Fundamentals of Renewable Energy

Mohammad Sadegh Valipour

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Aims

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- **Introduction to the concepts of renewable energies**
- **Acquire knowledge in various forms of renewable energy**
- **Introduction to power and heat cycles in renewable energy applications**
- **Introduction to the concepts of heat transfer, radiation and Convection**
- **Introduction to renewable systems, for example, solar collectors and heat analysis of these systems**

References

- **Fundamentals and Applications of Renewable Energy by Mehmet Kanoglu**
- **Fundamentals of Renewable Energy Processes by Aldo Vieira da Rosa**
- **Advanced Thermodynamic by Bejan**
- **Thermal Radiation Heat Transfer by Howell**
- **Heat Transfer by Holman**
- **Solar Engineering of Thermal Process by Duffie and Beckman**

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CHAPTER 1

Introduction to Renewable Energy

Why Renewable Energy?

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- **To meet its energy needs, the world community currently depends heavily on fossil fuels that are nonrenewable and unfriendly to the environment.**
- **Total global energy supply in 2017 was 589 Quad Btu, which is equivalent to 5.6 × 10e17 kJ.**

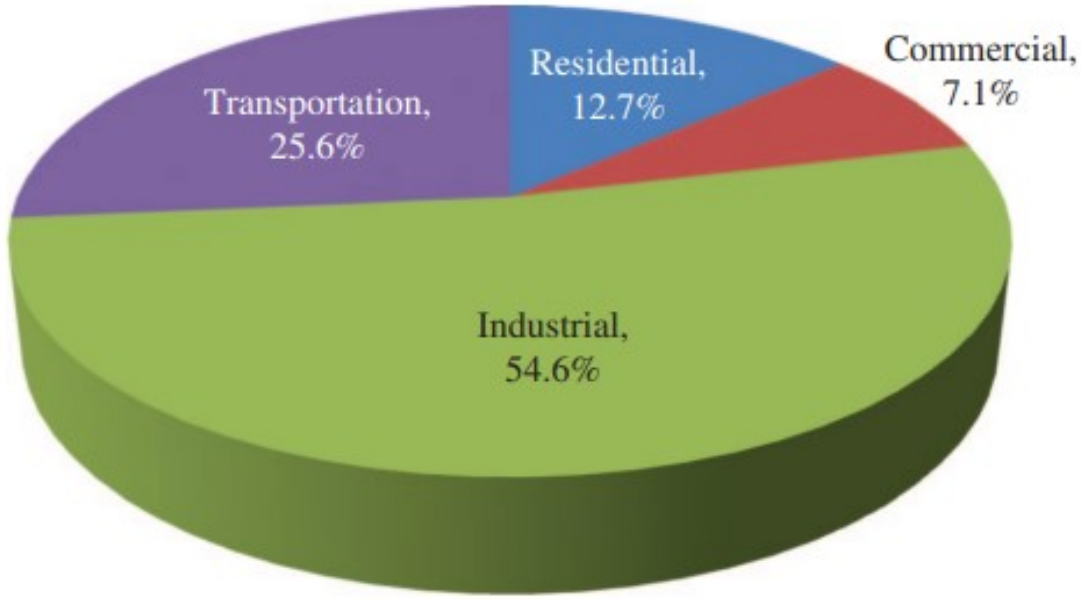

Figure 1-1
Percentages of global energy use by end-use sectors in 2017 (EIA, 2018).

Why Renewable Energy?

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- **Fossil fuels accounted for 82.7 percent (27.1% coal, 33.4% oil, 22.2% natural gas) of this total energy production.**
- **Renewable energy (including hydroelectric power), which is environment-friendly and can be harvested indefinitely, was responsible for 12.7 percent of the total**
- **Nuclear power supplied the remaini energy supply.**

