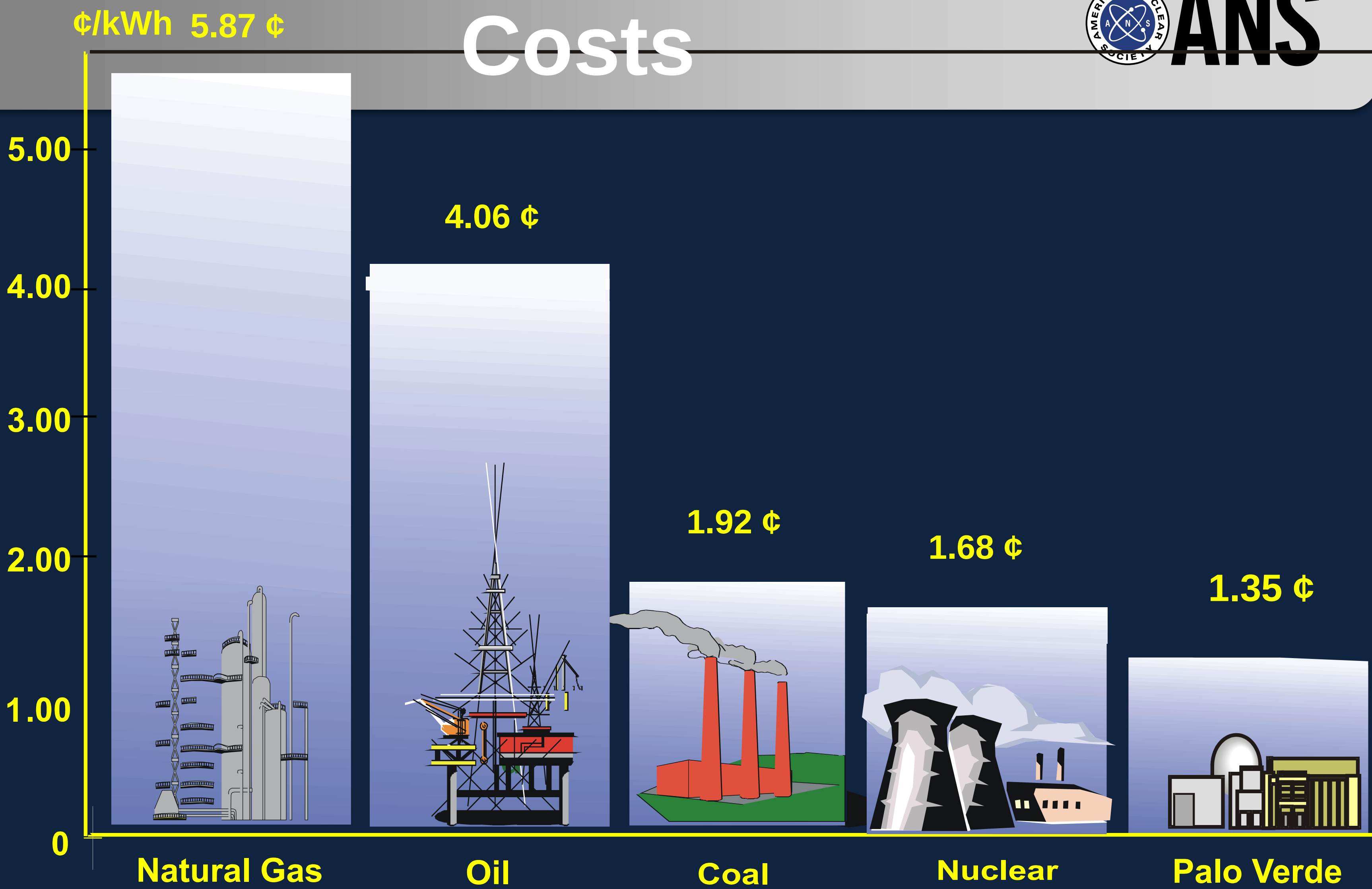






Palo Verde produces as much power as <u>seven Hoover Dams</u>!

Electricity Production Costs



Cost per fuel pellet

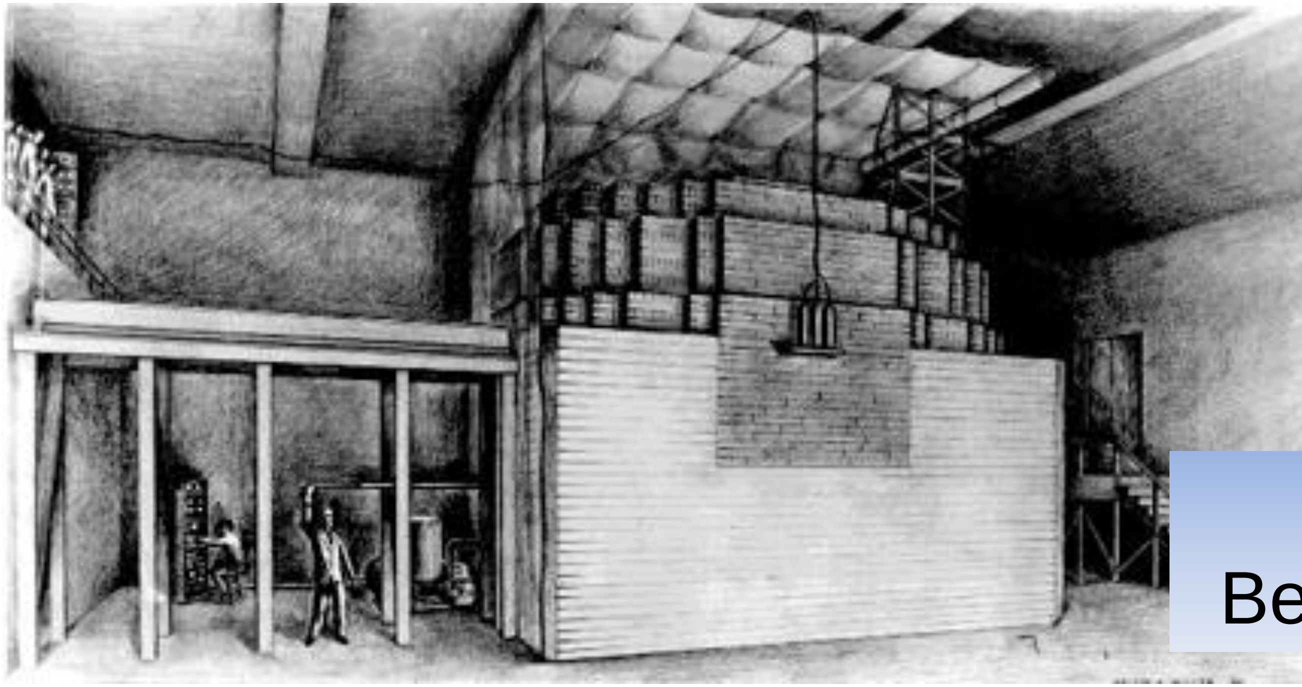
- Fuel pellet = ½ inch long
- Fuel rod = 14 feet in length
- 268 fuel rods = 1 fuel bundle
- Cost = $600,000 per fuel bundle

- Total fuel pellets = 2x12x14x268 = 90048
- Cost per pellet = $600,000 / 90048 = $6.66+

How Did It All Start?

Brief History of Nuclear Power

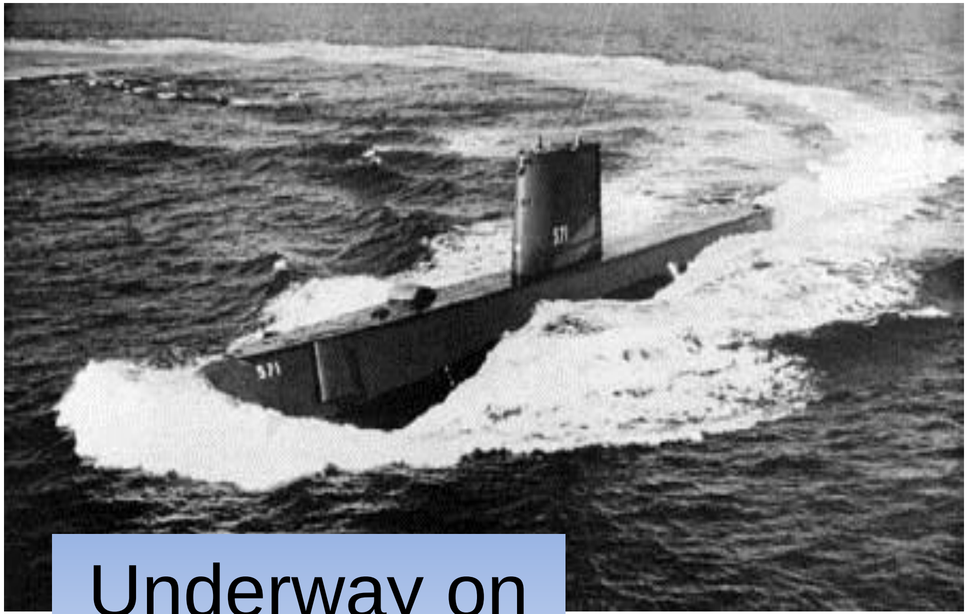
Nuclear Power - A Brief History



The Beginning

- December 2, 1942
- The first controlled chain reaction
- Called “Chicago Pile” because of its construction.

How Did It All Start?



Underway on Nuclear Power!

- 1954 -- U.S.S Nautilus, first nuclear powered submarine, is launched.
- Used a pressurized water reactor.
- Most of the world’s nuclear plants are this type.

Environmentally Friendly!

Environmental

ANS

- By building Palo Verde as a nuclear plant . . .
- PinWest Generation avoided the following emissions (through 1998):
  - 279 million <u>tons</u> of Carbon Dioxide
  - 1.6 million <u>tons</u> of Sulfur Dioxide
  - 1 million <u>tons</u> of Nitrogen Oxides
- Equal to 4,000,000 cars!

Environmental

The plant uses 20-billion gallons of recycled water each year

How ?
Why ?

The Operators

Plant Operators

Homer Simpson would not make it at Palo Verde as any employee, let alone a plant operator.

Plant Operators

- Types of licenses: SRO and RO.
- Two SROs and three ROs on duty.
- Average 1 1/2 years of initial training.
- One week out of five in re-training.

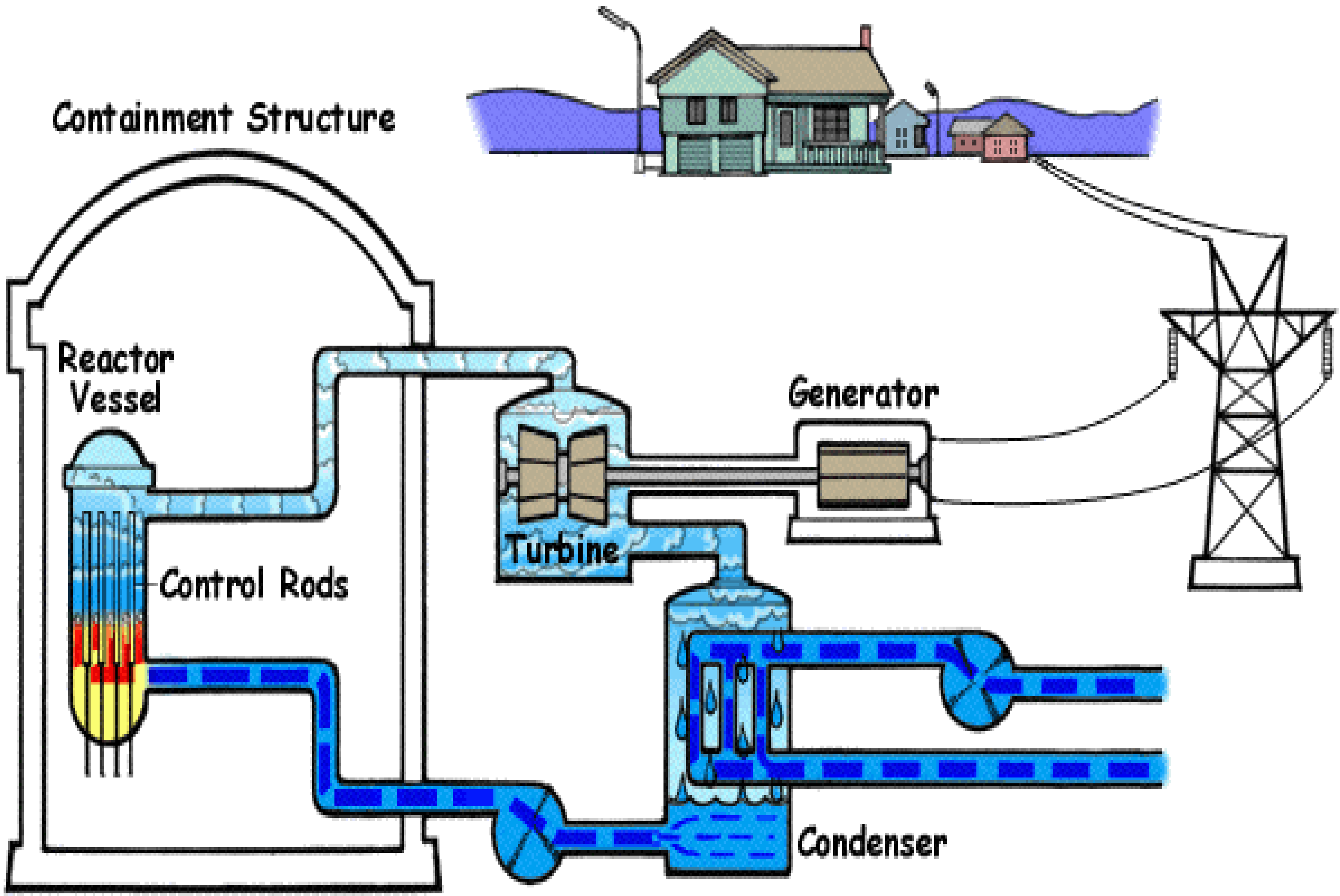
The Control Room (each Unit)

