APES Chapter 15

Nonrenewable Energy

**Core Case Study: Is the United States Entering a New Oil and Natural Gas Era?**

* Oil and natural gas
  + Two most \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ natural resources in the U.S.
* Oil consumption is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + New extractions from \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ cause environmental harm
  + Burning oil and natural gas will continue adding \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gases to the atmosphere

**15-1 What is Net Energy and Why Is It Important?**

* Energy resources vary greatly in their net energy \_\_\_\_\_\_\_\_\_\_

Net Energy Is the Only Energy That Really Counts

* Net energy yield
  + Total amount of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ energy available from a resource minus the energy needed to make the energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to consumers
* Energy return on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ per unit energy \_\_\_\_\_\_\_\_\_\_ to obtain it
* First law of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_:
  + It takes high-quality energy to get high-quality energy
    - Pumping \_\_\_\_\_\_\_\_\_\_ from ground, refining it, and transporting it
* Second law of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_:
  + Some high-quality energy is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ at every step

Some Energy Resources Need Help to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the Marketplace

* Cannot compete in open \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with alternatives that have higher net energy yields
  + Need \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from taxpayers
* Nuclear power
  + The uranium fuel cycle is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**15-2 What Are the Advantages and Disadvantages of Oil?**

* Conventional \_\_\_\_\_\_\_\_\_\_ oil is abundant and has a medium net energy yield, but using it causes air and water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and releases greenhouse gases to the atmosphere
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ heavy oil from oil shale rock and tar sands exists in potentially large supplies but has a low net energy yield and a higher environmental impact than conventional oil

We Depend Heavily on Oil

* Crude oil (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)
* Peak production – time after which production from a well \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Global peak production for all world oil
* Crude oil \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ be used as it comes out of the ground
  + Must be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Petrochemicals – \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Are We Running Out of Conventional Oil?

* Availability determined by:
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Rate at which we \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the oil
  + Cost of making oil \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Market price
* Proven oil reserves – available deposits
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Unconventional heavy oil
  + Higher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cost; \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cost
* Three major options:
  + Live with much higher oil \_\_\_\_\_\_\_\_\_\_
  + Extend oil supplies \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Use other energy sources

Use of Conventional Oil Has Environmental Costs

* Land disruption, greenhouse gas emission, air pollution, water pollution, and loss of biodiversity
* Burning oil accounts for \_\_\_\_\_\_ of global CO2 emissions

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**Case Study: Oil Production and Consumption in the United States**

* The U.S.:
  + Produces \_\_\_\_\_\_ of the world’s oil and uses \_\_\_\_\_\_ of world’s oil
  + Has about \_\_\_\_\_\_ of world’s proven oil reserves
  + Imports \_\_\_\_\_\_ of its oil
* Should we look for more oil reserves?
  + Extremely \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and financially risky

Heavy Oil from Oil Shale Rock

* Oil shales contain \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + After \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ – shale oil
* \_\_\_\_\_\_ of the world’s reserve is in arid areas of western United States
  + Locked up in rock
  + Lack of water needed for extraction and processing
  + Low net energy yield

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Heavy Oil from Tar Sands

* Tar sand contains \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Extensive deposits in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Oil sands have more oil than in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Serious environmental impact before \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_ net energy yield

**15-3 What Are the Advantages and Disadvantages of Using Natural Gas?**

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ natural gas:
  + Is more \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than oil
  + Has a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ net energy yield and a fairly low production cost
  + Is a \_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ fuel
* However, producing it has created \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ problems

