THE NATIONAL ENERGY DILEMMA: MODELS FOR POLICY EVALUATION

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Abstract

This study is about gaining a deeper and better understanding of the effects and implications of the current situation in the U.S. energy markets at a macro level. In order to test what macro-level theories might best explain the national situation, the research takes a system dynamics perspective to cope with the behavioral complexity of the problem. Questions to be addressed include what makes the energy markets so volatile? Can the U.S. Government help stabilize these markets by developing and selling some of its energy assets? How can the U.S. Gov. encourage more private investment in renewable forms of energy? System dynamics models are presented to study the U.S. energy situation with a view to gaining a better understanding and to providing useful suggestions for policy.

Introduction

Perhaps nothing is more vexing and potentially disastrous than the rapid rise or fall of energy costs in the U.S. Both situations (high energy costs and low energy costs) have the potential to derail the U.S. economy and take it into a recession. As energy costs go up, the cost of imported energy (oil, gas, etc.) goes up, and this leads to a further devaluation of the dollar, which leads to still higher costs for foreign oil. Meanwhile, consumers start to reduce their energy consumption and pull back their spending, which slows down the economic growth, and the price of energy will go down with it as well. The recession is currently underway. Additionally, the fluctuation of energy prices has made other commodities' prices volatile, patterned after the spot market price of oil. The research proposed in this paper is about energy, all forms of energy supply and demand. Not too long ago, people begin to be concerned about why oil has become so expensive and what we can do to reduce U.S. dependence upon foreign sources of energy. How can the U.S. government develop its energy resources to help pay off the annual budget deficit and pay down the federal debt? A few months later, oil prices move in the opposite direction, from $145 per barrel in July 2008 to $30 per barrel in the end of the same year. Analysts are wondering what is driving the market; Environmentalists are wondering how energy choices can lead to significant reductions in carbon emissions, largely believed to be responsible for global warming. Government is wondering what must be done to be in command of the situation. The relationships among energy, the economy, and the environment are well-known and will be assumed and utilized here. The primary focus of interest here is the U.S. national energy policy and what must be done to stabilize the direction of energy costs while simultaneously reducing carbon emissions and providing much-needed revenue for the U.S. Federal Government. Finally, this research aims to address the importance of sustainability of the U.S. energy market and arrive at different energy policy scenarios for the next fifty years.

The remainder of this paper is organized as follows: 1) an overview of the U.S. energy market; 2) discussion of the current U.S. energy problems and future projection; 3) road mapping for the U.S. energy system; 4) the concept of holism, research methodology, and national energy dynamics model; 4) simulation results and policy recommendations; 5) contributions of this research and potential future study areas.

Background Discussion of the U.S. energy market

The use of energy has been a key factor in the evolution of the U.S. Several energy transitions appeared in the development of the U.S. economy (see Figure 1).

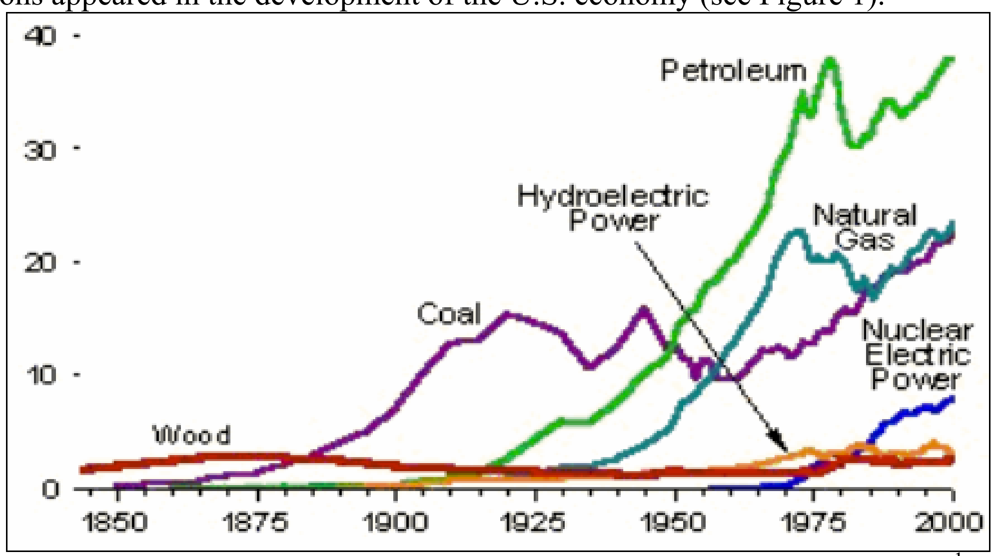

Figure 1: US energy consumption, by source, 1850-2000. Units: quadrillion BTU[1]

(Source: Energy use in the United States. from http://www.eia.doe.gov/emeu/aer/eh/frame.html)

Since energy plays an important role in every aspect of our daily lives, U.S. total primary energy consumption has grown dramatically over the past few decades. Although the United States is the world's leading energy-producing country, it also consumes approximately 1.4 times

[1] British thermal units (BTU or Btu) = a unit of energy used in the power, steam generation, heating and air conditioning industries. (source: http://en.wikipedia.org/wiki/British_thermal_unit)

as much as energy as it produces; therefore, the country has to heavily depend on outside energy sources, especially crude oil and natural gas (EIA). With a limited production capacity and an excess of quantity demanded over quantity supplied of nonrenewable energy sources, the U.S. has experienced an increase in overall national energy insecurity and vulnerability from price shocks that may have triggered turbulent effects on politics, economics, the environment, and other issues (Hopkins, 2006). According to the International Energy Annual 2006 published by the Department of Energy (DOE), Energy Information Administration (EIA), from 1980 to 2006, the annual percentage growth of the U.S. total energy production (TEP) was 0.21 percent,[2] with totals increasing from 67.23 quadrillion BTU to 71.03 quadrillion BTU; the annual percentage growth of the U.S. total energy consumption (TEC) was 0.95 percent,[3] with totals increasing from 78.12 quadrillion BTU to 99.86 quadrillion BTU. In the past, given that the growth rate of TEC has been much higher than that of TEP, how to reduce the gap between these two becomes a worry in the following decades. With the large increases in the national economic expansion, the growth in energy demand will continue to be driven by the high expectation of living standards, the increasing use of power generation, and the transportation needs. Since our current primary energy sources are mainly from nonrenewable energy that cannot be replenished in a short period of time, we are facing a big challenge of scarce resources in the near future. A report, *The Outlook of Energy Challenges: A View to 2030*, presented by the Exxon Mobile Corporation claims that the world's total energy demand will increase to 140 percent by 2030 when compared to the demand in 2005, even though nations have seen significant improvements in energy efficiency. Because nonrenewable energy resources are limited, the amount of energy supplied cannot possibly catch up to the actual quantity demanded. Thus, a consideration of global energy markets also raises worries about the reliability of energy supplies and the instability of price shocks. Such concerns suggest that the availability of renewable energy resources be explored and substituted for the current nonrenewable energy resources. Clearly, there must be a transition from nonrenewable sources of energy to renewable ones over the next several decades.

The U.S. energy problem

How much energy does the U.S. consume and where does it come from?

According to the International Energy Annual 2005, the U.S.'s TEC accounted for 22 percent of the world's total consumption. However, the total population in the U.S. was only 5 percent of the world (United Nations Population Division).[4] If we take a close look at the major usage sectors in the current U.S. economy, transportation eats up about 28 percent of the TEC in this country (EIA), of which 61 percent is supplied by gasoline (DOE, Transportation Energy Data Book, 2004). Meier, Roundtree, and Schaefer (1998) point out that the global population in 1950 was 2.5 billion and the number of automobiles in existence at that time was 50 million. After almost a half century, however, the number of automobiles increased tenfold to 500 million while the human population had just more than doubled. More seriously, among these 500 million

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[2] The annual rate of growth in the U.S. primary energy production= $\sqrt[26]{71.03/67.23}-1 \approx 0.21\%$.

[3] The annual rate of growth in the U.S. primary energy consumption= $\sqrt[26]{99.86/78.12}-1 \approx 0.95\%$.

[4] According to the database shown in United Nations Population Division, Department of Economic and Social Affairs Population Division, United Nations, in 2005, the U.S. population was 299,846,000; the world population was 6,514,751,000. Available from http://esa.un.org/unpp/index.asp

vehicles, there were over 225 million in the United States whose population was 285 million, according to a report from the Bureau of Transportation Statistics (http://www.bts.gov) and the United Nations Population Division (http://www.un.org). Based on the data discussed above, there were more than three motor vehicles for every four persons in the United States in the year 2000. The number of automobiles continued increasing to 250 million in 2006 (Bureau of Transportation Statistics, http://www.bts.gov).

Currently, the U.S. crude oil production is 3 billion barrels per year, but the country consumes 7 billion barrels per year while the world's consumption is a little bit more than 30 billion barrels per year (EIA). This means that Americans consume almost a quarter of the total world crude energy each year and must import 4 billion barrels annually from other countries. At \$80 a barrel, the annual cost to the U.S. for imported crude is \$320 billion a year. Compared with the amount of oil that the U.S. imported in 1973, by 2000, there was a 33 percent increase in foreign oil trading (Urbanchuk, 2001).[5] The U.S. DOE Information Energy Agency projected that the total imported crude oil amount will jump to approximately 70 percent by 2010. Moreover, from a report by BP Statistical Review of World Energy in 2007, the total proved oil reserves were estimated at approximately 1,201.3 billion barrels at the end of 2006, which is only enough to supply the current oil consumption for less than 40 years worldwide.

Why do oil prices fluctuate so much?

Today, crude oil and its by-products are widely used by manufacturers, industries, and within residences and commercial establishments. According to the historical data shown in the EIA, between 1981 and 1986, during the Iran/Iraq War, the monthly average price of crude oil rose to \$39 per barrel by February 1981. At the end of the war in 1986, the monthly average price rapidly dropped back to \$10.91 per barrel. From 1986 to 2003, the monthly average price of crude oil fluctuated between \$10 and \$30 per barrel. However, an upward movement in the price of crude oil occurred at the beginning of 2004 (see Figure 2). In April 2005, the price of crude oil hit a record high of \$58.28 per barrel in the United States and elsewhere (Bahree & Herrick, 2005). The price of crude oil continued to increase and hit another record high point of \$139.89 per barrel on the 16th of June 2008 while Saudi Arabia announced that it would boost its output over the weekend of June 14, 2008 (CNNMoney.com). A half-month later, the price of crude oil reached \$145.3 per barrel, which is the highest price ever in New York mercantile Exchange (NYMEX) market history, and then the price of crude oil rapidly dropped back to \$30.28 per barrel on the end of 2008 while the global oil consumption has not reduced that much. The idea of supply and demand for this commodity seems no longer to be the key trigger responsible for these price shocks.

[5] In 1973, U.S. imported 26.1% of crude oil requirements; in 2000, 59% of crude oil was imported from other countries.