Two Types of Nuclear Power Plants

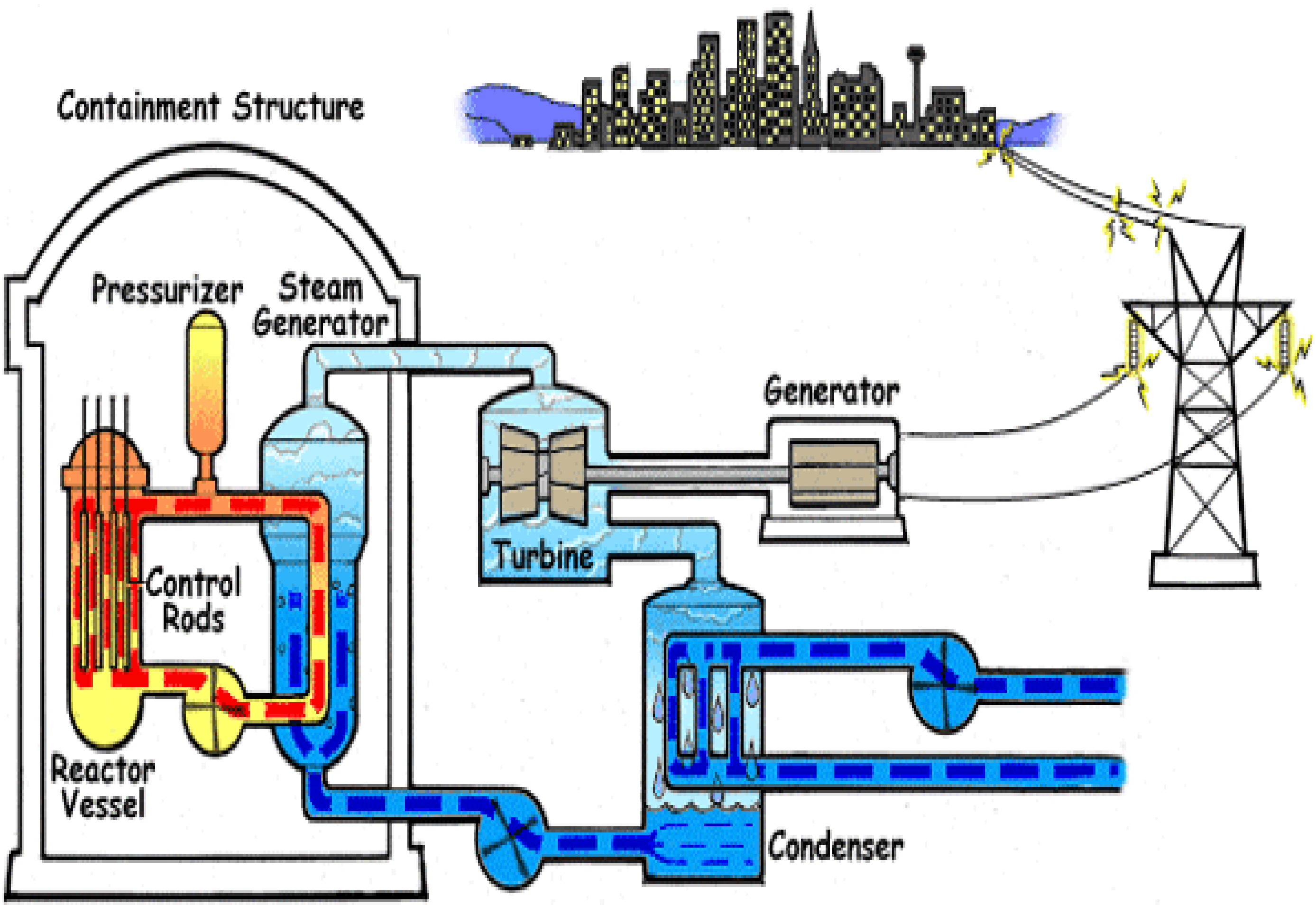
Boiling Water Reactor (BWR)

Pressurized Water Reactor (PWR)

Boiling Water Reactor

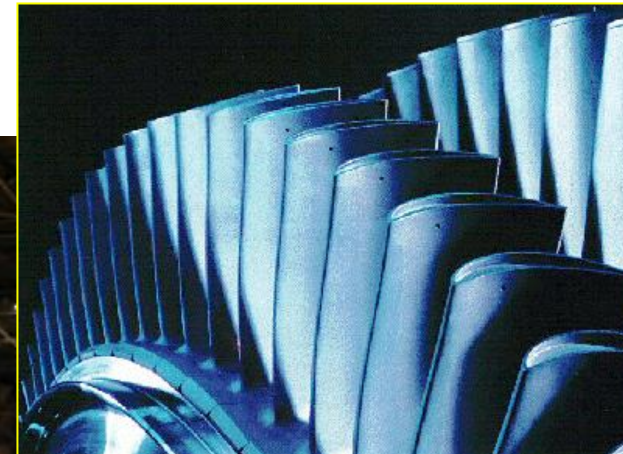


Pressurized Water Reactor

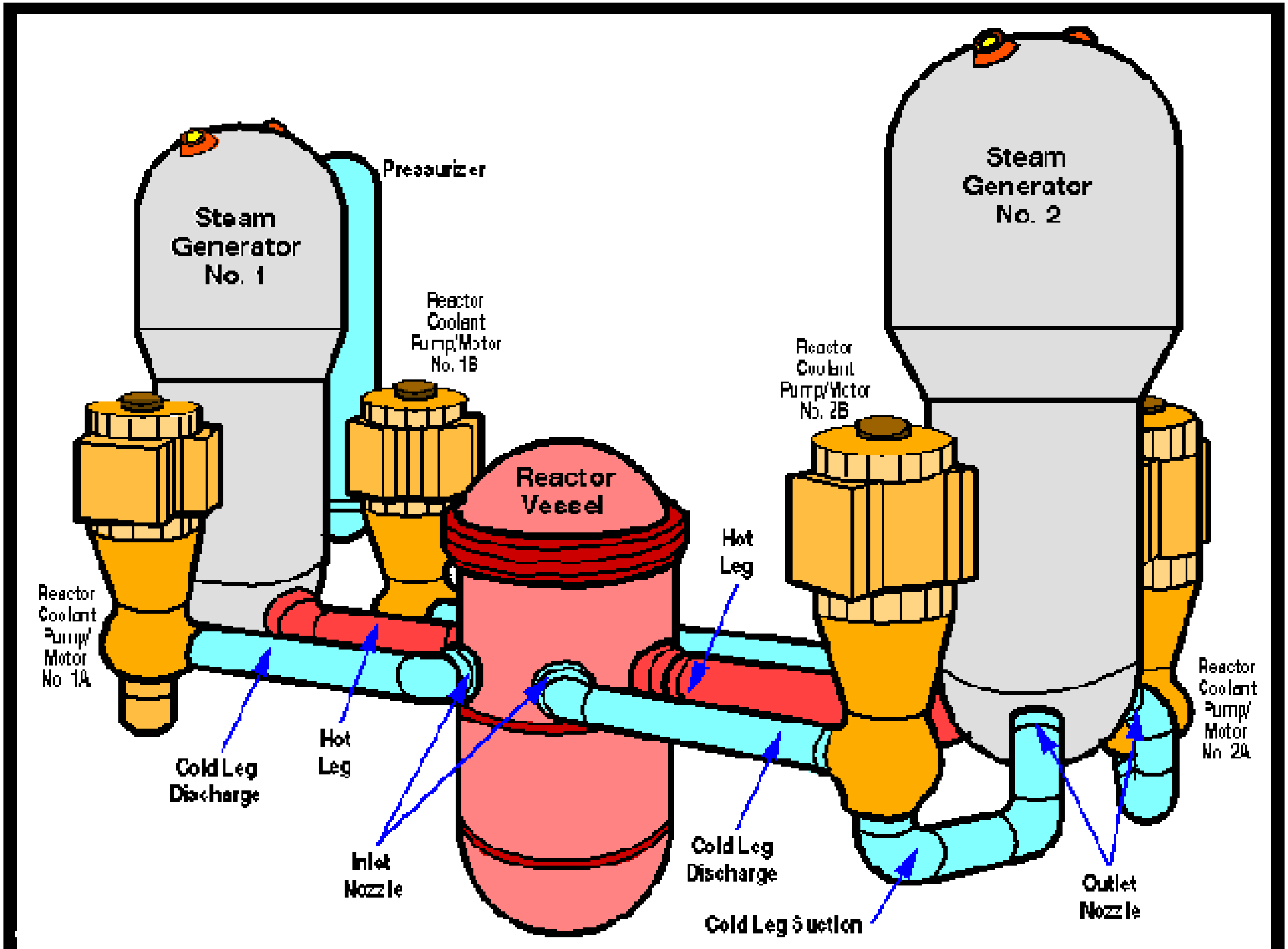


How the Plant Operates

How the Plant Works



Primary System



Primary System

Safe by Design

Stability and Engineering

Engineered Safety Features Systems (ESF)

- Inherent characteristics of the reactor
  - Nature made it that way!
- Reactor Protective System
  - Four totally separate instrument channels
  - Any two signals will release the control rods
- Reactor Control System (Startup and Shutdown)
  - Movement of control rods
  - Reactor power follows steam demand!

Stability and Engineering

Engineered Safety Systems

- Safety Injection
- Containment Spray
- Recirculation
- Containment Isolation
- Main Steam Isolation
- Emergency Feedwater

