Energy Choices

A Guide to Facts and Perspectives

ASME
SETTING THE STANDARD

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ACKNOWLEDGEMENTS

This book was produced and edited by Keith Thayer and Phil Grossweiler. It was sponsored by the ASME Committee of Past Presidents and the ASME Energy Committee chaired by Ken Kok.

Thanks to all the contributing authors who are listed, thanks to the many reviewers and special thanks to Lara Crawford for her assistance in compiling this book.

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The American Society of Mechanical Engineers (ASME) believes the societal debate over energy choices should be conducted by a knowledgeable citizenry. To that end, ASME underwrote and has made available this *Energy Choices – A Guide to Facts & Perspectives* booklet to help increase awareness and understanding of the potentials and limitations of the energy sources described in this booklet.

1.0 INTRODUCTION

This Energy Choices fact book is intended to supply the reader with basic information on sources of energy. It attempts to describe each source of energy, identify the infrastructure needed for its use, identify the positives and negatives associated with each source of energy, comment on impacts and potential future contributions of the respective sources, and suggest references for further study.

John Maynard Keynes once noted "It is **better** to be roughly **right** than precisely wrong." Some may want to debate the energy perspectives or absolute values of the numbers in this booklet. That's not the point. Individual readers are encouraged to take a close look at the facts in context and then form their own unique but informed perspectives and opinions. After all, as the late Senator Daniel P. Moynihan once said "You are entitled to your own opinion. You're just not entitled to your own facts".

This booklet is intended to give the reader some information to better understand the complexities of the energy world and its ongoing evolution. It provides a context for our total energy future – as we know it today. *Energy Choices: A Guide to Facts and Perspectives* is the result of the efforts of numerous members and associates of the ASME who have unique professional and technical backgrounds that are directly relevant to this undertaking. Their inputs are intended to provide an overview of energy issues at a relatively non-technical level. It is directed at the general public and other stakeholders who want more knowledge of energy sources, energy conversion, and energy end use and their challenges and limitations. While we hope this book serves as an information tool that will be utilized for educational purposes, it is also the sincere hope of the contributors to this document that it will be used to create informed opinions and perspectives on energy choices.

Energy Supply Projections

Projections of future energy supplies are from national and internationally recognized sources. These sources cited below include:

- International Energy Agency (IEA)
- United States Client Climate Change Science Program (CCSP). The CCSP results summarized below include analyses of:
  - MIT,
  - Stanford / Electric Power Research Institute (EPRI), and
  - Pacific Northwest National Lab / University of Maryland.

These projections are based, in part, on complex economic and energy systems models developed by each of the respective sources cited for predictions of future energy supplies. It is beyond the scope of this document to provide details on how each of these sources developed their predictions. Refer to the text boxes in the sections below for some background on these sources. Readers who are interested in more detail on how the various projections were developed are encouraged to go to the websites of the respective sources of future energy estimates.

The variations in the projections accent the impacts of the "unknowns".

1.1 ENERGY PROJECTIONS – INTERNATIONAL ENERGY AGENCY

About the IEA

The International Energy Agency (IEA) is an intergovernmental organization which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973–74, the IEA's initial role was to coordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries.

Source: http://www.iea.org/

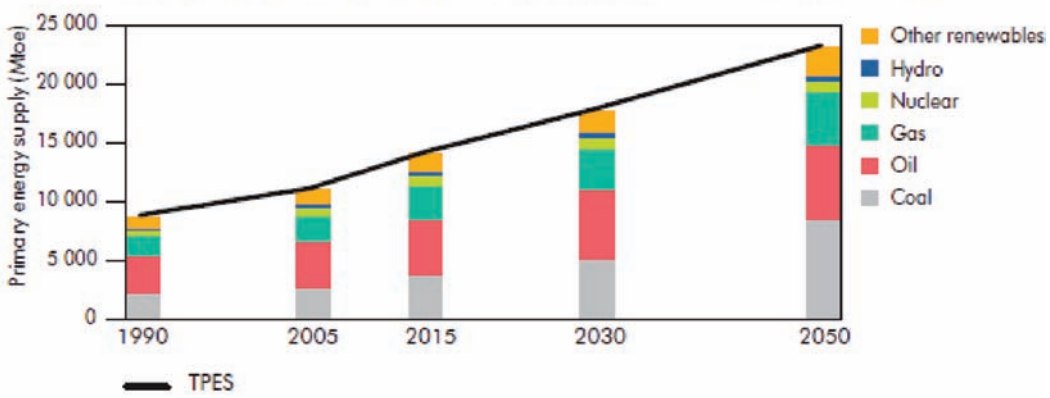
The "baseline" scenario is one in which the world energy supply continues under a "business as usual" baseline scenario in which there are no attempts to change current policies regarding greenhouse gas emissions or to develop new technologies in order to reduce greenhouse gas emissions. The following figure is taken from the 2007 IEA report Energy Technologies and Perspectives-Strategies to 2050. This shows IEA projections of future fuel supplies, by primary energy complement, in the years out to 2050.

The IEA Report developed scenarios and assessments for cases in which the United States and world economies implement actions to reduce greenhouse gas emissions. The following figure provides a comparison of IEA's estimates of future energy supplies in the year 2050 under three scenarios:

- The "Business As Usual" case (Baseline 2050)
- The "ACT Map" under which worldwide greenhouse gas emissions are limited to the emission levels in 2005 and using only existing technologies.
- The "BLUE Map" scenario is a case under which worldwide greenhouse gas emissions are reduced to 50 percent of current levels in the year 2050. This scenario also identifies major new energy technologies needed to achieve this level of CO_2 emission reductions.

Coal, oil, gas, and nuclear are well known sources of energy. The categories for biomass and "other renewables" are not as well known and several energy supplies in these categories are still under development.

Figure 2.37 ▶ World total primary energy supply by fuel in the Baseline scenario

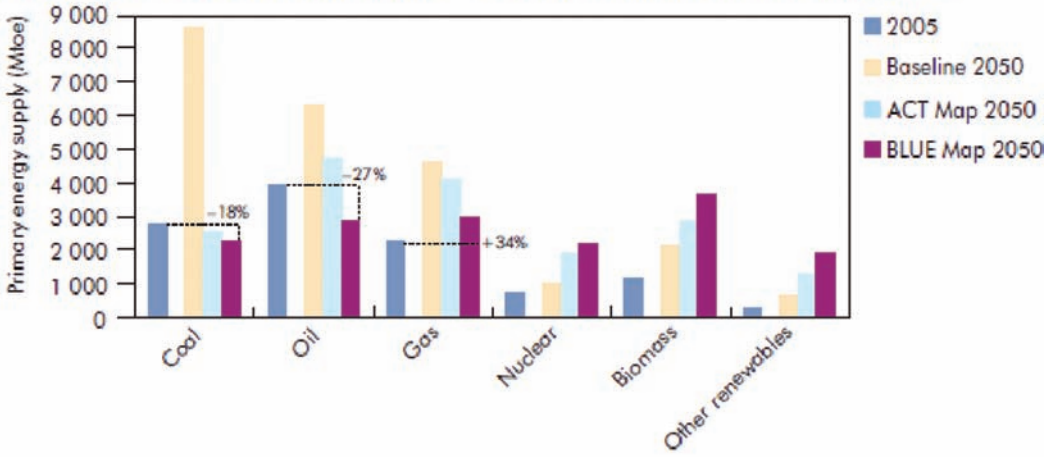


Key point

Primary energy use more than doubles between 2005 and 2050, with a very high reliance on coal.

Note: Energy Supply and Use are used interchangeably in the figure above.

Figure 2.38 ▶ World fuel supply for Baseline, ACT Map and BLUE Map, 2050

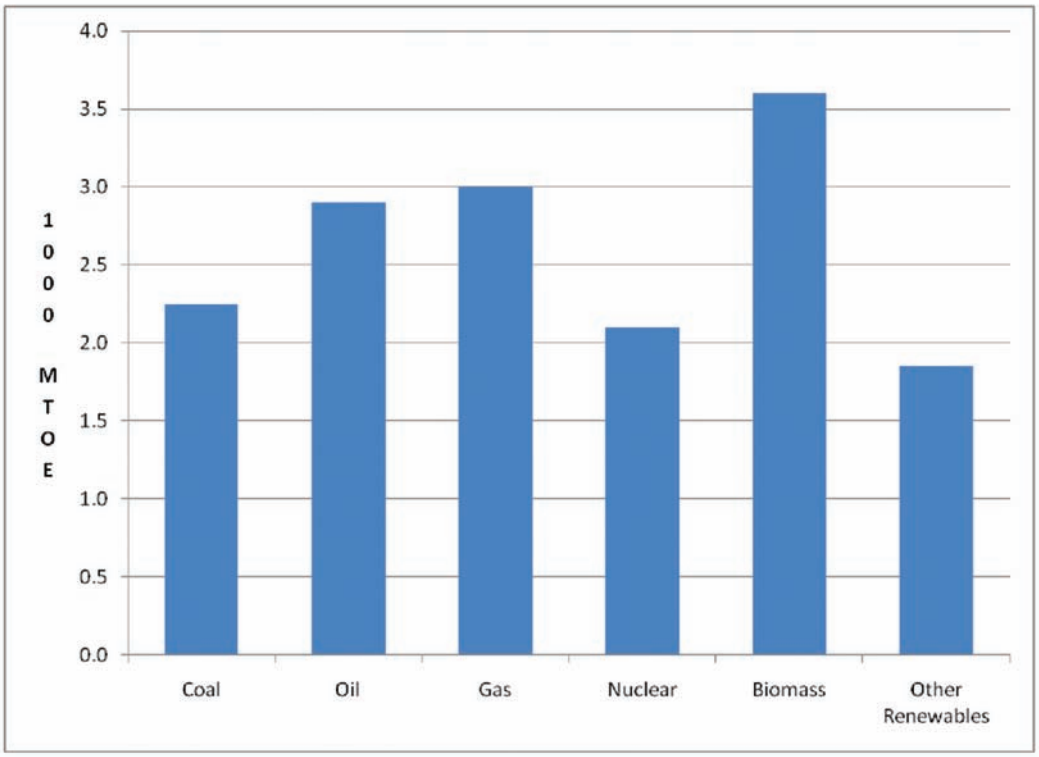


Key point

Fossil fuels continue to play a key role in the ACT Map and BLUE Map scenarios.

Note: The 2005 bars in the plot above refer to the "Business As Usual" case.

International Energy Agency-Blue Map Scenario
Projected Energy Supplies Year 2050



Notes: The above figure was derived from figure 2.38 "World Fuel Supply for Blue Map Scenario, 2050". The energy units in this figure are "million times oil equivalent".

Biomass includes the broad category of organic materials grown or harvested for energy use. This category includes sources such as corn or sugar-based ethanol, cellulosic ethanol, bio diesels, and waste to energy power generation plants.

The "other renewables" category includes energy supplies such as conventional hydropower, geothermal, wind energy, tidal, and solar.

Assuming the world moves forward with the Blue Map Scenario (reducing greenhouse gases emissions in 2050 by 50 percent of 2005 levels)

- Coal usage drops 18 percent relative to 2005 levels,
- Oil usage drops 27 percent relative to 2005 levels,
- Natural gas increases 34 percent above 2005 levels,
- Nuclear power increases 250 percent above 2005 levels, more than doubles,
- Biomass increases approximately 300 percent above 2005 levels,
- Other renewables, including hydropower, wind, and solar, increase approximately 800 percent above 2005 levels.

The following figure shows the relative contribution of each major fuel supply in the year 2050 under the IEA Blue Map Scenario

Energy conversion tables are readily available to convert these values to other energy units. One excellent source for energy conversions is available at the U.S. Department of Energy, Energy Information Administration at the following web site:

http://tonto.eia.doe.gov/energyexplained/

The key point in this figure is to see the relative contributions of the key energy supplies for the IEA predictions.

1.2 ENERGY PROJECTIONS – U.S. CLIMATE CHANGE SCIENCE PROGRAM

The energy projections shown below were derived from a report published by the United States Global Change Research Program (USGCRP) [formerly the U.S. Climate Change Science Program (CCSP)].

> The **United States Global Change Research Program (USGCRP)** integrates federal research on climate and global change, as sponsored by thirteen federal agencies and overseen by the Office of Science and Technology Policy, the Council on Environmental Quality, the National Economic Council and the Office of Management and Budget.
>
> Source: http://www.globalchange.gov/.

These projections were developed independently by:

- Stanford University / Electric Power Research Institute
- Massachusetts Institute of Technology Joint Program on the Science and Policy of Global Change
- Partnership - Pacific Northwest National Laboratory / University of Maryland

There is a wide variation in these projections of future energy supplies.

These projections below reflect the "most aggressive" emission reduction scenarios considered in the CCSP and correspond to CO_2 atmospheric concentration targets of approximately 450 ppm (in year 2100). The pre-industrial age concentration of CO_2 in the atmosphere, before the world began consuming large amounts of carbon-based fossil fuels, was approximately 278 ppm and the CO_2 concentration in 1998 was approximately 365 ppm.

The energy categories used in each of the analyses below include the following components:

Efficiency. All analyses started with a "business as usual" estimate of total energy usage. Efficiency (automobile fuel economy standards, appliance efficiency standards, higher building efficiency, improved power plant efficiency etc.) reduces the total energy supply requirements from all other sources.

Non-biomass renewable. This includes energy supplies such as conventional hydropower, geothermal, wind energy, and solar.

Biomass. This includes the broad category of organic materials grown or harvested for energy use. Corn or sugar-based ethanol, cellulosic ethanol, bio diesels, and waste to energy power generation plants are in this category.

Coal with Carbon Capture and Sequestration (CCS). CCS is the combination of technologies which removes CO_2 from the exhaust of coal fired power plants and injects the CO_2 into geologic formations underground to achieve long term sequestering of the CO_2 thereby preventing CO_2 discharge into the atmosphere.

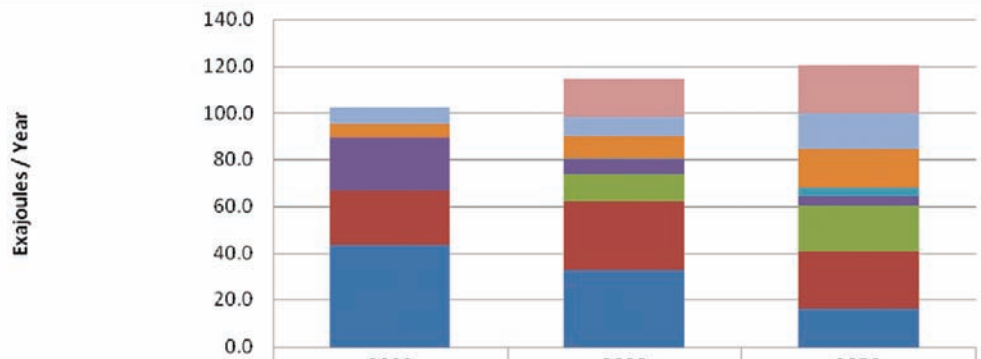
Nuclear. Power generated from nuclear fission reactors.

The reader is encouraged to review these projections to develop personal perspectives on potential future energy supplies based on the Stanford/ Electric Power Research Institute analyses.

Potential key observations include:

- The efficiency component reflects the amount of energy saved relative to a "business as usual" scenario.The totals of all energy supplies, including efficiency, show the amount of supply, which will be required if the United States does not implement any efficiency savings.
- Oil and natural gas drop 40 percent relative to current usage (based on 2000 level), but still provide approximately 40 percent of total energy supply in the year 2050 (after reduction from efficiency).
- Coal increases 4 percent from year 2000 current levels, but this is possible only with successful application of carbon capture and sequestration. Coal supplies 24 percent of total energy in 2050.
- Nuclear power doubles relative to year 2000 supply.

Stanford University/Electric Power Research Institute



	2000	2030	2050
Efficiency	0.0	16.5	20.6
Nuclear	7.2	8.1	15.4
Non Biomass Renewables	5.5	9.6	16.6
Biomass	0.0	0.5	3.2
Coal w CCS	22.8	6.0	4.2
Coal w/o CCS	0.0	11.8	19.6
Natural Gas	23.5	29.7	24.9
Oil	43.3	32.5	15.9

- Non-biomass renewables which include wind and solar triple from 2000 year levels, but provide only a 17 percentage of energy supply in 2050.
- Biomass supplies only 3 percent of supply in 2050.

Energy units, quoted by various sources can be complex and confusing. These estimates use the energy term "exajoules".

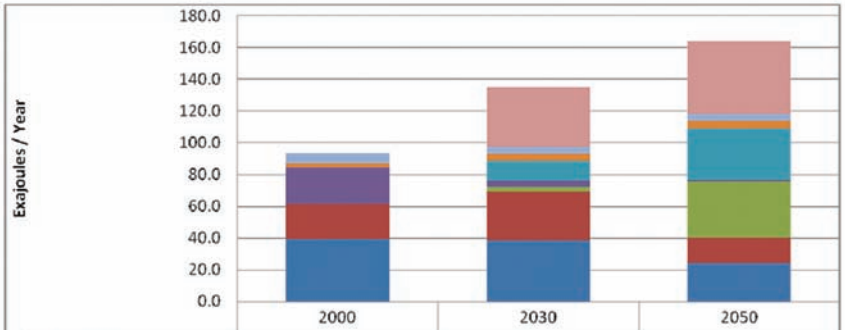
An exajoule is defined as $1*10^{18}$ BTUs.

An exajoule is approximately equal to 1 quadrillion BTU ($1*10^{15}$). Many of the reports on U.S. energy consumption use the unit quadrillion BTUs. Today, the U.S. uses approximately 100 quadrillion BTUs.

