

Higher Education for Sustainability

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Abstract

This paper discusses the contributions of US higher education institutions in achieving sustainable future. The paper provides an overview of various degree programs or curricula offered in the areas of sustainable development, and renewable energy. Sustainable development management and planning programs offer degrees in community, city, urban, and/or regional planning, sustainable design, ecological systems, and public policy. Renewable energy curricula include courses focusing on the fundamentals of various renewable energy sources and their advantages and disadvantages, and renewable energy generation and applications.

Keywords: Sustainability, Renewable Energy Courses, Energy Sources

1. Introduction

Higher education institution can play a pivotal role in achieving sustainable society for future generations. In the published literature, sustainable development is usually described as meeting the basic needs of world population while maintaining the Earth's ecosystems. To achieve this goal, future world population needs to be stabilized at the level that can be within the limits of the Earth's ecosystem, improve the efficiency of using natural resources, eliminate the concept of waste, and to develop and operate on renewable energy technologies. The quest for renewable energy should be considered as an integral part of the larger goal of sustainable future.

Higher education institution can play such a leading role for a variety of reasons. Higher education institutions interact with the majority of best minds of younger generations and educate, train, and prepare them to become future leaders and professional who work, manage, lead, and influence all of the society's institutions. Higher education research institutions plays major role in creating, developing, and disseminating the knowledge and skills needed to achieve sustainable society.

Achieving the goal of sustainable society requires long-term efforts to educate the public about the dynamic relationship between environment and society. A major change the mindset of the society is needed in order to eliminate wasteful practices in using natural energy resources. A close collaboration between educators, parishioners, and the public is needed in order to achieve these changes.

In the past two decades, many universities have created inter- and intra-disciplinary "sustainability science" degree programs and curricula that employ science, technology,

environment, and public policy in order to achieve a sustainable development for the society [1, 2]. Research centers at the university and national levels have been created in all aspect of sustainability-related sciences.

Sections 2 and 3 will discuss the major sources of energy at the national and global levels, the need for renewable energy, sources for renewable energy and their anticipated contributions in meeting the future demands of energy. Sections 4 and 5 highlight the US universities sustainability degree programs in general and renewable energy in particular, and research and development of renewable energy sources at the university and national levels. Section 6 gives some examples of the community outreach programs in the US universities.

2. Conventional Energy Sources

Conventional energy sources of the world are fossil fuel based sources. Fossil fuel has three major forms – oil, coal and natural gas [3]. Figure 1 shows the contribution of each type of fuel in meeting the energy demands of the world. The data provided in this paper can be found in the US Energy Information Administration website [4, 5, 6]. Figure 1 also shows that the world is heavily dependent on fossil fuel and such dependence has been increasing in the past two decades, even with the relentless efforts to develop and utilize of renewable energy technologies.

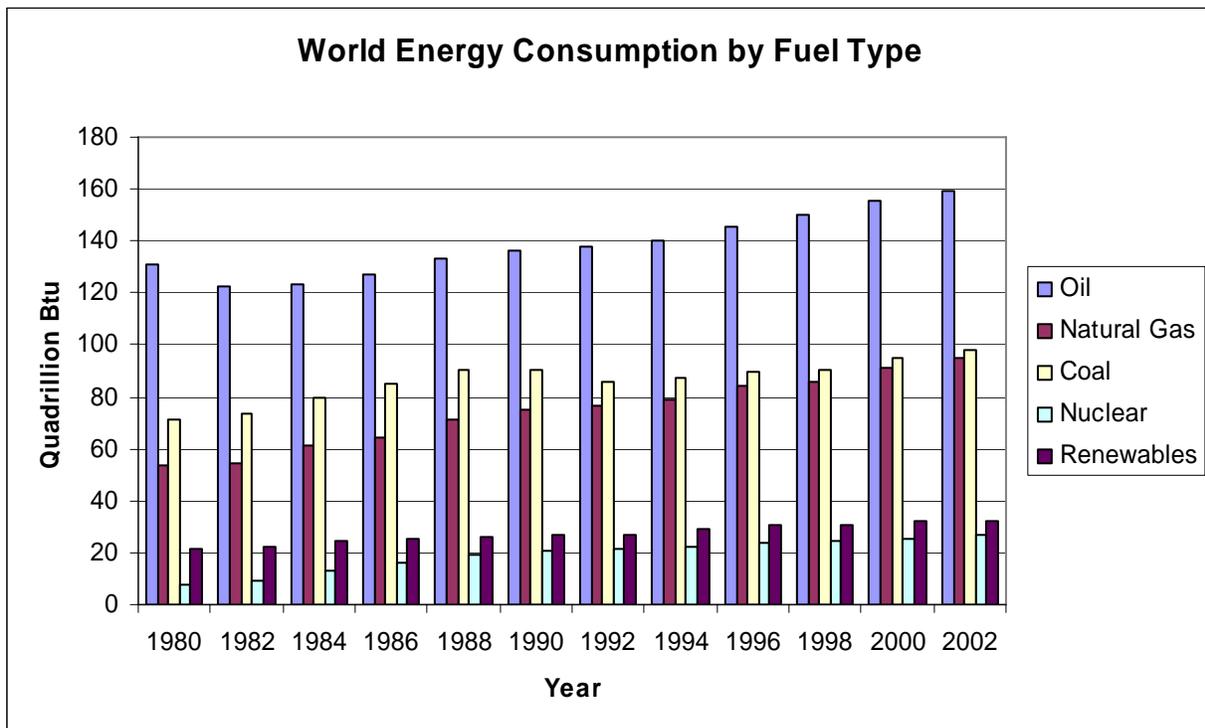


Figure 1: World energy consumption by fuel type.

The US current depends on fossil fuel to meet the vast majority of its energy demands, even with the continual development and deployment of nuclear and renewable energy technologies. Figure 2 shows the US fossil-fuel-based energy production by energy type in the past two decades. The latest statistics from the US Department of energy indicates that fossil fuels provide 85% of the

total domestic energy consumption [3]. The contribution of each source of energy to the total energy production in the US at 2005 is shown in Figure 3.

