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A Critical Assessment of Sustainable Energy Choices for the United States

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INTRODUCTION

Energy production and use constitutes a vast and complex system affecting almost all activities undertaken by human beings. Adopting ways and means of producing and using energy that are economically, socially and environmentally sustainable is a key issue facing our world nowadays. Fossil fuels that have powered our economies for many decades are being depleted sharply meanwhile world population is increasing and other countries are being developed, increasing the global energy demand and putting more stress on the environment.

Franz Schurmann stated that “If a dollar free-fall should take place, Americans will confront an energy crisis that will make the October 1973 oil shortage seem a mild nuisance.” Among others he have examined the economic effects of an energy crisis and linked an energy crisis with a deflating American dollar. William Catton emphasizing on the direct link between population size and energy supply, concluding that:

“ The faster the present generation draws down the fossil energy legacy upon which persistently exuberant lifestyles now depend, the less opportunity posterity will have to live in anything like the same way or the same numbers. Yet most contemporary political proposals for solving problems of economic stagnation or inequity amount to plans for speeding up the rate of drawdown of non-renewable resources.”

There is an urgent need to find alternatives and design an energy system that makes our environment sustainable, while providing the same level of development and reducing dependence on fossil fuels, which are mostly imported.

CHAPTER1: BACKGROUND

1.1 Generating a population trend

In order to generate a prediction for a future population a population growth trend would need to be generated from previous data. Since this study is only interested in the eastern United States individual data for each state in this grouping would need to be sorted out and then combined to form the overall eastern United States population. The Energy Information Administration under the Department of Energy released data of each state's population from 1790 predicted all the way up until 2030 [1]. From this data a trend can be extrapolated and thus a further expanded prediction can be made.

The data from EIA release was plotted and upon inspection a trend was observed. A least square regression showed that the data followed a 2nd order polynomial growth trend to a R2 value of 0.999. An exponential growth was expected, however the data has shown otherwise. This plot and the corresponding trendline are shown in Figure 1. Looking at the graph it becomes apparent that the equation developed from this trend will be able to relatively accurately predict each year's population for both the past and the future.

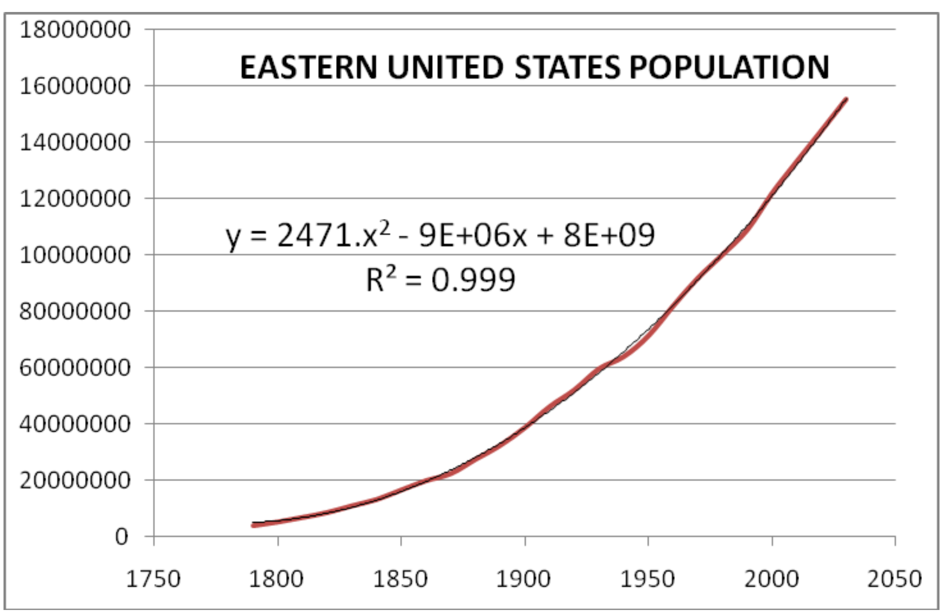


Figure 1: Eastern United States Population Growth and Trendline obtained from data from EIA release [1]

1.2 Energy Growth

Similarly to the population, energy usage or demand has also steadily increased from year to year. Energy growth is a very important parameter to observe and expand. Without predicting what the energy usage will look like in the years to come is will be near impossible to establish a scenario for energy sustainability of the eastern United States or any other location.

1.3 Generating an energy Trend

In order to generate a prediction for a future energy demand an energy demand trend would need to be generated from previous data. Since this study is only interested in the eastern United States individual data for each state in this grouping would need to be sorted out and then combined to form the overall eastern United States energy demand. The Energy Information Administration under the Department of Energy released data of each state’s energy demand from 1960 up until 2004 [2].From this data a trend can be extrapolated and thus a further expanded prediction can be made. The data from EIA release was plotted and upon inspection a trend was observed. A least square regression showed that the data followed an exponential growth trend to a R^2 value of 0.950. An exponential growth was expected and the data has backed up this assumption. This plot and the corresponding trend line are shown in Figure 2. Looking at the graph it becomes apparent that the equation developed from this trend will be able to relatively accurately predict each year’s energy demand for both the past and the future.

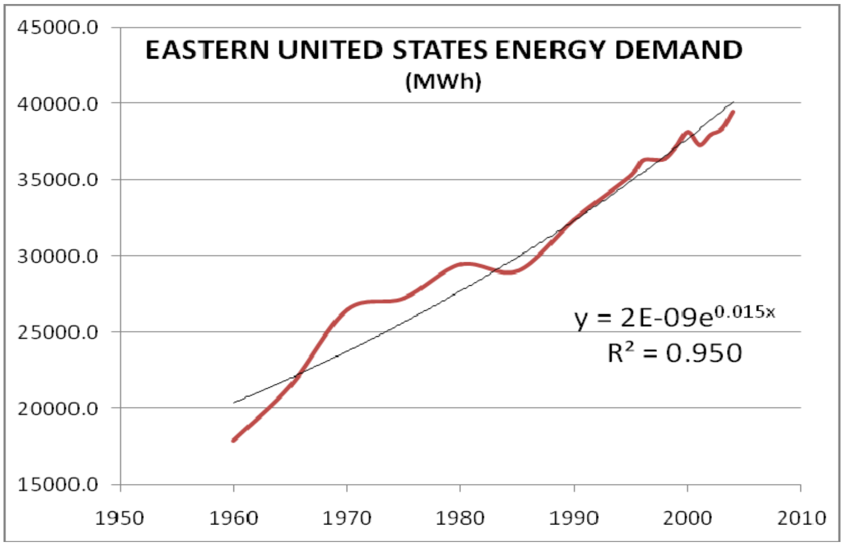


Figure 2 : **Eastern United States Energy Demand and Trendline developed from State Energy Data 2004 [2]**

1.4 Energy Demand Predictions

From Figure 2 an equation has been developed to estimate the future energy demand for the eastern United States. Using the exponential growth equation for the energy demand a prediction of 17553634293 megawatt hours in 2030 and 23885247541 megawatt hours in 2050 is obtained. These numbers give a good estimation of what the energy demand will be for these two periods and will be used to determine the how this region will improve towards a sustainable future.

1.5 Overview of the East Energy Potential

1.5.1 Nuclear

Nuclear power is a process in which enriched uranium or plutonium is utilized to transfer heat to water to generate steam and drive a turbine to generate electricity. By bombarding the uranium or plutonium nuclei with neutrons the nuclei split into two or more similar sized particles and give off energy. This reaction tends to lead to further fission and so on [3].

a. Current Usage of Nuclear Power

In the year 2007 nuclear power plants accounted for 379,686,764 megawatt hours of energy for the eastern United States [4]. This energy is utilized for electricity generation for all three of the zoning sectors. As of 2005 there were 31 states in the

United States operating nuclear power plants. Of these states producing nuclear power 15 are in the eastern United States.

In the eastern United States there are currently 35 Nuclear Plants utilizing 59 reactors to produce nuclear energy. Out of these 15 states Pennsylvania contains the most nuclear plants with five plants which are currently operating nine reactors [5].

b. Expansion of Nuclear Power

Currently in the United States there are plans in place to potentially build 24 new reactors on 16 different sites. The eastern United States has plans for 17 reactors on 11 different sites. These expansion plans have the potential to all be online by roughly 2020. These 17 reactors will be able to produce up to 21 thousand megawatt hours of energy or about 95% of the proposed expansion capacity. Figure 3 shows the planned expansion of nuclear power in the eastern United States [6].

c. Advantages to Nuclear Expansion

- Low Emissions – Unlike fossil fuels nuclear energy does not emit SOx, NOx or any greenhouse gasses.
- Decreases dependence on oil – Nuclear plants can produce large amounts of power and offset a need for more oil plants.
- Sustainability – Has the ability to operate at current capacity for an extremely long period of time.
- Use Less Fuel than Fossil Fuels – There is a much larger content of energy in nuclear fuel than in common fossil fuels.

d. Disadvantages of Nuclear Expansion

- Nuclear Waste – There has been no surefire answer to how to store spent nuclear fuel.
- High Risk – Although there are high standards and precautions an unlikely problem or failure could be devastating.
- Terrorism – Nuclear power plants are prime targets for terrorism.
- Proliferation – People could potentially turn spent fuel into nuclear arms.
- Long Build Times – These facilities can take anywhere from 10 to 20 years to become up and running.

- High Initial Cost – The cost to build a nuclear power plant is much higher than their fossil fuel counterparts.

1.5.2 Petroleum

The United States proven oil reserves declined to a little less than 21 gigabarrels as of 2006 according to the Energy Information Administration, a 46% decline from the 39 gigabarrels it had in 1970 when the huge Alaska North Slope ('ANS') reserves were booked. With production of around 5 million barrels per day as of 2006, this represents about an 11 year supply of oil at current rates [9]. With consumption at 21 million barrels per day (7.7 gigabarrels per year) (2007), US reserves alone could satisfy US demand for only three years. No oil fields of similar size to the ANS reserves have been found in the US since 1970. With over 2.3 million wells having been drilled in the US since 1949, there are very few unexplored areas left where another supergiant oil field is likely to be found. US oil reserve numbers are very accurate compared to those of most other countries [10].

In the United States crude oil production peaked in late 1970 at over 4 gigabarrels per year, but declined to 1.8 gigabarrels per year as of 2006. At the same time, US consumption of petroleum products increased to over 7.3 gigabarrels per year. The difference (5.5 gigabarrels) was mostly made up by imports, with the largest supplier being Canada, which increased its exports of crude oil and refined products to the US to 0.8 gigabarrels per year as of 2005 [8]. Imports of oil and products now account for nearly half of the US trade deficit [11]**.** As of 2007, the Energy Information Agency (EIA) of the U.S. Department of Energy projected that in 2007 oil consumption would rise to 20.9 million barrels per day, while oil production would fall to 5.1 million barrels per day, meaning that oil consumption would be nearly four times as high as oil production.

1.5.3 Natural gas

Natural gas is the third most consumed energy in the US after petroleum and Coal (Annex Fig. 12 [12]). Unlike Petroleum and Coal, the consumption of Natural Gas is expected to stabilize in the future as depicted on the figure. Since 2006, natural gas consumption currently accounts second in electricity generation in the country after coal

(Annex Fig. 13 [12]), however its future contribution in electricity generation is projected to decrease. It can be seen in the graph of Fig. 13 (Annex) that the decrease of natural gas in electricity generation will be compensated by an increase of renewable and nuclear sources in electricity generation. The natural gas price projection seems to be pretty stable (Annex Fig. 14 [12]). Natural gas is also the second most produced fuel in the US after coal; while its future production seems to look stable, coal production is expected to be growing steadily until 2030 (Annex Fig. 15 [12]). The share of natural gas in CO_2 emission is the lowest of all fossil fuels, making natural the cleanness of all the fossil fuels (Annex Fig. 16 [12]).

The US natural gas net import has been growing almost steadily since 1994 while the exportation increased between 1999 and 2004 started to drop (Annex Fig. 17 [13]). Trinidad and Tobago was the major supplier of Natural to the US in 2006, followed by Egypt and Nigeria (Annex Fig. 18 [13]). None of the states of the east coast is among the major natural gas producers in the US (Annex Fig. 19 [14]). This might explain the reason why the east coast constitutes the major point of entry for natural importation (Annex Fig.20 [14]). The natural gas distribution system is highly concentrated in the middle and the eastern part of the country (Annex Fig. 21 [14]), this is certainly due to the high concentration of cities and population in the east coast of the country. The total production of natural gas in the East in 2006 was estimated at 0.94 million MMcf; while consumption was estimated at about 6.5 million MMcf according to the data from the Energy Information Administration [14] and was distributed by end use as shown in Fig. 22 (Annex) where 36 % accounted for electricity generation, 24% for residential, 22 % for industrial, 18% for commercial activities. The share of vehicle fuels was insignificant.

1.5.4 Coal

From 1881 through 1951, coal was the leading energy source produced in the United States [15]. Coal was surpassed by crude oil and natural gas until 1982/1984, at which time coal regained its position as the top energy resource.

The most important coal deposits in the eastern United States are in the Appalachian Region, an area that encompasses more than 72,000 square miles and parts of nine states. Historically, this region has been the major source of U.S. coal, accounting for approximately 75% of the total annual production as recently as 1970. Today the region produces less than 50% of the United States' total, with 396 million short tons mined in 2002, with the reduction being due to increased coal production in the western United States.

Fuel switching to lower sulfur coals is chosen by many power generators to achieve emissions compliance. In the United States, the replacement of high-sulfur Eastern or Midwestern bituminous coals with lower sulfur Appalachian region bituminous coals or Powder River Basin coals is a control option that is widely exercised. This has resulted in a large increase in western coal production and use (Figure 4).

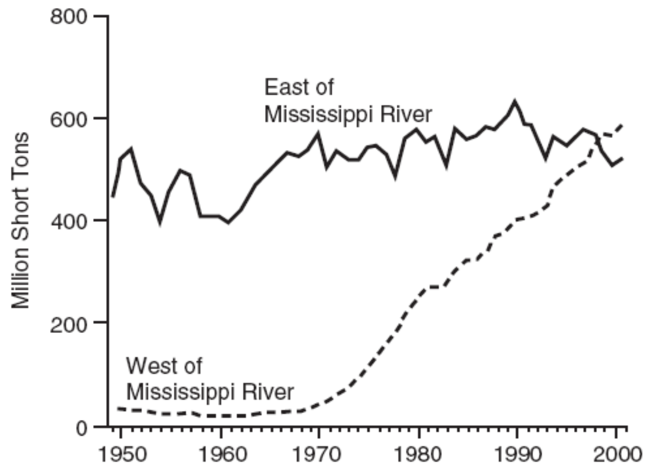


Figure 3 **Coal production by location in the United States [15]**

Nearly 92% of all coal consumed in 2002 was in the electric power sector, which includes both the electric utilities and independent power producers [15]. This coal is being used in order to produce 49% of the total electricity production of United States.

1.5.5 Biomass

Biomass refers all biological material used as fuel or for industrial production. Most commonly, biomass refers to plant matter grown for use as biofuel, but it also includes plant or animal matter used for production of fibres, chemicals or heat. Biomass may also include biodegradable wastes that can be burnt as fuel. It excludes organic material which has been transformed by geological processes into substances such as coal or petroleum [30].

Biomass is grown from several plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sugarcane and oil palm (palm oil). Production of biomass is a growing industry as interest in sustainable fuel sources is growing.

Included are the following feedstock categories: Agricultural Residue, Wood Residue, Municipal Discard, Dedicated energy crops

Although fossil fuels have their origin in ancient biomass, they are not considered biomass by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Their combustion therefore disturbs the carbon dioxide content in the atmosphere [32].

a. Bio-energy Resources and Consumption

Bio-energy is energy extracted from biomass, which means any plant derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials. Traditionally, conventional biomass is considered to come from three distinct sources: wood, waste, and alcohol fuels .Wood, the largest source of bioenergy, has been used to provide heat for thousands of years, and is derived both from direct use of harvested wood as a fuel and from wood waste streams. The largest source of energy from wood is pulping liquor or “black liquor,” a waste product from processes of the pulp, paper and paperboard industry. Waste energy is the second-largest source of biomass energy. The main contributors of waste energy are municipal solid waste (MSW), manufacturing waste, and landfill gas. Biomass alcohol fuel, or ethanol, is derived almost exclusively from corn and its principal use is to serve as an oxygenate in gasoline.

The USA figures significantly in biomass usage and the two figures below illustrate how its use has changed recently. Only alcohol fuels have grown significantly, having risen from about 100 trillion Btu in 1998 to over 150 trillion Btu in 2002.

1.5.6 Hydropower

Hydroelectric power has been widely used all over the world. In the beginnings of hydro utilization people would use a river or other flowing body of water to spin a water wheel that would then drive a mill that would produce flour. Typically a well flowing body of water is dammed off so that the water is forced to flow through a series of turbines which then turns the generator and produces electricity.