PALO VERDE

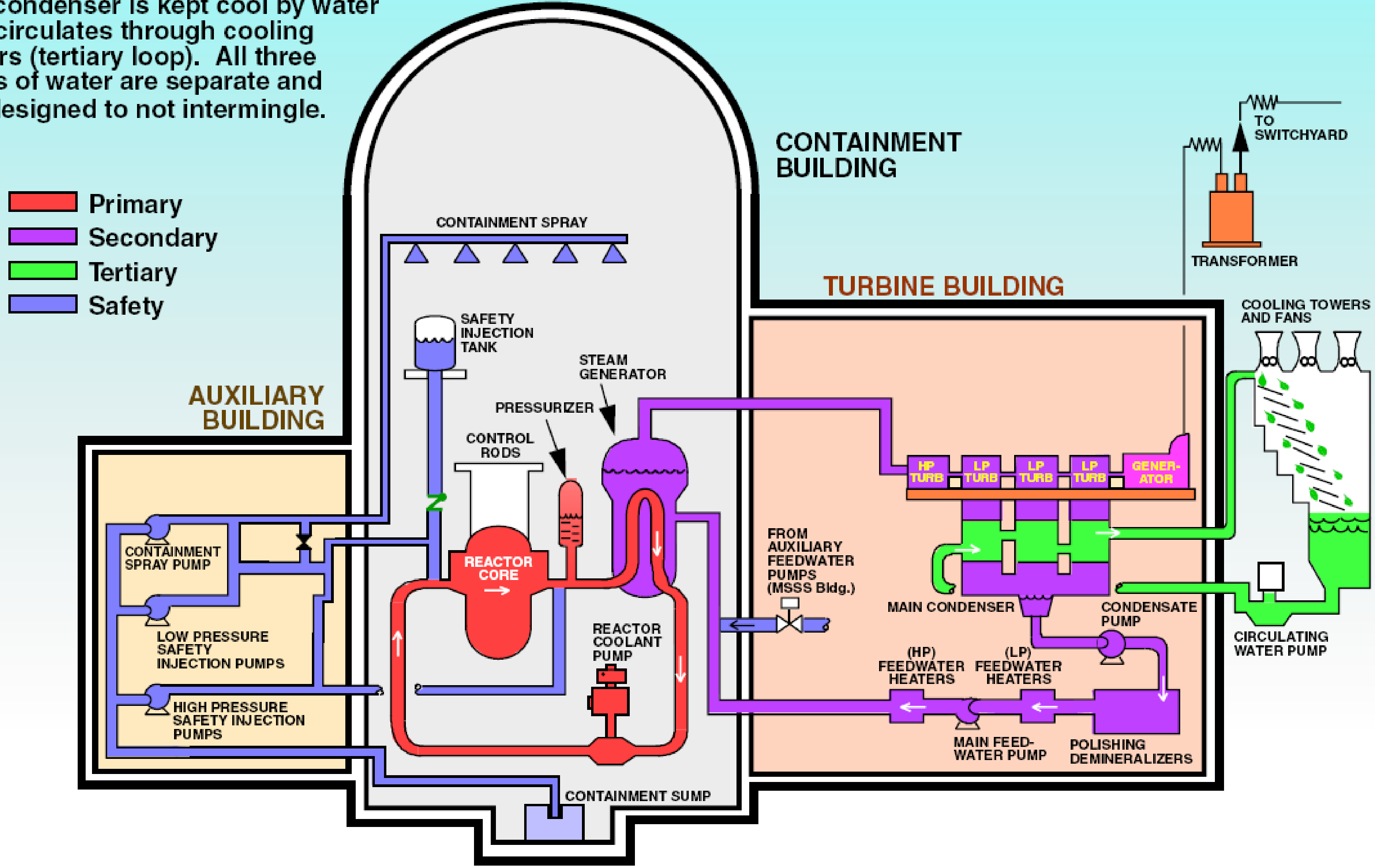
Nuclear Generating Station

How It Works

Graphic Artist: Chris Aanensen

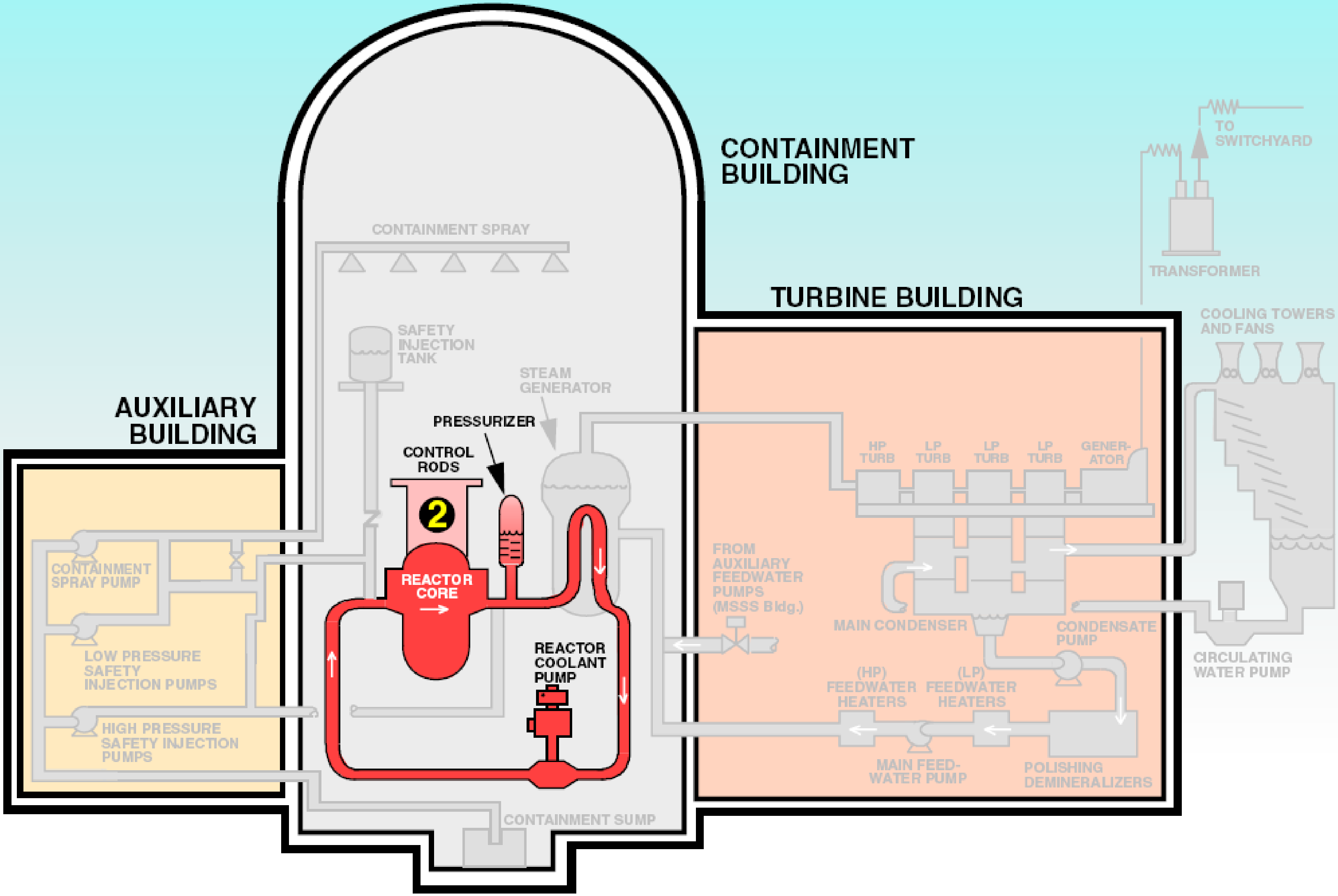
1 A Plant Overview

To produce electricity, Palo Verde needs heat, steam and an electrical generator. Heat comes from the reactor, where nuclear fission heats water to 610 degrees under great pressure so it doesn't boil. That superhot water (primary loop) circulates through the steam generator, where it boils water to produce steam. The steam (secondary loop) passes through turbines connected to electrical generators, which spin and produce electricity. The used steam then passes through a condenser where it is cooled into water and sent back to the steam generator to make yet more steam. The condenser is kept cool by water that circulates through cooling towers (tertiary loop). All three loops of water are separate and are designed to not intermingle.



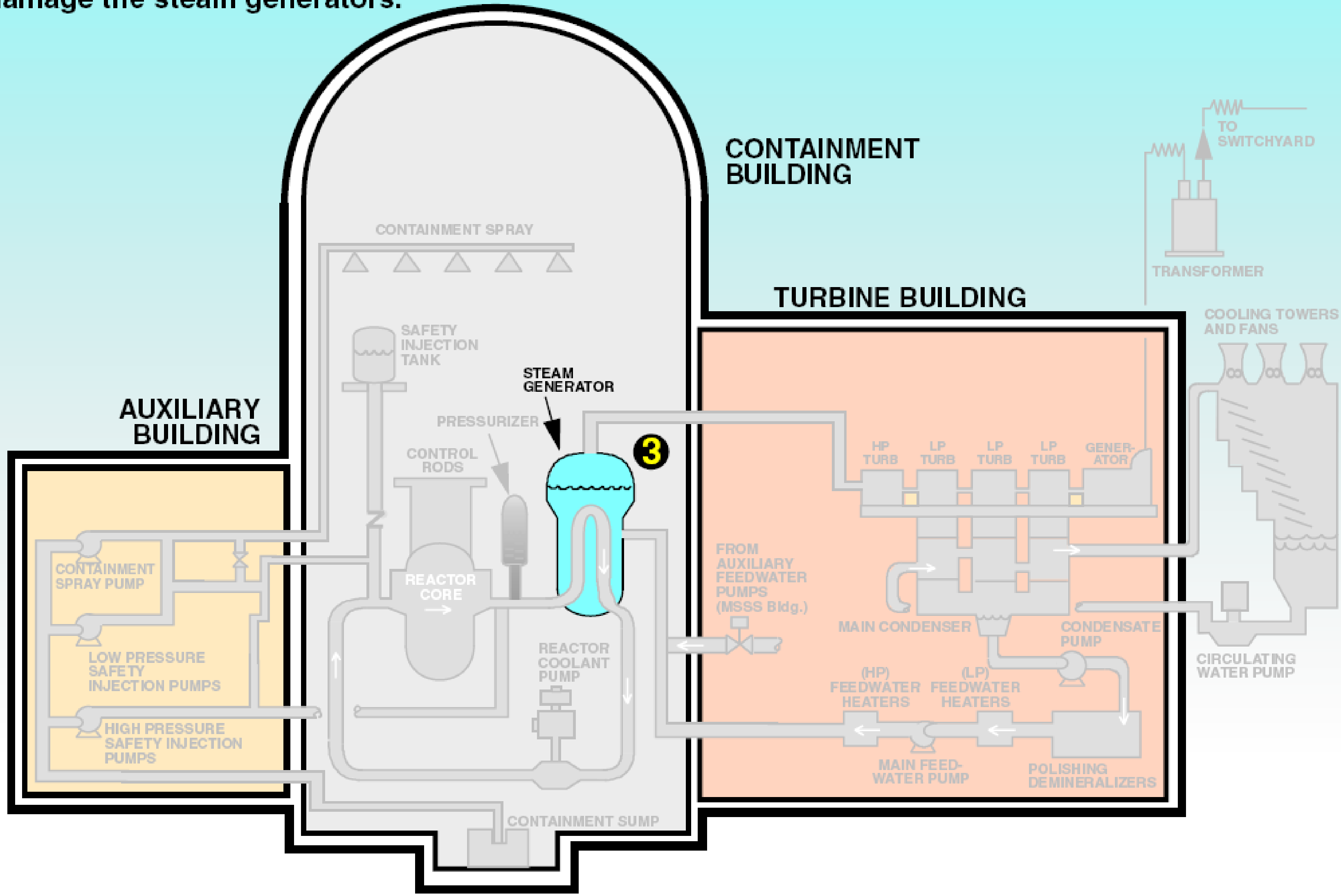
2 The Reactor

The fuel used at Palo Verde is made from uranium and sits inside the reactor. Through a controlled chain reaction called nuclear fission, uranium atoms split and give off heat inside the reactor. That heat eventually is used to boil water in the steam generators. The reactor can be shut down immediately using Control Element Assemblies. The control assemblies are made of boron, which blocks the chain reaction.



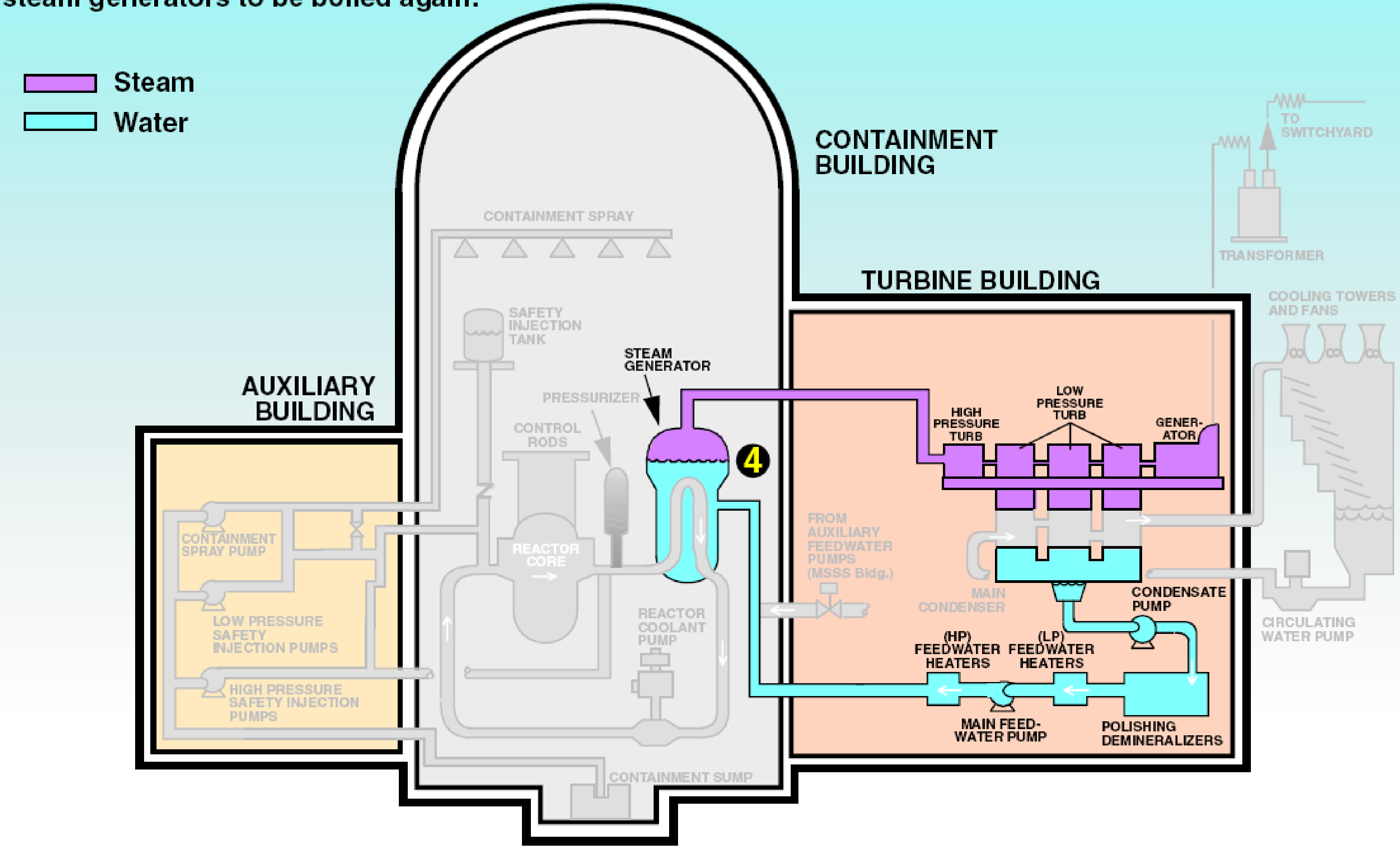
3 Steam Generators

Steam generators are large heat exchangers. Superheated water from the reactor, under pressure to prevent boiling, passes through thousands of tubes in the steam generators. Water on the outside of these tubes boils and produces steam, which blows through large turbines that spin to produce electricity. Maintaining a proper chemical balance in the boiling water is essential to prevent corrosion and deposits that can damage the steam generators.



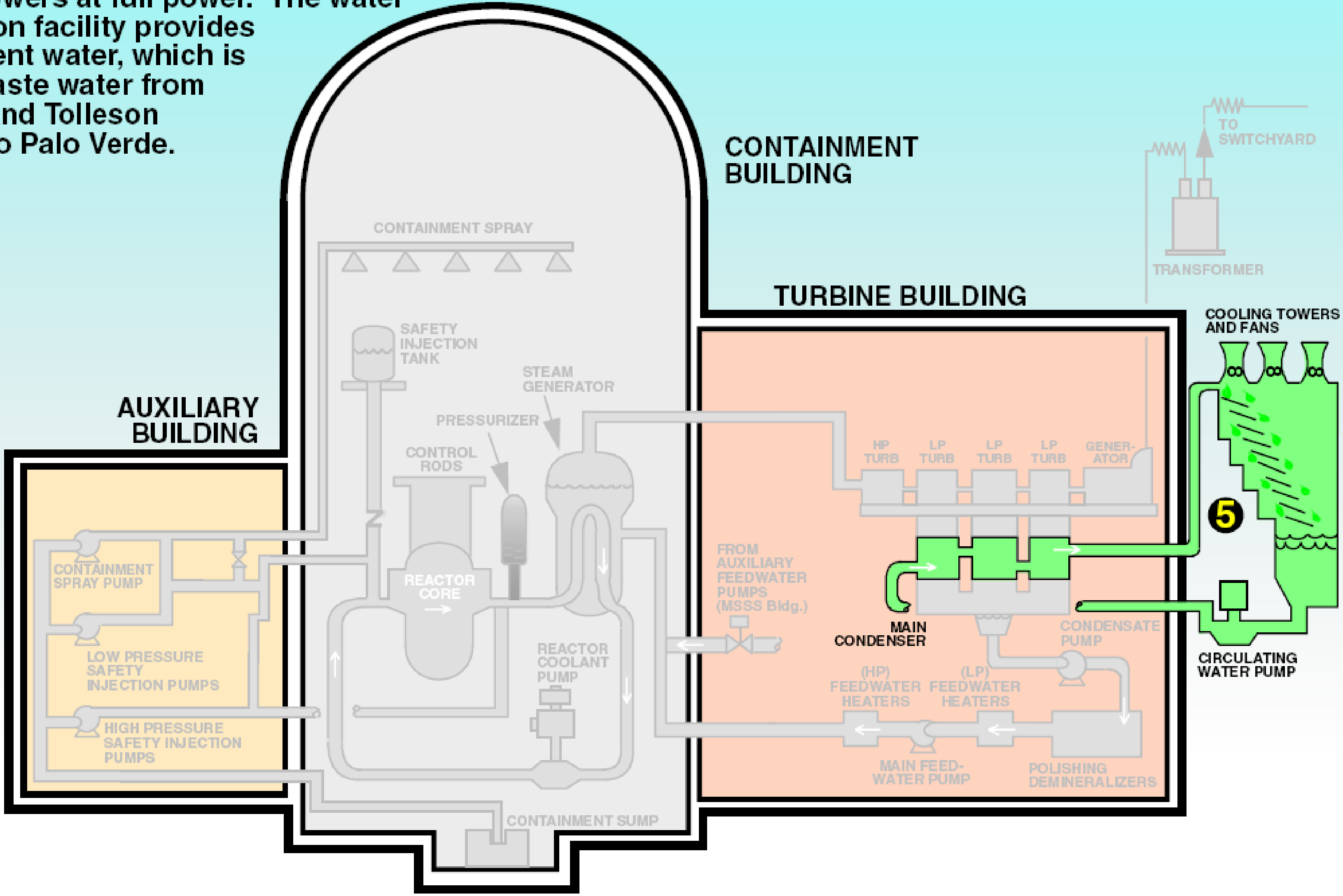
4 Secondary Loop

Steam produced in the steam generators actually turns four turbines that spin at 1,800 revolutions per minute. A shaft from the turbines is connected to the main generator, which can produce about 1.3 billion watts at full power. The used steam is then condensed back into water. The condensate system then pumps the water through filters and heaters to the feedwater system, which returns the water to the steam generators to be boiled again.



