Why Solar and Wind Energy is Inappropriate for Utility Power Backbone Grid Generation

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Every time someone mentions wind or solar power as the answer to our energy needs (for baseline or power grid generation,) the image that should form in your mind is that of 1 billion or more dying and starving children. If you do not yet understand why this is the case, you are forgiven. By the end of this piece you shall have been given the essential concepts and facts both to understand this essential fundamental truth, and to act to prevent it.

Begin with this. To maintain a global population in a condition resembling a modern 21st Century standard of living will require an installed electrical generating capacity of at least 3 to 5 kilowatts per capita. Today only the United States, Japan, Israel, and a few countries of Western Europe even approximate this level of generating capacity. Let us understand the meaning of this more clearly, before moving on to the crucial question of how we should and can generate this power the world so desperately needs.

Kilowatts are a measure of electrical *power*, the amount of work that can be done per unit of time. One of the first means of measuring *power* was to compare it to that of a working horse. The standard horsepower is equivalent to about 750 watts of electricity. That means that it takes 750 watts of electricity, driving a motor or other device, to do the same work as a standard working horse. Thus, 1 kilowatt (1,000 watts) of electricity is equivalent to the work of about 1.33 muscular horses of the working type. The horse cannot work all day, however, but only perhaps for one third of it, after subtracting the time for meals and rest. Thus one kilowatt of electrical generating capacity, available all day and night, could do the work of 3 times 1.33 horses equals 4 horses.

Here in the United States, we have about 3 kilowatts of electrical generating capacity available per capita—much less than we need to be a truly productive economy, but still something that most of the world comes nowhere near. Thus we could say that every person in the United States, on average, has the work of 12 horses available to him every hour of the day and night, in the form of electricity.[1] Without electricity, the work of those silent horses must be done by men and women, laboring to turn pumps, to carry water on their heads, to spend a whole day scrubbing clothes and another heating irons on a fire to press them, while such simple requirements as water and sewage treatment, refrigeration, even the light bulb, go wanting. Such and worse remains the condition of a majority of the world's population—some 1.7 billion people, who are entirely without electricity, and several billion more for whom the supply is intermittent and deficient.


Kilowatts of electricity available per capita in selected nations (2005)

	Developing Sector					*Advanced Sector*			
	Argentina	China	Egypt	India	Mexico	France	Germany	Japan	U.S.A.
Electrical generating capacity in gigawatts (10^9 watts)	28.2	442.9	19.3	137.4	51.1	112.7	120.4	249.9	956.7
Population (millions)	39.2	1,306	77.6	1,094	106.2	62.9	82.4	127.5	295.6
Kilowatts available per capita	**0.7**	**0.3**	**0.2**	**0.1**	**0.5**	**1.8**	**1.5**	**2.0**	**3.2**

Sources: U.S. Energy Information Administration, U.S. Census Bureau (International Data Base)

China for example, which produces a great part of the manufactured products consumed in the U.S.A., had only 0.3 kilowatts of generating capacity available per capita in 2005, which increased by 2008 to an estimated 0.5 kilowatts. Well over half of this electricity goes to power Chinese industry, the product of which is primarily exported. Thus, the amount available per person for use in China is less than 0.25 kilowatts, about one-third of a horsepower. Taken over the full 24 hours, we can say that the average person in China has available to him the work of one horse, compared to the 12 horses available in the U.S. The source of most U.S. manufactured products is the low-wage labor of millions of Chinese, many of them from families with no access to even the electric light. In India, Egypt, most of the rest of Africa, and large parts of South America it is far worse. In Mexico, another major source of U.S. manufactured goods, the electricity available per capita is about the same as China. Such an injustice cannot continue for long. How then will we remedy it?

No one can seriously propose that the world energy shortage can be solved with windmills and solar panels if such a proposal is to be subject to scientific rigor. The proponents of these systems have never addressed the world need, except to propose such politically correct, patronizing schemes as solar-powered refrigerators for African villages, which only work, if at all, when the Sun is shining; battery storage is simply too expensive. But even the proposals to use solar and windmills in the developed countries are apolitical expedient. They have never proven economically or technologically feasible, despite the enormous public expense in tax credits and subsidies which they have drawn upon. Take away the subsidies, and the economics is quite negative.

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To bring the present world population of 6.75 billion people up to a level of just 1.5 kilowatts of electrical generating capacity per capita will require that we build 6,000 gigawatts[2] (6 million megawatts or 6 terawatts) of generating capacity. The only feasible way to accomplish this is to embark now on a crash program to build nuclear power plants making use of our limited existing capabilities, and gearing up for a serial production capability for the new breed of fourth generation, high-temperature helium-cooled reactors, among other models.