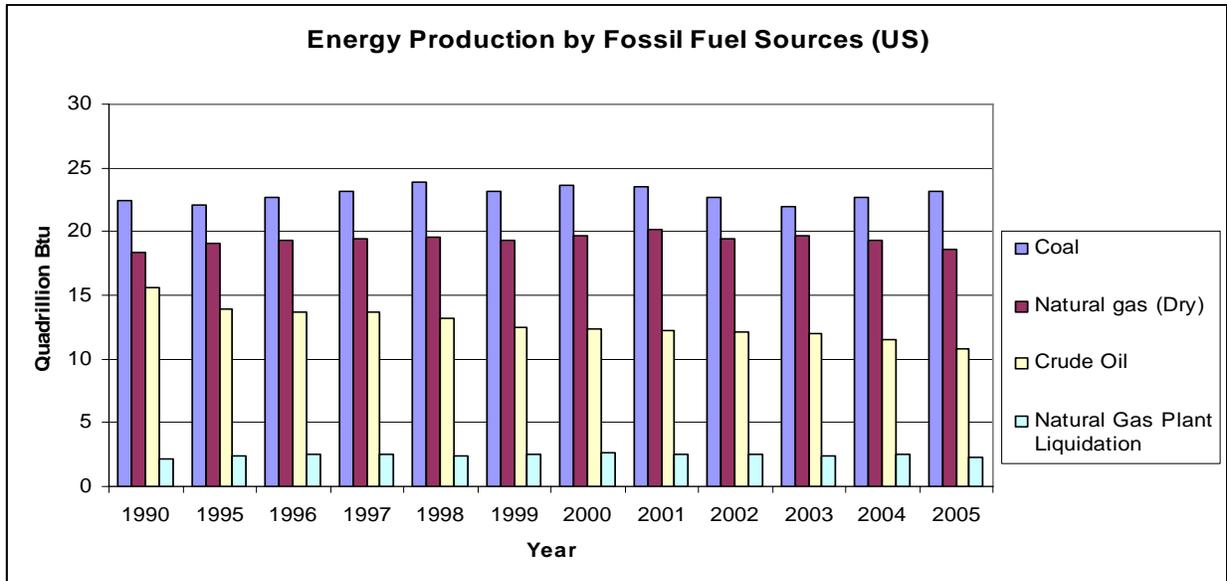


Figure 2: US production of energy by energy source

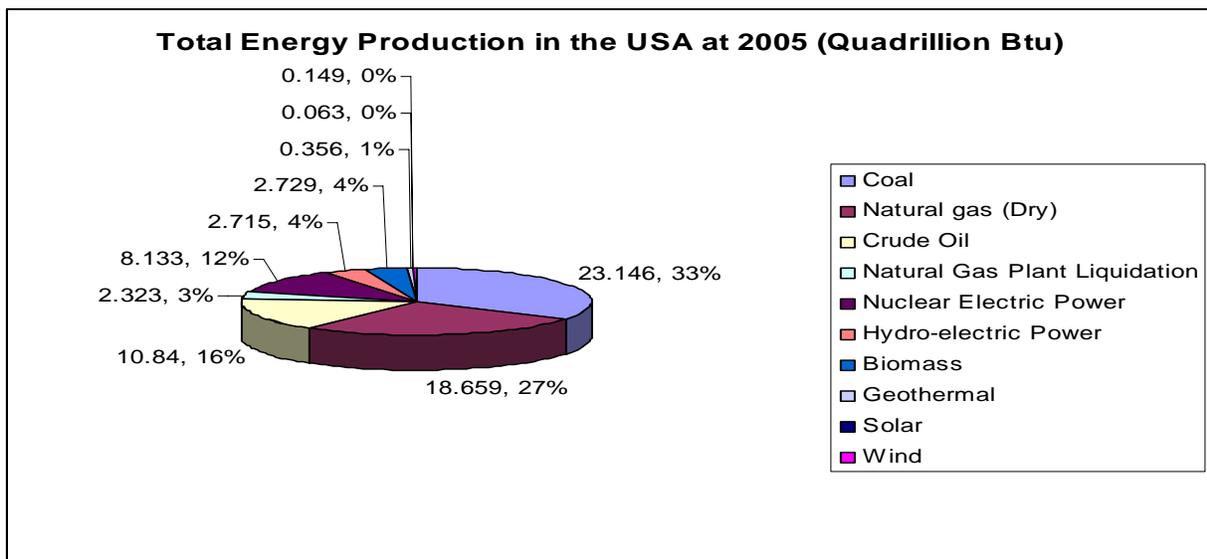


Figure 3: US total energy production by energy source in 2005

The demand for energy is expected to increase in the next two decades. Figure 4 shows the marketed energy consumption since 1970 and the estimated demand at 2025. It also show that the demand will grow from around 200 Quadrillion Btu in 1970 to about 650 trillion Btu in 2025, more than 300% increase in energy demand. Most of the estimated demand increase will come from developing economies such as China, India, and Brazil.

In the past century, fossil fuels provided the energy needed for the economic growth throughout the world. They will continue to be the major sources of energy for the foreseeable future. However, these energy sources are not renewable and the world reserve of oil is dwindling. Oil is the main source of automotive fuel used throughout the world. A brief overview of fossil fuel production and reserve follows.

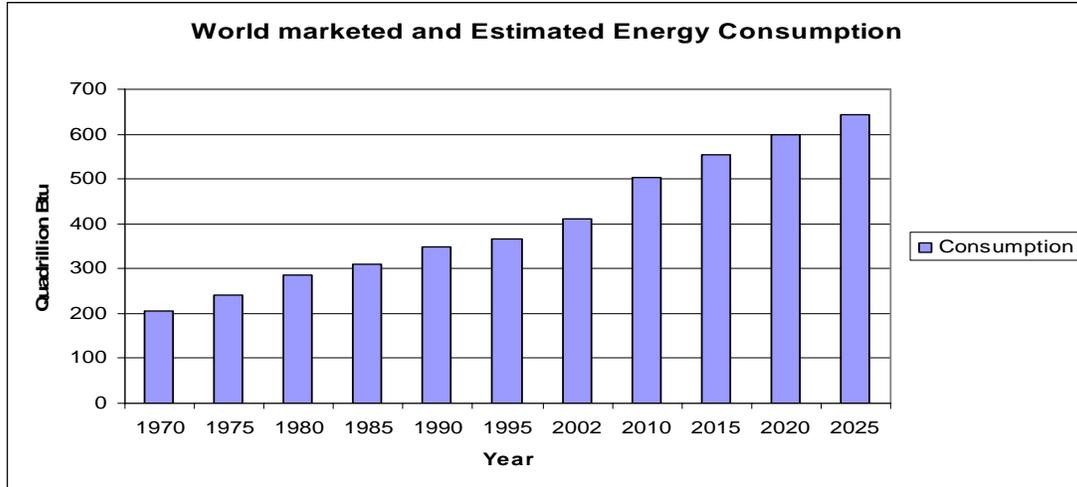


Figure 4: World marketed and estimated energy consumption in the period 1970-2025

a. Coal

The International Energy Outlook report [7] predicts that the use of Coal worldwide will increase by 3.0 billion short tons in the period between 2002 and 2025. The price of coal has risen significantly in the past few years; however, the use of Coal is expected to increase in all regions of the world except for Western Europe, where natural gas and renewable energy sources are used to replace coal as a fuel in the generation of electric power. The largest increases in Coal use are expected in the emerging economies, especially China and India. Figure 5 shows the world coal production since 1980.

The United States Coal reserve is about 280 Billion short tons, which is more than a quarter of the World's Coal reserve (1.0 Trillion short tons, approximately). The energy content of the Coal reserve in the US exceeds the energy contents of all known recoverable oil worldwide. Coal-fired electric generating plants produce more than half the electricity consumed in the United States. The cost using coal to produce electricity for consumption in the urban areas of the United States is much cheaper than that of most of renewable energy sources. Figure 6 shows the coal production throughout the world since 1980.

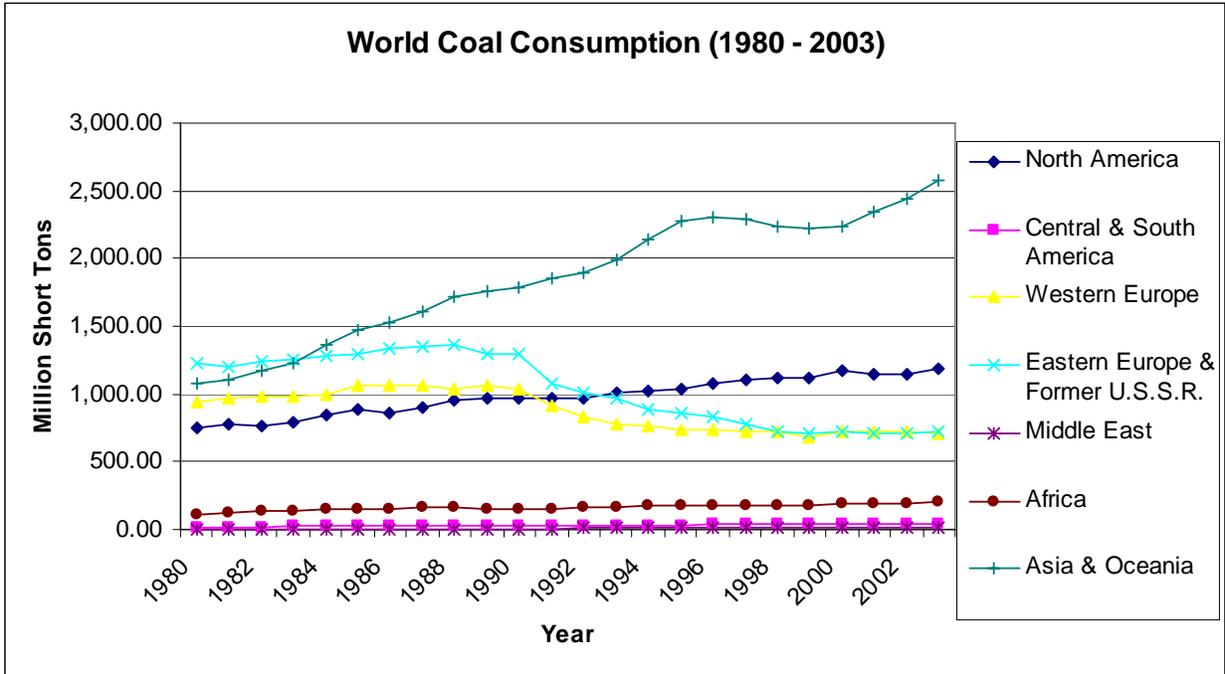


Figure 5: World Coal consumption since 1980.

