POWERING (HUMAN) LIFE ON EARTH

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Our energy needs are posing a severe threat to the climatic conditions that have allowed life to exist and flourish on earth. What are the sources of energy? How do we use it? Can we make energy choices that minimize our impact on the climate? This article is a tentative step towards exploring these questions.

While energy is the basis of existence of all life forms, our energy needs and ways of meeting them have played a key role in shaping human civilization. Over time, we have moved from harnessing heat from fires to developing a collective understanding of other sources of energy, ways of converting one form into another, and a range of specific uses for each form. This knowledge has helped unlock energy for uses well beyond our basic survival (access to food, water, shelter) — in mobility and transportation, health care, recreation, communication, managing waste, research, and the discovery of even more uses. Consequently, hunting-gathering societies have changed to agricultural, and then industrial societies (refer **Fig. 1**).

The Industrial Revolution in 1750 marked a turning point in the course of human civilization and our relationship with the planet. We became a civilization with high-energy needs, dependent largely on fossil-fuels (refer **Box 1**). Every form of energy that we have used since then has had impacts on the planet — from local clearing of land and deforestation, to global changes in atmospheric composition. When we burn fossil fuels to meet our needs — carbon, sulphur and nitrogen are released as gases into the atmosphere (refer **Fig. 2**). Thus, any shift to more energy-intensive ways of living, growing our food, or transportation, causes a corresponding increase in the levels of carbon dioxide, methane, oxides of sulphur and nitrogen released into the atmosphere.

This increase has a variety of impacts on life on earth. For example, it can lead to acid rain when oxides of sulphur and nitrogen combine with rainwater (refer **Fig. 3**). It can also result in an increase in average global temperatures as carbon dioxide, methane and nitrous oxide contribute to the Greenhouse Effect. Based on over four decades of climate data, we know that for the first time in the history of the planet, human activity has become a dominant factor in transforming planetary climatic conditions (refer **Box 2**).

Fig. 1. Our energy needs have shaped the evolution of human societies.

(a) Hunting-gathering.

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(b) Agrarian.

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(c) Industrial.

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Fig. 2. Carbon, sulphur and nitrogen oxides are produced by combustion of fossil fuels in (a) Power plants (b) Vehicles.

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Fig. 3. Acid rain is caused by the reaction of sulphur and nitrogen oxides with atmospheric water molecules.

(a) Acid clouds grow from emissions from a refinery on the island of Curaçao.

Credits: HdeK, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Cloud_formation_from_refinery_in_Curacao.jpg. License: CC-BY-SA.

(b) Its severe effects on vegetation in Great Smoky Mountains National Park, United States.

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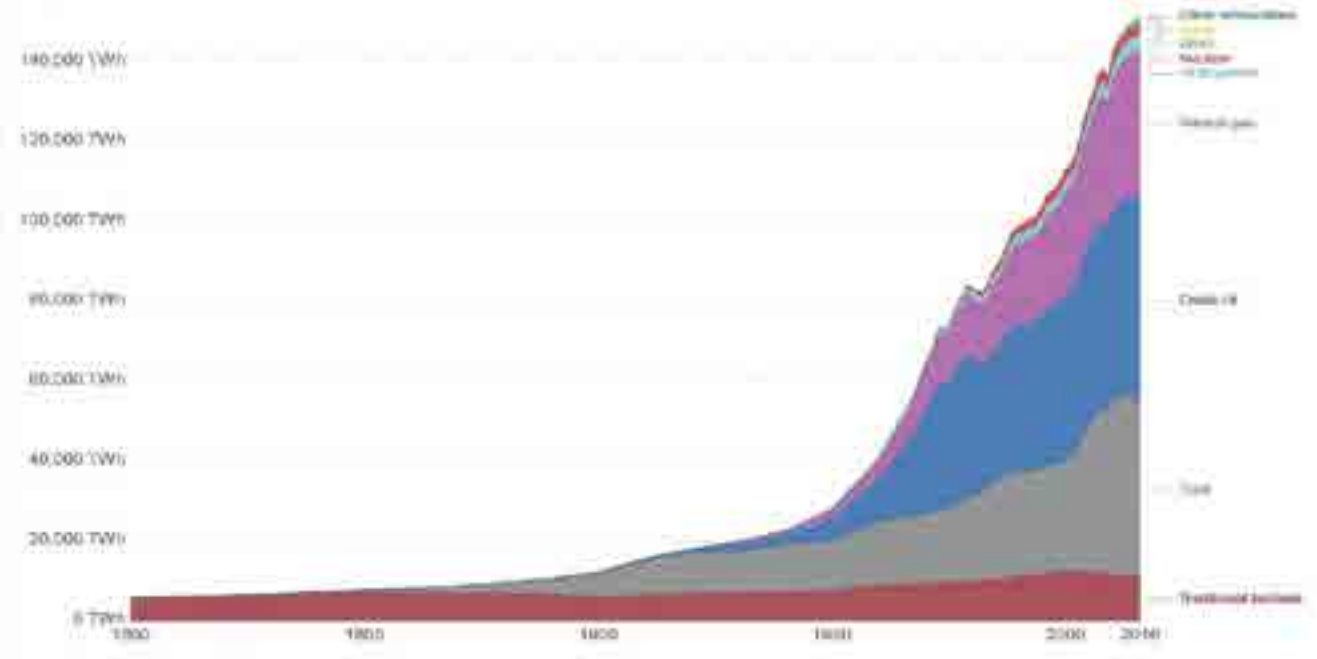
Box 1. What are fossil fuels?

