ARTICLE 3.6.3.1

AN OVERVIEW OF ENERGY IN SOCIETY

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Keywords

Energy, Electricity, Energy Sources, Comparisons, Reserves, Pollutants, Land Use, Costs, Safety.

Contents

Glossary

BTU	British Thermal Unit, non SI unit of energy equal to 1055 joules.
g	gram mass.
Gallon	(Imperial) non SI unit of volume equivalent to 4.546 litres
GJ	Giga-joule. 1E9 joules.
GW	Gigawatt. 1E9 watts.
J	joule, unit of energy.
kWh	kilowatt hour, a small unit of electrical power.
MeV	Million electron volts, a very small quantity of energy.
MWh	Megawatt hour. One thousand kilowatt hours, one million watt hours.
MW(e)	Megawatt (electrical).
TW	1E12 Watts of energy
TWa	Terrawatt year. One year of continuous energy production at the level of 1E12 Watts. The same as 8.76 trillion (8.76E12) kilowatt hours. This is about 8.5 percent of the entire world's requirement of energy during 2003.

Summary

The article provides a general overview of the need for abundant, assured and affordable energy and especially electricity throughout all advancing societies.

Some aspects of the historical development of energy from before the industrial revolution are provided, with some comparisons of relative per caput energy use in developed and undeveloped societies. There is an inescapable positive relationship

between the relative prosperity; the social, scientific and technical development of any nation; and its unlimited use of energy.

Lack of energy is an outgrowth of, as well as a direct cause of ignorance and poverty; the two most devastating human and environmental issues on the planet.

The article identifies the common energy sources generally available to us that are capable of meeting a substantial fraction of our energy and electricity requirements. Needed perspective on energy sources is provided by a detailed comparison of the major sources of energy as well as some minor potential sources of energy. The detailed comparisons - assuming that there is equal access to all of the energy sources - show their relative advantages, disadvantages, strengths, weaknesses, environmental impacts, costs and safety, as well as estimated reserves, energy densities and resource lives. Many countries do not have equal or ready access to all sources of energy and must make use of those that are available to them or which they can import from what are hoped to be reliable and politically stable sources. Certain sources of energy are unreliable and though they should not be considered for use in electrical generation, where reliability is essential, they do have niche applications, especially where alternatives are not readily available.

Today, energy has become a highly political and politicized issue. The article shows some of the unintended consequences of political interference and over-regulation in energy projects. It also shows the consequences of politically and environmentally contrived difficulties in siting and licensing of needed - but politically incorrect, for the moment, and discouraged - energy projects. The outcome of this experience continues to provide a lesson that is too easily forgotten; shortages of energy, or energy which is unaffordable, whether politically manipulated, market based, or seasonally related, have devastatingly severe social and international consequences.

As the above paragraph was being written (February 2003), North America had been steeped in a lengthy cold spell and was hit by massive snow storms; natural gas demand exceeded supply; natural gas prices had risen from about US\$2 GJ^{-1} to \$9 to \$18; oil prices were approaching US\$40 per barrel; electricity pricing was experiencing jumps from about US\$30 MWh^{-1} to about \$50 to \$100. Politicians were generally tying themselves in knots wondering how to address this problem and survive at the polls, and were generally coming up, as they usually do, with many answers, but rarely the correct ones. If there is a choice between making a correct but unpopular decision, or keeping the public happy with a popular decision that may be entirely inappropriate, the choice is not hard for most politicians, even though it may be devastating in the longer term for society. Since then (November 2005), oil is at \$60/bbl, gas is about \$12/GJ, coal is about \$100/T, and uranium is about \$34/pound.

Society always needs more, not less energy. This is neither immoral nor irresponsible, but is a matter of survival and progress at the least cost to humanity and the environment. The most immoral and irresponsible condition is that in which there is not enough energy, either because of efforts to deliberately limit its supply, raise its price, or because of some short-sighted belief that it is environmentally and socially responsible to limit its use. It is, however, environmentally and socially responsible to use the available energy sources that are the most abundant, cheapest, least environmentally damaging and are most safe. And with the least waste and needless use.

1. INTRODUCTION

1.1 Energy and Society

At least half of the world's population survives under conditions that most of us in more prosperous societies would never consider as even marginally acceptable. They are energy-poor and suffer social deprivation in education, health, technology and general social services that we, in more advanced and wealthy societies, have come to expect. They are striving to reach our standard of living and of wealth which took us more than 200 years of painful industrial revolution to achieve. They need access to energy and electricity to do so, but it is a Catch-22 situation. Without wealth they cannot afford significant energy development. Without significant energy development they cannot easily develop the wealth to provide health, education, or technology to develop energy. They need our help.

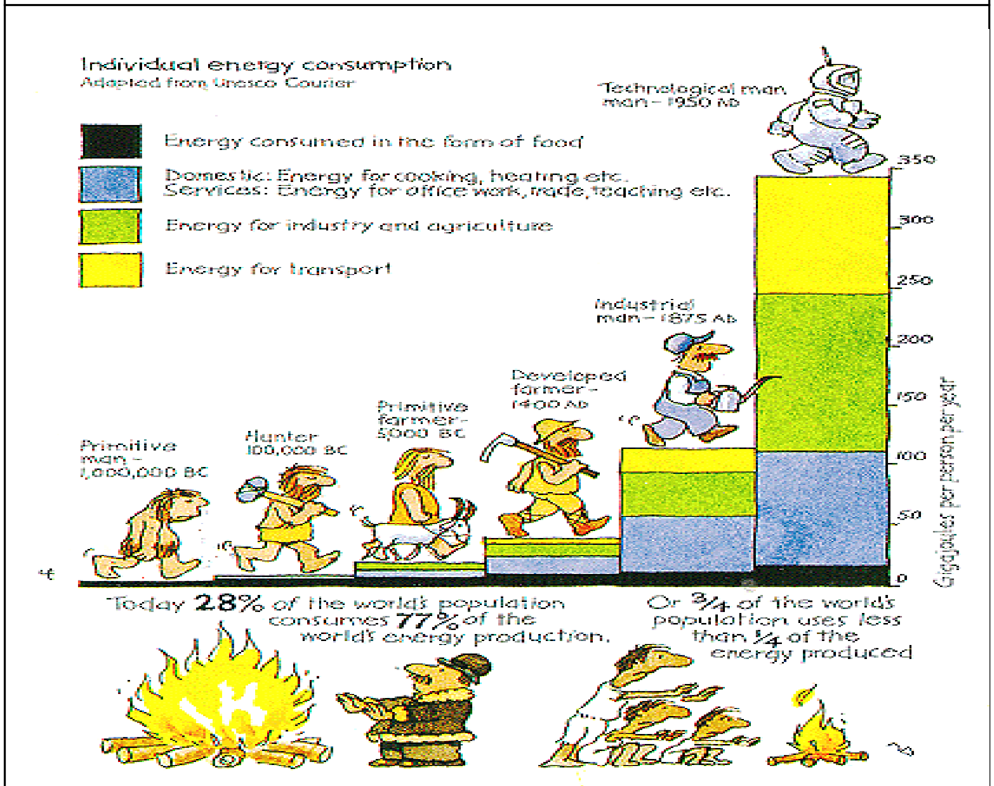
The importance of energy to any developing society is so obvious as to suggest that its necessity and benefits do not need to be pointed out or promoted. However, that assumption would be a mistake. Too many of us in our relatively secure and prosperous society have grown up taking energy and all of its hard-won benefits for granted. We have come to expect them and to believe that they will always be there without realizing that the quality of life and the security of any society is not only directly tied to its ability to exploit and use energy, but also to its ability to guarantee and protect that supply. Our complacency receives a jar, when for some reason we lose electricity for several hours on a cold winter's night; when we suffer gasoline shortages because of international politics; or we see prices of food as well as electricity, natural gas, and gasoline rise for reasons outside of our direct control, but sometimes for lack of planning and foresight. Such temporary interruptions are an annoyance. If they were to be extended and prolonged to days, weeks, months or longer, they would be life threatening to large, vulnerable, segments of society, especially the poor, the elderly, and children. We would begin to experience the conditions of some undeveloped countries.

1.2 History of Energy Development and Present Use

Surplus and useful energy, over and above that available from the sun's warmth, an open fire, or human or animal labor, was once not available and not an option. Most energy was food-related. During and following the Industrial Revolution and agricultural mechanization, surplus energy became an available, though expensive, luxury. Today, surplus energy is a necessity. Some progression in our use of energy from primitive times is shown in Figure 1.

The growth and development of industrial society from the time of the Industrial Revolution depended directly upon its expanding and more effective use of energy other than that inefficiently obtainable by human labor alone. Initially, this was produced by whatever means was amenable to development, be it mechanical energy from flowing or falling water, wind, thermal energy from burning wood or, increasingly, from coal, coke, coal gas, oil, and most recently from natural gas, and uranium. The only requirements were that whatever energy was needed, be available and affordable. Environmental impact was never a consideration until recently, and then it was considered only in wealthy societies which could afford to address it.

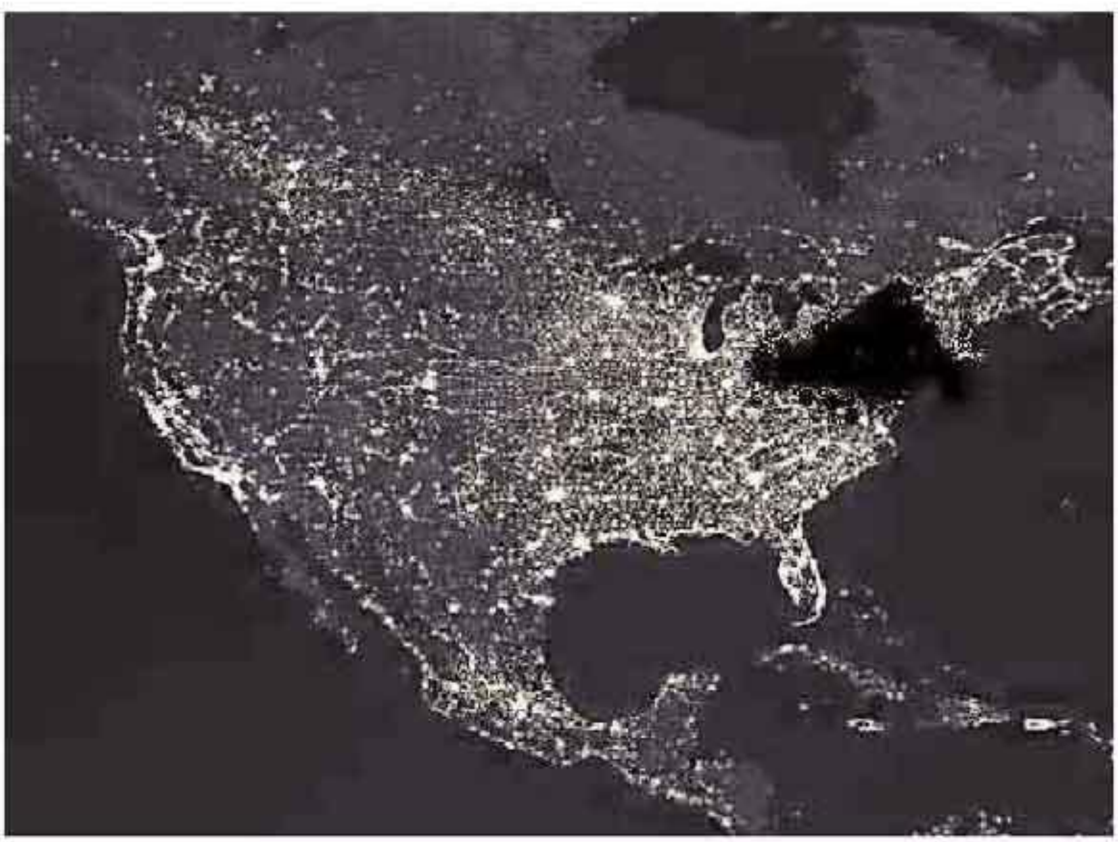
Figure 1. Progression in Individual Energy Consumption with Time. (UNESCO)