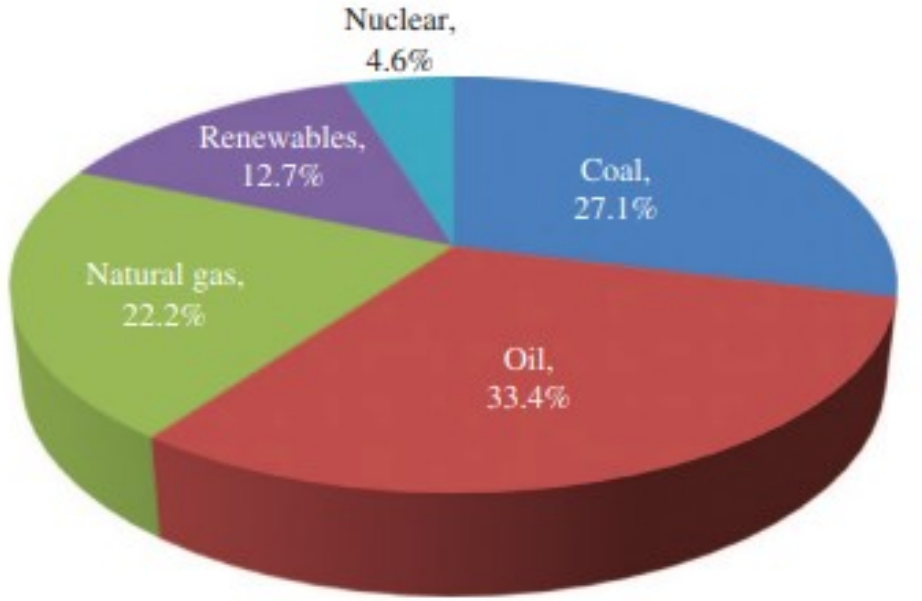

Figure 1-2
Percentages of total world primary energy supply by fuel in 2017 (EIA, 2018).

Why Renewable Energy?

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- **Renewables are currently the fastest-growing energy source in the world.**
- **Depletion and emission concerns over fossil fuel use and increasing government incentives can cause even higher growth in the use of renewables in the coming decades.**
- **The fastest-growing renewable sources are solar and wind.**
- **The installed wind capacity has increased from 18 GW in 2000 to 539 GW by the end of 2017.**
- **The solar power capacity has increased by 97 GW in 2017 bringing the global capacity to over 400 GW.**

Why Renewable Energy?

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The installed capacity of hydropower exceeds 1250 GW worldwide. Hydroelectric, geothermal, and wind power generation technologies are able to compete with fossil fuel–based electricity generation economically, but solar electricity generation is still expensive. However, steady decreases in solar electricity cost combined with increased government incentives are likely to help wider use of solar electricity in the coming years.

Consequences of Fossil Fuel Combustion

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Fossil fuels have been powering industrial development and the amenities of modern life since the 1700s, but this has not been without undesirable side effects. Pollutants emitted during the combustion of

ain, and numerous other ronmental pollution has ome a serious threat to llution has been the cause ma and cancer. But this since the estimated life of itch to renewable energy

Figure 1-3
Greenhouse gases, like those belched out by many industrial smokestacks, are among the most potent causes of climate change.

Consequences of Fossil Fuel Combustion

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The combustion of fossil fuels produces the following undesirable emissions:

- **CO2 primary greenhouse gas: contributes to global warming**
- **Nitrogen oxides (NOx) and hydrocarbons (HC): cause smog**
- **Carbon monoxide (CO): toxic**
- **Sulfur dioxide (SO2): causes acid rain**
- **Particulate matter (PM): causes adverse health effects**

✓ **Notice from this emissions list that CO2 is different from the other emissions in that CO2 is a greenhouse gas and a natural product of fossil fuel combustion while other emissions are harmful air pollutants.**

