1.1 Worldwide Energy Consumption

Worldwide Energy Consumption

Susan Peterson

Based on a presentation by Dr. Michael Evan Webber

Introduction

Excessive energy consumption is one of the most serious problems facing global society. While energy consumption is positively correlated with a robust economy, the quantities and sources of energy that humans use promote environmental degradation, expose nations to security risks, and destabilize global economic conditions. Reducing energy consumption and transitioning to better, cleaner energy sources will be one of the main tasks facing global leaders and citizens in the 21st century.

Energy consumption and sources

Humans consume energy at a higher rate now than they have at any other time in history, and our consumption continues to increase as more nations become industrialized. Baseline knowledge of the amount and kind of energy consumed is necessary in order to understand the scope of the problem and begin to devise technological and policy solutions that will address it.

Energy consumption rates

The U.S. and China are the highest energy consumers in the world. In 2005, Americans consumed 100 quadrillion British thermal units (BTUs) of energy. U.S. energy consumption represents 21.6 percent of the 462 quadrillion BTUs of energy consumed globally, despite possessing only 4.5 percent of the world’s population. Some smaller oil-producing nations such as Qatar, Trinidad and Tobago, and United Arab Emirates have higher per capita energy consumption, which does the same harm to the environment. Iceland also consumes very high levels of energy per capita, but the impact of their consumption is less severe because most Icelandic homes are heated using geothermal power, a renewable resource.

Energy sources

About 86 percent of the energy consumed globally is derived from oil, coal and natural gas, which are all fossil fuels. Not surprisingly, U.S. fuel consumption is heavily reliant on fossil fuels. The most significant difference between the proportions of fuels used in the U.S. and those used in the rest of the world is that the share of biomass fuels is lower in the U.S. This is because traditional biomass fuels, such as wood and dung, are used widely in the developing world for cooking.

In the U.S., commercial and residential sectors combined consume about 39 percent of total energy. These sectors together constitute the built environment and consume the greatest share of energy. The industrial sector is responsible for about 33 percent of total energy use, while the transportation sector consumes...
the remaining 28 percent. The building sector consumes most of its energy in the form of electricity. Coal power plants generate half of the electricity in the U.S., therefore the building sector is largely reliant on coal for its energy. Petroleum only makes up 3 percent of total fuel use for electricity. By contrast, the transportation sector is almost entirely reliant on petroleum for energy: 96 percent of transportation energy demand is met with petroleum.

The energy crisis in America

The American energy problem has three components. The first is resource depletion. Ultimately, world oil will peak, at which point production will begin to decline, resulting in higher oil prices, shortages and serious economic and social repercussion. It is difficult to predict the consequences of lacking sufficient affordable energy resources. The second component of the American energy problem is national security. Though our energy trade, we may enable countries to pursue actions, such as developing advanced weapons systems, that work against our foreign policy objectives. Finally, the last element of the American energy problem is environmental degradation. The most ominous contemporary threat caused by energy consumption is climate change, but energy consumption has other impacts on air, water, land and wildlife.

Resource depletion and national security

Media coverage of issues relating to oil has brought public attention to questions about resource depletion, costs, and reliability of supplies. It is difficult to know whether the world has reached peak oil and when it will reach peak gas, peak coal, peak wood, or peak phosphorus. Texas and the U.S. reached peak oil in 1971. The North Sea peaked in 1999. Some experts believe the world has already reached peak oil, while others believe that a large quantity of oil is still left in the ground. Presently, demand for oil is high and increasing, so the Organization for Petroleum Exporting Countries (OPEC) is charging the highest prices in recent history. However, the high oil prices have not stimulated additional oil production, which may indicate that the world has already reached peak oil. Decreased availability of fossil fuels will have an enormous impact on the American way of life. American infrastructure has developed during an era of cheap, abundant energy, and reversing fossil fuel dependence will not be undone quickly or easily. Cities such as Phoenix, Los Angeles, and Las Vegas could not have been built without the availability of large amounts of inexpensive energy. For example, the site on which Los Angeles has developed could support 150,000 people on its own resources alone, but it presently hosts 16 million. The city is only able to support this enormous population by using 5 percent of the state’s total energy to move water from the northern part of the state to be used by residents of the southern part of the state.
Environmental degradation: Impacts on global temperatures, air, land, and water

Perhaps one of the most serious threats to our way of life is the degradation of the global environment caused by energy consumption. Energy consumption causes environmental degradation at every phase in the life cycle of buildings and materials, including resource extraction and processing, transportation of assemblies and materials, use, maintenance, and end-of-life processes like demolition, reuse, recycling, and transport to a landfill. Energy production and consumption also impact every facet of the environment, polluting the air and water, using land, using and returning water for cooling, and affecting the natural habitats of wildlife.