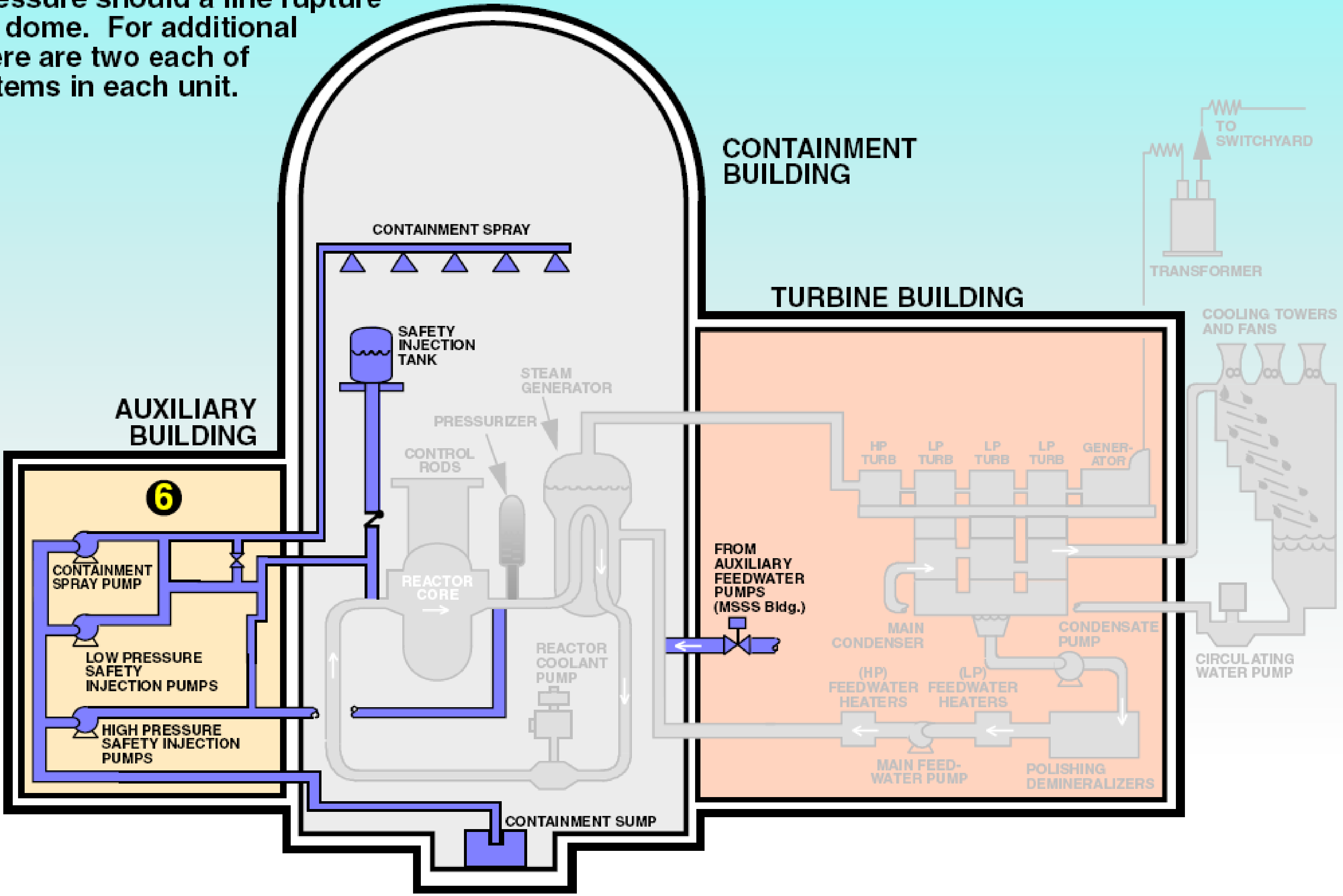
5 The Heat Sink

The circulating water system, the third loop in the plant cycle, removes heat from the steam after it passes through the turbines. As steam passes on the outside of thousands of tubes in the top of the condenser, water inside the tubes picks up the heat and passes it to the atmosphere. This is the water vapor seen rising from the cooling towers. About 14,000 gallons of water a minute evaporate from each unit's cooling towers at full power. The water reclamation facility provides replacement water, which is treated waste water from Phoenix and Tolleson pumped to Palo Verde.



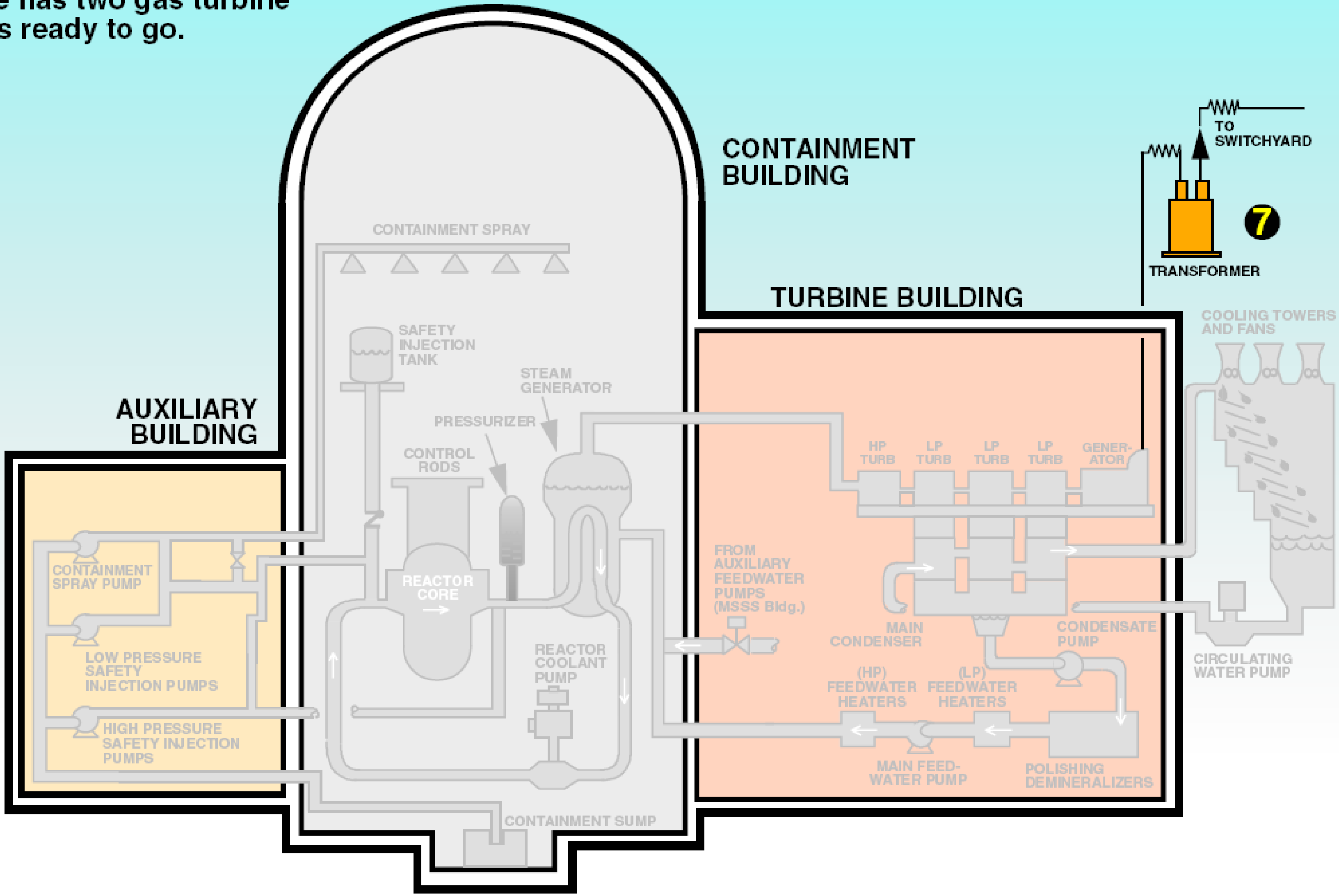
6 Safety Systems

The Safety Injection System includes safety injection, shutdown cooling and containment spray systems. Safety Injection can inject large quantities of water into the reactor for cooling in the event of a loss of reactor coolant. Shutdown cooling removes the residual heat and heat produced after the reactor is shut down. The containment spray system introduces a cool spray of water inside the containment dome to reduce pressure should a line rupture within the dome. For additional safety, there are two each of these systems in each unit.



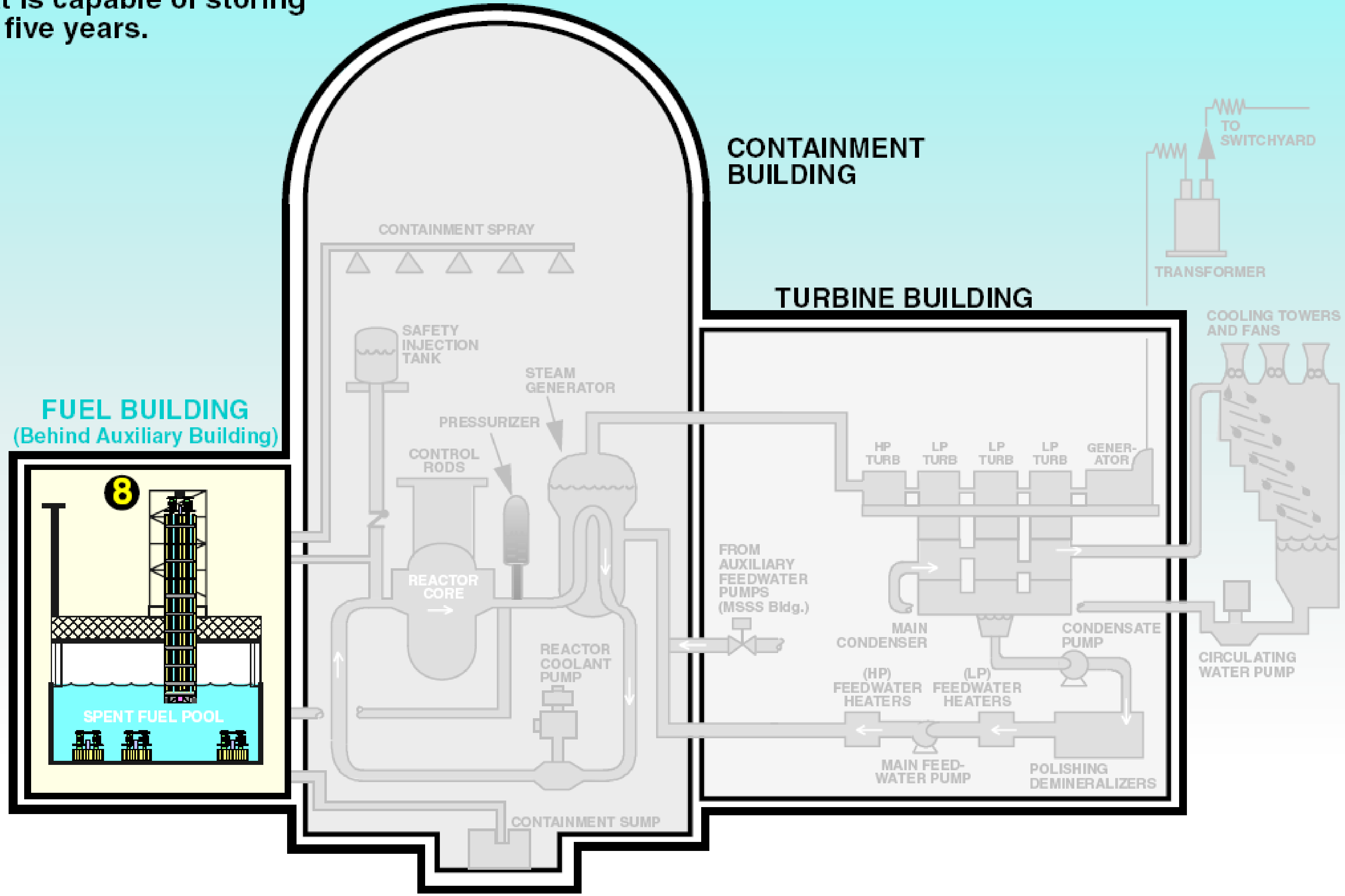
7 Electrical Generation

Power generated by Palo Verde's three units is sent to the switchyard, which distributes the electricity among the plant's seven owners. Under normal conditions, some of that power is returned to the plant for use in running the site. In the event of a loss of off-site power, two diesel generators will start and supply power to the various safety systems. If for some reason the diesel generators are not available, Palo Verde has two gas turbine generators ready to go.