Figure 2. NYMEX WTI Crude Oil Spot Prices, 2000 – 2009
(Data Source: U.S. Department of Energy, Energy Information Administration (EIA))

Since the cost of crude oil is the largest component for the retail price of gasoline, the rise in the price of crude oil directly affects the price of gasoline and a corresponding increase in Federal, State, and local taxes. According to the data collected by EIA, the price of gasoline has also risen. In March of 2005, the average price of a gallon of gas was about $2; in June of 2008, the average price of a gallon of gas reached $4 throughout the entire United States (see Table 1). While this is not a unique phenomenon to such states as California and Hawaii, which have seen similar increases before, it represents for the rest of the nation a radical departure from the norm. Transportation fuels therefore become more costly in daily expenditures. More importantly, according to the results of a quantitative exercise from the U.S. DOE, Information Energy Agency, a 40 percent oil price increase will result in a 0.4 percent decrease of the GDP in the OECD countries, an average loss of 0.8 percent of the GDP in Asia, and a 1.6 percent loss in very poor countries such as those countries in Africa. The turbulence of high oil prices may cause another economic recession in the U.S. soon.

Table 1. U.S. retail gasoline prices in major states (Units: dollars per gallon, including all taxes)

States	6/9/08	6/16/08	change from a week ago	change from a year ago
California	**4.433**	**4.588**	**0.155**	**1.352**
Colorado	**3.924**	**3.958**	**0.034**	**0.796**
Florida	**3.984**	**4.019**	**0.035**	**1.061**
Massachusetts	**4.001**	**4.044**	**0.043**	**1.09**
Minnesota	**3.933**	**3.909**	**-0.024**	**1.051**
New York	**4.198**	**4.259**	**0.061**	**1.098**
Ohio	**3.985**	**3.968**	**-0.017**	**1.065**
Texas	**3.907**	**3.947**	**0.04**	**1.053**

(Source: U.S. Department of Energy, EIA, U.S. retail gasoline prices, available from http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html)

What will happen in the future?

Consider the current situation relative to U.S. energy supply. The models to be explored include four different types of nonrenewable energy resources, specifically crude oil, natural gas, coal, and uranium. Crude oil is the most important one among these nonrenewable energy resources since the use of petroleum as a transportation fuel accounts for 97 percent of crude oil by-products (http://www.bp.com). It alone is capable of providing all the energy needs of vehicles in the transportation sector. However, as mentioned previously, the world's total crude oil can last for only about 40 more years. There are some substitutes in limited use currently, but none of them are viable options. For example, steam-powered cars use coal, which causes serious air pollution. Electric-powered cars will drive our electricity needs very high, thus shifting our demand for oil to a demand for coal, natural gas, nuclear power and renewables. Additionally, the transition of switching to electric-powered vehicles would likely take longer than what we expected. Natural gas has the potential to support the needs of the transportation sector, yet it is costly and we may run out of this natural resource as well. The effort to use natural gas (consider T. Boone Pickens plan) in the transportation sector may be futile eventually (http://www.androidpubs.com). These stumbling blocks mean that we need to pursue substitution of renewable energy that can be naturally replenished.

There is no doubt that there must be a transition from nonrenewable energy resources to renewable ones in the next several decades. However, for the near future, these renewable resources cannot possibly compete economically with any types of nonrenewable energy resources, as they are too expensive. Nevertheless, in the long run this transition may be necessary given the rate at which oil is being consumed and prices are growing. Additionally, in comparison with the finite sources and environmental impacts of nonrenewable energy, renewable energy resources are more promising since they make no contribution to global warming and produce no polluting emissions; they do have lifecycle cost advantages over some fossil fuels[6] in terms of all costs (operation costs and fuel costs) in the long-run; and there are no worries about depleting renewable forms of energy.

Numerous studies show that the potential to shift completely or partially from nonrenewable energy to renewable energy is achievable. For example, Zweibel, Mason, & Fthenakis (2008) proposed that photovoltaic technology is ready to provide almost 3,000 gigawatts (GW), which could supply 69 percent of the U.S. electric power requirements and 35 percent of the total energy consumption, by 2050. Meanwhile, U.S. carbon dioxide emissions would drop 62 percent, below 2005 levels, which may have a major reduction on global warming. If the technologies for other renewable energy forms (i.e. wind, biomass, and geothermal) were also developed, our nation's electricity can be powered 100 percent by these clean, carbon-free sources by 2100 and they will also be sufficient to supply 90 percent of total U.S. energy use.

The energy problem in the United States suffers from government policy that tends to take a short-range, myopic view. Because of the long development lead times required to get both renewable and nonrenewable energy production on line, a much longer public policy view needs to be taken. Since the 1973 oil crisis, energy became a popular topic of discussion in the U.S. (Hakes, 1998). Very few voices have warned of the emerging U.S. energy crisis since then. For example, Sasser (1976) claimed that a serious energy crisis would occur soon (certainly before the middle of the twenty-first century) if there were no alternative energy solutions; Basile (1977) asserted that other fossil fuels (i.e. oil shale, oil sands, and heavy oil) and renewable

[6] Coal has always been the most cost-effective way to make the large amount of electricity needed for modern life. (Source: Alliant Energy official Web sites, from http://www.alliantenergy.com)

energy sources would not make a major contribution to energy supplies before the year 2000; however, these resources could play important roles in the 21st century if research, development, and commercialization are pursued enthusiastically. The need for these potential energy sources is clear. Although they all present problems, hard choices, and trade-offs in some aspects, doing nothing now will definitely result in more difficult problems and choices, and more unpleasant trade-offs in the future (also see Schurr, 1979; Ridgeway and Conner, 1975).

A Roadmap for the U.S. Energy System

The structure of the energy market is formed in a very complex system with numerous usages (energy consumers), and a multitude of supplies (energy resources) and problems (energy issues). In general, the U.S. energy market comprises two different types of energy sources and four major usage sectors. They are nonrenewable and renewable energy resources used by industry & manufacturing, transportation, residential, and commercial sectors. Figure 3 depicts the U.S. energy supply in 2006: crude oil (or petroleum) supports the most U.S. energy needs, which is approximately 40 percent of the total energy supply; natural gas and coal supply about the equal amount, which is 23 percent; uranium (or nuclear), the least commonly used nonrenewable fuel in the U.S. energy market, only provides around 8 percent; the remainder of the 7 percent of the country's energy needs comes from renewable energy sources. Within those renewable energies, biomass and hydropower are the most popular ones while solar has the least contribution to the U.S. energy market.

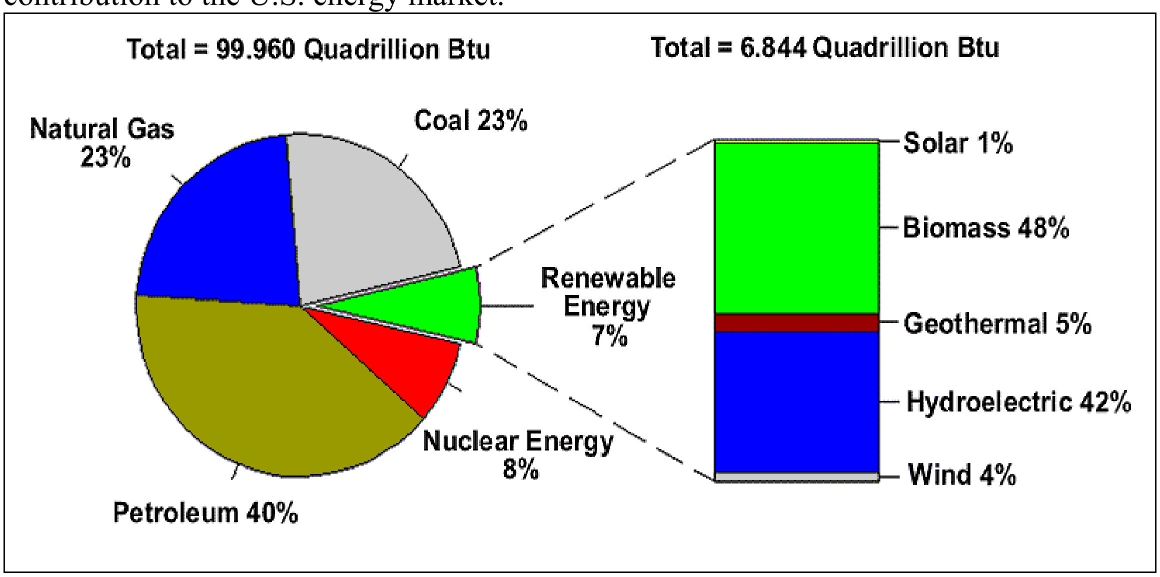

Figure 3: Renewable energy consumption in the U.S. energy supply, 2006 **(Source: EIA, Renewable Energy Consumption and Electricity Preliminary 2006 Statistics)**

U.S. energy supply

A nonrenewable energy resource is a kind of energy that cannot be recreated in a short period of time. Four major nonrenewable sources commonly used in the U.S. are crude oil, coal, natural gas, and uranium. Normally, such kinds of resources take millions of years to form; therefore, these types of energies have limited reserves and jeopardize the quantity supplied. For instance, the crude oil market is oligopolistic in nature and susceptible to the formation of cartels which provide substantial market power with ability to influence price by controlling supply

(Fletcher, 2008; Paula, 2007; Hoyos, 2005). Before the 1950s, the United States produced as much petroleum as the nation needed. However, by the end of that decade, the gap between production and consumption began to expand (see Figure 4) and imported petroleum became a major component of the U.S. petroleum supply. After 1989, the nation imported more petroleum than it produced. Today, more than 72 percent of U.S. oil consumption is imported and mostly used as a transportation fuel, states Annual Energy Review 2007, published by EIA.

