Beyond Petroleum : Unlocking Alternate Energy Potential

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Today, many are ready to accept, albeit, devoid of too much understanding, that the era of coal, petrol and gas is coming to an end. Coal, though available in plenty in China, India and many other parts of the world, is becoming unacceptable because of CO_2 emissions and global warming. On the other hand, oil and gas are peaking, that is, their production has reached its maximum (peaked) and now will keep on falling. The thought however that always follows is what about the alternatives? Nuclear, bio-fuels, hydro, solar, wind, and so on... There are two kinds of logic or reasons, if one might say, behind such questions.

One is that, people are not ready to accept a drastic change in their lives. It is akin to accepting a personal tragedy, sudden loss of job, death of a child, that one is an alcoholic etc. etc. Similarly, having got used to a certain life style or as George Bush said, 'we are addicted to oil", it is difficult to accept that all this will change; that the era of industrialization is over and that one will have to live at a much lower level of energy utilization. Psychologists use the term DABDA–Disbelief and Denial, Anger, Bargaining, Depression and finally Acceptance to describe the process of accepting the unacceptable. Drawing an analogy–today the world is mainly going through denial, while some are getting angry at loss of job, scaling down from set life styles etc. etc. Those who are secure today are going through a process of bargaining. It is they who are asking - but, what about the alternative sources of energy?

Two, there is also a genuine lack of understanding and knowledge about the nature of alternative sources of energy, of what is possible and what is not.

ENERGY GENERATION

To begin with, the production or generation of any form of energy from fossil fuel deposits or from other sources requires an initial expenditure of the same, also known as energy investment. To produce any energy, whether it is pumping oil out of the ground, or building and operating a wind turbine, you need to use some energy in the process. Very simply it means you need energy to produce, transport, store and use. If the energy returned is less than the energy used to produce it, then, it is generally not worth the bother! This significant (but hardly ever considered in popular debate) element in the generation of energy goes by the acronym EROEI–Energy Returned on Energy Invested or EROI–Energy Returned on Investment.

COMPARING DIFFERENT ENERGY PROCESSES

Given in the table are EROI values for various energy production processes. The break-even for EROI being 1.0, any figure less than 1.0, infers a net "loss". The value 0.8, for example would mean a net energy loss of 20%. That is, it would take 20% more to acquire, generate or produce a given quantum, than the energy available for use ...obviously not a good deal!

The EROI value in the 1940's for oil and gas stands at greater than 100 for discoveries. Meaning, at the wellhead i.e. where the oil/gas springs out of the ground, the energy returned by the oil/gas obtained is more than 100 times the energy utilized for its extraction...a very good deal!

Examining this table, a few things become clear. Both for coal and oil, the EROI decreases as resources deplete. Translated into economics this means a drop in profitability! Being a nonrenewable resource, a stage is bound to reach when it is no longer profitable to extract or mine it. In the case of oil, the world has already reached that stage! The stage is also known as “Peak Oil”. Gas may take another decade or so to peak. Coal is becoming unacceptable even before peaking occurs because; it is the dirtiest of all fuels causing pollution and global warming.

One of the problems of producing electricity from coal instead of from natural gas is the nearly 70% more carbon dioxide emissions, and the consequent pollution and cleansing costs. However, no other form of energy is anywhere near as efficient or profitable as coal and oil, being 10 to 30 times more efficient. Hence, none can replace coal and oil to the present level of consumption.

OTHER PROBLEMS WITH ALTERNATIVES

The other main problems with the alternatives to oil and gas are that:

- They are generally only of use in the production of heat and electricity and not the multitude of uses that oil in particular is put to from transport to plastics
- Each is accompanied by its own form of pollution
- Even increasing use to maximum potential, these would find it hard to meet present day requirements.

FUEL SOURCE AND POLLUTION PROBLEMS

Pollution problems of different fuel sources may be summarised as follows :

Oil : Global warming; air pollution by vehicles; acid rain; oil spills; oil rig accidents.

Natural gas : Global warming; pipe leakage; methane explosions.

Coal : Global warming; environment spoiling by open-cast mining; land subsidence due to deep mining; spoil heaps; groundwater pollution; acid rain.

Nuclear power : Global warming (despite what they say); radioactivity (routine release, risk of accident, waste disposal); misuse of fissile material by terrorists; spread of nuclear weapons.

Biofuels : Effect on landscape and biodiversity; groundwater pollution due to fertilisers; use of scarce water resources; competition with food production.

Hydroelectric : Displacement of populations; effect on rivers and groundwater; dams (visual intrusion and risk of accident); seismic effects; effects on agriculture downstream.

Wind power : Noise: visual intrusion in sensitive landscapes; bird strikes; TV interference.