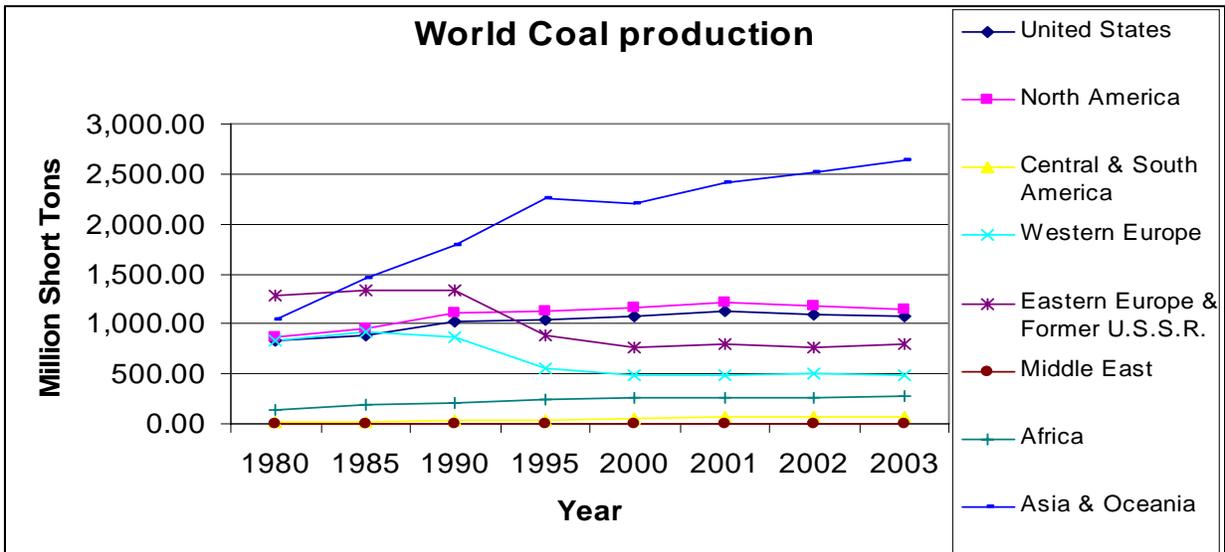


Figure 6: World coal production since 1980

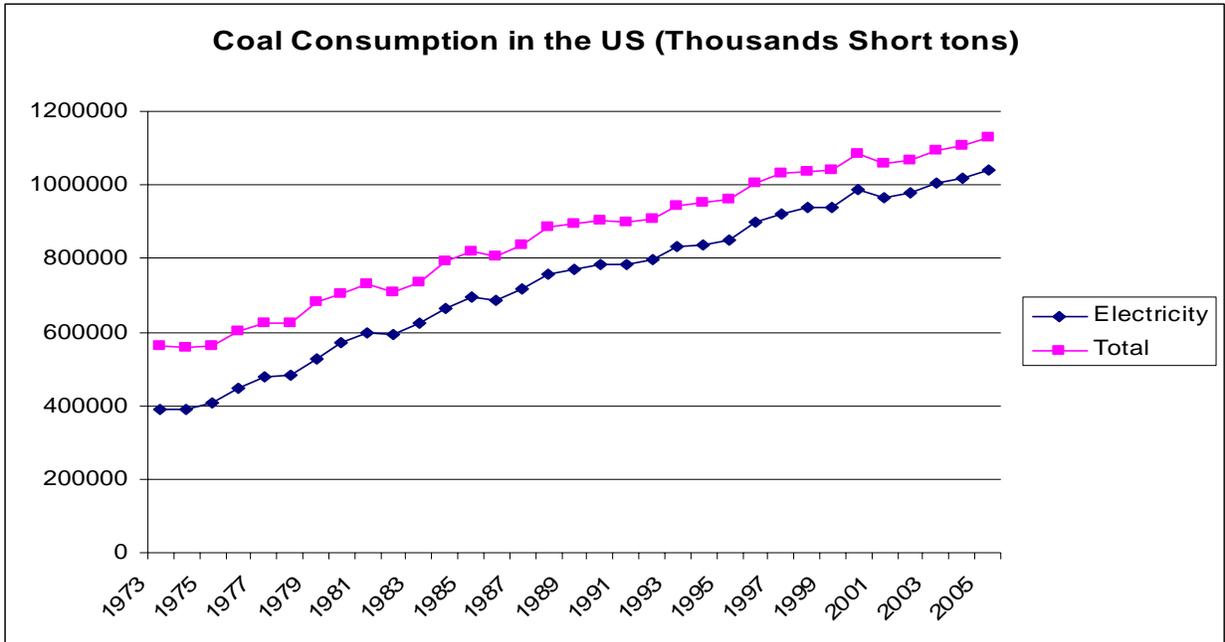


Figure 7: Coal consumption in the US

The majority of coal consumed in the US is used for electricity generation as shown in Figure 7. The abundance of coal in the US makes it a much cheaper source for electricity generation than any of renewable energy sources. It is expected that coal will be the major source of energy for electricity generation for the foreseeable future as seen in Figure 8.

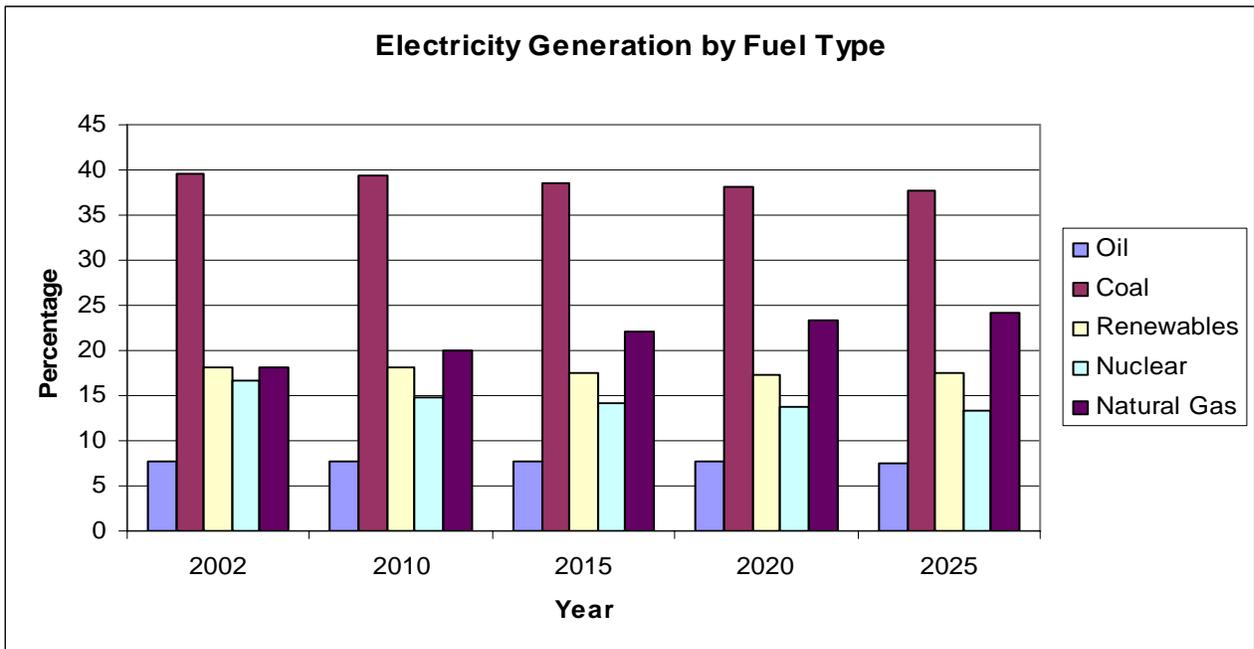


Figure 8: Electrify generation by oil fuel in the US

However, Coal-fired power plants are one of the major causes of air and water pollution. Major investment in pollution reduction is needed to capture and prevent greenhouse gases emitted from these plants from polluting the atmosphere.

b. Oil

The United States consumes about 20 million barrels a day, which is about a quarter of the world oil daily production, while producing less than 9 million a day (8.25 million barrel in 2005). The Chinese oil consumption rose from approximately 5 million barrel a day to about seven million barrels day in 2005. The rate of increase in oil consumption is also high in many emerging economies. Figure 9 shows the daily supply and demand of oil. Table 1 shows the oil reserve in the major oil producing countries. Table 2 shows that most of world’s oil reserve is in the Middle East and that the US oil reserve is very limited compared its daily consumption of oil. It should also be noted that new discoveries change the amount of oil reserve. In addition, the amounts of oil that can be economically extracted depend on oil prices, which keep changing daily. It is expected that most of oil reserves will be depleted between 2040 and 2060. In the US, oil is used mainly as automotive fuel. Therefore, as will be discussed later, fuel cell is the most active renewable energy research area

