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Marcellus Shale

THE SCIENCE BENEATH THE SURFACE

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Sources and Uses of Energy: A brief overview

A discussion of the sources and uses of energy, how they have changed over time and how the Marcellus Shale is contextualized within the larger energy system.

DID YOU KNOW?

- The four largest electric power plants in New York State are each fueled by a different source.
- In 2008, more electricity produced in New York State came from natural gas than from any other source.
- In 2009, more electricity produced in New York State came from nuclear power than from any other source.

Introduction

Human society was once powered only by biomass – biological material from living, or recently living, organisms: our own muscles (powered by the food we ate); the muscles of animals; or by the burning of wood. Over many millennia humans found other ways to tap into natural energy sources, from water and wind power, fossil biomass (like oil and gas), geothermal heat from inside the Earth, the sun, and the nucleus of atoms. The transition from brute force and wood-burning to the various industrial sources of energy – and the accompanying adoption of energy-intensive lifestyles, have occurred remarkably quickly -- in the course of just a few generations, and this has caused changes in virtually every aspect of human life, from economics to war to architecture. As recently as the late 1800s Pennsylvania's oil wells produced half the world's supply. Nuclear power has been a commercial source of electricity only since the late 1950s. Electric power has been widely used for a little more than a century. The United States was largely energy self-sufficient until after World War II, when the demand for energy - petroleum in particular - began to outstrip domestic production.

In 2009, petroleum, natural gas, coal, and nuclear power accounted

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for 92% of the energy Americans use with various renewable energy sources accounting for the remaining 8%.[1] Energy moves people and goods, produces electricity, heats our homes and businesses, and is used in manufacturing and other industrial processes.

Energy use varies substantially from region to region, and different energy sources are used to fuel different sectors of the economy. The transportation sector is almost completely dependent upon petroleum, while the overwhelming majority of both coal and nuclear power is devoted to electricity production. Natural gas use is split nearly in thirds among the industrial, residential and commercial, and electric power generation sectors, and only 3% of the transportation sector's energy comes from natural gas. Because it is a relatively versatile fossil fuel, how much natural gas we use and the ways in which we use it have shifted over time. The impact of developing "unconventional" fossil fuel resources, like the Marcellus Shale as a source of natural gas, cannot be fully understood without first understanding the impacts of modern energy use and production.

No energy resource developed on a commercial scale is environmentally benign, and the growth of both human population and per capita energy consumption in the developing world mean that the impact of even those energy sources that have relatively less environmental effect is increasing. Thus, while conservation and efficiency are essential parts of national and global energy strategies, the practical decisions that need to be made are substantial and not altogether obvious. There are no magic bullets. Understanding and contrasting the different impacts of energy *extraction* (in the case of fossil fuels and uranium), *capture* (in the case of wind, solar or geothermal), or *harvest* (in the case of biomass) and *use* will help us to make informed choices about future energy development that may occur in or near our communities, and to better understand the impacts of energy development far from home.

While predictions about changes in the way we procure and use energy in the future must be regarded as uncertain, we can gain some perspective on the way different energy sources and uses are likely to change in the coming decades. Oil and coal have dominated global energy production and use for generations, though easy-to-access deposits are drying up and the environmental costs of accessing unconventional deposits are becoming clearer. As we develop alternatives to oil and coal, energy development in the future is likely to occur in closer geographic proximity to the end users than it has in recent decades.

Energy sources have a complex range of environmental and economic impacts. This is an overview of where energy comes from: how we use energy, how sources for and uses of energy change, and the costs and benefits of different energy choices. Energy choices include more than energy sources, but also the decisions about what energy is used to do, the technologies used for extracting or developing energy sources, and the modifications to infrastructure associated with changing energy use, as well as the technologies that depend upon energy. Further, energy choices involve behaviors. How we live determines how much and what kinds of energy we use.

Most of the Energy We Use Comes from the Sun

Excluding nuclear and geothermal, and the influence of gravity in the very small percentage of commercial power captured from ocean tides, the energy sources that power society are ultimately all traceable to the Sun's energy (itself, a nuclear fusion power plant). Biomass energy, that which comes from the burning of wood, grass and other plant matter, releases stored energy that was a product of photosynthesis; fossil fuels are ancient biomass resulting from photosynthetic reactions that occurred millions and millions of years ago. Wind power made global trade possible by powering ships across the sea over a thousand years ago and wind is now providing a small but rapidly growing portion of our

conventional oil and gas*: produced or extracted using long standing practices in which gas and oil are extracted through a well drilled into a geologic formation in which the reservoir and fluid characteristics of the oil or gas permit ready movement to the drilled hole.*

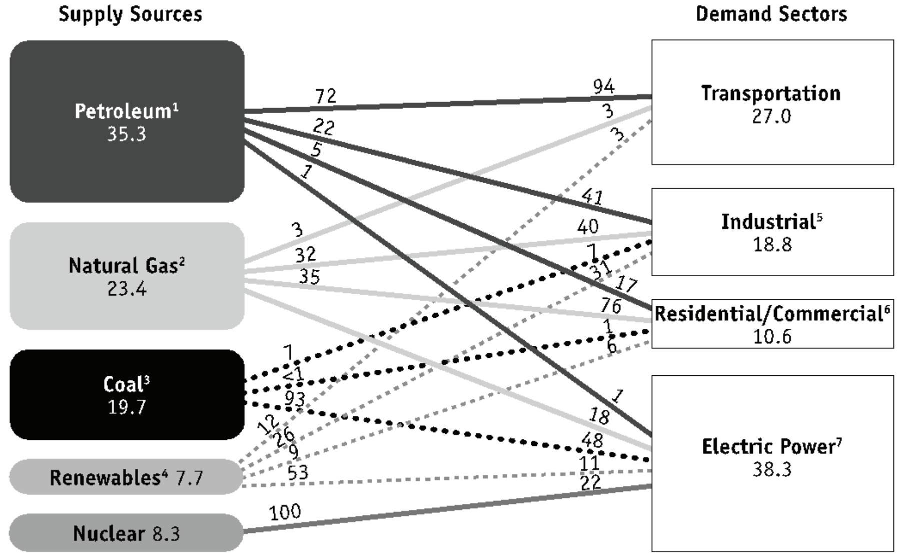
unconventional oil and gas*: produced or extracted using techniques other than conventional drilling for oil and gas. Sources include, but are not limited to oil and gas shales, oil (tar) sands, and coalbed methane.*

