

Student Name:

Teacher Name: Botelho/Rinaldi

Class Name/Subject: NGSS and Enhanced Physics

Period:

Assignment Week #: Week 3 and 4

Instructions

Week 3:

1. Read through and annotate each of different energy sources in the “Renewable and Non-renewable Energy” article.
2. Choose **TWO** of the energy sources to research more. You can use the links below for each energy source or research your own information.
 - For each article read and annotate, focus on:
 1. How it works
 2. Pros/cons
3. *** You will use these annotations and notes for Week 4’s assignment.

Additional Research links

- Solar
- Wind
- Wind Turbines (video) (Transcript)
- Hydropower
- Biomass
- Biofuels

Optional Readings/Videos

- Solar Photovoltaics video
- Geothermal

Please note that these readings only scratch the surface of the world of renewable energy sources! The DOE's "Energy 101" YouTube channel has a bunch of good, short videos about different energy sources, note that there are a lot more energy-related links on the EIA websites that you read just now. You could spend your whole career learning about them (as some people do), and still have more to learn. I encourage you to learn as much as you can about these and other sources. It may sound like hyperbole, but you can never know too much about energy. It figuratively and literally makes the world go 'round.

Renewable and Non-Renewable Energy

Reading from: <https://www.e-education.psu.edu/emsc240/node/506>

Learning Objectives Self-Check

Read through the following statements/questions. You should be able to answer all of these after reading through the content on this page. After going through the content, check the boxes next to the questions/statements that you feel at least somewhat confident answering. I suggest writing or typing out your answers, but if nothing else, say them out loud to yourself. This is to help you reflect on important content, and will help you prepare for this week's quiz. It will also help lay the foundation for future course content.

- What is the difference between renewable and non-renewable energy?
- Explain how wind, biomass, and hydropower get their energy from the sun.
- Identify 2-3 benefits and drawbacks of solar, wind, hydro, and biomass.
- What is the difference between a carbon-free and carbon-neutral energy source?
- Are each of the following energy sources a) **renewable** or **non-renewable**; b) **carbon-free**, **carbon-neutral**, or **neither**; and c) a **fossil fuel** or **non-fossil fuel**?: solar, wind, hydro, biomass, coal, oil, natural gas, nuclear.

Knowing whether a source of energy is renewable or non-renewable is important when considering energy and/or sustainability. Renewable energy is defined by the U.S. Environmental Protection Agency thus: "Renewable energy includes resources that rely on fuel sources that restore themselves over short periods of time and do not diminish" (Source: [U.S. EPA](#)). Non-renewable energy is energy that *cannot* restore itself over a short period of time and *does* diminish. It is usually easy to distinguish between renewable and non-renewable, but there are some exceptions (more on that in a minute).

Renewable Energy

It should be clear how most of these sources fit the definition of renewable energy ("resources that rely on fuel sources that restore themselves over short periods of time and do not diminish") and have various benefits and drawbacks:

- **Solar** energy comes directly from the sun, which comes every day in most locations and does not diminish appreciably over time. Yes, the intensity does ebb and flow on short and long timescales, but it is hopefully not going away anytime soon. If the sun burns out and stops shining, we have bigger problems than solar panels not working!
 - **Pros:** A few benefits of solar energy are that it is relatively predictable and reliable, and that it does not create any emissions/pollution when generating energy.
 - **Cons:** The main drawback is that it is intermittent, both in terms of the sun only being in the sky 50% of the time, and that weather can impact it significantly. Solar is also very diffuse, meaning that it is not very concentrated, and so,, usually a large area is required to provide a lot of useful energy.
- The **wind** gets its energy from the sun - it is caused mostly by differential heating across the surface of the earth - so cannot be "used up" either.
 - **Pros:** More good news is that the wind will never disappear as long as the sun shines and the earth is spherical, and like solar, wind does not generate emissions.
 - **Cons:** However, the wind is also variable - more in some locations than others - and is less predictable than solar energy in most locations.
- **Hydropower** is the power in moving water and gets *its* energy from the sun as well, and is even more consistent in most locations than the wind.
 - I want you to think for a moment how the energy in moving water started out as solar energy. (This is a good thought experiment in energy conversion.) Answer: Remember that water flows downhill, and so the *motion* energy in flowing water started out as *gravitational potential* energy. How does water get this potential energy, i.e., how does it get *uphill*? Mostly from evaporation caused by the sun!
 - **Pros:** In terms of other benefits, like solar and wind, hydropower does not generate emissions, and is very consistent and reliable in most locations.
 - **Cons:** There are some drawbacks associated with large hydropower installations (see the [EIA's Hydropower and the Environment website](#) [12] for some examples), and in some cases, very big environmental and social drawbacks (e.g., in the [Three Gorges Dam](#) [13] in China). All of these factors are important to keep in mind. Hydroelectricity is the single biggest source of *renewable* electricity in the world.