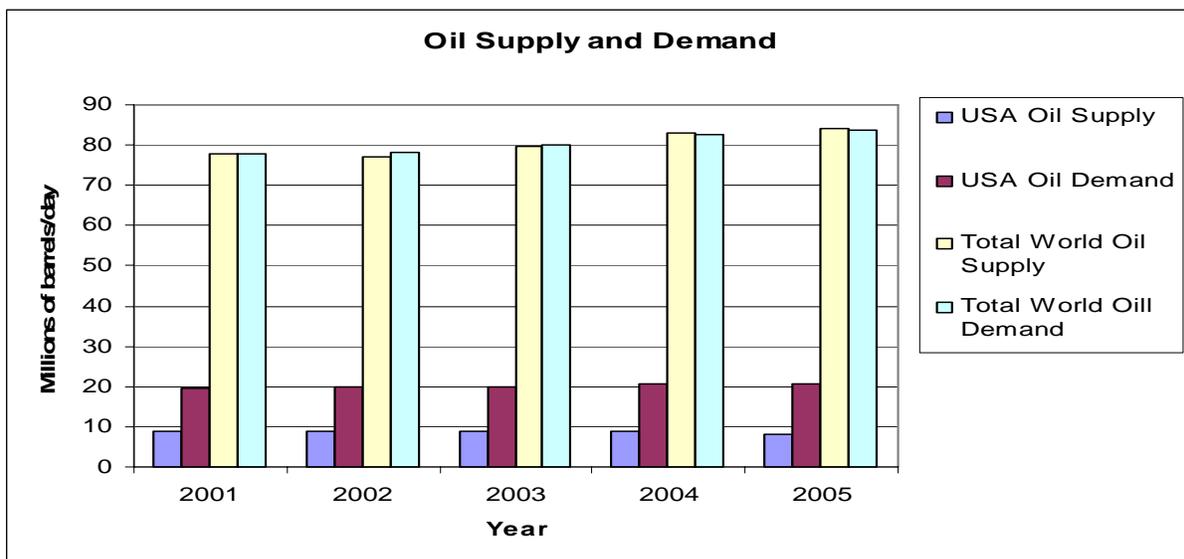


Figure 9: World oil supply and demand

Table 1: Estimated Crude oil Reserve per country Worldwide in 2004

Country	Oil Reserve (billions of barrels)	Natural Gas Reserve (Trillion Cubic Feet)
Saudi Arabia	261.775	68.853
Iraq	115.000	112.600
Iran	105.000	935.000
Kuwait	99.375	56.600
United Arab Emirates	66.230	204.050

Russia	65.393	2,340,500
Venezuela	52.450	149.210
Nigeria	33.000	180.000
Libya	30.500	46.000
Qatar	27.352	913.400
Other Former USSR	22.337	336.326
United States	21.891	189.044
China	15.509	47.911
Mexico	14.597	20.740
Algeria	14.000	171.500
Brazil	10.602	8.664
Norway	9.395	74.733
Angola	8.801	4.000
Oman	5.700	31.000
Indonesia	5.500	67.650
Canada	4.957	59.069
Egypt	3.610	7.125
Argentina	2.675	21.630

Source: Energy Information Agency/World Oil

Table 2: World Crude Oil and Natural Gas Reserve by Region

Country	Oil Reserve (billions of barrels)	Natural Gas Reserve (Trillion Cubic Feet)
North America	41.445	68.853
Central and South America	75.848	240.937
Western Europe	16.382	170.054
Eastern Europe and Former USSR	89.013	2,693.227
Middle East*	686.345	2,539.650
Africa	104.644	443.200
Asia and Oceania	37.703	449.910

* Middle Eastern Countries Located in Africa are listed with Africa.

c. Natural gas

Natural gas is a cleaner source of energy than coal. It has lower carbon content than oil or coal. The use of natural gas for electricity generation and industrial applications is expected to rise all over the world, especially in emerging economies, faster than any other primary source of energy. Natural gas is an important source of energy for electric power generation. The world's natural gas reserves by country and by region are given in Tables 1 and 2. These tables show that US, most of European countries, and middle-east oil producing countries have abundant supply of natural gas. Because of its lower carbon emission, many eastern European countries are replacing coal-fired power plants by natural gas plants. The US national energy plan calls for adding one or two new power plants weekly for the next several years. The majority of these

plants will be fired by natural gas. Government subsidies in form of income tax credits are being given mostly to natural gas industry since 1999.

The major problem associated with natural gas use is the major investment needed to liquefy it to either liquefied natural gas (LNG) or to petroleum liquid substitute. However, recent sharp increases in oil prices coupled with recent advances in gas-to-liquid (GTL) technologies are making such investment attractive. GTL fuels produce less carbon emission than conventional diesel and are compatible with existing automotive engine technologies.

In conclusion, fossil fuels were the major sources of energy needed for economic growth in the last century. They will continue to play a major role in meeting the demand for energy in the next few decades. However, their emission of carbon monoxide, sulfur dioxide, and lead are polluting the air, contaminating water and soil, damaging the environment and creating greenhouse gas buildup, and creating unhealthy environment for humans. Air pollution causes many lung diseases such as respiratory tract infection, asthma, and lung cancer. Figure 10 shows the enormous volume of carbon dioxide emissions at different regions of the world. The adverse effects of fossil fuels are becoming increasingly unacceptable and economically unaffordable.

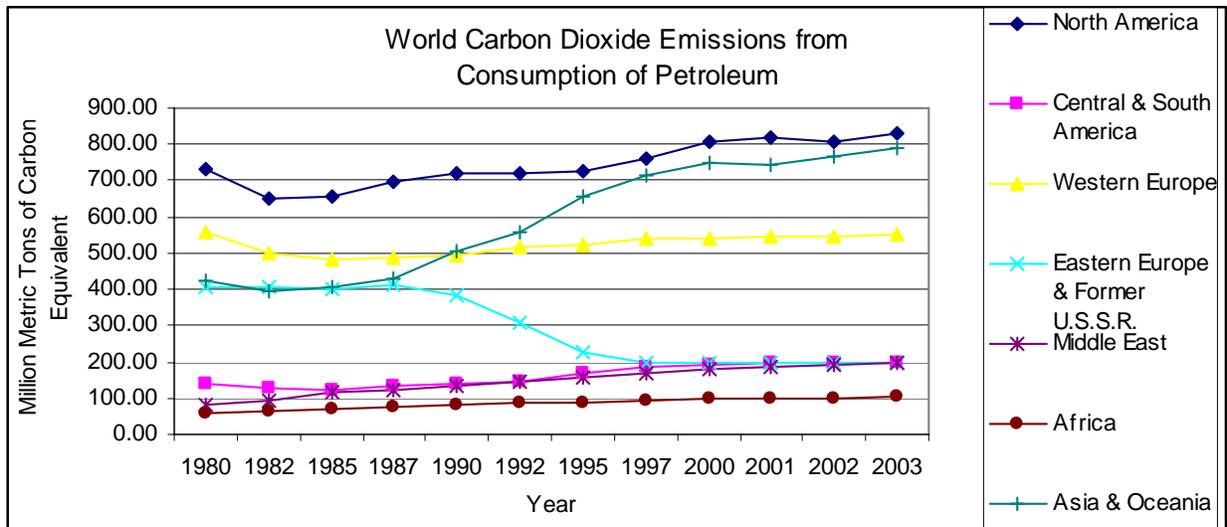


Figure 10: Carbon Dioxide emission

3. Renewable Energy

Renewable energy sources refer to those sources of energy that will never run out because nature is constantly replenishing them. These sources include solar, wind, hydro, biomass, geothermal, ocean, and hydrogen. Figure 11 shows the production of renewable energy in the US by source and Figure 12 shows the consumption of these energies by sector. In general, most of renewable energy sources produce no or little environmental problems. However, most of these sources are intermittent in nature and require large capital investment to implement. A brief overview of renewable sources of energy and their advantages and disadvantages follows.