With the development and use of railways, automobiles and the introduction and use of electricity, greater versatility and some choice of location of industry became possible. Drilled Oil, as a source of combustion energy, became important, eventually displacing whale oil and penguin oil from one of their many uses; that of illuminating the homes of the wealthy. Until then, the whale was pushed to extinction and penguins were slaughtered in their thousands to be rendered down for oil shipments to Europe. It took up to about 30 penguins - depending upon their size - to produce one gallon of such oil - '30 penguins to the gallon'. An early source of energy which served as an alternative to scarce coal in Egypt in the early part of the last century, was the use of tens of thousands of embalmed mummies to stoke the boilers of trains heading south from Cairo. The primary (tradable as commodities) energy resources: coal and oil - as well as hydropower

- and secondary energy - electricity - began to shape how society developed, and guided the nature of the industrialization process. Added to these, at the middle of the last century, was nuclear power - ideally suited to the generation of electricity and now producing about 17 percent of the world's electricity supply, with further use in some areas for district heating and production of potable water from seawater desalination. Natural gas from major discoveries, especially in Russia and the North Sea ('the dash for gas'), was added in significant quantities only since about 1970, though the Middle East is the major source of gas. However, Russia is now the biggest producer of oil and gas combined, in the world.

Increasingly, the most versatile and useful form of energy is electricity. With the use of electricity there came a new requirement of critical importance, that of reliability - continuously available whenever required and in the quantities necessary. An electrical interruption of even a fraction of a second can disrupt and close down an automated industrial process for several hours. Loss of electricity for hours can cause the steel and glass industries major losses if their molten charges begin to solidify, and can cause severe social disruption throughout society. Loss of electricity for any length of time means that neither pumped water supplies nor pumped sewage can be supplied or removed from cities; gasoline and natural gas cannot be pumped; food supplies go rotten without refrigeration; and public transit, underground railways and traffic lights no longer function, with rapid social breakdown. Skyscrapers become non-functional and uninhabitable. This became evident in various blackouts, especially those of 1965, 1977 and August 2003 (shown below from space, where the north-east and parts of Canada were blacked out for up to several days).



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Power interruptions and voltage sags cost North American industry billions of dollars each year.

Today, electricity is increasingly used to power communications; to heat and light our homes, offices, hospitals and factories; to light our streets; to power industrial processes; and eventually it may provide hydrogen fuel (by electrolysis of water) or battery power for many forms of transportation. However, hydrogen is not a primary energy source. The act of producing it consumes more energy than it could possibly return as a source of energy, as with ethanol production from corn, so how, where, and why it is produced and used must be carefully considered.

The world total energy capacity and use today (2003) from all sources, is estimated to be between 10E12 to 12E12 watts (12 TW) per year. Of this total, about 3.315E12 watts (3315 GW) is for electrical supply, resulting in about 14E13 kWh of produced electrical power in a year. This is equivalent to having 3,300 stations of 1 gigawatt thermal output operating at full capacity through one complete year. Various estimates suggest that by about the year 2025, energy requirements in the world will have doubled, and that an extra 3500 GW of electrical capacity will be needed to meet the demand for electricity, expected to be about 22 000E9 kWh, or about double the present capability. Other estimates call for a lesser, but still massive increase. If we do not rationally examine how we will meet this need now, at this time, we will encounter even more severe energy and social disruptions than we have ever previously experienced.

World energy consumption in commercially traded fuels in 1999 was provided by oil (40.6 percent), coal (25.0 percent), Natural gas (24.2 percent), nuclear power (7.6 percent) and hydro-electricity (2.6 percent). About 0.04 percent of the world's energy was provided by wind energy; about 0.06 percent came from geothermal sources (Iceland dominates this use) and almost none was provided by solar photo-voltaics.

Individual per caput average energy consumption across the world ranges from a high average of about 380 GJ in North America to a low average of about 4 GJ in, for example, Nigeria, with individuals in many countries much higher and many lower than these figures. A large percentage of those who live in developing countries have no access to electricity at all. The world average is about 62 GJ per caput (one GJ (1E9 J) is equivalent to 278 kWh). As undeveloped economies begin to catch up with those of the industrialized world, overall world energy consumption is likely to increase by a factor of from 2 to 5, over the next 25 to 50 years. The considerable uncertainties in estimates, arise mostly because of growing political efforts to manipulate and influence how much energy, and of what kind, we should have access to and use, rather than how much we need and must have in a reliably guaranteed, controlled and affordable supply.

Typically, world raw energy consumption has historically grown at about 2 to 3 percent each year, while electricity use has grown by about 7 percent. These growth figures are dependant upon the economic state of the major economies, all of which have shown signs of weakness for some years since just before the end of the 1990s. All indications are that energy use will continue to increase at about these rates despite concerns over a

possible relationship between fossil fuel use, associated pollution, and global climate change (alleged global warming), and despite political efforts at social control.
A tabulation of some common energy conversion factors, including the non SI British Thermal Unit (BTU) still commonly used in North America, is presented in Table 1.

The Einstein equation $e = mc^2$, indicates the energy potentially available if 1 gram of mass is completely converted to energy.

Table 1. Conversion Table for Units of Mass and Energy

	Erg	Joule (J)	MeV	kWh	Atomic mass unit - amu	g	BTU
1 Erg	-	1E-7	6.24E5	2.78E-14	6.27E2	1.11E-21	9.48E-11
1 Joule	1E7	-	6.24E12	2.78E-7	6.72E9	1.11E-14	9.48E-4
1 MeV	1.602E-6	1.602E-13	-	4.45E-20	1.07E-3	1.78E-27	1.52E-16
1 kWh	3.6E13	3.6E6	2.25E19	-	2.42E16	4E-8	3413
1 amu	1.49E-3	1.49E-10	931	4.13E-17	-	1.66E-24	1.41E-13
1 gram	**9E20**	**9E13**	**5.6E26**	**2.5E7**	**6.02E23**	**-**	**8.53E10**
1 BTU	1.055E10	1055.06	6.58E15	2.93E-4	7.09E12	1.17E-11	-

2. PRODUCTION AND USE OF ENERGY

2.1 Energy Overview

Society requires energy in various forms for home and commercial use; industrial use; and for transportation. Prior to the development of electricity, all energy sources of the day (wood, coal, water power) were consistently inadequate to meet the expanding industrial need, but were used to provide home heating (open wood, peat or coal fires) and thermal and mechanical energy to rapidly developing local industries.

The progressive change in sources of energy, as shown disproportionally in Figure 2 (early use is much exaggerated), was a function of both an expanding need, and the associated growth of technology to exploit them. It also took a major step forward with the development and use of electricity and transmission lines. Although static electricity was familiar to the Greeks, it was a scientific curiosity up until 1880, though Faraday had developed an electrical generator in 1830 - about the time of development of the first fuel cell - and Henry, the electrical motor in 1831. Electricity, as we know it, did not start to become socially important until about 1882 with Edison supplying a small area of New York with direct current electricity. Electric trams were soon common in major cities.

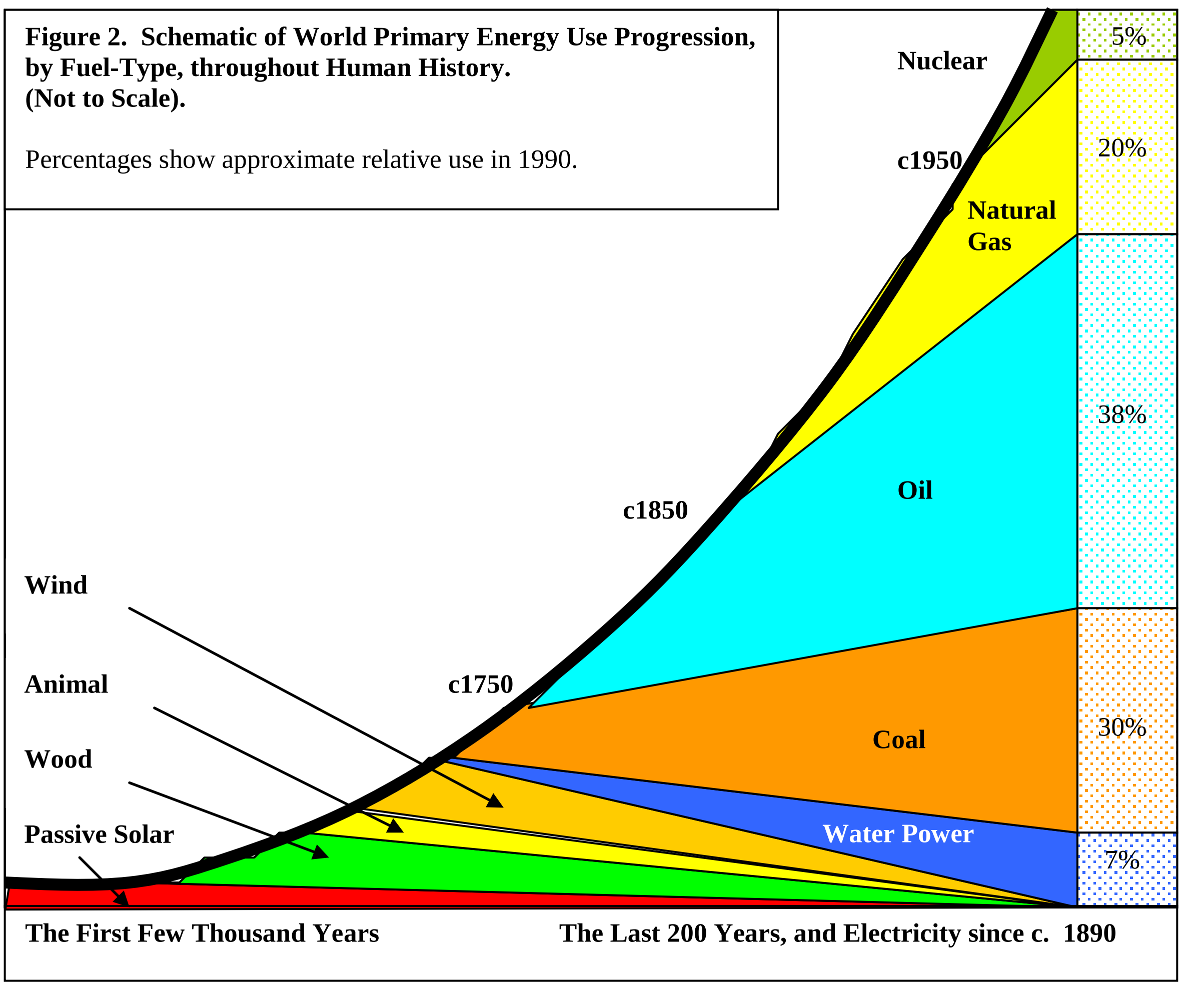


Figure 2. Schematic of World Primary Energy Use Progression, by Fuel-Type, throughout Human History. (Not to Scale).