Hydropower has multiple styles to generate power. Early hydro power utilized water wheels. This progressed to damming off large rivers and waterfalls and utilizing a turbine driving a generator to make electricity. Tidal power uses the predictable flow of water in and out of a body of water while wave energy utilizes a similar idea to produce power from the waves. There are two main styles currently to turning tides and waves into electricity generation. Operating very similarly to wind turbines, water turbines are placed in the flow where when water flows in either direction the blades spin and generate electricity. Another technology is a piston style turbine. When the water flows into the apparatus it forces a volume of air up through a turbine which drives a generator to produce electricity. In the case of tidal power the rising tide would drive air out of the piston assembly, and then when the tide lowers it sucks air back into the piston.

a. Current Usage of Hydropower

Currently it is believed that the potential of hydroelectric power as we currently generate it is very close to if not completely tapped out. Sources like Niagara Falls account for 76,357,067 megawatt hours of energy produced in the eastern United States in 2005 [6].

b. Advantages to Hydropower

- Free Energy Source – Beyond initial build and slight maintenance it is utilizing a free energy source. Overall cost is very low compared to other sources.
- No emissions – No combustion so no emissions.
- Predictability – Unlike some other renewable energy sources you can generally predict the amount of water that will be flowing at a certain point and velocity.

c. Disadvantage to Hydropower

- Tapped out – For conventional methods most sources are tapped already.
- Land displacement – Generally have to dam up a flowing body of water which will flood the area behind the dam destroying the ecosystem.

d. Expansion Possibilities

Although most of the conventional method of harvesting hydropower, damming of rivers and waterfalls, is tapped out there is still potential to expand. Advanced in technology and thinking outside the box have led to the development of two new methods of harvesting power from water.

Wave power technology will allow people to locate turbines underwater off the shore that will be able to utilize the force of waves flowing through, in most cases, the oceans to generate electricity for use on land. Offshore generations allows for the installation of vast amounts of turbines in area where the environment can be disturbed the least. A major disadvantage of this power source is that unlike other forms of hydropower waves are not extremely predictable and there can be large amounts of time where the turbines can lay dormant even in areas of high wave activity.

The other source of hydropower is tidal power. Unlike waves the tide is extremely predictable. As previously mentioned there are two forms of technology to utilize the energy in the water. There are currently two projects that are taking place to test the possibility of utilizing this energy source.

In the Bay of Fundy, Canada experiments are being designed to see how much of the tidal energy can be used without majorly disturbing the environment. The bay is already well known for having the largest tide in the world. The government of Nova Scotia is currently testing multiple turbines. Their department of energy has estimated that about 100 billion tons of water flow in and out of the bay. This is estimated as larger than all the freshwater rivers in the world combined [33].

The East River in New York City has been undergoing tests to see if there was a possibility of harvesting the power from the tide of the river. The long term goal is 300 turbines that will be able to produce 10 megawatts of power. Initial test tides were close to 20% more powerful than expected and the turbine blades were torn off. Although a setback in testing the appearance in a stronger than expected flow is a good thing as more energy can be harvest from stronger water sources. If this works out Verdant Power will be looking into similar projects on the St. Lawrence River in Ontario [34].

1.5.7 Solar Power

Solar energy is converted into a useful form by the photovoltaic effect. The photovoltaic effect is when photons from sunlight are absorbed by a semiconducting material. Electrons are then knocked from their atoms producing electricity [9]. Photovoltaic cells can be linked together into an array to produce larger amounts of electricity.

a. Benefits of Solar Power

- Free Energy Source – Energy from the sun bombards the Earth everyday with no cost to us.
- Cut down dependence on fossil fuels
- No moving parts – This means they operate without generating any sound.
- Can be utilized for multiple purposes – Can be used to generate electricity or heat.

b. Disadvantages of Solar Power

- Emissions – Although they do not emit anything upon use the creation of the silicon for the cells is not emissions free.
- Land Displacement – To produce large amount of power there needs to be a large amount of cells together in an array.
- Low Efficiency – Current technology only allows from a small portion of the spectrum to be absorbed.

c. Current Usage of Solar Power

As of February 28, 2008 there are only two solar power plants operating in the United States. Currently neither of these facilities are located in the eastern United States. Photovoltaics however are being utilized on a much smaller scale throughout the United States. It is hard to quantize the micro installments and how much power they are producing.

d. Expansion Possibilities of Solar Power

There is a lot of potential for the expansion of solar power. The concept of large scale utilization of solar energy is currently a difficult on but smaller scale use is extremely feasible. Building integrating photovoltaics is a concept where solar absorption is built into the facility itself. There are already multiple projects where photovoltaics have been installed on roofs and sides of buildings to help offset the energy use of that location. Solar energy has also been used for water heating and the possibility of expanding this style of use is extremely large. While large scale production may not be feasible smaller scale, decentralized use has high potential.

1.5.8 East coast wind potential

The east coast of the United Stated doesn't have enough onshore wind resource compared to the pacific and central part of the country. It can be depicted on Fig. 23 [36] (Annex) that only few states (Pennsylvania, New York, Vermont, New Hampshire, Maine, and Massachusetts) have acceptable wind speed adequate for wind energy. The overall East Coast capacity is estimated at 28.2 GW among which only 0.88 GW as been installed, giving a very weak contribution in total energy generation (less than 0.5 %, Fig.24 in Annex). Only three states in the East Coast (New York, Pennsylvania and West Virginia) are among the twenty top states with highest installed capacities [36].

However, huge offshore potentials exist in the coast of the Atlantic Ocean. Evaluated at 330 GW, the offshore wind potential of the East Coast is estimated to be able to reduce all the anthropogenic Green House Gases (GHG) emission by 57 % and carbon dioxide (CO_2) by 68 % of ten states (CT, DC, DE, MA, MD, NC, NJ, NY, RI, VA) [37]. This is a great opportunity for the East Coast and needs to be given a closer look.

The wind potential estimation for the East Coast is based on studies by Kempton et al. and Dhanju et al. [1, 2]. Our estimation will be limited to areas of 50 m and less water depth, since current technologies are operable at that depth; and will be subdivided into two bathymetry intervals: 0-20 m and 20-50 m. This is due to the fact that the investment cost of offshore wind plant is highly dependent on the water depth.

Taking into account exclusion areas political, safety, economical and ecological reasons (shipment lanes, areas of oceanic ship passage outside of shipping lanes, chemical disposal sites, military restricted areas, zones of unexploded mined, borrow areas for beach renourishment, bird flyways, etc…) which gave an exclusion fraction of 0.46 for 0-20 m depth and 0.40 for 20-50 m depth, Kempton et al. [1, 2] found available areas of 24570 km^2 and 46440 km^2 for 0-20m and 20-50 m respectively . Considering the GE 3.6 s with rotor diameter of 104 m, a spacing of 10 rotor diameters (1040 m) downwind and 5 crosswind (520 m) yields an area of 0.54 km^2 per turbine. Therefore the potential number of turbines that could be installed is 45500 and 86000 for the 0-20 and 20-50 m depths respectively; or a total number of turbines of 131500.

The area of the blade A = 8494.9 m^2, assuming an average with speed for the entire coast of 8.2 m/s [2] and using the wind power equation

$$p = \eta * \frac{1}{2} * \rho * A * V^3$$

where η is the efficiency, ρ the density of air (kg/m^3) and V the wind velocity (m/s), we obtain, assuming an overall efficiency of 35% , p = 1041.3 kW per turbine.

The wind power potential is therefore

P = 131500 * p

P = 137 GW

A year has 24 h/day * 365 days or 8760 hours, multiplying this with the power gives

E = 8760 * P

E ≈ 1200 TWh/yr which is the East Coast wind potential.

The levelized production cost (LPC) method gives the cost of energy using the following formula:

$$LPC = \frac{I}{a * E_0} + \frac{OM}{E_0}$$

Where I is the total investment,

a the annuity factor $a = \frac{1-\left(\frac{1}{1+d}\right)^{l}}{d}$

where d = discount rate (assumed 0.05 in this calculation)

l = lifetime (assumed 20 years)

OM is the operation and maintenance cost

The investment cost estimation is presented in table 1 [3].

Table 1: Data for investment cost estimation [3].

	$/kW
Turbine and Tower + transportation and erection	1301
Transformer station and main cable to coast	430
Internal grid between turbines	135
Foundation Cost	558
Design, Project Management	160
Environmental analysis	78
Miscellaneaous	16
Investment cost I	2678

The levelized production cost is presented in table 2.

Table 2: Levelized Production Cost

Lifetime (Years)	20
Discount rate d	0.05
annuity factor a	12.5
Operation and maintenance ($/kW)	50.0
Yearly operation (hours)	8760
Capacity factor Cf	0.4
Energy produced E_a (kWh)	3504
Levelized Production Cost LPC ($/kWh)	0.0756

We will consider installing 2 GW power every year, then

$E_a = 2*8760*0.4 = 7008 * 10^6$ kWh/year then the annual cost needed to achieve this goal would be:

$C = E_a * LPC \approx \$530$ Million/year

The annual monetary benefit is estimated as:

$B_a = \frac{E_a}{\eta} * p - OM$

Where p is the selling price of electricity and η the efficiency; in this analysis, the efficiency is considered to be close to 100% since the offshore production site to grid feeding, the distance should not be considerable.

If we assumed that electricity will be sold at 20% more the cost of production, then p = \$0.09072.

$OM = \$50/kW * 2*10^6\ kW = \$10^8$

Therefore B_a = \$535.8 Million / year

The simple payback period is estimated as:

SPP = Investment / $B_a \approx$ 10 years.

This basic analysis gives a very optimistic future for offshore wind energy development. You should notice that environment benefits and tax incentives, if added to this analysis , could make offshore wind energy in the East Coast very successful.

The production cost obtained (\$0.0756 / kWh) is high but could still be competitive on the current electricity market (the average retail price of electricity in the East Coast in 2006 was about \$0.102/kWh) if externality cost of fossil fuels is taken into consideration. Our project

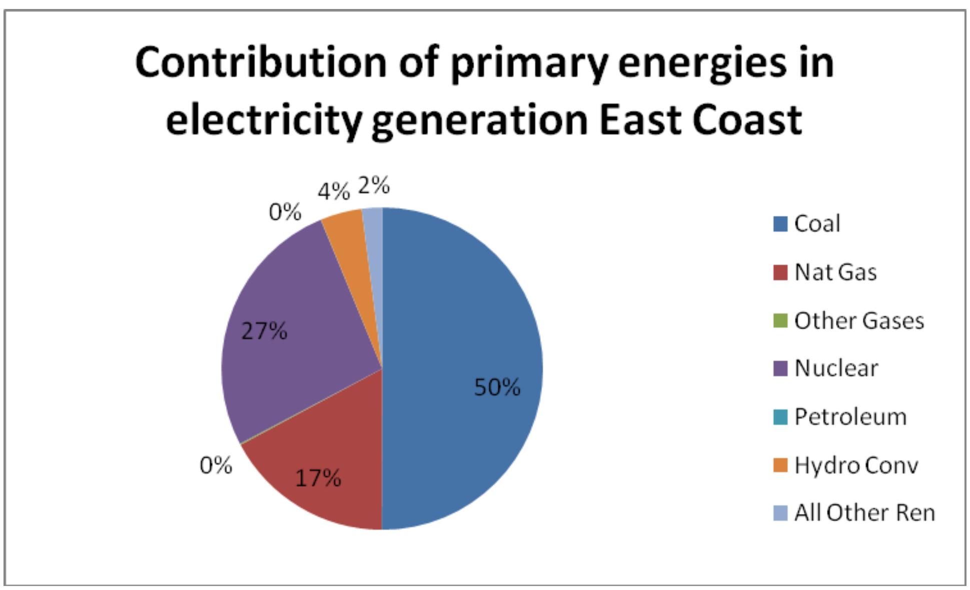


Figure 4: Primary energy contribution in electricity generation

can retail electricity to end users at or less than that price, therefore retailing electricity could recover our investment. So the cost of fossil fuel that would have been bought will be estimated here. The contribution of each primary energy source in electricity generation in the East Coast in 2006 was as presented in figure 1.

For coal (Bituminous) which is sold at an average of $60.9/ton, with a heating value of

8400 kWh / ton we obtain a fuel cost of $0.00725 /kWh

Natural gas is sold at $7.6/1000 cubic feet. A thousand cubic feet of natural gas contains 293.07 kWh so the fuel cost of natural gas is $0.0259/kWh.

Uranium is sold at about $41/kg or $41000/ton. One ton of uranium -235 contains about $7.4*10^{16}$ J or about $2.056*10^{10}$ kWh given a fuel cost of $\$1.9955*10^{-6}$/kWh

Assuming a conversion from primary energy to electricity of 33% (this is a very rough estimation since different technologies have different efficiency, for instance, coal to electricity is more efficient than natural gas to electricity) the total primary energy necessary to produce E_a, as well as the contribution of coal, Natural gas and nuclear to E_a are presented in table 3. These data are multiplied by the fuel cost estimated above to give our saving.

Table 3: equivalent primary energy consumption

	Fuel avoided (kWh)	Fuel Cost ($/kWh)	Savings ($)
Coal	10512000000	0.00725	76212000
Natural Gas	3574080000	0.02590	92568672
Nuclear	5676480000	2.00E-06	11327
Total			168791999

This simple analysis gives a saving of $168.8 Million/year on fuel for each 2 GW wind capacity installed.

Knowing the share of each source of primary fossil fuel in electricity generation in the region, we can estimate the amount of green house gases avoided by:

$$Q_i = \sum_j^n \text{Share of fuel j in electricity generation} * \text{Emission Factor of j} * \text{Ea}$$

Where i stands for the type of pollutants (CO_2, SO_2, and NO_x in this case); j the major fuel contributing in pollution during electricity generation (Coal and natural gas in this case). Nuclear energy doesn't emit these pollutants but it generates considerable amount of very toxic radioactive waste; however we will not take these into account and therefore concentrate only on fossil fuels.

The amount of CO_2, SO_2 and NOx avoided by using wind is presented in table 4, on an annual basis.

Table 4: CO_2 and pollutants avoided

	Emission Factors (kg/kWh of electricity generation) [4]			Emission (metric ton/year)		
	CO2	SO2	Nox	CO2	SO2	Nox
Coal	0.97	6.08E-03	3.45E-03	3398880.0	21304.3	12088.8
Natural Gas	0.48	3.16E-06	8.16E-04	571852.8	3.8	972.1
Total				3970732.8	21308.1	13060.9

If we give the pollutants a cost then the cost of pollutants is estimated (table 5)

Table 5: Cost of pollutants estimation

	Emission Avoided	Unit Cost of pollutants ($/ton) [5]	Cost ($)
SO2	21,308	906	19,305,125
NOx	13060.9	883	11,532,819
C	3,970,73	3.9	15,

O2	3		485,858
Total			46,323,801

1.6 Energy conservation

Energy conservation might be defined as any measure aimed at decreasing the energy consumption while trying to achieve the same service and satisfaction. It's not abstinence like some might conceive but rather an intelligent use of energy. It's believe to be a more efficient way of reducing energy consumption and green house gas (GHG) emission than even other alternative sources of energies. Teske et al. [48] believe appropriate energy conservation can cut the US CO_2 emission by up to 75 % (Fig. 28 [48]). The first step toward conservation is of course an efficient use of what is already available.

1.7 Energy efficiency measures

A typical US household spends about $ 1600 per year on utility bills [49], but a good fraction of the energy being paid for is just wasted. The situation is even exacerbated in old buildings; in fact it's believed that renovation can cut the energy consumption of old buildings as much as 80 % after implementing a better insulation and appropriate ventilation [48]. Moreover, studies have found that only 20% of houses built before 1980 are well insulated [49], this situation creates the needs of focusing on building efficiency when dealing with issue of energy and green house gas emission. A well insulated home creates a well distributed and uniform temperature, reduces outside noises and therefore creates comfort. The main areas of air leak in or out of building are, according to the office of Energy Efficiency and Renewable Energy: dropped ceiling, water and furnace flues, window frames, recessed light, all ducts, electrical outlets and switches, attic entrance, door frames, plumbing and utility access, sill plates, and chimney flashing. A distribution energy loss from these leaks is shown is Fig. 29 [49].

Space heating and cooling and selection of appropriate electrical appliances are also the major issues to focus on when trying to mitigate household energy consumption.

Space heating and cooling accounts for up to 45% of household utility bills and therefore needs to be given a greater consideration when improving home energy consumption.