Could solar or wind power possibly address the world electricity deficit? The largest existing solar power plant, the solar concentrator known as Nevada Solar One, produces less than 15 MW of power, averaged over the course of the day.[3] The largest solar plant using photovoltaic panels, is in Jumilla in southeastern Spain. It is rated at 23 megawatts maximum capacity. Divide this by four, and you have the actual average output of less than 6 megawatts! A single large nuclear power plant can produce 1,000 megawatts (1 gigawatt) or more of electrical power. It can do this all day every day, not just when the Sun shines, and on a land surface area hundreds of times smaller than the equivalent solar plants or wind farms.

What Is Energy Density?

But wind and solar power are "free" people say: The energy is there, a bounty of nature; we just have to use it. Yet once one analyzes such an argument, one sees that is meaningless sophistry, even on the face of it. Coal, oil, natural gas, Uranium and Thorium are "free" in the same sense. A certain amount of work has to be done to mine them and bring them to the place where they will be consumed, but work also has to be done to utilize wind and solar, a very large amount of work compared to the benefit received.

Instead of such loose use of language let us examine the two most important concepts in evaluating a power source, ***energy density*** and ***energy flux density.*** By the *energy density* of a fuel or power source, we mean the amount of useful work that can be derived from a given mass of the substance. By *energy flux density,* we mean the transformative power which can be obtained from that fuel source.

Let us examine the first term first, and see what we can learn from it.

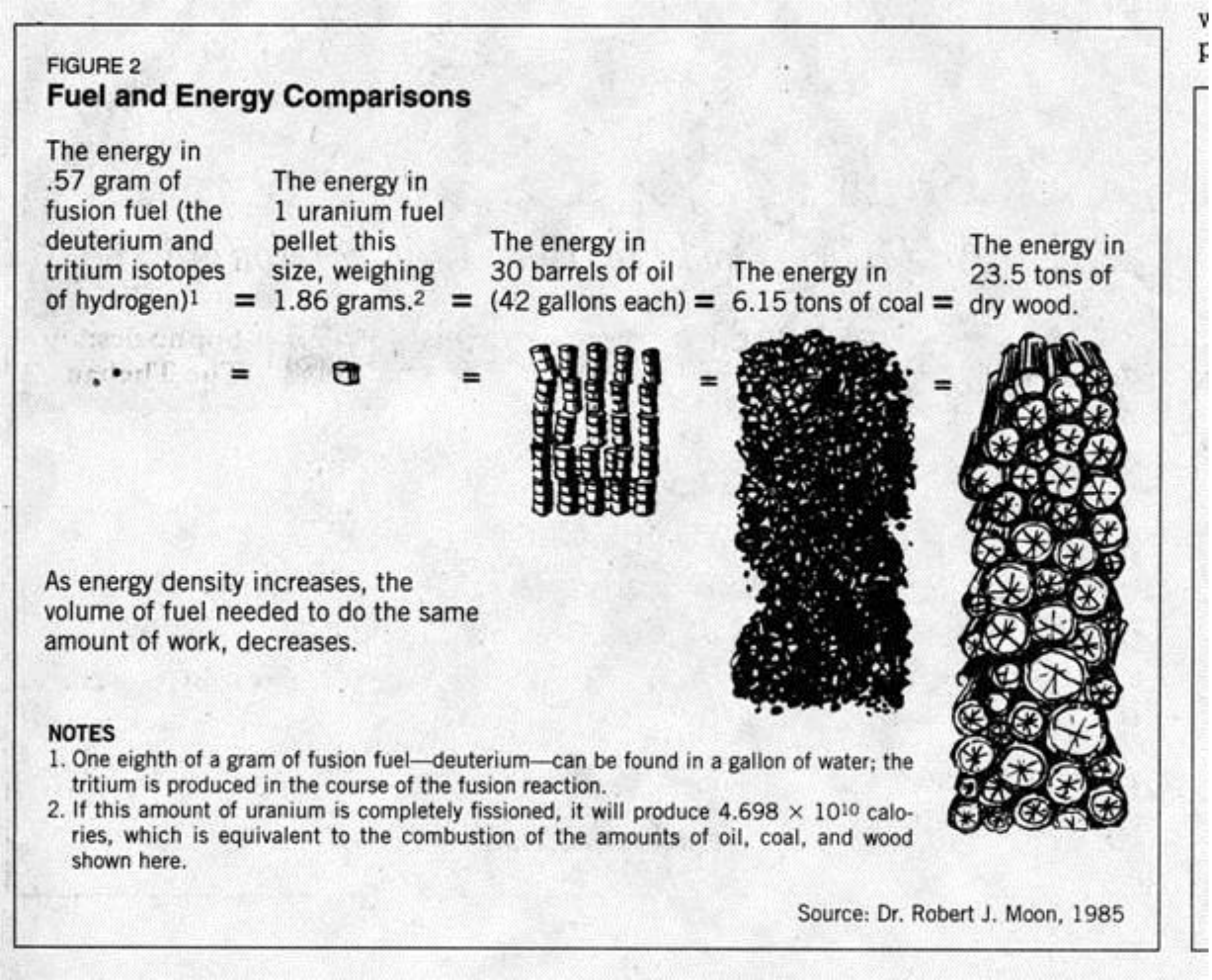
Over the course of human history, there have been several progressive increases in the *energy density* of the fuels employed. The transition from wood burning to coal (which is almost four times more energy dense than wood), took place in Europe in the 18th century. The higher temperatures and regulation that could be achieved with coal fires permitted the introduction of new technologies related to smelting of ores, steelmaking, and other techniques. Until the 1950s, coal was the primary energy source for industry and transportation, and it remains the principal fuel used for electricity generation in the U.S.A.