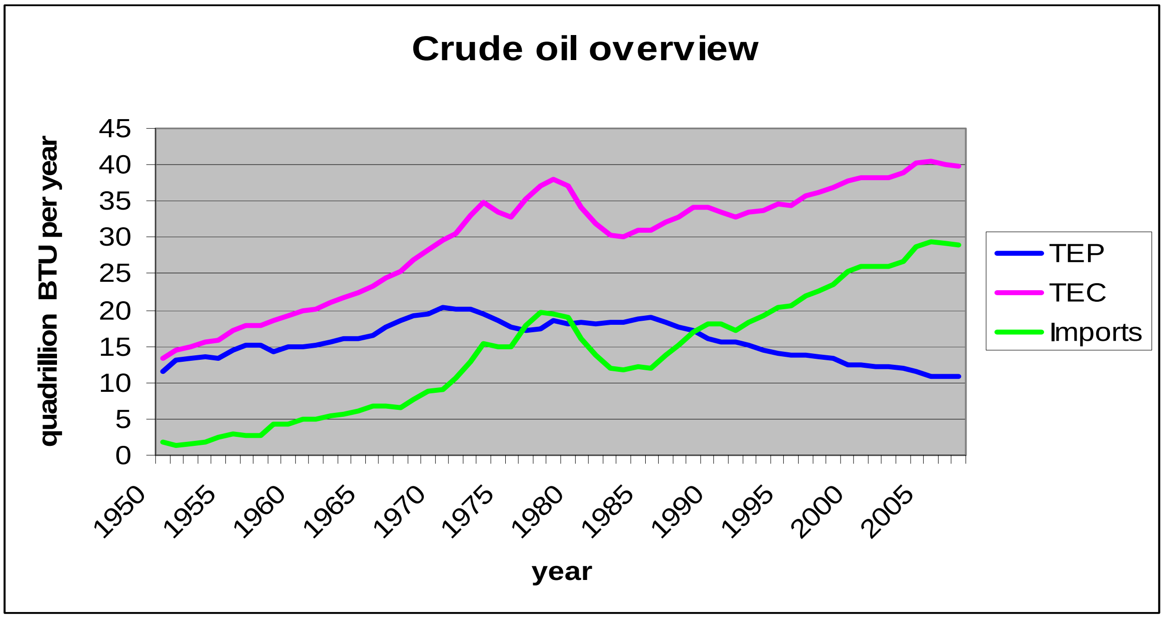

Figure 4: Crude oil overview: TEP[7], TEC[8], and imports since 1950 to 2007 (Data source: Energy Information Administration, Annual Energy Review, 2007)

Some of these energy resources are limited, but the reserves are in plentiful supply. Coal reserves, for instance, remain abundant and broadly distributed around the world. Other fossil fuel resources, however, will dry up and therefore become too costly to utilize. Coal continues its indispensable position among other energy resources for years because it is least affected by the price fluctuation (Yilmaz & Uslu, 2007; Metzroth, 2006). Moreover, the U.S. has the world's largest known coal reserves. According to EIA, coal will be in ample supply for the nation more than 200 years in terms of today's level of use.

Just like crude oil and coal, natural gas is also a fossil fuel. However, unlike them, natural gas is the cleanest burning fuel, which emits lower levels of potentially harmful byproducts into the air (NaturalGas.org). Therefore, it is the most popular choice for heating fuel in the residential sector. Today, more than half of the houses in the U.S. are heated by natural gas (Pacific Gas and Electric Company). Moreover, nearly 20% of U.S. electric power comes from natural gas. In addition, compressed natural gas (methane) can also be an alternative fuel for automobiles. Consequently, the quantity demanded for natural gas has increased greatly in the past few decades. Since the United Sates has large natural gas reserves, it was essentially self-sufficient on this energy resource. However, by the end of the 1990's, the total consumption began to significantly outpace the total production (see Figure 5). Imports therefore rose to make up the difference.

[7] TEP – Total Energy Production
[8] TEC – Total Energy Consumption

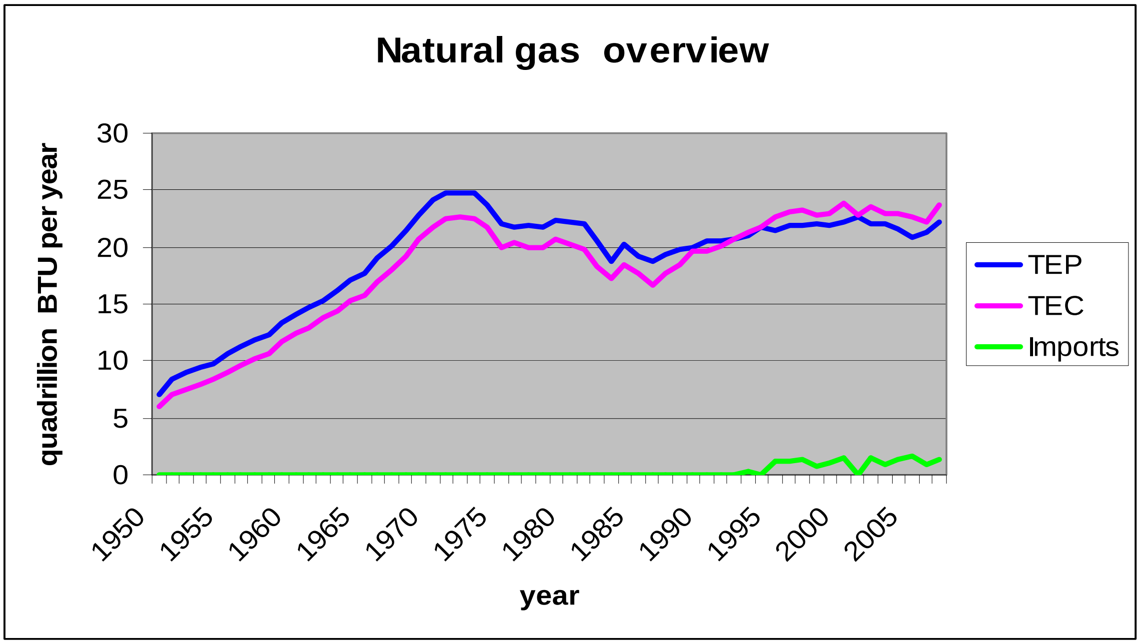

Figure 5: Natural gas overview: TEP, TEC, and imports since 1950 to 2007
(Data source: Energy Information Administration, Annual Energy Review, 2007)

Uranium atoms exist as U-238 (99.284%), U-235 (0.711%) and U234 (0.0058%) in nature. It can be found commonly in rocks all over the world; however, one kind of uranium, U-235, which is relatively rare, is widely used by nuclear power plants in a fission reaction.[9] When uranium is mined, the U-235 must be extracted and processed before it can be used as a fuel (McCarthy, 2006). Nuclear energy can be used to produce electricity. However, like all industrial processes, nuclear power generation has some by-product wastes: spent (used) fuels, other radioactive waste, and heat. Although nuclear power plants produce no air pollution or carbon dioxide, their by-product wastes are a principal environmental concern since these wastes contain low-level radioactivity. Therefore, these materials are subject to special regulations that govern their disposal in order to avoid contact with the outside environment (EIA, the office of Coal, Nuclear, Electric, and Alternate Fuels (CNEAF)).

By contrast, a renewable energy resource is a kind of energy which can be replenished in a short period of time, and it will never run out. The five major renewable sources that the U.S. commonly uses now are solar, wind, geothermal, biomass, and hydropower. Currently, using renewable energy has become more and more popular. Installation costs of renewable energy facilities are currently very expensive. But, the operation costs of the renewable energy resources are just the maintenance costs, and they give off no pollution (or much less than non-renewable resources) while producing energy. Figure 6 shows the amount of renewable energy used in the U.S. from 2001 to 2005.

[9] Nuclear fission: atoms are split apart to form smaller atoms to release energy. This is how nuclear power plants produce electricity.

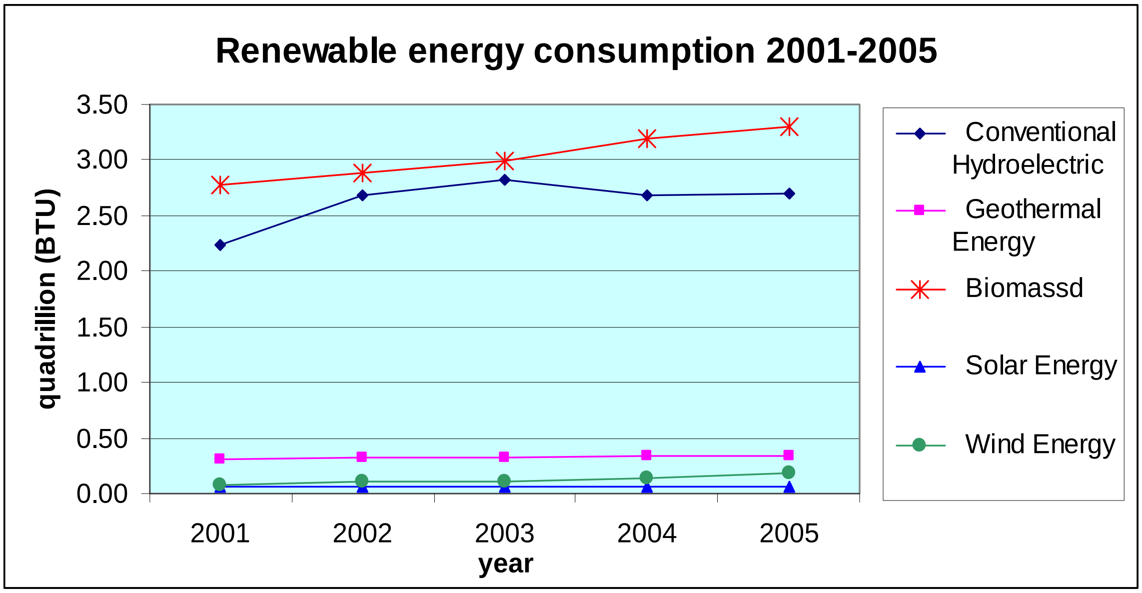

Figure 6: U.S. renewable energy consumption from 2001 to 2005 (Data source: EIA, Annual Energy Review, 2005)

The Sun has produced energy (sunlight and heat) for billions of years, and the energy can be converted directly or indirectly into other forms of energy, such as heat and electricity (EIA). The utilization of the radiant energy from the Sun is referred to as solar energy, which can be used for heating water, heating buildings, drying agricultural products, and generating electrical power (Kelly, 2007). Although solar energy is available everywhere everyday on the earth, it is the least commonly used among our current renewable energy resources. Some of the major reasons are that the initial cost of installation for solar panels is high and solar energy can only be generated during the daylight hours, states Clean Energy Ideas (http://www.clean-energy-ideas.com).

Wind is caused by the uneven heating of the earth. The warm air rises while the cool air goes down; when air moves, wind is created (EIA). The conversion of wind energy into a useful form is referred to wind power. Wind power can be produced by a single wind tower or a field of towers from a wind farm. Table 2 shows the states with the five largest capacities of wind energy plants. Horse Hollow Wind Energy Center, the world's largest wind farm, located in Taylor and Nolan County, Texas, has a total capacity of 735 megawatts (MW), which is enough to power 230,000 homes' electricity only per year (American Wind Energy Association). Today, the technology of wind farms is relatively mature. The operation cost of wind power, compared to a few years ago, makes more economic sense because of rising prices on crude oil and natural gas. Thus, once a wind farm is built, its operating cost is pretty much set for the duration of the facility (Hart, 2008; "Wind Power Fact Sheet," 2006).

Table 2: The five largest wind energy states in the U.S.

States	Texas	California	Iowa	Minnesota	Washington
Capacity (MW)	2768	2361	936	895	818

(Data source: Annual U.S. wind power rankings track industry's rapid growth, American Wind Energy Association)

Geothermal energy is literally the heat from inside of the earth. Studies have shown that the geothermal energy is available everywhere in the upper 10 kilometers of the earth's crust, with a mean temperature gradient of 20 to 30 °C/km depth and a mean emissive heat flux of about 1.5 $\mu cal/cm^2$ – sec (International Energy Outlook, 2002). Geothermal is considered a renewable energy because high temperatures are continuously produced inside the earth by the slow decay of radioactive particles, a process that happens in all rocks. Nature has provided four types of thermal resources: hydrothermal (vapor-dominated and liquid-dominated), petrothermal, geopressured, and magma (Kruger, 2006). The technology for conversion of geothermal fluids into electric energy is similar to the fossil fuels, but the conversion efficiencies are much lower. Geothermal energy is primarily used for electric energy generation, thermal applications and district heating systems (Kelly, 2007). Currently, within the States, only California, Nevada, Hawaii and Utah have set up geothermal power plants (EIA).