An important point to mention is the behavioral change that needs to be made in order to minimize household energy consumption. The followings are simple tips that we neglects to follow but that contribute in the long run and at large scale into huge energy consumption [49]:

- Turning computers and monitors completely off when not in use
- Connecting electronics on power strips and turn the power strip off when the equipment is not in use; electronics on standby still consume some energy
- Air drying dishes instead of using the dishwasher drying cycle
- Taking short showers instead of full baths
- Washing only full load dishes and clothes
- Using efficient electrical appliances, usually those having an Energy Star label on them
- Setting the thermostat comfortably low in the winter and high in the summer
- Lowering the thermostat on water heater to 120 ºF
- Using of compact fluorescent light bulbs instead of incandescent bulbs

1.8 Structural changes and policy

Energy conservation on large scale needs some structural change on the way our energy system is set up. Decentralized electrification for example is known to be more efficient that large and long distribution power lines. Centralized energy infrastructures waste more than two third of their energy (Fig 30 [48]). Creating a more decentralized energy system makes it easy to feed electricity produced locally from available fuels (wastes for example) into the grid and to pump generated heat in district heating system to heat neighboring houses. This option opens a way to the concept of waste to energy; however wastes have a very low energy content compared to conventional fuels used to generate electricity like coal and natural gas, and fluctuate seasonally. Nevertheless, biomass/wastes are neutral in terms of green house gas emission, therefore co-processing with coal in power plant reduces the total emission. Some critics have said that converting waste into energy hampers recycling programs. If everyone sends their trash to a waste-to-energy plant, they say, there will be little incentive to recycle. A study of cities that have both recycling programs and waste-to-energy plants showed higher recycling rates than other cities in the U.S. The results showed that people living in cities with waste-to-energy plants are more educated about municipal solid waste and strongly support their recycling programs [50].

Transportation is also to be stretched on when dealing with energy conservation. Using efficient vehicles could save a lot of energy, hybrid cars and mass transportation systems (buses, trains and subways) are to be advocated. Share rides systems need to be appropriately implemented while aggressive driving should be avoided.

Proper load management through timing of demand for electricity can be implemented by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. Washing machines for example can operate at night and refrigerators turn off temporarily during periods of high demand, with voluntary participation of consumers.

Generation management can take advantage of renewable energies through load optimization. Wind farms, for example, can be temporarily switched off when too much power is available on the network [48]. Excess energy can be stored in batteries or used to pump water into dams for further use in hydropower stations.

Good energy policy (Tax credits for factories/ consumers, raising federal fuel economy standards for cars and light trucks in regular steps) and energy/environmental education are also important areas for successful energy conservation achievement.

CHAPTER2: PROBLEM STATEMENT

According to conventional beliefs, the world is unlikely to run out of energy in the near future. However, current patterns of energy production and use have destructive impacts on the environment and, in recent years, environmental issues such as possible climate change resulting from greenhouse gas emissions have thrown the spotlight onto the links between energy and the global environment. The implications of an energy crisis are large, because energy is the resource used to exploit all other resources. When energy markets fail, an energy shortage develops and the impact is major on all economical and social activities of a nation.

The present study examines current patterns of energy supply and demand to provide some design an energy scenario for the east coast of the United States of America. A forecast into the future is the first step in such endeavor. With an accurate model of population growth and energy growth one can establish a common trend for energy per capita. The combination of these variables will be the key to the designing the energy scenario for the east coast of the United States.

CHAPTER 3: ENERGY SUTAINABILITY SCENARIO

-Lighting

Given the lack of precise statistics on the share of fluorescent lamps in residential energy consumption, we made some assumption in order to get some rational data.

Table 1 gives the share of fluorescent lamps use on an hourly basis [1].

Hour used per day	Average time	Fluorescent as percentage of all lights
1 to 4 (t1)	2.5	11.7
4 to 12 (t2)	8	13.2
More than 12 (t3)	18	20.5

Assuming that a household has only incandescent and/or fluorescent light bulbs, and taking into account the fact that the power of a fluorescent light bulb is one quarter that of an incandescent light bulb, the daily energy consumption of all lights in a household can be estimated in terms of the total number of lights, the power of an incandescent bulb and the amount of time used.

If W is the average power of an incandescent bulb, n the total number of light bulbs then the daily lighting energy consumption in each of the time interval in the above table will be:

1 to 4: $n*W*t_1* (0.883 + 0.117/4)$

4 to 12: $n*W*t_2* (0.862 + 0.132/4)$

> 12: $n*W*t_3* (0.795 + 0.205/4)$

Therefore $E_{total} = n*W * (0.91*t_1 + 0.895*t_2 + 0.846*t_3)$

Substituting t_1, t_2, and t_3 by the respective average time gives

E_{total} = 24.673 * n*W

E_F = 1.26 * n* W

E_I = 23.41 * n * W

So the share of fluorescent in lighting consumption in a household is 1.26/24.67, that's about 5 % while the share of incandescent is about 95 %.

The residential energy consumption estimate for East Coast gives 15.09 million BTU per household; with a 9% share of lighting we obtain 398 kWh per household due to lighting. Since 5 % of that consumption is already from fluorescent lamps, the remaining 95 % (378 kWh) comes from incandescent lamps. If incandescent bulbs account only for 10% lighting in 2050 then it will account for 378 * 0.1 = 37.8 kWh. The remaining 378 – 37.8 = 340.2 kWh will be reduced by 75% when fluorescent covers the remaining lighting need therefore a reduction of 340.2 * 0.75 = 255.2 kWh per household. The number of households in the East Coast is 50.1 millions, the overall electricity consumption is then reduced by 12.8 TWh which is about 38.4 TWh of primary electricity.

Electricity in the East Coast is generated from about 50 % Coal, 27% natural gas and 17% nuclear, so about 19.2 TWh of this saving would be from coal and 10.4 TWh would be natural gas.

	Emission Factors (kg/kWh of electricity generation) [3]			Emission (metric ton end year value 2050)		
	CO2	SO2	NOx	CO2	SO2	NOx
Coal	0.9700	0.0061	0.0035	18624000.00	116736.00	66240.00
Natural Gas	0.4800	0.0000	0.0008	4976640.00	32.76	8460.29
Total				23600640.00	116768.76	74700.29

Solar Water Heating Analysis

The design is for an active (use a pump to move the thermal fluid in the through the system) indirect system (use a thermal fluid other than water to collect the solar energy and direct to a heat exchanger to heat the water, this is important since water could freeze during the winter season). The water need estimation assumes 75.8 liters per person for the first 2 persons and an additional 56.9 liters for every person thereafter [1].

Assuming a household size of four, this make a daily hot water need of 265.4 liters. We then consider a thank size of 300 l. (Vc = 0.300 m3/day). Plante [1] recommends a storage temperature of 49 degree C in case a dishwasher with pre-heater is used and 58 degree C otherwise. We will size our collector taking into consideration the second case (Tf = 58 C). The solar water heating system will be designed to provide hot water only during the warm periods of the year (from March to October) and the regular heating system (Electric, natural gas, residual fuel oil or other) will be used during the winter. This will reduce the required collector surface area. Since this is the major costing equipment in solar thermal heating, a significant reduction in the cost is therefore expected. Between March and October, the lowest average temperature is recorded in March (Ti = 13.33 C); the lowest insolation is also recorded during this month (I = 5.03 kWh/m2/day). These numbers are computed from the National Renewable Energy Laboratory data and presented in table A1 in appendix.

The daily energy requirement (Load) to heat the water from 13 C to 60 C is estimated as:

Load (kWh/day) = Vc * ρ * Cp*(Tf-Ti)

Where ρ is the density of water (kg m^{-3}) and Cp its specific heat (J kg^{-1} K^{-1})

Load = 15.59 kWh/day

The collector area is calculated by:

A = (Load/(η*I)) * (% Solar availability)

Where η is the collector efficiency (0.45) and we assume 100% solar availability for now.

Values of Load and A for the states of AL, FL, GA, MS, NC, SC, TN, VA are and the average are presented in the appendix in table A2.

Based on the estimated surface areas for each state, and after reviewing different solar heater on the internet, we selected the Helio Pak HPT2408GAC which has two collectors of (4' * 8') for a total area of 5.9 sq meters for Florida and Helio Pak HPT3408GAC which has a three collectors of (4'*8') for a total area of 8.9 sq meter for the rest of states; all including a storage tank. Since the system will cover 67% (March to October: 8/12 or 2/3) of the energy need for heating, the remaining 33% of the heating fuel will still be from the regular system (electricity, gas, fuel oil or other). Having assumed a uniform energy consumption throughout the year and having estimated that water heating accounts for 16 % energy consumption in residential buildings in the East Coast (Residential Energy Consumption Survey, 2001), then the estimated energy consumption due to water heating is: 0.16 * 15.09 million BTU/Household which gives 708 kWh/Household/Year. Therefore 0.33 * 4267 kWh = 233.5 kWh will not be covered by the solar system.

Assuming an efficiency of electric water heating of 95 % [2] we can estimate the electric energy that will be used during the cooler months (November-February), as well as the cost of this consumption considering an average electricity price for the East Coast of $0.102/kWh. We can also estimate the fuel and money saved; these data are presented table 1.

Table 6: Fuel saved by the solar system and fuel consumed by the backup system

	Electricity
Consumption (kWh)	233.5
Efficiency factor (%)	95.0
Total Consumption (kWh)	245.8
Fuel Cost ($/kWh)	0.102
Cost ($)	25.1
Fuel Saved (kWh)	4073.3
Money saved ($)	415.5

If we assume an efficiency of electricity production of 30 % the primary energy saved is 4073.3/0.3 = 13577.7 kWh/year. Electricity in the East Coast is generated from about 50 % Coal, 27% natural gas and 17% nuclear, so about 6788.8 kWh of this saving would have been coal and 3666 kWh would have been natural gas. Table gives the amount of CO_2, SO_2 and NO_x avoided per household.

	Emission Factors (kg/kWh of electricity generation) [3]			Emission (metric tonnes/year)		
	O2	SO2	Nox	CO2	SO 2	No x
Coal	.97	6.08E-03	3.45E-03	6585	41	23
Natural Gas	.48	3.16E-06	8.16E-04	1760	0	3
Total				8345	41	26

We assume that a household has an average of 4 people and divide the total population of these states by four to have an estimate of the number of households in these states which is approximately fifteen millions.

The rooftop availability for solar water heating in the South Atlantic and South East Central according to Denholm [4] is 60%, therefore it's expected that 60% of the fifteen million household could install a solar water heating system. Among those household about 46% use electricity for heating while the rest use other means of heating giving a total of 4.14 millions. Posing that by the end of 2050 all these households would adopt a solar water heating system, we would then avoid $3.45 * 10^{10}$metric ton of carbon dioxide, 170 million metric ton of SO_2, and 107 million metric ton of NO_x from being released into the atmosphere.

We also save $0.5*13555.6*4.14*10^6 = 2.8 *10^{10}$ kWh of coal and $1.5* 10^{10}$ kWh of natural gas.

Analysis the economics of solar water heating investment, the levelized production cost (LPC) method gives the cost of energy using the following formula:

$$LPC = \frac{\frac{I}{a}+OM}{f*Load*N}$$

Where I is the total investment,

a the annuity factor $a = \frac{1-\left(\frac{1}{1+d}\right)^{l}}{d}$

d = discount rate (assumed 0.05 in this calculation)

l = lifetime (assumed 30 years for solar water heating)

OM is the operation and maintenance cost

N is the total number of days during the year when hot water is needed (365 days in this case)

f is the fraction of hot water requirement covered by the solar system. Assuming that water requirement is even throughout the year and since the solar water heating system is being designed to run from March through October, that's 8 months, then f = 8/12 = 2/3.

Assuming a solar heating system with electric back-up,

Table A3 gives the average Investment and the average operation and maintenance cost for the selected states.

LPC = \$0.156/kWh which is a little high if we do not consider externalities and financial incentives in favor of solar water heating.

The annual monetary benefit is estimated as:

$$B_a = \left(\frac{f * Load * N}{\eta}\right) * p - OM$$

Where p is the unit price of electricity.

We obtain B_a = \$216.5

The simple payback period is estimated as:

SPP = Investment / B_a = 29.

This doesn't look like an interesting investment if environment benefits are not taken into account, therefore policies should come into play to set conditions that favor investment in such environmentally friendly technologies.

Transportation

Passenger Transportation

Passenger transportation involves a number of transport modes: private passenger vehicles, public urban transit, intercity modes such as bus, rail and air. According to National Transportation Statistics (2008)[5], Table 1-37: U.S. Passenger-Miles, in 2005, the base year in our analysis, 88.4 percent of the total passenger transportation activities had been in highway sector, consisting passenger cars, trucks and buses. 10.6 percent are in air sector and only the remaining 1 percent is in rail and water sectors. In our study we have assumed that these percentage shares remain constant in the modeled scenarios. The total passenger-miles in US is considered to be 5,523,308 million which yields to 18,666 passenger-miles per person. This US average is assumed to be also valid in the east coast states. An exponential increase of 1.23% is assumed for this value based on historical trend since 1990 (Figure 1).

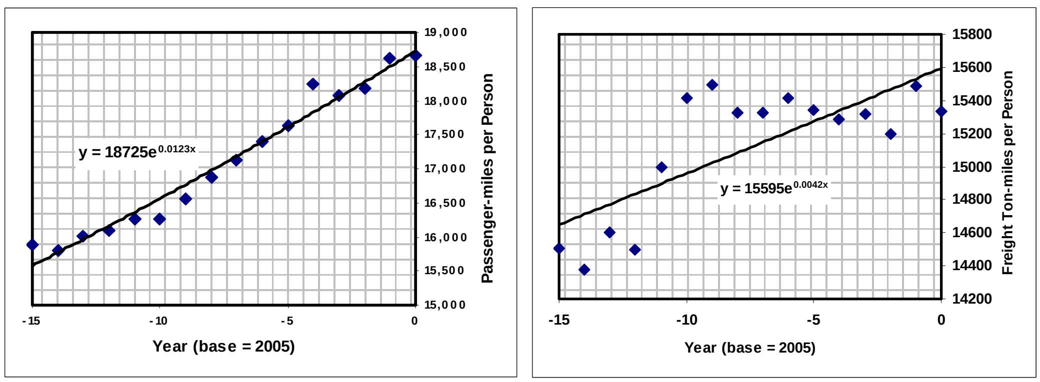


Figure 1. Passenger-mile and Freight Ton-miles per capita trend in US

Energy efficiencies can be in creased by improving the technology of all modes, shifting to more efficient modes and implementing measures that reduce demand for travel via the less-efficient modes, such as single-occupant automobiles.

Highway subsector

According to National Transportation Statistics (2008)[5], Table 1-37, 92.2 percent of the total activity of passenger transportation in highway subsector is by passenger cars and the rest is by buses.

Nationwide registrations for new hybrid vehicles rose to 199,148 in 2005 - a 139 percent increase from 2004 according to R. L. Polk & Co. and the total registered hybrid cars in US are 392,000 ones[6]. According to Table 1-11 in National Transportation Statistics (2008)[5], there are 247,421,120 registered vehicles in 2005. Thus the hybrids consist less than 0.2% of the total fleet. The growth rate of number of hybrid cars has been about 50% per year until 2008 [7]. In the business as usual scenario, it is supposed that the percentage share of hybrid cars will increase 50 percent every year until 2010, then it increases 20 percent per year until 2020 and then 5 percent per year until 2050.

The US historical trend of gallon per passenger-mile (Figure 2) is generated since 1993 based on National Transportation Statistics (2008)[5] Table 4-5, Fuel Consumption by Mode of Transportation, and Table 1-37, U.S. Passenger-Miles, together with passengers per vehicle trend (Figure 2) from Table 1-37 and Table 1-32, U.S. Vehicle-Miles. As seen in Figure 2, an exponential decrease of 0.66 percent is considered in Business as Usual scenario for energy consumption of both conventional and hybrid passenger cars. Hybrid cars are assumed to consume 60% gasoline of the conventional ones.

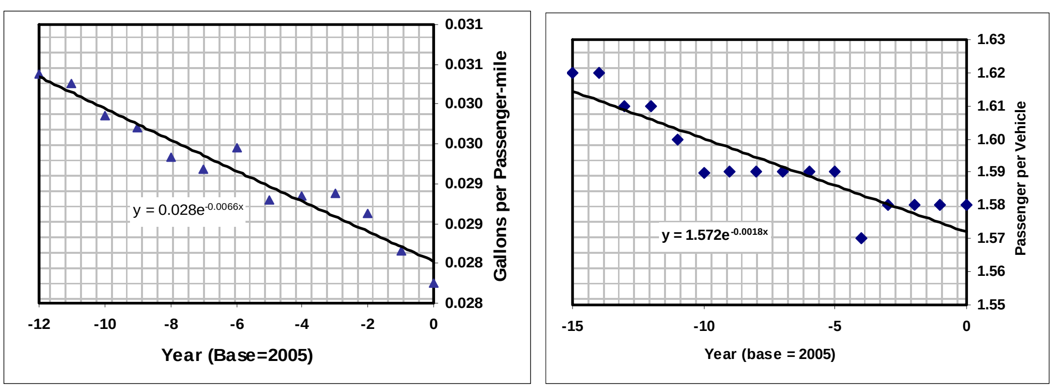


Figure 2. Gallons per Passenger-mile and Passenger per Vehicle trend in US

Passenger per vehicle and gallon per passenger-mile consumption trends for the bus subsector is also generated based on the above-mentioned sources. The results show a base value of 0.0067 gallons per passenger-mile and a exponential decrease of 0.54%. These values are implemented in the Business as Usual scenario.