- One additional drawback of all of the above sources is that they are each location-specific. In other words, some locations may have a lot of sun, wind, and/or hydro, while others may have very little. (This will be addressed in more detail in a future lesson.) This problem can be at least partially solved by transporting electricity, but that is not always easy, and often expensive.

All of these sources renew themselves over short periods of time and do not diminish. And though intermittent, none of these sources are going to disappear in the foreseeable future. They are textbook renewable energy sources.

Okay, so what about **biomass** and **biofuels**? They are both derived from living or recently living things (trees, corn, algae, sugarcane, etc.) They also get their energy from the sun (anyone sensing a pattern here?), and plants are usually pretty good at regenerating themselves. But I want you to take a minute to try to think about examples of biomass and/or biofuels that might not be "renewable," in the sense of the definition above. Can you think of any examples of *non-renewable biomass*?

Nearly all forms of biomass and biofuels are renewable. Corn-based ethanol is the most-used source of bio-based energy in the U.S. Corn can be grown in the same field year after year, so it is renewable. Whether or not it is *sustainable* is another question, which will be addressed later. The primary source of bioenergy in Brazil is sugarcane. Nearly all of Brazil's vehicles are able to use 100% sugarcane ethanol for fuel. (Contrast this with the U.S., where most automobile engines are only required to be able to handle up to 10% ethanol.) Sugarcane grows year round in Brazil, so is definitely renewable.

There are many other biomass sources that fit our definition of renewable, including animal dung, algae (for biodiesel), jatropha nut, soybean, switchgrass, and more. Wood is used around the world as a source of heat, particularly for cooking. Most trees and shrubs regrow relatively quickly, so they are generally considered renewable. But even a fast-growing tree like an oak (up to two feet per year, according to the [National Arbor Day Foundation](#) [14]) has limits. Though most biomass sources are considered renewable, keep this in mind: **if you harvest a renewable resource faster than it regenerates, it will not be able to renew itself over time.** We will revisit this point in a later lesson, but it is important to remember.

Not all Renewables Are Created Equal

Most renewable energy sources are **carbon-free**. This means that they do not emit any carbon dioxide when they generate energy. Solar, wind, and hydroelectric are carbon-free. Nuclear, though not renewable, is also considered a carbon-free energy source, because unlike coal and natural gas, it does not *burn*. As noted in a previous reading, nuclear energy generates heat through fission, not combustion. Biomass and biofuels are often considered **carbon-neutral** because they emit carbon dioxide when they are burned. **So, why are they carbon neutral?**



Figure 1.6: Carbon neutral wood pellets. This is printed on a bag of wood pellets, which are used for heating in a pellet stove. These emit CO₂ when burned, but effectively do not impact the level of carbon dioxide in the atmosphere. The pellets are made of leftover sawdust from timber operations.

Credit: D. Kasper.

Good to Know

The International Energy Association (IEA) is a good source of information for international energy data. The US EIA (not to be confused with the IEA) publishes some international data as well, but IEA is usually the first place I look. The chart below shows the estimated energy use by type worldwide in 2016, and the data are from their 2018 [Key World Energy Statistics](#) [15] document (the 2019 document will not be available until mid-2020). Note that the energy unit they use is Mtoe, which stands for million tonnes of oil equivalent. A Mtoe is equivalent to about 0.04 quads. In other words, there are about 25 Mtoe in a quad. The amount of energy is not important for our purposes, but please take note of the percent of the total that each energy source provides.

FYI, another good, reliable source of global energy data is BP's annual "[Statistical Review of World Energy](#)." It is worth browsing if you are interested!