Oil is about half again as energy dense as coal. The advantage of oil over coal as a fuel for powering steam ships became a factor in geopolitics at the close of the 19th Century, with the conversion of the British Royal Navy from coal to oil-fired steam boilers. The weight advantage of oil, and its ease of handling, not requiring manual stokers to feed the fire, increased the range and efficiency of warships. The lighter derivatives of petroleum, such as gasoline, benzene, and kerosene, are among the most energy-dense liquids, which made them desirable as a transportation fuel—as long as they last; present “burn rates, that won’t be very long.

But each of these improvements in the energy density of fuels was dwarfed by the discovery of atomic energy. As illustrated in the following diagram, a barely visible speck of uranium fuel, when fully fissioned, is equivalent to 1,260 gallons of fuel oil (weighing 4.5 tons), 6.15 tons of coal, or 23.5 tons of dry wood.

FIGURE 2

Fuel and Energy Comparisons



As energy density increases, the volume of fuel needed to do the same amount of work, decreases.

NOTES

1. One eighth of a gram of fusion fuel—deuterium—can be found in a gallon of water; the tritium is produced in the course of the fusion reaction.
2. If this amount of uranium is completely fissioned, it will produce 4.698×10^{10} calories, which is equivalent to the combustion of the amounts of oil, coal, and wood shown here.

Source: Dr. Robert J. Moon, 1985

When compared by weight, the advantage of uranium fuel over the older types is as follows:

Advantage per unit weight of Uranium . . . . [4]

. . . over Wood: **11.5 million** times

. . . over Coal: **3.0 million** times [5]

. . . over Petroleum: **2.2 million** times

We shall be modest and note that these figures are derived assuming that all of the fissionable uranium in the fuel pellet is burned up (fully fissioned). The fuel burn-up rate in many presently operating reactors may be only about 4 percent, though it is higher in advanced reactor designs. Thus the figures above need to be divided by 25, giving nuclear power, in the worst case scenario, an *energy density* advantage over wood, coal and petroleum of *only* 88,000 to

460,000. However, with fuel reprocessing, a form of recycling, the burn-up rate is greatly increased. Because of the production of extra neutrons in the fission reaction, new fuel can be created by nuclear transmutation as the old fuel burns up. The full nuclear fuel cycle, employing reprocessing and fuel breeding, is a virtually limitless cycle. Nuclear is the only fuel that replaces itself as it burns. In fact it does not burn. It converts mass to energy.

Energy Flux Density

To progress from the concept of *energy density* to *energy flux density,* it is necessary to have a deeper conception of the notion of *work*. In physics textbook terms, *energy* is the same as *work*. It was one of the great achievements of 19th Century physics, to demonstrate the equivalence of heat, electricity, and mechanical motion, resolving all these forms of energy (work), and others, to a common measure. Thus, the technical definition of *energy flux density* would simply be the amount of energy passing across a given surface area in a unit of time. An example of a higher energy flux density could be had by comparing the capability of a sharp knife to a dull one. Holding the sharper knife, the same work exerted by the hand is concentrated over a smaller surface area. The energy flux density is greater and the sharp knife is able to cut where the dull one cannot.