Percentages show approximate relative use in 1990.

Although the early electric motor and electric automobiles captured the hearts and minds of the wealthy shortly after 1900 and spelled the impending demise of horse-drawn conveyances, it was soon displaced by the development of the internal combustion engine which could range further and could carry additional fuel supplies with it, but which increasingly demanded major supplies of oil.

The development of larger and more efficient electrical generators, and the gradual spread of electricity and the electrical grid, further revolutionized society through the use of energy by converting thermal and mechanical energy which had to be used locally, to electrical energy which could be transmitted over long distances to be used almost anywhere and in many diverse ways – as modern society shows.

With the development of commercial nuclear energy in the 1950s, an entirely new, and major non-fossil and non-polluting resource became of great importance, especially for electricity production. More recently, the development and use of natural gas resources, associated with or close to major oil deposits, some of which were showing signs of depletion, was added to the energy mix. Formerly, gas supplies, released when oil under pressure was brought to the surface, were flared and wasted as some still are, but are now being used much more judiciously. Gas from major gas accumulations in many offshore locations is increasingly being used in home heating and in electricity production where a cleaner fossil fuel than coal is desirable, but the resource outlook is very limited and gas field depletion is occurring faster than had been previously thought, typically about 5 percent per year, but sometimes up to 25 percent each year for some discoveries. Increasingly, liquefied natural gas is being considered for importation and use.

In the early years of electrical development - to encourage the expansion of the electrical grid, and to bring electrical energy to the broader society - governments often granted monopolies to suppliers to allow them time to recover their investments, free of competition. In the 1920s and 1930s, once it became clear that private suppliers to industry could not adequately provide the desired service to the general public, governments generally took over the monopoly position by purchasing the diverse generating assets in a region, and by establishing a single electrical utility. At the same time they devised certain rules and regulations for the operation of the utility concerning an obligation to meet the electrical requirements of local industry and homeowners; obligation to provide adequate and affordable electricity to all who needed it; ensuring that electrical price reflected generating costs to avoid over-pricing, as profits were not permitted; and by providing the access to capital to build new supply as needed. Through these socially beneficial mechanisms, the electrical costs of the utility, and the costs passed on to consumers were maintained at the lowest possible level, other than for sometimes crippling interest charges on borrowed capital.

Towards the end of the last century, efforts at de-regulation; privatizing electrical supply; and encouraging competition with the perceived goal of lowering consumer costs, have met with mixed success. The general experience has been one of minor reduction of consumer costs in some higher priced markets that did not previously have easy access to lower cost electricity, which maybe could be supplied by neighboring utilities. Other regions have seen an almost catastrophic increase in prices because of shortages in electrical supply and competitive bidding wars where the limited supply of electricity was sold to the highest bidder, while other segments of society suffered costly and socially disruptive brownouts and even rolling blackouts. Privatization discourages building surplus and unused capacity to meet extreme weather conditions and need, and requires freedom to adjust prices and to sell into whichever market can most afford to pay the price. Long-term contracts are discouraged, and obligations to supply individual consumers may no longer apply.

2.2 Electricity

By far the most important and useful type of energy is electricity. It allows most fuels and most primary sources of energy to be used to produce an easily transmitted and immediately-useful secondary source of energy, though some fuels are best reserved for other uses as shown in Table 2, often because of costs, or issues of control, availability and reliability.

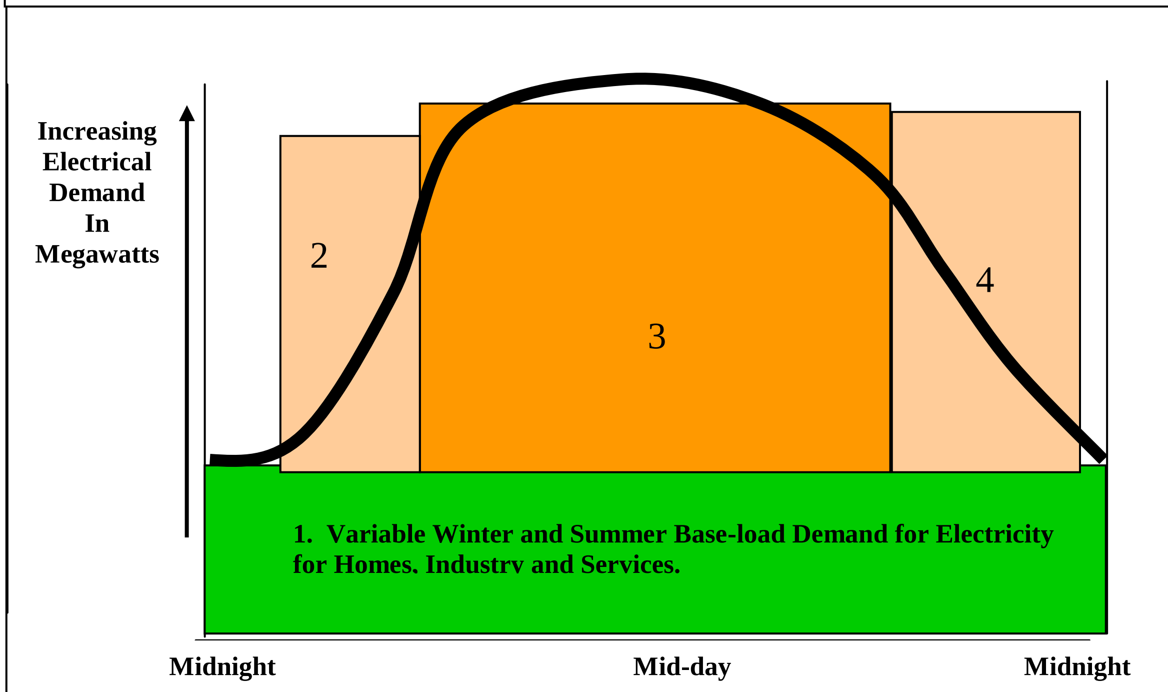
Table 2. Main Uses of Energy Sources Today

Source of Energy	**Present-day Main Use(s)**	**Transportation**	**Electricity**	**Heating**	**Other**
Coal, ranging in quality from brown coal to anthracite	Electrical generation	No longer used	Main use	Minor use	Petrochemicals, Metallurgical use, Coke, Coal gas
Oil (refined light oil)	Transportation (land and sea)	Main use	Subsidiary use	Heating fuel widely used	Petro-chemicals, Plastics, Lubricants
Oil (high density)	Electrical generation	Not used	Significant use	Not used	Industrial uses
Natural Gas, methane, propane	Home heating	Fuel Cells and direct combustion	Secondary use	Primary home heating in some regions	Petrochemicals
Nuclear	Electrical generation	Not used	Main use	Minor district heating	Desalination, Steam supply
Hydro	Electrical generation	Not used	Sole use	Not used	Mechanical Energy
Geothermal	Heating and electricity	Not used	Some use	Main use (Iceland)	Hot-houses.
Wind	Electrical generation	No longer used commercially	Minor use	Not used	Mechanical Energy, Pumping water
Solar	Photo-voltaic cells, passive heating	Not used other than in research and experimental projects	Marginal use by the relatively wealthy	PV Minor use, Passive heating significant by both wealthy and very poor.	Charging batteries
Tidal (three publicized developments, though others may follow)	None. They are mostly pilot projects; a seabed tidal project is being tested in Norway	Not used	Minor use in France, Russia, and Nova Scotia	No value	None. Tidal water wheels were used at one time.

Unfortunately, electricity cannot easily be stored in the quantities that we continuously need, 24 hours a day, so we must generate it continuously, in the quantities needed, and using reliable sources of energy.

Figure 3 indicates the typical 24-hour variation in demand for electricity in most developed societies. The largest demand is usually during the day when industrial and service requirements are at their greatest, and in summer when air conditioning demand is at a maximum in hot climates. In colder regions, the greatest demand can be overnight in winter, with a major demand spike in early morning between 7 and 8am as heating is turned even higher, especially when the temperatures can be well below freezing for days or weeks, and heating requirements put the biggest demand on the supply system. One widely-broadcast celebrity marriage (Tiny Tim and Miss Vicky, December 1969), created such a massive temporary demand spike on the electrical system, as millions of television sets were simultaneously turned on that evening, that system failures and power blackouts were caused throughout the northeastern U.S. Planning for such anticipated spikes during certain sports events and programs is routine for most utilities, but they can occasionally be caught off guard. Weather-related difficulties are common, for example, when ice storms bring down trees across power lines or, rarely, cause transmission towers and lines to collapse, as happened most notably in January of 1998 in the U.S. northeast and Canada.

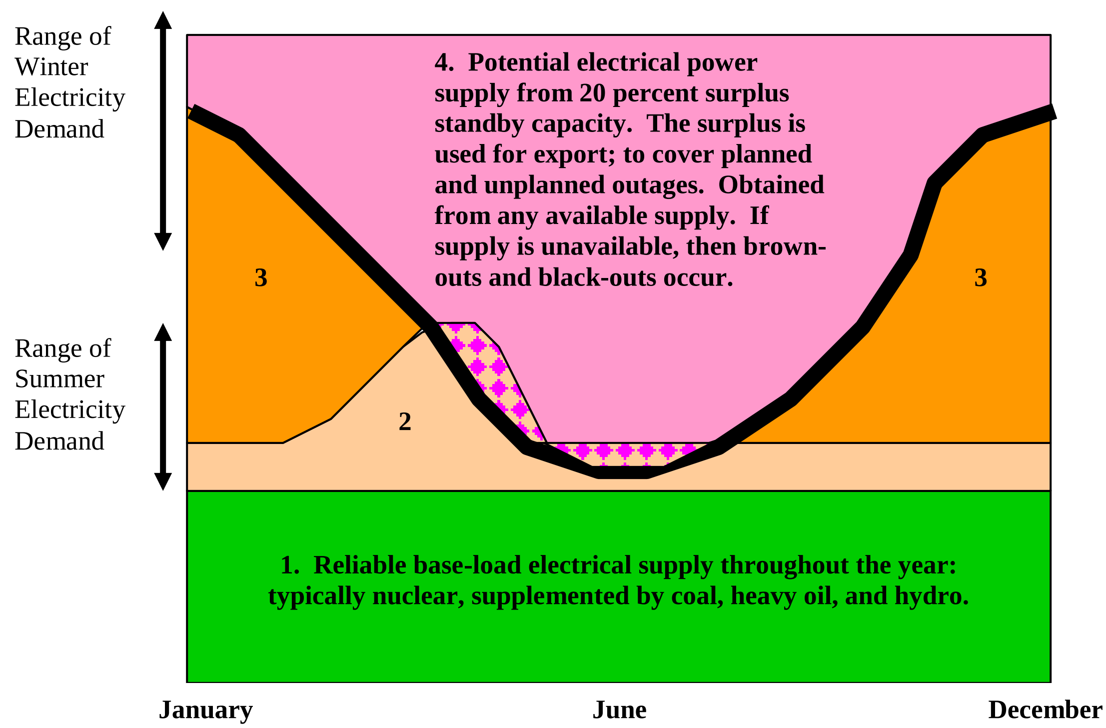
Figure 3. Expected and Typical 24-Hour Electrical Power Demand Curve



1. **Base-load supply for industry, office and street lighting, traffic lights, home heating, water pumping, sewage pumping, hospitals and other round-the-clock services.**
2. **Anticipated morning peak demand from additional home heating or cooling, breakfast cooking, and gradually increasing commercial-demand early in the day.**
3. **Typical demand from office, school, university, restaurant and day-industry load.**
4. **Anticipated evening peak-demand from evening meals, additional heating, entertainment, TV, evening restaurant demand, clubs, theaters, lighting, and fairly rapid decrease in demand as institutions and most industries wind down and close, and as the public sleeps.**

Figure 4 shows the approximate electrical demand from one season to the next for a cold northern-hemisphere region where winter electrical demand far exceeds that in summer.