Carbon and climate change

One of the most imposing and immediate threats to human existence is climate change, caused by the release of greenhouse gases into the atmosphere. Greenhouse gases are produced in many ways, but human society has caused a sharp increase in atmospheric greenhouse gas levels by burning fossil fuels to produce energy. The most commonly studied of these greenhouse gases is carbon dioxide. Therefore, climate change is often discussed in terms of atmospheric carbon dioxide levels, though other greenhouse gases also contribute to the warming effects of climate change. All sources scientists use to measure carbon dioxide, including ice core records dating back 600,000 years, show regular oscillations in atmospheric carbon levels. These oscillations typically rise and fall in a 10,000-year cycle, but recently, levels have continued to rise when they should be falling. At present, global atmospheric carbon dioxide levels hover around 380 parts per million (ppm). To avoid the worst-case scenarios of climate change, experts estimate that global greenhouse gas levels should be stabilized at 450 ppm.

NO\textsubscript{X}, SO\textsubscript{X} and particulate matter

Natural gas and coal power plants significantly impact the air we breathe. Power plants exhaust flue gases, consisting of carbon dioxide, nitrogen oxide (NO\textsubscript{X}), sulfur oxide (SO\textsubscript{X}) and solid particles. These substances can travel long distances and endanger the health of humans and the planet. SO\textsubscript{X} emissions are produced primarily by coal-burning plants, but also in smaller quantities by natural gas plants. Coal contains 1 to 3 percent sulfur, which becomes sulfur dioxide (SO\textsubscript{2}) after combustion. SO\textsubscript{2} combines with water to make sulfuric acid, also known as acid rain, which can travel great distances. Both coal and natural gas produce NO\textsubscript{X} as a result of high temperature combustion. NO\textsubscript{X} is poisonous and can be deadly when inhaled. The end products created by NO\textsubscript{X} interacting with the environment are nitric acid, ammonium nitrate and particulate matter.

Power plants also exhaust solid particles. Large particles include soot, fly ash, metallic particles, and dust. These larger particles typically fall near to the place where they are emitted. Plants also emit mercury, which can travel great distances. Very small particles, known as particulate matter (PM), present threats to human health. Particulate matter can be solid or liquid. When the diameter of the particles is less than 10 microns, the PM can be inhaled. When it is less than 2.5 microns, it can get into the lungs’ alveoli, which are the final branches in the lungs where gas exchange takes place. PM blocks these branches, thereby reducing the body’s capacity to breathe in oxygen and breathe out other gases. Asthma, an illness caused in part by PM, is the number one public health problem in the U.S.

Water

Energy production also impacts water resources. The thermoelectric power sector is the largest consumer of water in the U.S., accounting for half of all water consumption. The water is used for cooling in power plants. Though 97 percent of the water is returned, it is hotter when it is returned, which impacts the environment and the wildlife living in it. The water con-

Figure 3: Effects of elevated atmospheric carbon on climate factors
sumption of power generation makes certain regions more vulnerable to climate change. During heat waves, peak electricity demand rises because people turn on air conditioners to cool buildings. However, because of the heat the rivers have a diminished ability to cool the power plants. This situation can cause strain on the power system at times when demand skyrockets because people need to cool their buildings. This effect has been particularly problematic in France, which depends largely on nuclear energy. In 2003, during a heat wave that killed approximately 14,000 people, French power plants were forced to exceed temperature restrictions on exhaust water in order to maintain operations. This had a detrimental effect on the ecosystems of the rivers that received the exhaust water. Similar effects are possible during droughts.