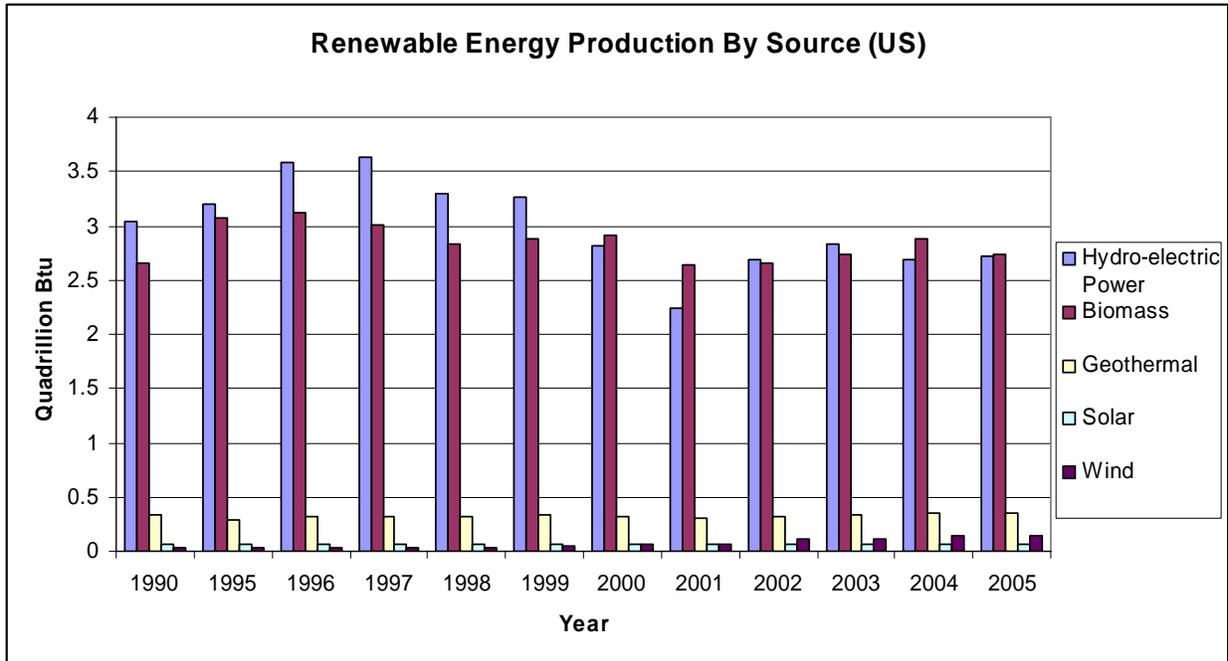


Figure 11: Renewable energy production in the US by source

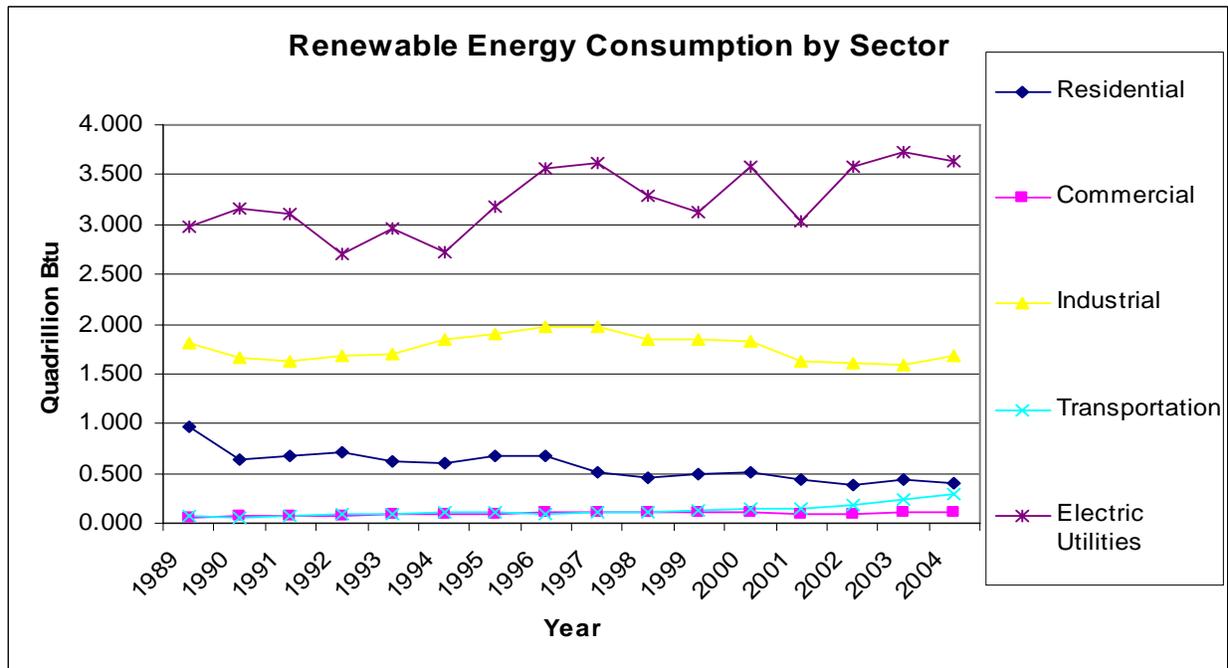


Figure 12: Renewable energy production in the US by sector

a. Solar Energy

The sun is the main source of most of renewable energies. Throughout the history, the solar energy has been used directly for lighting and heating of homes and other buildings, cloth and food drying, and for a variety of residential and commercial applications. Passive solar heating buildings in the northern regions of the world are designed with south-facing windows and with

walls and floors built of heat absorbing and retaining materials. For the past 40 years, solar energy is also used also to generate electricity. Solar cells (a.k.a. PV cells or photovoltaic) are used to convert sunlight into electricity. Solar cells are made of semiconductor materials (silicon doped with P-type or N-type materials). Solar photons absorbed by these materials increase the energy of some valence electrons and cause them to move away from their atoms. The flow of such free electrons is used to generate electricity.

Photovoltaic can help meet the demand for electricity with minimal environmental impacts. PV systems operate silently and have no exhausts or emissions. In addition, the operating costs of PV systems are negligible and their reliability is high. However, there are many problems associated with solar cells including:

- a) The cost of solar cells is in the range between \$7-12 per watt, which is high compared to other conventional sources of electricity generation. B)
- b) The efficiency of solar cells is low (in the range 5% - 15%) and decreases as the temperature of the silicon increases
- c) Large areas of land may be needed to construct a large collection areas needed for a mid-scale electricity-generating solar facility.

Solar energy is intermittent by nature and the sun does not shine whenever electricity is need. Therefore, energy storing systems composed of batteries, charge controller, DC/AC converter, grid interconnections, and other power electronics devices to store the solar energy produced during the day for night use. Sun tracking devices are often used to increase the daily amount of electricity generated by allowing PV modules to capture the most sun light throughout the day. Energy storage systems and tracking devices are expensive and require continual monitoring and maintenance.

Current research in Photovoltaic aims at improving the efficiency of the semiconductor materials through using amorphous silicates and thin film technology, and to use inexpensive manufacturing process in order to reduce the cost of solar cells production.

For commercial applications, solar concentrating systems such as parabolic-trough, power tower or dish/engine are used to generate electricity. Each of these systems uses a set of mirrors of a specific shape to concentrate the sun's heat on a pipe or a receiver containing either heat efficient material such as oil or molten salt or heat-transfer fluid that expands with heat. The heated oil or molten salt is used to boil water in a conventional steam generator to generate the steam needed to rotate large turbines, which activate electricity generators. The expanded fluid, in the dish/engine systems, produces mechanical power that runs an alternator to generate electricity. Currently, the majority of solar concentrating systems are built in federal or state run facilities that can afford the high initial capital costs of constructing these systems. The development of better and cheaper reflective materials needed for sun concentrating systems is an active area of research. The design of affordable household solar cooker, solar heater, and solar space heating and cooling systems is also an active area of research

The sun is the most important source of renewable energy for future generation. Regulatory and financial incentive programs (tax credit, utility rebates) coupled with consumer ever-increasing

demands for green power help expand the market for solar energy and reduce its production costs. The World Bank estimates that annual value of generated solar electricity worldwide will reach \$4 trillion within 30 years.

b. Wind Power

Winds are caused by the uneven heating of the atmosphere by the sun, rotation of earth around the sun, and irregularities of earth's surface. Therefore, it can be considered as a form of the ever-renewable solar energy. The propeller-like blades of wind turbines act as the wings of airplanes. Wind blows create a pocket of low-pressure air at the downwind side of a blade, which causes the turbine axis to rotate. The mechanical rotations can be used directly in tasks such as grinding wheat or pumping water, or converted into electricity.