- Efficiency accounts for 28 percent of future energy supply.
- Nuclear supply drops by one third. MIT analyses assume that political opposition will prevent any expansion of nuclear power.
- Coal increases 60 percent above year 2000 levels and supplies 30 percent of total energy supply in 2050, but this is possible only with carbon capture and sequestration.
- Non-biomass renewables which include wind and solar double from 2000 year levels, but provide only a 4 percent of future energy supply.

Potential key observations from a review of the Pacific Northwest National Laboratory and University of Maryland Partnership analyses include:

Integrated Global Systems Model (IGSM)
Massachusetts Institute of Technology Joint Program on the Science and Policy of Global Change

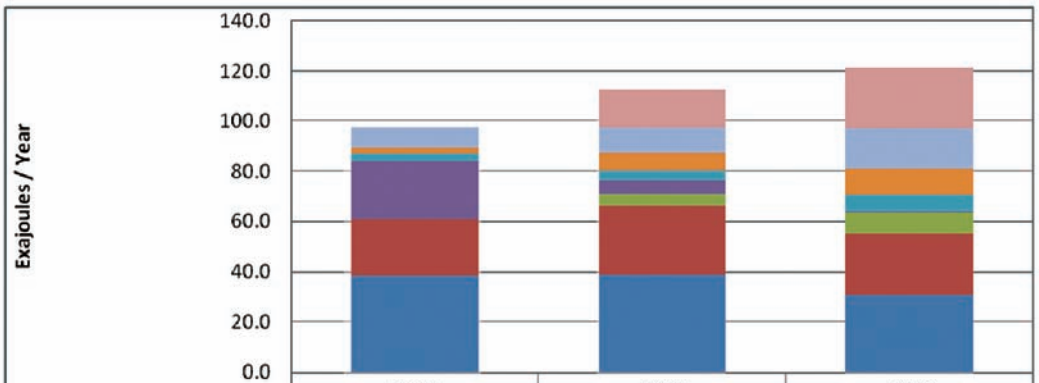


	2000	2030	2050
Efficiency	0.0	38.1	46.2
Nuclear	6.2	3.9	4.3
Non Biomass Renewables	2.6	4.3	5.0
Biomass	0.0	12.8	32.6
Coal w CCS	22.9	3.4	0.6
Coal w/o CCS	0.0	3.5	35.7
Natural Gas	22.2	30.5	15.8
Oil	39.4	38.6	24.4

Potential key observations from a review of the MIT analyses include:

- MIT forecasts a much higher total "business as usual" energy growth (164 exajoules/year versus 124 for the Stanford analysis) and also shows a much higher efficiency.
- Oil and gas drop 35 percent from year 2000 levels but still continue to provide 35 percent of energy supply (after adjustment for efficiency) in year 2050.
- Oil and natural gas usage in year 2050 drops only 10 percent relative to year 2000 usage and supplies approximately 57 percent of total energy supply (after adjustment for efficiency) in 2050.
- Coal drops 60 percent relative to current levels, but this is possible only with successful application of carbon capture and sequestration.
- Nuclear power doubles in order to make up for the reduced use of coal and contributes 16 percent of total energy supply.
- Non-biomass renewables which include wind and solar increase 300 percent from 2000 year

Joint Global Change Research Institute
Partnership-Pacific Northwest National Laboratory and
University of Maryland

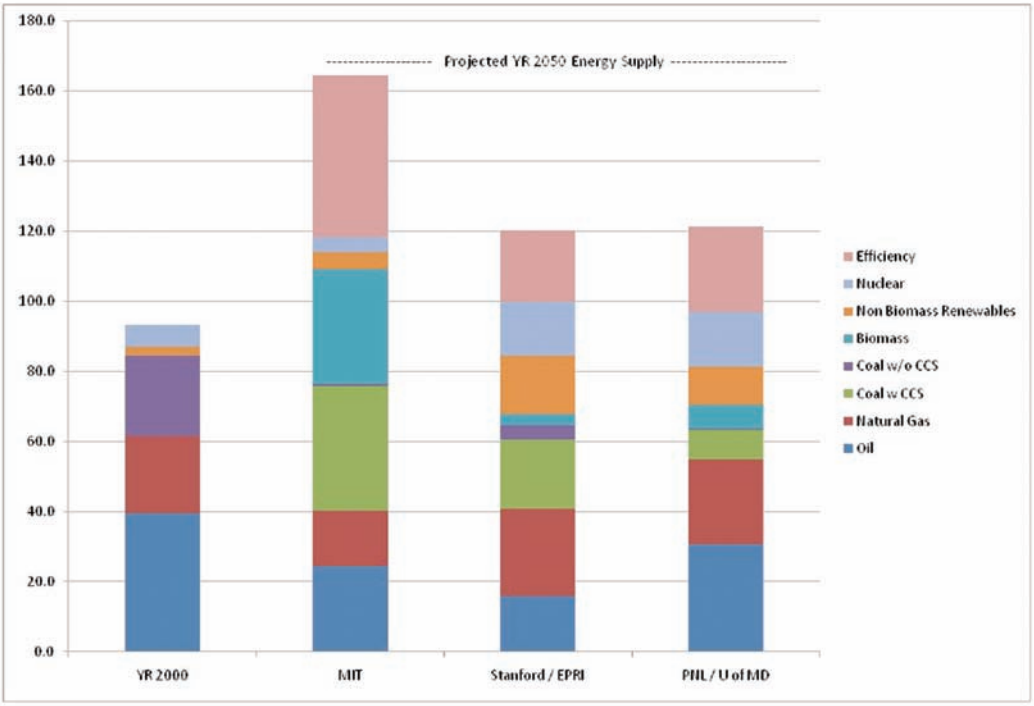


	2000	2030	2050
Efficiency	0.0	15.2	24.6
Nuclear	7.8	10.1	15.7
Non Biomass Renewables	2.7	6.9	10.7
Biomass	3.1	3.9	6.7
Coal w CCS	22.9	5.4	0.3
Coal w/o CCS	0.0	4.8	8.6
Natural Gas	22.7	27.8	24.3
Oil	38.3	38.7	30.6

levels and provide 11 percent of future energy supply.

- Biomass doubles from year 2000 levels and provides 7 percent of energy supply in year 2050.

The figure below provides a direct comparison of the CCSP assessments of projected energy supplies for the year 2050.



2.0 ENERGY SOURCES

Energy is available from many materials and systems. This section describes the key types of energy sources, which today, and in the future, will supply the energy needs of the United States and the entire world.

2.1 FOSSIL FUELS

Fossil fuels are fuels formed over geologic time by decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 500 million years. Fossil fuels contain high percentages of carbon, in the case of coal, and both carbon and hydrogen in petroleum based fuel sources.

2.1.1 COAL

Samuel C. Quigley, Intermountain Electronics, Inc.

Coal is a sedimentary rock formed from the decaying organic matter over geological time. It is one of the most important and prodigious fossil fuels. The various types of coals are designated by heating value starting with lignite, the youngest, having a heating value between 6000 to 8000 BTU/pound as well as high moisture content. Next are the bituminous coals with a heating value between 9000 and 15,000 BTU/pound and finally anthracite with a heating value between 14,000 and 15,000 BTU/pound. All coals contain some ash which is vaporized during combustion to cause undesirable emissions or slag that can foul the combustion chamber. Coal makes up 95 percent of our fossil fuel reserves in the United States.

In the U.S., 65 percent of the 1.2 billion tons of coal produced annually is produced by surface mining methods from mechanized mines using large machinery including trucks, hydraulic shovels and draglines. All surface and underground coal mining is subject to complete reclamation as required by the U.S. government under The Surface Mine Control and Reclamation Act. Underground mining methods including long wall and continuous mining that are used to produce 35 percent of the U.S. annual production. Coal that is produced from these surface and underground mines is shipped by automated trains or "unit trains" to power stations. At the power station the coal is then crushed, pulverized and burned in large boilers to generate electricity. Over 92 percent of the coal mined in the U.S. is used to generate electricity and 51 percent of the electricity produced in the U.S. is generated by coal. Coal is also an important fuel for production of electrical energy worldwide with emerging economies such as China and India relying almost entirely on coal for electrical generation. The burning of coal for the production of electricity is growing on a worldwide basis.

Advantages: Coal is the lowest cost fuel for the production of energy in the U.S. Coal is plentiful, the U.S. controls 24 percent of the known world resource, and the infrastructure is in place to use it efficiently. Technology and research are actively pursuing ways to use coal more effectively to reduce emissions and pollution. Coal Gasification, CO_2 Sequestration, Coal to Liquids and improved scrubbing are some of the topics being researched and developed. Coal is also used as a raw material for the production of some chemicals and medicines.

Disadvantages: Coal burning contributes to greenhouse gases and other types of air pollution. New pollution control technology is required to improve the acceptance of coal as a fuel for the future. This includes improved approaches for solid waste (slag and ash) disposal.

Prognosis: Coal will be a major factor in the energy supply system for the foreseeable future. Technology will mitigate many of the negative aspects associated with the use of coal.

Additional Information Sources: NRCCE (National Research Center for Coal and Energy) Rocky Mountain Coal Mining Institute, American Coal Council and National Mining Association.

2.1.2 COAL FIRED POWER PLANTS

Conrad M. Ladd, P.E., Senior Management Consultants, Inc., and Joseph A. Falcon, P.E.. J.A. Falcon & Associates

Description: The stored energy of coal is converted to electricity in coal fired power plants (CFP) for transmission to all power customers. Coal is fired in large boilers to produce high pressure, high temperature steam which is fed to a conventional steam turbine generator for the production of electricity.

While coal-fired plants today meet present emission standards the advent of climate change criteria and stricter emission standards, will force these and future plants to meet much more highly regulated requirements. This will have a direct impact on the capital and operating costs of future CFP.

Currently, the CFP supply 50 percent of the electric power requirements of the nation. They operate at low cost and serve as base load (24/7) units with an off-peak power cost of 1-2c/kwh.

Where Found: CFP are located near cities and often close to coal mines. Coal resources in all sections of the country are adequate for more than a century.

Infrastructure: Coal mining and transportation infrastructure is in place and is readily expandable to meet future needs. The nation is more than self sufficient in coal; there is no need to import any. The infrastructure for new coal fired power plants is in place domestically.

Positive Aspects: CFP have proven to be a reliable source of base load power. New CFP will operate at higher efficiency than current plants with the caveat as noted in the following section. These plants can be located near load centers, transmission grids, and coal mines and at other locations to best suit the particular situation. The high reliability of these plants provides stability to transmission systems. CFP have powered the U.S. economy for over a century.

Negative Aspects: CFP emit carbon dioxide CO_2, a greenhouse gas, and over time increases its atmospheric content. Current proposed legislation would require reduced CO_2 emissions and impose a "cap-and-trade" requirement on such emissions. In addition, it is being proposed that carbon capture and sequestration (CCS) take place. If all of this is legislated, efficiency and economics of CFP may become greatly impacted. In addition, the uncertainty of climate change makes the financing of such plants a high risk venture. All these and regulatory uncertainties are major factors in the development of a new generation of coal fired power plants.

Prognosis: Pending legislation on CO_2 emission reductions, CCS requirements and cap and trade policy all contribute to a slowdown in the construction and operation of new CFP.

Recommended Actions: The future of the U.S. energy supply should rely, in part, on its most abundant natural resource, coal. Continuing R&D on advanced technologies including clean coal technology, coal gasification, fluidized bed combustion and CCS will all be necessary to continue to make the CFP a part of our national energy mix.

Additional Information Sources: U.S. Energy Information Administration, US Department. of Energy, Electric Power Research Institute and the Edison Electric Institute.

2.1.3 PETROLEUM

Keith Thayer, P.E., GARUDA, U.S., Inc.

Petroleum is a dark, viscous liquid formed deep in the earth over millions of years from organic material. Globally, 70 to 75 million barrels/day (MMB/D) of oil are produced and consumed today.

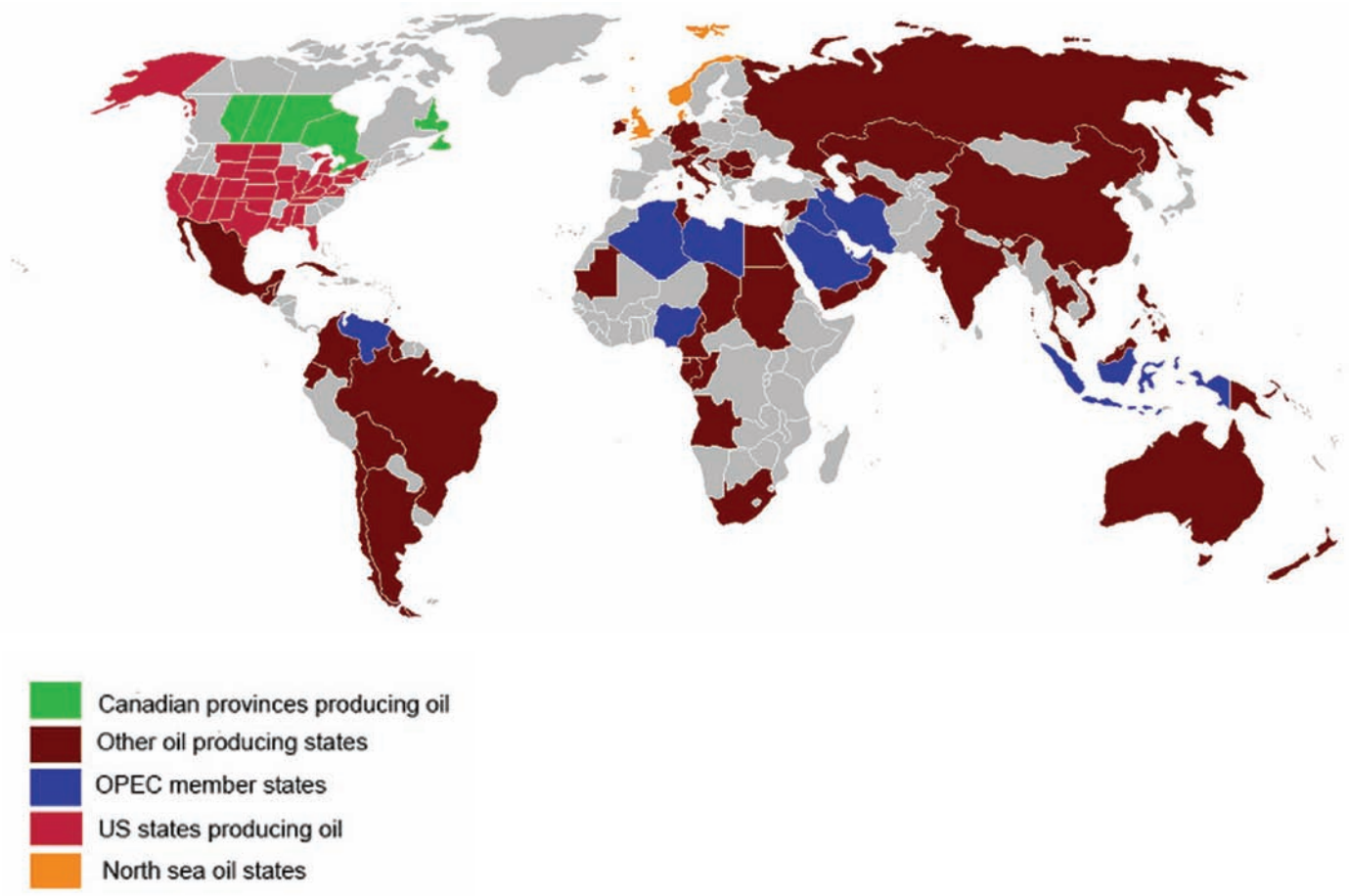
Source: Petroleum is found in reservoirs (not in underground "pools") that lie in depths from 500 to more than 20,000 feet below the earth's surface or the ocean floors. Geologists and geophysicists use seismic and other technologies to identify potential reservoirs. Oil companies drill wells to prove evidence of the oil and then produce the oil for refining into commercial products.

Infrastructure: The industry includes a wide range of petroleum business functions and entities: exploration, drilling, production, transportation (marine, pipeline, rail, truck, terminals), manufacturing (refining), marketing, and distribution. Facilities, capabilities, and technology are in place and well established. The energy content and portability of petroleum products have made them the world's primary transportation fuel. Petroleum accounts for nearly 100 percent of the world's transportation energy and approximately 43 percent of all world energy consumption.

Issues: Emissions from the combustion of petroleum, both the toxics and carbon dioxide, present air quality and global warming challenges.

Rising imports of oil, particularly from geopolitically sensitive countries, present energy security concerns.

Access to many potential drilling sites in the U.S. is prohibited by federal and state regulations.



Key worldwide oil producing regions.

Prognosis: The world demand for oil continues to grow, with China and India leading increases in consumption. The U.S. Energy Information Administration projects consumption to grow 50 percent to 109 MMB/D by 2030. Current demand strains present day production capacities, even in OPEC countries. Mature fields are declining at 5–15 percent annually. To meet future requirements, the oil industry will rely on investment; in conventional oil; on research to unlock heavy oil, shale oil, and other hard-to-produce sources; and on exploration and production of frontier areas, particularly deepwater.

Advances in oil and gas production technology include expanding drilling and production into offshore regions and in water depths exceeding 5000 feet. The United States restricts oil and gas offshore exploration to regions off the coasts of Texas and Louisiana. Other countries throughout the world permit oil and gas exploration in all of their offshore regions.

Oil is a major source of energy and the predictions of the world's supply are uncertain. Technology, efficiency and conservation, such as hybrid cars, hydrogen, solar, alternate fuels, and electricity from nuclear power plants will mitigate the rate of demand increase. Additional drilling, exploration, products of heavy oil, tar sands, etc. will extend the current supply. However, alternative sources of energy are needed.