Figure 4. Typical Electrical Demand Curve and Supply Sources for a Cold Northern-Hemisphere Climate (New Brunswick, Canada).



2. Hydro-electric supply availability, showing seasonal variation because of high spring run-off and low summer and winter water flows.
3. Required electrical supply provided by coal, heavy oil, or imported.

In more tropical locations, as in the southern and much of the south-west U.S., winter demand for heating is relatively low, while summer demand for air conditioning can be very high. Several decades ago, before the present electrical grid system allowed electrical trading over large distances, most utilities recognized the need to have about a 20 percent surplus of electrical capacity to allow for outages, and extreme seasonal demand. In recent years this margin has been reduced and in some cases altogether lost. Regional electrical supply disruptions are now more likely as, despite the existence of grid interconnections, surplus electricity may not always be available for trading, as weather systems can often be continent-wide, and the specter of deregulation ensures that utilities dare not invest in needed new facilities, or surplus systems from which they may never recover their investment (stranded assets).

California faced such an energy supply crisis in 2000 and 2001 and was faced with brownouts and rolling blackouts. These occurred even after the utilities had cut off electrical supply to those industries that had enjoyed lower electricity prices by signing interruptible or recallable supply contracts, and which they had never expected to have recalled. Other industries sold back to the utilities, their non-interruptible long-term low-price electrical contracts, ceased operation, and made more money by selling back the contract for several months at a much higher negotiated price, than they would have made from the sale of goods produced by operating for that period of time.

Although gas is being increasingly used for electrical generation in a few areas where additional electrical supply is needed with some urgency (California), it is generally too expensive and inefficient when used in this way as seen in Figure 5, though is relatively cheap for heating homes. Where free market forces exist, electricity produced by using natural gas cannot compete with generally cheaper electricity from hydro, nuclear, coal, or oil. Unfortunately, in some areas more dams are being removed than are being constructed. Where regulations are against the siting, construction, and licensing of coal, oil, hydro or nuclear facilities, but can be manipulated to favor natural gas, then it may be the only source of available energy in that location, and electricity prices will reflect the relatively high fuel cost.

Natural gas might, however (depending upon price and supply), be well suited as a relatively cheap source of home heating energy, where it may be cheaper than heating with oil or electricity in high population density markets. Unfortunately, gas prices can fluctuate dramatically according to high demand and short supply (February 2003), and any present price advantage in home heating use can very easily disappear. This is especially true where industry may demand an increasing share of the available supply and is prepared to pay for it, as it can pass all such costs along to the consumer, who may at the same time experience supply shortages for their own use, and much higher prices.

In early 2003 gas prices in New York, because of inadequate supply in the severe winter weather, reached US$18.50 GJ^{-1}, and many utility operators found that it was more profitable to sell gas into the public market than to use it for electricity generation. Such a situation of manipulated supply shortages in one market (public heating) or another (electrical generation) appear to be setting the stage for a new round of energy uncertainties, electricity shortages, and massively fluctuating prices.

The ideal and usually cheapest source of electricity is hydropower, though there are often severe seasonal limitations on availability and from competing uses, such as water supply for human use and for irrigation rather than power generation. The readily available alternative, which has no competing uses, is nuclear powered electricity - the least polluting source of energy - followed by that generated by burning coal. Light oil is not suited for electrical generation because of its relatively high cost, though is still used as a primary source of electrical energy in some areas where alternative fuels are not readily available. It is, however, an ideal fuel (diesel oil and gasoline) for temporary use in emergency electrical generators, and as backup or alternative short-term electrical supply throughout the world. Various forms of heavy oil, mostly unsuited for other purposes, are relatively cheap and can be cost effectively used for electrical production.

Fuel cells are of increasing interest as a possible means of converting certain primary fuels such as gas, into electrical power, typically for automotive use. They are not an energy source, as is sometimes wrongly and naively assumed, but are merely an energy conversion device.

Hydrogen, a possible automotive fuel, is an energy storage medium. It is a tertiary energy product formed from the electrolysis of water. With each stage along the energy production and conversion chain: primary fuel to secondary electricity, to tertiary hydrogen, there is loss of energy which cannot be recovered. For this reason, hydrogen produced by electrolysis, would never be rationally used to produce electricity again, though such energy cycles have been seriously proposed.

Some of the most significant engineering advances of the twentieth century are ranked in Table 3. Of these, the most significant technological achievement, resulting in the greatest social change in the last 100 years has been the introduction, growth and use of electricity, which has contributed to the development of most, if not all of the other top twenty advances.

Table 3. Ranking Of Some Of The Major Engineering Advances In The 20th Century. (National Academy Of Engineering)	
1. Electrification	11. Highways
2. Automobile	12. Spacecraft
3. Airplane	13. Internet
4. Water Supply and Distribution	14. Imaging
5. Electronics	15. Household Appliances
6. Radio and Television	16. Health Technologies
7. Agricultural Mechanization	17. Petroleum and Petrochemical Technologies
8. Computers	18. Laser and Fiber Optics
9. Telephone	19. Nuclear Technologies
10. Air Conditioning and Refrigeration	20. High-Performance Materials

One of the most recent proposed electrical developments is the marketing of reactors as floating nuclear power plants of about 35 MW(e) to 70 MW(e) capacity. This Russian development (the Severodvinsk Reactor), would allow electricity to be supplied to remote coastal communities and those on navigable rivers. The first of two units scheduled for 2008, and costing between $100 million to $200 million, is to be placed at Severodvinsk, about 80 km west of Archangel. Typically, such remote settlements in the far North rely upon expensive, though subsidized, diesel generation for electricity, but face difficulties of keeping the locations supplied with oil. District heating with small reactors and for electrical production could readily and efficiently replace these uses, and avoid fuel supply problems. Such mobile reactors could also be used to de-salinate seawater to provide drinking water supply in remote, coastally-located communities in desert locations.

Small reactors have been used to supply some remote Arctic and Antarctic U.S. military and research bases. A small barge-mounted reactor was used by the U.S. to supply electricity to the Panama Canal Zone electrical grid between 1968 and 1975. U.S. aircraft carrier reactors have also been used to provide emergency electrical supply to the grid of some pacific island areas hit by hurricanes, and can also supply potable water.

2.3 Summary of Energy and Electricity Issues:

1. Affordable and abundant energy, no matter how it may be produced, is a social necessity. It is essential for intellectual and social progress and for the continued health and growth of a peaceful society.
2. Technologically advanced societies use energy much more effectively and efficiently than others, and increasingly so, and have the wealth and technology to meaningfully address related environmental issues.
3. The demand for energy worldwide will continue to increase for the foreseeable future and by the middle of this century will be about 2 to 5 times higher than today.
4. The electrical energy requirements of society will be the fastest growing significant use of energy, growing at about 2 to 4 percent or more each year in many societies, and will constitute a continually increasing fraction of total energy demand.
5. The largest energy growth will take place in some undeveloped countries and will be mostly from the expanded use of fossil fuels - especially coal - with its added pollution burden to the earth's atmosphere.
6. Without burdensome and socially devastating regulatory restrictions on their use and emissions, fossil fuels are likely to be exploited until they become too expensive or are depleted as a resource, which may be towards the end of the 21st century for conventional oil and gas.
7. Energy must never be manipulated to be in short supply or unaffordable in order to meet some ill-judged politically inspired goal of the moment. The elderly or the poor should not have to decide whether to buy food or to stay warm.
8. Shortages of energy and higher pricing are usually temporary, and are typically caused by political interference rather than market forces.
9. Shortages of energy, no matter how they are created, are more socially and environmentally damaging than using any unsustainable resource until it is exhausted.
10. We will not run out of energy, but we will need to accept the already developed and widely-used, more advanced and environmentally friendly methods for producing it (nuclear), and sharing the technology with less favored nations.
11. Renewable sources of energy such as wind and solar are politically and environmentally 'correct' at the present time, but are too unreliable and expensive for the basic needs of a progressive society. They are incapable of supplying energy - year-round - in the quantities required in all but a very few ideal and non-industrial locations, especially where the electrical grid does not reach. In many applications, solar photovoltaic cells do not produce enough energy to cover their costs or the energy used in their production.
12. Hydropower is the one renewable source of energy that is generally cost-effective and worthwhile as it is reliable, if limited, and can be base-loaded in many applications, or used to provide peaking power for a defined length of time.
13. Uranium and thorium are virtually unlimited sources of energy. They have the significant advantage, when used in a nuclear power facility, of being extremely concentrated energy resources that are virtually infinite and are more than capable of meeting the world's total energy requirements safely, affordably, and cleanly.
14. We need to rationally define future energy requirements, and plan now.

3. SOURCES AND RESOURCES OF ENERGY

3.1 Sources of Energy

The common potential sources of energy in society are shown in Table 4. It is worth noting that most of these energy sources - all fossil fuels, wood, peat, hydro, solar energy, wind, biomass and ocean thermal energy - are derived directly and indirectly from the giant fusion reactor above us; the sun. The internal energy of the earth (geothermal energy), causing continental drift, earthquakes, thermal and volcanic activity is mostly attributable to the presence of uranium and thorium, and to the heat produced by the decay of their radioactive progeny in the earth (about 0.1 watt/tonne of uranium). Tides are mostly the gravitational effects of the moon and sun upon both land and water, as well as the interference of obstructing landmasses upon the free circulation of water as the earth rotates beneath the sun and moon. Most energy that we use or experience is, therefore, nuclear in origin.