By that method of accounting, the energy flux density produced by the fission of a single uranium atom can be shown to be from about 20 million to 20 quadrillion times greater than that gained by burning a molecule of an energy-dense fuel, such as natural gas.[6] However, even this astounding numerical advantage does not yet comprehend the essential difference. To understand energy flux density in the context of physical economy, a higher conception of *work* is required. It is not sufficient to regard *work,* as we do in physics, merely as the expenditure of energy measured in calories, joules, kilowatt-hours, or electron volts. Rather, when considering a physical economy, we must look at the transformative power of the work. Something akin to the skilled worker's maxim "don't work hard, work smart" is appropriate as a first approximation of the concept. Implied in the saying is the idea, that by application of the human mind, the same expenditure of effort can be made more efficient, perhaps by use of a different tool, or by the improvisation of a new one, or by organizing the process in a different way. In the case of nuclear, as opposed to chemical or mechanical processes, a higher order sort of innovation is at work. Here we are dealing with the introduction of a new discovery of *universal physical* *principle,* the revolution in physical chemistry which began with the Curie's separation of the first gram of radium, and proceeded through the identification of the radioactive decay process, nuclear transmutation, the energy-mass relation, the nucleus, the isotope, the neutron, the accelerator, the discovery of fission, the chain reaction, and so forth.

Apart from the questions of cost and efficiency, the fallacy of saying that wind and solar can be made to generate electricity, just as nuclear power can, is that it leaves out the transformative power which the application of this new universal physical principle permits. Nuclear energy works smarter, vastly smarter, than wind, solar, or fossil fuels ever can. The reason is not merely its superior *energy flux density*, measured in caloric terms, but the transformation in the physical economic process as a whole which it can accomplish.

With the fission of each uranium nucleus, several tiny entities, part particle and part wave, are released at velocities approaching that of the speed of light. These particle/waves, which we call neutrons, have the ability to penetrate the nucleus of another nearby atom and to transform it into a new element, a process known as transmutation. But this is only the beginning, for that new element may, in turn, spontaneously transmute into another, and another, producing a family of byproducts (isotopes) which finally settle into a stable form. By mastering the chemistry of these transformations, we have the ability to make new materials, some known and some yet to be discovered, which will be of benefit to future human life. We have also the benefit of the rays these isotopes give off, at least three different types, and each one at a different strength. Their uses in diagnosis and treatment of an array of dangerous diseases are proven, and every day brings new possibilities.[7]

Nuclear for Fuel and Water

In many parts of the world, including some of extremely high population density, such as the east coast of India, the supply of clean water is running out. Ground wells are becoming contaminated as the fossil water supply within the ground becomes exhausted. Substantial regions of the United States, including southern California and the American Southwest are also reaching critical water supply limits. Producing drinking water by desalination of seawater is a proven process. Presently, 40 million cubic meters of water a day are produced by desalination, mostly in the Middle East and North Africa. The leading methods are reverse osmosis, using electric-powered pumps to force salt or brackish water through a specially designed membrane, and flash distillation. However, desalination is an energy-intensive process.

The feasibility of using nuclear power for large-scale desalination was first demonstrated nearly 40 years ago in Soviet Kazakhstan. For 27 years, the Aktau fast reactor produced 80,000 cubic meters per day of fresh water and up to 135 megawatts of electric power at the same time. Japan has operated 10 demonstration desalination facilities linked to nuclear reactors, and India in 2002 set up a demonstration desalination plant at the Madras Atomic Power Station in the southeast with a 6,300 cubic meter per day output. Windmills and solar panels cannot supply the large amounts of electric power required to produce and pump fresh water in dry areas of the world, but nuclear plants can do it.

Nuclear power also offers the solution to the dependency on imported oil. The key is the two atoms of hydrogen contained in every molecule of water. Hydrogen is a fuel, which can be utilized on its own, or combined with carbon sources to produce liquid fuels quite similar to those we know use. Hydrogen can be obtained from water either by electrolysis or by thermo-chemical splitting. At the higher temperatures available from the new generation of modular helium-cooled reactors, the efficiency of both these processes is greatly increased. Nuclear-produced hydrogen or hydrogen-based fuels, combined with ample electricity for battery vehicles, will provide a stable local supply of the transportation fuel the nation needs. Instead of enriching the oil cartels by shipping petroleum across thousands of miles of ocean, we can produce our own, cleaner fuel at domestic nuclear power plants, while also providing our electricity and other needs.