As the name suggests, fossil fuels are fuels formed through the fossilization of organic matter. This process reportedly began about 4 to 2.5 billion years ago. It involved the gradual transformation of decaying and decomposing plant and animal matter through heat, pressure and geological processes into dense, combustible material. Examples include coal, crude oil (petroleum), natural gas, bitumen, oil shale, tar sands and heavy oils. All of these have to be extracted, processed and transported before they can be burnt to provide energy.

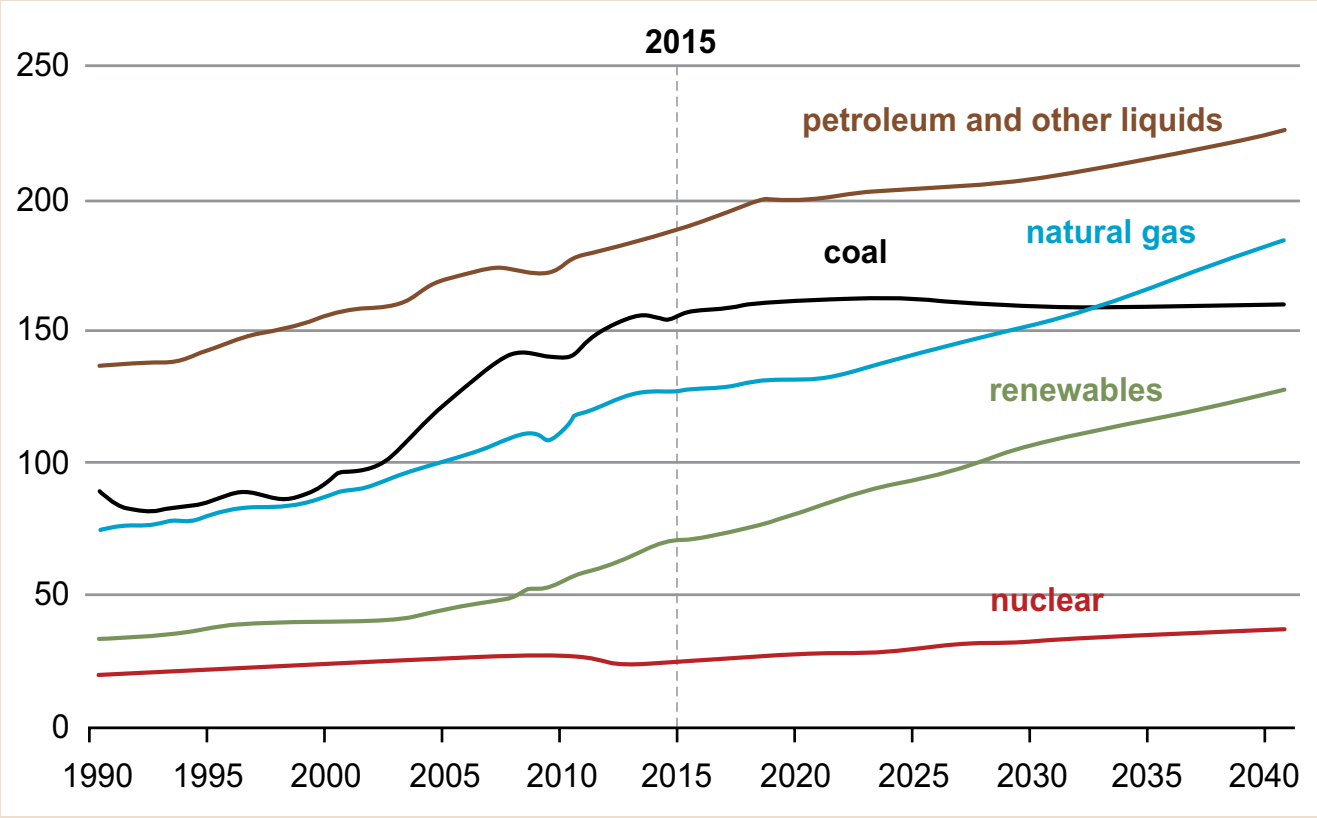
Our current energy needs are met primarily by the combustion of oil, followed by coal, and, then, natural gas. It seems likely that these may continue to be our fuels of choice well into the future (refer **Fig. 4**).