Consequences of Fossil Fuel Combustion

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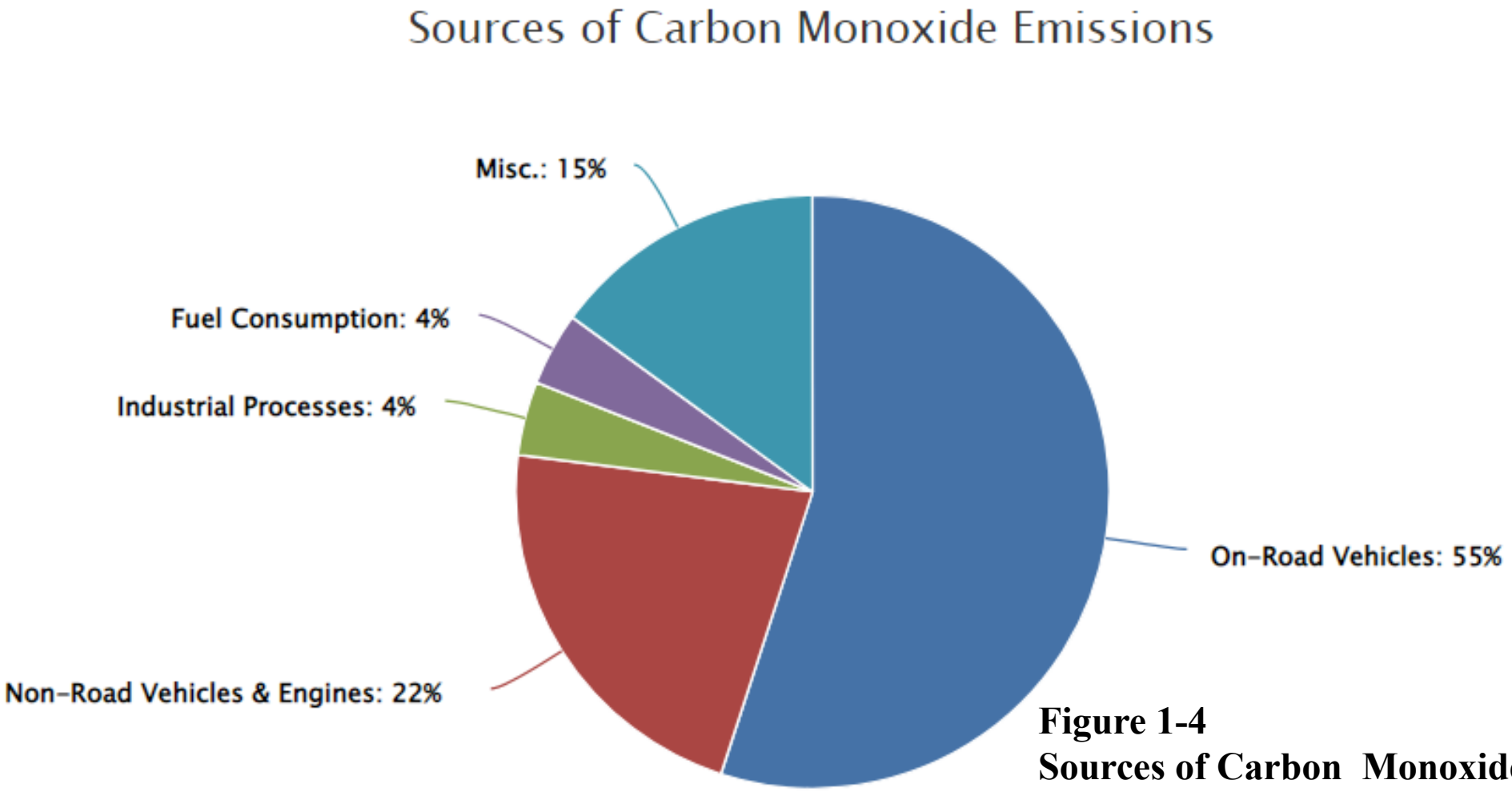