Industries and governments across the globe are investing in unconventional sources due to the increasing scarcity of conventional reserves. Although the depletion of conventional reserves is evident, unconventional production is a less efficient process and has greater environmental impacts than that of conventional production.

electricity. The wind is driven by convection caused by the Sun's uneven heating of Earth's surface. Hydroelectric power (and the waterwheels that preceded it) is made possible by the solar-powered water cycle. Taken together, these fossil and modern Sun-driven sources account for more than 90% of U.S. energy consumption.

Nuclear power is produced by the fission ("splitting") of the nuclei of relatively heavy atoms, such as uranium. Typically, the method for electricity production from nuclear fission is similar to that from fossil fuel power plants – the energy from nuclear reactions (rather than fossil fuels) is used to boil water that produces steam to turn turbines. Nuclear power accounts for about 8% of U.S. energy production. Geothermal energy uses Earth's internal heat either directly for heating or indirectly to produce electricity. Earth's internal heat comes largely from the decay of radioactive elements and from the residual heat left from Earth's formation. Geothermal currently accounts for less than 1% of U.S. energy production.

Figure 1. **Primary Energy Flow by Source and Sector 2009.**[1]



Low-Cost, High-Density Fuels Made Modern Society

Figure 1 shows the sources of the energy that drive our economy and the sectors that use that energy. For most of human history, burning wood and other biomass cooked meals and provided warmth. Fossil fuels (coal, oil, natural gas) produce much more energy per pound, have been present in huge quantities, and are easier to transport and store. The energy produced by burning wood from clearing a large forest pales in comparison to the energy produced from mining a large coal seam. The Industrial Revolution of the early nineteenth century was not powered by wood, but was in large part made possible with the advent of new technologies for extracting and burning coal.

In the short term (on the scale of years, decades, or even a century or more), the economic cost per unit of energy from fossil fuels also appeared to be remarkably low. The pairing of high energy density and low short-term cost is behind the structure of energy flows shown in Figure 1. Exploitation of these low-cost, "dense" energy sources is fundamental to what makes modern society what it is today. A gallon of petroleum-based fuel can move a typical car 20 miles or a ton of freight on a modern locomotive 500 miles. The convenience provided by these low costs and high energy densities, and the infrastructure we've developed to use and move these fuels, have made it difficult to bring other technologies or economic choices to fruition on a large scale. But, the easy-to-find-and-extract fossil fuels, referred to as "conventional" fossil fuel resources, have become considerably scarcer (especially oil and natural gas) at the same time that their longer-term environmental impacts (especially coal and oil), most notably climate change, have become clear. Costs of these energy sources appear low, however, only when longer-term environmental costs are not included. Understanding this idea is fundamental to understanding transitions in local and global energy sources and uses in the coming decades. Localized environmental impacts of the use of coal, like soot-filled skies, were obvious as fossil fuel use rapidly grew, while other impacts, like climate change and acid rain, were effectively invisible. Only now -- after well over a hundred years since the Industrial Revolution -- are we beginning to understand its unintended consequences for the environment.

A Closer Look at Energy Sources

Our energy comes from petroleum, natural gas, coal, renewable sources and the nuclear reactions that power some electric plants. That energy is used to meet four different kinds of demands: transportation, industrial processes, residential and commercial buildings, and electric power generation. Production cannot be understood independent of consumption. This section will provide a brief overview of the total energy picture for the U.S., and then describe where certain fuels come from and the history of its use; selected import and export data, and noted changes in use and/or production. Notable environmental impacts of using or extracting different energy sources are described in a later section.

Each energy source might reasonably be considered multiple sources, as there are a variety of reservoirs of each fuel source, and those reservoirs can vary substantially in nature, and can be found in many different parts of the world. Oil can come from a conventional land-based well in Texas, Pennsylvania, or Saudi Arabia; from deep below the sea floor in the Gulf of Mexico or the North Sea; from tar sands in Alberta, Canada; or oil shale from Estonia or China, for example. These sources all provide oil, but the environmental and economic costs of extraction vary considerably, as does the quality of the oil produced. Such an expanded description could be made for each of the supply sources, and a few of these "sources within sources" will be briefly explored.

We typically measure power in watts and energy in kilowatt-hours (kWh) or British thermal units (Btus). Light bulbs are labeled with their power usage in watts, with traditional incandescent bulbs ranging from 25 to 150 watts and compact florescent bulbs ranging from 5 to 30 watts to produce a comparable amount of light. The largest power plants produce power on the order of hundreds of megawatts (MW) to a few gigawatts (GW). A megawatt is one million watts and a gigawatt is one billion watts. One kilowatt-hour is the energy required to light a 100-watt light bulb for 10 hours. One Btu is the approximate heat and light energy released in the burning of a standard kitchen match or the amount of energy needed to raise one pound of water one degree Fahrenheit. One kWh is equivalent to 3412 Btu. A quadrillion Btus (10^{15} Btus), called a Quad, is equal to 293,000,000,000 kWh.

