# Thermal and Nuclear Power Generation

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many photos from M.A. El-Sharkawi, (c), University of Washington



## Overview

- Thermal power plants
  - Thermodynamic cycles
  - Plant components
    - Boiler, turbine, generator
    - Governor
- Nuclear power plants



## Discussion Questions

- The end-to-end conversion process in a steam plant
- Life cycle environmental damage from a steam plant
- Explain the thermodynamic cycles in a steam plant



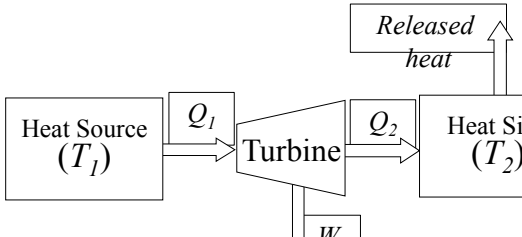
## * Thermal Energy Constant *

| Fuel Type | Thermal Energy Constant (Btu/kg) |
|---|---|
| Petroleum Oil | 45,000 |
| Natural gas | 48,000 |
| Coal | 27,000 |
| Wood (oven dry) | 19,000 |



1 Btu = 252 calories = 1.0544 kJoules

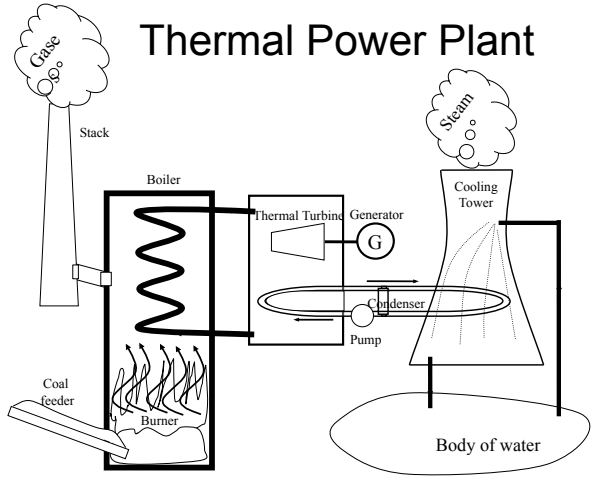
## Second Law of Thermodynamics




$$W = Q_1 - Q_2$$
$$W = T_1 - T_2$$

$$\eta_{ideal} = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1}$$

## Thermal Power Plant

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**What are the differences between a gas turbine and a steam turbine**

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Cogeneration, or Combined Heat & Power, CHP

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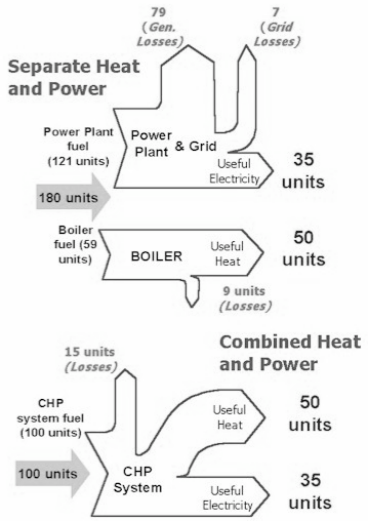
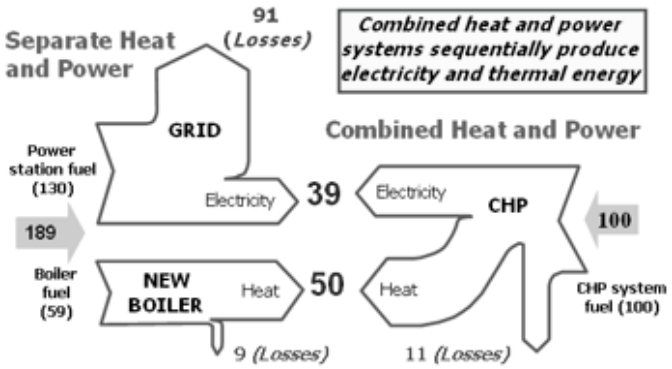
## Cogeneration




http://www.sdenergy.org/ContentPage.asp?ContentID=48&SectionID=66

## Cogeneration

http://www.eere.energy.gov/de/chp/chp_technologies/tech_basics.html

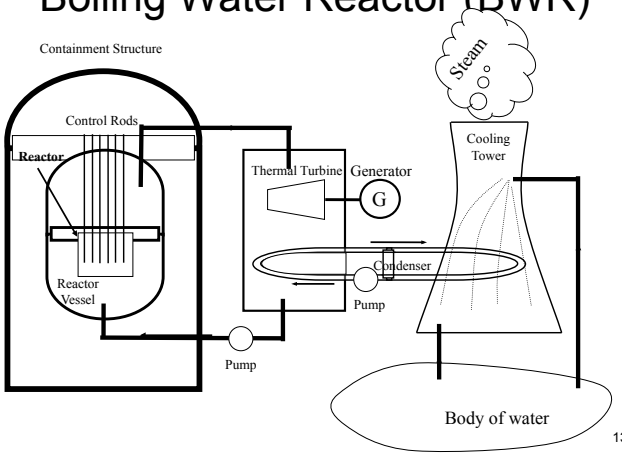



## Cogeneration and Efficiency

- What is the increase in efficiency from using cogeneration, according to these figures?
- What types of locations are best suited to cogeneration?