Additional Information Sources:
Energy Information Adminstration http://www.eia.doe.gov/
International Energy Agency http://www.iea.org/
BP Statistical Review of World Energy http://www.bp.com/

2.1.4 HEAVY OIL

Keith Thayer, P.E., GARUDA, U.S., Inc. [1]

Heavy oil is very heavy and viscous crude oil with a low carbon to hydrogen ratio, and high content of asphaltenes (large, complex hydrocarbons), metals, sulfur, and nitrogen. Tar sands share similar characteristics.

Most often heavy oil is considered having a density between 10 degrees and 20 degrees API. Note: API gravity is a relatively arcane term used by the oil industry to define flow characteristics of the various crude oils produced throughout the world. Lower API numbers correspond to heavier oils. The lighter, higher API gravity crude oils flow more easily and are more desirable and easier to refine. The "low API" petroleum sources are tend to be more like molasses and do not flow easily.

Bitumen, a form of extra heavy oil, (e.g., tar sands) generally has a density less than 10 degrees API.*

Origins: Recoverable volumes of heavy oils may equal as much as 20 percent of the yet-to-be-produced oil resources in the world. Large resource bases are found in Venezuela, Canada, and the western U.S. and Alaska. To produce heavy oils, the viscosity of the oil in the underground formation (reservoir) has to be reduced to make it mobile. Much of the heavy oil in place around the world is technically and economically unrecoverable because the heat energy required to produce it exceeds the energy produced. One potential breakthrough which could facilitate developing significant amounts of "unrecoverable" reserves would be heat sources from small scale nuclear power plants.

Technology: Many production methods have been tried, including cyclic steam injection, steam flood assisted gravity flow, CO_2 injection, and fire floods. The currently viable techniques involve injecting steam into the heavy oil reservoir to reduce the viscosity of the oil, allowing it to be pumped to the surface. Tar sands are developed with in situ mining processes requiring huge equipment and processing plants. At the well site, oil is separated from sand and water in heated separators and is stored in heated tanks. Transportation may be by rail tank cars (that can be heated for unloading) or by pipeline if there

are sufficiently available diluents such as condensate to reduce the viscosity.

Refining: Converting heavy oil into marketable products can involve high temperature thermal or catalytic cracking to change the complex molecules to the type in gasoline, jet fuels, diesel, etc. Even then, the contaminants – sulfur, metals, and nitrogen – plus the complex structure of the heavy oil molecules generally require complex hydro treating (reaction with hydrogen to remove the contaminants.)

Issues: Development of heavy oil resources can create large, long term footprints with aesthetics, noise, and emissions issues. Substantial capital commitments are required for production and upgrading to usable fuels.

Prognosis: Heavy oil resources have the potential to supply millions of barrels of oil per day, making a substantial contribution to total energy supply. The report "Hard Truths-Facing the Hard Facts about Energy" produced by the National Petroleum Council for the U.S. Department of Energy estimated that the potential for new production of heavy oil worldwide is in excess of 750 million barrels. Large projects in Heavy Oil recovery will be added as the price of the oil rises making it financially feasible to produce and refine the oil.

Additional Information Sources:

U.S. Geological Service,
http://pubs.usgs.gov/fs/fs070-03/fs070-03.html
U.S. Department of Energy
http://www.unconventionalfuels.org/images/Heavy_Oil_Fact_Sheet.pdf
Alikhen, A.A., and A. Farough, 1983. "Current status of non-thermal heavy oil recovery," SPE 11846-MS
Khan, M.R.M, 2007. "Crude value enhancement: an emerging opportunity of innovation in E&P," SPE, 112809-DL

* Extra heavy oil (bitumen, tar sands) is covered in Section 2.1.5.

(1)The Editors would like to acknowledge the contributions of George Haliday to this paper.

2.1.5 TAR SANDS

Keith Thayer, P.E., GARUDA, U.S., Inc.

Tars sands are a mixture of sand, clay, and bitumen, an extra heavy crude oil. The oil is difficult and expensive to produce since it requires mining/retorting or steam assisted heating of the reservoirs where it is found. The higher prices of the 21st century underwrite increasing investment in oil sands.

Origin: In Athabasca, Alberta, Canada, huge volumes lie beneath only several hundred feet of overburden (the soil between the surface and the deposits of tar sands). Other deposits at Cold Lake and Peace River are deeper, but the oil is more mobile. Some of the key oil shale deposits in the United States are in Colorado and Wyoming. Together they hold about 175 billion barrels of recoverable oil.

In the Orinoco Belt of Venezuela, the similarly large deposits of extra heavy oil are in warmer reservoirs and thus more mobile. About 267 billion barrels are thought to be recoverable.

Tar sands and extra heavy crude oil are thought to be the remnants of much larger resources, but over geologic time the lighter part of these resources either migrated away to the surface or was destroyed by microbial activity.

Technology: The preferred technique for recovery of the Athabasca tar sands is mining and separation. After removing the overburden, the tar sands are excavated with shovel and truck, dragline, or bucket-wheel operations. The oil sands are then processed in nearby plants to separate the oil from the sand and clay. The solids handled are about 16 times the weight of the recovered oil. At some other Canadian resource sites and in Venezuela, recovery of the oil is accomplished by injecting steam into the reservoirs to reduce the viscosity of the oil and make it mobile enough to pump to the surface.

Upgrading: Once the tar sands have been separated or produced, conversion to marketable oil products takes several routes. In Canada, some large, nearby upgrading plants process the extra heavy crude oil into a lighter form called syncrude.

In other locations, including Venezuela where upgrading plants have not been built, the extra heavy crude oil is mixed with local, lighter crude oil or condensate streams that allow the oil to be moved by pipeline.

When the diluted extra heavy crude oil reaches refineries, it has to be processed in the same way as the heaviest part of conventional crude oil, usually by thermal or catalytic cracking operations to produce gasoline, jet fuel, and distillate products.

Issues: In the near term, escalating costs of investment, labor, and operating costs are inhibiting company investment in Canadian tar sands. In Venezuela, lack of access to world capital markets and a national energy policy in flux has slowed development of this resource base.

Prognosis: Decades of research are now coming to fruition as higher oil prices make investment in tar sands attractive. Canadian production now exceeds a million barrels per day; Venezuelan production is over a half million barrels per day. Both are growing because of the growing demand for oil and oil products as well as the increasing price of that oil on the marketplace.

Additional Information Sources:
Energy Information Administration
http://www.eia.doe.gov/
International Energy Agency
http://www.iea.org/
BP Statistical Review of World Energy
http://www.bp.com/

2.1.6 NATURAL GAS – METHANE

Keith Thayer, P.E., GARUDA, U.S., Inc.

Natural gas (CH_4) composed of carbon and hydrogen is a clear gas that is found in formations in the earth and most of the time with crude oil and produced through wells drilled into the formation. Pressures, depths, composition, heating value, and corrosiveness vary with each source. The gas must be processed before it can be used. In addition to the oil producing formations, natural gas can be found in landfills, feedlot waste, sewage plants, coal mines, bogs, and marshes throughout the world. Biogenic gas is formed from the breakdown of organic matter in landfills, swamps and other confined organic deposits.

Natural gas is typically found associated with oil in the earth at depths of 5,000 ft or greater. A typical composition is Methane CH_4 70–90 percent, Ethane C_2H_6, Propane C_3H_6, and Butane C_4H_{10}. The produced gas may also contain hydrogen sulfide H_2S and is referred to as "sour gas". Hydrogen sulfide, even at trace levels, is highly toxic. Production of sour gas requires special processing and safety procedures.

Infrastructure: The natural gas is treated to remove contaminants, raise the heating value and compress it to the pressure required to store or transport the gas through pipelines. Liquids (NGL) are removed and used as fuel or raw materials for chemicals. The gas may be cooled using special refrigeration processes to condense the gas to a liquid (LNG - Liquefied Natural Gas). In some parts of the world gas is "stranded" and is flared in order to produce the associated oil. Where natural gas is available it is a preferred fuel because it is clean burning and easy to use.

Gas must be "pipeline quality" in heating value and purity and therefore is treated in gas treatment plants near the location where the gas is found. Natural gas is odorless. An odorizer is added to the gas to warn of the presence of leaks. It must then be compressed to pipeline pressure (1000psi +/–), measured for accounting purposes and transported to its point of use. One of the growing uses of natural gas is as a fuel for gas turbines and co-generation power plants to produce electricity. Other uses include building and home heating; steel making; glass making; industrial drying; incineration; and as a feed stock for chemicals. It can also be compressed and used as a fuel for transportation vehicles. Natural gas is a clean burning fuel and generates much less environmental pollutants than the other fossil fuels. The infrastructure for use is in place and functioning.

Issues: Much of the pipeline systems are difficult to inspect and maintain. Although the explosive range of natural gas is very narrow (in terms of concentration of natural gas and air), natural gas can explode when leaks and accumulations occur and a spark is present. To be transported efficiently the pressure must be high or the gas must be liquefied by refrigeration. Access to much of the world wide natural gas supplies is difficult (deep ocean and remote land areas with difficult terrain), which increases the costs of production and transportation. The Federal Energy Regulatory Commission regulates the U.S. Gas Industry.

Positive Aspects: Gas is a clean burning fossil fuel with an established infrastructure, with trained personnel worldwide familiar with operation and maintenance.

Negative Aspects: Natural gas is an odorless, colorless mixture of hydrocarbons. It is a highly flammable when mixed with air. It is handled under pressure. If a gas cloud collects, contact with an ignition source can result in a violent explosion.

However, because methane has a much lower percentage of carbon to hydrogen atoms relative to coal, burning methane produces only about 40 per-

cent of the greenhouse gas emissions relative to a corresponding amount of energy produced by burning coal.

Prognosis: The cost of natural gas will continue to rise, which may slow the future usage. The long range supply and use of methane is tied to oil exploration and production. Gas is forecasted by the International Energy Agency (IEA) to supply approximately 22 percent of the energy used for power generation in 2030. The IEA acts as energy policy advisor to 28 member countries in an effort to ensure reliable, affordable and clean energy for their citizens. Natural gas is a fossil fuel of choice for energy production and will continue to be a major supplier of energy.

Additional Information Sources:
http://www.naturalgas.org/ (website of the Natural Gas Supply Association)

Natural Gas Production Worldwide

Distribution of Worldwide Gas Reserves

Country	TCF	Percent
Russia	1,680	30.5%
Iran	812	14.8%
Qatar	509	9.2%
Saudi	225	4.1%
UAE	212	3.9%
USA	184	3.3%
Algeria	160	2.9%
Venezuela	148	2.7%
Nigeria	124	2.3%
Iraq	110	2.0%
Indonesia	93	1.7%
Australia	90	1.6%
Norway	77	1.4%
Malaysia	75	1.4%
Canada	60	1.1%
Trinidad	24	0.4%

Region	TCF	Percent
Middle East	1,980	36.0%
Former Soviet Union	1,953	35.5%
North America	252	4.6%
European Union	111	2.0%

On an Oil Equivalent Basis ½ of worldwide petroleum resources are natural gas.

The large amount of gas reserves and long distances to markets are key drivers toward worldwide growth in liquefied natural (LNG) gas industry.

Source: Oil & Gas Journal

6

2.1.7 LIQUEFIED NATURAL GAS

Sam Sharp, P.E., Process Project Engineering Consultants

Origin: Liquefied Natural Gas, (LNG), typically consists of 85 to 95 plus percent methane, along with a few percent ethane, some nitrogen and minor amounts of propane, and even less butane and heavier components. The exact composition of the LNG is dependent upon the source of the natural gas from which it is produced.

Natural gas is produced from gas reservoirs and from "associated gas," or gas that is produced along with oil. LNG is odorless, colorless, non-corrosive and nontoxic. LNG provides a means to produce "stranded gas" or gas that cannot otherwise be brought to market via a pipeline.

Technology: LNG is produced by condensing natural gas to a liquid at –256°F, (–160°C). The volume of the liquid is about 1/600 of the volume of the gas at atmospheric pressure. LNG is stored at near atmospheric pressure at about –256°F, in large insulated tanks that typically hold 135,000 cubic meters, with tanks of 200,000 cubic meters and larger being designed and constructed. The LNG is pumped to LNG tankers and transported to Regasification Terminals where the LNG is converted back to natural gas for distribution in a pipeline system.

A number of processes are used to manufacture LNG from natural gas. Most common LNG processes in use today utilize a multi-component refrigerant mixture in a closed loop system to achieve the cold temperatures necessary for condensing the natural gas. Other processes use the natural gas (methane) itself as the refrigerant in the final stage of an "open loop" refrigeration system.

Floating Liquefaction facilities may be built to produce smaller gas reserves of less than five trillion cubic feet (TCF). Floating Liquefaction facilities provide mobility for when the field is depleted or in the event political issues warrant and may also enhance security. Floating Regasification facilities can be placed beyond the horizon, out of sight from shore and often lessen the impact and opposition to such a facility. Floating Regasification facilities require pipelines to connect them to shore. Although Floating LNG Liquefaction has been studied for years, no vessels have been built to date.

Infrastructure: Development of a LNG "Chain" is capital intensive and usually depends on developing agreements for the purchase of the LNG, typically twenty year contracts, to obtain financing for the construction of the facility. However, in recent years LNG markets have become more similar to oil markets, that LNG is being "commoditized" as its use increases, whereas in the past it was sold mostly by contract.

Currently, there are approximately 33 facilities producing about 170 Million Metric Tons per Annum, (MMTPA), with several more facilities scheduled to come on line in the next few years. World LNG production is expected to grow to about 350 MMTPA in the next ten years. Major exporters of LNG include Qatar, Indonesia, Malaysia, Algeria, Nigeria, Australia and Trinidad.

Issues Including Safety: LNG provides a means of supplying "clean" natural gas to energy markets worldwide. However, there has been opposition to construction of LNG Regasification facilities, particularly in the United States because of fears of a catastrophic facility or shipping related explosion or similar disaster. Although LNG itself cannot explode, the natural gas cloud that would be produced from an LNG tank failure could catch fire. LNG with quantities of Liquefied Petroleum Gas (LPG) components such as ethane and propane in such a gas cloud would possibly create a more dangerous situation. Nevertheless, LNG will evaporate and disperse upward into the atmosphere and unlike oil; a spill will typically result in minimal damage, if any, to the environment.

Prognosis: The LNG industry has seen the costs for construction of new facilities just about double in the three year period from 2005 through 2008. This increase in cost has caused some projects to be put on hold although many projects that were

sanctioned prior to the rapid increase in costs have progressed.

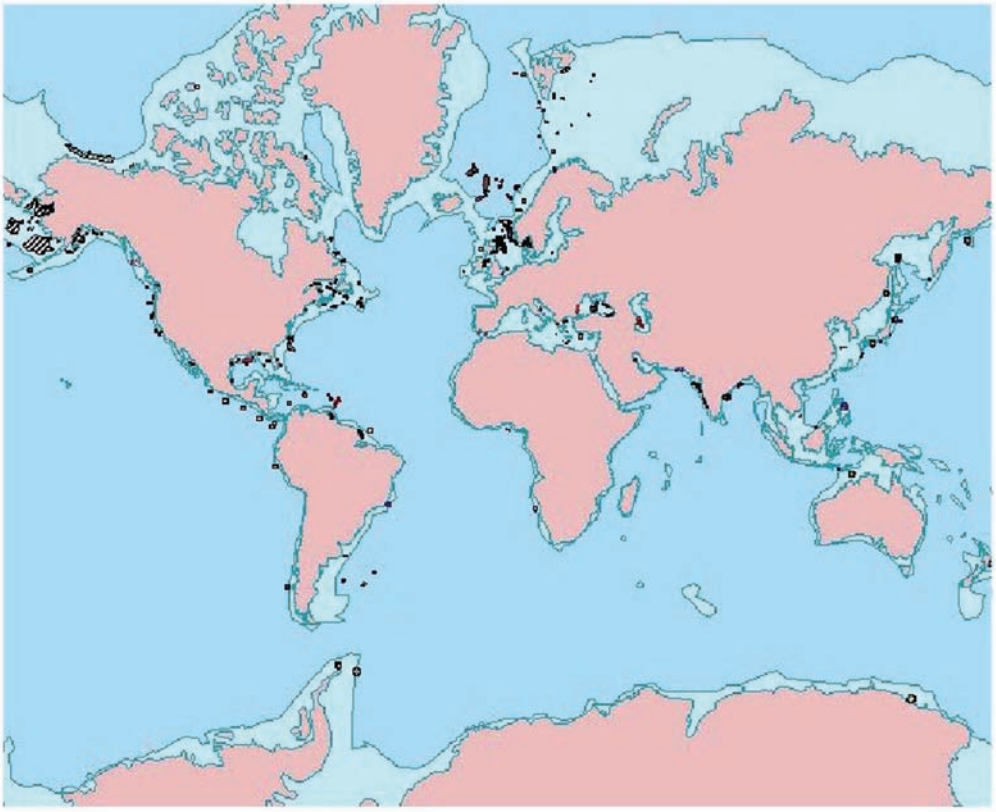
As the demand for natural gas increases in the world, the LNG industry is expected to grow. Countries such as Qatar, with over 800 TCF of gas reserves and a fleet of LNG carriers in the 260,000 cubic meter capacity "Q-Max" ships, (commissioning in 2008), will have an ever increasing influence in the world energy supply.

Additional Information Sources:
http://www.energy.gov/sciencetech/index.htm
Natural Gas Supply Association
http://www.naturalgas.org
Center for Liquified Natural Gas
http://www.lngfacts.org/
American Petroleum Institute
http://www.api.org/

2.1.8 METHANE HYDRATES

David Huey, P.E., Stress Engineering

Origin: Hydrates are ice-contained gas molecules found in natural deposits. They form when water molecules freeze in a cage-like crystal structure encapsulating gas molecules. In the most common and interesting forms of hydrates, the dominant gas molecule is methane, creating methane hydrate. A cubic foot of fully formed solid hydrate contains about 165 standard cubic feet of methane gas. Methane hydrates are stable in solid form under certain conditions of naturally occurring low temperature and high pressure. Known as fire ice, burning ice hydrates look like dry ice, but will support a candle-like flame when burned at atmospheric pressure and temperature as the water liquefies and the methane vaporizes.