Biomass is organic material made from plants and animals. It is one of the oldest energy sources on earth, and may become one of the largest-scale energy sources in the future. According to EIA, biomass energy has been used more widely than other renewable sources. Part of the reason is that biomass is easy to extract. Unlike other renewable energy resources, biomass does not need an advanced technology to convert it into the useful resources. Some examples of biomass fuels are wood waste, crops, manure, and some garbage. The chemical energy in biomass will be released as heat when burned. Therefore, wood waste or garbage can be burned to produce the biomass fuels which can make electricity or provide heat for heating systems; crops like corn, sugar cane, and soybean can be fermented to produce the transportation fuel – ethanol or bio-diesel. Due to the increasing gasoline price, more and more automobile manufacturers are developing ethanol-based engines (Belsie, 2002). However, making ethanol from corn is very expensive. "The energy input/output is not very good (p.44)," says Stephen Ploasky, a professor of ecological and environmental economics at Minnesota University (Rotman, 2008). Bio-diesel, another type of transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Bio-diesel refers to the pure fuel before blending with diesel fuels. When bio-diesel blends are denoted as B15, it means that 15 percent of bio-diesel and 85 percent of petroleum diesel are contained in the blend (The National Biodiesel Board).

Hydropower, the energy of moving water, is the most often used among the renewable energy sources that generate electricity. When swiftly flowing water flows in a big river or through a pipe or penstock from a very high point, it carries a great deal of energy in its flow. The water is not reduced or used up in any of the processes because the water cycle is an endless, constantly recharging system. Hydropower, therefore, is considered a renewable energy (Energy Efficiency and Renewable Energy). Currently, renewable energy accounts for 9 percent of the total electric power capacity in the U.S. and hydropower provides about 75 percent of supplies, states EIA. Moreover, hydropower is also the most widely used renewable energy resource in the world, states Kelly (2007). Compared to other means of generating electricity, hydroelectric power can be very cheap. More importantly, hydropower basically produces no carbon dioxide or other harmful emissions. It is one of the cleanest forms of electric generation; therefore, it is not a contributor to the global warming through CO_2 (National Hydropower Association). However, hydroelectric power systems may contain considerable environmental risks since dams and reservoirs may cause significant flood damage and wipe out local ecosystems (Kelly, 2007).

U.S. energy demand

Energy is an important part of our daily lives. It lights our cities, powers our vehicles, warms our homes, cooks our food and operates our machinery; we use energy to do work and to produce our necessary goods. Everything we do is connected to energy somewhere in one form or another. There are four major usage sectors in the current U.S. economy (see Figure 7):

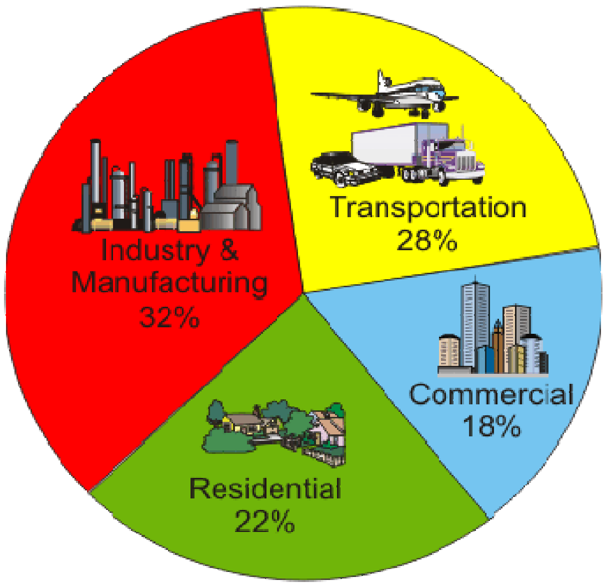

Figure 7: The major usage sectors in the current U.S. economy
(Data source from EIA, http://www.eia.doe.gov)

Industrial & manufacturing sector

Table 3: Fuel used for industrial & manufacturing sectors

Type of Fuel	Natural Gas	Other Sources	Electricity	Coal	Fuel Oil	Coke & Breeze	LPG (propane)
%	36%	33%	17%	7%	2%	4%	1%

(Source: Energy Information Administration, 2002 Manufacturing Energy Consumption Survey)

The United States has the largest and most technologically powerful economy in the world. Industry and manufacturing contribute most to this achievement; therefore, they use about one-third of the total energy in this country (see Figure 7).

The most common heating fuel in the industrial and manufacturing sector is natural gas (see Table 3). Two main usages here are boiler fuel and process heating. Boiler fuel produces heat that is transferred to the boiler vessel to generate steam or hot water; process heating raises the temperature of products in the manufacturing process while using energy directly (EIA). In energy distribution and transmission systems, energy sometimes can be lost. Boiler losses represent energy lost due to an inefficient boiler. Several factors may cause boiler inefficiency: the age of the boiler, maintenance practices, fuel type, etc. In the energy conversion system, energy is lost from processes whenever waste heat is not recovered and when waste by-products are not utilized. Furthermore, energy can be transformed into another type of energy, but it cannot be created or destroyed. Energy always exists in one form or another, states EIA. Again, if not all of the energy is converted, some energy is lost. This means that there are some opportunities that energy escapes.

Transportation sector

Table 4: Fuel used for transportation sector

Type of Fuel	Petroleum (crude oil by-product)			Natural Gas	Other
	Gasoline	Diesel	Jet Fuel		
%	61%	25%	8%	2%	4%

(Source: U.S. Department of Energy, *Transportation Energy Data Book*: Edition 24-2004)

Table 4 shows how types of fuels are used in the transportation sector. About 28 percent of the total energy we use goes to this sector (see Figure 7). Among this, almost 70 percent of the energy used is for passenger transportation; the other 30 percent less is for freight transportation, states EIA. America is a country on the move. Energy use in the transportation sector is primarily for passenger travel and freight movements. Cars, vans, and buses are commonly used to carry people; barges and pipelines are used to carry freight; trucks and airplanes, and railroads are either for people or for freight.

Since the late 1970's, the total energy consumption has increased as GDP grew. Population has increased, and people are traveling more as the distance between work and home has increased. Freight has been transported over greater distances in the U.S. Data shows that the number of vehicles in the United States continues to increase (the Bureau of Transportation Statistics). Compared to people in other countries, Americans love their automobiles and the U.S. has the largest number of vehicles among all nations. Based on the information from the Transportation Energy Data Book in 2004, automobiles, motorcycles, trucks, and buses in the United States drove over 2.8 trillion miles in 2002. It is like driving to the Sun and back approximately 15,000 times.[10]

Freight transportation in the United States experienced a great transformation in the 20th century. Before the 1950s, rail freight transportation was the major choice when transporting commercial goods. In general, rail transport is an energy-efficient and capital-intensive means of transportation; however, it has a great limitation because of railroad- track availability. With the development of technology and the investment on infrastructure, several forms of surface transportation have joined this sector. Today, rail, truck, water transport, and pipeline are all vital components of the freight system. In order to satisfy needs from different regions, freight transportation is coupled with a more even distribution of traffic among the modes. Not surprisingly, energy consumption in the transportation sector has shown significant growth.

According to data shown in Table 4, crude oil by-products (petroleum) accounts for 94 percent of transportation fuels in the U.S. Since three of every four residents have their own vehicles and people normally live far away from their work places, nearly one-fourth of the world's crude oil is used to transport people and goods from one place to another, states EIA. Such a great quantity of demand for crude oil and its by-products explains why the United States is the world's largest crude oil consuming country in the world.

[10] The minimum distance from the Sun to the Earth is 91 million miles; the maximum distance from the Sun to the Earth is 94.5 million miles. (Source: Windows to the universe store, http://www.windows.ucar.edu).

Commercial sector

Table 5: Fuel used for commercial sector

Type of Fuel	Electricity	Natural Gas	District Heat	Fuel Oil
%	55%	32%	10%	3%

(Source: Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey)

Commercial buildings account for 18 percent of the total energy used in this country (see Figure 7). A short list of building types includes offices, hospitals, schools, hotels, warehouses, shopping malls, etc. In this sector, almost 40 percent of the energy is used for cooling and heating, states EIA. Electricity and natural gas are the most common energy resources used in commercial buildings (see Table 5). During extreme heat and cold, energy consumption appears much higher than other times. Although it is more efficient to have a central heating and cooling system for the whole building, it is a waste if only a few or no workers are inside. For example, in commercial buildings, the central heating or cooling systems are not shut down after business hours. While a shut down creates pressure on the motor, this factor is not significant enough to offset the high cost of heating and cooling when nobody is in the building. Another consideration is to avoid wear and tear on the heating and cooling systems that occur from turning them on or off. However, the amount saved by turning the system off will more than offset any increase in maintenance costs. Studies show that shutting down the air conditioning systems in the campus buildings for three-day weekends can result in a noticeable drop in electricity usage (Friedlein et al, 2005). As a result, a surefire way to save energy is to adjust the temperature after business hours in order to consume less energy.

The same concept can be also applied to the lighting system. About 23 percent of usage in this sector is for lighting systems, states EIA. This seems like a huge amount compared to cooling and heating systems because lighting wattage is much lower than that of cooling and heating systems. One suggestion is to use dimmers to control lightness in the working environment according to daytime, nighttime, and room occupancy. More usage needs to be made of building energy control systems.

Residential sector

Table 6: Fuel used for residential sector

Type of Fuel	Natural Gas	Electricity	Fuel Oil	LPG (propane)
%	50%	39%	7%	4%

(Sources: Energy Information Administration, 2001 Residential Energy Consumption Survey)

With the development of technology, the capability of maintaining desired temperatures is no longer difficult. However, keeping our homes comfortable uses a lot of energy. Almost half of the average house's energy consumption is used for heating, and 24 percent of the energy used in homes is for lighting and appliances, states EIA. People want to enjoy their life while they are at home; however, there are several ways to help us enjoy the same quality of life and still use energy efficiently. For example, most people still use the traditional incandescent bulbs at home. These have a much shorter life, but use more energy than the compact fluorescent bulbs (or "CFLs"). Although CFLs are more expensive than the traditional ones, they produce significant savings over the lifetime of the bulb. If people use CFLs instead of the traditional bulbs, it will save considerable energy ("Advantages of CFL," Duke Energy). In addition, natural gas is the most widely used energy source in American houses (see Table 6). It is used mainly for house heating. In North America, temperatures below freezing are not unusual during the winter months. People have to turn on heaters to warm homes. Since people usually do not want to suffer coldness, they turn the temperature high to be comfortable and then leave the same level of temperature while they are gone. Conversely, they tend to adjust air conditioning to very cold and leave it that way even when they are not home. These habits result in much more energy being consumed than is actually needed. For members of each single family, it may not be overly significant to leave the heater or air conditioner at the same temperature while they are not at home. However, if all United States' families followed this practice, a huge energy loss would result.