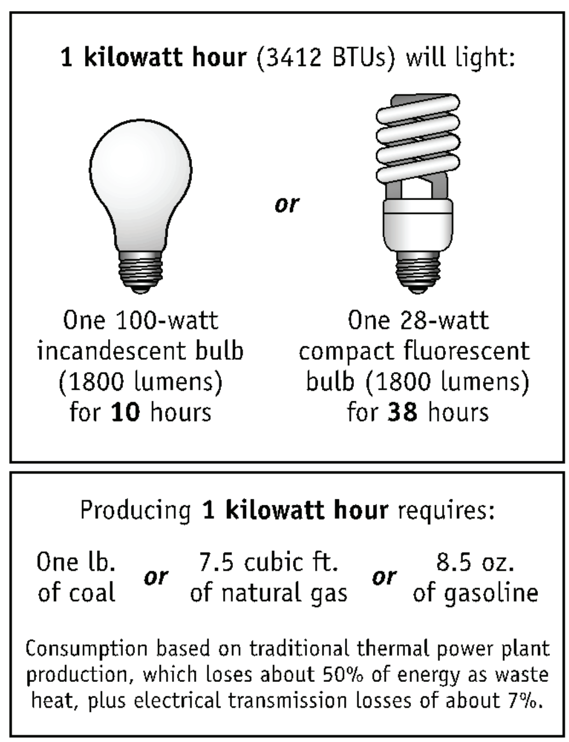
Steam-driven turbines produce most (but not all) electricity; the transportation sector is nearly completely driven by internal combustion engines; industrial processes are largely heat-driven; and our homes and businesses are mostly warmed through burning natural gas, oil, coal or biomass. That means that the Btu and the Quad are more fundamental units of energy than the kWh. In 2009, 94.6 Quads of energy flowed through the U.S. economy. Figure 1 shows U.S. energy flow by source and sector. If all that energy were converted (with 100% efficiency) to electricity, it would equal 27.7 trillion kilowatt hours.

Power plants, however, are never 100% efficient. Typically, about half the energy content of a fuel is lost as waste heat at the power plant. Newer combined heat and power plants are more efficient, but even these plants lose a third of the energy content of their fuels as waste heat. And another roughly 7% is lost as heat from transmission lines.

Some energy sources tend to be used in specific ways, and some energy needs can be met with more than one kind of fuel. The largest source of energy for the U.S. in 2009 was petroleum at 35.3 Quads, and 72% of the petroleum the country uses is used in the transportation sector. *All* commercially produced nuclear energy and almost all the coal burned in the U.S. (93%) are used for electricity production. Natural gas generates almost a quarter of U.S. electricity. Thus, sources of electricity are diverse, with coal providing slightly less than half (45% in 2009) of our electricity – a percentage that has been decreasing in recent years.[1]

The decrease in coal's share of electricity production has occurred in tandem with an increase in natural gas's contribution. Between 1989 and 2009, for example, coal dropped from producing four times as much electricity as natural gas to less than twice as much. After six

Figure 2. **Producing and consuming a kilowatt**



decades of steady growth, the use of coal for electricity production began to fall sharply in 2007. During the *six decades* prior to 2007, electricity production from coal increased almost every year. During those sixty years, production never dropped two years in a row, but production has now fallen for three successive years. There are multiple reasons behind the decline in coal use (see discussion below), importantly including the economic recession, so the likelihood of this trend continuing is uncertain. On the other hand, it seems more certain that the share of electricity generated by coal will continue to decline relative to gas.

Petroleum had been used as an illuminant, a lubricant, and an ingredient in patent medicines long before it was widely used as a fuel. The first commercial oil well was drilled in Northwestern Pennsylvania in 1859. Petroleum production peaked in the U.S. in the early 1970s, and in 1994, oil imports surpassed domestic production for the first time. Net oil imports generally rose until 2005 when they plateaued for two years and then began to fall. The fall in oil imports coincides with a fall in domestic consumption. In 2009, 9.7 million barrels per day was imported and 7.2 million barrels per day were produced domestically.[1] Petroleum accounts for most of the 24% of the U.S. energy supply that is imported. Similarly, only 36% of domestic oil use is from domestic sources.[2] With less than 5% of the world's population, the U.S. consumed 22.5% of world oil production in 2008.

Canada is our largest source of foreign oil. More than 40% of crude oil production in Canada is from tar sands. Tar sands, also known as oil sands or bituminous sands are naturally occurring mixtures of sand, clay, water and a very thick kind of oil known as bitumen. Like the Marcellus Shale, tar sands are an unconventional energy source. The process of extracting oil from tar sands is very water and energy intensive. While the country that is the second largest supplier of foreign oil varies from year to year, the second largest region (after Canada) to supply U.S. oil is the politically unstable Middle East.

The convenience provided by these low costs and high energy densities, and the infrastructure we've developed to use and move these fuels, have made it difficult to bring other technologies or economic choices to fruition on a large scale.

Natural Gas was used by the Chinese to boil brine in salt production over 2,000 years ago. In the U.S., the first commercial gas well began operation in1825 in Fredonia, New York. Natural gas is often co-produced with oil, and was once often simply burned off as waste from oil wells. Most U.S. natural gas is produced and used domestically, with imports averaging about 15% of supply over the last decade, dropping to 12% in 2009. The overwhelming majority of imports come by pipeline from Canada. Pipeline imports also come from Mexico and some natural gas is exported from the U.S. to both Canada and Mexico.