Table 4. Potential Sources of Energy in Society

Transportable	Intermittent & Unreliable	Local
Coal Petroleum Natural Gas Uranium Thorium (Tar Sands) (Oil Shale)	Solar Ocean Waves Wind Tides - (intermittent but reliable)	Wood Water (hydro) Geothermal Biomass Ocean-thermal Peat Hydrogen

Not all countries are equally endowed with energy resources or access to them. In general, those countries which have significant energy resources - coal, oil, gas or uranium - exploit them and either use them locally, or export them into the world market as a tradable commodity to those countries that are energy-resource poor (France, Japan and others). Others develop an energy resource by damming rivers (most) or, rarely, attempting to manage the energy in tidal flows (France, Russia) or ocean waves (Norway). Local energy resources - with the exception of hydro-generated electricity - are usually of limited value and use. With the development of the international electrical grid system, electrical energy derived from any of these resources can be transmitted into many regions and remote areas that may be devoid of easily exploited energy resources and would otherwise be unable to take advantage of them.

In remote inhabited areas too far from the electrical grid to be able to tap into the electrical system, either a primitive way of life can be tolerated, with few amenities and no significant industry, or other ways of producing energy must be considered. In such locations even wind or solar energy can contribute to basic local needs, provided long periods of calm, overcast, or extreme conditions in other ways, can be tolerated.

Before 1940, there were about 6 million windmills operating in U.S. prairie regions, mostly to pump water. When the electrical grid reached these areas, most windmills were allowed to fall into decay or were dismantled. Very few areas of the world, other than those totally without access to reasonable energy sources or access to the electrical grid, can afford to tolerate such intermittent and expensive sources of energy.

It is often mistakenly assumed and widely publicized, that demonstration of effectiveness or of competitive operating costs for wind or solar energy systems in one ideal area of the world, suggests comparable applicability and competitiveness in all areas of the world. Typically, wind energy is available about 20% of the time in most locations. Unfortunately, the 20% is neither predictable nor controllable.

Although wind energy is publicized to have the biggest rate of growth - in percentage terms - of any electrical energy resource, this misuse of figures is misleading. It is actually the slowest growing source of electrical energy, as so few megawatts are added to the very small base supply each year (which was about 25 GW of installed capacity in 2001) – hence the large percentage increase. Despite broadly publicized wind power programs, and a major flurry of activity in response to 'politically-correct' and politically-safe environmental initiatives, the reality is that even heavily subsidized wind power growth is continually losing ground to the major reliable energy sources: coal, oil, gas, nuclear and hydro, which are generally growing each year by the addition of many thousands of megawatts of installed capacity each year in the world, or by efficiency improvements. This is because of one very simple and overwhelming social problem: - wind power is unreliable and cannot be controlled. **When there is no wind, there is no power from any windmill, no matter how many thousands of them there may be.**

At such a time – which occurs often - society must have sufficient, reliable, controlled energy resources using fossil fuels, nuclear power, or hydropower to supply all of its needs and as required. This begs the obvious question of why construct any capital intensive and unreliable project where other more reliable and cheaper sources of energy must be available to meet the entire demand, and must be maintained in (often spinning) reserve at all times? Expenditures in two capital-intensive projects when only one of them is reliable and is required most of the time anyway, is not good market economics. Nonetheless, they are developed where subsidies, tax breaks, short amortization periods, forced purchases of ‘green’ electricity, free access to transmission facilities, high depreciation allowances or other artificial advantages encourage development in the hope and expectation that they will become competitive. Unfortunately, experience shows that once such subsidies are not forthcoming, or expire, many wind projects are allowed to languish, as they remain uncompetitive, producing power only about 20 to 30 percent of the time (Denmark's figures suggest 17%), and never predictably or controllably.

Wind’s critically unreliable energy contributions to society through electrical grid interconnections are likely to remain small and relatively insignificant, as wind is entirely unsuited to this purpose. This is true even in those locations where it is widely encouraged by politically correct ideology, and is heavily subsidized, (Denmark (10 percent contribution to electricity, where it contributes notably to grid instability), California (about 1 percent), and Germany (about 3 percent, and rapidly increasing)). In other uses, such as pumping water in remote regions where there are no alternative energy sources and reliability is therefore not an issue, it can provide a valuable service, though it is usually neglected.

Solar photovoltaic energy is, so far, of value only in niche applications or remote regions where reliability and expense are not typically considered, such as charging batteries, powering calculators, powering university (solar car) research projects, powering refrigerators used for storing and transporting vaccines and medical supplies in remote tropical regions, and in other small localized applications.

There is a basic human desire to be self-sufficient. This leads those who can afford it, to consider installing solar collectors and selling surplus electrical power to their local utility where regulations force the utility to purchase such excess and at an inflated price. However, the general trend in the U.S. over the last decade or so, shown in U.S. Census Bureau data reproduced in Table 5, indicates that many home owners who had installed solar power systems in the expectation of making a profit or at least offsetting high costs, have now had them removed. There will, however, always be a basic market for such solar powered facilities from those who are initially unfamiliar with their weaknesses, can easily afford them, and who can also afford to ignore the costs that they are unlikely to recover, so the actual retirements (and purchases) which offset each other, are undoubtedly much more than might appear in the table.

Table 5. Solar Heated U.S. Homes in 22 States so far Profiled by the U.S. Census Bureau.

	1990	2000
Alaska	56	44
California	13 399	13 508
Connecticut	360	284
Hawaii	5578	6085
Illinois	1139	773
Indiana	573	443
Kansas	545	266
Maine	387	166
Massachusetts	1000	400
Mississippi	223	196
Montana	185	179
Nebraska	256	124
Nevada	652	375
New Hampshire	383	180
North Dakota	36	39
Oklahoma	433	299
Oregon	633	476
Rhode Island	171	114
South Dakota	115	96
Vermont	123	90
Washington	759	374
Wisconsin	713	409

Because of the nature of census data, there are large uncertainties in many of these numbers

3.2. Estimated Energy Resource Reserves

Estimated energy reserves and resource life, shown in Table 6, have generally risen over the last century as exploration has uncovered new deposits, and costs and efficiency of extraction have improved and permitted exploitation of lower grades of resources.

Concerns over impending resource shortages have always been unwarranted and premature. This has been well exemplified by the ever-present concerns, continuously stated since about 1900, that oil supplies would run out in just the following decade or so. At the present time, almost 100 years later, conventional oil reserves are close to an all-time high, and even they are dwarfed by the oil contained in Tar Sands, which occur abundantly in northern Canada (with currently estimated reserves of about 180 billion barrels), and in oil shales. Current fears about impending natural gas shortages may also be premature though there is a disturbing downturn in production from some fields, and there is a current shortage of pipeline capacity to move the gas that could be produced into the consuming areas at times of high demand. However, society is approaching a time when exploitation at the present rate will not be sustainable. Society will by then have already moved its energy requirements into other sources of energy as is so clearly indicated by the energy progression shown in Figure 2. Because of the increasing difficulty of expanding the use of fossil fuels, these will likely be based largely upon uranium and thorium use. This will only happen when the public and politicians are faced with obvious and unpalatable outcomes from not having adequate and assured energy once it becomes very clear to them that renewable sources of energy are incapable of meeting all but a relatively small fraction of demand. Politicians usually respond correctly only when they are backed into a corner from which there is no obvious escape. They then try to take credit for having made a painful decision, but without admitting that it should have been decided decades before.

Table 6. Estimated Years Remaining at Current Rates of use (2002), Using Uranium in Fission Reactors without Reprocessing, and without Development of the Fast Breeder Cycle.

Resource	Years remaining at current rates of use
Coal	200
Oil (conventional)	40
Gas	60
Uranium	130
Estimates of Resource Availability with Universal Spent Nuclear Fuel Reprocessing; with Wider Use of the Breeder Reactor; and with Development and Adoption of the Fusion Reactor.	
Uranium Reprocessing	10,000
Uranium and Thorium in the Breeder Reactor*	Millions of Years
Fusion Reactor (Under Research)	Virtually Unlimited. (Our own sun is a fusion reactor)

Various data sources.
* The use of the Breeder cycle (researched since 1944 and currently in pilot and limited commercial use) economically opens up much lower grade uranium and thorium resources, including seawater in which uranium is present at a concentration of only 3 parts per billion.

Any estimate of energy resource reserves is strongly influenced not only by a zealous search for new accessible reserves, but also by commodity pricing, as well as by government-imposed regulations. Such regulations may proscribe the free development of certain resources no matter how large the untapped resource, as has happened with some coal and oil deposits in what are regarded as sensitive or remote locations (The North Slope of Alaska). Resource substitution, can also rapidly remove any depleting or uneconomic resource from consideration as a source of energy. This happened when coal replaced a rapidly depleting wood supply, and is happening less obviously as nuclear power replaces some coal energy applications, though with a temporary reversal in the U.S. because of energy pricing and shortages. Politically enforced pollution concerns, rather than the application of free market forces, may dictate early abandonment of the development or use of certain fossil fuel resources in some locations.

Some few locations in the world control most of the world's natural energy reserves and are in a position to influence market price and even market availability of sensitive energy supplies, as with the concentration of oil reserves in the Middle East. Thus, although it is possible to estimate the remaining years of resource use based upon presently known reserves and current rates of use, there is no guarantee that this resource will be available to any market for this length of time or indeed that it will be exploited to the point where economically exploitable reserves can be regarded as non existent.

It is unlikely that any energy resource will be depleted. As soon as fossil reserves begin to fall significantly such that prices rise, there will be a gradual switch to alternative and cheaper sources of energy, where reserves or even commodity pricing may not be an issue. This will occur with the use of uranium and thorium in advanced breeder reactors, or by adopting different operational cycles by reprocessing nuclear spent fuel rather than storing it indefinitely and treating it as waste. Some countries already re-process spent fuel. In contrast to fossil fuels, the resource outlook for uranium is essentially unlimited, as it will be cost effective to extract uranium from seawater (even at 3 parts per billion) if a breeder reactor cycle, which more fully utilizes uranium-238 to provide about 60 times more energy than from the same fuel load in existing fission reactors, is widely adopted. The development of advanced nuclear cycles is largely dependant upon the price of uranium increasing to at least three or four times the present (2005) price of about US$60 kg^{-1}.

4. CHARACTERISTICS OF ENERGY SOURCES

4.1 Energy Source Advantages, Disadvantages

Comparing energy sources and looking at their relative advantages/disadvantages and strengths/weaknesses, is not a popular exercise with most special interest factions, as it too easily exposes their attempts to mislead the public.

Some of the major advantages and disadvantages associated with using specific sources of energy are given in Tables 7 and 8. However, any advantage is increasingly subject to the uncertain whims of political decision-making and pressure upon politicians, and through litigation inspired by special interest factions. This is especially true with respect to the actions that may be politically imposed in response to the assumptions concerning the uncertain human contribution, if any, to alleged global warming.