Since the United States is a highly developed and industrialized society, it needs to use a lot of energy on the industrial/manufacturing sectors. However, while the residential sector does not physically contribute any GDP into our economy, it consumes about 18 percent of our total energy usage (see Figure 7). Thus, we need to seriously pay attention to the amount we use in the residential sector. Overuse of this energy (not leading to productivity) is considered a waste or loss. According to the International Energy Annual 2007 published by EIA, the United States and China are the two largest energy producers and consumers in the world. In per-capita usage, data shows that on average, each person in the United States consumes almost seven and half times the energy used by each person in China. Partially accounting for this disparity is the fact that China is classified as a developing country and it has a large population. The energy is used mainly in the modern cities, and it is not equally consumed by individuals. However, historical data shows that China's energy needs increased dramatically in the past decades because of economic expansions. Similar situation also happens in Asian countries such as India, Indonesia, and Malaysia (Chazan & King, 2008). It is apparent that an increasing demand for energy from other developing countries becomes the cost driver in the global energy market. Like the U.S., China has a lot of coal. It is known that China intends to build on coal-fired power plant a week.

In 2004, the Swedish Minister for Sustainable Development, Ms. Mona Sahlin, announced that Sweden aimed to become the first oil-free country in the world by 2020. She said, "There shall always be better alternatives to oil, which means no house should need oil for heating, and no driver should need to turn solely to gasoline" (Vidal, 2006). Obviously, not much attention has been paid to this announcement. Prospects for the price of crude oil reaching above $150 per barrel will happen soon (JP Morgan Investment Bank). Since most of our energy resources are nonrenewable, and their continued availability becomes questionable. Currently, most renewable energy is used for the electric power, but this type of energy only accounts for only 9 percent of the total energy resources in our electric power generation sector (EIA). Therefore, it is time for us to seriously consider the possibility of using alternative renewable energy resources to achieve our energy independence. More importantly, everyone needs to take his or her own responsibility, and the government also needs to take action on energy policy planning.

A roadmap for the U.S. energy system

As mentioned from previous sections (U.S. energy supply and U.S. energy demand), our natural energy sources can be divided into two different types: nonrenewable energy and renewable energy. Based on a variety of purposes and a mixture of users, energy can be changed into different forms to create power.

During the late 19th and early 20th centuries in the U.S., energy became essential to its citizens. However, a huge percentage of the energy supply is derived by burning fossil fuels, which are nonrenewable energy sources; only a small portion of energy use is obtained from renewable energy sources. Today, the United States consumes a large scale of energy, and the growth rate of energy consumption is faster than its environmental, political, and economic capacities (Kelly, 2007). Therefore, renewable energy development starts to emerge as a viable, long-term investment as an alternative energy source for the government and many other energy businesses (Rowley & Westwood, 2001). In order to clarify the situation and provide significant strategic opportunities for the national energy policy, it is important to understand the interrelationship between numerous energy consumers and a multitude of energy sources within the U.S. energy system.

Figure 8 exhibits energy resources used in different consumption sectors. Electric power supply has a distinct variety of options since all of the existing energy sources can be used to generate electric power. Fossil fuels and biomass are primarily burned for electricity, and the rest of the alternative energy sources (solar, wind, geothermal, and hydropower) are harnessed passively or actively by new developments to absorb heat or to turn turbines in order to generate electricity. One such technology, photovoltaics, is able to convert solar energy directly into electricity at efficiencies that have increased substantially in recent years and now approach 42.8 percent ("UD-led Team," 2007). The sources for the transportation sector are from crude oil, natural gas, bio-fuels, and electric utilities. The sources for the residential/commercial sector are from crude oil, natural gas, bio-fuels, solar, and electric utilities. The sources for the industrial sector are from crude oil, natural gas, coal, solar, hydropower, and electric utilities. By knowing and identifying the status of energy usage, this study can move to the next chapter where a discussion of research methodology and research models is presented.

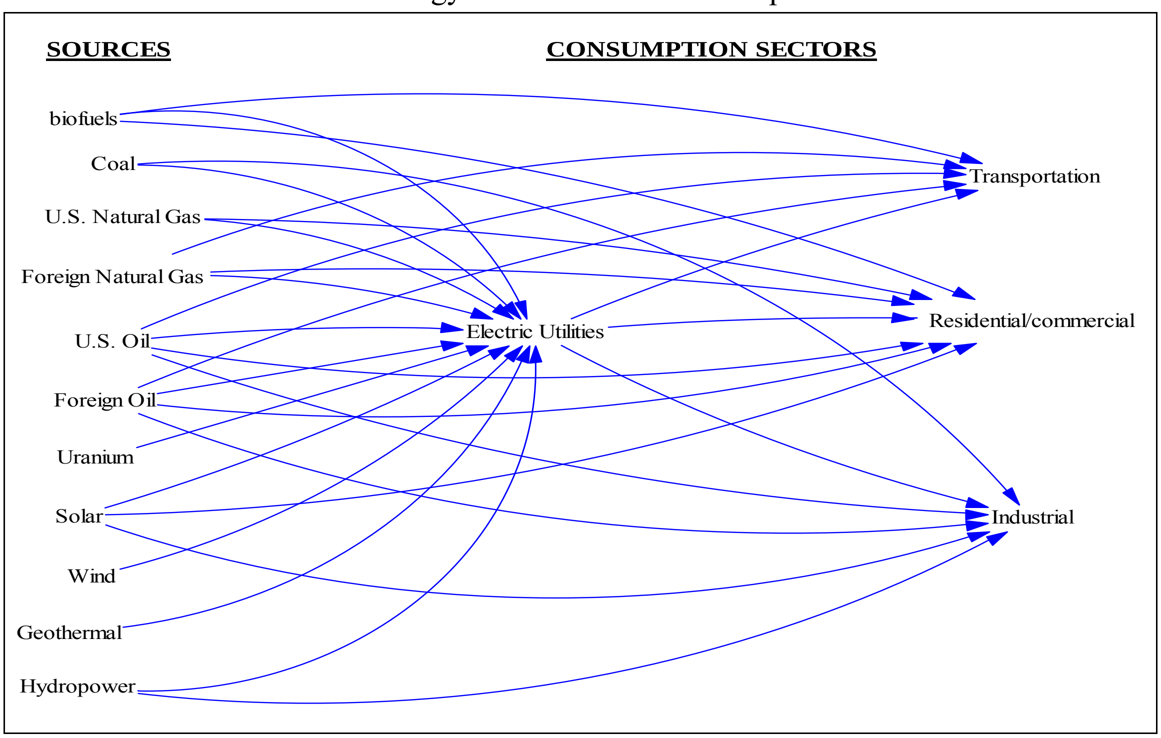

Figure 8. Overview of the U.S. energy system

Research Methodology & Research Model

Concept of System Dynamics Model

The structure of the U.S. energy market is formed in a very complex system with numerous usages (energy consumers), and a multitude of supplies (energy resources) and problems (energy issues). Unlike other problems we have experienced in the past, the influences of our current energy policy may have instantaneous positive and/or negative effects, delayed effects, or no effects because of unforeseen reactions of nature. Senge (1990) says “Today’s problems come from yesterday’s solutions” (p.57). All too often, our best efforts to solve a problem actually just make it worse. Looking at each problem individually and fixing only that problem without regard to the whole issue will not help our current situation. Additionally, no problem exists in isolation; all matters are connected to each other in the energy world. That is why we need to implement the concept of holism to view our energy problems. The basic concept of holism, summarized by Aristotle, a Greek philosopher, in the Metaphysics, is that “The whole is more than the sum of its parts” (http://en.wikipedia.org/wiki/Holism). Correspondingly, the energy system cannot be determined or explained by its component energy sources alone. In the present day, energy issues have become a question of national strategy (Yergin, 2006). They are no longer a problem on their own; instead, policy makers should look at the predicament from multiple perspectives, understand the sources of policy resistance, and learn more about dynamic complexity to design more effective policies. When we observe the problem as a whole, we can fix the problem as a whole. It has been proved that systems thinking has the ability to look at a problem as a complex system, in which we recognize that we cannot just take an action on a single problem and do nothing else on others since everything is connected to each other (Sterman, 2000). Therefore, there is an urgent need to understand the system from a holistic perspective and study the characteristics of each sector (usages, supplies, and problems). Moreover, according to historical data, the trend of energy consumption is clearly an upward movement. Inevitably, there will be some economically ruinous shocks to energy markets in the future. By studying the national energy model, we can go beyond the system to point out immediate problems and other relative issues, and come up with the best suggestions and/or solutions.

Energy System Dynamics Models

The Original Sasser Model (Sasser, 1976)

The original Sasser model for national energy usage was developed 30 years ago at Sandia to support the contention that a serious energy problem was developing in this country. The model shows that, in the absence of alternative (renewable) energy solutions, the energy-consuming sectors of the U.S. economy will collapse in the first half of this (the 21st) century if the policies of the recent past continue unabated. Such policies have, until recently, meant little or no renewable interventions, light water reactors only, increasing dependence on imported oil, and continued growth in the energy-consuming sectors.

The original Sasser model (Sasser, 1976) considered four energy consumption sectors: industry, the residential/commercial sector, transportation, and electric utilities. The model also considered five energy sources: coal, oil, gas, uranium, and foreign oil. A crisis develops as all four energy-consuming sectors begin a downward trend before the year 2050. The trend results from the depletion of U.S. domestic reserves of the non-renewable fuel sources, coal, oil, gas and uranium. The Sasser model belongs to a growing inventory of energy models that use a variety of different modeling methodologies, including system dynamics, econometrics, and Leontief input/output dynamical modeling. The model is of moderate size and consists of 250 equations, 25 of which are stocks. The model exhibits exemplary usage of system dynamics methodology and serves its avowed purposes with excellence. Extensive validation and parameterization runs made by Sasser enable his model to track historical data remarkably well in the period from 1950 to 1970. Depicted in Figure 9 below is the basic behavior of the original Sasser model.