Known Hydrate Deposits

Methane hydrates, which are natural deposits, occur in abundant supplies under oceanic floors on continental shelves around the world, under permafrost in Arctic (and probably Antarctic) continental structures, and even under some deep lake floors. Solid stability exists generally where temperatures are less than 20C and at pressures in water greater than about 1000 ft. depths. The Earth's increasing temperatures at greater depths are too high for hydrate stability as a solid, and any methane trapped below is gaseous.

Infrastructure: The acoustic properties of the interface between the hydrates and the gaseous methane beneath create easily identifiable Bottom Simulating Reflectors (BSRs) in seismic surveys, although drilling confirmation has shown that BSRs are not always definitive in indicating whether gaseous methane and no hydrate deposits are present. Natural oceanic hydrates have been also been found as seafloor outcrops, and sometimes even appear mixed in sediments as granules, chunks, or, rarely, as solid "ore bodies".

Interest to the Energy Industry: Methane hydrates impact the energy industry in five ways.

1) Under certain operating conditions, hydrates can form in gas pipelines where they can clog lines and processing equipment.
2) Hydrates in sediments around offshore platforms can destabilize due to drilling activity, sometimes resulting in platform foundation problems.
3) Methane that is released when hydrates spontaneously dissipate and reaches the atmosphere creates greenhouse gas.
4) Because hydrates are more stable at higher temperatures than LNG there is some interest in possible conversion of methane in stranded natural gas deposits to hydrate form rather than liquefaction for transport as solids by seagoing vessels.
5) And, most significantly, many believe that methane from oceanic hydrates can be recovered as an energy resource.

Prognosis. The potential world resource of methane from hydrates is huge, although estimates of quantities vary considerably. Recent research suggests that the energy from oceanic methane hydrates could be 2 to 10 times all other natural gas resources and 20 to 50 percent of all fossil fuel resources.

Issues. Production of offshore methane from hydrate beds is still unproven and may never be economically viable. However, some countries with limited conventional hydrocarbon reserves are pursuing the possibility. In 2008 a Japanese group produced methane gas for six days from hydrate beds 2500 feet under the northwest Canadian Arctic permafrost as a demonstration of potential future energy extraction technology. Plans are in place for pilot projects to demonstrate feasibility of offshore production as early as 2009 or 2010.

Additional Information Sources:
http://www.netl.doe.gov/technologies/oil-gas/
http://www.giss.nasa.gov/research/features/methane/

2.2 NUCLEAR

Energy is released in the form of heat when the nucleus of an atom absorbs a neutron and is split (fission).

Energy is also produced when two light atoms combine (fusion).

The materials used and the conditions for these reactions are complex. The following pages provide some information on the basic options for producing energy from either fission or fusion reactions.

2.2.1 NUCLEAR TECHNOLOGY

Komandur Sunder Raj,
General Physics Corporation

Description: Primary application of nuclear energy technology is for generating electricity. Current nuclear power plant designs utilize predominantly two types of reactors: Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR). The technology was developed in the 1950s to 1960s (first generation).

Where Found: Besides the U.S., France, Japan, Canada, UK and Russia, other countries using nuclear energy include India, South Korea, Taiwan, Spain, Mexico, Belgium, Romania and Hungary.

How Used: The major use of nuclear energy is in generating electricity. Non-electricity applications in use or being considered include: space missions, nuclear medicine, nuclear-powered ships, industrial and environmental management, process heat for desalination, synthetic and unconventional oil production and hydrogen production.

Positives: The safety records of nuclear power plants in the aftermath of the 1979 Three Mile Island (TMI) accident have been excellent. Capacity factors have increased from 60 percent to about 90 percent. Additional positive changes included the creation of the Institute of Nuclear Power Operations (INPO) and increased oversight by the United States Nuclear Regulatory Commission (NRC) to monitor and improve safety, reliability, operation and performance of nuclear power plants.

Reactor type	Main Countries	Number	GWe	Fuel	Coolant	Moderator
Pressurised Water Reactor (PWR)	US, France, Japan, Russia	264	250.5	enriched UO_2	water	water
Boiling Water Reactor (BWR)	US, Japan, Sweden	94	86.4	enriched UO_2	water	water
Pressurised Heavy Water Reactor 'CANDU' (PHWR)	Canada	43	23.6	natural UO_2	heavy water	heavy water
Gas-cooled Reactor (AGR & Magnox)	UK	18	10.8	natural U (metal), enriched UO_2	CO_2	graphite
Light Water Graphite Reactor (RBMK)	Russia	12	12.3	enriched UO_2	water	graphite
Fast Neutron Reactor (FBR)	Japan, France, Russia	4	1.0	PuO_2 and UO_2	liquid sodium	none
Other	Russia	4	0.05	enriched UO_2	water	graphite
	TOTAL	439	384.6			

GWs = capacity in thousands of megawatts (gross)
Source: Nuclear Engineering International Handbook 2007
For reactors under construction see paper Plans for New reactors Worldwide.

Following deregulation of the electric power industry in 1990s, there has been a consolidation of nuclear plant ownership.

Negatives: The terrorist attack of September 11, 2001 has led many to question the security of nuclear facilities and the ability of the structures to withstand impact of an aircraft. There are also serious public concerns with long-term storage of radioactive waste and reprocessing of spent fuel.

Prognosis: Oil prices are at high levels and expected to increase due to increasing global demands. Due to environmental concerns with the use of coal including CO_2 production, nuclear energy is becoming more attractive to meet growing energy needs.

Volatility in the price of natural gas and oil is expected to continue with coal and nuclear fuel prices relatively stable. Nuclear power is staging a comeback with plant owners realizing that capacity additions, upgrades in rated power plant capacity, and operating license renewals may be realized at low incremental costs, with minimal environmental impact.

Prospects for new power plants have increased and several power companies have announced plans to build new plants utilizing advanced reactor designs. These designs have improved safety features and maintain a safe state without use of active control components. Due to concerns with greenhouse gases, various options are being considered by the Congress, including "cap-and-trade" programs that would impose a price on emissions of carbon dioxide, the most common greenhouse gas. If implemented, such limits would further encourage the use of nuclear technology since it does not produce greenhouse gas.

Additional Information Sources:
World Nuclear Association –
http://www.world-nuclear.org
Nuclear Power's Role in Generating Electricity – May 2008 A CBO Study
U.S. Department of Energy – EIA (Energy Information Administration) –
http://www.eia.doe.gov
U. S. Nuclear Regulatory Commission –
http://www.nrc.gov
World Energy Council –
http://www.worldenergy.org

2.2.2 NUCLEAR ELECTRIC POWER

Conrad M. Ladd, P.E., Senior Management Consultants, Inc., and Joseph A. Falcon, P.E., J.A. Falcon & Associates

Description: The fuel for nuclear reactors is uranium which when mined consists of 99.3 percent uranium238, U-(238) and 0.7 percent uranium 235, (U235). Only U235 is fissionable. Natural uranium has to be slightly enriched to about 3 percent U235 for use in most nuclear reactors. This composition of nuclear fuel is not suitable as a weapons grade material. The fission process releases large quantities of heat in a small volume (the nuclear reactor vessel); the heat energy is removed from the reactor by a primary coolant, usually water. The steam produced is fed to a conventional steam-turbine generator system for the production of power.

Of the worldwide 437 nuclear plants, two types of water cooled reactors dominate the industry. These are: the Pressurized Water Reactor (PWR) where the heated fluid generated in the reactor passes through an outside heat exchanger for the generation of steam and the Boiling Water Reactor (BWR), where the steam is generated within the reactor vessel and sent directly to the turbine. In the U.S., there are 104 operating nuclear facilities, either of the PWR or BWR type. They are located in 31 states and provide 20 percent of the nation's electricity needs. They are base-loaded, i.e. the plants run continuously at full rated power. Other types of nuclear facilities, either in service or being considered, are: helium cooled reactors, heavy water natural uranium reactors, breeder reactors and pebble bed reactors.

Where Found: Uranium deposits are being mined economically throughout the world with Canada and Australia being the largest suppliers. The U.S. reserves of uranium ore are abundant, with the Rocky Mountain area being the prime source of domestic uranium.

Infrastructure: Mining and milling of uranium ores started during WWII in the US and expanded rapidly around the world during 1950-1970. U235-enrichment for nuclear power plants started after WWII and expanded after 1960. Fuel elements for nuclear power plants have been routinely shipped

and delivered to plant sites nationwide without hazardous radiation exposure to people since the 1950s. The U.S. government legally assumed responsibility for reactor spent fuel in the late 1970s. Spent fuel elements will continue to be stored at each power plant until suitable, long-term storage in a geologic formation is identified. The Department of Energy had been developing a storage site at Yucca Mountain in Nevada. In 2009 the Obama Administration canceled plans to develop the Yucca Mountain site.

Positive Aspects: Nuclear power has proven to be a clean, safe and reliable source of power and is economically competitive with coal-fired plants. A nuclear power plant does not emit any greenhouse gases. Nuclear plants in the United States have had no deaths from radiation, and have averaged (in 2006) 0.12 industrial accidents/200,000 worker hours, far below other manufacturing industry safety records.

The U.S. nuclear power plant operates as a base load operation with average off-peak production cost of 1.65 cents/kwh in 2006. With spent fuel reprocessing, nuclear power is sustainable for hundreds of years of low cost electric power production. Research is currently underway to develop the fuel reprocessing technology. Fabricated fuel elements and spent fuel in casks have been safely shipped by rail for over 50 years without any hazard to the public.

Negative Aspects: Public perception of safety of operation and handling, including potential reprocessing of spent reactor fuel; natural fear of radioactivity, and the uncertainty of the regulatory and permitting process for new plants.

Prognosis: Nuclear power for almost 40 years continues to be commercially competitive with fossil fueled plants. The regulatory/permitting process is being streamlined in the US. In early 2008, 17 companies have announced plans to build 31 large new nuclear power plants at mostly existing sites. Our national concerns about global warming have elicited a public awareness of the safe, clean and reliable operation of nuclear power. Until recently, the Global Nuclear Energy Partnership (GNEP) was being accelerated to demonstrate spent fuel reprocessing and fast neutron reactors; however, in 2009, federal funding for this program was in jeopardy. Long range R&D efforts would reduce nuclear weapons proliferation risks and enable efficient energy recovery from uranium for several centuries.

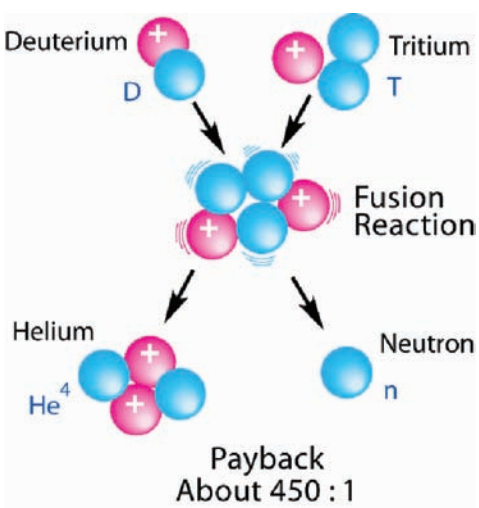
Additional Information Sources:
Websites of: the
U.S. Nuclear Regulatory Commission;
U.S. Energy Information Administration;
International Energy Agency;
U.S. Nuclear Energy Institute;
American Nuclear Society;
U.S. Department of Energy

2.2.3 FUSION

Bob Simmons, P.E., Princeton Plasma Physics Laboratory (Contributors - Adam Cohen, Stewart Prager, Mike Williams, John DeLooper, Tony DeMeo, and Phil Heitzenroeder)

Fusion, the energy source of the sun, converts small quantities of matter to energy when two lighter nuclei (e.g., certain forms of hydrogen) combine to form a heavier nucleus (e.g., helium). Overcoming the electrostatic repulsion of the positively charged nuclei requires high particle energies to promote collisions and fusion. Such energies can be achieved on earth in a very hot (100 million degrees centigrade) ionized gas, or plasma. If this plasma is held together (confined) long enough, then the fusion reactions will produce sufficient energy to generate the needed temperature, with the excess available for production of electricity.

Technology: The sun and the stars achieve the needed energy for fusion through gravitational forces. On earth, the high temperatures needed for energy production can be achieved either through magnetic or inertial confinement. In magnetic confinement, the light nuclei fuel in the plasma is contained inside a magnetic bottle and heated through a combination of methods, such as microwaves, energetic particle beams, and inductively. Alternatively, in inertial confinement a tiny pellet of frozen hydrogen is compressed and heated by intense radiation, such as X-rays or laser beam, so quickly that fusion occurs before the atoms fly apart.



Research in the field continues throughout the world. In this country, the U.S. Department of Energy funds research in:

- Basic plasma science and computational programs
- Innovative experimentation directed at practical fusion
- High performance plasmas
- Burning plasma physics
- Inertial fusion energy and high energy density physics

In addition, the U.S. is part an integral partner with the European Union, Japan, the Russian Federation, China, Korea, and India in designing and building ITER (International Tokamak Experimental Reactor), an experimental facility to study and conduct experiments with burning plasmas. The facility is expected to demonstrate break-even and deliver ten times the input energy and to produce 500 MW of fusion power. "Breaking even" is the level of energy production at which the fusion reactor delivers more energy than what is required to drive the fusion reaction. The facility is being constructed in France with a target start date of 2018.

Prognosis: While commercialization of fusion power is several decades away, the benefits make this an attractive technology to pursue for the long-term. These include:

- Worldwide long-term availability of energy at competitive costs to generate electricity
- A steady energy source with a small footprint and little energy storage requirements and locatable where needed
- No chemical combustion products to contribute to acid rain or increased atmospheric CO_2 – no greenhouse gases
- Short-lived radioactive waste – low risk of nuclear proliferation
- Intrinsically safe – no possibility for runaway nuclear reactions

Additional Information Sources:
U.S. Department of Energy -
http://www.sc.doe.gov/Program_Offices/fes.htm
Others:
http://www.iter.org
http://www.usiter.org
https://lasers.llnl.gov/

2.3 BIOFUELS

Biofuels are, in general, energy sources derived from organic material. This includes fuels derived from crops such as corn, ethanol or switch grass.

2.3.1 ETHANOL FUELS

Joseph Falcon, J.A. Falcon & Associates

Ethanol (ethyl alcohol) comes from starchy crops (mainly corn today). The starch is converted to sugar, the sugar fermented to alcohol, and the alcohol separated by distilling or using a mole sieve to purify the alcohol. In the U.S., over a hundred of small ethanol plants or bio-refineries have been built in recent years. Total production capacity exceeds 7 billion gallons per year.

Infrastructure: Typically one bushel of corn (at 25.4 kg of corn with 15 percent moisture by weight) yields about 2.8 gallons of ethanol. An acre of corn yields about 500 gallons of ethanol. Generally ethanol plants use field grade corn (used for livestock feed), rather than sweet corn used for human consumption. Still, the ethanol industry competes with the food industry for essential resources. Recently, about 17 percent of the U.S. production of corn was dedicated to ethanol manufacture. However, the bio-refineries currently also produce some by-product livestock feed rich in vitamins, minerals, and fiber.

Alternate biomaterials, switch grass, algae, and others may prove competitive with corn and relieve the competition for arable land and the resulting price pressure on other cash crops.

Pipeline companies will need to address the problem that ethanol cannot be transported by conventional pipeline, even blended with gasoline. Ethanol's affinity for water, prevalent in almost all petroleum pipelines, causes the ethanol to separate from the gasoline blend. Ethanol currently moves to the depots around the country to be splash-blended with gasoline into the trucks delivering to gas stations.

Application: Ethanol is suitable for blending with conventional gasoline at varying percentages. The most popular blend contains up to 10 percent ethanol. Blends with 85 percent ethanol, known as E-85, can be used only in cars with special car engines, known as flexible fuel vehicles.

Issues: The energy balance for the manufacture and distribution of ethanol is contentious. Some studies indicate that the net energy consumption from planting to the fuel pump equals about 75 percent of the energy content of the ethanol, with every gallon of ethanol reducing dependence on foreign oil by 0.25 gallons. Other studies conclude that creating ethanol consumes more energy than is delivered in the form of automotive fuel, increasing foreign oil dependence. Emission of pollutants and greenhouse gases of ethanol versus oil faces the same estimating dilemma.

The Energy Policy Act of 2005 mandated that at least 7.5 billion gallons of renewable fuels (essentially ethanol) be blended into U.S. gasoline by 2012. At that time U.S. gasoline consumption may be about 150 billion gallons per year, so ethanol will represent about 5 percent of U.S. gasoline consumption at that time. To provide incentives for production, the U.S. government subsidizes ethanol manufacture the equivalent of about 51 cents per gallon.

Prognosis: The contribution of ethanol from corn and other biomaterials can grow to millions of barrels per day but sizable government subsidies would probably continue to be required.