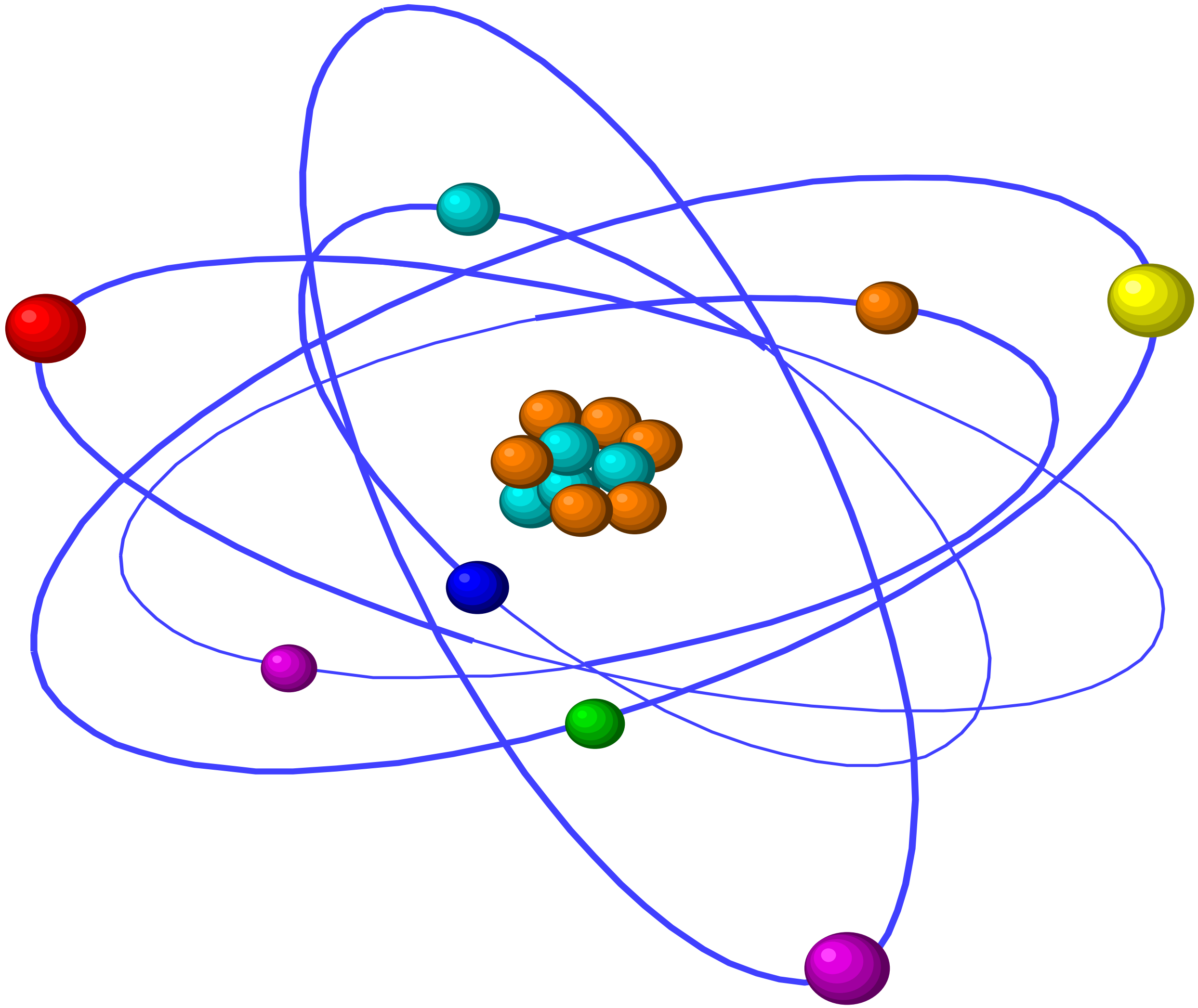
8 Spent Fuel Pool

Palo Verde's used uranium fuel is stored in three spent fuel pools, one in the fuel building of each unit. The spent fuel pool can hold up to 1,329 spent fuel assemblies. It also is possible to store spent fuel in large, dry concrete and steel drums. Some low-level radioactive waste, usually in the form of slightly radioactive trash, is shipped off-site for disposal. Most, however, is stored in a storage facility north of Unit 1 that is capable of storing
waste for five years.



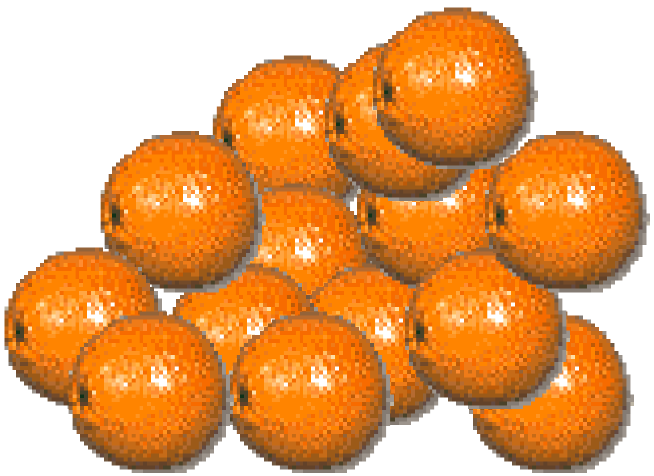
The Energy Source - Fuel

The Energy Source



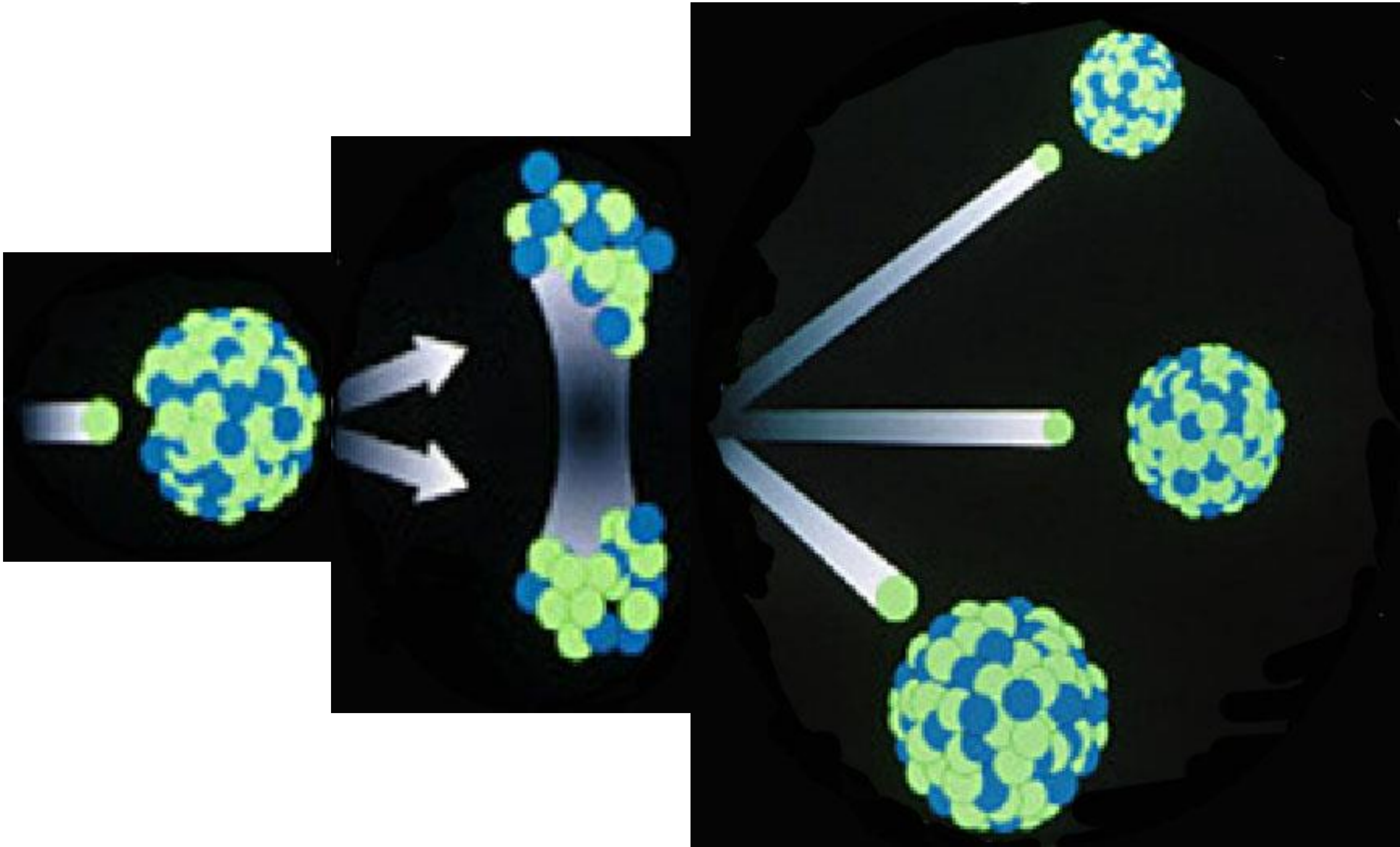
The Energy Source

- Uranium - and all elements - come in <u>isotopes.</u>
- Only difference is the <u>*number of neutrons*</u>.
- For every 1000 uranium atoms:
  - <u>993</u> have <u>146</u> neutrons
  - <u>7</u> have <u>143</u>

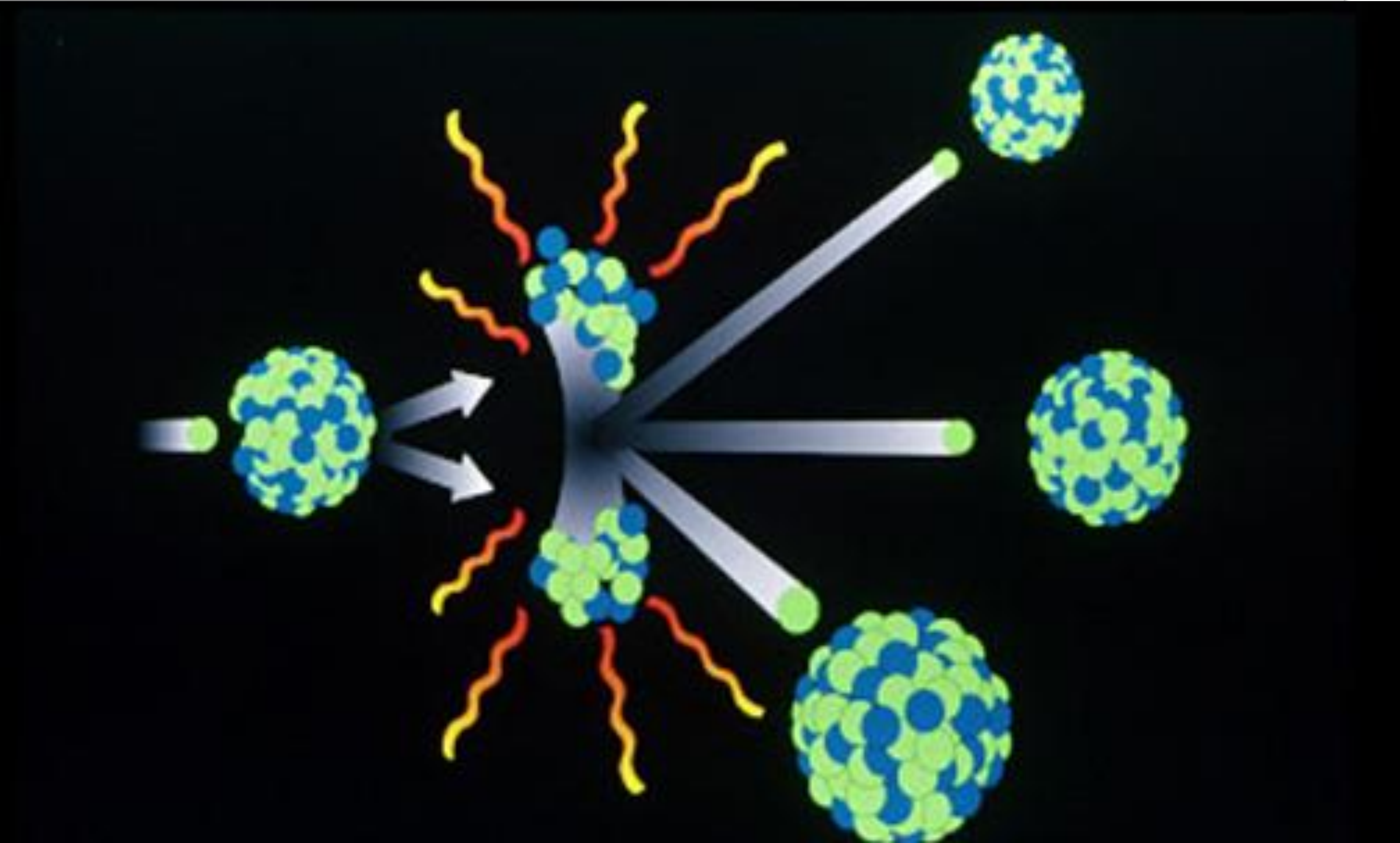


Isotopes are like oranges, they all look the same on the outside

The Energy Source

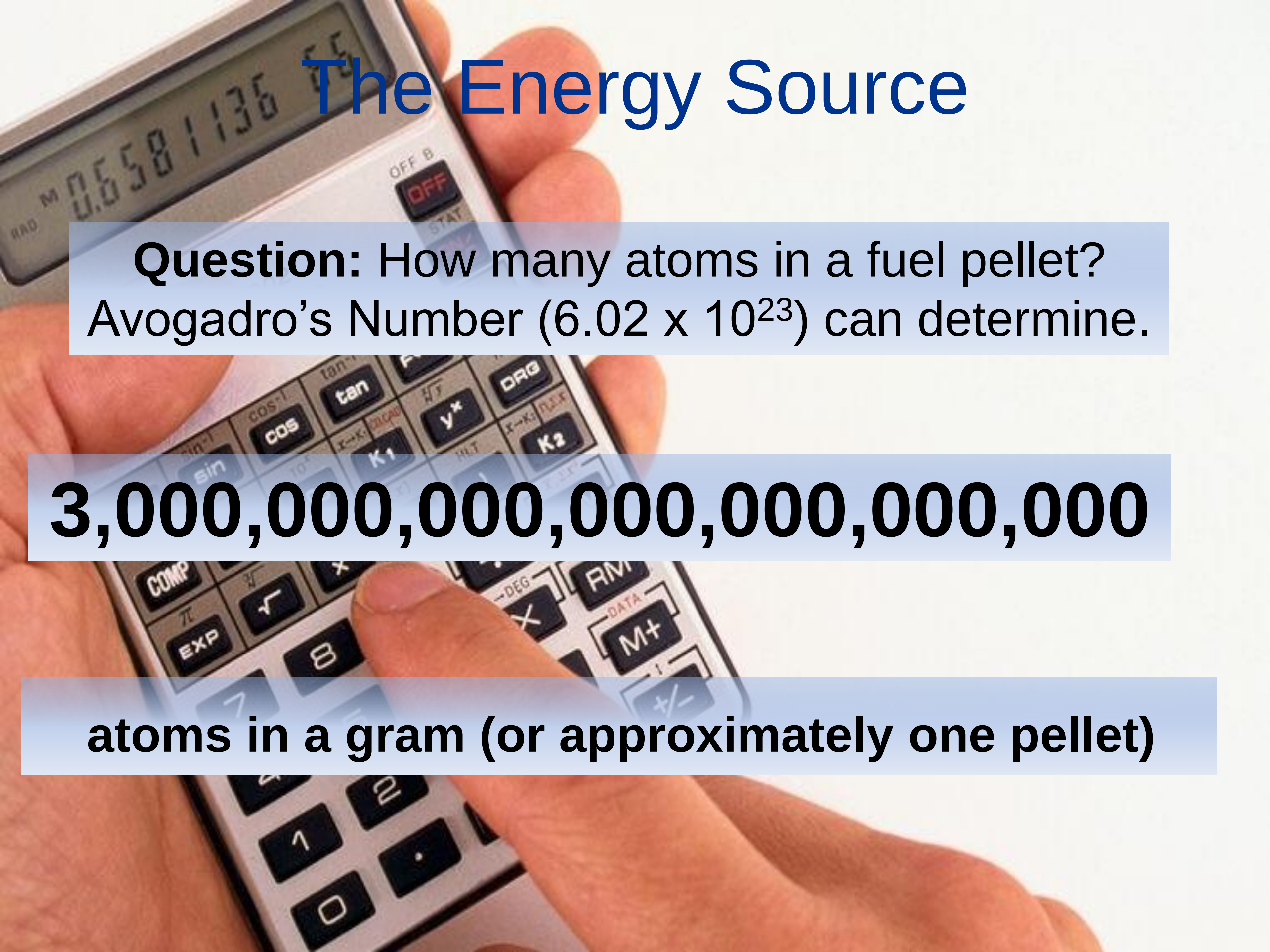


The Energy Source



The Fuel

- Uranium is cheap and plentiful.
- All uranium has two normal "isotopes"
  - U_{238} = 99.3% (of all)
  - U_{235} = 0.7% (of all)
- But, only U_{235} can be used for nuclear fuel.