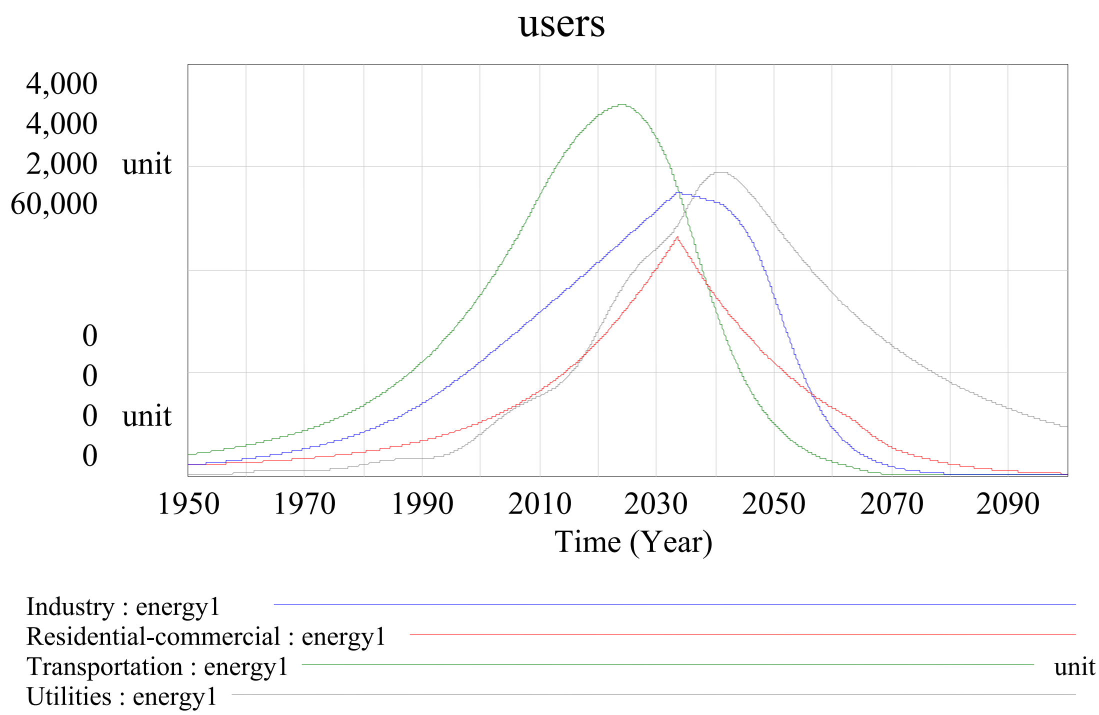

Figure 9. Dynamic Behavior of the Original Sasser Model

Updated Behavior of the Original Sasser Model

The original Sasser Model (Behavior depicted in Figure 9) started in the year 1950 and terminated in the year 2050. With the initial values it used for coal, domestic oil, foreign oil, domestic gas and uranium, it showed the consuming sectors peaking between the years 2030 and 2050. That was because reserves of domestic oil, natural gas, coal, uranium and foreign oil were all declining rapidly by the year 2030. It showed almost all of the recoverable reserves of domestic oil, domestic gas and uranium were used up by the year 2030. The updated version of the original Sasser Model starts in the year 2003 and continues through the year 2103. With the updated initial values used for the year 2003, the model exhibits the following behavior.

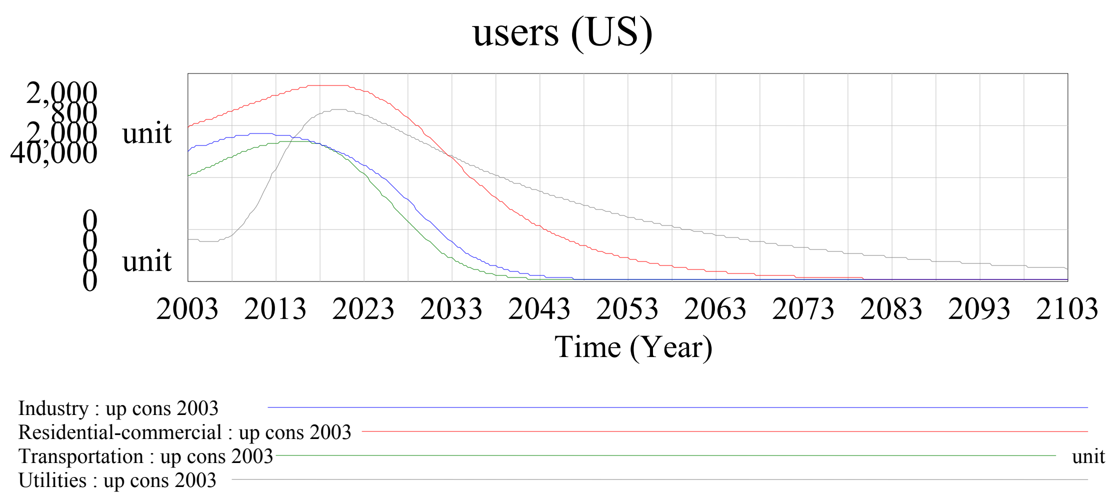

Figure 10. Baseline run with known proved reserves in 2003

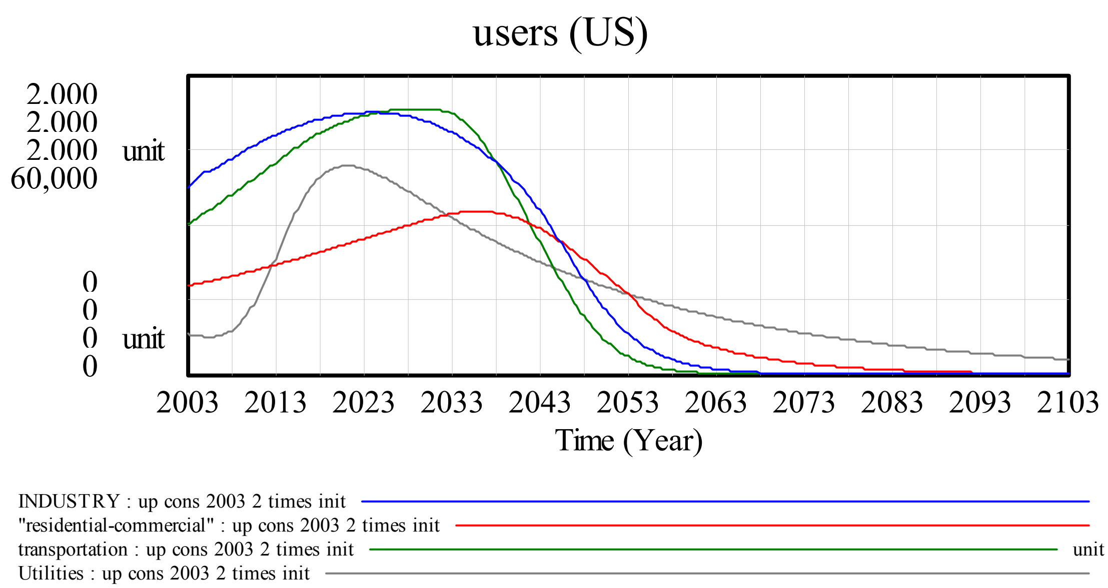

Figure 11. Updated Behavior of the Original Sasser Model with assumed reserves of twice those in Figure 10.

Clearly, Figure 10 suggests that, with the known initial values for domestic and foreign oil, domestic and foreign gas, uranium and coal (but no renewable fuels), declines in domestic U.S. consumption are eminent. All the energy consumption sectors are reaching peaks by the year 2020. This suggests that renewable sources of energy are needed now, given the lead times required to get them operative. Again, the downward trend in the energy consumption sectors is the result of essential depletion of non-renewable energy resources. In this run of the model it is assumed, that no renewable energy sources are available, light-water reactors only are used, there is increasing dependence on imported oil, and there is continued growth in the energy-consuming sectors. The behavior in the electric utilities sector requires further study.

In Figure 11, we have doubled the initial reserves for each of the non-renewable energy resources. Our reason for doing this is because the initial values used in Figure 10 are proved reserves for each category. This does not take into consideration possible unproved reserves. By doubling each of these initial values, we have given consideration to unproved reserves. What we are seeing is that the peaks and declines in the energy consumption sectors occur just ten to 13 years later. We conclude that there is substantial need for an aggressive development of renewable energy resources now.

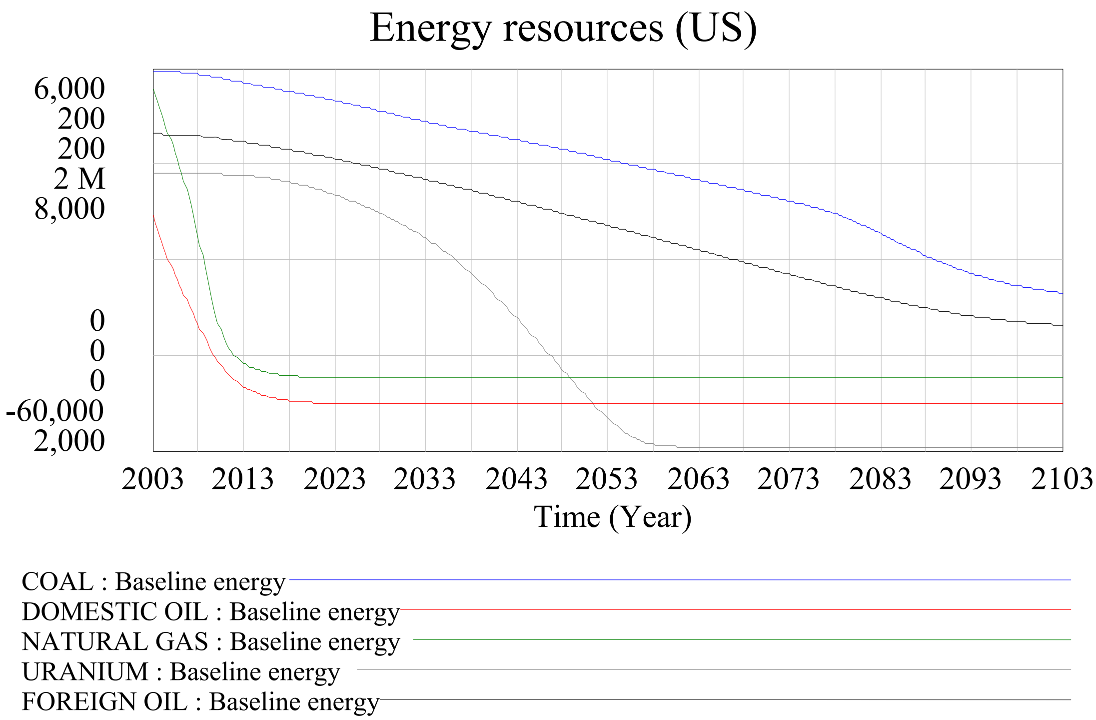

Figure 12. Depletion of non-renewable energy resources assuming two times proved reserves

Figure 12 exhibits how the model depicts the depletion of non-renewable energy sources. Figures 12 uses the same initial values as Figure 11. Domestic oil and gas fall off rapidly, while domestic uranium lasts for another forty years. Coal and foreign oil provide most of the required energy resources after the year 2030.

How we Modified Sasser's Model

We reformulated Sasser's model in VENSIM. Since much more is known about reserves remaining for nonrenewable energy sources than was known 33 years ago when Sasser's model emerged, we have updated all of these initial values in the above scenarios. The following table summarizes the old and the new initial values used for each of the non-renewable energy sources. The 2003 initial values are estimates based on known proved reserves and do not include otherwise unknown and unproved reserves. The 2*2003 initial values assume that both proved and unproved reserves are available for use and that unproved reserves are equal to proved reserves, thereby doubling the amount of initial reserves available in 2003.