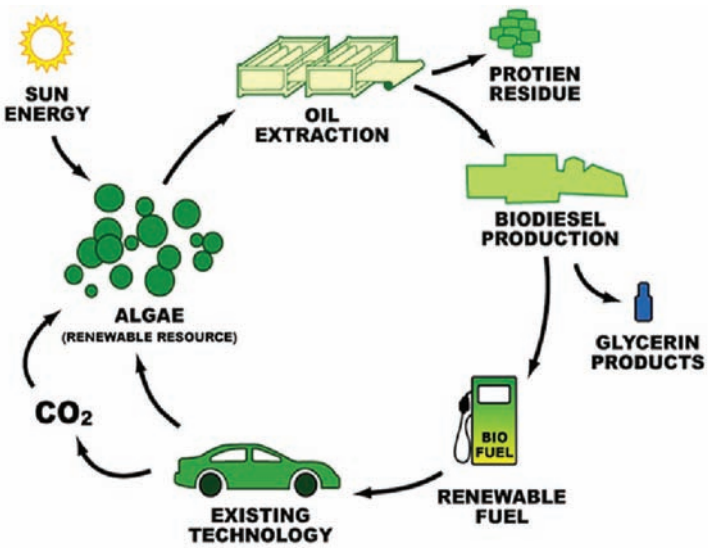
Additional Information Sources:
Energy Information Administration
http://www.eia.doe.gov/fuelrenewable.html
Renewable Fuels Association
http://www.ethanolrfa.org/

2.3.2 ALGAE BIODIESEL

Jaden D. Crawford

This diesel fuel substitute is derived from oil extracted from algae that can be grown and cultivated in almost any climate.

Source: Algae grows in almost any damp or wet environment. Ponds, canals, trenches, tanks, or any other objects that will hold water provide an ideal environment for algal growth.



Like many of the crops traditionally utilized for biodiesel production, algae contain oil that can be extracted and converted to biodiesel through a process called transesterification. In this process, the oil from the algae is reacted with alcohol and caustic soda. The products of this reaction are methyl ester (biodiesel), and glycerin.

Algae biodiesel can be used in any diesel engine without modification.

Infrastructure and Process: While there are not yet any operational production scale algae facilities, current lab scale production facilities are utilizing both open ponds, and closed loop systems called photo-bioreactors. The advantage to the open pond system lies in its simplicity to build. In the most basic sense, this system only requires a shallow hole in the ground that can be filled with water, an algal algae culture, and nutrients.

Photo-bioreactors are generally comprised of a series of clear tubes, a tank, and a pump. The water, algae, and nutrients are circulated from the tank through the tubes, and back in to the tank. This system provides maximum surface area available for light absorption and the ability to carefully control CO_2 and nutrient content.

Once the algae are harvested, it must be dried. This is generally done with a centrifuge, and a large oven-like structure called a dryer.

After the drying process the oil is removed from the algae with an oil press. From there, the oil is run through a biodiesel refinery to create the algae biodiesel.

Issues: The largest issue facing algae biodiesel production is cross contamination of the algal strains. In an open pond system, contaminant algal strains often contain less oil and reproduce faster than the intended strain, effectively "choking out" the desired strain. This issue is virtually eliminated by a photo-bioreactor system, but a production scale photo-bioreactor requires far more capital investment and maintenance than an open pond system.

Advantages and Prognosis: With increasing global demand for fuel, and diminishing petroleum reserves, biofuels have become both a source for viable petroleum alternatives, and a source of contention, since seasonal crops traditionally used for biofuels production often compete with the demand for those same crops, and farmland, used in the food market.

Algae differ from other biodiesel crops because they can potentially be grown and harvested continuously throughout the year, without competing with food production.

As a result, it is estimated that up to 15,000 gallons[1] of oil per acre can be harvested from some strains of algae per year. When compared to the annual 45 to 50 gallons of oil per acre soy bean yield, the hope of algae producers is that more oil, and subsequently more fuel, can be produced on much less land.

The costs of producing this biodiesel and the commercial development will be dependent on current local conditions including access to water supplies.

Additional Information Sources:
National Algae Association
http://www.nationalalgaeassociation.com
Oilgae.com http://www.oilgae.com
http://www.biodieselnow.com

[1]Additional investigations might possibly result in increasing this amount. At some point the cost per gallon of this bio diesel, compared to the current cost per gallon for diesel fuel may not totally solve the diesel fuel availability problem, but it would possibly be worthwhile pursuing this option to relieve current and increasingly serious future, diesel availability problems.

2.3.3 JATROPHA OIL BIODIESEL

Kapilan Natesan
NTIK Deemed University, India

Description: Jatropha curcas is a bush or small tree with spreading branches that grows to 20 feet under favorable conditions. The seeds from the jatropha plant contain 37 percent oil. Each tree yields 20–200 kg of seeds, depending on its growth.

Origin: Jatropha is native to Africa, Asia, and the Americas but is now cultivated worldwide. It grows in tropical and subtropical climates and is resistant to low levels of rainfall and drought. It has been used successfully in wastelands, dry lands, along roadsides and canal banks on a commercial scale and in forestry programs. Depending on the soil and rainfall, oil can be extracted from the jatropha nut two to five years from planting. The oil contains palmitic acid, stearic acid, oleic acid, and linoleic acid. The calorific value of the oil is about 10,000 Kcal/kg. The oil has traditionally been used for manufacturing soap, cosmetics, antiseptic latex with anti-microbial properties for healing wounds, and as a pain reliever for rheumatism. The oil cake is a fertilizer having high nitrogen content.

Infrastructure: Delivery of diesel fuel from jatropha starts in plantations and requires seed collection, oil extraction, refining, chemical conversion, storage, and transportation. A modest trading market exists and development will depend on economic conditions and technical acceptance.

Technology: The oil content of the seeds is 35–40 percent and the kernel is 50–60 percent, similar to soy, rapeseed, and palm oil. Jatropha oil contains 21 percent saturated fatty acids and 79 percent unsaturated fatty acids. The fatty acids can be chemically transformed to biodiesel. Glycerin is a co-product.

The properties of the jatropha biodiesel generally meet accepted standards for diesel fuel. Jatropha biodiesel is thought to generate considerably less toxic emissions compared to conventional diesel. The flash point of jatropha biodiesel is higher than diesel, making it safer to transport.

Issues: Jatropha biodiesel may not combust as well as conventional diesel. Commercial processes have not yet demonstrated the competitiveness with diesel fuel. In addition, jatropha biodiesel has a higher freeze point than diesel, limiting its application as a motor fuel in cold weather.

The leaves and nuts of jatropha are toxic, containing Phorbol esters and curcin, a highly toxic protein similar to ricin in Castor.

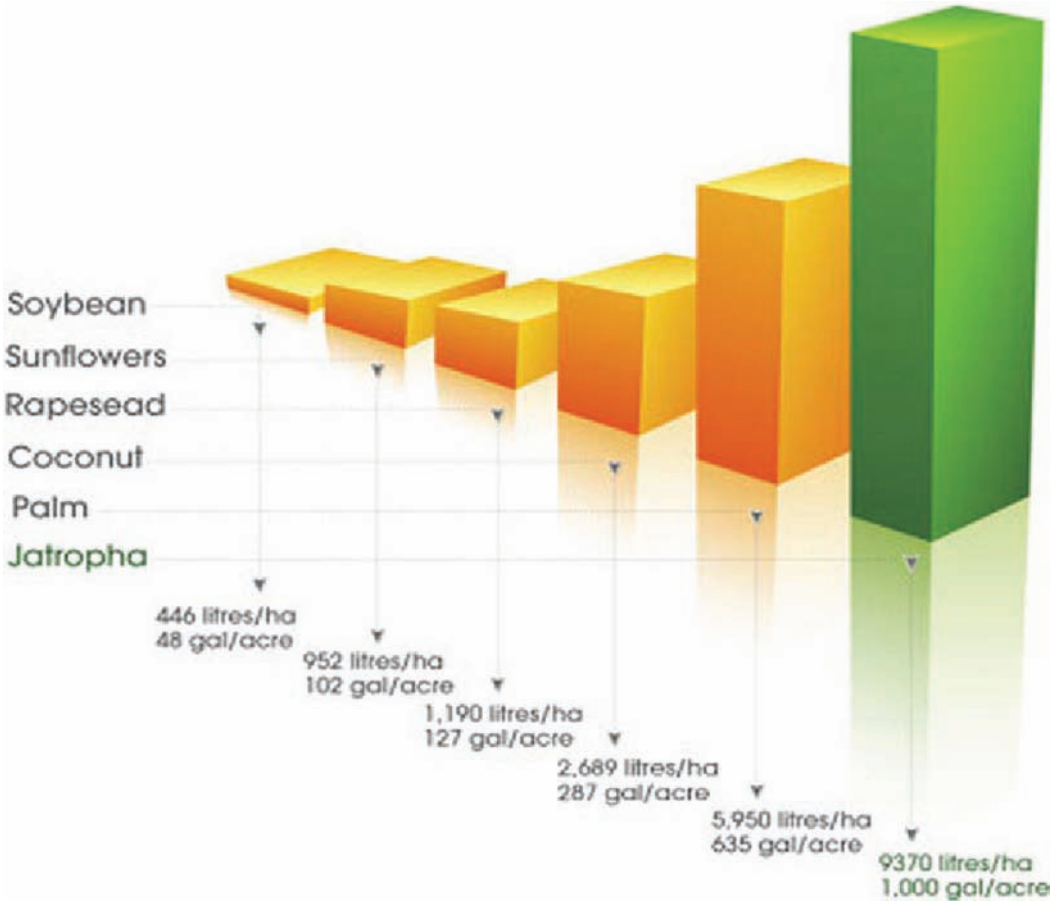
Prognosis: Jatropha oil now represents less than a tenth of a percent of the world's middle distillates supply. Growth as a biodiesel fuel depends on further research and acceptance into several parts of the value chain, particularly scale-up in extraction and chemical conversion and in mitigating the performance flaws. Supply could grow to several percent of the total demand. Government subsidies similar to those for corn-based ethanol may be required and projects will be affected by economic conditions.

Additional Information Sources:

Rockefeller Foundation and Scientific & Industrial Research Development Centre, Zimbabwe
http://www.jatropha.de/rf-conf1.htm

Ministry of Agriculture and Land Reclamation, Egypt
http://www.fao.org/docrep/x5402e/x5402e11.htm

Philippines Alternative Fuels Corporation
http://www.pla.gov.ph/?m=12&fi=p071024.htm&no=15



2.3.4 MAHUA OIL BIODIESEL

Kapilan Natesan
NTIK Deemed University, India

Mahua oil comes from the seeds of the mahua tree, a medium to large tree with a wide round umbrella. Mahua seeds can be processed to produce a diesel fuel substitute.

Origin: The mahua tree is native to the Indian subcontinent. Mahua oil has been used for: manufacturing soaps and various domestic oils; for treating skin diseases, rheumatism, and headaches; and for other commercial uses such as lubricating grease, fatty alcohols, and stearic acid.

Technology: Each tree yields 20-200 kg of seeds, depending on it growth.The recoverable oil content of the mahua seeds is about 35 percent. Conversion to biodiesel is done by a catalyzed chemical process. Mahua oil is predominantly a free fatty acid, which can be reacted with methanol to produce methyl esters (the biodiesel). The co-product of the process, glycerin, has applications in the petrochemical industry.

Mahua biodiesel performs adequately in diesel engines but is said to have lower toxic emissions than conventional diesel fuel.The flash point of mahua oil biodiesel (129° C or about 250° F) is higher than diesel, making it safer to handle.

Infrastructure: Delivery of biodiesel fuel from mahua starts in plantations and requires seed collection, oil extraction, refining, chemical conversion, storage, and transportation.

Issues: Mahua oil is locally popular in India because of its readily available, and its benign properties. It is renewable, and biodegradable. Scale up to broader world markets has not yet been demonstrated.

Prognosis: The cost of mahua oil depends on the location and on the seed yield of the mahua trees. Some estimate that in India, the potential annual supply of the mahua seed is 0.5 million metric tons yielding extracted oil of about 325,000 barrels per day. The current world middle distillates consumption is about 30 million barrels per day.

Additional Information Sources:

National Oilseed and Vegetable Oils Development Board, "Report on Oilseeds and Vegetable Oils." http://novodboard.com/mahua.pdf

EC-FAO Partnership Programme (2000–2002), "Information and Analysis for Sustainable Forest Management, Linking National and International Efforts in South and Southeast Asia." http://www.fao.org/forestry/nwfp/en/

2.4 BIOMASS

Traditional biomass classes of energy sources include wood, paper waste products, manure, and dung.

2.4.1 WASTE TO ENERGY

Charles O. Velzy, P.E., Consulting Engineer
Leonard M. Grillo, P.E., Grillo Engineering Co.

Municipal solid waste (MSW) typically consists, as-collected, of about 50 percent combustible material such as paper, plastics, wood, and rubber. About 25 percent is noncombustible. Another 25 percent, which can vary widely, is moisture. The heat content of this MSW material usually averages about 5,000 btu/lb.

Studies have shown that even after solid waste is processed for recyclable material, the remaining waste has about the same heating value as the original waste.

Origin: MSW in U.S. urban and suburban areas is collected by both private companies and government agencies. In either case government regulates the environmental aspects of disposal. Collected household and commercial waste in urban areas averages about four pounds per capita per day. Industrial solid waste, generally collected separately, increases urban averages by roughly one pound per capita per day. This number varies considerably by community. In total, the U.S. generates about 250 million tons of MSW per year.

Technology: The values inherent in MSW can be recovered before disposal in landfills by recycling some of the combustibles, mainly paper and some plastics, and then by burning the remaining combustible fraction and recovering the heat to produce steam and/or electricity. Combustion of MSW generally reduces the volume of material by about 90 percent and reduces the weight by about 70 percent. Recyclable material, such as ferrous and non ferrous metals, can be removed from the combustion residue before final disposal in landfills. Currently 86 waste-to-energy plants, using several different technologies, operate in the U.S.

Issues: Waste-to-energy (WTE) plants can significantly reduce the volume of MSW before disposal in landfills. These plants also generate electricity which helps offset the financial burden on the taxpayers that ultimately pay for waste disposal.

WTE plants now incorporate the latest technologies to reduce pollutant emissions below the point of endangering public health. Siting new WTE plants has been difficult due to the Public's perception based on older plants that may have created hazardous emissions. Also, the emissions from the inevitable truck traffic, plus the visual pollution of both, weigh heavily on siting considerations.

Regulatory requirements instituted in 1992 are among the most stringent for any combustion technology, in part because of the variable nature of solid waste. This has caused costly retrofits on existing plants and added to the capital and operating costs of new ventures. Issues related to air emissions and the greenhouse gas footprint must also be addressed when developing new WTE plants.

Prognosis: The currently operating waste-to-energy plants contribute a very small share of the total U.S. energy needs. But if all the MSW were combusted (after recycling 30 percent), plants with the latest technologies would contribute 3–4 percent of the total U.S. energy needs. The European Union has mandated the removal and use of 98 percent of the combustibles in solid waste before land filling is allowed. Thus, there is significant room for expansion of the use of modern waste to energy technology for production of electrical power from this renewable resource in the U.S.

Additional Information Sources:
U.S. EPA Office of Solid Waste
Integrated Waste Services Association
Solid Waste Association of North America
Waste-to-Energy Research and Technology Council

2.4.2 LANDFILL GAS

Charles O. Velzy, P.E., Consulting Engineer
Dee & John Eppich, P.E.'s, Consulting Engineers

Landfill gas (LFG), a product of the decomposition of solid waste, collected from landfills has a heating value of 400–500 Btu/cu-ft. (That compares to natural gas with a heating value of 1050 Btu/cu-ft.) Digester gas (DG) is collected from sewage sludge decomposing in digesters and has a heating value of about 650 Btu/cu-ft. The higher the heating value the better the energy usage.

Origin: LFG is generated by decomposition of solid waste in operating and closed landfills. Currently more than 65 percent of all municipal solid waste (MSW) is land- filled; about 25 percent of solid waste is recycled with the residues from recycling also going to landfills. Less than 8 percent of MSW is used as fuel to generate steam or electricity.

In operating landfills, the LFG output continues to increase until the landfill stops receiving MSW. Then, LFG output begins a slow decline. The speed of decrease depends on the moisture in the landfill. In a dry climate and dry landfill, the LFG may have a half life of approximately 20 years. In this context the "half life" is the time during which half of the remaining LFG gas in the landfill is produced. In wet climates and wet landfills, the half life is much shorter. DG is generated during the breakdown of the solids which are separated from the sewage and decompose in digesters as long as the plant is in operation.

Technology: The composition of DG is typically 65/35 percent methane and carbon dioxide. The air entrained in LFG gives it its lower heating value. In most large landfills, LFG is gathered through a vacuum collection system to prevent migration offsite. LFG can be used as a fuel for onsite electric power generation in internal combustion engines, gas turbines, or gas-fired boilers and steam turbines. The electricity is usually sold to a local utility. LFG can also be sold to a nearby customer.

Large wastewater treatment plants use the DG to heat their digesters and to generate electricity to power their facility. Smaller wastewater treatment plants can use DG to heat digesters and burn excess gas in a flare when it is not needed as a fuel.

Issues: The methane in LFG and DG gives them 20 times more impact, as greenhouse gases, than carbon dioxide. Collecting and combusting this gas not only provides usable energy but also reduces the overall effect on greenhouse gas accumulation. In fact, landfill and wastewater treatment plant operators are required by federal regulation to collect the emitted LFG and DG and combust them.

Permitting power generation systems at existing landfills and wastewater operations can be difficult due to local objection, despite the improvement to the environment and net energy generated. The costs to permit and construct these facilities can be high, but are generally recovered from the value of the energy generated.

Prognosis: New landfill operations require several million tons of MSW in place before enough LFG is generated to justify capital expenditures for a recovery system. Still, after the landfill closes, the facilities remain in use, even as the LFG supply begins a slow decline. In contrast, the DG recovery facilities at a wastewater treatment plant can be fully engaged shortly after the plant starts up.

Additional Information Sources:
U.S. EPA Landfill Methane Outreach Program
http://www.epa.gov/lmop/
The Solid Waste Association of North America
http://www.swana.org/

2.5 OTHER RENEWABLE ENERGY

These sources of energy are generally "inexhaustible" and result from the energy of the sun impacting on the earth. These sources include solar, wind, ocean currents, ocean waves, and ocean thermal energy.