Figure 1-4
Sources of Carbon Monoxide Emissions

Consequences of Fossil Fuel Combustion

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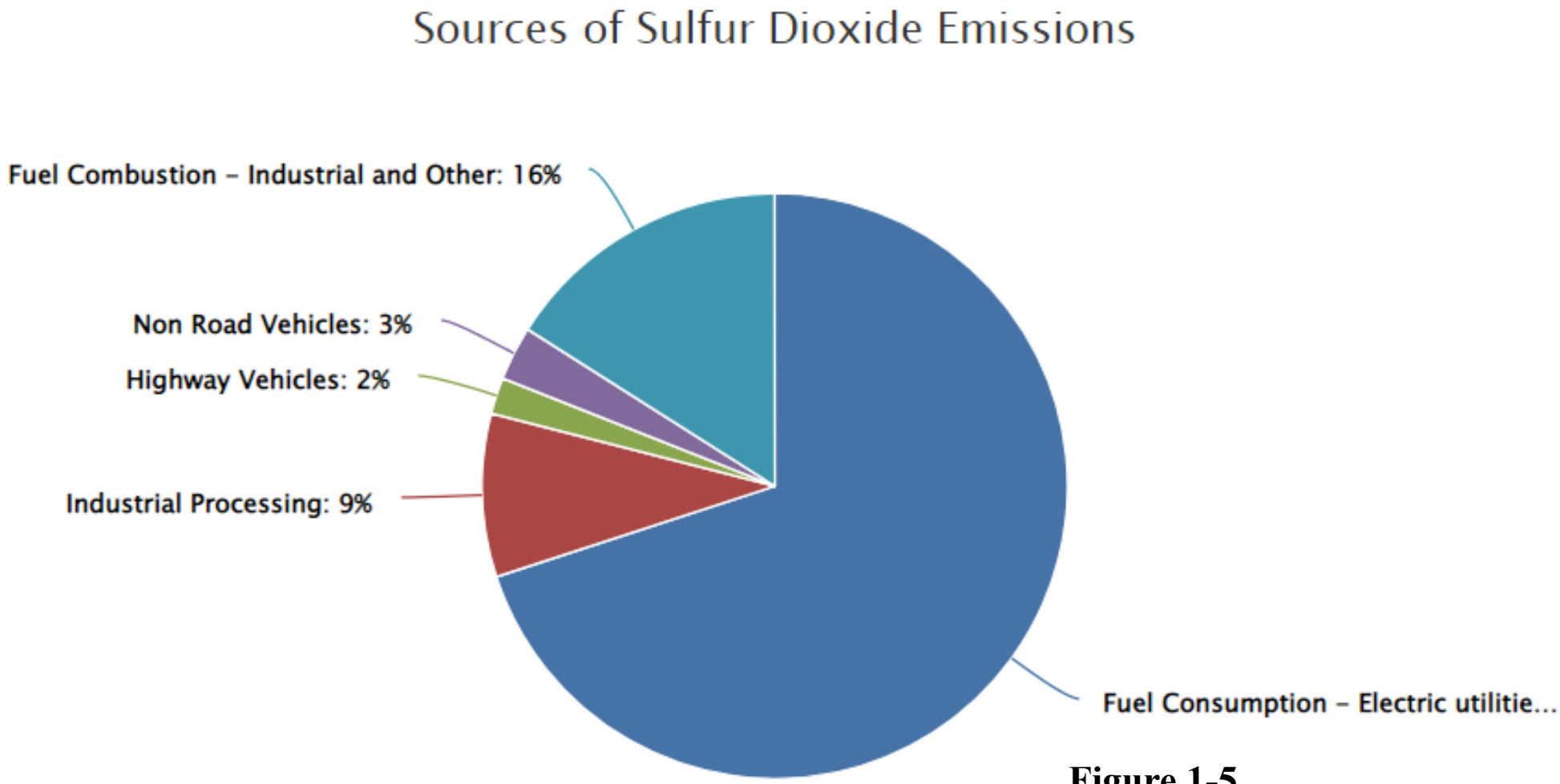