Fig. 4. Fossil fuels meet most of our current (a) and projected future (b) energy needs.



(a) Global primary energy consumption measured in terawatt-hours (TWh) per year. 'Other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.

Credits: Vaclav Smil (2017). Energy Transitions: Global and National Perspectives & BP Statistical Review of World Energy. URL: https://ourworldindata.org/grapher/global-primary-energy. License: CC-BY-SA.



(b) World energy consumption by energy source.

Can we make energy choices that minimize the impact of human activity on planetary conditions? Is it possible to imagine a world without fossil fuels? A world powered by **'renewable sources'** of energy like wind, water, and the Sun (refer **Box 3**)? And, more importantly, one where we consume less and, therefore, use less energy?

Something to think about as we move to new forms of energy!

".....Every transition to a new form of energy supply has to be powered by the intensive deployment of existing energies and prime movers: the transition from wood to coal had to be energized by human muscles, coal combustion powered the development of oil, and ... today's solar photovoltaic cells and wind turbines are embodiments of fossil energies required to smelt the requisite metals, synthesize the needed plastics, and process other materials requiring high energy inputs..." — Vaclav Smil, Energy and Civilization, MIT Press , 2017, p. 230.

The energy choices we make are not just about technology: they are social, economic, ecological and political choices, with the power to affect the quality of life of humans and other life forms.

The main source of energy in pre-industrial times was solar power! Unlike today, however, this power was in a form captured by plants — biomass. Biomass (wood, agricultural residue, dung cakes etc.) continues to be used even today for heating and cooking in several countries, including India, in Asia, Africa and Latin America (refer **Fig. 7**). Some forms of biomass are also used to meet other needs. For example, floating logs of wood are used to transport goods and people down a river **(what do you think is the source of energy in this example — biomass or water?)**. Wind powered sails enabled trade till the early 19th century. On land, wind and water (refer **Box 4**) have been used for at least 2000 years for milling and grinding grain, extracting oil from oilseeds, and powering industry. These were replaced by coal-powered steam engines in 1820.

While shifting from non-renewable to renewable sources of energy can reduce the amount of carbon dioxide released into the atmosphere, it is not a magic bullet — solar power plants and windmills need land (refer **Fig. 8**); and the machinery for both are manufactured using fossil fuels (refer **Box 5**). The real question then is — can we reduce how much we consume so that we need less energy?

Box 2. Fossil Fuels and Climate Change

The burning of fossil fuels for energy combines carbon in the fuel with oxygen in the air to produce carbon dioxide. Carbon dioxide is a greenhouse gas – it traps enough heat to keep the global average surface temperature of the planet at a level essential for sustaining life. But, excessive concentrations of this gas in the atmosphere can lead to global warming (refer **Fig. 5**).