These are the things we as a nation need. They are also the things the world needs. They are but some of the immediately knowable practical advantages of the use of this new physical principle, which has defined the 20th century revolution in science. Much more lies ahead, waiting to be discovered. Some breakthroughs, such as the **practicable development of thermonuclear fusion energy, are almost now within our grasp.** Others are yet to come. To deny its application to our economy, and to return to 18th century and earlier modes of power generation, is to stop human progress.

—end

Appendix 1:

Calculation of Energy in Electron Volts from Burning a Fossil Fuel [8]

(Example is methane, the principal component of natural gas)

Heat of combustion of methane (CH_4) = 891 kilojoules/mole …

(8.91 x 102 kJ/mole) / (6.02 × 1,023 molecules/mole)

= 1.48 x 10-21 kilojoules/molecule of methane

1 kilojoule = 6.24150974 × 1,021 electron volts …

(1.48 x 10-21 kJ/molecule) × (6.24 x 1021 eV/kJ)

= 9.24 electron volts per molecule of methane [9]

The energy released in the fission of a single uranium atom is 200 million electron volts, making the simple advantage of uranium fission over combustion of natural gas about 20 million to 1. However, the figure does not include the surface area over which the work occurs. In comparing nuclear to chemical reactions, we must consider the ratio of the surface area of the nucleus (about 10-24 cm^2) to that of a molecule (about 10-15 cm^2 for methane). Thus an additional factor of 10^9 (1 billion) must be factored in, bringing the potential *energy flux density* advantage of nuclear fission over fossil fuel burning to approximately 20 quadrillion to 1. This advantage is not yet realized in the present design of nuclear reactors, but demonstrates the potential still contained within this new regime of energy production.

Footnotes

[1] A useful pedagogical device that used to be found more often at science museums and other public displays was the bicycle-driven generator. By mounting on the bicycle, the student could discover just how much work, in the form of pedaling, was required to keep a single 100 watt light bulb glowing, thus getting a sensuous appreciation for the labor-saving efficiency of modern electrical power generation.

[2] 1 gigawatt = 1 thousand megawatts = 1 million kilowatts

[3] Beware of labeling. The plant has a peak power output of 64 megawatts. But like all solar plants, that is the amount it can produce at high noon. As the Sun falls in the sky, the output of the solar plant falls with it, until, for half the day, the solar plant produces no power at all. When

shopping for a solar power plant, divide the manufacturers claimed output by four to five, and you will have a clearer idea of the con-job you are about to buy into. Also remember, that for most of the day, solar concentrator plants require back-up power from natural gas-powered heaters to keep the working fluids flowing. And don't forget that the Sun doesn't shine every day. In order to integrate such an erratic power source into the grid requires sophisticated planning, electronic circuitry, and maintenance work, the cost of which is rarely considered.

[4] Derivation of figures in this table:

Weight of oil equivalent (at sp. gr. = 0.9):

30 bbls × 42 gals/bbl × 7.2 lbs/gal × 453.6 grms/lb. = 4.12 × 106 grams

Weight of coal equivalent:

6.15 tons × 2000 lbs/ton × 453.6 grms/lb = 5.58 × 106 grams

Weight of wood equivalent:

23.5 tons × 2000 lbs/ton × 453.6 grms/lb = 2.13 × 107 grams

Dividing these weights by 1.86 grams of uranium, which when fully fissioned is equivalent to the energy content of the above weights of oil, coal, and wood, gives the results shown in the table .

[5] The weight comparison to coal is not academic, as coal accounts for nearly half the tonnage carried on U.S. railroads. Gradually replacing coal-fired plants with nuclear power will be an important step in creating a viable rail freight transportation system.

[6] See appendix 1 for calculation.

[7] Alas, the United States is falling far behind in the use of medical isotopes, because we have nearly shut down our capability to produce all but the commonest of them, and now must import more than 90% of what we use. The chances for survival of certain types of cancers are far greater in a hospital in Europe than here, because U.S. doctors do not make use of the relevant targeted radioisotope therapies.

[8] An *electron volt* is the work required to move an electron through a potential difference of 1 volt.

[9] Calculated per atom, the advantage for uranium increases somewhat more. This may be seen by dividing the result for methane by 5 (the number of atoms contained in the molecule), resulting in 1.85 electron volts per atom. For ethane, the figure would be 2.02 eV/atom and so forth, the figure increasing with the molecular weight of the hydrocarbon in question.