Figure 1-5
Sources of Sulfur Emissions

Consequences of Fossil Fuel Combustion

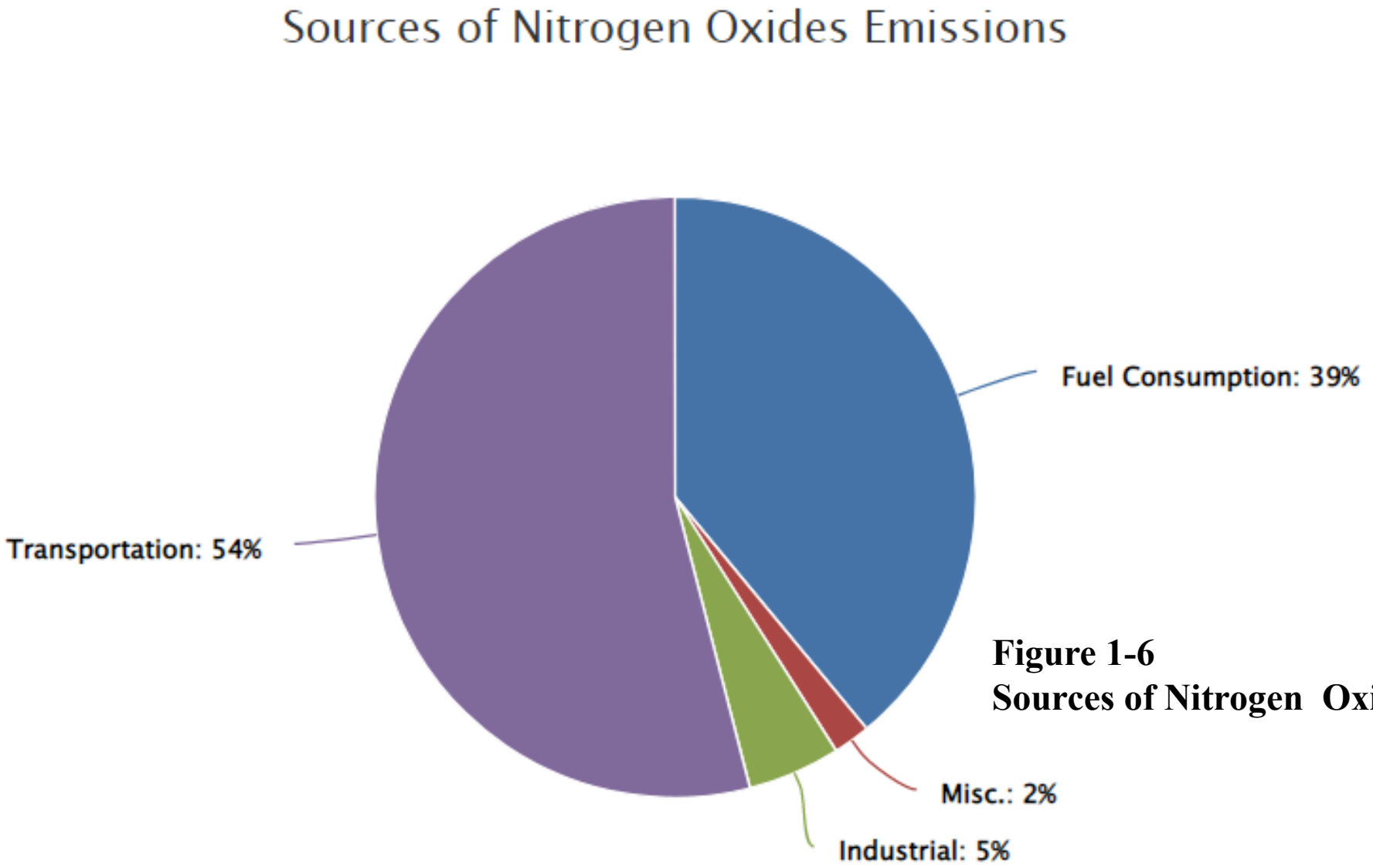

Figure 1-6
Sources of Nitrogen Oxides Emissions

Consequences of Fossil Fuel Combustion

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The concern over the depletion of fossil fuels and pollutant and greenhouse emissions associated with their combustion can be tackled by essentially two methods:

1- Using renewable energy sources such as solar, wind, hydroelectric, biomass, and geothermal to replace fossil fuels.

2- Implementing energy efficiency practices in all aspects of energy production, distribution, and consumption so that less fuel is used while obtaining the same useful output.

Renewable Energy Sources

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The main renewable energy sources include solar, wind, hydro, biomass, and geothermal. Energy sources from the ocean, including ocean thermal energy conversion (OTEC), wave, and tidal, are also renewable sources, but they are currently not economical and the technologies are still in the experimental and developmental stage.

An energy source is called renewable if it can be renewed and sustained without any depletion and any significant effect on the environment. It is also called an alternative, sustainable, or green energy source. Fossil fuels such as coal, oil, and natural gas, on the other hand, are not renewable, and they are depleted by use. They also emit harmful pollutants and greenhouse gases.