World total primary energy supply (TPES) by fuel

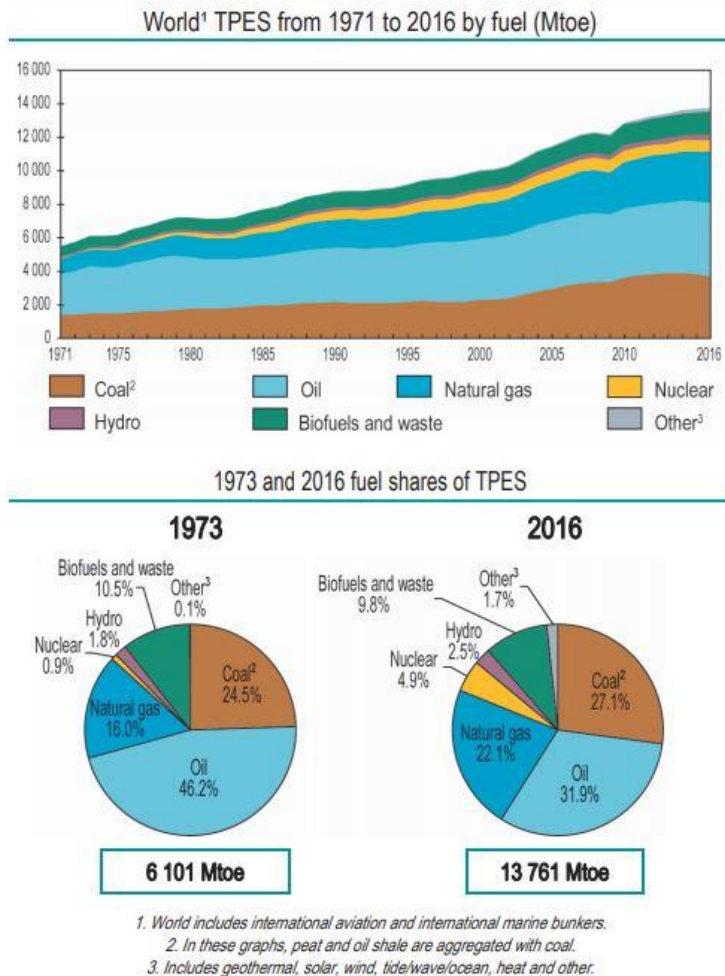


Figure 1.7: 1973 and 2016 fuel shares of TPES Click for a text description

Credit: [International Energy Agency](#) [15]

There are a few interesting things to point out from the chart above.

- First of all, **Total Primary Energy Supply (TPES)** refers to all *original or primary* energy consumed. For example, if your electricity is supplied by a power plant, the energy your electronic device is using right now is *not* primary energy because the electricity was converted from an original source (e.g., coal, oil, natural gas, nuclear). Given that electricity generation is always less than 100% efficient (sometimes *much* less, per the previous section), the *primary energy* used by your device is *greater* than what shows up on your electric bill. Incidentally, the "energy sources" on the left-hand side of the sankey diagram that you looked at earlier this lesson are primary energy.

- Another interesting thing to point out is that biofuels are lumped together with "waste." In many parts of the world, including many states in the U.S., if you burn garbage to produce heat and/or electricity, it is considered a biofuel, and thus renewable. I'll leave it to you to think about whether or not that is reasonable. But note that biofuels (and biomass) constitute the majority of that "slice" of the global energy pie.

- Hydro is at only 2.5%. But where are wind and solar? We hear about them all the time in the U.S., and in other parts of the world. If you read the fine print at the bottom, you'll see that wind and solar's contribution was so small that it was lumped into the "other" category, at a measly 1.7%. This has improved since

2015 (and was 1.1% of the total in 2012), and in fact has been growing at an all-time high rate, but there is still a long way to go before wind and solar make a major dent in the global energy regime.



Figure 1.8: Sugarcane field in Brazil. Brazil is the world's leading producer of sugarcane and sugar-based ethanol. Even the waste material from the sugarcane extraction process can be used for energy generation, or to make secondary products like compostable plates and silverware.

Credit: [José Reynaldo de Fonseca](#), CC-BY 2.5 [17]

Non-Renewable Energy

Non-renewable energy sources diminish over time, and are not able to replenish themselves. In other words, they are finite, and once they are used, they are effectively gone because they take so long to reform.

You have already read about the four non-renewable energy sources: coal, oil, natural gas, and nuclear. Let's start with coal, oil, and natural gas, which (as you read earlier) are referred to as **fossil fuels**. Fossil fuels were created from the remains of dead plants and animals. The source material is renewable (it's biomass!), but since they take millions of years to form, they are not replenished over a "short" period of time, so are non-renewable. Fossil fuels are forming somewhere under your feet right now, but don't hold your breath waiting for them to finish.