2.5.1 SOLAR THERMAL POWER

Yogi Goswami, Ph.D
College of Engineering - University of South Florida

Solar radiation can be converted to heat, mechanical energy and electrical power using known engineering principles. Therefore it has the potential to provide all of our energy needs. The amount of sunlight striking the earth's atmosphere continuously is 1.75 x 10^5 TW (Terawatts). A Terawatt is 10^{12} (or 1,000,000,000,000) watts. For comparison purposes, the total U.S. energy consumption in 2004 was approximately 3.3 Terawatts.

Considering a 60 percent transmittance through the atmospheric cloud cover, 1.05 x 10^5 TW reaches the earth's surface continuously. If the irradiance on only 1 percent of the earth's surface could be converted into electric energy with a 10 percent efficiency, it would provide a resource base of 105 TW, while the total global energy needs for 2050 are projected to be about 25–30 TW. Solar thermal systems provide efficiencies of 40–70 percent. With the present rate of technological development these solar technologies will continue improving, thus bringing the costs down, especially with the economies of scale.

Technology: Solar radiation can be absorbed on a black or selective absorber to convert to heat which can be used for many applications including hot water or air, industrial process heat, cooling and refrigeration, and electrical power. The type of solar thermal collector used (see Table 1) depends on the temperature requirement of the process. Low temperature (below 1200° C) solar thermal applications have been well developed and the worldwide market is growing at a rate of about 25 percent per year.

Technology: Solar thermal power plants use high temperature collectors and thermodynamic cycles used in all of our present thermal power plants. Solar thermal power plants as large as 350 MW have been built and have been operating continuously since 1990. At present, a total of more than 3000 MW capacity of these plants is under planning or construction around the world. The capital costs of these plants are around \$3000–\$4000/ kW and have the potential to go down to less than \$2000/kW. The cost of power from these plants (which is so far in the range of 12 to 16 U.S. cents/kWh) has the potential to go down to 5–7 U.S. cents/kWh with scale-up and creation of a mass market.

Positive Aspects: An advantage of solar thermal power is that thermal energy can be stored efficiently, for example using molten salt systems, and fuels such as natural gas or biogas may be used as back-up to ensure continuous operation. If this technology is combined with power plants operating on fossil fuels, it has the potential to extend the time frame of the existing fossil fuel resources.

Negative Aspects: The biggest problem with the use of solar energy is that it is intermittent because of weather and night time durations which require the use of backup fuels or storage. Addition of storage systems increases the costs making it uneconomical at present. Therefore it is an important area for further development. Solar power requires at least 10 times the acreage to equal a conventional fossil fuel plant.

Table 1. Typical concentration ratios and working temperature range of solar thermal collectors

Type of Collector	Concentration Ratio	Typical Working Temperature Range (°C)
Flat plate collector	1	≤70
High efficiency flat plate collector	1	60–120
Fixed concentrator	3–5	100–150
Parabolic trough collector	10–50	150–350
Parabolic dish collector	200–500	250–700
Central receiver	500–>3000	500–>1000

2.5.2 SOLAR PHOTOVOLTAICS

Yogi Goswami, Ph.D. College of Engineering
University of South Florida

Solar Photovoltaic (PV) Conversion: Solar energy can be converted directly to electrical power via solid state PV panels. A PV panel is made of a number of interconnected solar cells, and a PV system consists of an array of interconnected panels and inverters, batteries and controls.

Solar cell efficiencies as high as 40 percent have been achieved, however, overall system efficiencies on the market today are in the range of 10 percent – 15 percent. At present, most of the PV panels on the market are crystalline and multi-crystalline silicon based. However, thin film PV panels (CdTe, CIS, and CIGS) are expected to take a major share of the market in the next decade.

Solar PV panel prices have come down from about $30/Wp (Watts Peak Rating) to less than $3/Wp in the last 30 years and have the potential to go down to below $1/Wp (thin film). However, the total system costs (panels and balance of the system) are around $6/W (watt) today, which is still too high to compete with other resources for grid electricity. There are many off-grid applications where solar PV is cost-effective. With governmental incentives, such as feed-in laws and other policies, even grid connected applications such as Building Integrated PV (BIPV) are becoming cost-effective. As a result, the worldwide growth in PV production has averaged over 30 percent per year from 2000 onwards.

Issues: To be economically successful solar energy needs to be part of a systematic approach coupled with other acceptable sources of energy production.

Positives Aspects: It is clean and has the potential to contribute to our energy needs in the future. Because of the distributed nature of the resource, the energy can be produced locally where needed which provides inherent advantages of security, local employment and economic development. With research and development, efficiencies have gone up and costs have come down by an order of magnitude and have the potential for additional improvements.

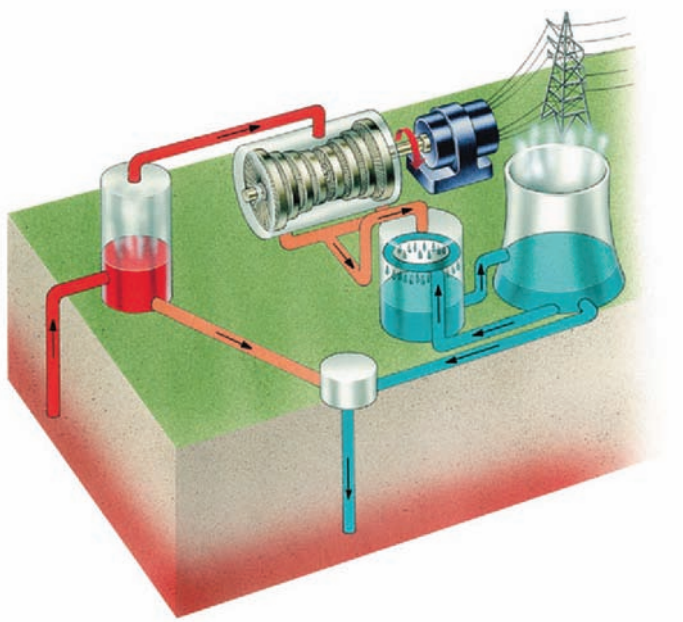
Negatives Aspects: Because of its intermittent nature, it needs either a back-up fuel or storage to provide energy on demand. Storage increases costs making it uneconomical at present. Backup systems could include wind and biodiesel. However wind is also intermittent and could be used as a backup only in cases where wind during nighttime complements solar power generated during the day. This form of energy, to be economically successful, needs to be part of a systematic approach coupled with other acceptable forms of energy production.

Future Prognosis: With continued R&D, the efficiencies will continue to improve and costs will continue to go down. Therefore solar energy technologies are expected to become cost competitive in the future without governmental support. The worldwide private investment activity in the solar energy technologies is at a level of multi billion dollars per year and is expected to continue to grow for the near future.

2.5.3 GEOTHERMAL

Keith Thayer, P.E., President, GARUDA, U.S., Inc.

Geothermal power comes from hot water and steam reservoirs under the surface of the earth.These temperatures are approximately 150 to 200 degrees C. (300F—390F) at depths of 5000 to 13000 feet. Hot formations of rocks at 300°C can be used as EGS (Enhanced Thermal Systems) to produce geothermal energy.

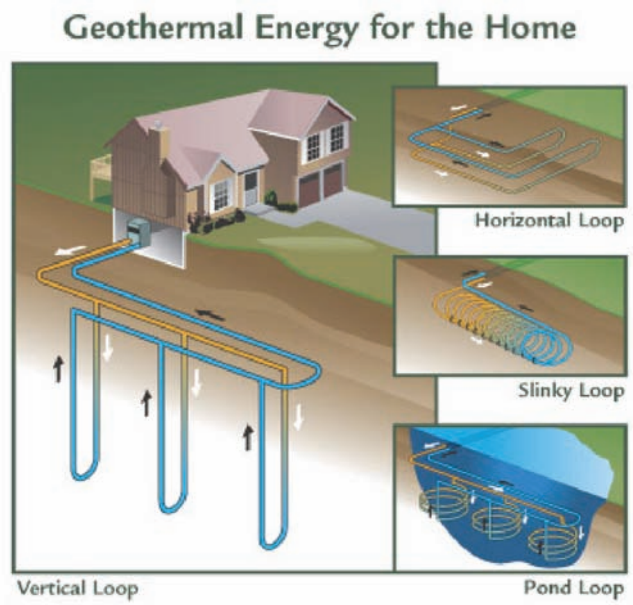


In the U.S. these reservoirs are in Nevada, Utah, Wyoming, Montana, Idaho, Oregon and California. Many countries in the world have geothermal resources.

Naturally occurring, The Geysers are an active geothermal area within the Clear Lake volcanic field in Northern California.

A recent study conducted by the Massachusetts Institute of Technology (MIT) concluded that as much as 100,000 megawatts (MW) could be culled from geothermal by mid century. Since the very early twentieth century, scientists have known how to use heat from the reservoir to make steam to drive turbine generators. Enhanced geothermal systems (EGS) produce the power by injecting water into the hot formations to make steam.

Ground source heat pumps used for heating and cooling homes and buildings are also a potential major application for capturing geothermal energy.



Positive Aspects: Geothermal plants can produce steady electricity with minimal environmental impact compared to other base power sources. Heat pumps can provide heating and cooling for buildings. The technology is available and proven. In 2006 the National Renewable Energy Laboratory (NREL) released a report, Geothermal—The Energy Under Our Feet, which estimates that 26,000 MW of geothermal power could be developed by 2015, with direct use and heat pumps contributing another 20,000 MW of thermal energy. By 2025 more than 100,000 MW of geothermal power could be in production, with direct use and heat pumps adding another 70,000 MW of thermal energy. Geothermal power is not affected by weather conditions and reduces reliance on fossil fuels. It is also scalable (can provide power for building heating and cooling).

Negative Aspects: The cost of building and maintaining these plants is high, Geothermal plants are in remote locations with respect to electrical grids making transmission difficult. Transporting the

steam cannot be done over long distances because the heat dissipates. Geothermal steam may be corrosive and require special compliments and materials in heat exchangers or special treatment in order to be used in steam turbines. Geothermal could affect ground stability in applications where water is injected into hot dry rock formations.

Prognosis: Currently geothermal accounts for just 0.35 percent of the U.S. domestic energy portfolio. As new technology comes on the market the cost of building and producing the plants will decrease, and as the price for conventional power increases these installations will become more viable. Deeper drilling and discovery of useable reservoirs will encourage growth.

Additionally, oil and gas exploration may benefit by adding a geothermal power plant to the existing facilities and utilizing the power producing opportunities twice over.

Additional Information Sources:
NREL (National Renewable Energy Laboratory)
U.S. Department of Energy

2.5.4 WIND POWER

Source – DOE Energy Efficiency & Renewable Energy and National Renewable Energy Laboratory (NREL) Wind Programs

Origin: Wind power refers to the process of using the wind to generate mechanical power or electricity. Wind turbines convert the wind's kinetic energy into mechanical power. As the Department of Energy (DOE) explains, this mechanical power can be used for specific tasks (such as grinding grain or pumping water), or converted by a generator into electricity.

Infrastructure: A wind power plant is composed of a group of wind turbines that are connected to a generator. This generator turns the mechanical power into electricity, which is then sent through transmission and distribution lines to businesses, homes, and schools within the utility grid.

Technology: The DOE divides current wind turbines into two basic types, depending on the orientation of the turbine blades. Most are of the horizontal-axis variety and some are of the vertical-axis variety.

A typical horizontal-axis wind turbine has two or three blades, which face into the wind. Blades rotate up to 20 rpm, resulting in a blade tip speed of nearly 200 mph. Together, the blades and hub form a rotor, which may be 150 to 300 feet in diameter for an average land-based utility-scale turbine. The rotor turns on a horizontal axis about as high from the ground as it is wide.

Advantages: The DOE calls wind energy a "clean fuel source" because it does not pollute the air as does fossil-fuel-combustion, or produce atmospheric emissions leading to acid rain or greenhouse gas effects.

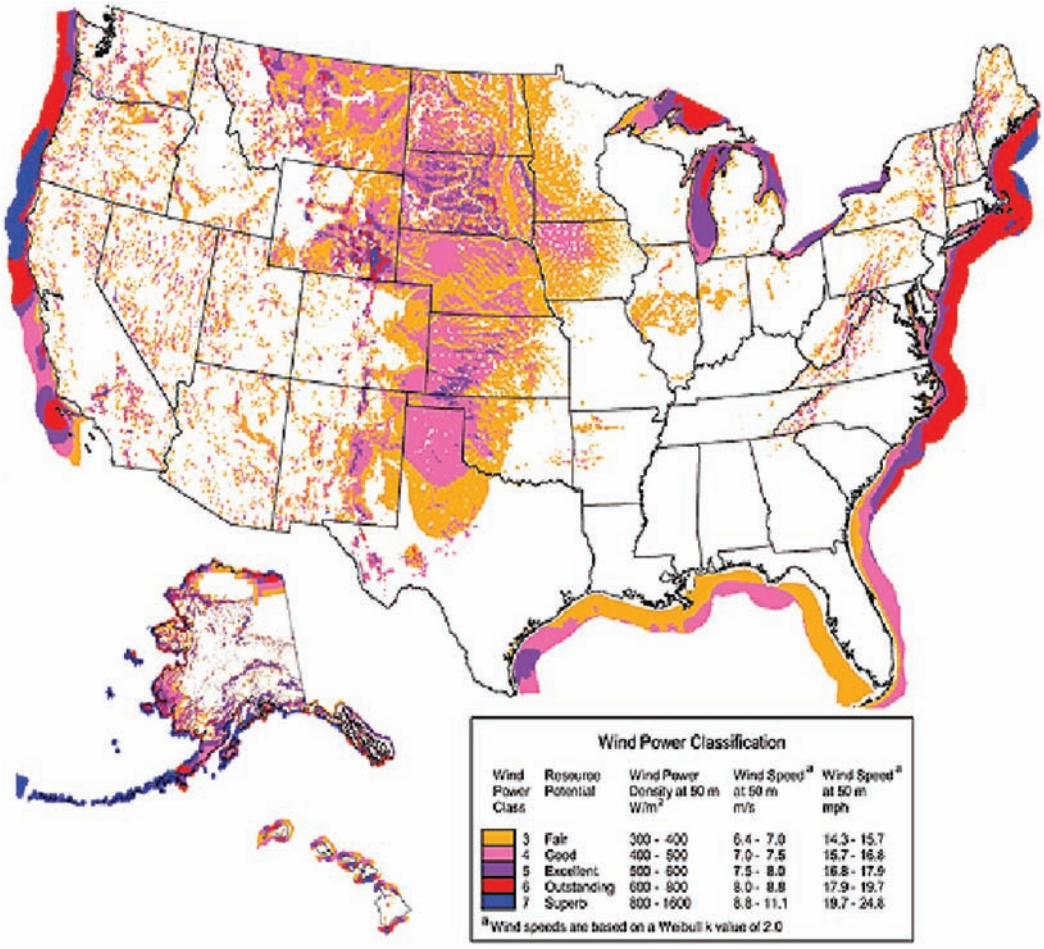
Additionally, wind is a renewable energy source because it is abundantly available and cannot be used up. The DOE reports that wind power is one of the lowest-priced renewable energy technologies available today.

Furthermore, wind energy has an abundant, domestic origin, and can support rural economies. Farms or ranches in the rural areas can offer many of the best wind resource locations for building turbines. While still allowing the farmers and ranchers to work much of the land, wind power plant owners make rent payments to the landowner, supporting agricultural communities.

Issues: Although the DOE reports a dramatic reduction in the cost of wind power over the last decade, this energy source requires higher initial investments than are needed for fossil-fueled power generation. Wind is a challenging power source because it blows intermittently, requiring backup sources, energy storage capacity, or both. Not all sites offer sufficient wind, and good sites are often remote and may require costly transmission lines.

Prognosis: The United States has enough wind resources to generate electricity for every home and business in the nation, according to the DOE's Office of Energy Efficiency and Renewable Energy (EERE). Multiple corporations and government organizations are working to determine the most suitable areas for wind energy development, and it holds promise as part of a stabile, reliable U.S. energy sector's diverse portfolio of sources.

Additional Information Sources:
http://www1.eere.energy.gov/windandhydro
http://www.nrel.gov/wind/
http://www.nrel.gov/learning/re_wind.html
http://www.ieawind.org/



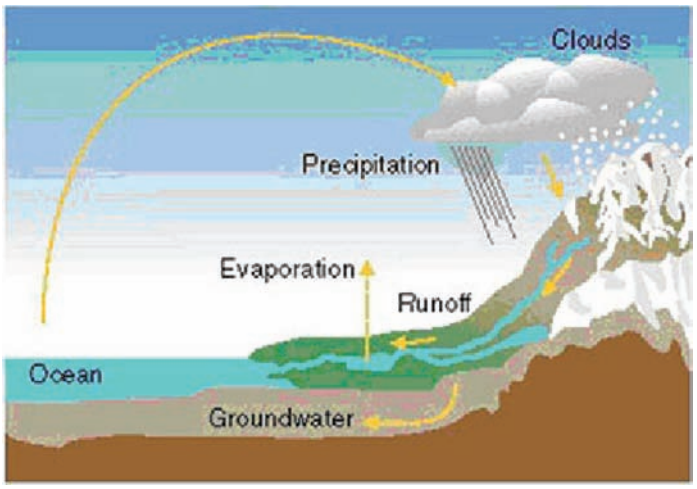
*Darker areas have higher resource potential for wind power

Source: http://www1.eere.energy.gov/windandhydro/wind_potential.html

2.5.5 HYDROPOWER

Carl E. Atkinson, III, P.E., Voith Hydro, Inc.

Hydro electric power or hydropower is the power of moving water. In nature, water is constantly moving through the hydrologic cycle in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, and then flows back to the ocean.