Liquefied Natural Gas (LNG) is natural gas that has been cooled into a liquid state so that it takes up only 1/600 of the volume of natural gas. LNG is imported from a variety of countries. Trinidad and Tobago is the lead exporter to the U.S. LNG's small portion of U.S. domestic use grew rapidly early in the last decade, but the U.S. Energy Information Administration projects that it will remain minimal through 2035.[2] The development of shale gas increases the likelihood of gas exports and decreases the likelihood of further imports.

Coal was used as a fuel long before the other fossil fuels – as early as 1100 BCE. Widespread use began in the Middle Ages, when the invention of fire bricks in the 1400s made chimneys cheap and practical. Britain was a coal exporter, including to the colonies of North America, in the 1700s. Although the U.S. burned some coal early in its history, more wood than coal was burned here until the late 1800s.[3]

Between 2008 and 2009, coal consumption fell in the U.S. by 11%. The majority of the drop in usage is attributed to reduction in use for electric power generation. The absolute decrease was 123.1 million short tons.[i] The drop in coal production is a result of two primary factors – new gas-fired power plants coming online in the last decade, and diminished demand due to the struggling economy.

Almost all coal used in the United States is mined here, and some of it

i. 1 short ton = 2,000 pounds

is exported. In 2009, production fell considerably (8.3%) to 1075 million short tons with exports of 59.1 million short tons and imports 22.6 million short tons. The quality of coal varies substantially in BTU production and amount of particulates and other pollutants that are emitted by burning.

Nuclear power has only been a commercial source of electricity since 1957 and its substantial growth stopped (or paused) in the United States in the late 1970s as a result of a combination of prohibitive economic cost and environmental concerns, highlighted by the 1979 accident at Pennsylvania's Three Mile Island Nuclear Generating Station, and the long-term handling of nuclear waste. Unlike the later accidents at Chernobyl and Fukushima, there were no documented deaths associated with U.S.'s most well known nuclear accident.

In 2009, the U.S. imported 58.9 million pounds of uranium and produced 4.1 million pounds domestically. The U.S. is the largest producer of electricity from nuclear power in the world, but the much smaller population of France gets 74% of its total electricity from nuclear power.[5] In 2009, nuclear power accounted for 8.3% of all U.S. energy production and 22% of its electricity.

Renewable Energy

Renewable energy is energy that comes from sources that are naturally replenished. It accounted for 8% of U.S. energy consumption in 2010 and comes in many forms. *Biomass* has thousands (if not millions) of years of history as an energy source and it is still the largest renewable source of energy. Wood and wood products still account for just over half of U.S. commercial biomass energy production, but it is now nearly equaled by biofuels (ethanol and biodiesel). This does not include much of the home heating provided by wood burning. Energy from waste, including landfill gas, is also included as biomass. Landfill gas is a mixture of methane and other gases produced by microorganisms breaking down biomass within a landfill. *Hydropower* is the longest established renewable energy source used for electricity production, and still accounts for the largest portion of renewable electric generation in the U.S. The world's first commercial-scale power plant began operation at Niagara Falls in 1881. Hydropower accounts for about 7% of U.S. electricity use, and because most substantial river systems have already been dammed for electricity use or their damming has been deemed too environmentally costly to pursue, there is little likelihood that the U.S. can obtain more energy from traditional hydropower.

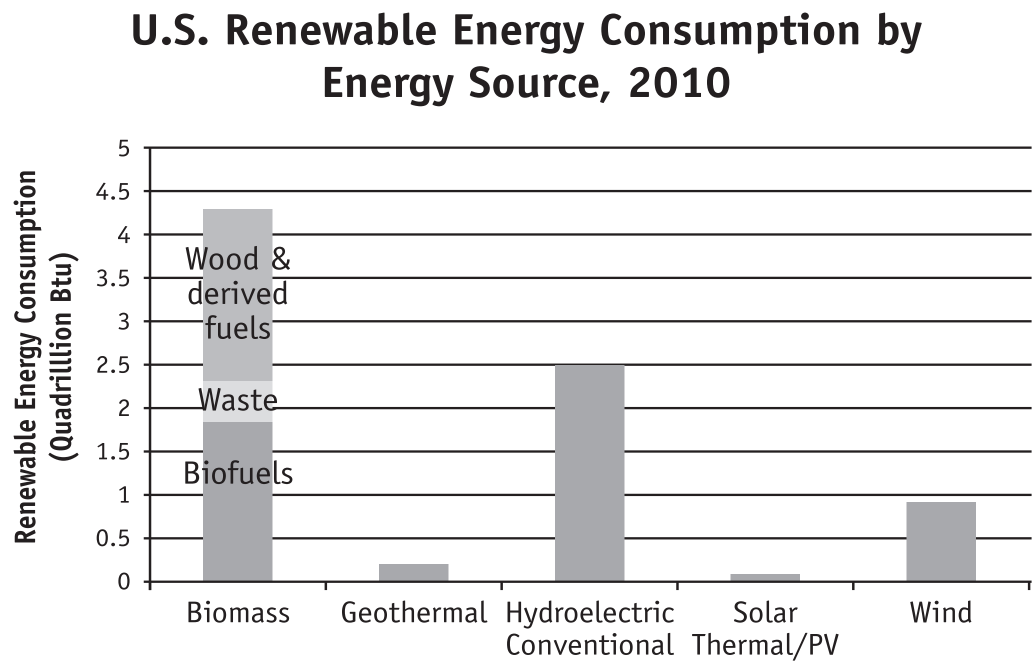
U.S. *wind power* generation grew from 4.5 GW in 1999 to 73.9 GW in 2009 and wind power led all other sources of electric power in terms of *new* capacity in 2008 and 2009. *Geothermal* both provides direct heat and generates electricity, using Earth's internal heat as an energy source. It has long been used on a small scale for heating where the heat release is high – at hot springs, for example. In recent decades, capturing Earth's heat for power production has grown substantially, but it remains a small part of the global energy portfolio. Geothermal energy systems sometimes use hydraulic fracturing to increase the flow of water through the rock, which regulates heat and controls energy production. Also in the last few decades, small-scale geothermal systems have been effectively used to preheat air in winter or cool it in summer, thus reducing HVAC costs in homes and buildings. Globally, geothermal electricity production has grown 20% since 2005, but its total contribution is still comparatively small at 11 GW of installed electric generating capacity.[6]