## Nuclear Power Plants

## Boiling Water Reactor (BWR)

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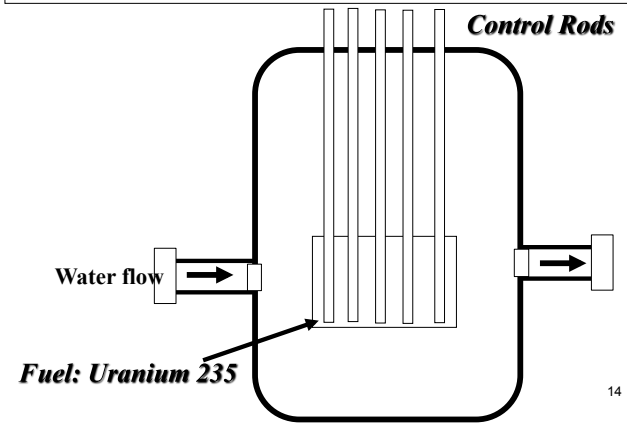
## Reactor Vessel

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## Types of Nuclear Power Plants

- ***Fission***
  - Nuclear fuel
  - The fission process – splitting atoms
  - Types of reactors
    - pressurized water reactors
    - boiling water reactors
- ***Fusion***
  - Two lighter elements are combined into a heavier element, and release energy in the process

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## Nuclear Fuel

- Natural uranium is a mixture of three isotopes
  - $U^{234}$, $U^{235}$ (0.7%) and $U^{238}$ (99.2%) (superscript is atomic mass)
- Only $U^{235}$ can fission in nuclear reactor
- Enrichment process is used to increase the concentration of $U^{235}$
  - For nuclear power generation, the concentration is ~ 3-5%
  - For nuclear weapons the concentration of $U^{235}$ is 90%.

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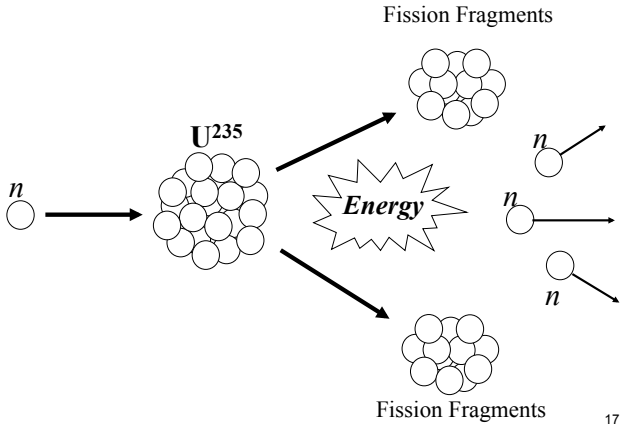
## *Fission Process*

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## Fission Process

- The newly released neutrons hit other uranium atoms causing additional fission processes
- As atoms are split
  - Some mass is lost
  - This lost mass becomes energy

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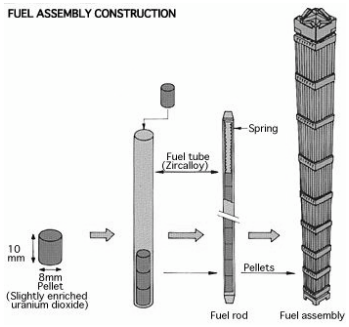
## Nuclear Fuel

- $U^{235}$ comes in the form of ceramic pellets about 10mm in size.
- The pellets are inserted into tubes and placed inside the reactor
- Each pellet contains the energy equivalent of
  - 2,000 lb of coal
  - 150 gallons of oil

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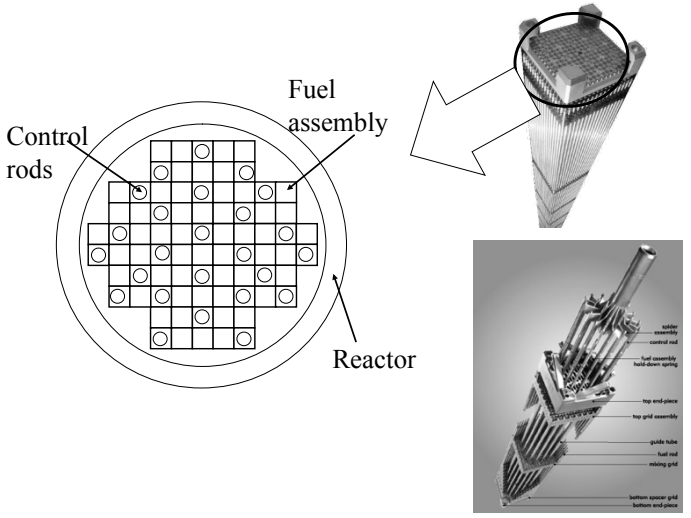

## What Happens To Used Fuel?

- "fission fragments“ left over after the atoms have split (cesium-140, rubidium-93) are radioactive.
- The fragments are cooled and stored in concrete pools lined with stainless steel.



## Nuclear vs. Chemical Reactions

- Nuclear reactions
  - Binding energy of nuclei
  - On the order of 17 MeV
- Chemical reactions
  - Energy holding electrons to the nucleus
  - On the order of 13.6 eV



## Summary

- Thermal power plants
  - Boiler
  - Steam turbine
  - Electric generator
  - Cogeneration
- Nuclear power generation