- Air subsector

Using the data from National Transportation Statistics (2008)[5], Table 4-5: Fuel Consumption by Mode of Transportation and Table 1-37: U.S. Passenger-Miles, the trend of current gallons per passenger-mile for air subsector is generated. It shows a value of 0.0245 gallons per passenger-mile and a exponential decrease of 2.21%.

Freight Transportation

The standard of living in the United States is supported by moving more than 15 tons of freight per capita each year. Freight transportation involves a number of transport modes: trucks, rail, water, pipelines and air. According to National Transportation Statistics (2008)[5], Table 1-46b: U.S. Ton-Miles of Freight, in 2005, the base year in our analysis, the ton-mile percentages of each of these subsectors are as follows: Trucks 28.5%, Rail 38.2%, Water 13%, Pipelines 19.9% and Air 0.4%. In our study we have assumed that these percentage shares remain constant in the modeled scenarios. The total freight transportation in US is considered to be 4,537,921 million tone-miles which yields to 15,330 tone-miles per person. This US average is assumed to be also valid in the east coast states. An exponential increase of 0.42% is assumed for this value based on historical trend since 1990 (Figure 1).

For the reference scenario (business as usual), consumption intensities (in term of gallons per tone-mile) for each o f the mentioned subsectors, together with their growth rates, r, are calculated using Tables 4-5 and 1-46b of the above reference. The results are mentioned in Table 1, Figures 3 and 4.

Table 1. Consumption intensities for different carriers

	Trucks	**I**	**P**	**Wate**	****	**W**

Fuel Consumed	Diesel/ Biodiesel	ail Diesel	ipeline Gas	r Residual Oil	ater Diesel	ater gasoline
Consumption (Ton-mile /Gallon)	0.0289	0.0025	0.621 (per cf)	0.0141	0.0138	0.0132
Growth Rate	-1.35%	-2.17%	-2.17%	+1.98%	+1.98%	+1.98%

According to biofuel evaluation section, 1.11 million Gigajoules of bio diesel is produced in the east coast with a growth rate of 4% per year which is about 0.05% of the total energy consumption of the trucks freight transportation subsector.

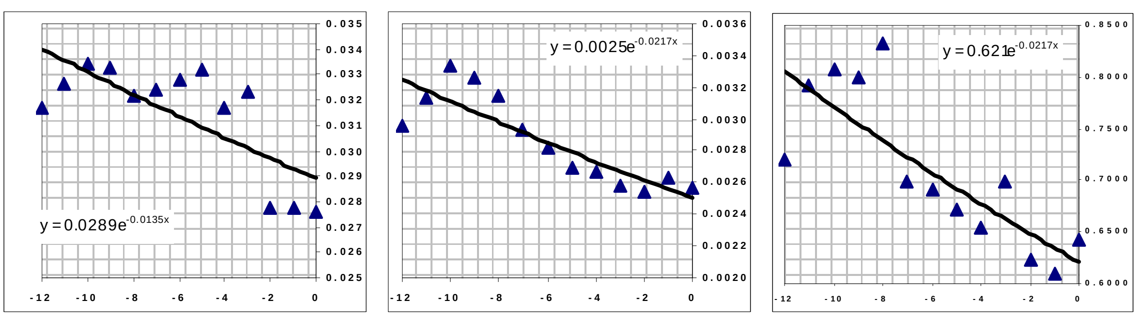


Figure 3. US Consumption intensities trend for Trucks, Rail and Pipeline careers

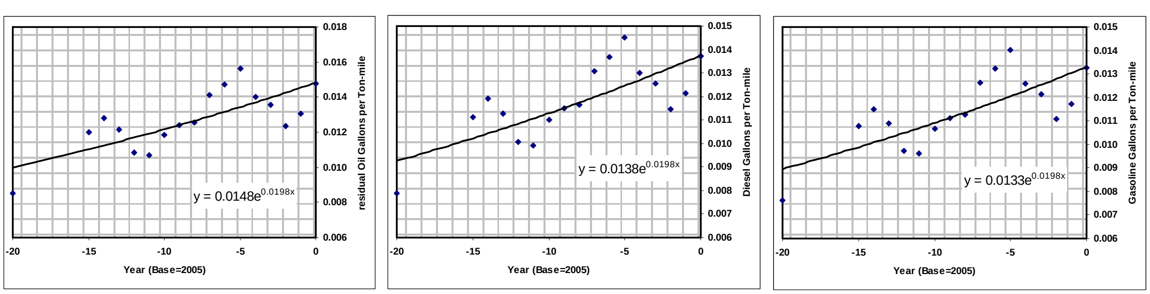


Figure 4. Fuel consumption intensities for waster transportation subsector

Environmental Loadings

As described in the IPCC (1996)[8], the calculation of CO_2 emissions from fuel combustion may be done at three different levels referred to as Tiers 1, 2 and 3. The Tier 1 methods estimate the emissions from the carbon content of fuels supplied to the country as a whole.

The IPCC methodology breaks the calculation of carbon dioxide emissions from fuel combustion into six steps:

Step 1: Estimate Apparent Fuel Consumption in Original Units

Step 2: Convert to a Common Energy Unit

Step 3: Multiply by Emission Factors (Table 2) to Compute the Carbon Content

Step 4: Compute Carbon Stored

Step 5: Correct for Carbon Unoxidised

Step 6: Convert Carbon Oxidised to CO_2 Emissions

Table 2. Emission factors used in environmental loading calculations

		ICCP Technology	CO2 (Ton/TJ)	CO (Kg/GJ)	Methane (Kg/GJ)	Volatiles (Kg/GJ)	NOx (Kg/GJ)	N2O (Kg/GJ)
Conventional Cars	Diesel	Moderate Controlled	74	0.167	0.002	0.049	0.156	0.003
Hybrid Cars	Diesel	Moderate Controlled	74	0.167	0.002	0.049	0.156	0.003
Conventional Buses		Urban Average Diesel	73	0.9	0.006	0.2	1	0.003

				7		0		0.		0.		0		0
	Jets	Jet Kerosene	1		.12		002		018		.29		.002	
				7				0.		0.		0		0
	Trucks	Diesel	4			1	005		2		.8		.006	
				7				0.		0.		1		0
	Rail	Oil	3			1	005		2		.2		.006	
	Water-Residual			7		0		0.		0.		2		0
Oil		Ocean ships-Residual Oil	7		.046		007		052		.1		.002	
				7		0		0.		0.		1		0
	Water-Diesel	Ocean ships-Diesel Oil	7		.18		007		052		.8		.002	
				7		0		0.		0.		1		0
	Water-Gasoline	Ocean ships-Diesel Oil	7		.18		007		052		.8		.002	

- Fuel Efficient Scenario

In order to design a more fuel efficient scenario, three different influencing factors are taken into consideration: use of hybrid passenger cars, biodiesel use in Trucks subsector of the freight transportation and renewing the water transportation fleet.

- Hybrid Passenger cars

In the Business as Usual scenario, an exponential growth rate of 50% per year was supposed for the percentage share of hybrid cars in total passenger cars activities till 2010 which decreased to 20% from then to 2020 and then 5% till 2050. In the fuel efficient scenario it is assumed that the percentage share of hybrid cars will grow to 35% until 2030 and then grow by 5% each year so that in 2050, 93% of the total passenger cars would be hybrid ones.

Biodiesel Trucks

The percentage share of biodiesel run trucks is supposed to grow 18% each year (compared to 4% increase in the business as usual case). As a result in 2050, 86% of the total truck freight transportation fleet will run on biodiesel.

Water Transportation

As discussed before, water transportation is the only freight or passenger transportation subsector in which fuel consumption intensity has had an increasing rate for the past 25 years (Figure 4).

As can be seen in Figure 4, the transportation vessels had been much more fuel efficient in 1985 than what they are in 2005. This fact indicates that the water transportation fleet is in need of a fundamental update. In our energy efficient scenario it is supposed that the consumption intensity rate will decrease to -0.5%.

Results

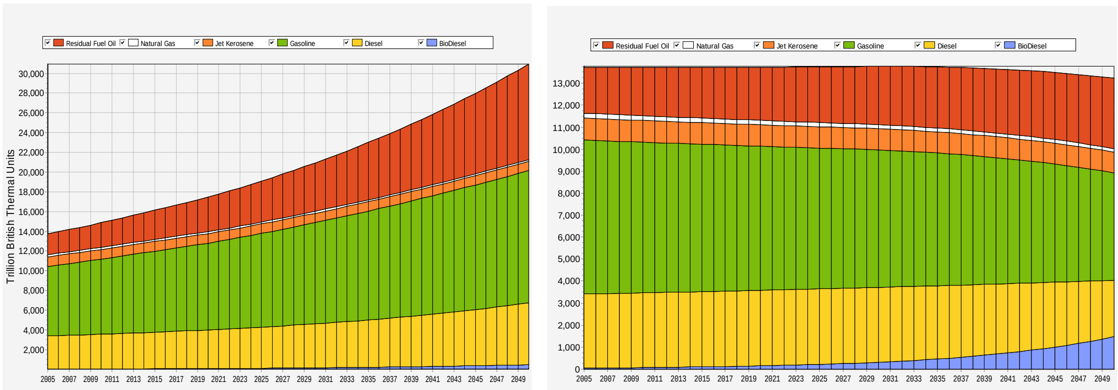


Figure 5. Total energy consumption of transportation sector for the business as usual and efficient scenarios

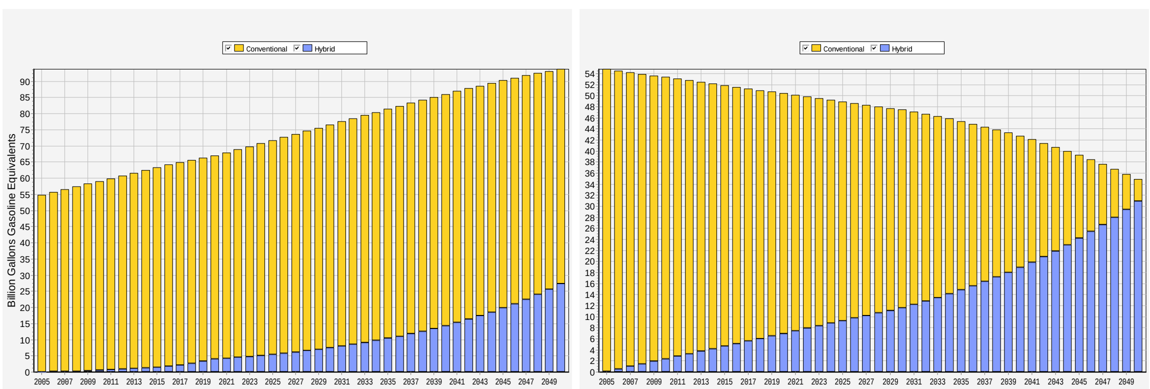


Figure 6. Energy consumption of passenger car subsector (conventional and hybrid) for the business as usual and efficient scenarios

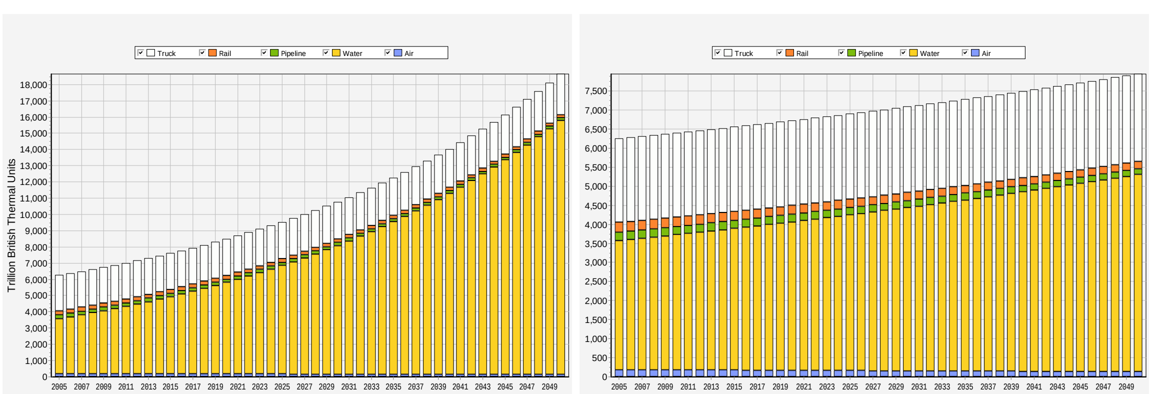


Figure 7. Energy consumption of the freight transportation subsector for the business as usual and efficient scenarios divided by the modes of transportation

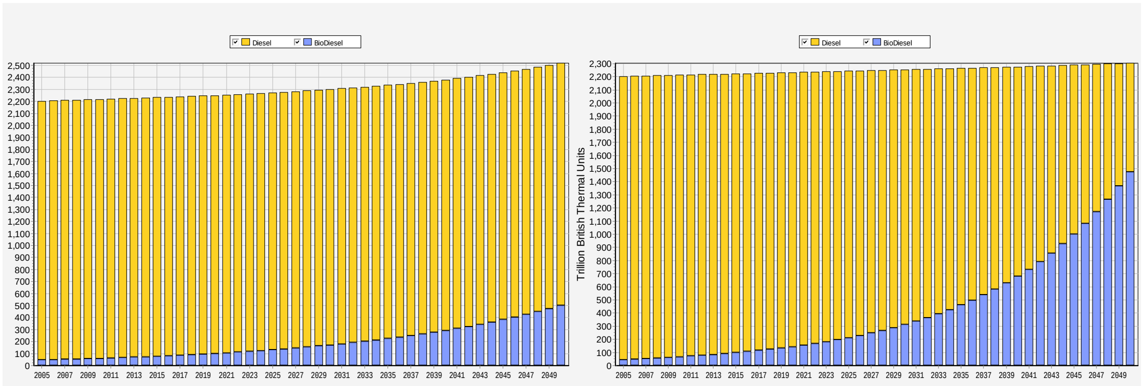


Figure 8. Energy consumption of Trucks freight transportation subsector for the business as usual and efficient scenarios

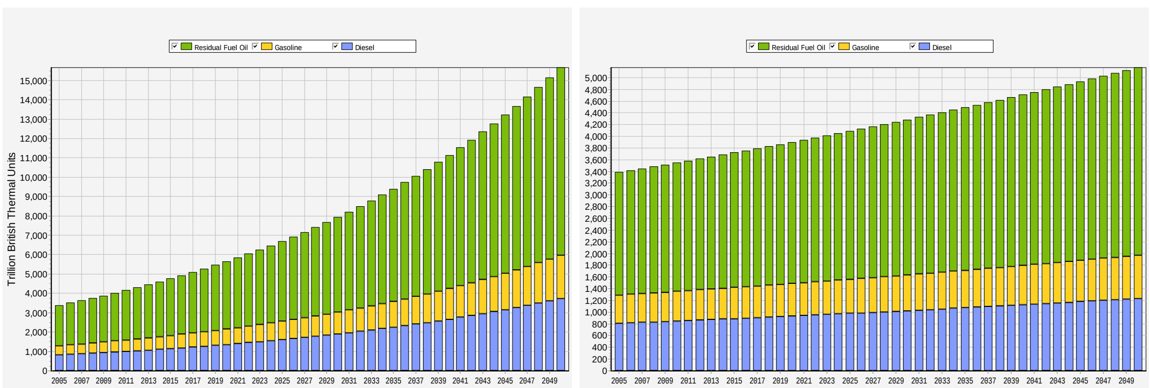


Figure 9. Energy consumption of waterborne transportation subsector for the business as usual and efficient scenarios for different fuels consumed

After evaluation of fuels consumed in different subsectors of the designed scenarios, emissions are calculated based on the values mentioned in Table 2 (Figure 10). Global warming potential (GWP) factors recommended by the IPCC [8] (Intergovernmental Panel on Climate Change, 2001) are used to assess the global warming potential of the designed transportation scenarios. GWP factors are specified for both a 100 year and a 500 year time horizon. For example, methane has a 100 year GWP of 23, but a 500 year GWP of only 7. Since GWPs are always expressed relative to carbon dioxide, the GWP of Carbon Dioxide is set to 1.0 for both the 100 year and 500 year time horizons. The 100 year GWP value of the reference scenario changes from 1006 Billion Kilograms in 2005 to 2222 Billion Kilograms while it will be 849 Billion Kilograms in 2050 for the efficient scenario.