In addition to photosynthesis (which is what green plants do to convert solar energy to biomass), two processes convert the Sun's rays to

Table 1. **Coal Classification by Type.** [4]

	Percent of U.S. Production (2008)	Range of Heating Values (thousand Btu/lb)
Lignite	6.9	4.0 – 8.3
Sub-bituminous Coal	46.3	8.3 – 13.0
Bituminous Coal	46.9	11.0 – 15.0
Anthracite Coal	< .1	> 15.0

Figure 3. **U.S. Renewable Energy Consumption by Energy Source.**[7]



power for our life and work: *solar thermal* uses the Sun for heat; and *photovoltaic (PV) cells* convert light into electric current. Solar power offers examples of sources within a source as there is not only solar thermal and PV, but many different technologies used for both of these subtypes of energy production. Both are growing rapidly, with global PV generating capacity more than doubling between 2008 and 2010 (from 16 to 40 GW). Both solar thermal and PV systems can range in scale from very small household systems to very large power plants. Global solar thermal capacity, excluding systems to heat swimming pools, grew 16% in 2010, to 185 GW.[6] Solar energy production (thermal + PV) in the U.S. increased 60% between 2006 and 2010.[7] Further, passive solar building design coupled with good insulation and control of airflow can eliminate or practically eliminate the need for heating systems.

Possible future sources of energy include nuclear fusion, cellulosic ethanol, hydrogen fuel cells, tidally driven turbines and many others. Efficiency, conservation, and lifestyle changes also have the potential to greatly lower energy demand. But lifestyle changes and economic development – and in addition, population growth - also have the potential to *increase* energy demand.

All Large Scale Energy Sources Have Negative Environmental Impacts

It has become common knowledge that the extraction and use of fossil fuels damages the environment in a number of ways. However, environmental impacts are associated with *any* type of large-scale energy development.

Coal is frequently mined in ways that risk human life and dramatically alter the landscape, for example by removing entire mountaintops.[ii] Its use contributes to acid rain and has history of yielding huge spills of coal slurry that decimate landscapes. Coal can be surface mined or mined from below ground. When burned, coal has a range of impacts. In recent years, attention has been given to

ii. "Mountain top removal" is a form of surface mining commonly used in the Appalachian Mountains of the Eastern U.S. It requires the removal of mountain or ridge tops to allow easy access to coal seams and has substantial environmental and human health impacts.

climate impacts, but coal has historically blackened cities and released mercury and pollutants that yield acid rain. In addition, black lung disease and coalmining accidents have killed thousands around the globe every year. Coal mining and accidents also contaminate streams and rivers. The Martin County, Kentucky coal sludge spill of 2000 sent an estimated 300 million gallons of sludge into two tributaries of the Tug Fork River.

Environmental impacts are associated with any type of energy development, especially when that development is on a large scale.

Oil can spill during extraction, shipment, or end use. Oil and natural gas extraction are also hazardous. Less than a month after the 2010 disaster at the Upper Big Branch Mine that killed 29 came the explosion of the Deepwater Horizon Drilling Platform, and with it the death of 11 crewmembers and the beginning of the worst oil spill in the nation's history. More locally, impacts of Marcellus Shale gas drilling have been reported from numerous regions in Pennsylvania, and traffic accidents are anecdotally on the rise. Natural gas lines can blow and leak. Other environmental, public safety, and public health issues related to shale gas development are detailed throughout this series of pamphlets.

There remain huge reserves of fossil fuels in the world, but the remaining reserves are increasingly difficult and expensive to recover, are generally more water and energy intensive than conventional extraction, and hold substantial environmental risks. And, while substantial reserves remain, fossil fuels are a finite resource. Fossil fuel extraction methods are distinct and each has a suite of overlapping environmental concerns. See the Life Cycle Analysis Pamphlet in this series for a more detailed look at the impacts of different fossil fuel energy sources.