Hydropower taps this natural cycle to convert the energy of moving water into mechanical or electrical energy for use in homes and factories. It is one of mankind's first energy conversion technologies. The Greeks used hydropower to drive grinding wheels over 2000 years ago. Hydropower technology has been improved and optimized to provide various forms of useful power in every century since then.

Today, hydropower is most efficiently used to drive specially designed waterwheels or turbines, which are connected to and used to drive electric generators. The energy of the moving water is extracted by the turbine, and the water is returned to the river or channel to continue its journey through the hydrologic cycle. Hydropower is a renewable energy source. As with wind, solar, and geothermal energy production, the "fuel" (i.e. water) used to produce hydroelectric power is not depleted or consumed in the process.

Types of Hydropower

There are many different types of hydropower facilities and applications including:

Reservoirs: Dams or natural impoundments are used to store water that is then released through the turbines to produce hydropower when needed. The reservoir may also be used for other purposes like flood control, irrigation, recreation, and water supply.

Run-of-River: Flowing water is passed through a turbine. The water flow is not stopped behind a dam or other structure. Water that is not passed through the turbine passes around the turbines over a spillway.

Pumped Storage: Water is pumped from a lower reservoir or river up to an upper reservoir (usually man-made) using energy generated during the low demand periods, mostly evenings and weekends. This water is then run through turbines to generate power during high demand periods. Both pumping and generating is accomplished using a reversible type pump/turbine connected to a reversible type generator/motor. The water goes back to the lower reservoir to start the cycle over again.

Ocean Energy: The motion of ocean waves and tides can also be used to produce hydropower (see the Tidal Energy fact sheet for more information).

Advantages:

Hydropower provides many advantages including:

- **Highly efficient.** Modern hydropower equipment converts more than 90 percent of the potential and kinetic energy available in the moving water to electricity.
- **Security.** Hydropower is a purely domestic resource that is not subject to disruption from foreign suppliers or cost fluctuations.
- **Clean.** Hydropower creates no air or water pollution.
- **Reliable and flexible.** Water turbines can quickly change loads or regulate changing loads, providing starting power, peaking power needs or black start capabilities to failed electrical systems.
- **Multi-purpose.** Additional beneficial uses include flood control, navigation, irrigation, and recreation.

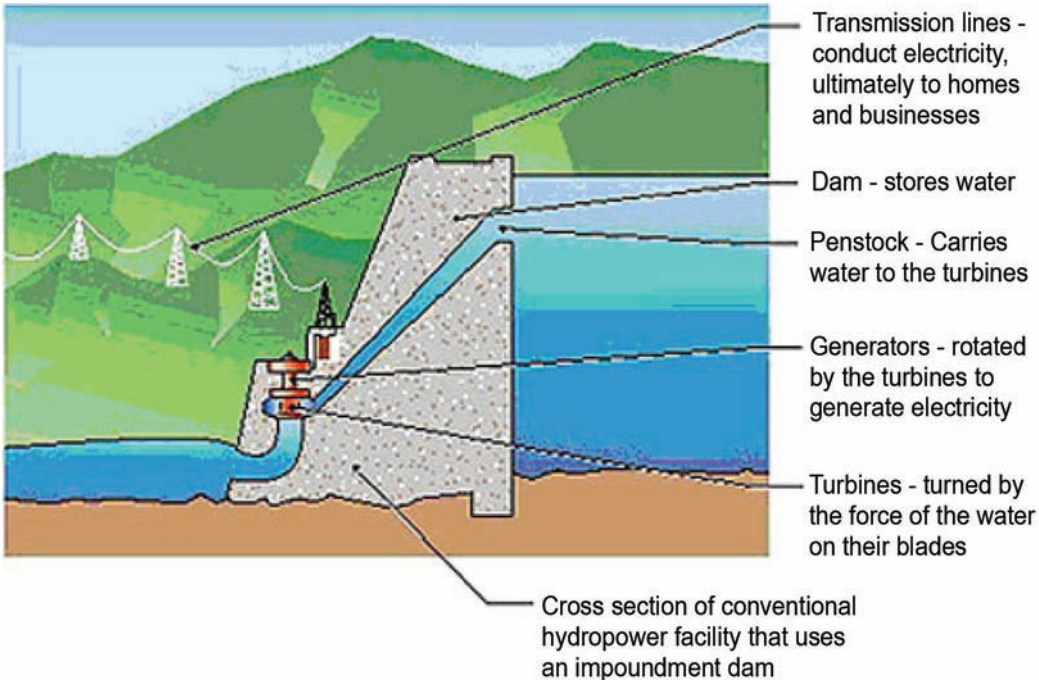
- **Economical.** The hydropower has no fuel costs, which keeps the price of hydroelectric power very low.
- **Renewable and sustainable.** As long as the hydrologic cycle continues, hydropower will be a viable source of power generation.

Negative Aspects

Hydropower also has some disadvantages. Like any other energy resource, hydropower projects have environmental impacts, particularly on river habitats and the fish that live in those rivers. In areas where fish migrate up and down the river, hydropower dams impede this natural migration and impact the reproductive cycle of these species. By extracting the energy from the moving water, hydropower can also slow the river currents leading to impacts on water quality like sedimentation and dissolved oxygen depletion. Hydropower is also dependent on the environment. In drought years, hydropower production may be impacted. Sites for hydropower are impacted by natural conditions and governmental policies and may affect large populations.

Hydropower is a clean and reliable source of renewable electric power generation, with opportunities for additional development and growth. Continued understanding, mitigation, and elimination of hydropower's impacts will allow the resource to continue its contribution of low-cost renewable power to the U.S. energy mix well into the future. The development of ocean energy technologies will supplement conventional hydropower resources to take better advantage of the energy available in the entire hydrologic cycle.

Additional Information Sources:
http://www1.eere.energy.gov/windandhydro/hydro_technologies.html
http:/science.howstuffworks.com/hydropower-plant.htm
http://hydropower.inel.gov/hydrofacts/how_hydro_works.shtml
http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html



2.5.6 TIDAL ENERGY

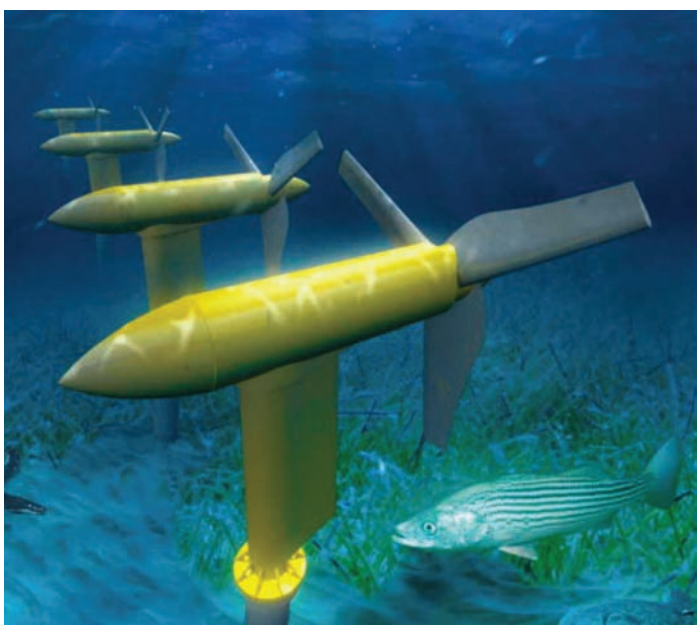
Frank Kreith, University of Colorado
Aaron Hernandez (Verdant Power)

Tidal energy originates from the gravitational pull of the moon and the sun on the seas' waters. It can be harnessed either by building long low dams, called barrages, to direct and contain the tidal flows across suitable estuaries, or by placing horizontal axis 'free-flow' turbines underwater directly in high-velocity tidal currents.

Functionality: Barrages – As the tide comes in, it enters the tidal basin through sluices in the barrage. When the tide ebbs, the water behind the barrage is let out through turbines that generate electricity, similar to a hydroelectric power plant.

Free-flow Turbines – Free-flow turbines are installed underwater directly in high-velocity tidal flows. The natural flow of the tidal currents rotates the turbine blades, which are linked to grid-connected generators. Free-flow turbines do not require dams to operate.

Examples of free flow turbines are shown in the following figure.



Technology: For barrages, the most practical way to capture tidal energy is still the tidal mill scheme. In operation, after a basin fills through the sluices in the barrage, the turbine gates are not opened until the sea level falls enough to create sufficient head across the barrage. Then, as the difference in levels dissipates, the sluices are opened, turbines disconnected and the basin is filled again. Some proposed schemes have turbines that operate in both directions. The amount of energy a barrage-style tidal power plant can produce is in proportion to the difference in height of the water between high and low tides and the amount of water trapped behind the barrage.

While small tidal power mills, like wind mills, have been used in Europe for a millennium to power grain grinding, there are only a few large commercial barrage installations today (e.g., the 240 MW La Rance Tidal Power Plant in France, the 18 MW Annapolis River Plant in Nova Scotia, the small 400 kW Kislaya Guba Plant near Murmansk.) The La Rance plant is the most successful. It has been operating since the 1960s and consists of a 330 m dam built in front of a 22 km^2 tidal basin where the tidal range is 8 m. It has 24 turbine generators rated at 10 MW each.

The free-flow industry began to flourish in the early 21st century, with various designs for free-flow tidal turbines being put forth for development and testing at the time of writing. Turbine designs range from simple three-blade horizontal-axis turbines resembling wind turbines, to more complex twin-rotor and ducted units. Like wind turbines, free-flow turbines can be clustered into fields to maximize resource availability. Many free-flow turbines are also bi-directional, meaning that they change rotational directions to extract energy on both the ebb and flow tides. The first grid-connected field of free-flow turbines was installed at the Roosevelt Island Tidal Energy Project, which began operating successfully in New York City's East River in 2006.

Issues: Tidal energy does not produce any emissions of greenhouse gases and can offset consumption of an equivalent amount of fossil fuels. The energy source is also more predictable and reliable than wind and solar power. However, due to the oscillating nature of the tides, tidal energy must still be coupled with other energy sources to provide constant energy to the grid.

The challenges facing barrage-style tidal devices today are that their capital costs are relatively large. However, these plants, like the one at La Rance, can

supply long-term power at low overall cost because of their longevity: 40+ years. The initial costs appear to have been a barrier to more aggressive investment. Those costs accrue to third parties, but can be accommodated by appropriate pricing schemes.

The siting of a barrage project can also have many of the same objections as hydroelectric power plants. They interrupt navigation (unless locks are also provided) and disturb the ecology of the estuary, particularly the movement of fish to and from the sea and birds feeding on mud flats. Because the free-flow industry is still in its early stages, these projects also carry high capital costs.

However, as with the wind industry, it is expected that these costs will diminish as the industry matures and more economies of scale are leveraged. Free-flow turbines do not carry the same level of environmental concerns as barrages or hydroelectric plants, as they do not disturb the natural flow of the water body, nor do they require the installation of major civil works such as dams to operate. The turbines are also silent and, in some cases, fully invisible from shore, creating another advantage over wind power systems.

Studies are underway with various unit demonstrations to understand any impacts the units may have on underwater marine environments, though early indications are that these will be far less than those of barrages or hydroelectric plants.

Prognosis: By some estimates, the world's tidal action is an annual equivalent of 300–600,000 gigawatt hours. A fraction of this is realistically recoverable by barrage technologies, perhaps in a range from 50 to 100 gigawatt hours. Early estimates show that free-flow tidal technologies could generate in this same range. For perspective, the world's present electricity consumption is about 16,000 gigawatt hours. Overall, tidal energy projects will be determined by local conditions, ecological and political appetites. A project in Nova Scotia (Bay of Fundy) is in progress.

Further Reading:
http://www.raeng.org.uk/news/publications/list/

3.0 ENERGY STORAGE & SECONDARY ENERGY CARRIERS

Energy storage systems and storage devices are needed to buffer and match the instantaneous energy available from the energy sources with the instantaneous energy demands. In general the energy storage needs are driven by electrical power generation, distribution and end use.

3.1 GENERAL ENERGY STORAGE ISSUES

Condensed Version from
Robert Schainker, IEEE

Energy storage devices are needed to level the mismatch between renewable power generators and consumption and / or to store the surplus power from renewable sources for later use during non-generation or low power generation time periods.

The ability to store electricity on a large scale would have a profound strategic effect on the electric utility industry. Supply and demand would not have to be balanced instantaneously and electric utilities would have much greater flexibility. This load shifting, stockpiling approach would also be applied to transmission and distribution assets. Thus, storage technologies provide a unique opportunity for dramatic increases in asset utilization of many types of currently underutilized generation, transmission and distribution equipment.

Other important insights, related to the importance of energy storage today, respond to the following realities:

a) in an uncertain future of how electric infrastructure will evolve in the near future to long-term, energy storage plants in many cases provide lower-cost alternatives to building new transmission, distribution, and generation equipment;
b) storage plants are likely to greatly enhance the utilization of renewable plants (particularly, solar and wind power generation) and provide an effective way to respond to likely CO_2-based regulations;
c) storage plants provide an effective load management means to lower the capacity and installed cost of distributed generators since storage plants could take care of the peak demand thus allow-

ing the distributed generator to operate, in general, as a base-loaded device; and

d) storage plants have undergone significant techno-economic advantages over the last 5 to 10 years that have yet to be fully exploited: namely, storage plants are now less costly, more reliable, and sitable. Battery systems have incremental energy storage costs 1/10 that of previous battery systems. Super capacitor and flywheel modules have successfully undergone proof of principle and field tests at the small module size. Compressed air energy storage plants now have cost effective designs for above ground air storage as well as underground air storage.

Current Status

Pumped Hydroelectric Storage

In operation worldwide for more than 70 years, pumped hydro plants are still the only energy storage technology in widespread use. Such plants use off-peak power to pump water uphill to an elevated reservoir. When electricity is needed, the water is released to flow to a lower reservoir, and its "potential" energy is used to drive turbines producing electricity.

Compressed Air Energy Storage (CAES)

CAES plants use off-peak electricity to compress air into an underground reservoir or surface vessel/piping system. When electricity is needed the air is withdrawn, heated via combustion with any one of a variety of fuels, and run through expansion turbines to drive an electric generator.

Batteries

EPRI, U.S. Department of Energy, U.S. utilities (and others, worldwide) are developing advanced batteries that pack more energy into a smaller package, last longer, and cost less than lead acid batteries (i.e. sodium sulfur and various flow batteries).

Superconducting Magnetic Energy Storage (SMES)

A prospect that holds considerable promise, due to its innate high-efficiency and storing DC electric energy is SMES. Off-peak AC power, converted to direct current, is fed into a doughnut shaped electromagnetic coil of superconductivity wire. The coil is kept at superconductive temperature by a refrigeration system designed to meet the superconducting properties of the special materials used to fabricate the magnetic coil.

Recent advances in so-called high temperature superconductors (that successfully operate at liquid nitrogen temperatures) enhance the ultimate attractiveness of this technology.

Flywheel Energy Storage

The flywheel energy storage takes advantage of the kinetic energy charge and discharge capability of a spinning wheel. In general, small flywheels (up to 1 kW for three hours and 100 kW for 30 seconds) have had good commercial success. Larger wheels (approximately 250 kW) for 10 to 15 minutes are under development.

Super Capacitor Energy Storage

Like most capacitors, super capacitors are ideal for high power, short discharge applications; and they have very long cycle life. Currently, commercial applications for super capacitors are less than 100 kW and have less than a one to about 10 seconds of discharge time.

Hydrogen Energy Storage

Major applications are for electric vehicles and electricity production via fuel cells. The long-term vision for hydrogen production is that hydrogen would not come from reforming methane or via any other chemical process using fossil-based fuels: but rather, hydrogen would be produced by electrolysis of water using off-peak electricity (i.e. from hydro, wind, photovoltaic or nuclear plants). One of the key technical advantages to accomplish this is the development of a safe, reliable, and low-cost storage system for the off-peak generated hydrogen. At present, hydrogen is produced at a low pressure (i.e. at 30 to 300 PSI) and is then mechanically compressed and stored in high pressure tanks and vessels and transported in pipelines at higher pressures (i.e. at about 5000 PSI). High-pressure electrolyzer's are currently in the conceptual design and lab scale, proof of principle stage. When coupled with high-pressure storage vessels, economically attractive electric energy storage systems based on a hydrogen cycle could materialize as commercially viable.

Conclusions

Energy storage plants will ultimately play an important role in a sustained energy future.

Additional Information Sources:

http: //www.oe.energy.gov/storage.htm

3.2 HYDROGEN

Frank Kreith
University of Colorado

Hydrogen is the most abundant element on Earth. However, it exists chemically bound in other materials such as water and organics (biomass and fossil fuels.) Hydrogen can be separated from the organics by chemical processes and from water by electrolysis. Fuel cells using hydrogen can generate electricity and emit only water rather than any greenhouse gases.

Infrastructure: Separated hydrogen comes primarily from natural gas (95 percent in the U.S., 50 percent in the rest of the world) plus oil and coal. Only about 5 percent comes from electrolysis, mostly in those countries that have cheap hydroelectric power. Almost all hydrogen is presently consumed in chemical plants, fertilizer plants, or oil refineries. Most hydrogen is generated at or near the point of consumption. Transportation is by short pipeline, with only a minor amount moved by truck.

Technology and Economics: Using chemical processes or electrolysis requires more energy input than the resulting hydrogen contains. So using fossil fuels to make hydrogen generates more, not less emissions in the chain from the (oil or gas) wellhead to the wheel or the burner tip.

Using natural gas to make hydrogen, the natural gas cost accounts for about 45 percent of the total. Hence the following:

Natural Gas: Price	Hydrogen: Cost
$5/mmbtu	$1.00/kg
$10/mmbtu	$1.50/kg

Hydrogen from electrolysis, where the cost of the electricity accounts for 85 percent of the hydrogen cost gives $3/kg for hydrogen when electricity costs $0.05/kwh. A kg of hydrogen has about the same energy content as a gallon of gas. While these economics compare favorably to fossil fuels, the difference in transportation costs present a barrier. There is no pipeline infrastructure to move hydrogen to consumers and movement by truck costs several times the cost of producing hydrogen.