Solar energy : Sequestration of large land areas; use of toxic materials in manufacture of PV cells; visual intrusion in both rural and urban environments.

ALTERNATIVES

Of all the alternatives, the nuclear option is not acceptable at all, albeit, being advertised most! The Indian government is hell bent on getting nuclear energy in spite of opposition from all sides of the debate.

In the nineteen fifties this writer was in school. At that time, the US government launched the programme—'Atoms for Peace'. It used Einstein's famous equation between mass and energy, which implied, one can get enormous energy from splitting the atom as demonstrated by the atomic bomb. It also said that energy will be so cheap that it will not be worthwhile billing it. Many people including this writer were all impressed.

Many years later (1967-68) this writer actually worked at the Saha Institute of Nuclear Physics, Calcutta. The *Bulletin of Atomic Scientists*, however, radically changed the nuclear perception of this writer. Established in 1945 by scientists who felt guilty about having helped to produce the atom bomb, it aimed at the scientific community readership, to inform them about the misuse of science. The contributors to the bulletin were several important physicists and other scientists, many of them Nobel Laureates including Einstein. In 1967, this writer was a fresh graduate in Electronics Engineering and was naturally impressed by these 'Gurus of my Gurus'. The bulletin informed that the nuclear energy programme was essentially a civilian front for the weapon programme and that on its own it is not at all a viable energy programme. Soon, this writer left the Institute and vowed that the knowledge of science and technology would never be used against mankind and nature.

Today no one speaks of 'Atoms for Peace' as it has been demonstrated as a total lie. There have been campaigns against nuclear arms and energy for decades, the most famous being, Campaign for Nuclear Disarmament (CND) in England. There is also a chapter of CND in India. They have published enormous literature on the subject and established beyond doubt that :

- In spite all the hype about nuclear energy, the total contribution of nuclear energy to a country's energy supply has never exceeded 20% except in France (78%), Belgium (54%), South Korea (39%), Switzerland (37%) and Japan (30%)). Not even in the USA, where the first nuclear chain reaction was performed! They went on to make the first atomic bomb and used it on Hiroshima and Nagasaki in Japan.
- Nuclear power stations have a life of 30 years or so, after which, they have to be decommissioned. The nuclear waste and the old plant have to be then protected from causing radiation damage for thousands of years. The myth of electricity produced from nuclear power being cheap holds true to the extent of operating costs only. Even then, the EROI is only 4 as compared to oil, coal and hydro-power which are in the range of 10. When the cost of research, development, construction, de-commissioning, storage and disposal of waste are included, nuclear is the most expensive conventional energy source.
- Many countries that have a nuclear energy programme also have a weapon programme including India and Pakistan. Some have hidden programmes like Israel and Iran. Countries that do not have a weapon programme but have nuclear energy are decommi-ssioning their plants and are not building new

ones. Countries that have a good stockpile of weapons, like the USA have not commissioned a new plant for decades. Accidents at Three Miles Island and Chernobyl have also acted as a deterrent.

- France has a weapon programme and a real energy programme which contributes some 78% to its energy requirements. The reason is, France has no coal and oil and it is forced to build nuclear power stations with huge subsidies culled from taxpayers' money. Belgium, South Korea, Switzerland and Japan have a similar problem. However, these countries are rich, have a trade surplus and can afford it!
- In all other cases, nuclear power stations have only if ever, been built with huge subsidies. British nuclear power industry has cost tens of billions of pounds over the last 50 years. Decommissioning old nuclear power stations is costing over £70 billion and rising.
- What it implies is, in all the countries that have weapon programme (open, hidden or potential) nuclear power stations have been built as a civilian front for the weapons programme. Nuclear weapons and nuclear power share a common technological basis. Skilled workers and continuing research are beneficial for both industries. The process of enriching uranium to make it into fuel for nuclear power stations can be a step towards further enriching it to make nuclear weapons. Used fuel (spent nuclear fuel) from nuclear power stations can be separated out to recover any usable elements such as uranium and plutonium through a method called reprocessing. Plutonium is a by-product of the nuclear fuel cycle and can also be used to make nuclear weapons.
- India's nuclear programme, including the deal with the US is problematic. It seems that it will give India the energy at enormous costs and may not give the weapons. Unlike Japan, India cannot afford it. The programme essentially bails out the nuclear power plant industry in the USA, France, Russia, their Indian collaborators like the BHEL, and, helps the building industry. Even then, its prospect of adding to India's power generation is negligible because the plants have a gestation period of 15 years and old plants have to be decommi-ssioned regularly.

BIO-FUELS

Bio-fuels are made by converting biomass into a fuel. It is used in running machinery and vehicles of transportation. It is the only alternative fuel that can almost directly replace oil and gas. The diesel engine after all was originally designed to run on a variety of fuels and can be used for bio-fuels with little or no adjustment.