Natural Gas Is a Useful, Clean-Burning, but Not Problem-Free Fossil Fuel

* Natural gas – \_\_\_\_\_\_\_\_\_\_ methane \_\_\_\_\_\_\_\_\_\_
* Conventional natural gas
  + Liquefied \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gas (LPG)
    - Stored in tanks
  + Liquefied \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ gas (LNG)
    - Low net energy yield
    - Makes U.S. dependent upon \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ countries like Russia and Iran
* The U.S. produces gas conventionally and from shale rock
  + Increasing environmental problems with shale rock \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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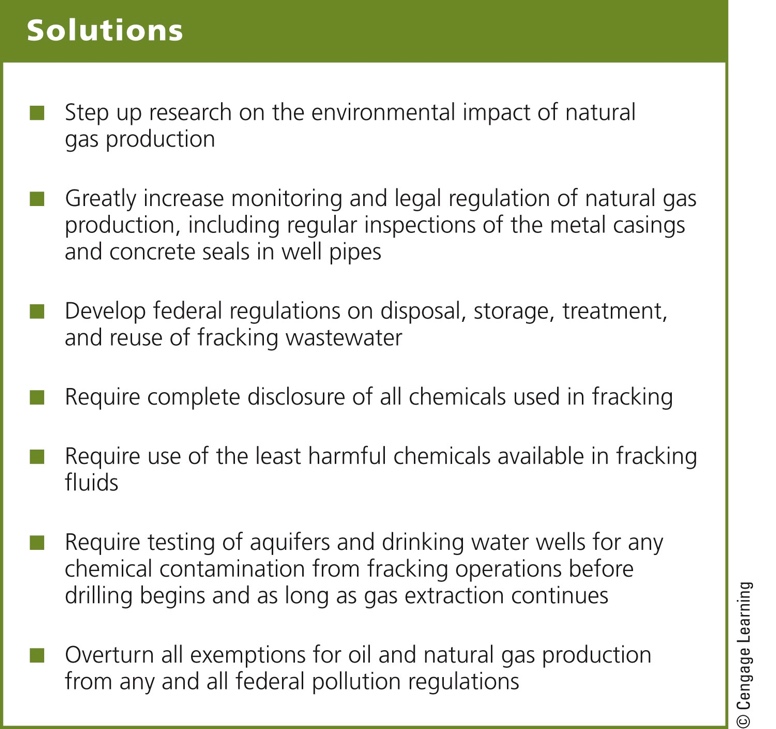
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**Case Study: Natural Gas Production and Fracking in the U.S.**

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Drilling wells; using huge amounts of water, sand, and chemicals; dealing with toxic wastewater; transporting the natural gas
* Drinking water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with natural gas can catch fire
* Fracking has several \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ environmental effects



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Natural Gas

* Coal bed methane gas
  + In coal beds near the earth’s surface; in shale beds
  + High environmental impacts of extraction
* Methane hydrate
  + Trapped in icy water; in permafrost environments; on ocean floor
  + Costs of extraction is currently too high

**15-4 What Are the Advantages and Disadvantages of Coal?**

* Conventional coal is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and has a \_\_\_\_\_\_\_\_\_\_ net energy yield at \_\_\_\_\_\_\_\_\_\_ costs, but using it results in a \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_ environmental impact
  + We can produce gaseous and liquid fuels from \_\_\_\_\_\_\_\_\_\_, but they have \_\_\_\_\_\_\_\_\_\_ net energy yields and using them would result in \_\_\_\_\_\_\_\_\_\_\_\_\_\_ environmental impacts than those of conventional coal

Coal Is a Plentiful but Dirty Fuel

* Coal
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ fossil fuel
* Burned in power plants
  + Generates \_\_\_\_\_\_ of the world’s electricity
* Abundant – world’s largest coal reserves
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Environmental costs of burning coal
  + Severe air pollution
    - Sulfur released as \_\_\_\_\_\_\_\_\_\_
    - Large amount of \_\_\_\_\_\_\_\_\_\_
    - \_\_\_\_\_\_\_\_\_\_
    - Trace amounts of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and radioactive materials

The Clean Coal Campaign

* Coal companies and energy companies have fought:
  + Classifying carbon dioxide as a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Classifying coal ash as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ waste
  + Air pollution standards for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The 2008 clean coal campaign
  + Note: there is no such thing as clean coal

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We Can Convert Coal into Gaseous and Liquid Fuels

* Conversion of solid coal to:
  + Synthetic natural gas (SNG) by coal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Methanol or synthetic gasoline by coal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Are there benefits to using these \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ fuels?

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**15-5 What Are the Advantages and Disadvantages of Using Nuclear Power?**

* Nuclear power has a \_\_\_\_\_\_\_\_\_\_ environmental impact and a very \_\_\_\_\_\_\_\_\_\_ accident risk, but its use has been limited by:
  + A low net energy \_\_\_\_\_\_\_\_\_\_, high \_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_ of accidents, and long-lived radioactive \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Its role in spreading nuclear \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ technology

How Does a Nuclear Fission Reactor Work?

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ nuclear fission reaction in a reactor
  + Light-water reactors
  + Very inefficient
* Fueled by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ore and packed as pellets in fuel rods and fuel assemblies
* Control rods absorb \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Water is the usual coolant
* Containment shell around the core for protection
* Water-filled pools or dry casks for storage of radioactive spent fuel rod assemblies

What Is the Nuclear Fuel Cycle?