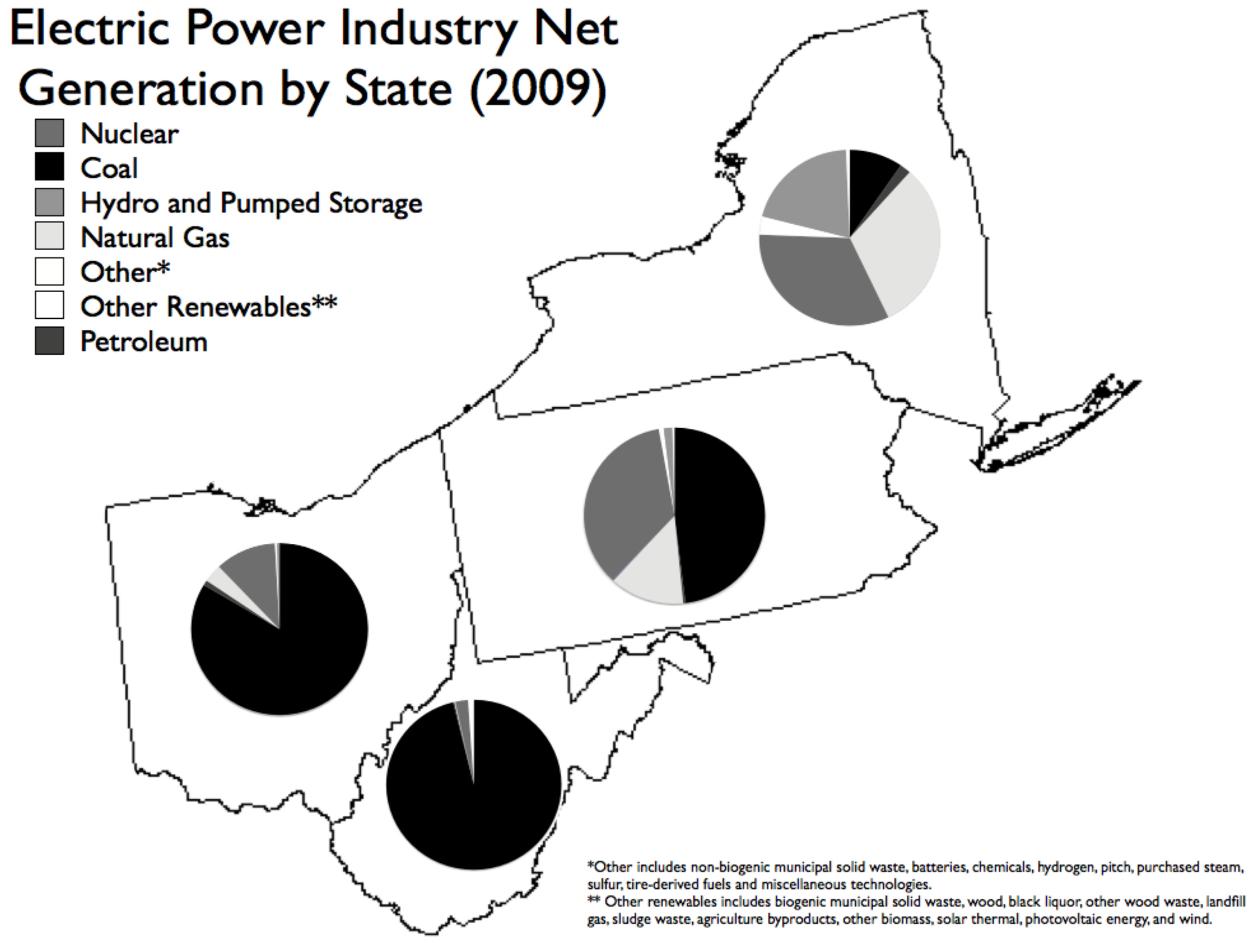
Negative environmental impacts are not limited to fossil fuels. The burning of biomass, like fossil fuels, yield carbon dioxide and often other emissions, though carbon emissions are cancelled out if the rate or regrowth of the same or similar biomass equals the rate of harvest. Wind development industrializes rural landscapes in some ways that parallel shale gas development. There is initial heavy construction and the building of access roads in formerly wild places, with similar storm water pollution and habitat fragmentation issues. It involves substantial truck traffic for the delivery and pouring of massive amounts of concrete for the turbine towers (and cement production is a large contributor to carbon dioxide emissions). Further, the physics and economy of wind turbines favors the construction of large diameter blades. This brings permanent structures to rural landscapes that are scores to hundreds of feet high. While impacts upon bird populations appear smaller than initially believed, current designs of turbines may have substantial impacts on bat populations. Turbines also make noise and cast flickering shadows that may impact sensitive residents' well-being.

Solar energy produces no emissions once systems are installed, but there are concerns about the manufacture and disposal of photovoltaic solar cells, and related to the mining practices, particularly outside the U.S., of rare earth metals used in PV and battery production. Whether a commercial-scale solar energy installation generates heat or electricity, it must cover and industrialize considerably more physical area compared to other kinds of power plants that generate the same amount of energy, though solar energy systems can be roof-mounted, reducing these concerns.

There are very serious concerns about nuclear power, especially related to accidents and the long-term management of highly toxic waste material. Accidents in the nuclear industry are uncommon but when they do happen they appear devastating in scale. However, power production driven by fossil fuels has led to many times more documented fatalities than nuclear power production. Technological advances have drastically cut the amount of radioactive waste used by newly designed nuclear power plants, but cost and environmental concern for accidents remain. Commercial scale hydropower appears unlikely to expand substantially in the U.S. using current technology as the flooding of gorges or valleys typically required for such generation destroys human and wildlife habitat. Indeed, many hydropower plants have been removed in recent decades because of their impact on wildlife, particularly fish migration.

Consider that one large nuclear plant produces the same amount of electricity as 3,000 large wind turbines or 50 square miles of photovoltaic cells. It is not a simple question to determine the most environmentally benign energy source, and the answer may vary depending on local contexts. There is no such thing as

Figure 4. **Electric Power Industry Net Generation by State within the Marcellus Region.**[8]



a free megawatt, with the possible exception of the one that is not consumed in the first place. The environmental impact of an energy source is a complicated issue, and while it is clear that some energy sources are more environmentally friendly than others, *all commercial energy production has negative environmental impacts*. For any energy source, there is a wide range of factors to consider, and those factors should be considered in contrast to current energy practices.