	1950	2003	2*2003	
Initial Coal	3.98E+12	2.71E+11	5.41E+11	tons
Initial Natural Gas	1.45E+15	1.89E+14	3.78E+14	cubic feet
Initial Domestic Oil	4.30E+11	2.19E+10	4.38E+10	barrels
Initial Foreign Oil	2.00E+12	1.27E+12	2.29E+10	barrels
Initial Uranium	2.40E+06	5.24E+05	2.86E+06	tons

We have also added structure for the renewable portion of the model. A renewable energy sector was fabricated for every energy-consuming sector in the original model. Each renewable energy sector represents that fraction of the energy requirement that is serviced by renewable energy in the respective consumption sector. The basic structure of each sector is depicted in Figure 13.

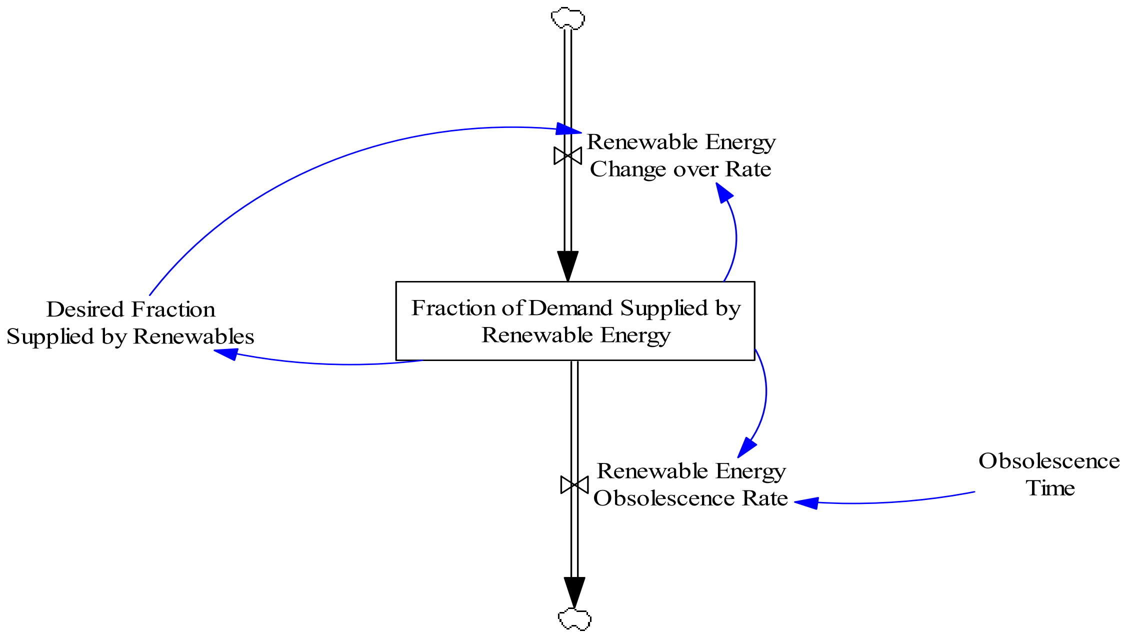

Figure 13. Generic Template used to Characterize the Contribution Renewable Energy makes to an Energy Consumption Sector.

The structure of the renewable energy subsystem is depicted in Figures 14 and 15. The stock variable in each renewable energy sector (IRCAP, RCRCAP, UTRCAP, OR TRRCAP) represents the capacity (expressed as a fraction between 0 and 1) of renewable energy needed to supply the energy requirements in the associated energy consumption sector—industry, residential/commercial, utilities, and transportation, respectively.

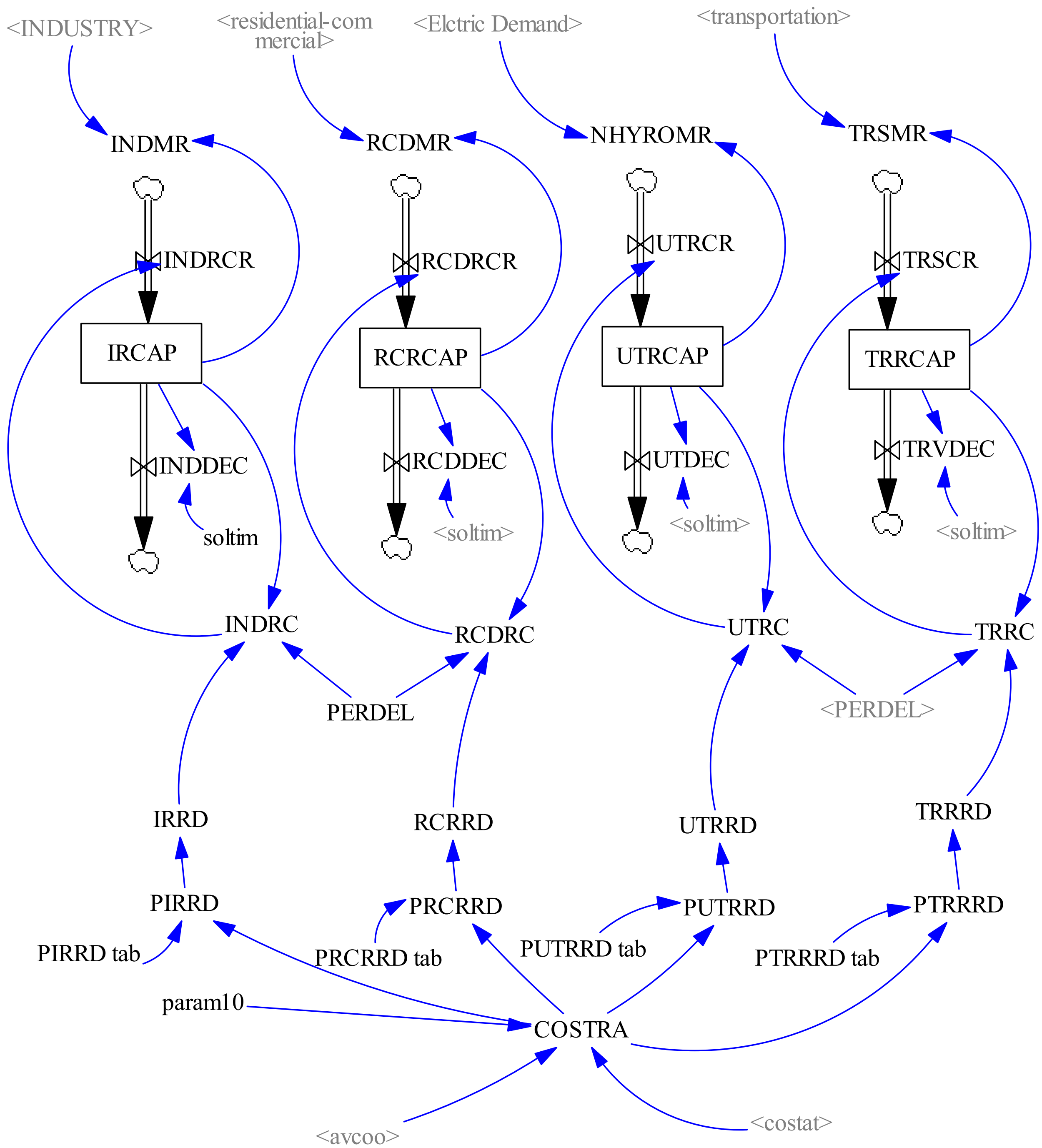

Figure 14. A portion of the Structure of the Renewable Energy Subsystem

In Figure 14 above, COSTRA represents the cost ratio of the after-tax cost of renewable energy taken in relation to the average weighted cost of nonrenewable fuels. From this variable a perceived fraction of renewable participation in meeting energy demands is computed as a table function of COSTRA, resulting in values for PIRRD, PRCRRD, PUTRRD, and PTRRRD. The variables IRRD, RCRRD, UTRRD, and TRRRD are clipped versions of their predecessors to prevent these variables from going negative. The stocks IRCAP, RCRCAP, UTRCAP, and TRRCAP are initialized to their known values (fractions between 0 and 1) in the year 2003. The auxiliary variables just below the flow structures that end with …RC measure the discrepancy between the desired level of participation and the actual fraction of energy supplied by renewable in each sector.

Next to be described are the four flow structures. The rates ending in DEC determine the obsolescence rate of the renewable infrastructure in each energy-consuming sector, while the rates ending in …CR are clipped versions of the auxiliaries ending in …RC. Actually, we use the MAX() function to prevent these rates from ever becoming negative. The rates ending in CR characterize the installation rate of renewable technology in a consumption sector. We do not expect construction rates to ever become negative. The variables ending in …CAP, which characterize the fraction of the energy requirement for each sector that is supplied by renewable sources, are stocks. At the top of Figure 14 are auxiliary variables that end in …MR. These are used to compute the actual units of industry (IND), transportation (TRV), residential/commercial (RCD) and non-hydroelectric power (NONHYD) that is not serviced or supplied by renewable energy sources. This information is then passed on to the Sasser model, where it is used to compute demands for the nonrenewable fuel sources—coal, oil, gas, and uranium.

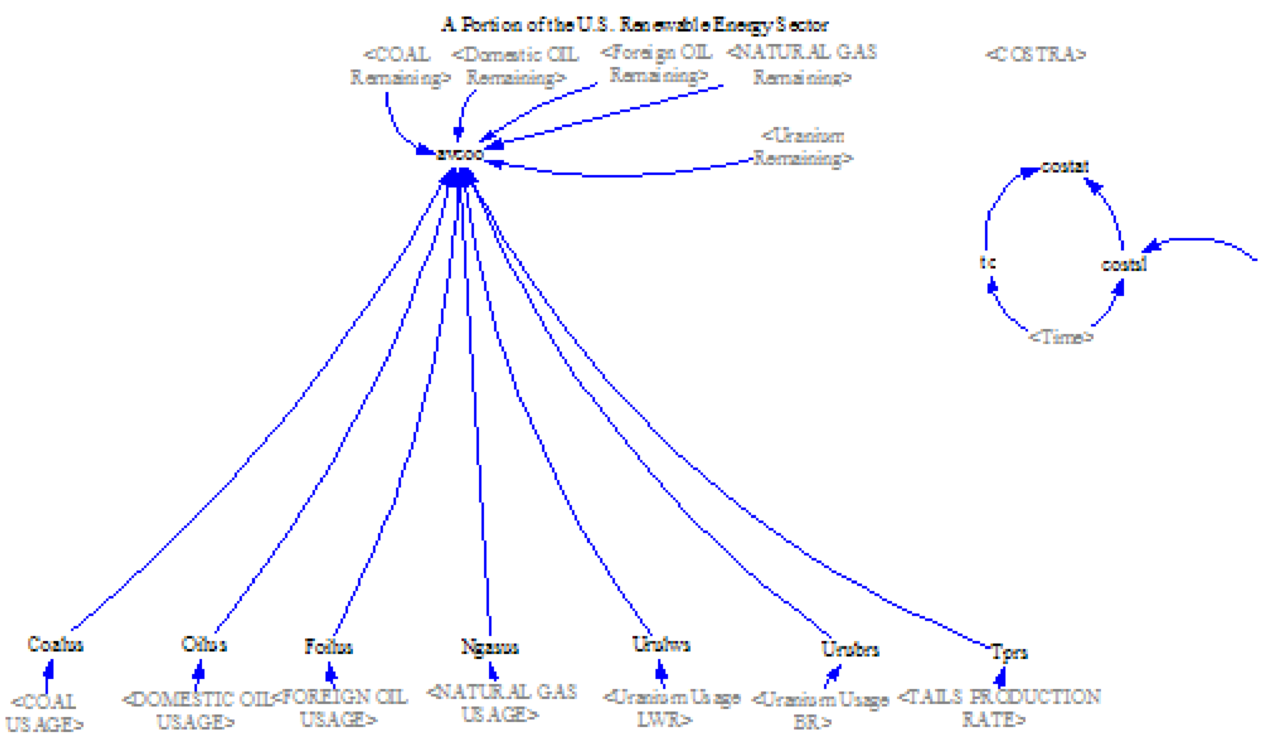

Figure 15. Structure used to determine the contributions of renewable energy taken in relation to the various forms of non-renewable energy to total energy supply.