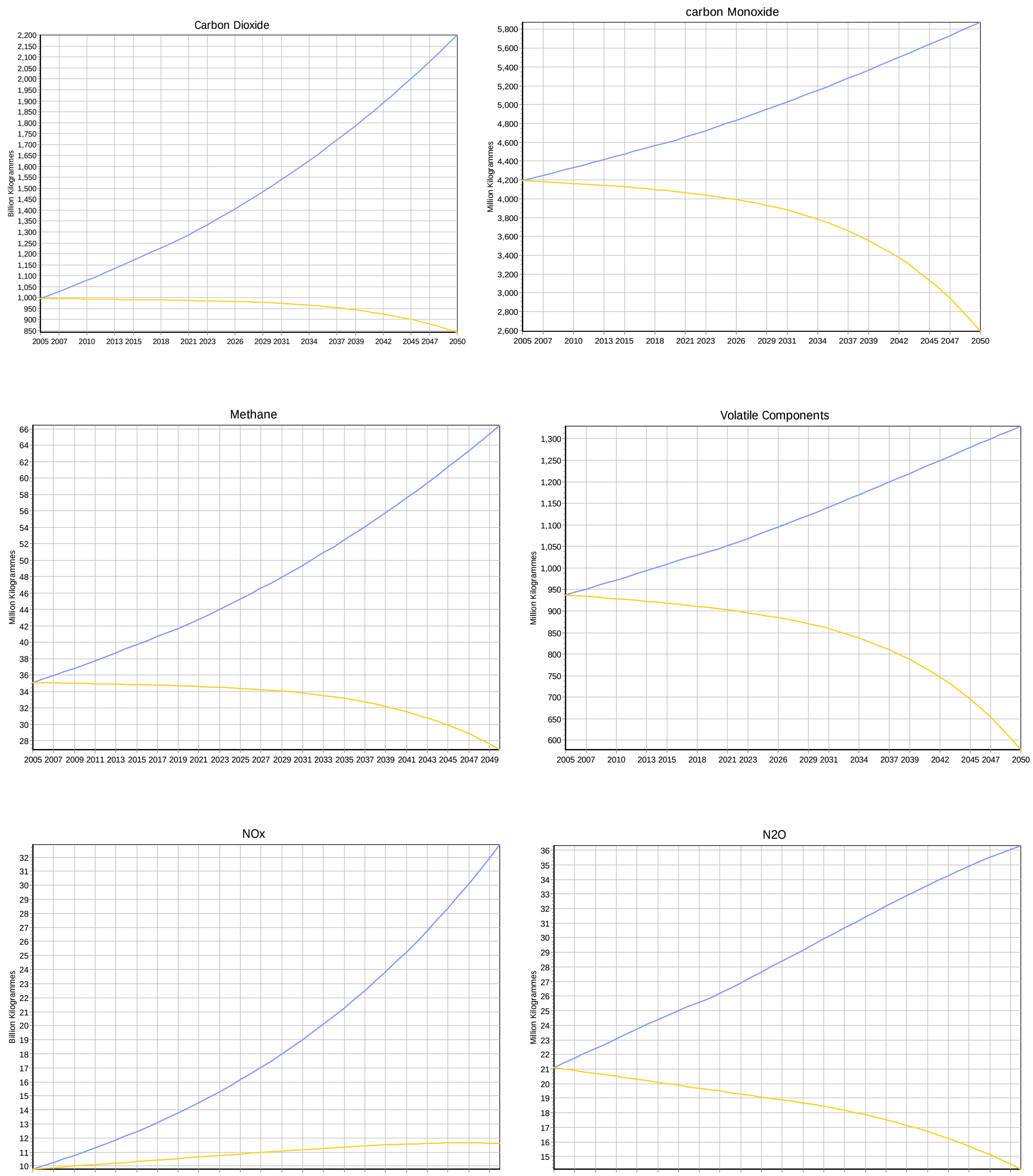


Figure 10. Different Pollutants' emissions trends for business as usual and efficient scenarios

Externalities Cost

Externality costs for each effect representing abatement, damage, or other cost estimation methods can be taken into account. These costs can then be included in cost-benefit calculations.

It is important to recognize that there is no single correct effect externality costs. Not only will the cost be site specific (i.e. the same level of pollutants will have different impact costs depending on where they are released), but also any cost will be dependent on how it is defined (e.g. as an abatement or damage cost). It is important to recognize that any values are subjective (e.g. the costs placed on an injury). Nevertheless, this evaluation allows to see the impacts on conventional benefit-cost analysis of judgments, which often are left implicit in energy planning exercises.

Triangle Economic Research[9] reports externality costs per ton of each pollutant based rural, metro fringe or urban sites (Table 3). Because of relatively high population density of east coast in general, the reported metro fringe values are used in this study.

State Public Utility Commissions have suggested very different externality costs for CO2 emissions which range from 24$/Ton for Massachusetts and Nevada to 1$/Ton for New York[10]. A value of 10$/Ton is used here.

Table 3. Damages per Ton of pollutant ($) [9]

	Rural	Metro Fringe	Urban
Particulate Matter	633	2,155	4,798
Nitrogen Oxides	15	54	130
Sulfur Dioxide	21	54	126
CO	0.29	0.99	1.57
Lead	401	1,719	3,302

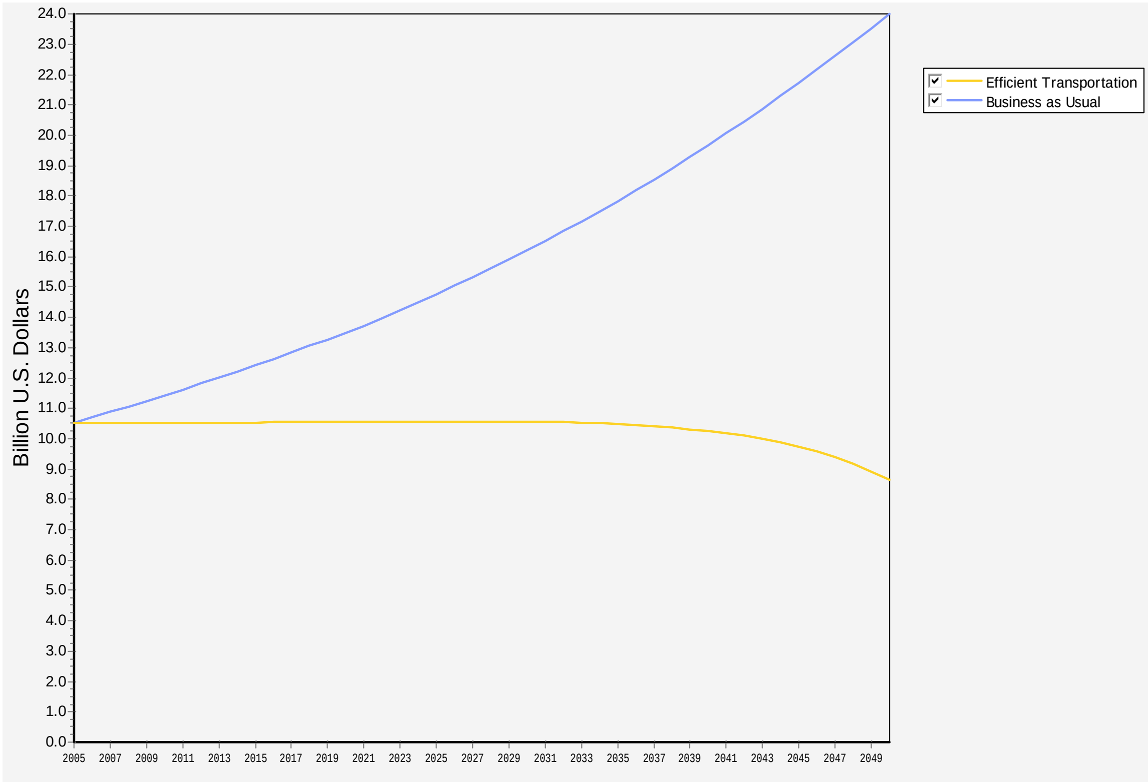


Figure 11. Externality costs for business as usual and efficient scenarios

Validation

Parameters

The parameters taken into account in this simulation to develop the energy demand are the individual sectors energy demand and their trends as seen from the past 45 years of data. The amount of energy that can be supplied by non-fossil fuels was developed from the non-fossil fuel usage over the last 45 years and the growth trends observed. To incorporate our scenario an expansion function was added to each of the fuel sources. Along with increasing the use of non-fossil fuels it is also necessary to incorporate some conservation methods which lowered the energy demand.

A change from incandescent light bulbs to fluorescent light bulbs was added to the residential demand and an increase in fuel efficiency of all vehicles was subtracted from the transportation demand.

The overall comparison from the proposed scenario and current trends will be done through the fossil fuel demand. This simulation calculated the overall energy demand by sector and then subtracts out the energy conserved by the conservation methods and the non-fossil fuel energy production and expansion. This resulting value gives you the amount of fossil fuel energy needed. The simulation also shows the growth of fossil fuels following the same trends that are observed in the data from 1960-2005. The fossil fuel usage for the “Business as Usual” scenario is then compared to the Fossil Fuel need from the presented scenario. The overall goal is to make the calculated fossil fuel demand less than the current trends demand.

Obtaining Data

In order to formulate the current situation and the trends accompanying the usage profile data was obtained for both end sector and fuel source from 1960 until 2005 (EIA DOE cite). Since the design was only for states in the eastern portion of the United States data was only obtained for the states being observed. The annual energy review provided data for individual state and the entirety of the United States by sector and fuel source. The data was then complied and energy demand by sector and fuel source for the eastern United States was obtained for every year. The compiled data was then plotted for each sector and fuel source separately and a trend as a function of the year the data came from was obtained. The trends observed from the plot extrapolated from the trendline were used in the simulations.

Simulink Design

From the EIA data a trend was generated for energy growth and demand, non-fossil resource supply, and fossil fuel supply. To create the energy demand predictions the demand of all four sectors (residential, commercial, industrial and transportation) were added together. Based on the trends generated from the data the functions developed would predict the future energy need assuming that the trends observed over the last 45 years continued. These needs are depicted in Simulink in black. A simple way to decrease the amount of fossil fuel usage is to reduce our overall usage. Conservation methods will do exactly this. These methods are linked directly to the individual sector demands before they are complied and are in blue. The other method to reduce the need for fossil fuels is to increase the amount of renewable and other non-fossil fuels energy produced. For each of these non-fossil fuels the potential for expansion on the east coast was observed. Once the potential for expansion was determined a trend was then generated so that the predicted change would occur around the year 2050. The non-fossil fuel supply and expansion is depicted in green in the Simulink design.

The Simulink simulation was designed to provide a good estimate of the energy future of the eastern United States. The simulation predicts the energy demand from each of the four sectors and the amount of energy that can be supplied by non-fossil fuel sources. The difference of these two figures will be the amount of fossil fuel energy that will be supplied. By modeling the fossil fuel demand over the last 45 years expanded out to 2050 we can directly compare the two and see how the changes implemented in the simulation reduce the need for fossil fuels. The model of the fossil fuel usage, business as usual, is depicted in red in the Simulink simulation.

Estimating Renewable Expansion

As previously stated the hydroelectric resources in the eastern United States are very close to tapped out. However, there can be expansion due to new technologies and the advent of tidal energy. Increased efficiency of existing turbines and other parts will help maintain the current trend of increasing hydroelectric power usage. Further expansion has been assumed to be due to tidal power being developed and installed. Upon literature review it was found that the potential of the North East has been estimated to be 120 TWh/yr (385.56 Trillion BTU's per year) (www.rnp.org/RenewTech/tech_wave.html#potential). This was brought into the model by assuming the growth of this new energy source would be at 1% of the overall production increase per year. This production was then added to the growth of hydroelectric power already stated and the sum became the overall hydroelectric product on a yearly basis.

Since the overall usage of wind power in the Eastern United States is relatively small it has been lumped into the category of "Other" renewable sources with the likes of geothermal and solar power. We assumed that our expansion on wind power would come from offshore wind farms. The maximum wind energy that can be farmed is 1200 TWh per year which is equivalent to 4094.57 Trillion BTU's per year. The potential expansion has been calculated out to be 3.5 GWh or .0119425 Trillion BTU's per year. This expansion would provide the east coast with

.537 Trillion BTU's in the year 2050. A growth rate of .0119425 Trillion BTU's per year was programmed into Simulink and then added into the "Other" renewable fuel source category.

Previous work has explained how biomass; in the form of corn oil, soybean oil and municipal waste, can be utilized to produce energy for the east coast. Taking the data obtained a trend was developed for both the maximum amount of energy that could be generated per year and the actual percentage of that that was utilized for energy generation. The data for the soybean showed a decrease in potential from 2003 to 2005. This created an issue with defining a growth function for this feedstock. To make the numbers work out in a manner such that the potential would increase as the years went on the values for 2004 and 2005 were averaged and then the year 2004.5 was used in the plot. This yielded an increasing function. This percentage was then plotted so that it would linearly increase to 40% for all of the biomass fuel sources. The extrapolated trend for the maximum potential was then programmed into Simulink and then multiplied by the function for the percentage used for each source. These numbers were then added together to form the expansion of biomass in the east coast.

Transportation Savings

In the year 2005 the average vehicle in the United States has a mpg rating of 22. Legislation has already been passed so that the average mpg rating must be up to 35mpg in the year 2020. Extrapolating this data at an assumed mpg growth of 2% a year will make the average mpg in 2050 to be 54mpg. To calculate the energy savings the following calculation was done:

$$\frac{12000\ miles/yr}{22.0\ mpg} - \frac{12000\ miles/yr}{54.0\ mpg} = 545.54\frac{gal}{yr} - 222.22\frac{gal}{yr} =$$

$$323.323\ gallons\ per\ year\ saved\ per\ car$$

This all equated out to an overall savings of 59.28% in fuel usage over the 45 year period, which is a decrease in fuel usage by 1.317% per year from 2005. A function was placed into the Simulink simulation as vehicle conservation which reduced the anticipated need for transportation by the percentage corresponding with that year such that there would be a savings of 59.28% from the expected demand in the year 2050.

Conclusion

As we implement our plan to replace fossil fuels as much as possible with expanding the usage of non-fossil fuels not only are we prolonging the lifespan of what resources we have now we also cut down on the amount of CO_2 emitted. Without any implementation carbon dioxide emissions should go from 2200 million tons to approximately 2800 million tons. When we implement all of our changes this number will decrease to about 300 million tons. By reducing our carbon dioxide emissions by the year 2050 we will be able to hopefully slow down or possibly even reverse the effects of global warming.

Energy conservation and a move away from fossil fuels is a must do. The plan proposed here for the East Coast will do exactly that without a huge change in lifestyle. Conservation methods and better engineering of vehicles, higher mpg ratings, will reduce the energy demand without any alterations to business as usual. Moving to renewable fuels not only helps the environment but it will also help individuals economically. As a generalization renewable energy sources have their principle investment and then it is a free energy source. This aspect will reduce the cost of the production of energy and thus reduce individual energy bills.

Appendix

Table

A1:

tates		Cities	an	eb	ar	pr	ay	un	ul	ug	ep	ct	ov	ec	nnua
		Birmingham	.70	.40	.10	.60	.60	.60	.40	.60	.30	.20	.10	.50	
		huntsville	.50	.20	.80	.50	.60	.70	.60	.70	.30	.00	.90	.30	
		Mobile	.70	.50	.00	.60	.50	.40	.10	.20	.10	.20	.30	.60	
		Montgomery	.80	.60	.20	.80	.80	.80	.60	.70	.40	.30	.30	.70	
	Insolation (kWh/m2/day)	Average	.68	.43	.03	.63	.63	.63	.43	.55	.28	.18	.15	.53	
		Birmingham	.56	.78	2.22	6.67	0.00	4.44	6.67	5.56	3.33	7.78	2.22	.22	6
		huntsville	.33	.67	1.11	6.11	0.00	4.44	5.56	5.56	2.22	6.11	1.11	.67	5
		Mobile	0.00	2.22	6.11	0.00	3.89	6.67	7.78	7.78	5.56	0.00	5.56	2.22	9
		Montgomery	.78	0.00	3.89	8.33	2.22	5.56	7.22	7.22	5.00	8.89	3.89	0.00	8
L	Temperature (C)	Average	.67	.17	3.33	7.78	1.53	5.28	6.81	6.53	4.03	8.19	3.19	.03	7
	Insolation	Daytona Beach	.30	.90	.70	.30	.00	.50	.50	.60	.30	.00	.60	.10	
L	(kWh/m2/day)	Jacksonvillle	.60	.30	.20	.10	.10	.80	.70	.50	.00	.50	.90	.40	

		Key West	.90	.50	.10	.40	.00	.50	.60	.70	.50	.40	.00	.70	
		Miami	.70	.20	.70	.10	.60	.10	.40	.50	.10	.10	.70	.50	
		Tallahassee	.00	.70	.40	.00	.90	.60	.40	.40	.30	.40	.60	.00	
		Tampa	.50	.10	.80	.30	.00	.50	.30	.40	.20	.40	.80	.40	
		West Palm Beach	.40	.00	.60	.00	.60	.20	.40	.40	.10	.90	.50	.30	
		Average	.34	.96	.64	.17	.89	.46	.47	.50	.21	.10	.59	.20	
		Daytona Beach	4.44	4.44	7.78	0.00	3.89	5.56	7.22	7.22	5.56	3.33	8.89	5.56	1
		Jacksonvillle	1.11	2.78	6.11	9.44	3.33	5.56	7.78	7.22	5.56	1.11	6.67	2.78	9
		Key West	1.11	1.67	3.33	5.00	7.22	8.89	8.89	8.89	8.89	6.67	4.44	2.22	5
		Miami	9.44	0.00	2.22	3.89	5.56	7.22	8.89	8.89	7.78	5.56	3.33	0.00	4
		Tallahassee	0.56	2.22	5.56	8.89	3.33	6.67	7.22	7.22	5.56	0.00	5.56	2.22	9
		Tampa	5.56	6.67	9.44	1.67	5.00	7.22	7.78	7.78	7.22	3.89	0.00	6.67	2
		West Palm Beach	8.33	8.89	1.11	3.33	5.56	7.22	7.78	8.89	7.78	5.56	2.22	9.44	3
	Temperature (C)	Average	5.79	6.67	9.37	1.75	4.84	6.90	7.94	8.02	6.90	3.73	0.16	6.98	2
A	Insolation	Athens	.90	.60	.20	.80	.70	.70	.60	.60	.40	.20	.30	.70	