Wind resources are expressed in wind power classes ranging from one to seven. Each wind class represents the mean speed of wind at a specified height above the ground. Available wind turbine can be used to produce wind energy form areas with wind classes 4 and above. Updates of the US wind atlas have begun in 2000 to produce accurate and high-resolution wind maps for all regions in the US. It is estimated that about 6% of the contiguous US land areas have wind classes of four and above. These areas have the potential for supplying the electricity demands of the US. However, land values in some of these areas prohibit its use for electricity generation.

Wind power is proportional to v^3 , where v is the velocity of the wind. However, the efficiency wind turbines are low and highly dependable on the actual wind speed. Wind turbines are grouped into horizontal-axis blades and vertical axis blades (Durries model). Horizontal-axis blades with either two or three blades are the most common types of wind turbines.

Wind energy has the following advantages and disadvantages:

Advantages

- Wind energy is a clean source of energy that does pollute atmosphere
- For many areas in the US, wind energy is the cheapest of renewable energy available.
- Wind farms built in farms can benefit the economy of rural areas
- It is one of the best alternatives for individual homeowners.

Disadvantages

- Cost of wind power generation is high than that of fossil fuel
- Wind energy systems requires higher initial investment than that of fossil-fueled generators
- Wind is intermittent and wind does not blow when it is needed.
- Wind is highly fluctuating source of energy and cannot be harnessed to meet timing of electricity demands. Therefore, wind energy can only be used as supplemental source in windy areas
- Wind turbines have relatively low efficiency.
- Wind energy cannot be stored unless efficient energy storage (batteries) is needed.
- Rotating blades of wind turbines are noisy and may kill some of flying birds.

c. Biomass Energy

Biomass energy is generated from three main sources: wood, waste, and Alcohol fuels. In the graph below, Alcohol fuels consists of Ethanol derived from corn, which is used primarily for transportation. Wood energy is derived from round wood and wood byproducts and is used primarily for industrial and electricity generation applications. A small portion of wood energy is derived from wood fuel and is used in residential and commercial sectors. Waste energy is derived from municipal solid waste, manufacturing waste, and burning of landfill garbage. Most of Waste energy is used in electricity generation, and the rest is used in residential and commercial sectors. Figure 13 shows biomass energy production in the US by energy type.

Biomass energy is generated from converting organic matter (agriculture crops and residue, timber industry scrap, solid waste) into energy. Biomass can be used to generate fuels as well as chemicals. In the past few years, electricity generated using biomass is comparable to get generated using hydropower. In addition, corn grain and kernels are being used to generate billions of gallons of fuel ethanol. Other agriculture products containing cellulose are also being used to generate ethanol fuels and chemicals.

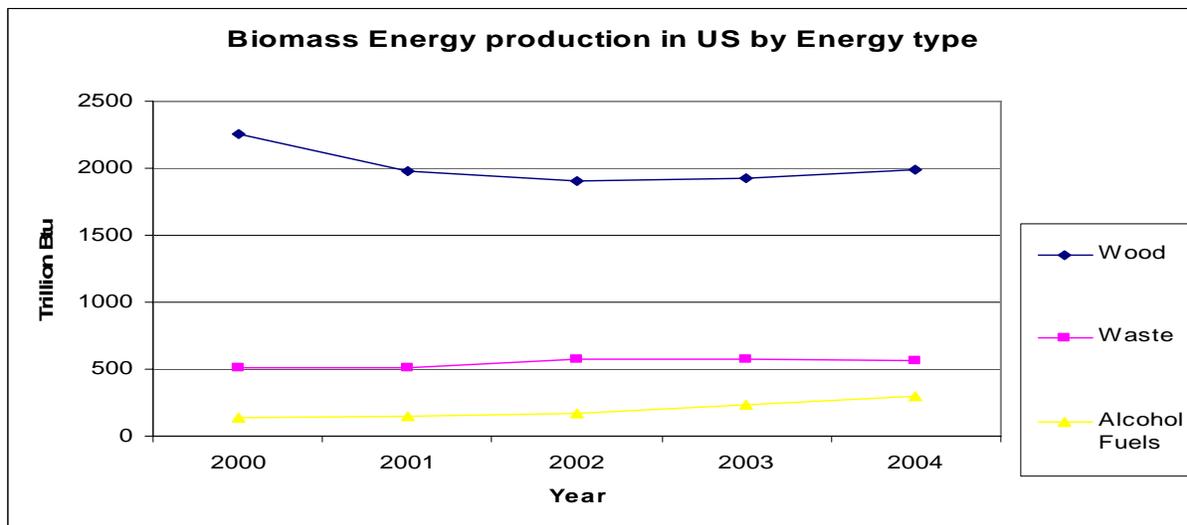


Figure 13: biomass energy production in the US by energy type

Gasification technology is also used to convert biomass into liquid or gas. By heating biomass materials with limited oxygen, biomass is gasified into “syngas”, which burns cleaner than raw biomass. Syngas is composed mainly of hydrogen and carbon monoxide and can be used to generate hydrogen for fuel cells. Heating biomass materials in the absence of oxygen produces bio-oil, which can be used to generate electricity or a variety of chemical products.

In closed tanks, microorganism (digesters) can be used decompose solid waste (sludge, cattle manure, and other types of cellulose waste) and generate biogas, a mixture of methane, carbon dioxide and traces of other gases. Biogas can be burned to generate electricity.

Biomass materials are natural products that used to generate energy through burning or converting it into fuel. However, major research is needed to improve the economic of

converting biomass into fuel. The high moisture content in some biomass materials makes it economically unfeasible to transport such materials for processing in far-away large-scale plants.

d. Hydropower

Hydropower uses the kinetic energy of flowing water to generate electricity. A conventional hydropower plant consists of a dam that is built across a river to stop the water flow and store it in a reservoir behind the dam. Therefore, the water level in the reservoir is much higher than that in front of the dam. Hydro turbines are constructed in the body of the dam. To generate electricity, water is released from the reservoir to the river in front of the dam. The kinetic energy of the flowing water is proportional to difference in water level behind and in front of the dam. The released water flows through hydro turbines and causes them to spin and generate electricity.

Hydropower has the following advantages:

- It is a clean source of energy, which does not pollute the atmosphere.
- The water cycle on earth makes it a renewable source of energy
- Through the control of water flow, electricity can be generated whenever needed
- It is one the cheapest sources of energy

Hydropower has also the following disadvantages:

- The high cost of building hydropower plants
- It alter the hydrological cycle of water, which adverse impacts on the environment
 - o It prevents the migration of fish from downstream to upstream and vice versa
 - o Altering water flow in a river can lower the level of dissolved oxygen in the water, which is harmful to riverbank habitats
 - o It degrades the water quality of the river.

The US produces about 80,000 Megawatt of electricity from hydropower resources, which is about 7% of electricity consumption. It also has about 30,000 Megawatt of undeveloped capacity. Environmental concerns are halting the construction of new hydropower facilities.

A new scheme of unconventional hydropower systems have started to emerge in the past few years. It involves the design of inexpensive Pico propeller hydro turbines that can produce a few kilowatt of power. These turbines are easy to manufacture locally in the developing countries for the use of their rural communities. More than 1000 of these systems have been installed in countries such as Nepal and Peru [8].

e. Hydrogen and Fuel Cells

Hydrogen and oxygen are the two elements of water. Electrolysis process of water is used to separate hydrogen from oxygen. Hydrogen can also be produced from a variety of other sources including biomass. Hydrogen can be burned as a chemical reaction between hydrogen and oxygen. Hydrogen burning produces water and small amount of nitrogen oxide. For use as a secondary fuel (energy carrier), it needs to be stored and transported as liquid at 20° K

($-253^{\circ}C$). As a liquid, Hydrogen has energy density per unit weight. Fuel cells electromechanically combine hydrogen and oxygen to produce electricity without combustion. Fuel cells have higher efficiencies and less noise than internal combustion engine (ICE). They also have the potential to replace ICE in all vehicles. Fuel cells have the capacity to operate also using a variety of fuels such as ethanol, methanol, and natural gas. However, major investment in research and development is needed to solve many problems associated with current fuel such as durability, reliability and cost. In addition, the majority of currently produced hydrogen is produced by steam reforming natural gas process, which pollutes the atmosphere by releasing carbon dioxide.

Fuel cell is the most active area of research in renewable energy in the US. It is developed as a replacement of internal combustion engine in vehicles, thus replacing petroleum gas with hydrogen as the fuel. Reducing dependency on foreign oil is one of the most important goals of the US energy policy. In addition, fuel cells cause much less pollution and noise than conventional internal combustion engine. A very long and detailed list of US colleges and universities with fuel cell-specific and/or research programs can be found in [9]. The list specifies the current fuel cell research activities at each of these institutions, and the list of courses offered.