Renewable Energy Sources

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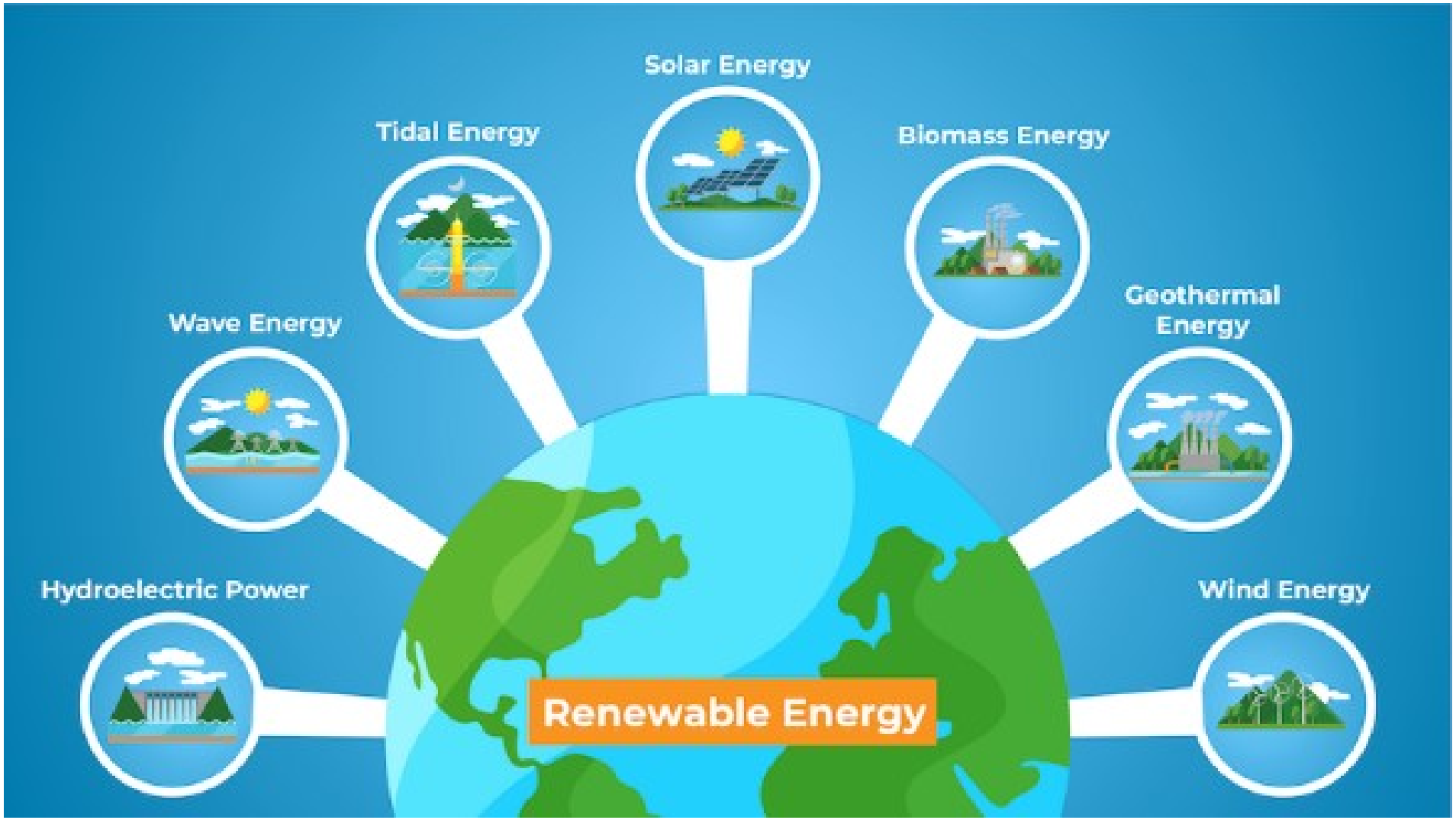
Figure 1-7
Renewable energy



Renewable Energy Sources

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The best-known renewable source is solar energy. Although solar energy is sufficient to meet the entire energy needs of the world, currently it is not used as extensively as fossil fuels because of the low concentration of solar energy on earth and the relatively highcapital cos

Figure 1-8
Solar energy

Renewable Energy Sources

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The conversion of kinetic energy of wind into electricity via wind turbines represents wind energy, and it is one of the fastest-growing renewables as wind turbines are being installed all over the world.