In addition to placing a strain on water supplies during power production, energy consumption can pollute water resources. Oil spills are a contemporary threat that continues to destroy ocean and coastal habitats. Perhaps the most famous and devastating oil spill in recent history was the Exxon Valdez disaster in 1989. However, oil spills have taken place as recently as November 2007, when oil spills occurred in the San Francisco Bay and the Black Sea. In December 2007, a large oil spill happened off the coast of Korea. In December 2007, a large oil spill happened off the coast of Korea. The risk of oil spills makes it important to proceed cautiously with offshore drilling. California is still wary of offshore drilling because of the 1966 oil spill in the Santa Barbara Channel. In Florida, offshore drilling was completely banned because its coastal tourism is more valuable than the oil that could be extracted there.

Land

Land impacts are an often overlooked element of energy provision. While renewable energy sources, such as hydroelectric, wind, and solar energy, have a reduced impact on air and water, these resources are quite land-intensive. For example, capturing solar energy requires a great deal of surface area. For solar energy to meet a significant proportion of a region's energy needs, companies would need to build massive plants in sparsely populated areas capable of producing more than a gigawatt of electricity. Some architects and other building sector stakeholders have begun using rooftop solar panels to provide on-site power. However, while rooftop solar panels may be able to provide energy for a building the size of a single-family home, they cannot provide enough energy for taller commercial buildings. Tall buildings are designed for higher density occupancy and have less rooftop space relative to their volume. Until solar technology becomes much more efficient, it is unlikely that solar energy will supply a significant proportion of energy needs in high density urban areas. The only energy source with a positive land impact is a process that converts waste to energy. It actually spares land, rather than consuming it, because it diverts waste from landfills. Converting waste to energy serves a dual purpose, by disposing of trash while producing energy.

A global economic paradigm shift to address the energy crisis

While threats to national security and national resources have almost always been a part of national discourse, climate change is new to the policy agenda. Climate change is a man induced environmental problem unlike any the world has ever faced. There is a time lag between the generations that must take action to mitigate climate change and the generations that will suffer the consequences of inaction. In addition, Western countries contributing the most greenhouse gases will be impacted the least, whereas developing world countries in Africa and Southeast Asia who contribute the least to climate change will suffer the most. How, then, do we address a problem that will have the greatest impact on unborn people on the other side of the world? The decision to take action to mitigate climate change depends on our beliefs about future generations. If we believe future generations will be richer than us -- that is, if we think that they will have more resources to expend solving the problem -- it may make sense to leave the action to them. If we believe that future generations will be poorer, or that climate change may impoverish them, it makes sense for the present generation to take responsibility for acting to solve the problem. The decision to act also depends on how we value future generations. It is an ethical question: If we believe future generations are less deserving than we are, then perhaps we do not need to take action to reduce our energy consumption and use cleaner fuels. If we believe future generations have the same right to a safe, pleasant, healthy, productive planet that we do, it is imperative to act.

The need for collective action

“There is excessive confidence in the potential of particular technical fixes that are seen to hold (often near-magical) solutions to our problems and whose early commercialization is forecast to bring prosperous future.”

- Vaclav Smil, Energy at the Crossroads

In his 2006 State of the Union address, President George W. Bush said, “We have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology.” His statement is representative of the deep faith Americans have that new technology will “fix” the energy problem. Faith in technology places the burden on the very small proportion of the popula-
1.1 Worldwide Energy Consumption

Economics motivated the Industrial Revolution. Its underlying premise was that nature is abundant, and people are scarce. Therefore, it would benefit people to increase labor productivity through automation and mechanization. A new economic theory for the green industrial revolution should be based on the premise that people are abundant and nature is scarce. It benefits people to increase resource productivity rather than human productivity. This kind of philosophy would promote high efficiency and resource reuse rates. The energy problem is potentially catastrophic. The risks of national security consequences, climate change, and resource depletion are too severe to ignore. To avert these crises, the world will have to undergo an energy transition. Before the industrial revolution humanity, along with all the other earthly species, relied on solar energy as an original energy source, converted into usable energy by plants through photosynthesis. We now rely largely on fossil fuels for energy, but they are finite. Once they run out, we will again rely on solar energy. Whether we will manage the transition ourselves or be forced to transition after we burn up all the fossil fuels is still unclear.