Research area

- Hydrogen production technologies and costs
- Hydrogen delivery infrastructure
- Fuel cell research and development in the areas of material, performance, hydrogen storage, efficiency, reliability, durability and lifespan, cost-effectiveness, size and weight, and fabrication costs.
- Integration and control of stacks of fuel cells into reliable power systems.
- Conventional proton exchange membrane (PEM) fuel cell system development including simulation, dynamic testing, and rapid prototyping.
- High temperature PEM fuel cells
- Nanostructure design and modeling of PEM fuel cells
- Novel types of fuel cells including molten carbonate and solid oxide fuel cells.
- Commercial and military applications of fuel cell systems to accelerate its large-scale acceptance and use

e. Geothermal Energy

Geothermal energy technologies use the heat of the earth at different depth beneath the Earth's surface to heat water for direct use as heat source or to generate electricity. Geothermal heat pumps can be used almost anywhere in the US to provide heating or cooling for buildings. Deep underground reservoirs of steam can be used to generate electricity. Geothermal energy is sustainable and its production technologies produce little or no harmful emission to the atmosphere. In the US, geothermal resources (hot water reservoirs) are concentrated in the western states, Hawaii, and Alaska.

Geothermal energy research in the US is done in a very small number of universities such as Wayne State University (WSU), Oregon Institute of Technology, and some DOE-run facilities in Hawaii. The research concentrates mainly on producing geothermal maps, evaluating geothermal resources, and on improving the efficiency of heat pumps.

f. Ocean Energy

Ocean energy is a clean renewable energy that is derived from the sea such as wave energy, ocean current energy, tidal energy, ocean thermal gradient energy, and offshore wind. Ocean energy is enormous. However, most of its sources are intermittent and it requires extremely expensive infrastructure, which may cause some damage to coastal environment.

4. The role of Higher Education in Energy Management

Education plays a key role in achieving successful sustainable development at the city, urban, community, regional, and global levels. The US higher education institutions offer a variety of interdisciplinary Sustainable Future undergraduate, graduate and professional degree programs or curricula at the Certificates, Bachelor of Arts, Bachelor of Science, Master of Arts, Master of Science, and PhD levels. These programs can be divided into three categories: Planning and Management, Renewable Energy development, and Community Outreach.

The largest number of US university sustainable future programs is in the areas of planning and management. These programs aim at:

- Providing intensive treatment of planning, energy resources and development, environmental justice, ecology, public and environmental policies, and sustainable development
- Understanding the complex, interacting and dynamic relation between human actions and environmental responses at the local, regional, and global scales
- Developing and disseminating critical knowledge needed to achieve sustainable future.

The areas of emphasis of planning and management courses are:

- Urban/community/city/regional planning strategies and development
- Environmental design and planning
- Sustainable development implementation and strategies
- Environmental and public policies planning and strategies including policy advocacy, social responsibility, political ecology, sustainable development and environmental politics in the US as well as in developed and developing countries
- Environmental education including energy and society, environmental justice, environmental society and technology, pollution reduction, hazardous materials management, and water quality
- Environmental conservation and restoration with emphasis on ecological integrity, ecological economics, conservation and terrestrial ecology
- Management of sustainable community-based organizations, development sociology, land-use regulations, waste reduction, infrastructure and community design, and development practices
- Management of natural resources, conservations, and development
- Feasibility studies of sources of renewable energy.

- Modeling and analysis of energy, environment and resources
- Energy infrastructure management
- Urban design and architectures with focus on design of future home and transportation

A list of the universities with degrees or programs in planning for sustainable development can be found in [10]. A list of universities with PhD programs in planning can be found in [11].

5. The role of Higher Education in the generation of Renewable Energy

Renewable energy courses and curricula offered by colleges of engineering in the US are interdisciplinary in nature and cover all aspects of renewable energy development, generation, and infrastructure, as well as a wide array of sustainability sciences. The courses at some of these schools can be summarized as follows.

- The state of Arizona has many universities that teach graduate and undergraduate courses in the generation and storage of renewable energy. These universities include:
 - a) Arizona State University offer classes in the design of photovoltaic systems with different configurations including stand-alone and integrated (grid-connected) solar systems and hybrid systems. These courses also discuss fuel cell and environment sustainability.
 - b) Northern Arizona University offer courses in solar energy analysis, design, and applications, solar cell materials and fabrication, solar radiation, thermal energy storage and application, economics of solar systems, energy and ecology, social and economic impacts of renewable energy on human race. They also discuss conventional and renewable energy sources.
 - c) The University of Arizona offer classes in computer energy analysis. Modeling, simulation, and design of green buildings and passive solar systems are also taught.
- Virginia Polytechnic Institute and State University has a center for automotive fuel cell systems. In addition to a wide variety of fuel cell technology and systems, they also teach courses at all academic levels in alternative energy systems, environmental systems, and energy infrastructure management.
- Wayne State University (WSU) is operating a national Biofuel Energy lab for research in biodiesel production, and development of biodiesel systems. WSU offers a Master's degree program in alternative energy technology
- St. Clair County Community College offers a one-year alternative energy certificate program. The program offer courses in the design and maintenance of alternative energy systems including solar, wind, and passive solar systems. St. Clair County Community College is planning a two-year alternative energy associate degree program.
- The University of Massachusetts (UMass) at Lowell offers a Master of Science in energy engineering with emphasis on solar energy generation and applications. The renewable energy research laboratory (RERL) at the University of Massachusetts (UMass) at Amherst is a renewable energy technologies research and educational facility focusing on wind energy and hybrid power systems.
- Massachusetts Institute of Technology (MIT) offers an interdisciplinary Master's degree program in technology and policy. The curriculum combines technical courses in renewable energy fundamentals and technology, and implementation policies and social sciences such as economics, law, politics, environment, and management.

- The State University at New York (SUNY) is planning to offer a four-year bachelor degree in alternative and renewable energy starting at the fall 2006 semester. The curriculum is expected to cover all forms of alternative energy technologies.
- The department of Mechanical Engineering at Lawrence Technological University at Michigan is offering a course in alternative energy fundamentals that evaluates alternative and sustainable energy sources to determine what is practical for large-scale development and implementation.
- The Energy and resources group at the University of California at Berkeley offers an interdisciplinary graduate research and teaching program at the MA, MS, and PhD academic levels. The program offer engineering courses in energy resources and development and a variety of sustainability-related courses in the areas of environment, biological diversity, economics public policy and social sciences. The group operates the Renewable and Appropriate Energy Laboratory (RAEL), which is one of the leading sustainability research facilities at the US.
- The Humboldt State University offers a Bachelor of Science degree with a major in environmental resources engineering. The program offers a variety of sustainability-related courses including energy resources engineering, which focuses on solar energy development and application, passive solar systems design, green building design, and fuel cell technology.
- San Juan community college in New Mexico offers a renewable energy associate degree program of applied science and a one-year certificate program. Both programs focus on Photovoltaic System Design and Installation
- The Technology Department at Appalachian State University in North Carolina offers a Bachelor's degree in Appropriate Technology. The program curriculum contains courses in renewable energy technologies, design and construction of energy efficient solar building, and technology and society.
- The Renewable Aviation Fuels Development Center (RAFDC) at Baylor University assists pilots in converting their aircrafts to run on renewable fuels. The Environmental department studies at Baylor offers a wide variety of environmental, appropriate technology and sustainability-related courses
- Many universities in the state of Texas offer undergraduate and graduate courses in a variety of alternative energy sources. These universities include:
 - a) The Center of Energy and Mineral Resources at Texas A&M University offer courses and research in biomass energy.
 - b) Texas Southern University offers courses and research in solar and wind energies.
 - c) The Department of Civil Engineering at Texas Tech offers a graduate program specialized in wind engineering
 - d) The Mechanical Engineering Department at the University of Texas at Austin offers a graduate program in solar energy systems and design. Current research activities include the development of Texas Solar Radiation Data Base. The University of Texas at Austin sponsors the efforts of the Longhorn Solar-Vehicle Team to develop solar-electric transportation.
 - e) The Department of Engineering Technology at the University of Texas at Brownsville plans a program in solar systems, small-scale wind and other renewable sources of energy.