Table 7. Consideration of the Major Advantages of Most Energy Sources	
Energy Source	**Major Advantages**
Coal	Abundant in some regions. Accessible to modern mining techniques. Suitable for electrical baseloading. Reliable source of energy used for hundreds of years. Relatively cheap in some locations (Figure 5).
Oil (Conventional, non-conventional)	Abundant in some regions. Mostly used for transportation, heating and petro-chemicals. Lower grades of oil and orimulsion ® can be used for electricity production. Suitable for electrical baseloading where coal or nuclear are not available. Tar sands and oil shales represent a major non-conventional oil resource for hundreds of years, if economically exploitable.
Natural Gas, Sub-sea methane	Abundant in some regions. Less polluting than coal or oil. Plants can be rapidly, approved, constructed and licensed for electrical supply where coal, oil or nuclear facilities are politically opposed or are not readily approved. Sub-sea methane, in very large quantities, is a recently discovered resource of unknown exploitability or value.
Hydro Power (dams or run-of-river)	Abundant in some regions. Minimally polluting, Cheap source of electricity. Dammed supplies are ideal for supplying peaking power at times of brief high demand. Run-of-river, supplies most power during times of high river flow in spring. Displaces fossil fuel pollutants.
Nuclear Power Uranium, Thorium	Extremely large energy-density fuels and associated low rate of transportation accidents and costs. By far, the safest large source of energy. Occurs in many regions and can be profitably extracted from some coal ash, phosphate fertilizer, alum shale, some copper ores, and seawater. Can be used anywhere in the world that there is a source of cooling water, and reactors can be very small, barge mounted, mobile, and operable for as long as 30 years without refueling. Ideal for remote-location, cold regions. The Least environmental impact and least atmospheric polluting of any energy source (Table 10). Essentially non-polluting. Low volumes of radioactive wastes, which are 100 percent managed. Low fuel costs are a minor part of electricity costs, which are thus relatively stable and low (Figure 5). Ideal for base-loaded electricity production, desalination and district heating. Unlimited resource for millions of years with advanced breeder cycles. The world's 443 (2003) commercial nuclear facilities, displace about 3 billion tonnes of carbon dioxide each year and millions of tonnes of gaseous, solid, and highly toxic metal pollutants. Most professional bodies, scientific organizations, and many environmental groups favor nuclear energy development as an inexhaustible and non-polluting source of affordable energy, though this support is rarely communicated to the general public.
Tidal Power (barricades or run-of-channel)	No significant advantages. Little used, though it is a reliable, if limited and intermittent resource. Now being considered for use in California, and with a seabed tidal project being built in Norway.
Wind Power	Minor advantages in some uses. Useful beyond the electrical grid in low reliability electrical applications such as battery charging, and in non-electrical applications such as pumping water.
Photovoltaic Solar power	Minor advantages in some uses. Useful in niche applications away from the electrical grid such as water heating, medical refrigeration, battery charging and in minor applications where cost is not an issue, such as hand-held calculators.

Table 8. Consideration of the Major Disadvantages of Most Energy Sources	
Energy Source	**Major Disadvantages**
Coal	Relatively low energy-density fossil fuel. Billions of tonnes required each year. Variable fuel costs, dependant upon labor costs, mining method, depth, coal seam thickness, quality, and transportation costs. Not available in all regions. Mining accidents are common. Transportation costs are high and accidents are common. Atmospheric pollution (Table 10) and related public health effects (Tables 12 and 13) are common. Mercury, and other volatile metal pollutants are emitted upon combustion. Large tonnages of toxic solid wastes. Finite and limited resource. Resource outlook out to about 200 years in favored countries, a few decades in a few others. Many countries lack, or have depleted their coal resources. Environmentalist opposition.
Oil	Relatively low energy-density fossil fuel. Billions of barrels required each year. High, and variable fuel cost (Figure 5). Political manipulation of supplies is a major problem. Transportation costs are high, and major accidents are common. Atmospheric pollution (Table 10) is significant. Limited resource. Conflict over oil supplies has been the cause of most recent wars and international conflicts. Resource outlook out to a few decades in favored countries. Many countries lack this resource. Environmentalist opposition.
Natural Gas	Relatively low energy-density fossil fuel. High fuel cost if used for electricity production (Figure 5), but generally lower cost than oil for home heating (though this can change). Demand can outstrip supply. Massive variations in price present serious difficulties for home heating affordability. Transportation costs are high. Accidents are common. Atmospheric pollution is significant (Table 10). A highly flammable and explosive gas. Gas fires are a major cause of death following earthquakes (California and Kobe), and leaks. Limited resource. Resource outlook no better than a few decades. Many countries lack this resource. Environmentalist promotion and opposition.
Hydro Power	Relatively limited, but sustainable energy source that is mostly fully exploited. No fuel cost. Few exploitable sites remain. Some countries are devoid of significant sites. Population relocation issues. Seasonal variation of run-off. Water management issues and irrigation conflicts. Siltation and fishery management problems. Environmentalist promotion and opposition. Many dams are being removed at this time.
Nuclear Power	Poorly understood by the public. High capital cost. Subject to emotional misinformation and a persistent radiation mythology. Fear of accidents. Public concerns due to lack of understanding of waste management. Security, and nuclear proliferation issues. Lengthy time frame of radioactive wastes management. Minor, but widely publicized opposition based upon misinformation.
Tidal Power	Limited energy supply resource. High capital cost. Intermittent and limited though predictable and reliable. Costly. Storm damage effects. Concrete deteriorates in salt water. Siltation effects. Navigation, coastal and fishery effects. Environmentalist promotion and opposition.
Wind Power	Limited and low energy-supply resource of about 8 kW/ha. Costly. Unreliable, uncontrollable and intermittent - operates about 20 percent of the time. Relatively high capital cost. Few suitable sites. Subsidized more than any other energy project. Expensive to connect to the grid because of numerous small generators in remote locations. Generally unsuitable for grid supply. Cannot be baseloaded. Large numbers of generators required on coasts or on scenic high ground. Adverse effects on bats and many rare or endangered bird species in bird migration routes. Difficult to service in all seasons. Numerous service personnel required. High energy-consumption servicing with frequent winter and off-road accidents (Table 13). Windmills are damaged and demolished by adverse winter weather, icing, and wind gusts. Causes grid unreliability because of gusting and short-term power fluctuations. Environmentalist promotion and opposition.
Photovoltaic Solar power	Limited energy supply resource. Very high capital cost. Unreliable, intermittent. Uncontrolled. Not considered for grid supply. Few suitable sites only in low latitudes, large areas of collection required and associated large numbers of servicing personnel and related injuries (Table 13). Units are unlikely to recover their costs.

4.2. Energy Densities of Fuels

The energy densities of most sources of energy are compared in Table 9. There is no way to reliably quantify any comparable figures from hydro, wind or solar energy facilities as they do not consume a definable commodity, and their operations are intermittent, variable and, except for hydro power, largely beyond human control.

The Einstein mass/energy equivalence (expressed as $e = mc^2$) shown in Tables 1 and 9, is the theoretical energy that is provided by the complete conversion of mass to energy. This happens to a small degree in nuclear reactor processes, as atoms are fissioned, but even that small destruction of mass, produces relatively large amounts of energy. In fossil fuel combustion the energy released is from chemical exothermic oxidative changes.

Table 9. Approximate Energy Equivalence Numbers for 1 Kilogram of Fuel

Fuel (thermal conversion to electricity is only 30 to 40 percent efficient)	**Amount of electricity (kWh) produced by one kilogram of fuel**	**Fuel for 1000 MW (e) for one year (8 760 000 MWh)**	**Approximate fuel cost $U.S. for this electrical production**
Hardwood	1	8 760 000 tonnes	$200 000 000
Coal	3	2 920 000 tonnes	$146 000 000 ($50 T^{-1})
Heavy Oil	4	2 190 000 tonnes (15 330 000 barrels)	$263 000 000 ($120 T^{-1})
Natural Gas (methane)	6 (at 40 percent thermal efficiency)	1 460 000 tonnes	$788 000 000 ($10 GJ^{-1})
Einstein mass to energy: $E = mc^2$	**2.5E10 (25 billion)**	**350 grams (in theory, and for 100 percent efficiency of conversion)**	**Not applicable**
Uranium (natural, once-through) (e.g. CANDU)	50 000	About 175 tonnes	$17 000 000 @ $2 000 per CANDU fuel bundle
Uranium (low enriched, once-through)	250 000	35 tonnes	$55 000 000
U closed cycle or breeding	3 500 000	2.5 tonnes	$60 000 000 estimated
See also the relative electrical generation costs for various fuels in Figure 5.			

Energy density of fuel is also only part of the consideration. It is instructional to consider how much energy is consumed in extracting an energy resource or in bringing an energy facility into an operating state. For example, to extract three barrels of oil from tar sands, takes about one barrel or more, of oil energy. Another example, that of ethanol production, which consumes about 70 percent more energy to produce ethanol than is returned when the ethanol is used as an additive to gasoline, indicates the difficulties which arise by political interference in energy markets. Ethanol has been seriously considered as an automotive fuel since before 1930, and it is still relatively pointless. An ethanol-based economy, as with one using only wood, wind or solar power, would consume more energy than it could produce to reasonably sustain itself and humanity, and to replace itself or grow. This is only one reason why the so-called renewable sources of energy: wind and solar, were rapidly abandoned over the last few hundred years, and were replaced by more efficient, capable, and reliable alternative energy, and higher energy-density sources - fossil fuels, nuclear energy, and transmitted electricity. The ability to use relatively concentrated energy producers like coal and local waterpower, and to scale them up, was the main reason why the industrial revolution was able to take place. Industrial growth and social progress since that time has taken advantage of the increasing and useful energy margin that can be derived from succeeding and larger energy-density fuels such as oil, gasoline, natural gas and uranium, which are amenable to being used in larger and larger quantities at one location, to take advantage of the economy of scale.

4.3. Pollutants from Energy Use

All of the various effective ways of using energy, produce wastes at some point in their cycle or have an adverse environmental impact in other ways. Combustion wastes – pollutants, shown in Table 10, when thrown into the atmosphere - as most of them **are** from the combustion of fossil fuels - are implicated in premature deaths (180 000 per year) from atmospheric pollution and from volatilized toxic metals such as mercury. Releases and build-up of carbon dioxide from combustion of fossil fuels is suggested as being implicated in alleged global climate warming and contributing to its assumed negative effects upon the environment and humanity. However, carbon dioxide is not a pollutant in the same sense as the other emissions. There are no adverse health effects because of it in the atmosphere, and it is an essential gas for all living things to thrive.

Table 10. Atmospheric Pollution and Solid Waste from World Energy Use
(Millions of tonnes produced in 2000)

Source	**Sulphur Dioxide**	**Nitrogen Oxides**	**Partic-ulates**	**Carbon Monoxide**	**Carbon Dioxide**	**Solid Waste**
Coal	100	>20	500	3	9000	>300
Gas	<0.5	2	<0.5	5	4000	minor
Oil	40	10	2	200	9000	15
Wood	0.2	3	100	200	5000	50
Nuclear	0	0	0	0	0	0.04
Hydro	0	0	0	0	0	0

These are approximate estimates. The use of gasoline in automobiles produces about 200 million tonnes of carbon monoxide each year, worldwide. In total contrast to the highly controversial atmospheric pollution from fossil fuels, including mercury, the entire waste product from nuclear power operations is managed and controlled. The 40 000 tonnes a^{-1} of nuclear waste is totally managed by the industry. Spent nuclear fuel, produced at the rate of about 15 000 tonnes a^{-1} in the entire world, is not waste, but represents a recyclable resource as only about 1 to 3 percent of the contained energy is used in the first pass through the reactor cycle. All non-nuclear energy wastes are mostly true wastes, though some scrubbed sulfates may be used in wallboard, certain combustion ashes are valuable as pozzolans in concrete, and some heavy oil combustion wastes are a commercial source of vanadium. The bulk of such wastes however is either rejected into the atmosphere or is discarded into landfills.