The nuclear energy we use comes from an isotope of uranium called U-235. Unlike fossil fuels, U-235 has cosmic origins: it was formed by one or more supernovae around 6 billion years ago, about 1.5 billion years before the Earth was formed

(a supernova is a collapsing star, "supernovae" is the plural form of supernova) (source: [World Nuclear Association](#) [18]). Again, this is not renewable on a human timescale.

All fossil fuels emit carbon dioxide (CO₂) and other emissions when they are used to generate energy. Recall that they are made mostly of hydrogen and carbon, and the carbon mostly ends up as CO₂. Nuclear is considered carbon-free, because it is not burned, and it is not made of carbon. Remember that energy is extracted through fission, or splitting of atoms. This generates heat, but no emissions. (It is important to note that it does result in very dangerous and long-lasting radioactive waste, but that will be addressed in a future lesson.)

To summarize:

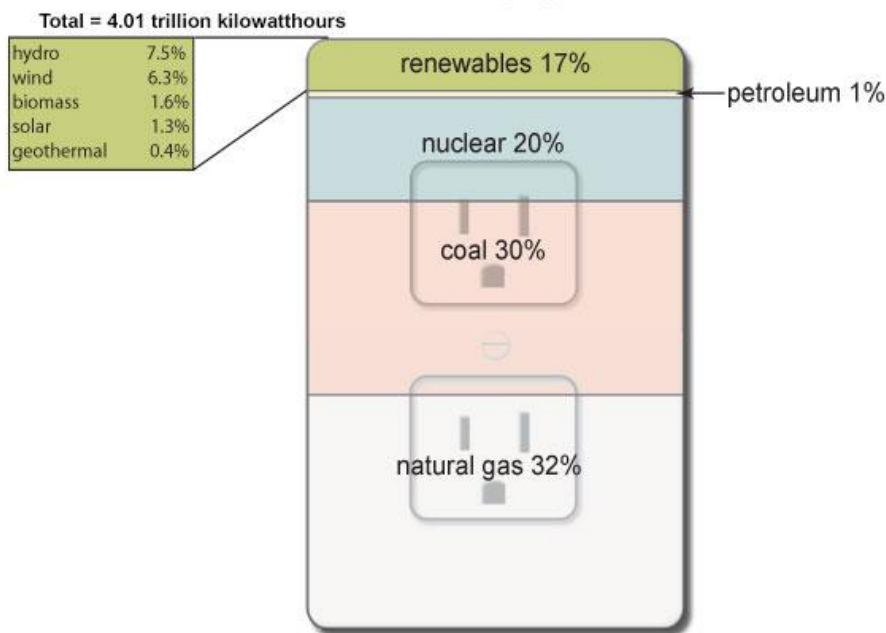
Non-renewables

- **Coal, oil, and natural gas** are fossil fuels. Even though they all get their energy from the sun, none of them are renewable. They all emit CO₂ and other emissions when burned.
- **Nuclear** is also non-renewable, but *not* a fossil fuel. It is carbon-free, but causes radioactive waste.
- Most importantly, for all intents and purposes, whatever coal, oil, natural gas, and nuclear exists today is all that we will ever have.

Renewables

- **Solar, wind, and hydro** are renewable and carbon-free, and effectively inexhaustible.
- **Bioenergy** is renewable and carbon-neutral. It emits CO₂, but no more CO₂ than was originally pulled from the atmosphere. Even though it is considered renewable, it is possible to use bioenergy unsustainably by harvesting it more quickly than it can be replenished.

Sources of U.S. electricity generation, 2017



Note: Electricity generation from utility-scale facilities.

Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2018, preliminary data



Check Your Understanding

All of the carbon dioxide emitted from coal, oil, and natural gas was originally pulled from the atmosphere to make the plants from which it was derived grow. In other words, the amount of carbon dioxide emitted is no more than the amount of carbon dioxide it originally removed from the air. **Why are they not carbon-neutral energy sources?**

Good to Know

We hear a lot about renewables and natural gas in the U.S., as their use has been growing rapidly for some time now. But as you can see in this chart from the EIA, coal and nuclear still constitute about 50% of all electricity generation in the U.S.

Figure 1.9: U.S. Electricity Generation 2017, by Source. Click for a text description

Credit: [U.S. EIA](#)