	(kWh/m2/day)	Atlan ta	.80	.60	.30	.80	.80	.80	.70	.70	.40	.20	.20	.70	
		Augu sta	.90	.70	.30	.90	.80	.70	.60	.50	.30	.30	.30	.80	
		Colu mbus	.90	.70	.30	.90	.80	.70	.50	.60	.40	.30	.40	.80	
		Mac on	.90	.70	.30	.90	.80	.70	.50	.60	.30	.30	.40	.80	
		Sava nnah	.00	.70	.40	.00	.80	.70	.60	.40	.10	.10	.40	.90	
		Aver age	.90	.67	.13	.88	.78	.72	.58	.57	.32	.23	.33	.78	
		Athe ns	.56	.78	2.22	6.67	0.00	4.44	6.67	5.56	3.33	6.67	2.22	.22	6
		Atlan ta	.00	.22	2.22	6.67	0.00	4.44	5.56	5.56	3.33	6.67	2.22	.22	6
		Augu sta	.67	.33	3.33	7.78	1.67	5.56	7.22	6.67	3.89	7.78	2.78	.33	7
		Colu mbus	.78	.89	3.89	8.33	2.22	6.67	7.78	7.22	4.44	8.89	3.89	.89	8
		Mac on	.22	.89	3.89	7.78	2.22	5.56	7.22	6.67	3.89	8.33	3.33	.89	7
		Sava nnah	.89	1.11	4.44	8.89	3.33	5.56	7.78	7.22	5.00	9.44	4.44	1.11	8
	Tempe rature (C)	Aver age	.85	.70	3.33	7.69	1.57	5.37	7.04	6.48	3.98	7.96	3.15	.61	7
	Insolat ion	Jacks on	.70	.50	.20	.70	.80	.80	.70	.80	.50	.30	.20	.60	
S	(kWh/m2/day)	Meri dian	.60	.40	.00	.60	.60	.60	.40	.50	.20	.20	.10	.50	

		Average	.65	.45	.10	.65	.70	.70	.55	.65	.35	.25	.15	.55	
		Jackson	.67	.89	3.89	8.33	2.22	5.56	7.78	7.22	4.44	8.33	3.33	.89	7
		Meridian	.22	.89	3.89	7.78	1.67	5.56	7.22	7.22	3.89	7.78	3.33	.89	7
	Temperature (C)	Average	.94	.89	3.89	8.06	1.94	5.56	7.50	7.22	4.17	8.06	3.33	.89	
		Ashville	.90	.60	.10	.60	.40	.40	.30	.30	.00	.00	.10	.60	
		Cape hatteras	.80	.50	.20	.90	.80	.70	.70	.60	.40	.90	.20	.60	
		Charlotte	.80	.50	.20	.70	.70	.70	.60	.60	.30	.10	.20	.60	
		Greensboro	.80	.50	.20	.70	.60	.60	.60	.50	.20	.00	.10	.60	
		Raleigh	.80	.50	.20	.70	.70	.70	.60	.50	.20	.90	.10	.60	
		Wilmington	.00	.60	.40	.90	.80	.60	.50	.40	.20	.00	.40	.80	
	Insolation (kWh/m2/day)	Average	.85	.53	.22	.75	.67	.62	.55	.48	.22	.98	.18	.63	
		Ashville	.22	.33	.33	2.78	7.78	0.00	3.33	2.22	8.89	3.33	.89	.44	2
		Charlotte	.33	.67	0.56	4.44	9.44	4.44	5.56	5.56	2.22	6.11	1.11	.67	5
		Greensboro	.78	.44	.89	4.44	8.89	3.33	5.00	4.44	1.11	4.44	0.00	.00	4
C	Temperature (C)	Raleigh	.33	.56	0.56	5.56	9.44	3.89	5.56	5.56	2.22	6.11	1.11	.67	5

		Wilmington	.22	.33	2.22	6.67	1.11	5.00	6.67	5.56	3.89	8.33	3.89	.89	7
		Average	.78	.67	0.11	4.78	9.33	3.33	5.22	4.67	1.67	5.67	1.00	.33	
	Insolation (kWh/m2/day)	Charleston	.00	.70	.50	.10	.80	.60	.60	.40	.20	.20	.50	.90	
		Columbia	.90	.60	.30	.90	.70	.70	.60	.50	.30	.20	.30	.80	
		Greenville	.00	.60	.30	.80	.60	.60	.50	.50	.20	.20	.30	.70	
		Average	.97	.63	.37	.93	.70	.63	.57	.47	.23	.20	.37	.80	
	Temperature (C)	Charleston	.89	0.56	4.44	8.33	3.33	5.56	7.78	7.22	4.44	9.44	4.44	0.56	8
		Columbia	.67	.33	2.78	7.78	1.67	5.00	7.22	6.67	3.33	7.78	2.78	.33	7
		Greenville	.44	.67	1.11	5.56	0.00	3.89	5.56	5.00	1.67	6.11	1.11	.67	5
C		Average	.67	.52	2.78	7.22	1.67	4.81	6.85	6.30	3.15	7.78	2.78	.52	7
	Insolation (kWh/m2/day)	Bristl	.30	.90	.70	.30	.40	.50	.40	.40	.10	.80	.60	.10	
		Chattanooga	.50	.10	.80	.40	.40	.50	.40	.50	.00	.90	.80	.20	
		Knoxville	.40	.00	.70	.40	.50	.60	.40	.50	.10	.90	.70	.10	
		Memphis	.70	.40	.00	.60	.80	.90	.00	.00	.40	.20	.90	.40	
N		Nashville	.50	.20	.80	.60	.70	.90	.80	.70	.30	.90	.60	.10	

		Average	.48	.12	.80	.46	.56	.68	.60	.62	.18	.94	.72	.18	
		Bristl	.11	.78	.33	2.78	7.78	1.67	3.33	3.33	0.00	3.89	.33	.33	3
		Chattanooga	.78	.56	0.00	4.44	9.44	3.89	5.56	5.56	2.22	5.56	0.56	.00	5
		Knoxville	.22	.44	.89	4.44	8.33	3.33	5.00	4.44	1.11	4.44	.89	.44	4
		Memphis	.44	.67	2.22	7.78	1.67	5.56	8.89	7.22	3.33	7.78	2.22	.67	7
		Nashville	.22	.44	0.00	4.44	0.00	4.44	5.56	5.56	2.22	5.56	0.00	.00	4
	Temperature (C)	Average	.56	.78	.89	4.78	9.44	3.78	5.67	5.22	1.78	5.44	0.00	.89	4
		Lynchberg	.90	.60	.30	.70	.70	.80	.70	.70	.30	.00	.00	.60	
		Norflok	.60	.30	.90	.40	.50	.60	.40	.40	.10	.60	.90	.40	
		Richmond	.60	.30	.00	.40	.50	.60	.50	.50	.20	.70	.90	.30	
		Roanoke	.70	.30	.00	.50	.50	.60	.50	.50	.10	.90	.90	.40	
		Sterling	.50	.20	.80	.30	.50	.70	.60	.50	.10	.60	.60	.10	
	Insolation (kWh/m2/day)	Average	.66	.34	.00	.46	.54	.66	.54	.52	.16	.76	.86	.36	
		Lynchberg	.11	.78	.78	3.33	7.78	2.22	4.44	3.89	0.00	3.89	.89	.33	3
A	Temperature (C)	Norflok	.33	.00	.89	3.89	8.89	3.33	5.56	5.00	2.22	6.11	2.22	.67	5

		Richmond	.22	.33	.89	3.89	8.89	3.33	5.56	5.00	1.11	4.44	0.00	.44	4
		Roanoke	.67	.78	.33	3.33	7.78	2.22	4.44	3.89	0.00	3.89	.89	.33	3
		Sterling	0.56	.11	.67	2.22	6.67	1.67	4.44	3.33	9.44	2.78	.22	.67	2
		Average	.56	.00	.11	3.33	8.00	2.56	4.89	4.22	0.56	4.22	.44	.89	3

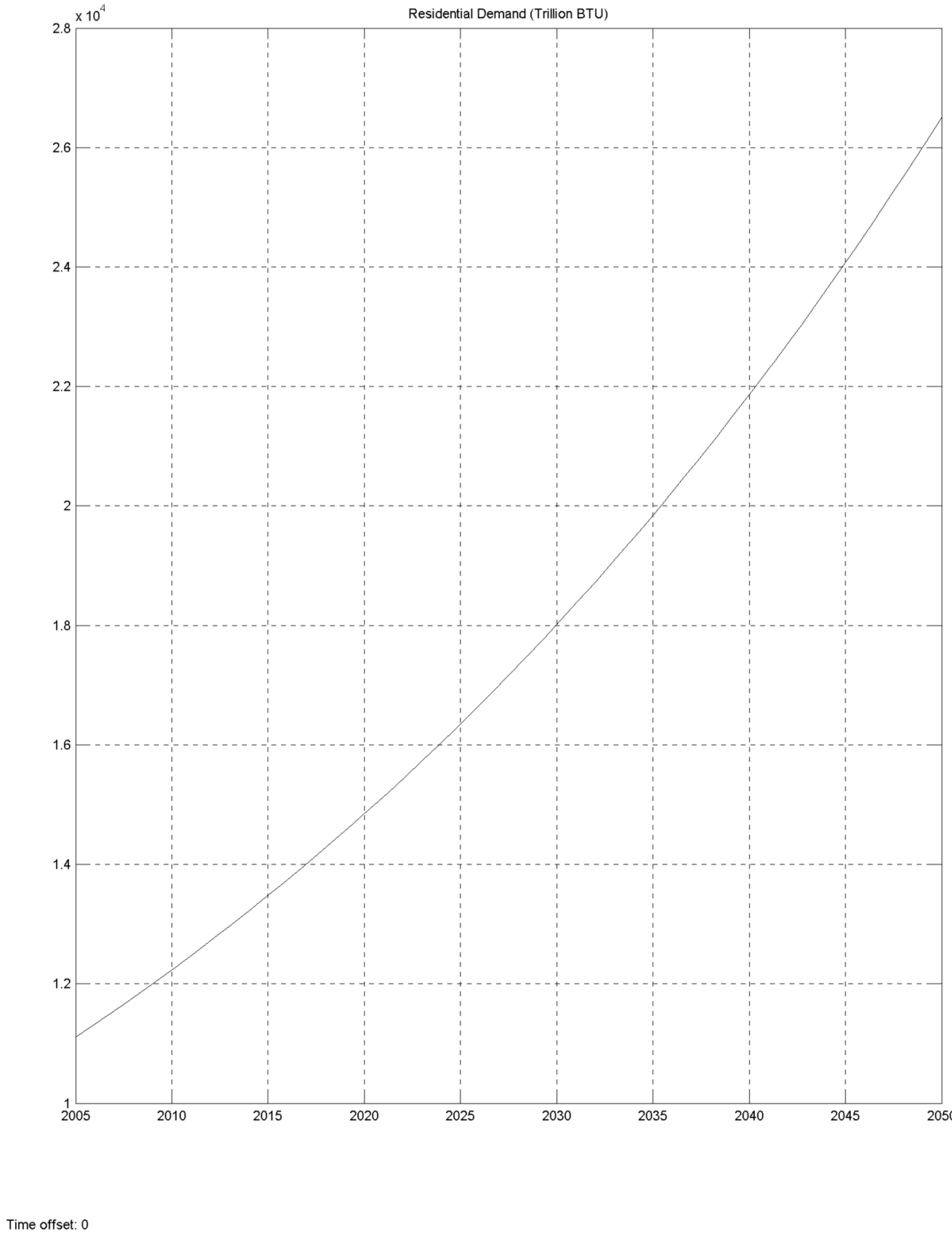
Table A2: Estimate values of the load and the collector area

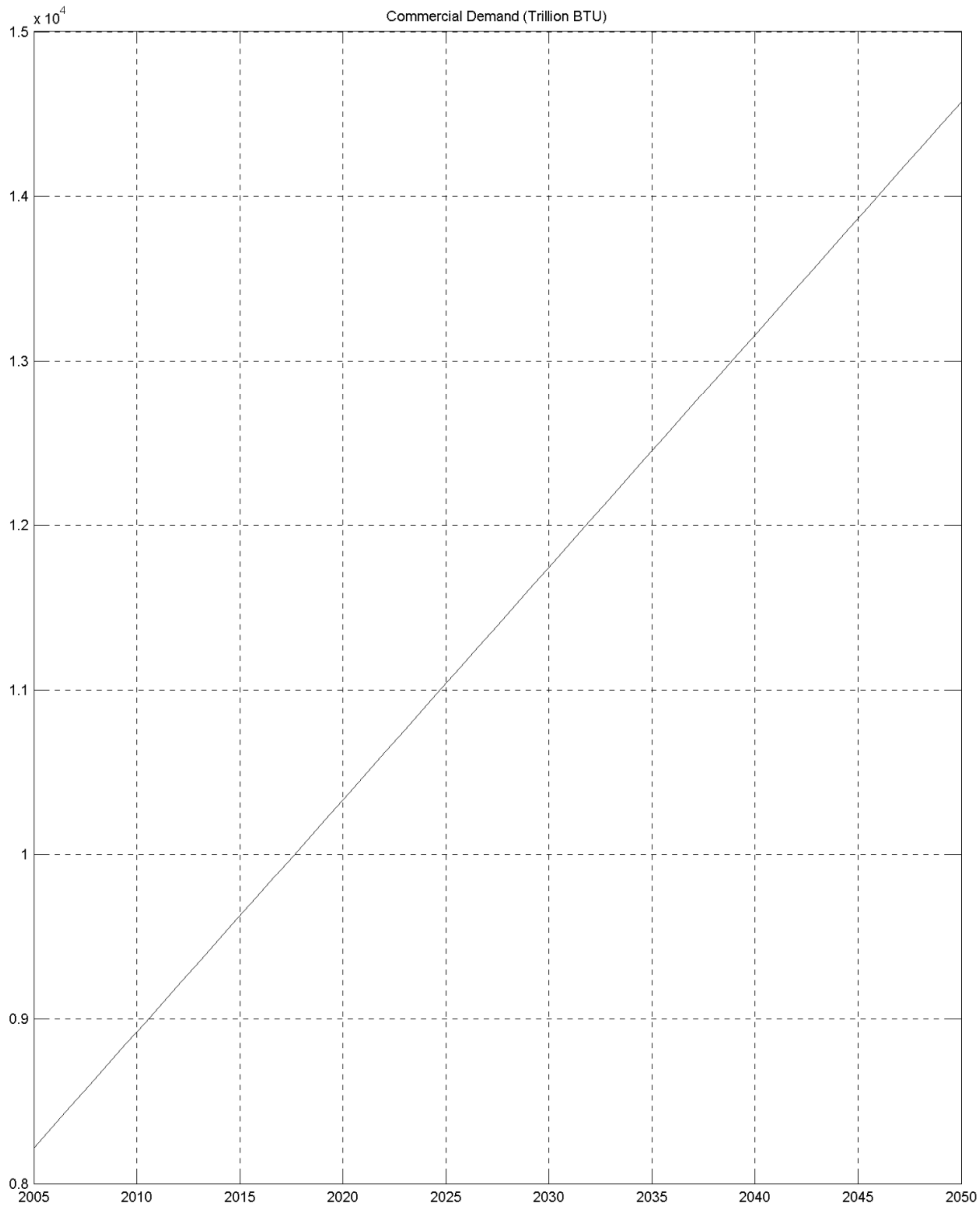
	i	I (kWh/m2/day)	Load (kWh/day)	A (m2)
AL	3.33	5.02	15.59	6.90
FL	9.37	5.64	13.48	5.31
GA	3.33	5.13	15.59	6.75
MS	3.89	5.10	15.39	6.71
NC	0.11	5.22	16.71	7.11
SC	2.78	5.37	15.78	6.53
TN	.89	4.80	16.79	7.77
VA	.67	5.00	17.91	7.96
Average			15.90	6.88