Energy Production and Use Varies Considerably by Region and Over Time

The four states within the Marcellus region have substantially different energy portfolios. West Virginia, which has substantial coalfields, is especially dependent upon coal for both its economy and its energy with 98% of electricity generated by coal. West Virginia leads the nation in net interstate electricity exports. In contrast, 2009 statistics show that coal accounts for only 10% of New York State electricity production. While this is the smallest percentage in many decades, the percentage of New York electricity that comes from coal has not reached 20% since 1993. Natural gas and nuclear each produced roughly one third of New York State's electricity. Hydropower, mostly from Niagara Falls, accounted for 21% of generation. Thus, the energy status quo depends greatly upon what energy sources exist near where you live.

The diversity of New York's electricity portfolio is unusual for the region. The four largest electric power plants in New York State are powered by four different sources (from larger to smaller: hydroelectric, natural gas, nuclear and petroleum). The 2,353-megawatt Robert Moses Niagara plant, harnessing power from the Niagara River, is one of the largest hydroelectric facilities in the world and is the largest single power plant in New York State. The Ravenswood Generating Station in Queens is a very close second. Ravenswood burns primarily natural gas, but can also burn petroleum. Four of the plants rounding out the top ten are powered by natural gas and none of the ten biggest power plants in New York State are coal-fired. In both Ohio and West Virginia, nine of the ten largest power plants are coal-fired. In fact, the eight largest plants in both states are coal-fired. The largest power plants in Pennsylvania, Ohio, and West Virginia are all coal-fired and all larger producers than Niagara Falls' Robert Moses hydroelectric plant. All three of these states also have active commercial coalmines, while New York does not.

The energy portfolio also varies substantially over time. In 1990, more New York State electricity was produced from petroleum than from any other source. Since then, hydroelectric, natural gas and nuclear have all taken turns as the leading source of electricity generation in the state. Since 1994, either nuclear (for seven of those years) or natural gas (for nine of those years) has led production.[9] Energy costs vary over time and by source, and power plants are built, retrofitted to use different fuel sources, and are temporarily taken offline for maintenance or repairs.

What Do We Use Energy For? Energy Demand Sectors

Different energy sources tend to be used to power different things. Consider lifting a satellite into orbit; powering that satellite; powering the GPS unit that depends upon the satellite; and powering the vehicle with the GPS unit inside it that takes you to your heated or cooled home. Each step requires a different energy source, though the GPS functions through the vehicle's transformation of one energy source into another.

The Energy Information Administration describes energy use as falling into one of four demand sectors: transportation; industrial; residential and commercial; and electric power. We will discuss the two largest sectors: electric power and transportation.

Electric Power

North America's electricity grid is the world's largest machine. Electric power is the largest energy demand sector. Electricity is also the largest source of U.S. greenhouse gas emissions, accounting for 34% of all U.S. emissions according to the EPA. Due to its dominance in both use and emissions, and due to its complexity, electricity receives more attention in this document than the other demand sectors. The electrical system is also tremendously inefficient– the majority of the energy input into the system is lost, primarily as waste heat. So, the electrical system is the biggest machine, the biggest source of greenhouse gas emissions, and one of the biggest sources of wasted energy.

Spinning coiled wires in a magnetic field generates electricity. Most electric power is generated in this way, converting mechanical energy into electrical energy through the use of a turbine. Power plants heat water to generate steam to turn turbines. The most common sources of that heat are coal and natural gas, with dependence on coal decreasing and natural gas increasing in recent years. Coal and natural gas plants and plants powered by biomass or waste burn fuel to produce heat. Wind and hydro use the movement of air or water, instead of steam, to turn turbines. Photovoltaic (PV) solar cells involve a fundamentally different process (than turbines) in which light strikes a semiconductor and this moves electrons from the surface of the semiconductor or between different bands within the material, thus generating electricity.

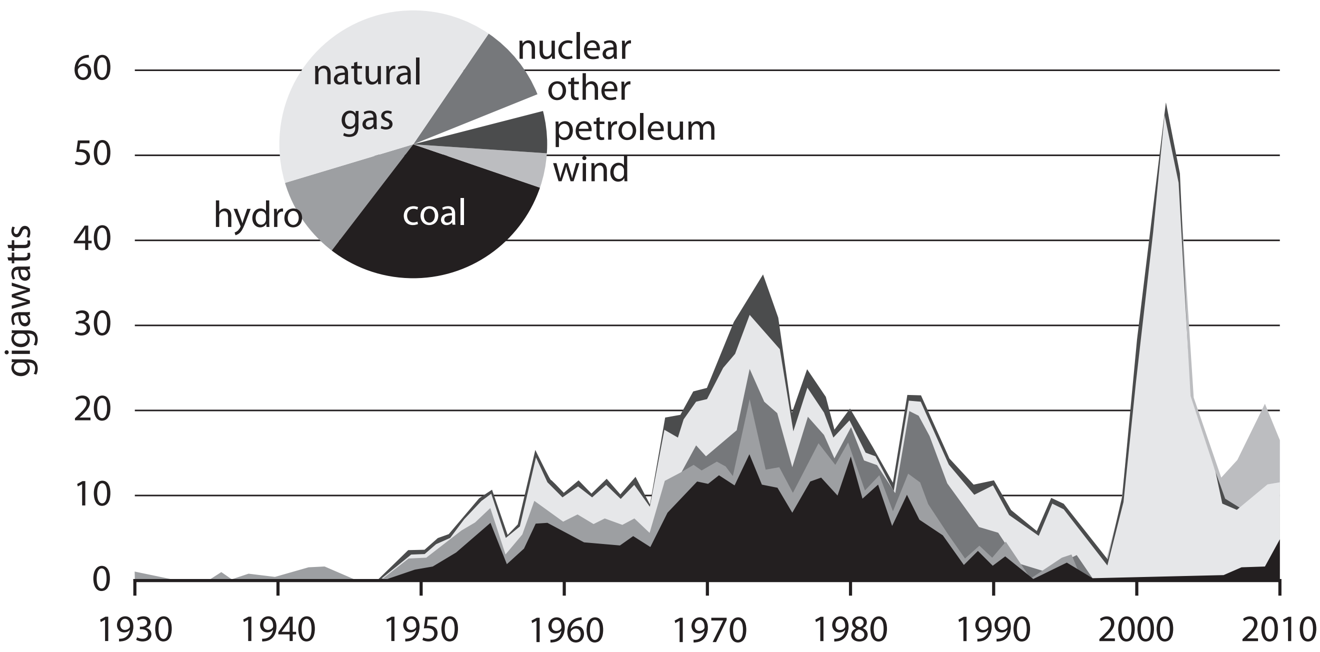
The heat in fuel burning plants does not all go to drive the turbines. Traditionally, some heat has been exhausted as waste, but an increasing number of plants now use it for other purposes. These are referred to as cogeneration or combined-heat-and-power (CHP) facilities and are substantially more efficient in the conversion of fuel to usable energy. As Figure 5 shows, most of generating capacity that came online in the last decade was natural gas-fired. Most of this new generation, and most (65%) of the natural gas plants that have come online since 1980, are CHP plants.