Conclusion: A new take on economic growth

Current economic theory holds that growth is the objective of economic activity and the measure of economic progress. Growth can take place at the personal, city, state or national level. Present-day goals include population growth, increased consumption, and building bigger cities, taller buildings, faster cars and wider roads. Economic growth in this traditional sense demands higher rates of resource use, greater environmental impacts, and the destruction of natural assets. Growth-oriented economics motivated the Industrial Revolution. Its underlying premise was that nature is abundant, and people are scarce. Therefore, it would benefit people to increase labor productivity through automation and mechanization. A new economic theory for the green industrial revolution should be based on the premise that people are abundant and nature is scarce. It benefits people to increase resource productivity rather than human productivity. This kind of philosophy would promote high efficiency and resource reuse rates. The energy problem is potentially catastrophic. The risks of national security consequences, climate change, and resource depletion are too severe to ignore. To avert these crises, the world will have to undergo an energy transition. Before the industrial revolution humanity, along with all the other earthly species, relied on solar energy as an original energy source, converted into usable energy by plants through photosynthesis. We now rely largely on fossil fuels for energy, but they are finite. Once they run out, we will again rely on solar energy. Whether we will manage the transition ourselves or be forced to transition after we burn up all the fossil fuels is still unclear.

The U.S. will not be able to end its dependence on fossil fuels with traditional economic, philosophical, cultural and engineering approaches. Instead, we need to find new philosophers. Solving the energy crisis will require new thinking, collective action, and the cooperation of government and industry.

Glossary

British thermal unit: The amount of heat required to raise the temperature of one pound of water 1 degree Fahrenheit. One kWh is equal to 3413 BTUs.

Fossil fuels: Carbon or hydrocarbon fuels found in the Earth’s crust. They are considered non-renewable resources because they take millions of years to form, and therefore the supply is finite.

Geothermal power: Geothermal power is a renewable energy resource derived from heat stored in the earth. Heat is harnessed using geothermal heat pumps and deep wells that bring hot liquids to the surface to be used in a variety of energy applications.

Peak oil: Oil is a finite, non-renewable natural resource. The rate of oil “production,” meaning extraction and refining of crude oil, has grown every year for the last century. Once the world has used about one half of natural oil reserves, it is likely production will begin to decline, resulting in higher oil prices, shortages and serious economic and social consequences.

Figure 5: Solar panels on this Tibetan building provide a sustainable source of energy.
Notes


6. Michael Webber is the Associate Director of the Center for International Energy and Environmental Policy in the Jackson School of Geosciences, Fellow of the Strauss Center for International Security and Law at the LBJ School of Public Affairs, and Assistant Professor of Mechanical Engineering at the University of Texas at Austin, where he trains a new generation of energy leaders through research and education. Prior to joining UT Austin, Michael studied policy issues relevant to energy, innovation, the U.S. industrial base, and national security, at the RAND Corporation. Michael has published more than twenty peer-reviewed scientific articles; been awarded two patents; and given more than 75 lectures, speeches, and invited talks, including briefings for members of Parliament, senior decision makers in government, and executives in the private sector.

Michael's educational background includes a B.S. with High Honors (Aerospace Engineering) from UT Austin, an M.S. (Mechanical Engineering) and a Ph.D. (Mechanical Engineering, Minor in Electrical Engineering) from Stanford University, where he was a National Science Foundation Fellow from 1995-1998. In 2005, Michael was recognized by the College of Engineering at UT Austin as an Outstanding Young Engineering Graduate, and in 2006 was honored as the commencement speaker for the spring graduation ceremony. Michael has been featured in the New York Times, The Daily Telegraph, BBC, ABC, CBS, Discovery, Scientific American, Popular Mechanics and MSNBC. His commentaries on American energy policy and international affairs have been published in the Austin American-Statesman, Dallas Morning News, San Antonio Express-News, Fort Worth Star-Telegram, and the Houston Chronicle, and featured in a documentary about biofuels by the PBS national weekly newsmagazine NOW. More about his research can be found at his website, www.webberenergygroup.com. Michael lives in Austin, Texas with his wife and three children.

Images


Image 3: International Panel on Climate