Nuclear power is the least polluting source of sustainable and affordable energy. Through the application of fission reactors, and by progression to advanced nuclear cycles - even without considering the possibility of future nuclear fusion - it can supply base-loaded electrical energy for many millions of years. At the present time it displaces almost three billion tons of emitted carbon dioxide and about 100 million tons of solid wastes a year from the coal that would otherwise have been used. In a future, possibly hydrogen, economy it could theoretically displace the more expensive and politically sensitive petroleum fuels from most of their relatively inefficient uses in transportation, and further cut back on pollution.

The issue of environmental impact of our use of energy has recently begun to shape our considerations of where we derive our energy and how much of it we use throughout society. However, the environmental impact of technology is a continuously changing, and usually lessening function, as technology improves and societal wealth increases. History has shown that advances in existing technology, efficiency, and new developments, lessen and sometimes eliminate earlier environmental problems while creating newer and usually lesser ones. However, as Indira Ghandi, a former leader of India, sagely pointed out, ***poverty is the worst polluter.***

Recent history shows that once a certain level of wealth has been achieved in any society, then environmental issues begin to be addressed and reduced, but not before. It also shows that environmental problems are most often solved by technology, wealth and progress, and rarely by any other means. Therefore, environmental issues should generally be secondary to the primary issues of energy availability, sufficiency, technological progress and scientific development. Usually, the public and media can be persuaded to believe just the opposite - mostly through ignorance of society, the environment and technology - and that the root cause of environmental problems - whatever they may be - is technology and progress.

Recent measures of environmental quality in the industrialized world, show dramatic improvements in most sensitive areas of air and water quality (Pacific Research Institute), despite broadly held beliefs to the contrary. These improvements were the direct result of technology, and occurred despite the major hindrances arising from over-regulation and activist misinformation and obstruction.

5. ECONOMICS AND SAFETY OF ENERGY USE

5.1 Land Use Requirements

A comparison of the environmental 'footprint' for equal use of the various energy options is given in Table 11.

Table 11. Approximate Relative Land Use Comparisons for the Same Energy Production*

Option	**Required Land Use (km^2 $40GW^{-1}$)**
Nuclear	10
Natural Gas	20
Coal	30 - 40 (much more if the coal is open-pit)
Oil	20
Solar (photovoltaic)	630
Hydro-electric	200 - 15 000
Biomass (Wood)	25 000+
Windmills	10 000

*Most data are from the Institute for Risk Research of the University of Waterloo - 1992, with some modifications.

5.2. Energy And Electricity Costs

Energy costs vary from one jurisdiction to another and are dependant upon such things as international commodity prices, long-term contracts, costs of extraction, processing and transportation, and imposed taxes and pollution penalties. Electricity costs are typically made up of capital cost recovery of the generating facility including interest charges, operating and maintenance (O&M) costs and fuel costs.

In the U.S. and many other developed countries, environmental regulations, and the way in which these regulations are misused through court interventions, can sometimes double and triple the basic costs of major projects and make them entirely uneconomic. In response to this in California - where requirements for environmental assessments; environmental restrictions on emissions; roadblocks in licensing, and regulations for the siting, construction, and operation of power plants - new, and desperately needed, gas and oil energy facilities are being built across the border in Mexico. Within a few miles of the U.S. border, there are sites earmarked for the construction of about 20 to 30 large energy projects to supply the California and Western U.S. power market, free of the regulatory and environmental encumbrances that have stalled most domestic projects in the U.S. and especially in California for the last two decades, and which led to the most recent crises.

Although long-term energy contracts are generally preferred as a means of controlling major uncertainties and price variations, these may not always be available or even chosen. Where energy or electricity shortages occur, those without such contractual protection face significant spot price variations of up to several hundred percent, and bidding competition that can severely drive costs up, as happened with gas supplies and electricity costs in California in 2000 and 2001.

Indications of relative electricity costs and their fluctuations and trends in the U.S. market, which is fairly typical of most developed countries, are shown in Figure 5, showing U.S. Electricity Production Cost Estimates (combining Operating, Maintenance and Fuel costs) from the use of Oil, Gas, Coal and Nuclear, from 1981 to 2000 as detailed by the U.S. Utility Data Institute.

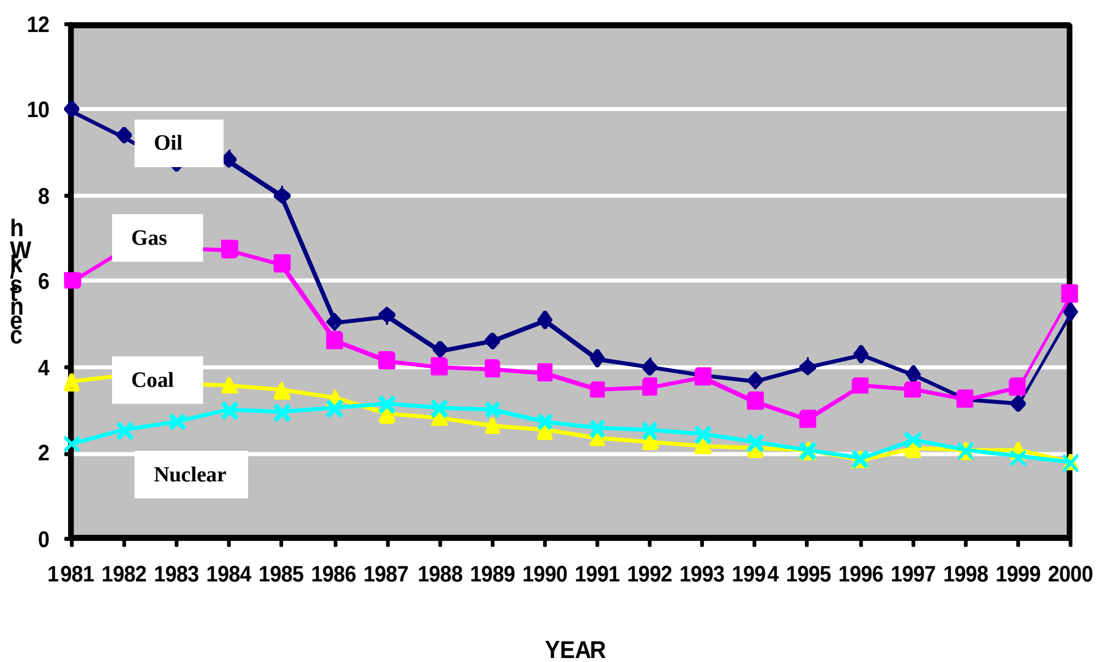
Unfortunately, though oil and gas are consistently the most expensive of the fuels shown, they are still used in some areas for electricity production, especially where reliable alternatives are not available. In some regions the use of relatively expensive gas to produce electricity is on the increase. This is occurring in those areas that are still facing potentially dramatic shortages of electricity and massive price hikes, like California, where it is now easier to gain regulatory approval for construction of a relatively cleaner burning gas plant than any other facility. Regulatory hurdles typically favor the construction of gas facilities by ensuring that environmental reviews are shorter and relatively unopposed, construction times are shorter, and operational approvals are less onerous than for a new coal or nuclear facility.

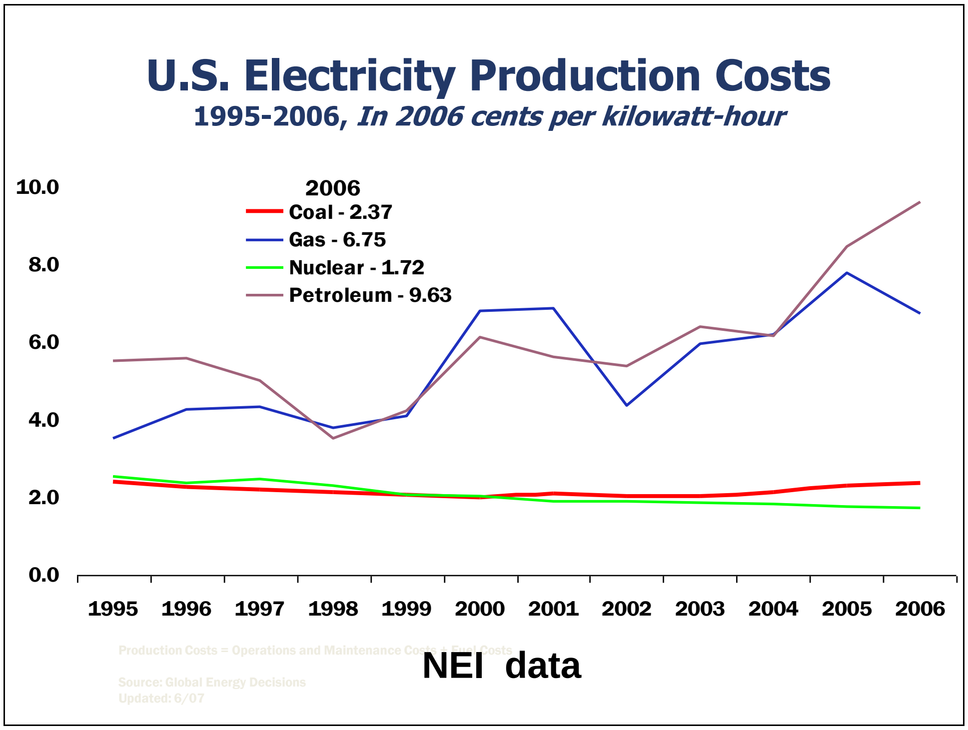
As Figure 5 shows, coal and nuclear are generally cost competitive in the U.S., and (except for the least costly hydro-power) are the less costly options for electricity production, as domestic prices are better controlled and resource availability is not an issue. However coal has major pollution problems and accidents associated with its use, and nuclear power facilities have a much higher capital cost and longer payback time (though comparable running cost at the present time). For obvious political reasons, coal has a greater advantage in coal producing states. Where coal burning facilities are located at the pit head, and the coal is typically low sulfur as in the Western States, there are significant cost advantages through not needing to transport coal any distance, and through not yet needing to consider installing and operating sulfur scrubbers or carbon dioxide reduction technologies which may take about 25% of the produced energy to operate. This temporarily gives a cost advantage to coal plants in those locations. Where coal transportation costs are high and neither coal, nor oil, nor gas are readily available (France, Japan and many other countries and regions) then nuclear facilities generally have a significant advantage.

Since 2000, the price of gas has been notably volatile such that the indicated cost of electricity using gas, has steadily risen to a level even higher than that indicated in the graph for the year 2000.

Figure 5. U.S. Electricity Production Costs

(O & M and fuel, in constant 2000 cents/kWh) (Source: U.S. Utility Data Institute)





Unfortunately, gas prices and assured supplies of imported gas are not predictable, as demonstrated by the extreme price variability for gas starting in 2000. However, gas fuel costs, no matter how high, can be passed directly along to the consumers without regulatory intervention, so total fuel and capital cost recovery times can be short. This is desirable for investors, and extremely important in markets where open market competition, because of partial deregulation, can make a long amortization or payback time a distinct impediment to investment in any energy generating facility.