In 2009, electric power generation dropped 4.1%. Most of the drop in generation was from coal-fired power plants. Nuclear power generation also dropped by 0.9% while production from natural gas, hydro, petroleum and renewables all increased.[11] The decline in demand is primarily a result of two factors – the economic recession and improvements in appliance efficiency. That the drop in electric production primarily was a drop in electric production from coal is a result of substantial increases in electric production from wind and natural gas.

Transportation

In the first half of the 20th century, coal – used to fuel trains - was the dominant fuel for transportation. Coal was an important transportation fuel through the 1940s but its use in this sector fell rapidly in the 1950s. Now, with the widespread use of cars and trucks, ninety-four percent of the sector's power comes from petroleum. The remaining six

Figure 5. **U.S. Energy Capacity by Energy Type, 2010** *Data for 2010 are preliminary. Generators with online dates earlier than 1930 are predominantly hydroelectric. Data include non-retired plants existing as of year-end 2010. This chart shows the most recent (summer) capacity data for each generator. However, this number may change over time, if a generator undergoes an increase or decrease in generating capacity.*[10]



percent of the sector's energy is split nearly evenly between renewables and natural gas. Most of the renewable contribution to the sector is in the form of biofuels.

Like in the electric generation sector, most of energy input into the transportation sector is lost as waste heat.

California vehicle regulations have a history of influencing energy in the transportation sector. A change went into effect in the summer of 2011 that limits single occupant riders in California's High Occupancy Vehicle (HOV) lanes to pure zero emission vehicles (100% battery electric and hydrogen fuel cell) and compressed natural gas (CNG) vehicles. Prior to July 1, 2011 certain gasoline electric hybrid vehicles were allowed in HOV lanes. This change in regulation, along with federal tax incentives, is rapidly bringing new demand for the production of electric and CNG vehicle.

Predicting future energy use and availability is challenging

In 1954, the Chairman of the United State Atomic Energy Commission predicted, "Our children will enjoy in their homes electrical energy too cheap to meter…" Predictions about a topic as complex as energy are bound to sometimes widely miss the mark, and therefore should be read with a skeptical eye. The Energy Information Administration makes predictions about future energy use and development in their *Annual Energy Outlook*. These projections look decades into the future and typically include a range of likely outcomes based on things like the potential for technological advances, political will, global economic situations, and past use. Looking back to *Annual Energy Outlook 2001 with Projections to 2020*[3] shows some discussion of the development of natural gas from onshore unconventional sources and substantial growth in supply from this source. Natural gas production was projected to rise just above 20 trillion cubic feet per year for the lower 48 states and this is exactly what happened, however the rise in production was not as linear as projected. That same report placed the high renewables case projection for wind development at about 8 GW for 2010. The actual value for the year was more than three times higher than the highest projection - in excess of 34 GW.

Summary

Our energy system is ever changing and differs widely across regions. Every energy source has substantial environmental and economic impacts that ripple through the connected systems that form our environment and shape our society. It is not the purpose of this pamphlet to propose the use of one energy source over another, but rather to provide both a snapshot of current energy production and use to describe aspects of how the energy system has changed over time. New technologies and societal wants and needs will bring continuous change to where we get our energy from and how we use it. Throughout human history, the ways in which we produce and use energy have changed both slowly and very rapidly. Often, one part of the system changes gradually while another is quickly transformed. Almost all the nuclear power plants in the U.S. were built in the course of twenty years. Almost all of the wind generated electrical capacity in the world has come online in the last few years. While our transportation system has been driven by petroleum for decades, it has not always been so. Our transportation system moved from domination by animal power to coal (for trains and shipping) to petroleum in steps that each took only a few decades, after a new technology showed clear advantage. These sweeping and difficult to predict changes in our energy system will doubtless happen again and again, while other parts of the system will change remarkably slowly. Any change in the energy system impacts both the environment and the economy. Most or all increases in energy production and use will damage aspect of the environment, and need to be considered in the context of current energy practices. By better understanding the components of our energy system, their interconnections and how these things have changed in the past, we can make more informed decisions about our energy future.

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