Bio-diesel is a chemically altered vegetable oil while another common fuel, ethanol, is a fuel-grade form of alcohol produced from grain fermentation and as profitable byproduct in sugar industry. However, bio-fuels have their own problems, especially where farming is carried out specifically for this purpose.

- Bio-fuels are not cheap. The EROI is less than 2 and can even be less than 1 in which case it is not even worth producing. Growing maize [used to create ethanol in the USA] appears to use 30% more energy than the finished fuel produced, leaving eroded soils and polluted waters behind.

- With limited land available it may be prudent to use it for farming or forestry. The grain required to fill the petrol tank of a Range Rover with ethanol is sufficient to feed one person per year. Assuming the petrol tank is refilled every two weeks, the amount of grain required could keep a few families well fed for a year.
- The irresponsible growing of bio-crops can do tremendous harm. The rise in the production of palm oil for bio-diesel could turn out to be catastrophic, threatening to put more carbon dioxide into the atmosphere than it could save. This is because countries like Malaysia are cutting down vast areas of rainforests to grow the crop, not only endangering the flora and fauna, but releasing enormous quantities of carbon dioxide trapped within trees.

In light of the above, bio-diesel should not be looked upon as a replacement for oil but, at most, as a temporary measure in a tide over towards a more sustainable future. Ultimately people need to travel far less than they presently do, if they are to resolve the twin demons of climate change and peak oil.

HYDROELECTRICITY

Flowing water has been used to generate electricity since the 1880s and has been used to create mechanical power for centuries before that. It is the most advanced, efficient and important renewable source at the moment, contributing to about 19% of the world's electricity supply with a potential of nearly five times that figure, including areas in Asia and Africa. Although expensive to construct, it is very cheap to maintain, store and release quickly, on demand- a quality few other energy sources have. The largest power station today is the Itaipu plant between Brazil and Paraguay, with a capacity of 12 GW—ten times that of a coal or nuclear station.

It is, however, not all good news.

- The damming of rivers can create many serious environmental problems and destroy valuable farmland which is often found in valleys. Existing inhabitants are often forced to move and the collapse of a dam or even release of water during heavy monsoon can prove catastrophic for those living downstream.
- Dams have a finite life. Their performance begins to downslide in about 30 years due to silting of the reservoir. This raises the bed of the reservoir, increases its area and inundates more fertile land. Rise in the bed level also reduces its capacity to hold water. Water may then have to be released during the monsoons, causing heavy floods downstream. Hence, instead of controlling floods, it may be the cause of more floods! Indian scientists in the 1950s cautioned about this possibility when the first dams under Damodar Valley Corporation (DVC) were proposed.
- Today, many studies are available which prove that the harm done by dams far exceeds its benefits. The actual performances of most dams are far below their design capacities.
- Thus, while India is supposed to have huge potential for hydro electricity, there is widespread opposition to it. The Narmada Bachao Andolan (Save Narmada Movement) is one of many such resistances. While a large number of dams are proposed in the North East and in Uttarakhand, in the face of opposition, and the economic crisis, it is unlikely any of these dams will ever be built.

WIND POWER

Wind power has seen the largest growth as an energy source in recent years. A single wind turbine with an output of up to 3 MW can now be built.

There are many advantages to wind power. Most countries have large areas where the wind blows fairly reliably and stronger winds can usually be harnessed by simply building higher. They do not take up much space as the land beneath the turbines can be used for farming or storage. Also, they cannot be built too close to homes or workspaces because of the noise and interference with microwave transmittance. The wind (which of course does not blow all the time) tends to blow strongest during the winter and during the day- periods when demand is highest. The fuel for the turbine is free and the environmental effects limited when placed in areas of low bird movement.

With a typical modern wind turbine, electricity would begin to be generated at a starting wind speed of maybe 3.5 m/s and power output would increase with wind speed until it reaches a maximum for example 225 kw at 13 m/s. Any increase in the wind after that would not produce any greater output. Finally, there would be a maximum speed when the turbine would have to be protected to stop it spinning dangerously fast. This might be at about 25 m/s. But these high speeds are rarely reached. In the UK, a wind turbine on average will generate power for 80-85% of the time.

However, with maximum EROI of only 2, wind power is neither cheap nor efficient. It has limited use in specific areas and its contribution to the total energy will be less than 10%. In India, while the installed capacity of wind power has already exceeded nuclear power, their actual production appears to be much below designed capacity.

SOLAR ENERGY

Solar energy is the acquisition of heat or power directly from the rays of the sun, unlike biomass and ground source heating which use the Sun indirectly. (In the long run this indirect harvesting of the Sun is the most sustainable form). The amount of sunlight falling on any area of ground obviously depends on its location and the time of year. As the Sun does not shine at all at night in India and is much weaker in the winter (1/6 of the summer energy) when demand is higher, massive batteries would be needed for storage. Nevertheless, solar can contribute significantly to reducing energy needs and should not be overlooked.