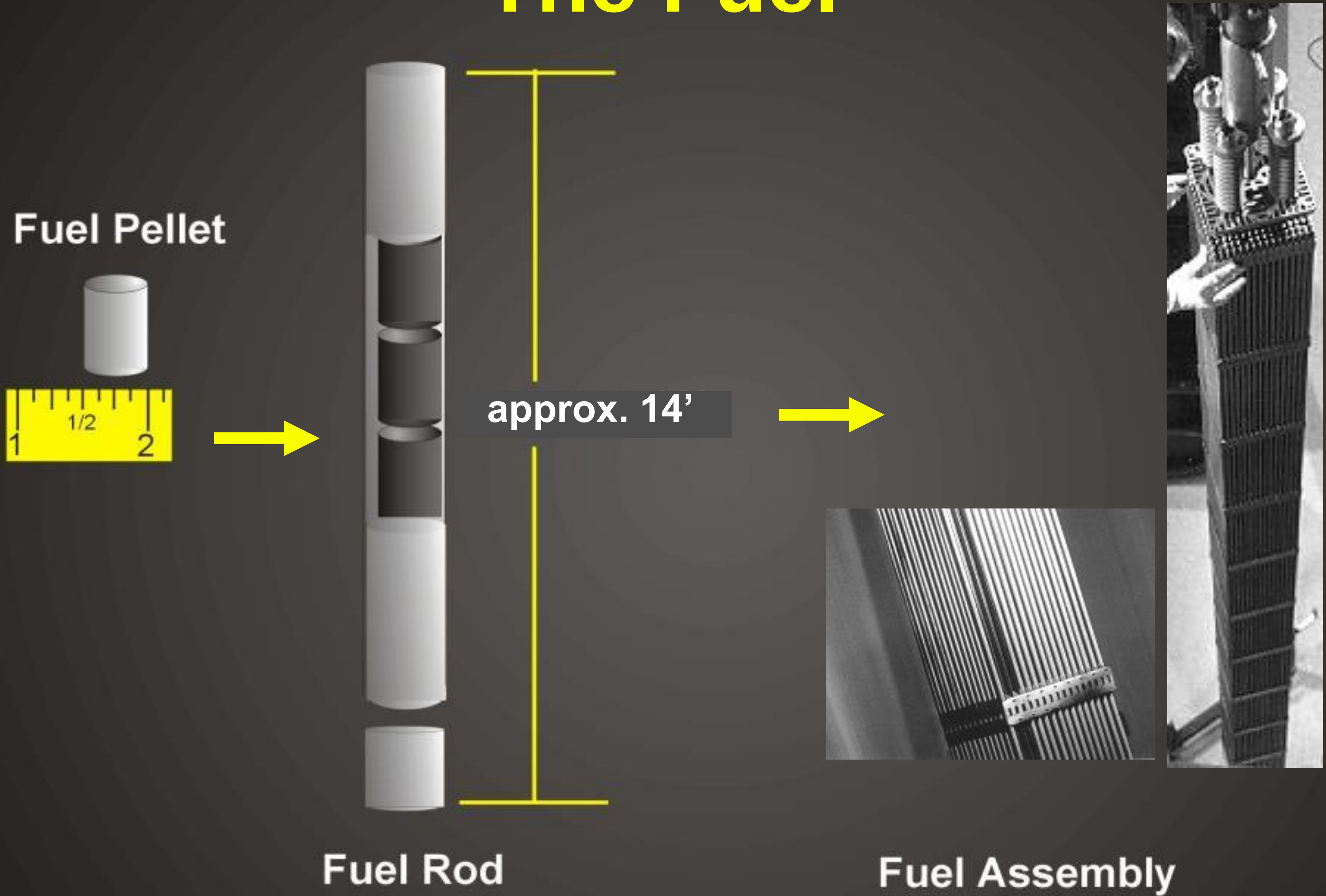
The Energy Source

Question: How many atoms in a fuel pellet?
Avogadro's Number (6.02×10^{23}) can determine.

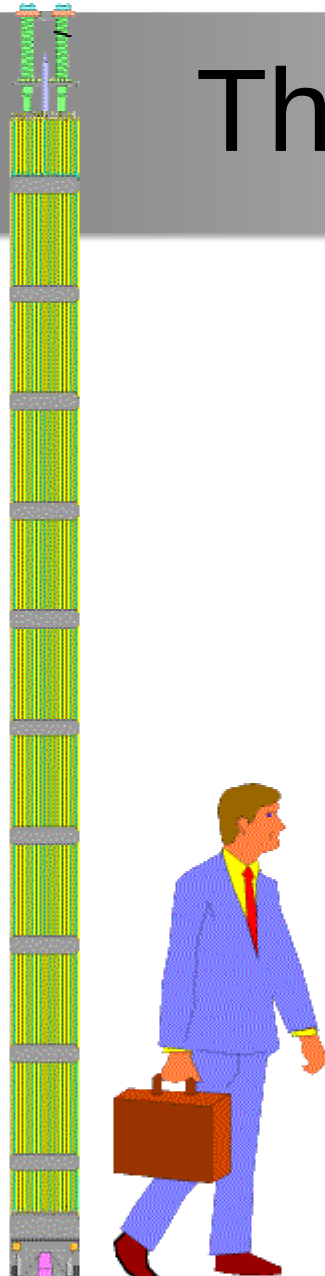
3,000,000,000,000,000,000,000

atoms in a gram (or approximately one pellet)