Most politicians have not yet realized that de-regulation and freeing the market to trade electricity without requirements to preferentially supply any domestic market needs first, will often result in regional electricity shortages and price bidding spikes, as electricity flows to the higher priced markets. In such a competitive situation, inefficient, old, highly-polluting and costly facilities will be operated as long as possible, and then retired rather than refurbished at great cost. New, costly plants will not be built without likelihood of a fast cost recovery, as with natural gas facilities. Surplus capacity, that might never be used, is a crippling expense, and is not tolerated or planned. The resulting tight supply of electricity will be traded to the highest bidders and those left without electricity will suffer the social consequences. The lessons learned from California's painful experience in this regard were a wake-up call for other jurisdictions to think carefully and proceed with caution, but few appear to have understood this lesson.

5.3 Energy Safety

No source or use of energy is entirely safe, or can be made so. All sources of energy have risks associated with their exploitation, transportation and use, including from their wastes and maintenance. This is equally true of many sources of energy that are mistakenly regarded as being relatively safe, such as wind or solar. Honest evaluation of energy and energy use risks, requires that they all be compared as far as possible in the same frames of reference so that their relative risks per unit of use or of electrical generation can be compared. This is not a popular exercise with many special interest factions who are more interested in making extreme, highly emotional and unfounded allegations about specific targeted sources and uses of energy, in order to create concern and fear in their audience, usually about nuclear power.

Comparison of actual recorded fatalities because of accidents in each major energy industry in a recent 18-year interval is shown in Table 12.

Table 12. Severe Accidents (2300) and Acute Fatalities (18,431) Reported in the Energy Industries Worldwide, 1969 to 1986 (Many Closed Societies did not Report Accidents at that Time).						
Energy Source	**Number of Events with Fatalities (approx.)**	**Causes**	**Installation**	**Immediate Fatalities per Event (approximate)**	**Total Immediate Fatalities**	**Immediate Fatalities per GW(e) per Year.**
Coal	62	Various Mine Disasters	Coal Mines	70	3900	0.4
Oil	160+	Capsizing Fire/explosion Fire/explosion Transportation accidents	Platforms, Refineries, Tank Farms, Tankers	40	6200	0.3
Gas	80	Fire/explosion Earthquake/fire	Gas Wells and Distribution	50	3100	0.4
Hydro	20	Overtopping Failure	Dams	300	5200	2.0
Nuclear	1	Design and Operation	Chernobyl	31	31	<0.01
Data, inevitably incomplete, are from various sources: Nuclear News, Paul Scherrer Institute, and others. Longer-term injuries and fatalities are significant for mining activities and from fossil fuel pollution effects, though these latter effects are usually not readily assessed or scientifically defined. Long-term health effects from nuclear power use (low dose, and low dose-rate exposures at much less than natural background dose) are relatively insignificant.						

Human safety because of energy use is rarely considered by the public unless specific issues are drawn to their attention as with pollution effects upon health, or the outcomes of accidents as with coal mining, gas explosions, oil spills and fires, amputations or deaths of maintenance workers on windmills or while traveling to them, bird kills from windmills, or a nuclear accident like Chernobyl where allegations of injury far outweigh actual injuries.

Since 1900, there have been almost 90 000 coal mining deaths in North America alone, with the period before 1920 being the worst. The year 2002 in the U.S. was recorded as having the fewest number of mine-related fatalities since 1900, with only 67 deaths - 20 of them coal-related - in a survey of more than 300 mines. There are considerably more such coal mining deaths, but with much less, if any publicity, in the relatively unsafely-managed and less well-regulated coal industries in countries like China and the Ukraine, in which there are thousands of deaths each and every year, and tens to hundreds of accidents. The public is so familiar with such events that they receive only scant attention even when they are publicized.

A comparison of the actual relative safety of most energy generation options, from industrial and epidemiological data accumulated over the last 50 to 100 years and more, is presented in Table 13 and in Figure 6, which attempts to include the estimated relative risk from natural gas fires and related deaths in the widespread gas fires from disrupted gas supply pipe-lines in cities following earthquakes. The same general risk relationships are maintained in Figure 6, apart from those of natural gas and hydro-power.

The most important safety or loss-of-life figure of all, is the one that is most difficult to define. It is the human fatality rate that would exist if none of these energy sources were used. What is known, is that as undesirable are the fatalities associated with the use of any energy generation option, lack of sufficient energy, and energy that is too expensive, translates into fatalities many thousands of times higher, along with social chaos. Some hint of this is obtained at different times in many countries, as for example in countries like the U.S. and Russia. In a severe winter in Moscow, several hundred people freeze to death in some winters, with fewer overall cold deaths in the U.S. Deaths from heat also occur in poor sections of large cities in more prosperous countries like the U.S. where elderly people cannot afford air conditioning and die in heat waves each summer in northern areas where air conditioning is not usually essential (Chicago). In the heatwave of the summer of 2003 in most of Europe, about 15 000 premature deaths in France were attributable to the unusual heat in the region and the lack of air conditioning. Deaths are more often attributable to extreme cold, than extreme heat.

Table 13. Approximate Relative Human Impact of Most Energy Producing Options as Derived from World Data (for the same energy output). Data for all except wind and solar energy are from the IAEA 2002.

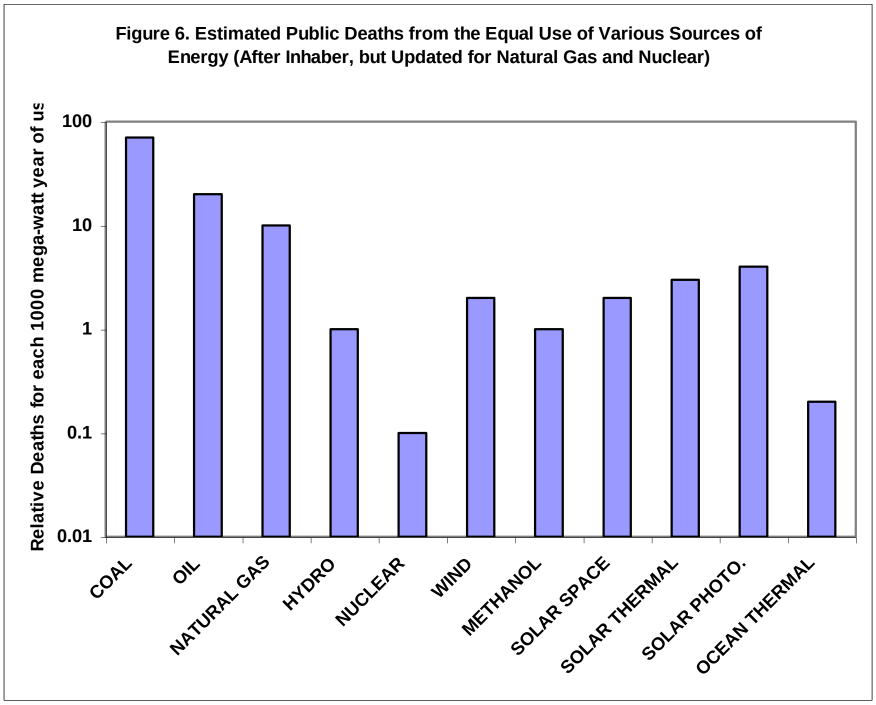
Energy Source	Relative Human Fatalities for the same energy generation.
Nuclear Power	1
Natural Gas	9 *
Hydro power	80
Wind	100
Solar - Photovoltaic	110
Oil	360
Liquefied Gas (LNG)	3100
Coal	3200

* This number does not take into account the major public loss of life in gas fires following earthquakes in major cities, as occurred in the most recent California and Kobe earthquakes.

Comparable data from the Paul-Scherrer Institute for 1969 to 1996, showing relative human fatalities from 4290 energy-related accidents, indicate that for each terrawatt-year of energy use, the following numbers of fatalities were recorded:

Nuclear Power	8
Natural Gas	85
Coal	342
Oil	418
Hydro	884
LPG	3280

The relative positioning of coal, oil and hydro are somewhat different, but that of nuclear power remains unchanged; being much safer than any of them.



6. CONCLUSION

6.1 Energy Requirements of Society

Progress from the primitive existence of the Stone Age, through the industrial revolution to the communications age in which we live, was achieved largely by our ability to progressively use more advanced sources of energy, in greater quantity, and more efficiently. Life expectancy increased and the quality of life and health were improved by such changes. With such an important and much publicized subject - our energy-needs today and in the future - open to manipulation by competing interests, many of whom are clearly not at all informed about the issues, it is vital that readers become broadly informed for themselves, and draw their own conclusions about energy choices and use, based upon their own region, climate, industry, personal lifestyle, social requirements and future expectations for themselves, their children, and society.

Only some of the voluminous data are presented here, but additional data providing the essential perspective to rationally address the issue, are readily obtained from the numerous reliable industry and (most) government web sites and alternative references.

The author's biases - and everyone is biased one way or another whether they care to admit it or not, or decisions would never be made - are based upon more than 20 years of work in the energy industry, and the comprehensive facts that are readily available with some research; by asking searching questions; demanding solid factual data rather than empty promotional statements and testimonials; and by comparing and contrasting all sources of energy in the same frame of reference. It is also very helpful to recognize when there is an attempt to avoid providing needed data, and to view most energy statements from untested and unaccountable organizations, with some skepticism. Emotional pronouncements and allegations of health effects and environmental impact, targeting the public and politicians through the media, are usually indicative of a lack of honest purpose, and reveal a studied avoidance of the kind of perspective that is broadly presented here.

The overall value of energy and electricity in society is directly related to the fundamental requirements of being available, affordable, abundant and assured in approximately that order. Any source that can easily meet all four, is desirable. Some regions must settle for fewer, and sometimes none of them, especially if they must import energy from other, politically unstable countries. Such uncertainties have led to war.

If we have choice of energy sources which can meet those basic requirements, then we can compare them to decide which has the least cost, the least human risk associated with its use, and which has the least environmental impact. The correct order, for any rational society will always put survival ahead of environmental considerations, though this is sometimes difficult to convey with a constant barrage of emotional pronouncements that favor the reverse, but without understanding why it cannot be so. Only wealthy, stable societies can consider all of them, and act upon them all, but such rational ranking and consideration are rare when emotions are so easily manipulated to influence public and political choices.

In reality, there is no shortage of energy that is not caused by political interference and market manipulation. We have mostly developed the readily useable hydro resources; fossil fuels will eventually be limited either because of resource depletion and higher prices, or because of regulation, following concerns about climate change; wind and solar power are costly, and could supply only a minuscule part of the energy needs of society, and unreliably at best. Nuclear energy is the only rational, affordable choice that remains at the present time. Society has access to sufficient nuclear energy resources to last for many thousands to millions of years. They are affordable, relatively non-polluting, and are already in widespread use in many countries that do not have reliable access to fossil fuel resources.

When it comes to debating energy issues and coming to grips with what we would like to see in our future, we would be wise to remember the words of Homi Bhabha of India, who so simply, but accurately, stated, 'No energy is more expensive than no energy.' He might have added 'or is so socially limiting or environmentally damaging.'

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