There are two ways of using solar energy : solar heating and photovoltaic (PV).

SOLAR HEATING

The simplest and practical use of solar power is the solar box cooker. With cooking gas supply decreasing there will be tremendous pressure on the already delicate state of firewood supply. Solar cookers can supply at least half the energy required for cooking. Another similar application is solar driers. They can be used for drying a large variety of household necessities. Larger ones can be used for drying wood.

Solar water heaters are another popular use of solar heating. This usually involves piping water through insulated boxes, which have glass covers and black-painted insides. These act like ‘mini-greenhouses’, heating water as it is pumped through the box (known as a ‘collector’). This water is then used either directly or transfers its heat to the domestic supply. The heat generated is not likely to do away with the need to use other fuels to heat water, especially as there would be no solar input during the night and part of the daytime. Nevertheless, it could be used to pre-heat domestic water to a temperature of 35°C or so, thereby reducing the overall fuel bill.

On a larger scale, it is possible to use this principle to create a solar power station. This would invoke positioning hundreds of mirrors to reflect their radiation onto a boiler at the top of a tower. The liquid here is heated enough to generate steam and turn turbines to generate electricity. Another option is to create a tall hollow tower in the centre of a vast greenhouse. As the air is warmed by the sun, it rises and turns turbines.

These large-scale power stations are still a rarity as they suffer from the same problems of no Sun at the night and little in the winter. However, in sunnier climates like India, Australia or California, they are likely to be more useful.

PHOTOVOLTAIC (PV)

PV, known to everybody from solar cells in calculators, turns the light of the Sun directly into electricity rather than via heat. However, a calculator uses very little power. Generating enough electricity to make a significant contribution towards illuminating a house or office is another thing altogether.

Initial solar cells were only 4.5% efficient. They grew to about 15% in the 1960s and are about 30% efficient now. A square metre on a sunny day would keep a 100 watt light bulb going. At the moment, PV electricity is one of the most expensive of the renewables. No doubt it will become cheaper as production increases and new cells are developed. It remains to be seen how significant the contribution of this energy source will be.

On the whole, passive use of solar energy (solar cookers, driers and solar water heaters) will certainly grow, whereas generation of electricity will be limited. One reason being, the former is a low technology product and can be manufactured locally. EROI for solar power generation is also below 2 and demands superior technology.

IN CONCLUSION

“We are used to a certain life style’’ or as George Bush said, ‘‘we are addicted to oil’’. It is difficult to accept that all this will change, that the era of industrialization is over, and that, we will have to live at a much lower level of energy.”

The main purpose of this essay is to prepare a basis to accept the inevitability of this change. Once one accepts this, it may be possible to plan a transition that will be smooth and may even be exhilarating as people have seen in Cuba.

For a smoother transition, one basic rule is : that the transition be incremental.

Given the present social system, the rich and powerful have a greater resistance to change and they will continue to carry on the irrational social, political and economic system. The reality however is that, technological fixes alone do not solve problems. The solution will have to be holistic and will be carried out by the victims of the present system, that is, the working people. Only the organized working people with a rational plan can bring about such a transition. For this, people's struggles against inequity and injustice will have to continue and at the same time an implementable plan for a rational fossil fuel free society will have to be executed. The incremental changes can only be carried out in the context of such struggles and plans. □□

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Table of Comparative EROI Values
NONRENEWABLE RESOURCES

PROCESS	**EROl**
Oil and gas (domestic well head)	
1940's	Discoveries > 100.0
1970's	Production 23.0, discoveries 8.0
Coal (mine mouth)	
1950's	80.0
1970's	30.0
Oil shale	0.7 to 13.3
Coal liquefaction	0.5 to 8.2
Geopressured gas	1.0 to 5.0
Renewable Resources	
Ethanol (sugarcane) Ethanol (corn)	0.8 to 1.7 1.3
Ethanol (corn residues)	0.7 to 1.8
Methanol (wood)	2.6
Solar space heat (fossil back up)	
Flat- plate collector	1.9
Concentrating collector	1.6
Electricity Production	
Coal	
U. S. Average	9.0
Western surface coal	
No scrubber	6.0
Scrubber	2.5
Hydropower	11.2
Nuclear (light-water reactor)	4.0
Solar	
Power satellite	2.0
Power tower	4.2
Photovoltaic	1.7 to 10.0
Geothermal	
Liquid dominated	4.0
Hot dry rock	1.9 to 13.0

[*source : Energy and the US Economy : A Biophysical Perspective,*

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