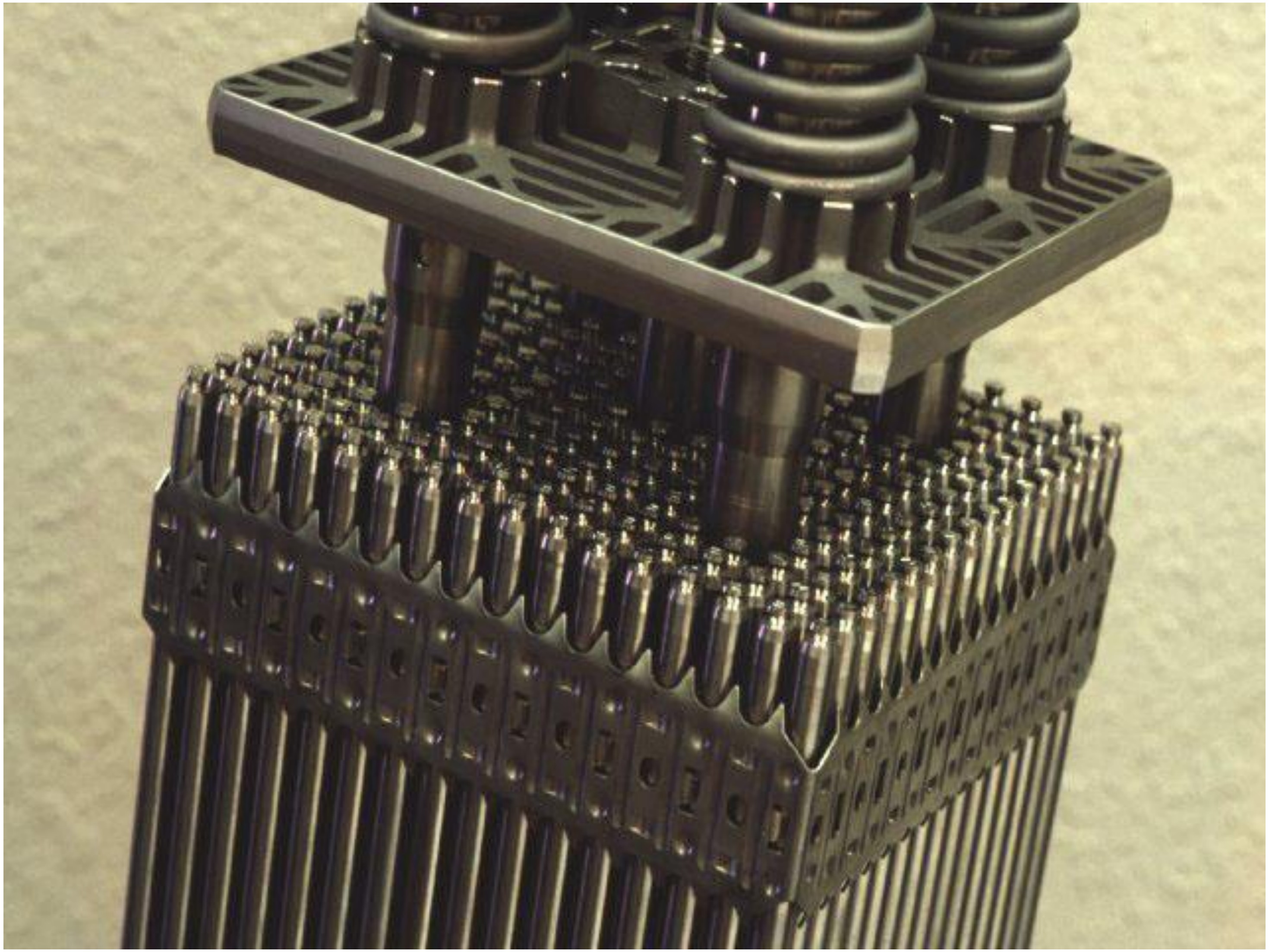
The Fuel



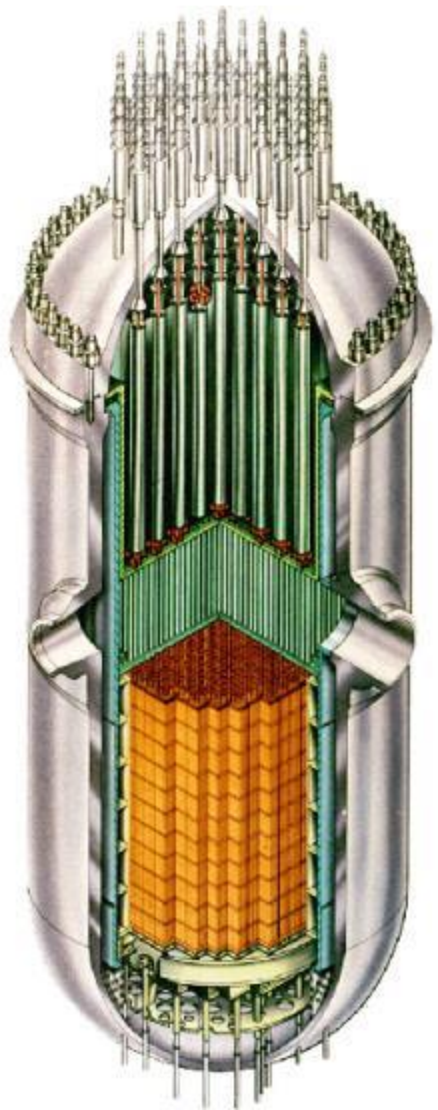
The Fuel



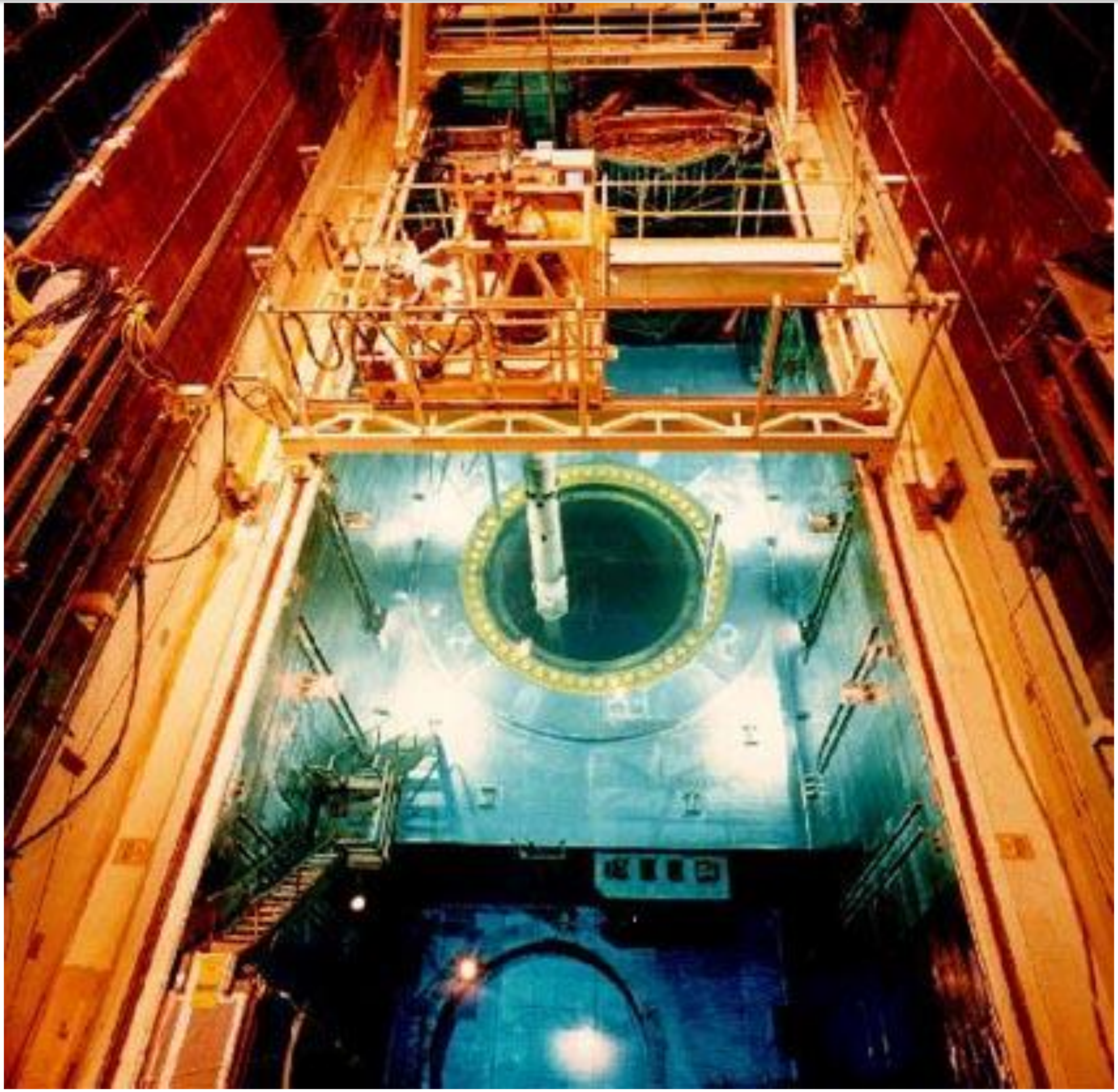
The Fuel



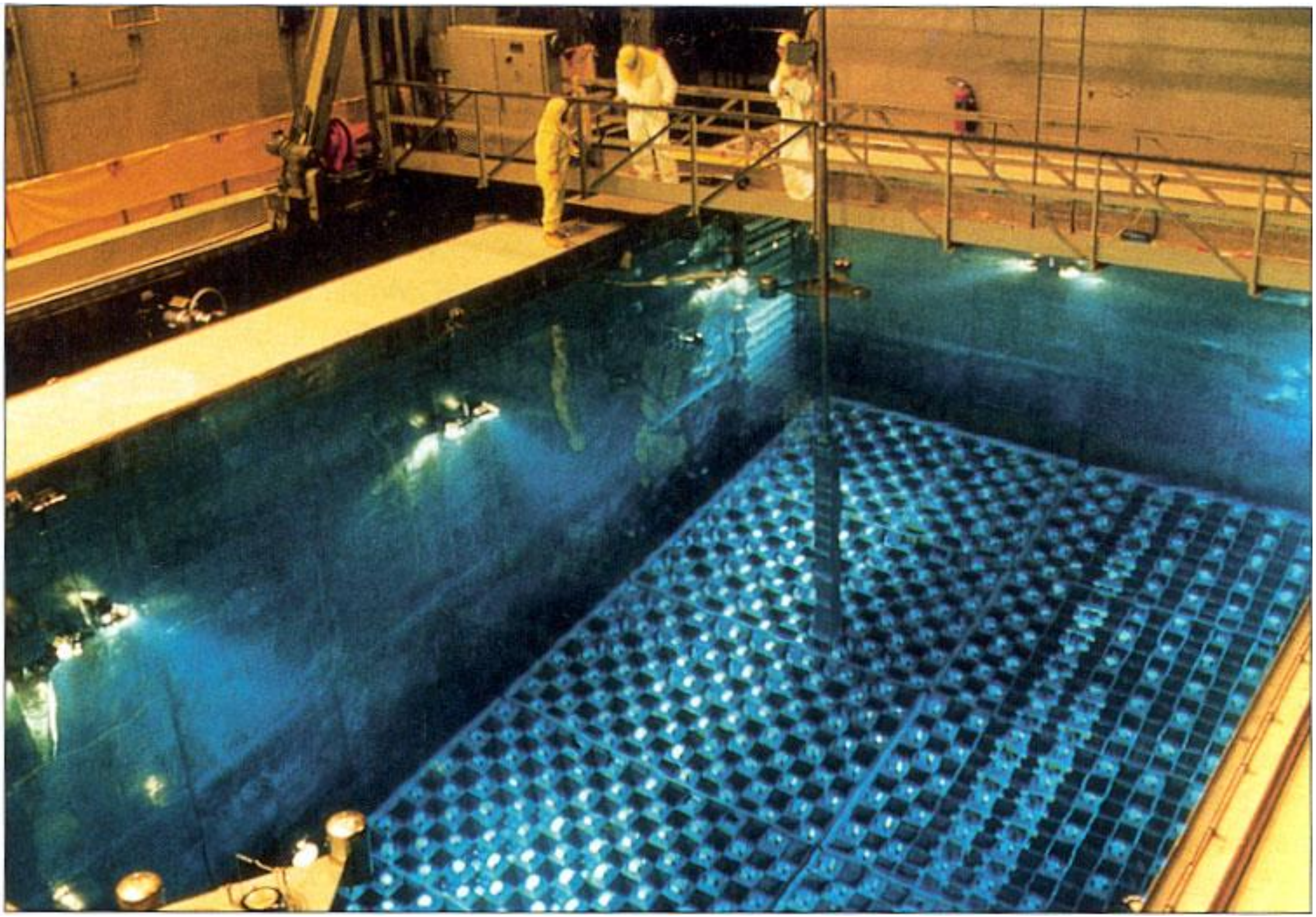
The Fuel



The Fuel



The Fuel?



Used Nuclear Fuel Storage

- Nuclear Waste Policy Act (1982): Guaranteed repository by January 31, 1998

- DOE won't begin accepting fuel at Yucca Mountain before 2010

Used Nuclear Fuel Storage

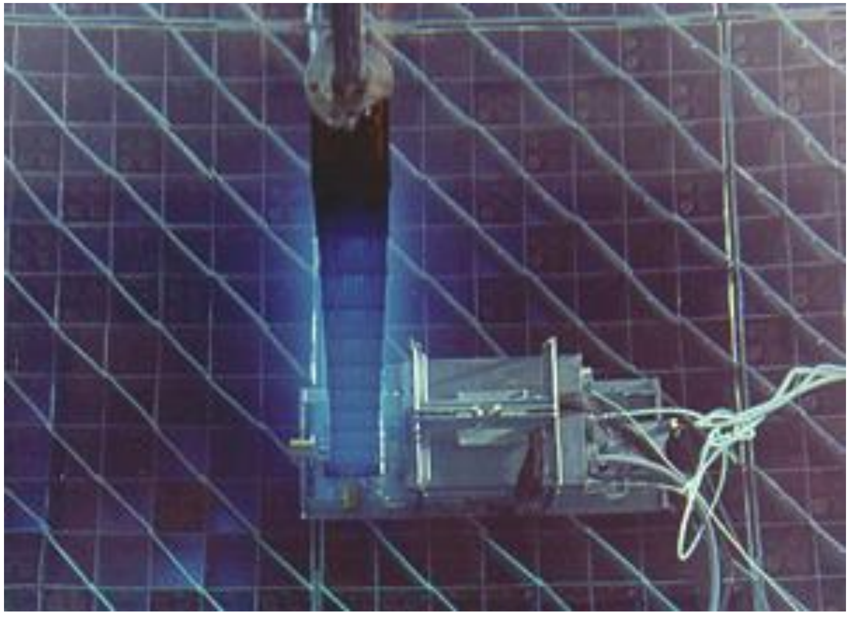
ANS

- To-date, utilities have paid more than $14 billion into the Nuclear Waste Fund (1/10 of a cent/kWh)

- Only about one-third of that money has been invested in the Yucca Mountain Project

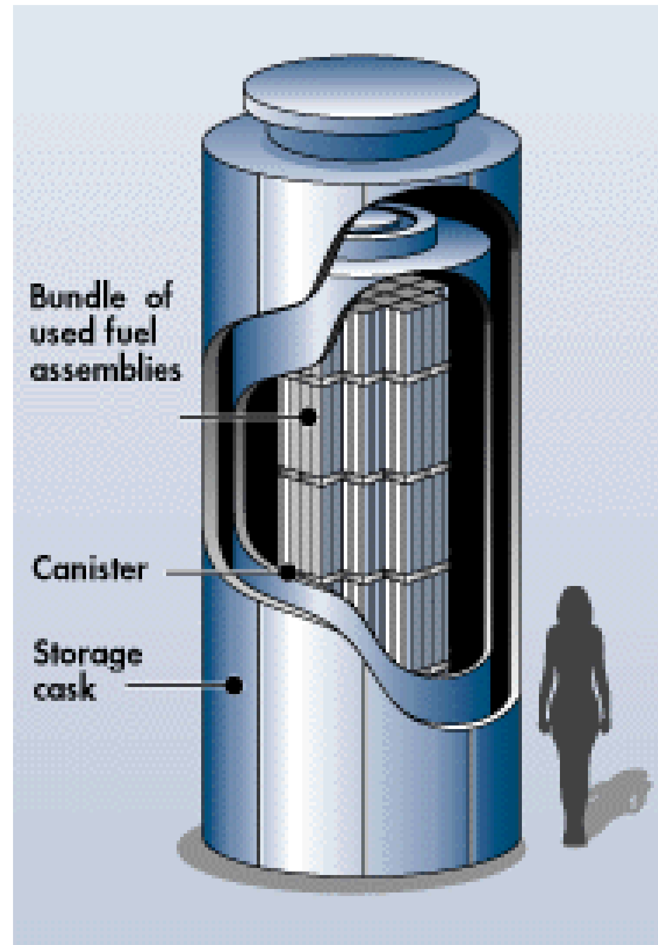
Used Nuclear Fuel Storage

- About 2,000 tons of used fuel generated annually by nation's plants
- About 30,000 tons being stored on-site at 70 nuclear stations
- That amounts to about enough waste -- from 30 years of commercial nuclear operation -- to fill a football field, four yards deep



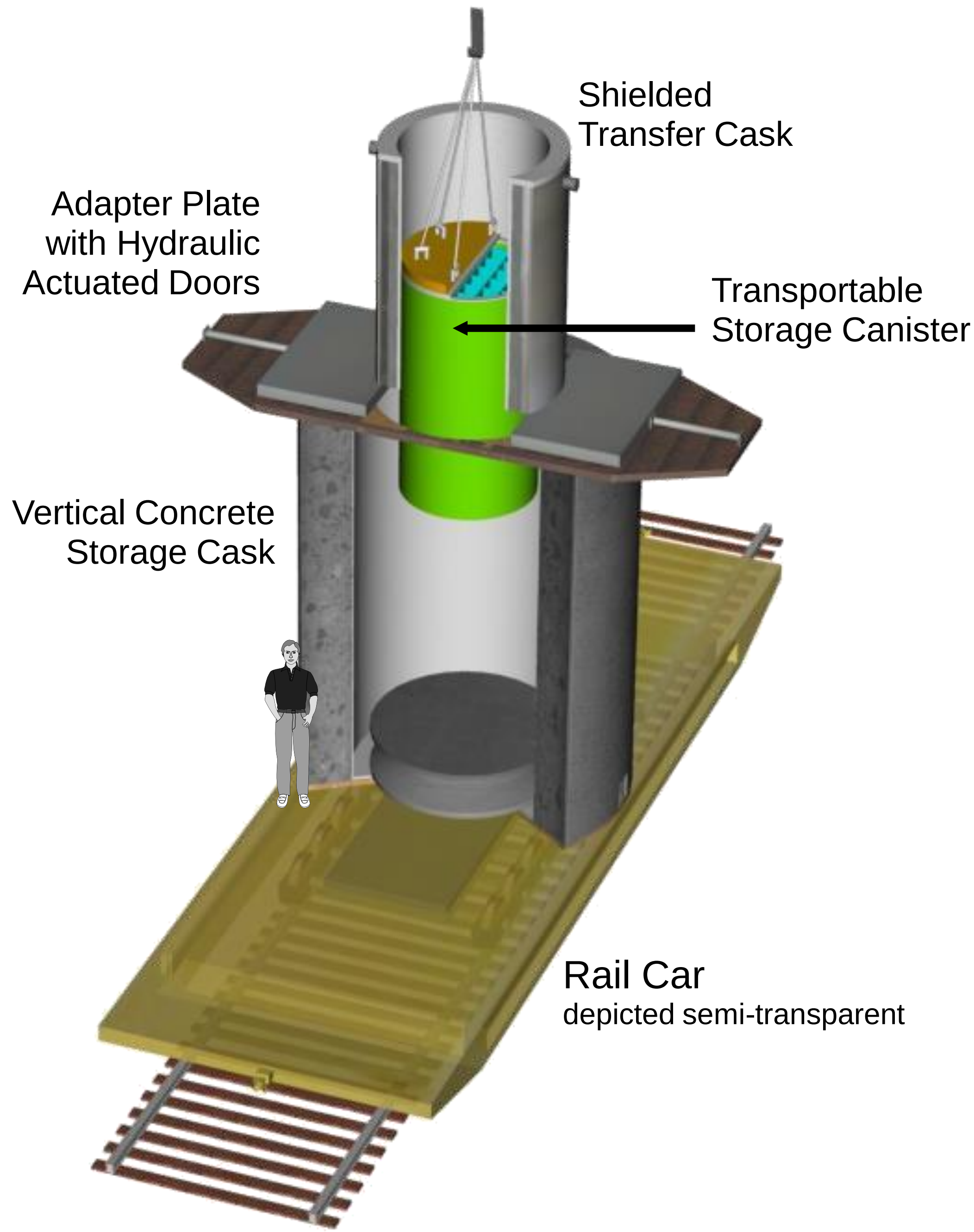
Used Nuclear Fuel Storage

- Steel and concrete containers: 18 feet tall, 11 feet in diameter, 165 tons filled
- Start using in Fall 2002
- A person could stand beside a container for an hour and receive
  less radiation exposure than from
  a coast-to-coast flight
- Dry storage currently used at 10 plants around the nation



Palo Verde Dry Cask Storage Principal Components

(Cut-away View)



Schedule: Load first system December 2002

Dimensions:

Transfer cask	Ht. 16 ft. 11 in.
	Dia. 7 ft. 1 in.
Loaded canister	Ht. 15 ft. 11 in.
	Dia. 5 ft. 7 in.
VCC	Ht. 18 ft. 10 in.
	Dia. 11 ft. 4 in.

Weight:

Transfer cask	60 tons
Loaded canister	35 tons
VCC	119 tons
Loaded system	154 tons

Concrete Cask Construction

Completed VCCs

Did You Know?

If all the electricity used by one person throughout his life was produced by nuclear power, that person's share of nuclear waste would fit in a single soda can

Questions?

Nuclear Accidents

Two historical events

1. Three Mile Island

2. Chernobyl

Three Mile Island

- In 1979 at Three Mile Island nuclear power plant in USA a cooling malfunction caused part of the core to melt in the # 2 reactor. The TMI-2 reactor was destroyed.
- Some radioactive gas was released a couple of days after the accident, but not enough to cause any dose above background levels to local residents.
- There were no injuries or adverse health effects from the Three Mile Island accident.

Chernobyl

- The Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel.
- The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind.
- Two Chernobyl plant workers died on the night of the accident, and a further 28 people died within a few weeks as a result of acute radiation poisoning. Total death toll 56

Differences

- Chernobyl reactor did not have a containment structure like those used in the West or in post-1980 Soviet designs.
- coolant failure could lead to a strong increase in power output from the fission process
- concept of 'defense in depth' was conspicuous by its absence

Future of Nuclear Power

Over thirty countries are actively considering embarking upon nuclear power programs.

These range from sophisticated economies to developing nations.