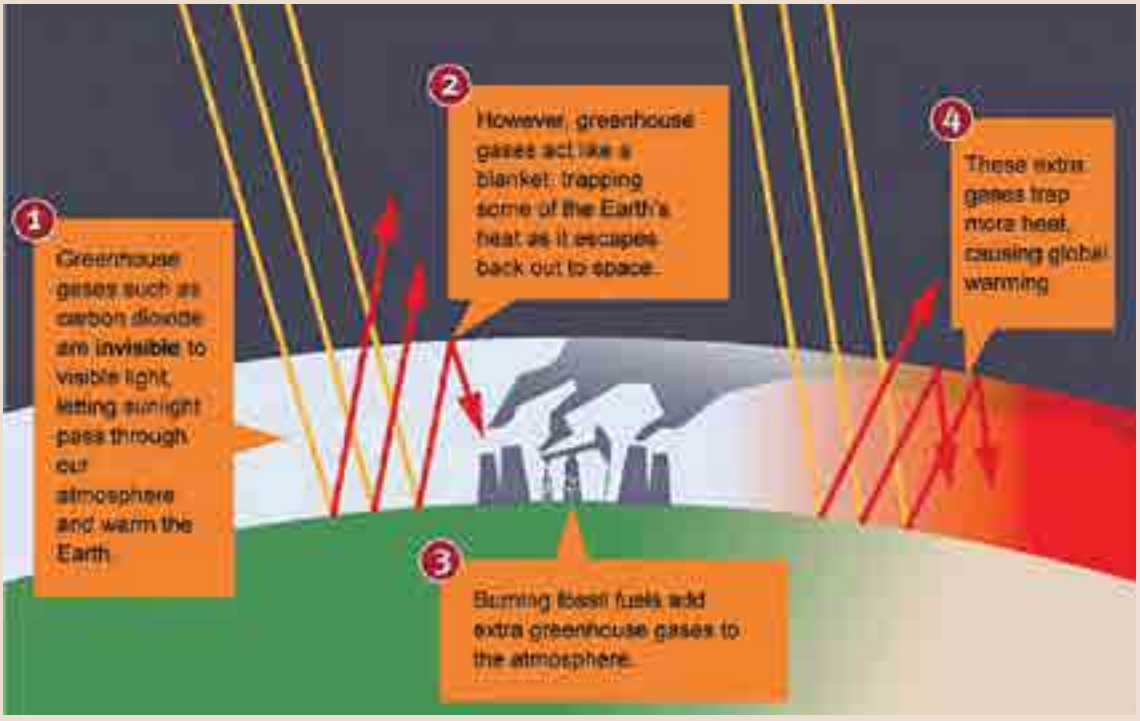


Fig. 5. Excessive concentrations of greenhouse gases like carbon dioxide can lead to global warming.

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According to the Intergovernmental Panel on Climate Change (IPCC), the concentration of carbon dioxide in the atmosphere has increased by more than 30% since pre-industrial times. Given our current energy needs, atmospheric carbon dioxide is still increasing at an average rate of ~ 0.4% per year. This has led to a corresponding increase in global average surface temperatures (refer **Fig. 6**), with serious impacts on global climate and climatic patterns.

What does this mean for human society and other life forms? Higher surface temperatures result in the faster melting of glaciers (as shown by scientific data from the Arctic, Antarctic and, closer home, the Himalayas), leading to a rise in sea levels and the submergence of coastal areas. Changing climatic patterns result in extreme weather conditions (higher-than-average temperatures, changing precipitation patterns, the increased incidence of storms and cyclones) and their associated impacts on life and property.