Table A3: Investment and operation and maintenance costs

	(m2)	Make and Model	Cost Solar ($)	Co st Electric	Invest ment($)	O &M
AL	.9	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
FL	.3	Helio Pak HPT2408GAC	4 500	75 0	5250. 0	2 00
GA	.8	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
MS	.7	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
NC	.1	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
SC	.5	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
TN	.8	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
VA	.0	Helio Pak HPT3408GAC	5 600	75 0	6350. 0	2 00
East Coast Average					6212. 5	2 00

Appendix B.1


Residential Demand (Trillion BTU)
x 10^4
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Time offset: 0



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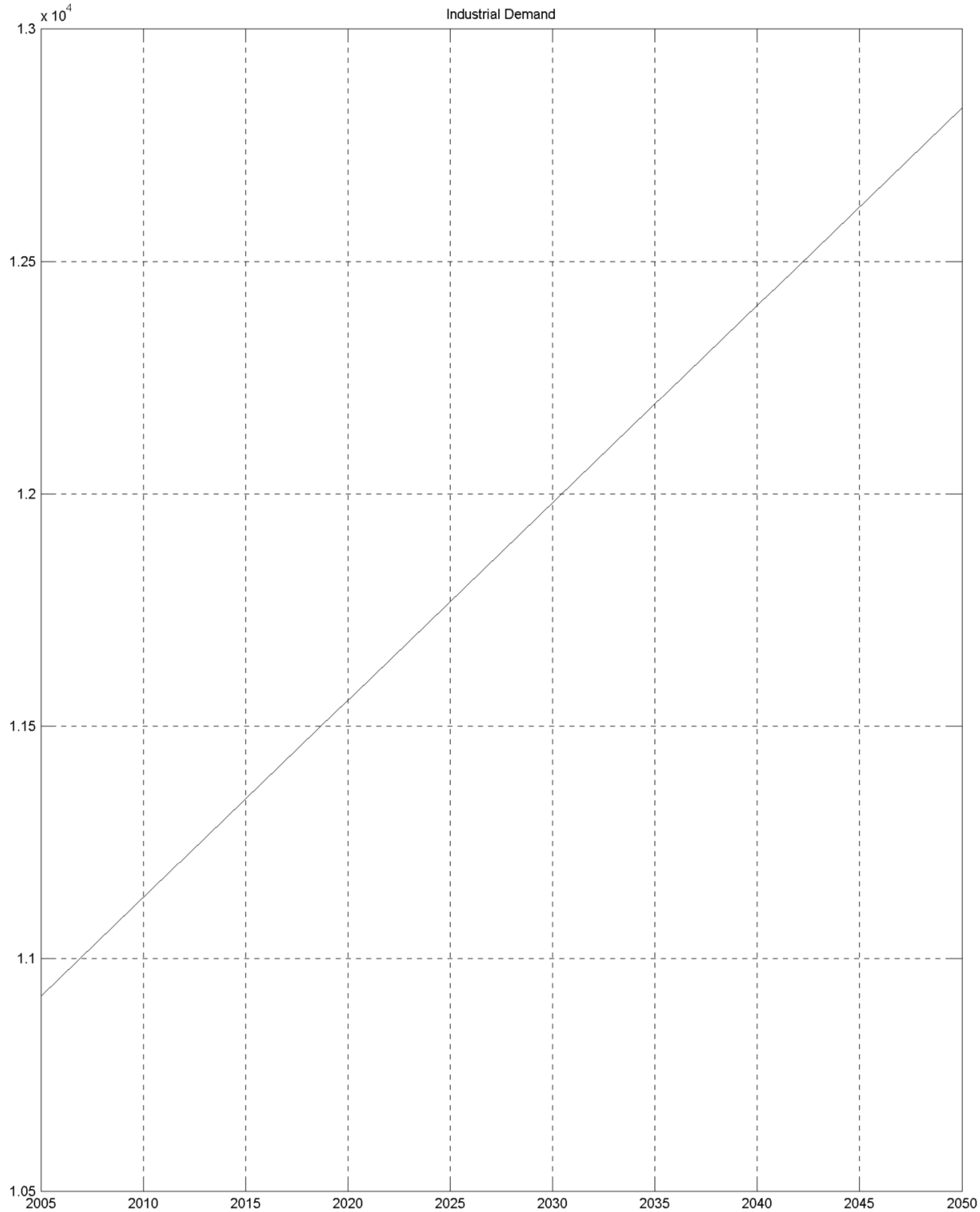
Appendix B.3



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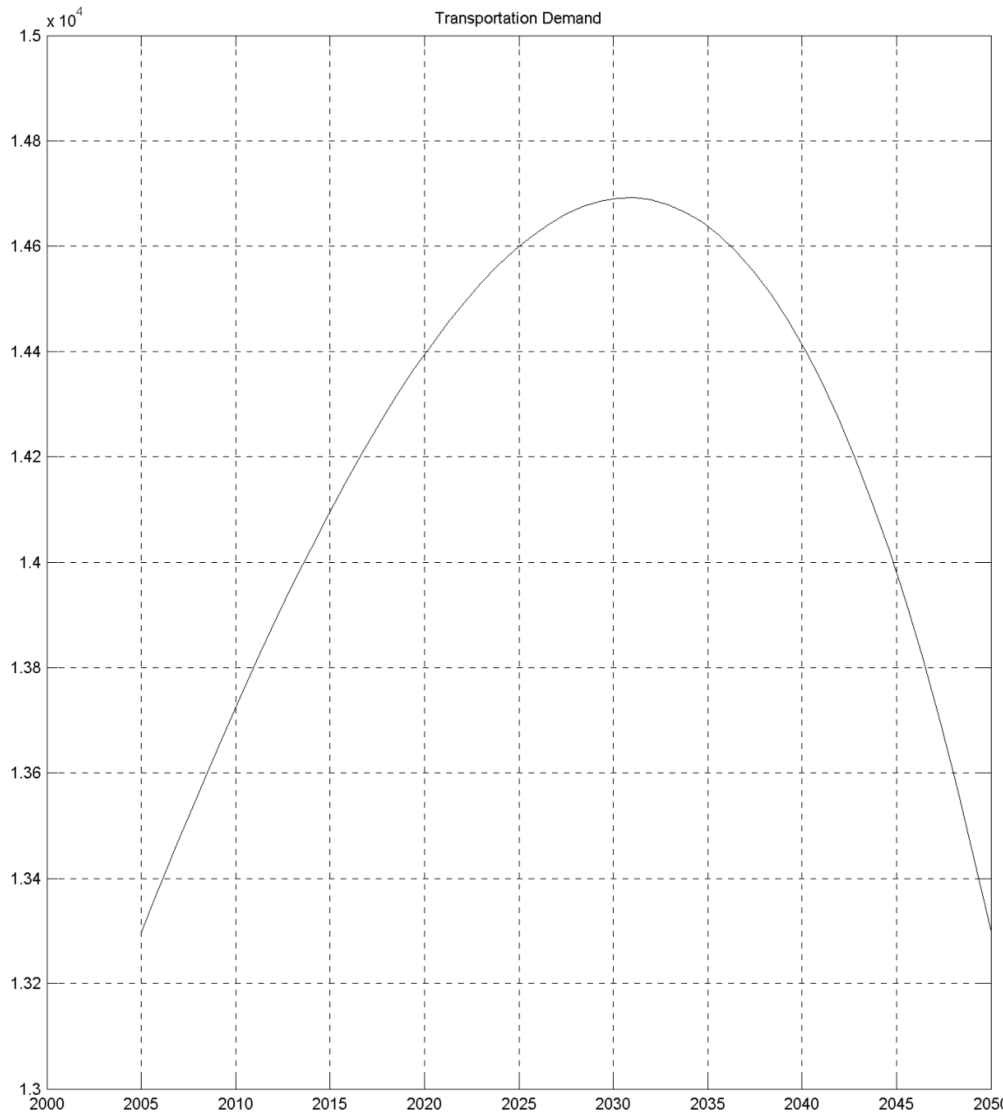
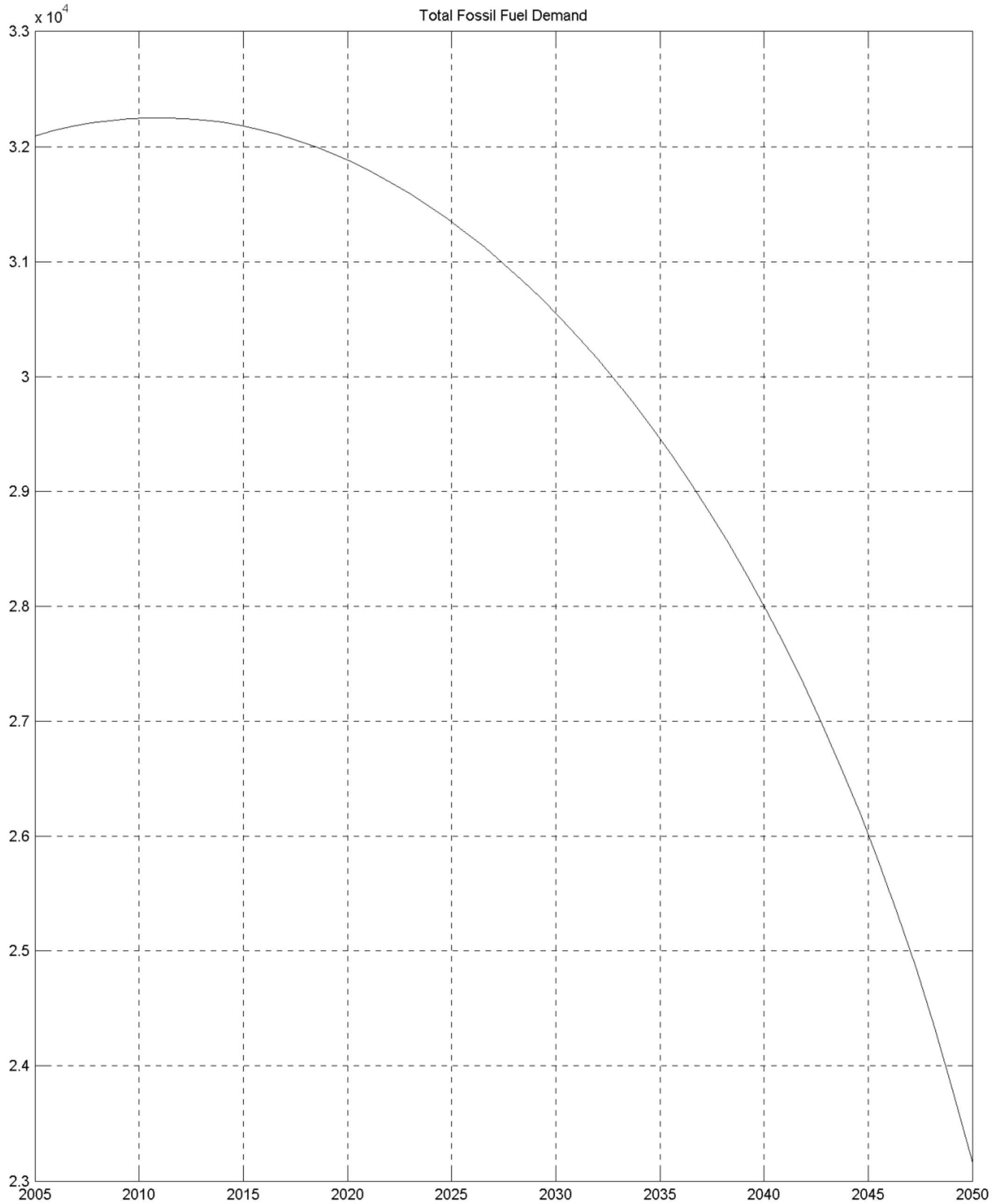
Appendix B.4