Further, storage techniques are currently available, but all require large amounts of energy to operate. Hydrogen can be cryogenically cooled to below 330 K (Kelvin) and stored as a liquid. It can also be compressed to 8000 psi and stored in pressure cylinders.

Concerns:

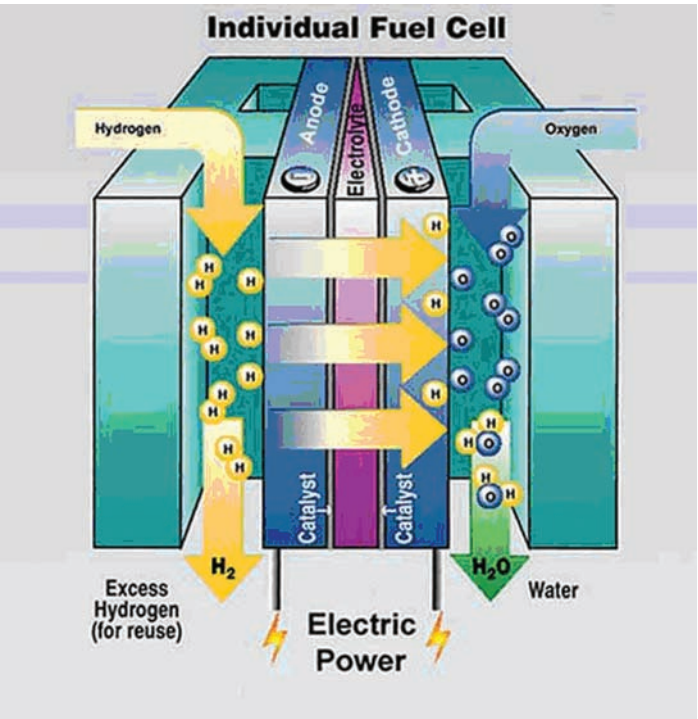
At the present time, approximately 3 kW-hr of electricity are necessary to produce 1 kW-hr of electricity by this sequence of steps. Advanced technology is projected to require 2 kW-hr of electricity to produce 1kW-hr of electricity, as shown by the following considerations: With an input of 1.9 kW-hr to produce the hydrogen by electrolysis with 85 percent efficiency, a fuel cell at 65 percent efficiency would produce 1 kW-h of electricity. Similarly, if all of the steps involved in a so-called well-to-wheel analysis are considered, the overall efficiency of a hydrogen vehicle would only be 12–13 percent, compared to a vehicle using a diesel engine that can, with current technology, easily achieve an efficiency of 26 percent.

3.3 FUEL CELLS

Keith Thayer, P.E., GARUDA, U.S., Inc.
Edited by Lara Crawford

Fuel cells are battery–like devices that generate electricity using electro-chemical reactions. They consist of two electrodes separated by an electrolyte.

Though a fuel cell is similar to a battery in the sense of applying an electrochemical process, its importance to the general public is as a prime mover and an electricity generator using hydrogen or other fuels.



Origin: The origin of fuel cells is thought to go back as far as 1880 when researchers began experimenting with converting coal or coal gas directly into electricity.

Technology: Passing a hydrogen containing material over one electrode and an oxidant over the other electrode results in a chemical reaction that produces heat, water and an electrical current.

Applications: Fuel cells are being tested in many applications such as standby power units, automobiles, electronic devices (cell phones, calculators, alarms etc). Some applications are commercially available.

There are many types of fuel cells each with their particular properties. Most require materials such as platinum for the catalysts and special materials for the electrolyte. The operating conditions vary widely for the different fuels and materials.

The positive aspects of the fuel cells are they produce minimal pollution; they convert the energy in the fuels efficiently compared to other energy sources. They are quiet and technology has made great progress towards making them practical.

Issues: Today, because fuel cells require special fuels that are not abundant, nor meet a specific quality and composition, the short term progress of this type of power is limited. Also, some materials required for the production of fuel cells are costly to use. Currently, there is no practical infrastructure that is in place for wide spread availability of fuel. Some car companies are beginning to experiment with fuel cell powered vehicles. Hydrogen powered vehicles are operating in trial situations with experimental hydrogen fueling stations in California.

It is probable that technology will continue to develop that will make fuel cells competitive with other types of energy producers.

Additional Information Sources:
http://www.hydrogen.energy.gov

4.0 TRANSPORTING FUELS AND TRANSMISSION

Energy sources and end users are generally at different locations. Systems are needed to transport the energy from where it is produced to where it will be consumed.

4.1 PIPELINES

Art Reine, P.E., AR Pipeline Consultants, Inc.

Pipelines are the safest, most efficient, and least expensive method to transport large quantities of liquid and gaseous fuels or materials. They can move more material; operate twenty-four hours a day (almost 365 days a year), and can move anything that is liquid or gas.

Besides the typical hydrocarbons and derivatives such as propane, butane, ethylene, and propylene, pipelines also transport coal slurry, wood chips, molten sulfur, copper concentrate, CO_2, nitrogen, oxygen, hydrogen, and helium.

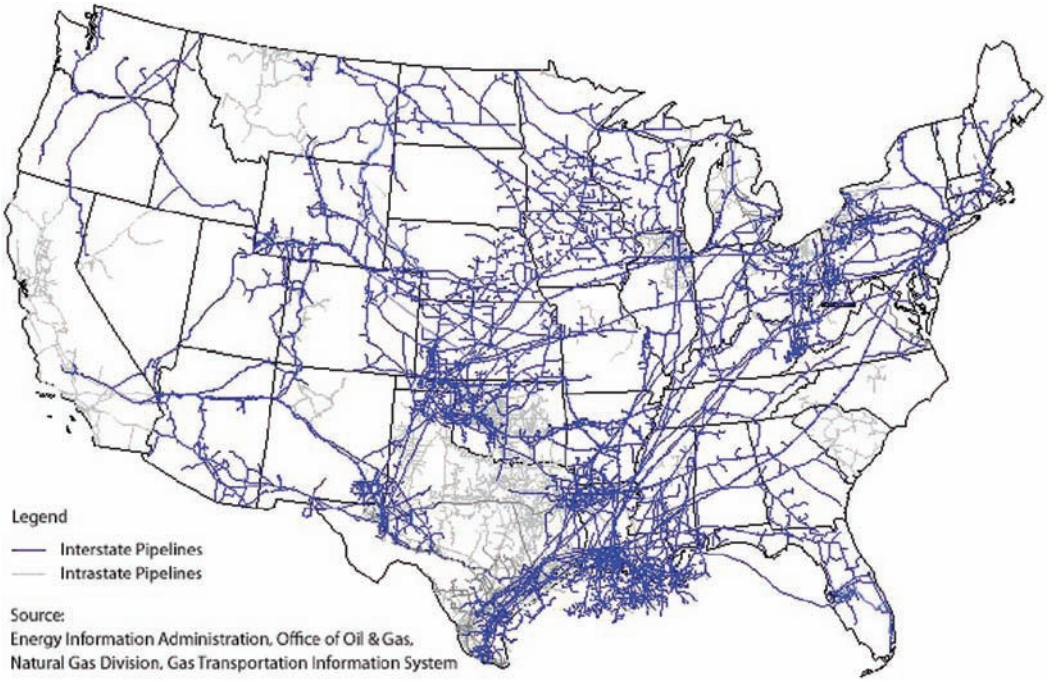
Pipelines commonly connect the source of the energy producing materials (such as the wellhead) to the refineries and plants for processing and then on to the final users.

Pipelines require some pressure source to move material through the line. This pressure may be from the wellhead or developed by a pump to move liquids or a compressor to move gases. Some material is kept under pressure to keep it in a liquid state; while at atmospheric pressure it would be a gas, (i.e. LPG – liquefied petroleum gases).

Significance: The gas we use to heat and cool our homes came to us through a pipeline and almost every product people use in their daily lives was in some way delivered in a pipeline. We don't see the pipelines because they are buried out of sight and do not interfere with other modes of transportation, such as trucks, railroads, or cars. The gasoline that fuels our cars is delivered to a central station via a pipeline and then trucked to retail outlets. As another example, pipelines carry oil products to plants so that the material can be made into plastics that are used to hold so many of the products we buy.

Pipelines are indispensable in our everyday lives because they deliver much of the fuel needed to run our society.

Technology: Most pipelines are made from conventional steel. However, conventional or common steel is not adequate for all pipeline installations. A special metallurgical formula is required to pro-



duce" low temperature" steel in extremely cold regions, such as Alaska and Canada. For helium or hydrogen, which have a minimum molecular composition, special "fine grain" steel is required. Future: Transportation of energy producing material in the USA is a relatively mature industry, while pipelines in most foreign countries are still in their infancy.

The motivation for a new pipeline is still based largely on business principles with governmental guidelines and restrictions based on technical society codes and standards for safety. If these conditions remain tolerable, more pipelines will be constructed as demands dictate.

Due to the congestion in cities near the coasts, a future plan may be to tether ships close to shore, and feed the energy demands on shore through a pipeline, tying into the existing distribution systems. With this plan, operational hazards and emissions will not affect the cities. This process is already in use by offshore lightering of large crude ships and unloading LNG (liquefied natural gas) ships into existing gas pipelines. Note: "Lightering" is the practice in the marine industry in which ships too large to come into ports transfer their cargo to ship small enough to come into the ports at which the cargo is to be discharged.

Negative Aspects: The increase in population density in the USA has made it more difficult to obtain the necessary right-of-ways to construct new pipelines. Environmental concerns are another problem developers face in locating pipelines. The use of "eminent domain" to acquire right-of-way has helped for locating gas pipelines, but can still be costly and create delays.

Additional Information Sources:
Code of Federal Regulations; Title 49 – Transportation; Dept. of Transportation Part 192 and 195.

4.2 ELECTRIC POWER TRANSMISSION

Lara Crawford, Green Habits Consulting

Electric Power Transmission is the link between power plants and the distribution systems that deliver electricity to consumers. It enables distant sources such as hydroelectric power plants to supply population centers, from hundreds to several thousand miles away. Further, transmission lines have provided a cost advantage and improved reliability of electricity delivery by allowing available generating capacity to be shared over broader geographic customer bases. To capture these benefits, regional electric power transmission networks or "grids" require centralized operating coordination.

Origin: Long distance transmission dates to the nineteenth century in Germany. Originally the lines operated with direct current (DC), as invented by Thomas Edison. Alternating current (AC) soon proved to be a more reliable mode.

Infrastructure: In the U.S. and parts of Canada, electric transmission systems are owned both by independent companies and integrated electricity providers. However, transmission entities generally operate independently to assure the appropriate (usually the most cost effective) electricity generator provides power to the grid covering their geographic area.

The North American Reliability Council oversees the grid through a dozen regional councils. Their role is to assure and improve the abilities of the grids to reliably deliver power where needed.

Technology: Long distance power transmission lines (mostly overhead) typically operate at high voltages (110,000 volts or more). Equipment at either end of the lines steps up or down the voltages.

The resistance from metallic lines causes losses in the amount of generated electricity as it travels. Superconductive materials operating at cryogenic (very low) temperatures have been demonstrated to eliminate almost all these losses. Research in this

area over the last three decades has led to a recent 2000 foot electric power transmission line demonstration project in Long Island funded by a government-industry partnership.

Issues:
An aging workforce and recruitment barriers threaten the supply and quality of the workforce.

Prognosis: Continued increases in electricity demand will continue to require new grid infrastructure and improvements in efficiency. At the same time, distributed power generation, where innovative technologies place generating sources near the end user may reduce the need for adding additional electric power transmission lines in some areas.

One major issue facing policy makers and the power industry is expanding the capabilities of the nation's current electric grid into a "Smart Grid." This will include additional transmission capacity to deliver power from the areas in which power is produced (in particular new renewable solar and wind sources) to areas where the power is consumed. Smart Grid technology will also require the capability to continuously monitor instantaneous power consumption at individual loads and automatically shed power loads to match and stay within available power capacity. In the future the Smart Grid will allow maximizing use of available power generation capacity to supply power to charge "plug–in" hybrid electric vehicles.

Additional Information Sources:
http://www.oe.energy.gov/

4.3 RAIL TRANSPORT

Lara Crawford
Green Habits Consulting

Rail transport is the conveyance of passengers and goods by means of wheeled vehicles specially designed to run along railways or railroads. Rail transport is part of the logistics chain, which facilitates international trade and economic growth in most countries.

Origin: The history of rail transport dates back nearly 500 years and includes systems using horse power and rails of wood or stone. Modern rail transport systems first appeared in England in the 1820s. These systems, which made use of the steam locomotive, were the first practical forms of mechanized land transport and will remain a primary form of mechanized land transport. The steam locomotive has been replaced by locomotives using diesel engines driving electric generators which provide the power to the traction motors which drive the wheels.

Infrastructure: Freight rail transportation and electric power generation are mutually dependent network industries. Railroads accounted for over 70 percent of coal shipments to power plants in 2005, and due to economic and physical limitations on other modes (truck, barge, and conveyor) the heavy dependency of the power industry on rail transportation is likely to continue into the future. From the standpoint of the rail industry, coal transportation is an important business, accounting in recent years for about 20 percent of freight revenues for the major railroads. Containerized and intermodal shipping will likely be a growth area for railroads. Technology developments will impact all aspects of rail transport.

Issues: Rail transport's role in the energy arena includes the energy used to power the trains (diesel, biodiesel, electric grids, and coal) as well as delivering the fuel sources to power plants.

Positives: The established infrastructure and functionality of rail transport is universally accepted.

Prognosis: Current rail transport relies primarily on diesel fuel to power the engines. As the cost of fuel and cost of properly handling CO_2 emissions is raised, technological advances being made in electric rail transportation could reach parity with current diesel technology allowing for a change to occur. Currently, there is no incentive for rail transport companies to upgrade or change existing facilities.

Additional Sources of Information:
Federal Railroad Administration
http://www.fra.dot.gov/

5.0 EFFICIENCY & CONSERVATION

One of the major "sources" of energy in the future will be using energy more efficiently. Each unit of energy saved through better efficiency in production, transmission or end use and energy reductions (conservation) reduces the amount of energy which must be produced from existing or new energy sources.

5.1 ENERGY CONSERVATION VS. EFFICIENCY

Dr. Sriram Somasundaram, FASME; FASHRAE
Pacific Northwest National Laboratory

Some consider energy conservation synonymous with energy efficiency. Others think conservation results in fewer or lower quality energy and energy services. More appropriately, energy conservation involves *keeping energy from being lost or wasted.* Energy efficiency means *producing the desired effect or product with a minimum of energy input.*

Energy Conservation: Energy conservation is a societal mindset and an individual choice. To some it conjures up visions of making sacrifices or changing a way of life to accommodate having less amenities or being uncomfortable in order to save energy. But comfort and conservation are not incompatible. Energy conservation usually means being more careful in the way energy is used or habit improvement. From a societal perspective, it is possible for individuals to have a quality standard of life and comfort while consuming less energy.

Each individual also has the option of further steps by foregoing some luxuries in the desire to be *greener*, *simpler*, or just reduce costs. Some analysts, including many outside the U.S., embrace energy conservation as an umbrella term for energy efficiency, with changes in personal habits and changes in system design (such as spatial planning, product redesign, and materials reuse.)

Energy conservation examples include thermostat turn-down, programmable thermo-stats, and using mass transport.

Energy Efficiency: Professionals engaged in energy efficiency have different views of its meaning. To engineers, efficiency involves a physical output/input ratio. Economists think further in terms of monetary output/input. Some extend the meaning to doing more and *better* with less, improving the productivity of efforts with less monetary (and energy) input.

In the end, energy efficiency is aimed at delivering the same or better comfort, performance, jobs, productivity, cooling, heating, lighting, affordability, control, and/or quality with less money, pollution, energy, and waste.

Examples if energy efficiency efforts include:

- Installing or replacing heating/cooling systems that use less energy while maintaining comfortable temperatures.
- Installing or replacing windows with ones with lower heat or cooling loss.
- Driving the same number of miles in a fuel efficient car without sacrificing comfort, power, safety, or style.

Prognosis: New technologies, market prices, and government support continue to give incentive and opportunity to learn and implement energy efficiency activities. Some think that the second law of thermodynamics underpins a potential improvement in energy efficiency of almost an order of magnitude during the 21st century. Note: The second law of thermodynamics is a general principle which places constraints upon the direction of heat flow and the best possible efficiency of heat engines.

Additional Information Sources:

Alliance to Save Energy
http://ase.org/section/_audience/consumers/conservationvsefficiency
Rocky Mountain Institute: http://www.rmi.org/
Keith, F., Chapter 1: Introduction to Energy Management and Conservation, *Handbook of Energy Conservation*, 2007, CRC Press, FL
Jochem, E., *Energy End Use Efficiency in World Energy Assessment*, 2000 pp. 173–217, U.N. Development Project, NY

This fact book is the result of the efforts of numerous members and associates of the ASME who have unique professional and technical backgrounds that are directly relevant to this undertaking, and it is intended to supply the reader with basic information on a broad range of energy sources. The authors describe each source of energy, identify the infrastructure needed for its use, identify the positives and negatives associated with each source of energy, comment on impacts and potential future contributions of the respected sources, and suggest references for further study.

This book is intended to provide an overview of energy issues at a relatively non-technical level. It is directed at the general public and other stakeholders who want more knowledge of energy sources, energy conversion, and energy end use and their challenges and limitations. We hope this book will be an information tool that will be utilized for educational purposes. It is the sincere hope of the contributors to this document that it is used by open-minded readers to create informed opinions and perspectives.

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