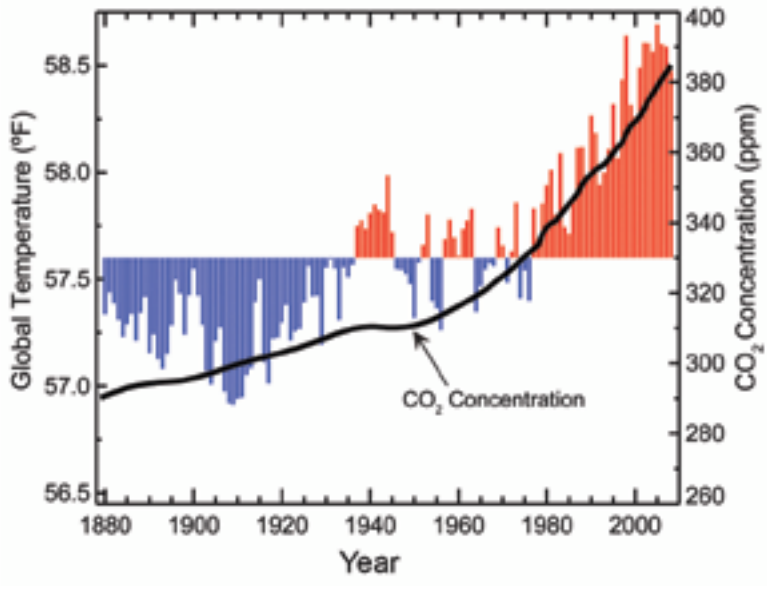

Fig. 6. Atmospheric carbon dioxide concentrations and global annual average temperatures in the period 1880-2009. Global annual average temperature is measured over both land and oceans. Red bars indicate temperatures above and blue bars indicate temperatures below the average temperature for the period 1901-2000. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm).

Credits: Created by NOAA/NCDC in Global Climate Change Impacts in the United States, Cambridge University Press; and uploaded by Enescot on Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Atmospheric_carbon_dioxide_concentrations_and_global_annual_average_temperatures_over_the_years_1880_to_2009.png. License: Public Domain.

Box 3. Renewable and Non-Renewable Energy Sources

Based on their origins, energy sources can be classified into two categories — renewable and non-renewable. A renewable source of energy is one that is replenished at a rate faster than it is consumed. Examples include solar, wind, geothermal, hydro, and some forms of biomass. According to the International Energy Agency (IEA), renewable sources of energy contributed 13.2% of the world's total primary energy supply in 2012, and 22% of it in 2013. By the year 2020, their contribution to the total energy supply is predicted to increase to 26%. In contrast, a non-renewable energy source is one that is formed by geological action on organic matter over extremely long periods of time. Even if non-renewables were consumed in decades or centuries, the rate of their consumption would be much faster than the rate at which they are formed. Examples include coal, oil, and natural gas.

It is interesting to note that both renewable and non-renewable energy sources are ultimately derived from the Sun. Photosynthesis converts solar energy into organic matter or biomass, which decomposes under high pressure to form fossil fuels. Sunlight is directly converted into solar energy by photovoltaic cells; while heat from the Sun drives the wind and water cycles used to generate renewable energy.

Fig. 7. Different forms of biomass are still used in India to meet energy needs for cooking and heating.

(a) Firewood.

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(b) Agricultural residue.

URL: https://www.maxpixel.net/Summer-Sunset-Landscape-Autumn-Field-Straw-Farm-1677853. License: CC0.

(c) Dung cakes.

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Fig. 8. Setting up solar and wind farms has impacts on land-use.

(a) A solar farm.

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(b) A wind farm.

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Box 4. Is water renewable?

Share details of the increasing scarcity of water resources due to:

(i) Changes in precipitation patterns

(ii) Increasing contamination of surface and ground water sources

(iii) Overexploitation of groundwater sources and

(iv) Over-extraction of surface water sources.

Encourage students to use this information to debate on whether water can really be thought of as a renewable resource today.

Parting thoughts...

Imagine a scenario where coal and oil have not been discovered. Would the use of wind, water and biomass as sources of energy have made our lives different from what they are today? How?

Box 5. Questions & Activities for students:

1. Can you think of an activity which does not use some form of energy?
2. Can you identify a task that requires only human energy?
3. Map your day to list out things you can do without using electricity.
4. Find out: (a) what the primary source of electricity in your home and city is, and (b) where the raw material for this source is derived from. For example, if the primary source of electricity in our home is a coal- or gas-fired thermal power plant, where is the coal or natural gas coming from?
5. In which aspects of your daily life can you replace energy from fossil fuels with that from renewable sources? How would you do this?

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