- USA
- Pacific Rim
- Europe

Europe

- As of February 2010 there is a total of 194 nuclear power plant units with an installed electric net capacity of 168 GWe in operation in Europe and 17 units with 14,7 GWe were under construction in six countries.


Finland 4
Sweden 10
Netherlands 1
Belgium 7
Russia 31
19
United Kingdom
Germany 17
Ukraine 15
France 58
Spain 8
Switzerland 5
Romania 2
Bulgaria 2
Hungary 4
Slovenia 1
Czech Republic 6
Slovak Republic 4

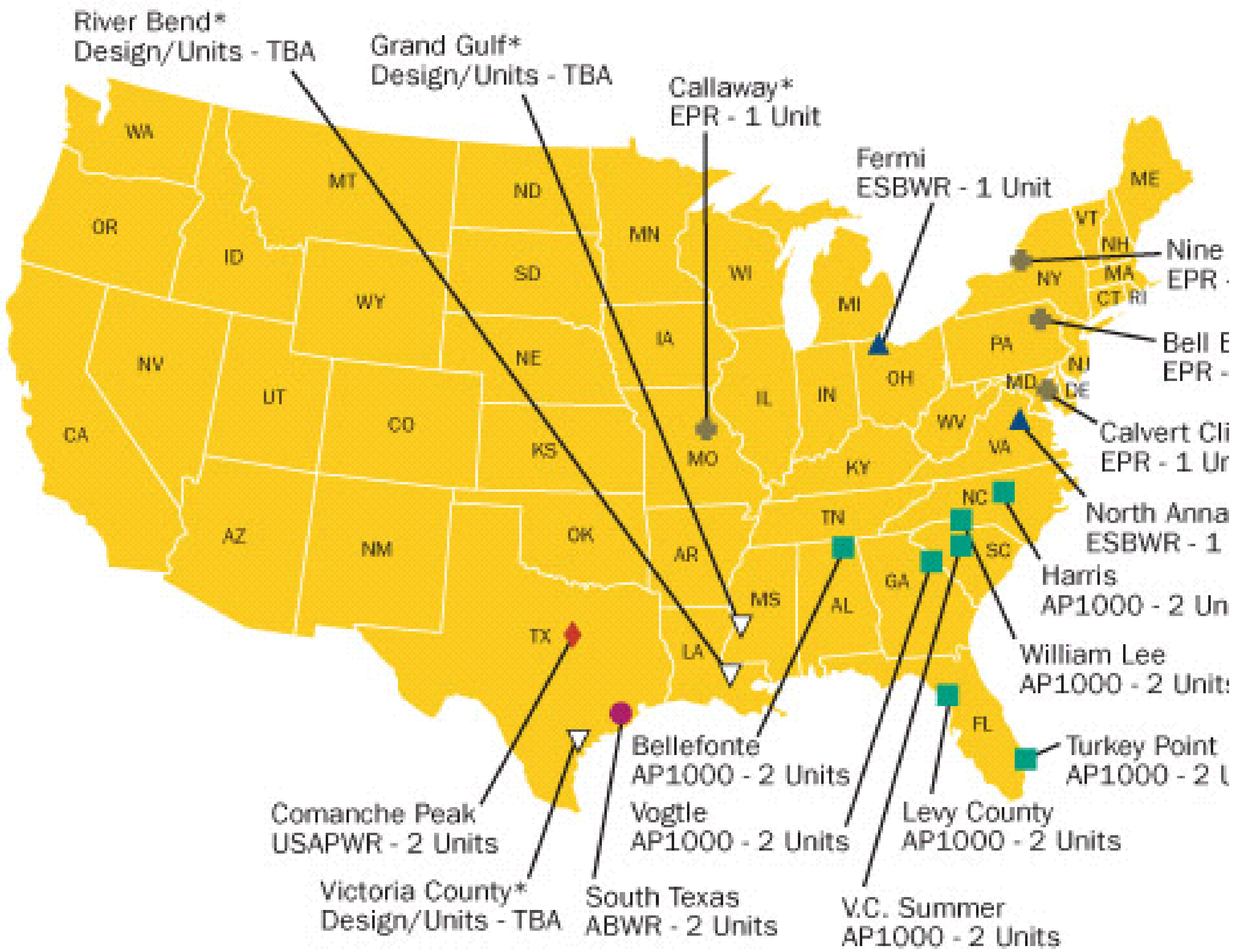
ANS

Pacific Rim

- Asia is the only region in the world where electricity generating capacity and specifically nuclear power is growing significantly.
- In East and South Asia there are over 111 nuclear power reactors in operation, 21 under construction and plans to build about a further 150.
- The greatest growth in nuclear generation is expected in China, Japan, South Korea and India.

Location of Projected New Nuclear Power React

For applications that have been received by the NRC, you may select a site name t NRC's website for the specific COL application. Websites for the remainder of the a, be created when they are received.



You may click on a design name to view the NRC's Web site for the specific design.

● ABWR ■ AP1000 ✚ EPR ▲ ESBWR ♦ USAPWR ▽ Design/Units - TBA

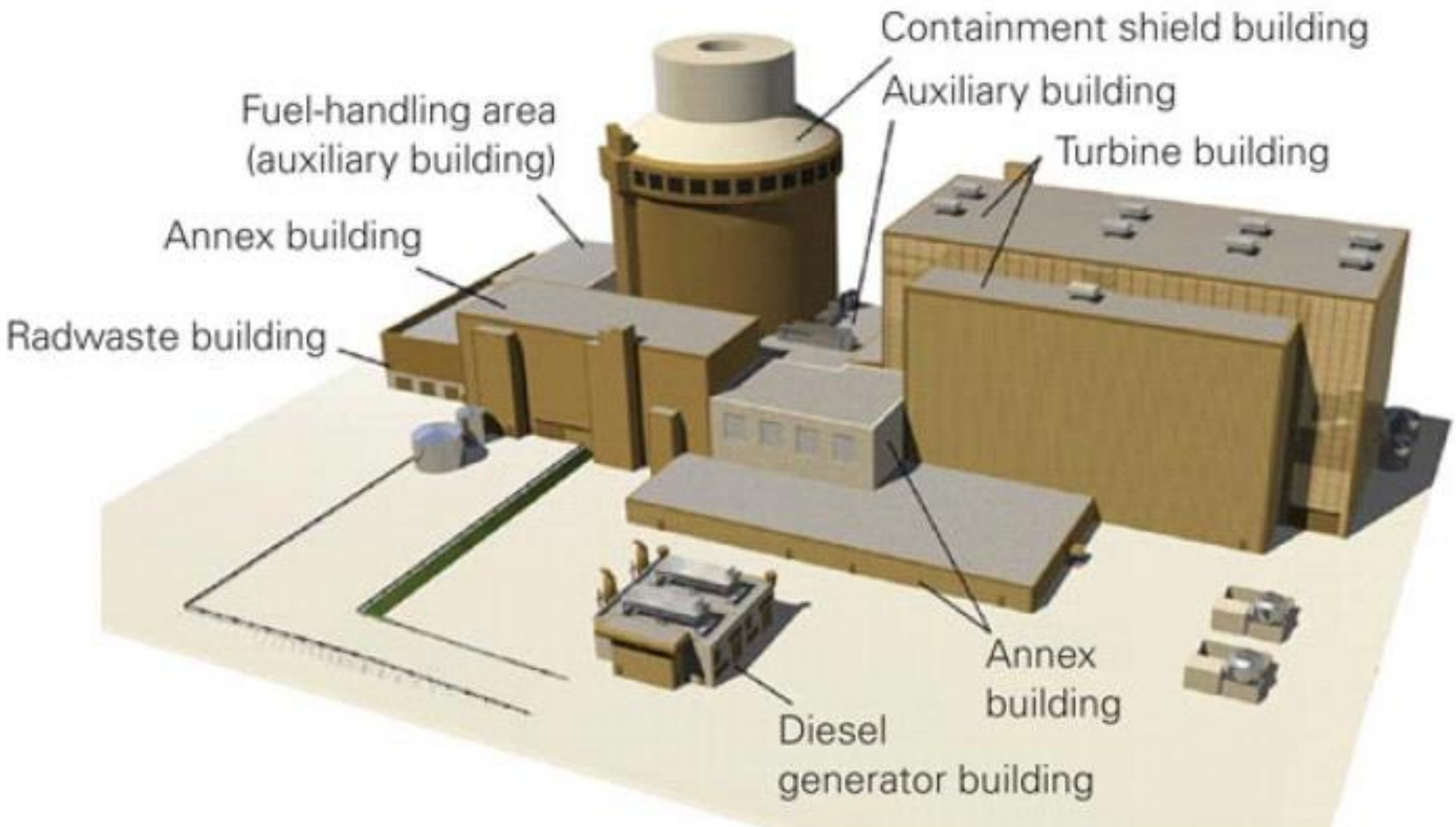
ANS

Southern Nuclear- Vogtle Nuclear Site

- The NRC’s issuance of an ESP and LWA (completed August 2009)
  - Early Site Permit (ESP)
  - Limited Work Authorization (LWA)
    - LWA allows a narrow set of construction activities at the site

LWA at Vogtle

Westinghouse AP1000 PWR



Westinghouse AP1000 PWR

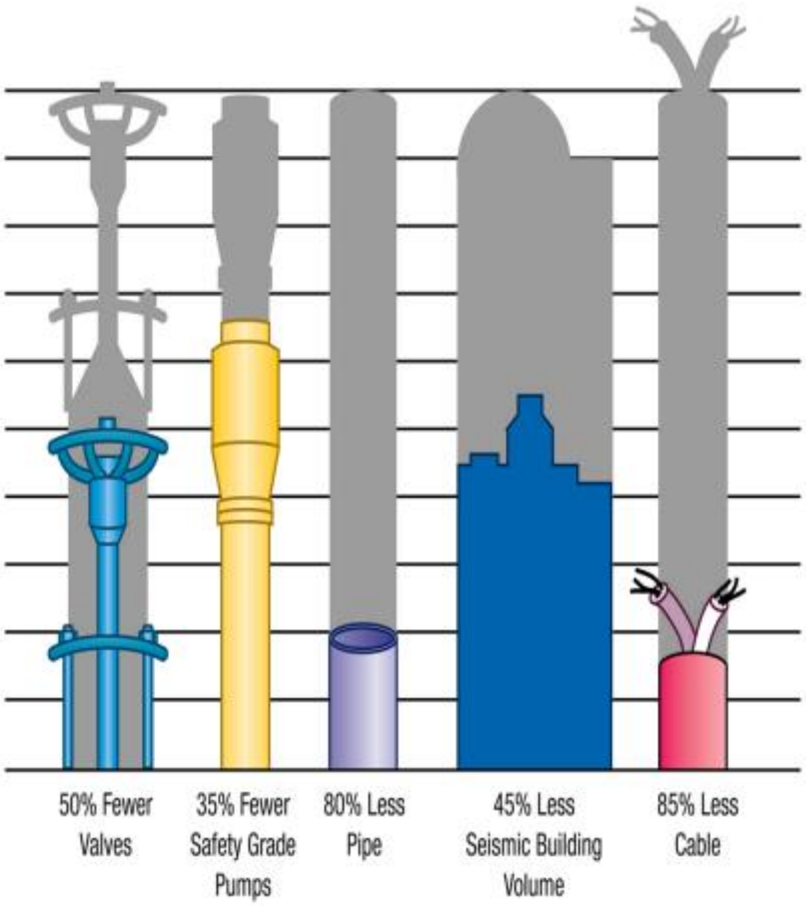
ANS

- AP1000 features proven technology, innovative passive safety systems
- Simplification was a major design objective

- http://ap1000.westinghousenuclear.com/index.html

AP1000 design saves money

- 50% fewer safety-related valves
- 80% less safety-related piping
- 85% less control cable
- 35% fewer pumps
- 45% less seismic building volume



Defense-in-depth of the AP1000

- The following features contribute to defense-in-depth of the AP1000:
  - Non-Safety Systems
  - Passive Safety-Related Systems
  - In-vessel Retention of Core Damage

AP1000 passive safety systems

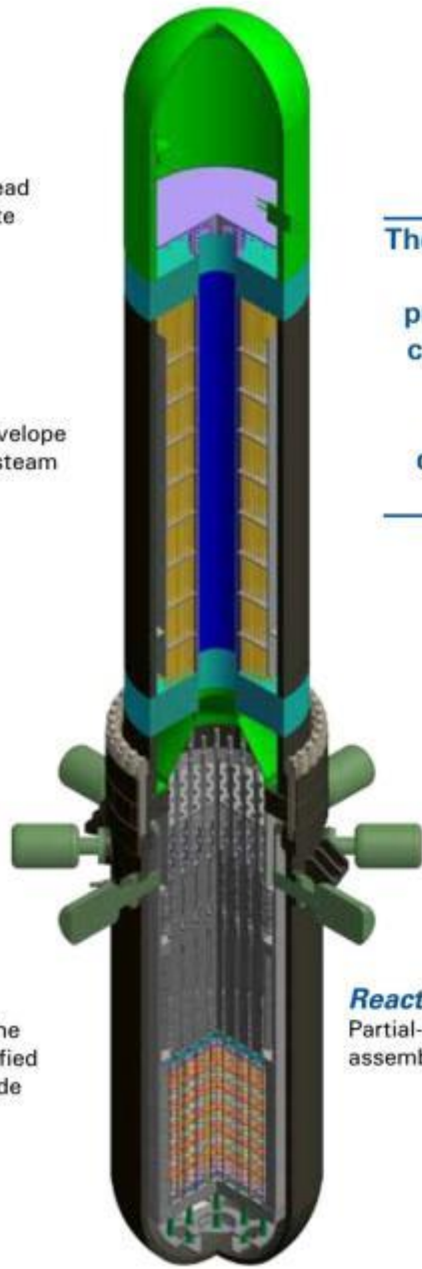
– Passive core cooling system
– Containment isolation
– Passive containment cooling system
– Main control room emergency habitability system

Pressurizer
Integration into reactor vessel head eliminates the need for a separate component

Steam Generator
Achieves a compact physical envelope with an innovative approach to steam separation

Reactor Coolant Pumps
Proven, horizontally-mounted axial-flow canned motor pumps provide the driving head for the reactor coolant system while eliminating the need for pump seal injection

Reactor Vessel Internals
Based on the AP1000® design, the reactor vessel internals are modified for the smaller core and to provide support for the internal control drive rod mechanisms



The Westinghouse SMR design offers options to power producers. The SMR design can provide a clean solution that fits local needs, while contributing to a diversified energy portfolio and fuel price control.

Reactor Core
Partial-height derivative of the 17x17 fuel assembly design used in the AP1000® reactor