- f) The Alternate Energy Institute (AIE) at West Texas A&M University offers a renewable energy program specialized in wind, and solar energy systems design including passive and thermal applications of solar energy systems.
- The Department of Marine and Environmental Systems at Florida Institute of Technology offer undergraduate and graduate courses in renewable energy and the environment. These courses teach the fundamentals of all sources of renewable energy, renewable energy generation, management, and application.
- The Department of Electrical Engineering at North Dakota University offer undergraduate and graduate courses in renewable energy systems. These course focus on the development, applications, and economics of wind, solar, and fuel cell energy systems.
- The Department of Civil and Environmental Engineering at Stanford University offers degree options in Atmosphere and Energy at the BS, MS, and PhD levels. The courses focus on the impacts of fossil fuel consumption on the environment, impacts of wind and solar radiation on the atmosphere, and energy efficient building designs
- Oregon Institute of technology is the only academic institute that offers a Bachelor of Science in Renewable Energy Systems. The program curriculum provides the fundamental of renewable energy and their impacts on the society, renewable energy generation and application of renewable energy, economics of various types of renewable energy and their suitability for large-scale-use, and fuel cell technology. The program also discusses renewable-energy transportation systems, and zero net energy buildings.

The areas of emphasis of these courses can be summarized as follows:

a) Energy

- Human energy needs and energy types
- Energy conservation and efficiency
- The effects of producing and utilizing energy on local environmental conditions and global climate
- The dynamic interactions between technology, environment, economics, and sociopolitical of energy supply and use at the regional, national, and international levels
- Typical energy consumption patterns now and future trends
- Relative and total costs of all sources of energy

b) Conventional Energy Sources (Oil, Coal, Natural gas, Hydro, and Nuclear)

- Energy infrastructure systems
- Energy generation
- Coal, oil and natural gas reserves and advanced extraction techniques
 - o Basics of petroleum economy: oil production, oil brands, oil-based industries, fuel and carbon emission, consumption by energy sector, future availability and prices
 - o Basics of Natural gas: dry and liquid gases, production, transportation, reserve, pollution, consumption by energy sector, future availability and prices
 - o Basics of Coal: coal types, production, transportation, reserve, pollution, consumption by energy sector, future availability and prices
- Limitation exist in terms of extracting useable energy
- Role of electricity generated using fossil or nuclear fuel
- The social and environmental impacts of using fossil and nuclear fuels
 - o Climate changes

- Pollution
 - Evaluate the total cost and economic consequence of using fossil and nuclear fuels
 - Emission control in electric utility industry
- c) Renewable Energy and Sustainability
- Renewable energy and the concept of sustainability
 - Feasibility studies of the practicality of use of each form of renewable energy starting from individual homeowner level and up to national level.
 - Obstacles associated with wide-spread use of alternative energy
 - Environmental, social, and economical impacts of renewable energy sources
 - Fundamentals of renewable energy sources (solar, wind, hydro, biomass, geothermal, ocean, and hydrogen) and their advantages and disadvantages
 - Environmental, and social impacts of renewable energy
 - The role of public policies in improving the economics of renewable energy
 - Renewable energy conversion systems design, control, and characteristics
 - Economics of distributed energy systems
 - Energy storage technologies and systems
 - The cost of required infrastructure to deliver a certain amount of energy using various renewable energy sources
- d) Solar and Thermal Energy
- Solar energy resources and solar maps
 - Photovoltaic systems
 - Fundamental of photovoltaic energy conversion systems
 - Principles of operations: collection, instrumentation
 - Design of efficient semiconductor solar cell devices
 - Evaluation of the viability of various photovoltaic systems
 - Economic of solar electricity vs. conventional electricity
 - Thermal systems
 - Solar energy concentrators
 - Passive solar systems
 - Solar cooker
 - Solar water heater
 - Solar food dryer
 - Aero derivative turbines
 - Storage of solar and thermal energies
- e) Wind Energy
- Wind energy resources, distribution and wind maps
 - Wind power production: low and high wind turbine systems, and turbine designs
 - Wind energy conversion systems
 - Wind farms and land use
- f) Hydro power
- Typical hydropower facilities

- Adverse effects of constructing dams on fish migration, water quality, and riverside habitat
- Hydro turbine designs
- Non-Conventional Pico hydro turbines design and use

g) Biomass

- Biomass Resources
- Bio-sources of fuel and their energy content
- Energy Extraction Methods
 - Gasification
 - Prolysis
 - Anaerobic digestion
 - Biogas
 - Land fill
 - fermentation
- Bioenergy
 - Availability, economics
- Biofuel

g) Hydrogen

- Fuel cells
 - Basic science of fuel cells, their types and operation
 - Fuel reforming methods
 - Fuel cell energy storage and conversion systems, and electronic controls
- Hydrogen generation
 - Hydrogen production systems, and handling and storage
 - Electrolyzers
- Hydrogen economy
 - Advantages of hydrogen power and its impact on carbon emission
- Geothermal
 - Geothermal reservoirs
 - objective evaluation of geothermal power
- Ocean
 - Tide and wave energy technologies and their viabilities
 - Economic of tide and wave energy generation

Green Architecture

- Green building designs
- Passive heating/cooling systems
- Zero net energy building designs

Energy Modeling

- Sophisticated modeling of energy sources and systems

Transportation

- Hybrid and all electric vehicles
- Fuel technologies and economics
- Automotive technologies and fuel efficiency

Hybrid systems

- Wind and diesel
- PV and diesel
- Wind, PV, and diesel
- Integration of various technologies into a system to provide continuous uninterrupted power system

Public Policies

- Effects of public policies on renewable energy generation systems development
- Incorporation of environmental concern issues in public policy debates and environmental regulation laws
- Energy industry and its impacts on energy supply chain
- Effects of tax incentives on wide-spread use of renewable energy
- Structural and strategic changes affecting energy industry and their impacts on consumers

6. Community Outreach Programs

Many universities have initiated outreach programs to educate the public in their communities understand the economic and environmental implications of relying on fossil fuel and the need for renewable energy sources. These programs include short courses that teach the fundamentals of renewable energy sources, design and installation of various renewable energy systems and green architecture designs. Examples of these programs follow:

- The University of Vermont has initiated a series of seminars titled “Exploring Alternative Energy”. These seminars focus on solar, wind, micro-hydro, and hybrid car technology.
- The national Alternative Fuels Training Consortium headed by West Virginia University has 26 national training centers that provide training in the use of alternative fuel, and alternative fuel vehicles.
- The Wisconsin K-12 Energy Education Program (KEEP) located on the University of Wisconsin-Stevens Point campus teaches K-12 educators about renewable energy and the need to encourage energy efficiency and use of renewable energy. The program also initiates, facilitates, and disseminate information and curriculum materials about the implementation and evaluation of energy programs within Wisconsin schools.
- The University of Massachusetts (UMass) at Lowell integrated service learning in a variety of engineering courses. The service learning components of these courses include house thermal design, design of energy efficient houses and solar systems, and design of solar hot water and crop drying systems.
- The University of North Carolina offers a non-credit Renewable Energy Technologies Diploma programs with weeklong courses. These courses are geared toward electrical and civil contractors, plumbers, and other individuals who want to gain a higher level of training in the use and installation of alternative energy systems.

In addition, many universities adopt green energy initiatives that encourage the design of green buildings, energy conservation, and green power purchases. These schools include Carnegie Mellon University, Harvard University, Penn State, University of California at San Diego, University of Colorado, University of Oregon, University of Vermont, etc. Currently, Oregon Institute of Technology is the only geothermally heated university campus in the US.

7. Conclusion

This paper outlined some of the major initiatives of US universities in the area of future sustainability. These initiatives include technology, management, marketing, and public policy components. The technology aspects of the sustainability initiative include the development of renewable energy sources and systems, and educating professionals in the design, manufacturing, and maintenance of renewable energy systems as outlined in section 5. In the area of Management, universities have included a variety of programs in planning and management of sustainable communities at various levels as outlined in section 4. The marketing aspects of the sustainability initiatives include educating public about environment, renewable energy fundamentals, and renewable energy systems. It also includes major efforts to improve the efficiency and reduce the cost of manufacturing these systems. Finally, Universities have added many courses in the area of energy policies and the role of government at various levels and non-government organization in promoting sustainability concepts including the use of more environment-friendlier forms of energy such as those generated using renewable energy sources.

Renewable energy sources are expected to be the major sources on energy for future generation. However, no one can assume that these sources will be able to meet exponential growth of energy demands in the same way as fossil fuels in general and petroleum products in particular did since last century. To attain energy sustainability, major shift in the way we produce and consume energy are needed. For the reasons outlined earlier, universities are the natural candidate to lead such changes in the society.

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