* Mine the uranium
* Process the uranium to make the fuel
* Use it in the reactor
* Safely store the radioactive waste
* Decommission the reactor

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Storing Radioactive Spent-Fuel Rods Presents \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Rods must be replaced every three or four years
* Cooled in water-filled pools
* Placed in dry casks
* Must be stored for thousands of years
* Vulnerable to terrorist attack

Dealing with Radioactive Nuclear Wastes Is a Difficult Problem

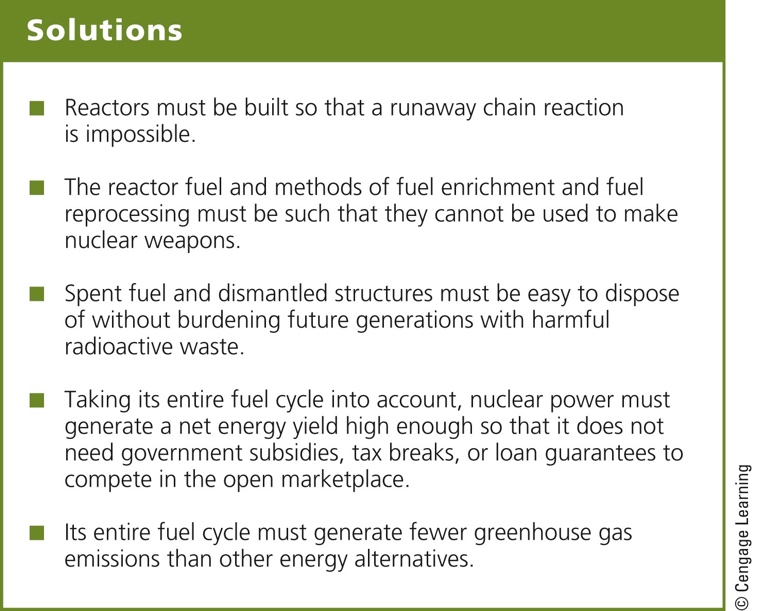
* High-level radioactive wastes
  + Must be stored safely for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ years
* Where can it be stored?
  + Deep burial: safest and cheapest option
  + Would any method of burial last long enough?
  + There is still no facility
  + Shooting it into space is too dangerous
* Plans in the U.S. to build a repository for high-level radioactive wastes in the Yucca Mountain desert region (Nevada)
* Many problems including:
  + Cost of \_\_\_\_\_\_\_\_\_\_ billion
  + Rock fractures
  + Earthquake zone
  + Decrease national security
* Dealing with old nuclear power plants:
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or retire the power plant
  + Dismantle the plant and safely store the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ materials
  + Enclose the plant behind a physical barrier with full-time security until a storage facility has been built
  + Enclose the plant in a tomb
    - Monitor this for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of years

Can Nuclear Power Help Reduce Climate Change?

* Nuclear power plants – no CO2 emission
* Nuclear fuel cycle – emits CO2
* Opposing views on nuclear power
  + Nuclear power advocates
  + Oxford Research Group
* Need high rate of building new plants, and a storage facility for radioactive wastes

Experts \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ about the Future of Nuclear Power

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of nuclear power:
  + Fund more research and development
  + Pilot-plant testing of potentially cheaper and safer reactors
  + Test breeder fission and nuclear fusion
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of nuclear power:
  + Fund rapid development of energy efficient and renewable energy resources
* New technologies
  + Advanced Light Water Reactors
    - Safer
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ based reactors
    - Less costly and safer



**Case Study: The 2011 Nuclear Power Plant Accident in Japan**

* Triggered by a major offshore \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and resulting \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Four key human-related factors:
  + No worst-case scenarios
  + Seawalls too short
  + Design flaws
  + Relationship between plant owners and government

Is Nuclear Fusion the Answer?

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Two isotopes fused together to form a heavier nucleus
  + Releases energy
* Technology is very difficult to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Three Big Ideas**

* A key factor to consider in evaluating the long-term usefulness of any energy resource is its net energy yield
* Conventional oil, natural gas, and coal:
  + Plentiful and have moderate to high net energy yields
  + Use of these fossil fuels, especially coal, has a high environmental impact
* The nuclear power fuel cycle has a low environmental impact and a very low accident risk, but limited use because of:
  + High costs
  + A low net energy yield
  + Long-lived radioactive wastes
  + Its role in spreading nuclear weapons technology

**Tying It All Together: A New U.S. Oil and Natural Gas Era and Sustainability**

* Conventional fossil fuels have high net energy yields
* We cannot recycle energy
  + Recycling materials can help reduce energy needs
* Relying on a diversity of energy resources
  + Will reduce environmental impacts