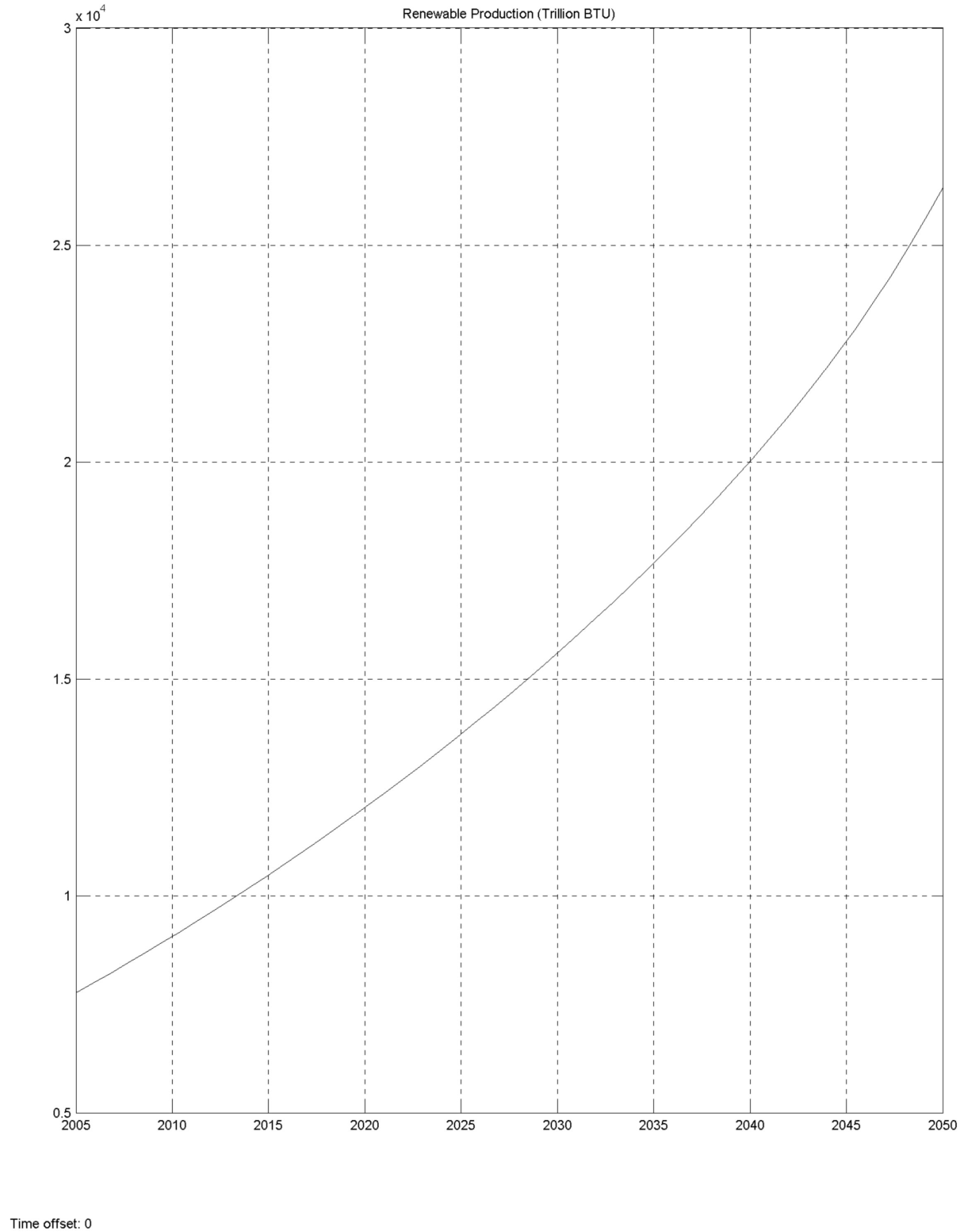
Time offset: 0

Appendix B.5



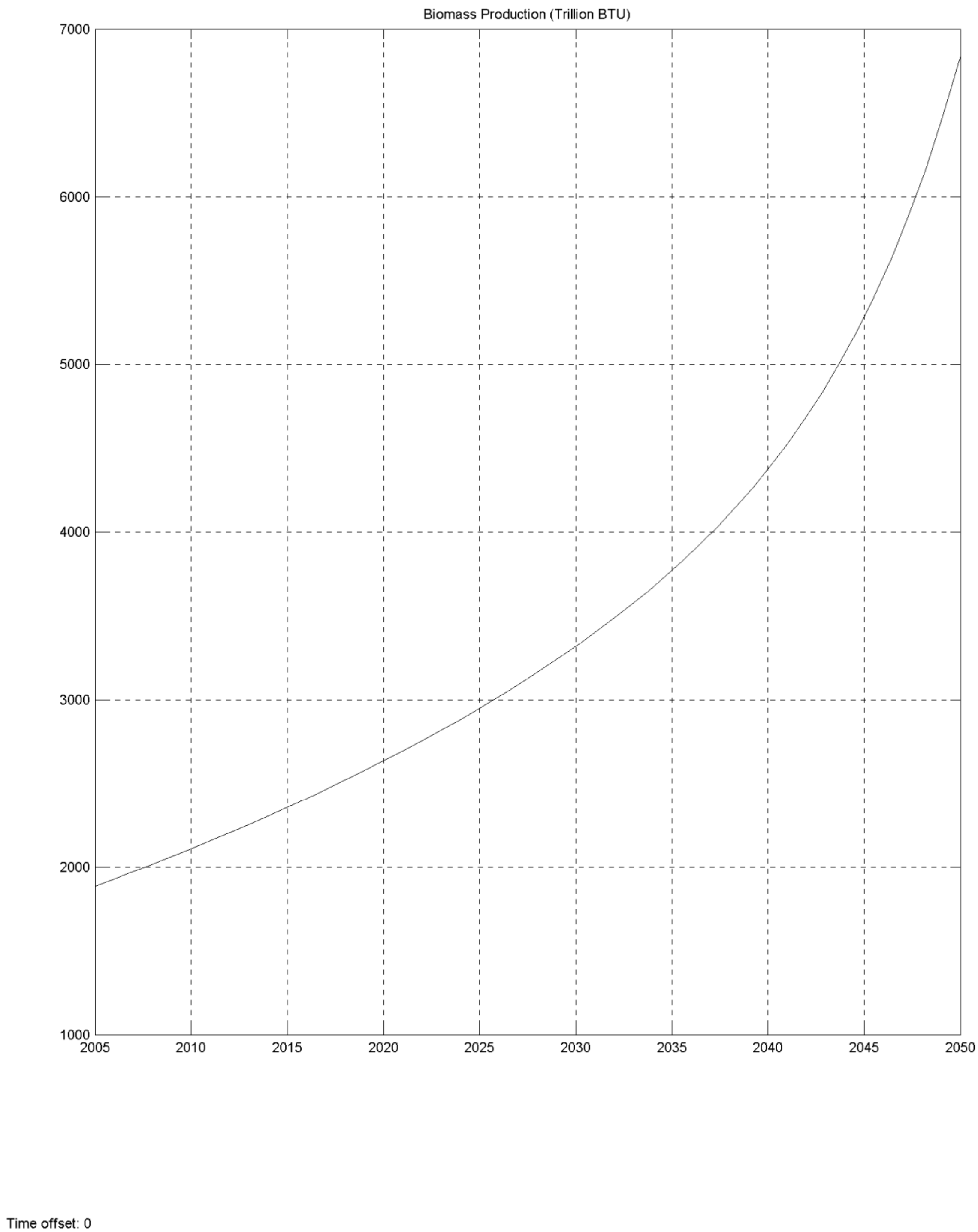
Time offset: 0

Appendix B.6

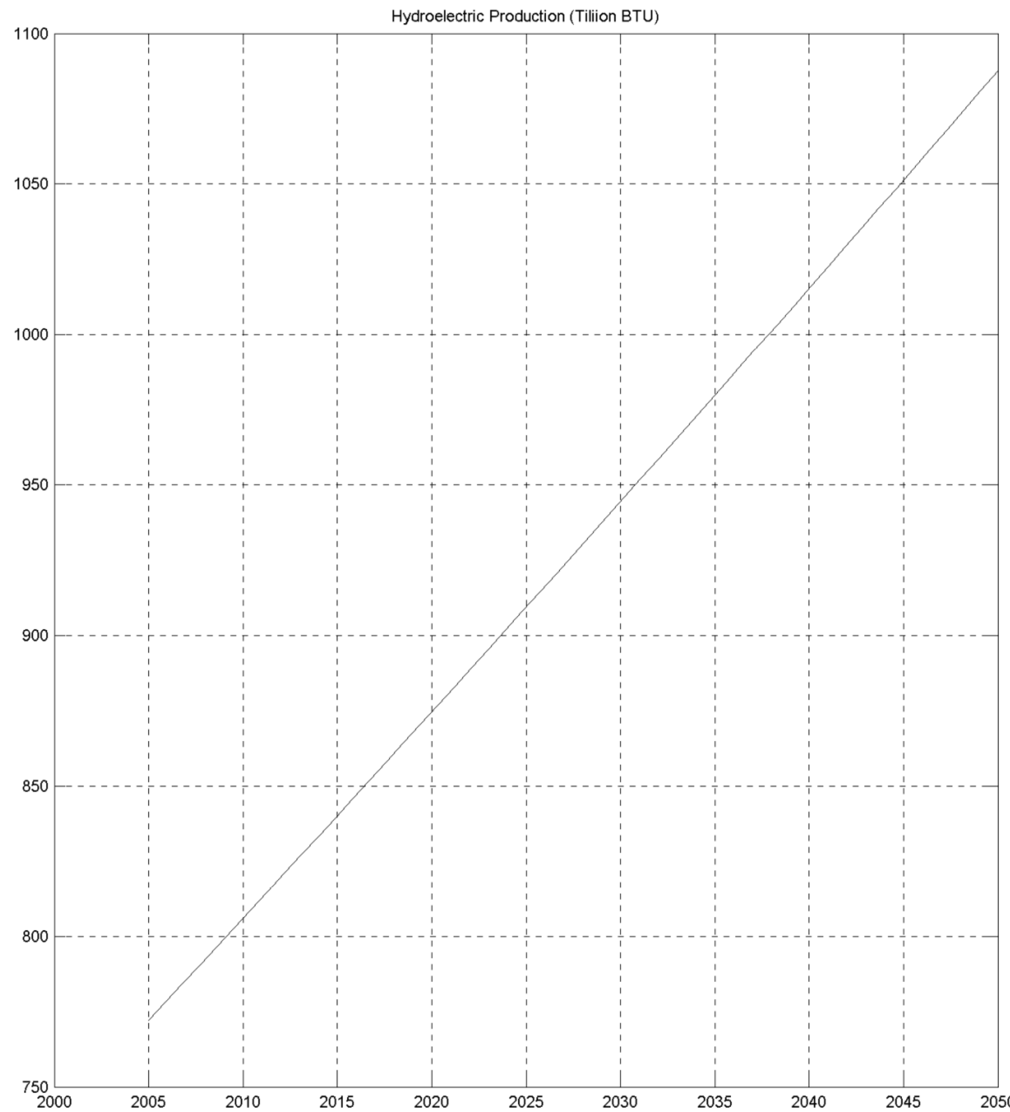


Renewable Production (Trillion BTU)
x 10^4
3
2.5
2
1.5
1
0.5
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Time offset: 0

Appendix B.7

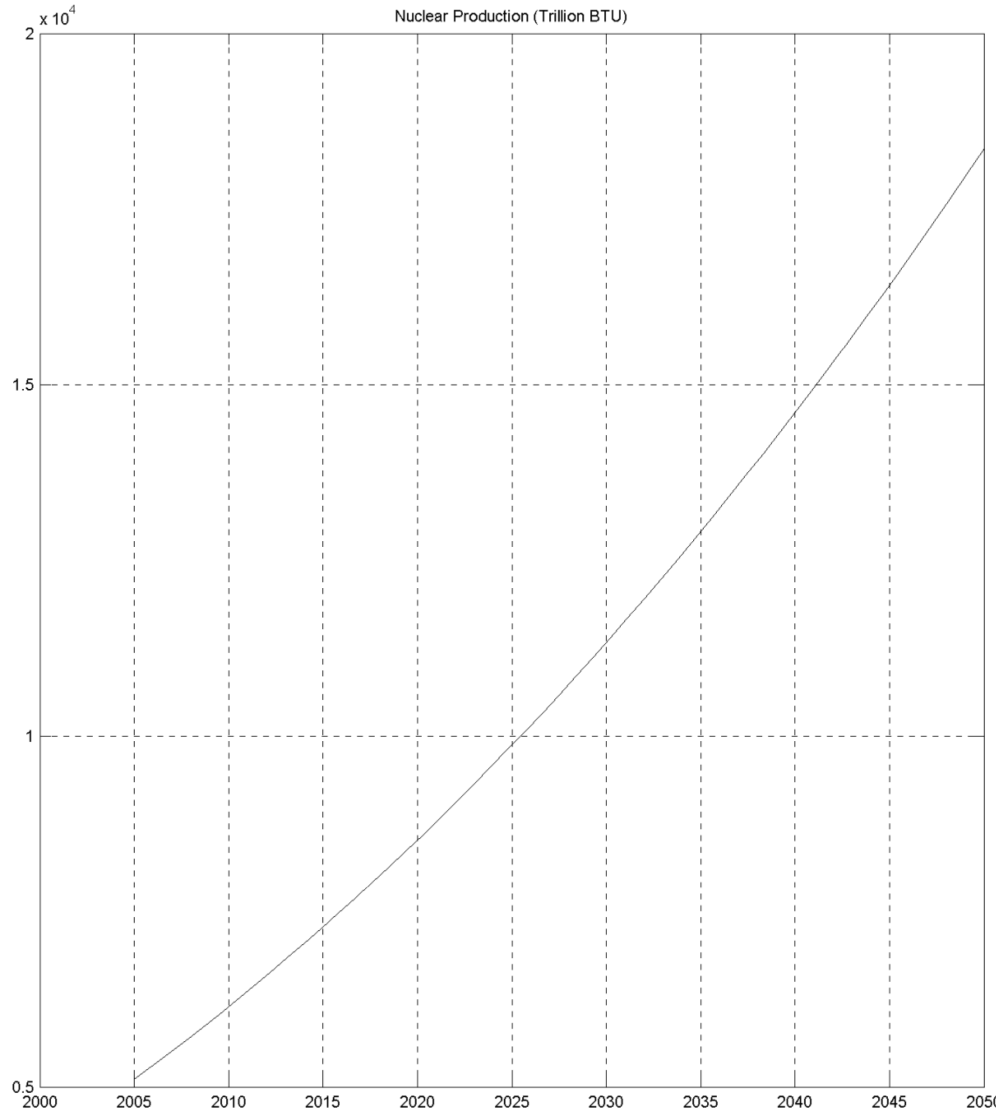

Biomass Production (Trillion BTU)
7000
6000
5000
4000
3000
2000
1000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Time offset: 0

Appendix B.8



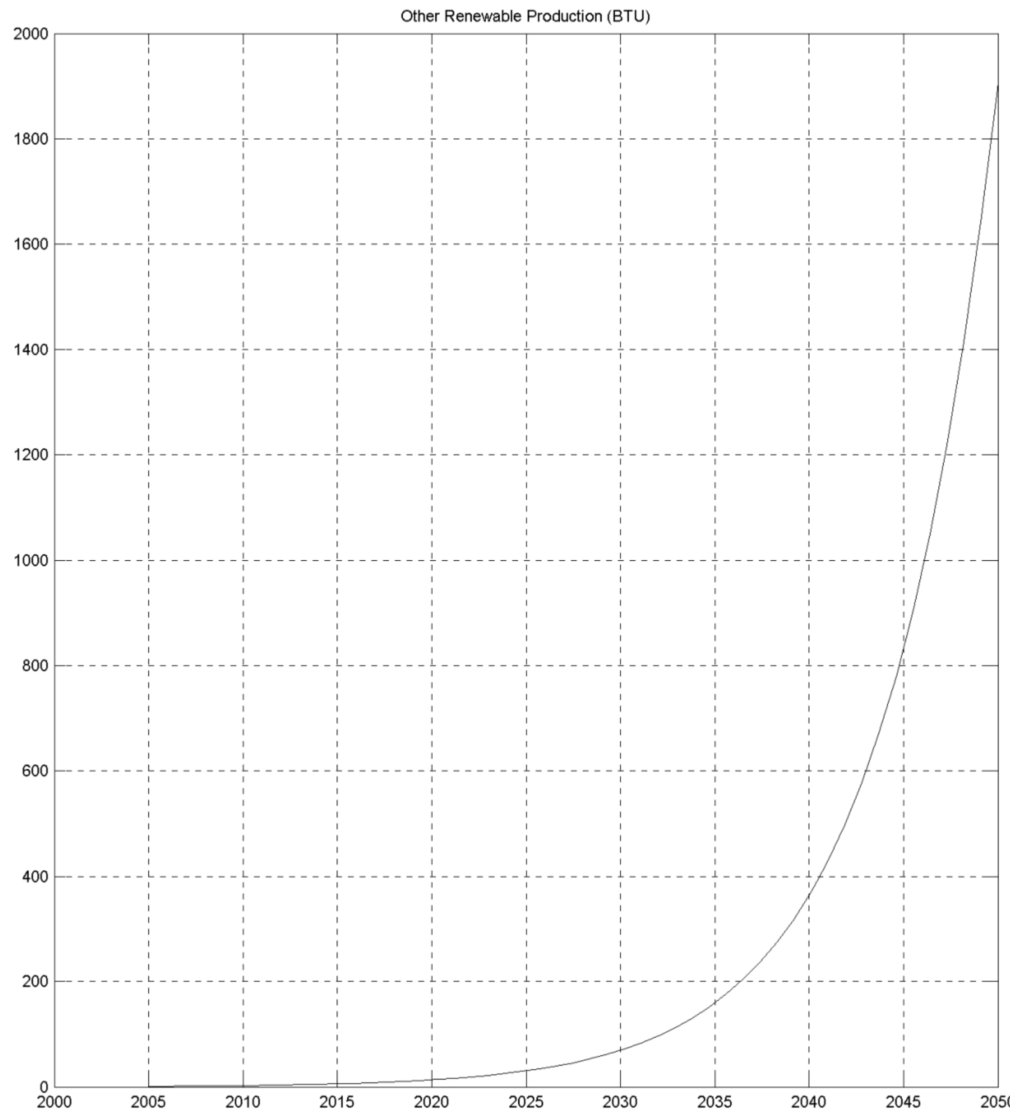
Time offset: 0

Appendix B.9

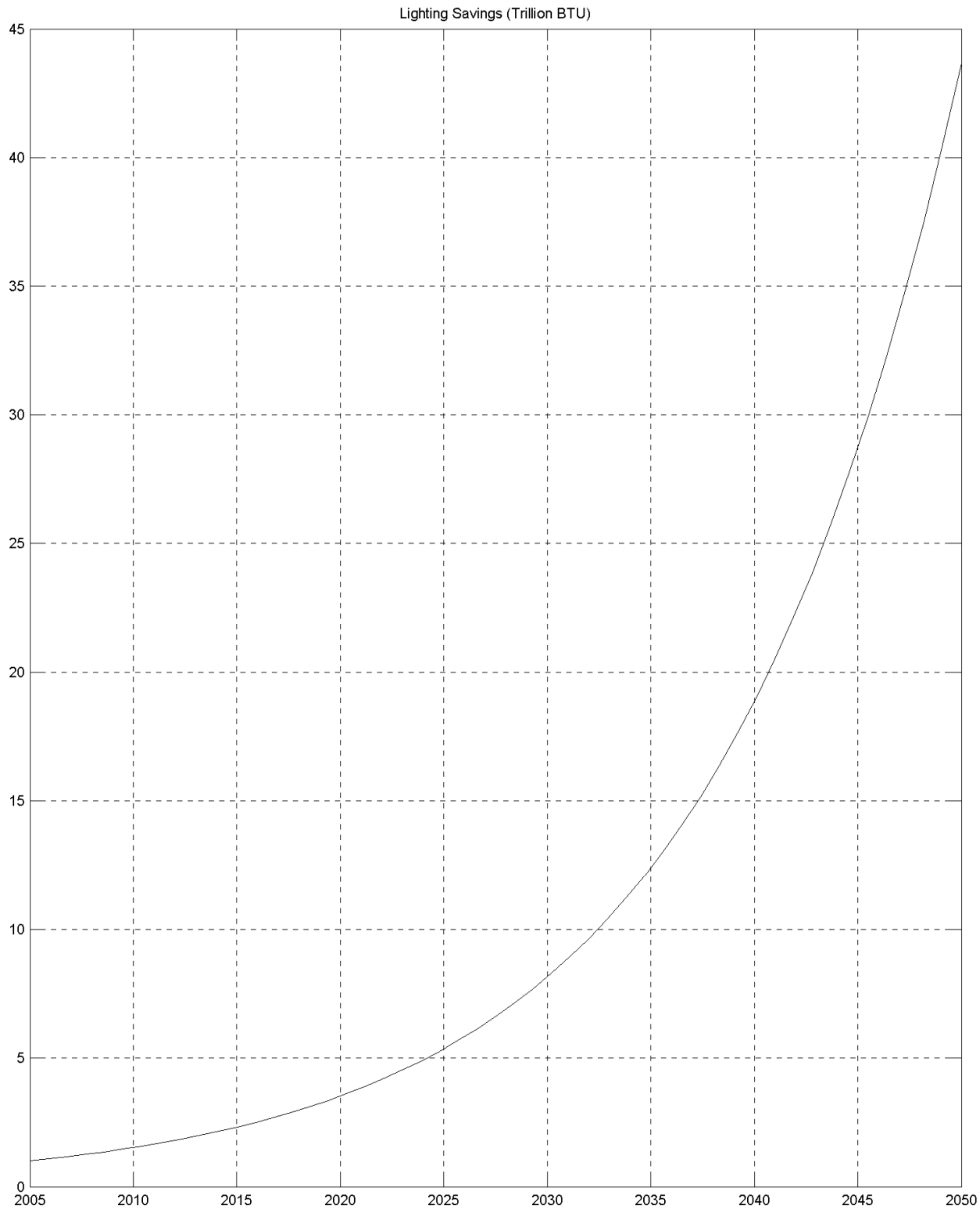


Time offset: 0

Appendix B.10



Time offset: 0



Time offset: 0

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