In Figure 15, we delineate the structure we use to determine how much of the energy needs of each consumption sector can be displaced by renewable energy. This structure supports the structure used in Figure 14 by enabling a calculation of COSTRA that is the basis for calculations in Figure 14.

Results & Discussion

In the absence of renewable sources of energy, the model suggests we will see declines in all of the consumption sectors in the next 20-30 years. The model makes a strong case for renewable forms of energy being developed now.

The simulation results suggest that renewable energy sources will be able to reduce our dependence upon foreign sources of energy. However, if we assume a 20-year life for the renewable capital equipment, we find that, in the beginning we are subsidizing and providing tax credits to make the renewables cost competitive. In the end, new technology makes the renewables more efficient and cheaper, while non-renewables become more expensive because of their increased scarcity. But the use of renewables imposes a tremendous drain on such other resources as steel, other metals, glass, land, electric power grids and the energy required to produce these items. The model is not able to tell us whether renewables can completely replace non-renewables. (In the transportation sector, it seems unlikely that commercial aircraft will ever run on anything other than fossil fuels—hydrogen is not a viable alternative.) If they cannot, then, even with renewable energy, growth in the energy consuming sectors may abate and possibly decline because of the depletion of non-renewable energy resources. However, the use of renewables does postpone the possible abatement and decline of the energy consuming sectors. Thus continued growth in the energy consuming sectors can take place for a longer period of time than would otherwise be possible without renewables.

The model does not explicitly address the environmental issues associated with renewables vs. non-renewables. However, as indicated in the discussion, renewables will reduce the amount of carbon emissions necessary to provide energy sustenance to the consumption sectors.

Such issues as whether to pursue exotic forms of nuclear power in lieu of renewables, which of the renewables is most promising in terms of the economics have yet to be addressed by the model.

REFERENCES

Advantages of Compact Fluorescent Light Bulbs. Duke Energy official Web site. Retrieved May 28, 2008. Available from http://www.duke-energy.com/ohio/savings/advantages.asp

Allen, W. B., Doherty, N. A., Weigelt, K., & Mansfield, E. (2005). *Managerial economics: Theory, applications, and cases* (6th ed.). New York: W. W. Norton & Company, Inc.

Alliant Energy's PowerHouse official Website. Retrieved February 4, 2009, from http://www.alliantenergy.com

American Wind Energy Association (AWEA) official Web site. Annual U.S. wind power rankings track industry’s rapid growth. Retrieved March 10, 2009, from http://www.awea.org

American Wind Energy Association (AWEA) official Web site. Green power. Retrieved February 3, 2009, from http://www.awea.org

Basile, P. S. (1977). *Energy supply-demand integrations to the year 2000: global and national studies: third technical report of the Workshop on Alternative Energy Strategies (WAES).* Cambridge, Mass: MIT Press.

Belsie, L. (Eds.). (2002). *Soybeans and corn power their way into fuel options* (M. Hostetter). New York: H. W. Wilson Company. (Original work published 2001)

BP Statistical Review of World Energy 2007. Oil. Available from http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2007/STAGING/local_assets/downloads/pdf/oil_section_2007.pdf

BP-Statistical review data. BP p.l.c. official Web site. Retrieved March 15, 2009, from http://www.bp.com

Chazan, G. & King, N. (2008, May 14). IEA Forecast Suggests Oil Prices Are Easing Demand. *Wall Street Journal (Eastern Edition)*, p. C.24. Retrieved January 31, 2009, from ABI/INFORM Global database.

Clean Energy Ideas official Web site. Retrieved December, 29, 2008, from http://www.clean-energy-ideas.com

CNNMoney.com. (2008, June 16). *Oil makes sudden $5 surge to record: Crude prices hold steady as traders look ahead to Saudi oil meeting.* Retrieved November 26, 2008. Available from http://money.cnn.com/2008/06/16/markets/oil.ap/index.htm?section=money_topstories

Energy Information Administration, 2001 Residential Energy Consumption Survey.

Energy Information Administration, 2002 Manufacturing Energy Consumption Survey.

Energy Information Administration, 2003 Commercial Buildings Energy Consumption Survey.

Energy Information Administration, History of Energy in the United States: 1635-2000. Available from http://www.eia.doe.gov/emeu/aer/eh/frame.html

Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels (CNEAF). Retrieved March 4, 2009. Available from http://www.eia.doe.gov/cneaf/

Fletcher, S. (2008). OPEC's position strengthens. *Oil & Gas Journal, 106*(12), 68. Retrieved July 8, 2008, from ABI/INFORM Global database.

Friedlein, M. T., Changnon, D., Musselman, E., & Zielinski, J. (2005). Using dew points to estimate savings during a planned cooling shutdown. *Meteorological Applications*, *12*(4), 319-328.

Hakes, J. E. (1998). 25th Anniversary of the 1973 oil embargo. Washington, DC: U.S. Department of Energy, Energy Information Administration.

Hart, J. (2008). Green issue: Capital markets - renewables - renewable enthusiasm - instability in many of the regions supplying oil and gas, coupled with escalating costs in the fossil fuel market, has caused the financial markets to look towards the renewable energy sec. *The Banker, June*. Retrieved July 9, 2008, from ABI/INFORM Global database.

Hopkins, R. (2006). Energy descent pathways: Evaluating potential responses to peak oil. (Doctoral dissertation, University of Plymouth, 2006).

Hoyos, C. (2005, June 18). Producers reap benefits as oil prices exceed dollars 58 OPEC revenue. *Financial Times*, p. 10. Retrieved January 8, 2009, from ABI/INFORM Global database.

International Energy Agency, *International Energy Outlook* – 2002. Paris: IEA, 2002.

Kelly, R. A. (2007). *Energy supply and renewable resources.* New York: Facts On File, Inc.

Manned Mission to Mars office Web site. Retrieved June 26, 2008, from http://www.androidpubs.com

Meier, R., Roundtree, J., & Schaefer, M. (1998). Oil shock. A paper from Obele Oil Corporation. Sedona, AZ.

Metzroth, L. (2006). Can U.S. coal supply meet projected demand? *Power Engineering: The Resurgence in Coal,* 12-16. Retrieved September 28, 2008, from ABI/INFORM Global database.

Pacific Gas and Electric Company (PG&E) official Web site. Retrieved July 4, 2008. Available from http://www.pge.com/microsite/safety_esw_ngsw/ngsw/basics/whatis.html

Paula, D. (2007). Study projects influence of national oil companies. *Oil & Gas Journal, 105*(10), 28-31. Retrieved July 8, 2008, from ABI/INFORM Global database.

Ridgeway, J., & Conner, B. (1975). *New energy: understanding the crisis and a guide to an alternative energy system*. Boston: Beacon Press.

Rotman D. (2008). The price of biofuels. Technology Review, January/February 2008.

Rowley, W., & Westwood, J. (2001, October). Hype aside, renewable energy emerging as viable long-term energy industry business opportunity. *Oil & Gas Journal, 99*(43), 20-26. Retrieved September 22, 2008, from ABI/INFORM Global database.

Sasser, D. W. (1976). A system dynamics model of national energy usage. Albuquerque, NM: A report from Sandia Laboratories.

Schurr, S. H. (1979). *Energy in America's future: the choices before us: a study*. Baltimore: Published for Resources for the Future by Johns Hopkins University Press.

Senge, P. M. (1990). *The fifth discipline: The art of practice of the learning organization* [hardcopy] (1st ed.). New York, NY: Bantam Doubleday Dell Publishing Group, Inc.

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World.* New York: McGraw – Hill Higher Education.

The National Biodiesel Board official Web Site.. Retrieved from July 5, 2008. Available from http://www.biodiesel.org/resources/biodiesel_basics/

U.S. Department of Energy, Energy Efficiency and Renewable Energy official Web site. Retrieved July 6, 2008, from http://www1.eere.energy.gov/windandhydro

U.S. Department of Energy, Energy Information Administration official website. Retrieved November 25, 2008, from http://www.eia.doe.gov

U.S. Department of Energy, *Transportation Energy Data Book*: Edition 24-2004

U.S. Department of Transportation, Research and Innovative Technology Administration official Web site. Bureau of Transportation Statistics. Retrieved October 15, 2008, from http://www.rita.dot.gov

UD-led team sets solar cell record, joins DuPont on $100 million project. (2007, July 23). *UDaily, University of Delaware*. Retrieved September, 23, 2008, from http://www.udel.edu/PR/UDaily/2008/jul/solar072307.html

United Nations Population Division, 2000. Department of Economic and Social Affairs Population Division. Retrieved September 20, 2008, from http://www.un.org

Urbanchuk, J. M. (2001). Ethanol's Role in Mitigating the Adverse Impact of Rising Energy Costs on U.S. Economic Growth. AUS Consultants. Moorestown, NJ. Available from http://www.ethanolrfa.org/objects/documents/123/mitigatingcosts.pdf

Vidal J. (2006, February 7). Sweden plans to be world's first oil-free economy. The Guardian. Retrieved November 16, 2008, from http://www.guardian.co.uk

Wind power fact sheet. (2006, September 15). Kansas Chapter, Sierra Club. Available from http://kansas.sierraclub.org/Wind/WindPower-FactSheet.htm

Windows to the universe store official Web site, Retrieved August 28, 2008, from http://www.windows.ucar.edu

Yergin, D. (2006). Ensuring energy security. *Foreign Affairs, 85*(2), 69-82. Retrieved June 6, 2008, from EBSCO database.

Yilmaz, A. O., & Uslu, T. (2007). The role of coal in energy production-Consumption and sustainable development of Turkey. *Energy Policy, 35*(2), 1117. Retrieved July 8, 2008, from ABI/INFORM Global database.

Zweibel, K., Mason, J., & Fthenakis, V. (2008, January). A solar grand plan. *Scientific American*, 298(1), 64-73.