Figure 1-9
Wind energy

Renewable Energy Sources

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The collection of river water in large dams at some elevation and then directing the collected water into a hydraulic turbine is the common method of converting water energy into electricity. Hydro or water energy represents the greatest amount of renewable electricity production, and it supplies most of the electricity needs of some countries.

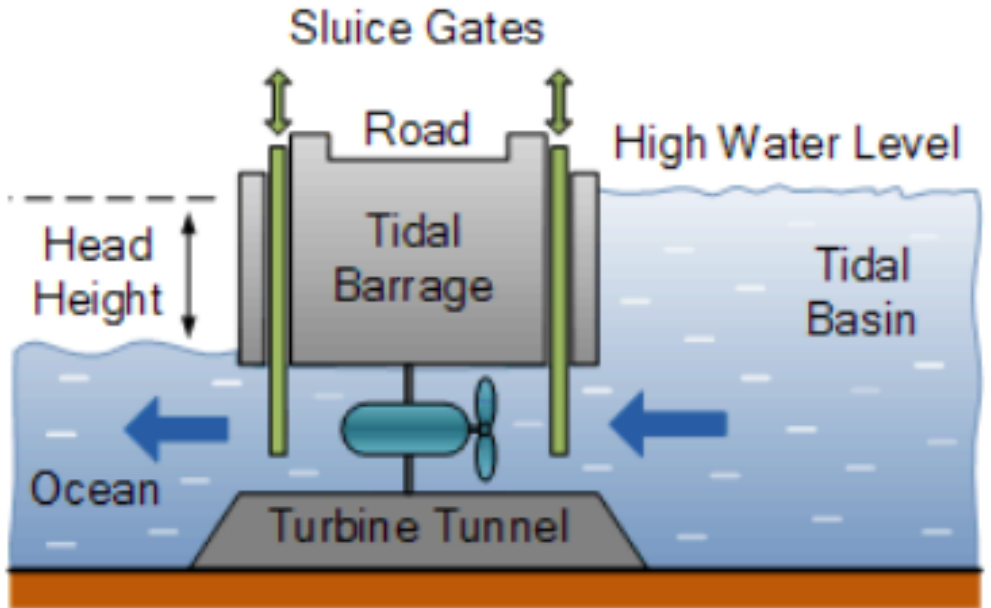

Figure 1-10
Tidal energy

Renewable Energy Sources

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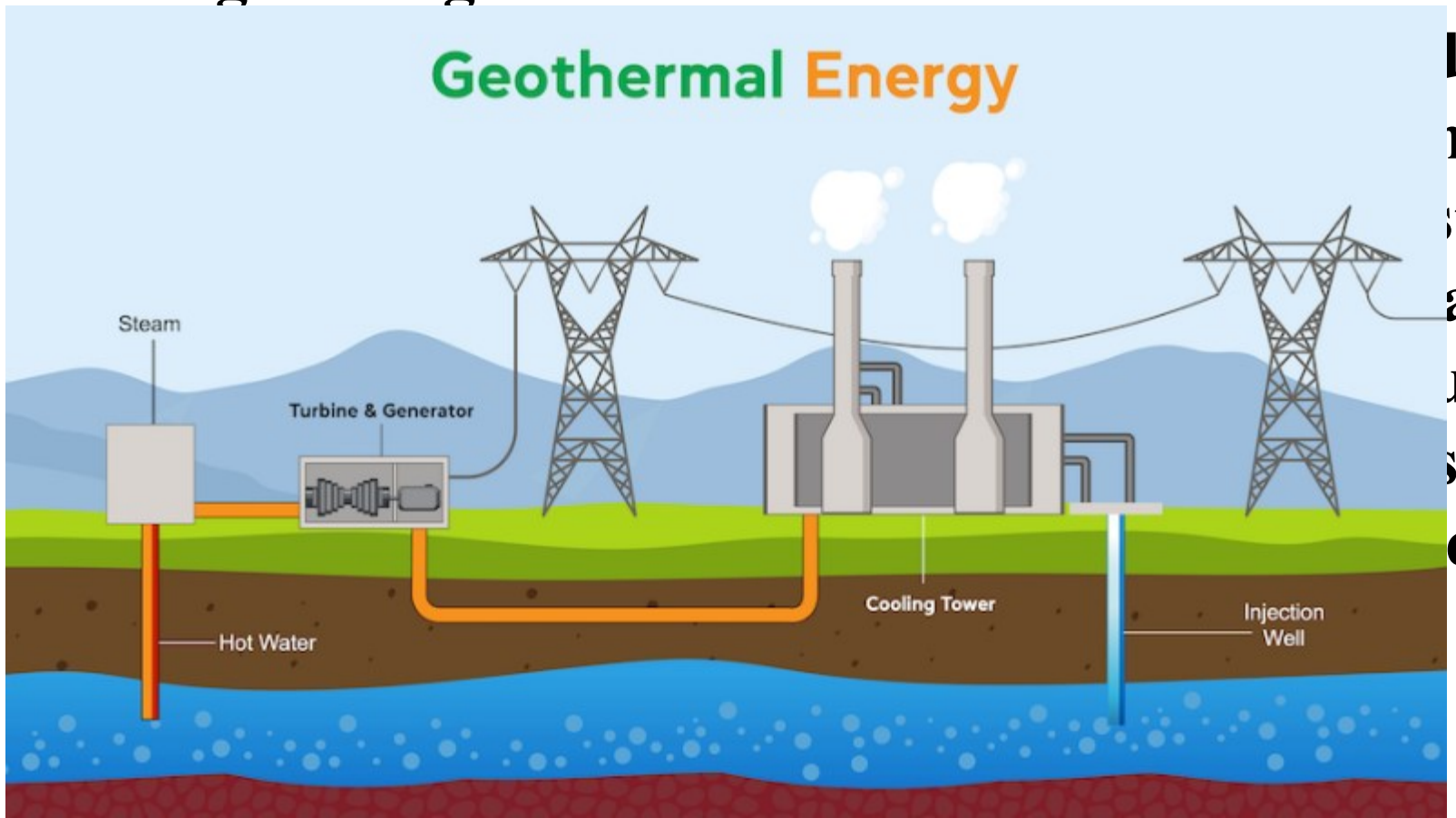
Geothermal energy refers to the heat of the earth. High-temperature underground geothermal fluid found in some locations is extracted, and



l to electricity or heat. nost mature renewable stly used for electricity able energy is referred ulture, forest, residues, ss energy. Biomass is e variety of available

Figure 1-11
Geothermal energy

Renewable Energy Sources

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Wave and tidal energies are renewable energy sources, and they are usually considered as part of ocean energy since they are available mostly in oceans. Thermal energy of oceans due to absorption of solar energy by ocean surfaces is also considered as part of ocean energy, and this energy can be utilized using the OTEC system. Wave and tidal energies are mechanical forms of ocean energy since they represent potential and kinetic energies of ocean water.

Hydrogen is an energy carrier that can be used to store renewable electricity. It is still a developing technology, and many research activities are under way to make it viable. Fuel cells convert chemical energy of fuels (e.g., hydrogen) into electricity directly without a highly irreversible combustion process, and it is more efficient than combustion-based conversion to electricity

Renewable Energy Sources

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All renewable energy sources can be used to produce useful energy in the form of electricity and some renewables can also produce thermal energy for heating and cooling applications. Wind and water energies are converted to electricity only while solar, biomass, and geothermal can be converted to both electricity and thermal energy (i.e., heat).

Electricity

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Electricity is the most valuable form of energy. Fuels cannot directly replace it because the vast majority of devices, equipment, and is produced in power s and in nuclear power solar, wind, geothermal,

Figure 1-12
Electricity production

Electricity

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The contribution of renewable electricity is expected to increase in the coming years, but the incorporation of wind power and solar power into the grid involves some irregularities and uncertainties due to changing wind and solar conditions on hourly, daily, and seasonal basis. This requires a more flexible electrical grid system than the existing conventional system in order to accommodate the inconsistent supply of renewable electricity. This new grid system is called a smart grid, which is an important area of research and development for electrical engineers.

Energy storage

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Energy storage systems also help to deal with the irregularities of wind and solar electricity generation. Several techniques for storing energy have been suggested, but the two most common types are batteries and pumped storage. The former is well known since we all use

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mping water "uphill"

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Figure 1-12
Energy storage