
A NEW HORIZON FOR RENEWABLE ENERGY

OR

MOVING OUT OF THE FUEL AGE

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"…And the angel of the LORD appeared unto him in a flame of fire out of the midst of a bush: and he looked, and behold, the bush was not consumed.

Exodus 3,2

Summary

a. Very much can be done in reducing the use of fuel burning by more efficient use of energy, thereby saving in Israel more than 20% fuel burning by investments with a payback of less than 5 years. Much more can be saved in the U.S.A.

b. By using the fruits of the sun, not its direct radiation, Israel could replace about 20% of its electricity production. 10% could be produced turning municipal and agricultural waste into biogas. Another 10% could be produced using wind turbines. In many countries the use of wind energy could reach 20%. As the electricity production use about one third of the fuel, this means about 7% reduction of fuel use. Israel has no significant sources of hydropower.

c. 30% of the fuel could be avoided by providing heat through the direct use of solar radiation.
The largest solar contribution could be not in producing electricity, but in the supply of heat for home and for industry by using solar radiation. With several technical improvements and the right regulations this is also an immediate subject for our society. It can easily reach 30% of the energy use.

d. Items a, b and c add up to 50-60% of the fuel that could be replaced by simple economical justification even without any environmental ideology. It should be the immediate target of the human society and every effort should be put into it.

e. A new, revolutionary technology called "Energy Towers" uses also the fruits of the sun which were not utilized so far. It is hot and dry air in two belts around the globe, one is North the equatorial belt and one is South of it. The new technology shows a way to use a latent heat of evaporation with an efficiency of about 1.2% in turning it into electricity provided to the consumer.

The technology gets the cheapest electricity known. It has the potential to supply about 15-20 times the global use of electricity today.

This technology leads to many by-products. One of them is desalination of huge amounts of sea water at about half the cost today (about 25 ¢/m^3); huge irrigated areas to produce bio-fuels can be provided in desert areas, so far unused, i.e. substitution of fuel for transportation without competition with present day agricultural production. It also provides fish farming at a potential larger than all the sea and pond fishing today. Altogether this new technology of "Energy Towers" has 9 different tangible-material by-products and a similar number of environmental, economical and strategic by-products. There is no doubt that this is the most important energy technology for the immediate use and for the coming few decades.

f. Electricity peak demand could be avoided to a great extent by the right pricing policy, by storage methods and other technical means to conform the supply to the demand. This would lead to a great saving.

g. Much of the research effort today became fashions and is wasted on ideas that seem almost useless in principle. This is if we expect to replace with them massive parts of the fuel for energy at the near foreseeable future without the ideology that contradicts common economical rules.

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1. The reason we left the Stone Age

One of the most interesting questions about the men in the Stone Age is why they have moved from the Stone Age on. Is it really because they ran out of stones? Is it because stones were expensive? Or is it because the use of stones has spoiled the environment?

The urgent need to find substitutes for fossil fuel is not necessarily because we run out of it, and not necessarily because of global warming and not even because of cost.

Most recently, a new debate started - what is most important: replacing fossil fuel or even reducing its use or concentrate on helping the poor? This debate assumes that the fuel substitutes for energy are, by definition, more expensive.

Leaving the Stone Age was very expensive. Think what it takes to discover metals, glass and ceramics, to learn how to use them and start an industry. What did it take to develop the use of lime for construction and the cement obtained by mixing the lime with volcanic ashes or grounded burned clay?

There is a whole list of problems involved with the use of fossil fuel under the present day global situation. However, reducing its use and transforming to sources of renewable energy are not necessarily all more expensive. Of course, where it is done in a wrong way, it is certainly not attractive economically and calls for carrying ideological flags.

In most of the cases when there is a conflict between common economic rules and environmental preferences, it is not because we have to pay high prices for our environmental ideology, but because of extremely poor design and decision making and most often simple ignorance.

The debate about staying with fossil fuel is led most often by conservative people and financed by oil companies. The other extreme is led by people that not always can prove their point. Do we have a way out of this debate?

These days there is a consensus that the main problem is the emission of greenhouse gases, mainly CO_2 by fuel burning. There are very sound proofs that volcanic changes in the globe, changes in the solar radiation and the path of the globe around the sun are the main causes for climatic changes, for the formation of ice or its melting. They are not man-made.

Any attempt to argue with this point meets the reaction that reminds the Inquisition that have warned Galileo for arguing that the globe goes around the sun. Furthermore, part of the whole Kyoto Protocol's philosophy is that one may buy the so called "indulgences" so that he can keep on living in sin.

2. The real reasons we should consider moving to renewable energy sources

2.1 Finite sources of fossil fuel

There is absolutely no debate that these sources are finite. There is a lot of debate about how much is left and how serious would be "the effect of a last minute" change in the energy source.

Even the optimists admit that long before we run out of fuel, the resources which still exist, will become more and more expensive. This is because the cheaper resources have been used first and because those who were left with the resource will blackmail the users even worse than now. The life expectancy of oil and natural gas is only few decades. Coal could be supplied much longer.

2.2 Local environmental damage by the burning products

There is absolutely no question about the fact that burning fuels in power stations, in space heating and in transportation vehicles pollute the air. The number of people who die due to such pollution in urban areas exceeds the casualties by road accidents by an order of magnitude. In Tel-Aviv it has been estimated that 1100 people die every year of air pollution. There are very high percentages of people, especially children, who suffer from breath system diseases.

Measurements of solar radiation made in Israel (Beit Dagan) showed that over the years the traffic pollution have slowly reduced the incoming solar radiation by about 20%. One day a year, when there is practically no traffic - the Atonement Day (Yom Kippur) - the sunshine goes up again coming closer to the original value. It is possible to attempt translating the above into economical terms. If for example one human life and medical treatment are estimated at a value H and there are N deaths. The product N*H could become 10 billion Shekels in Israel. This adds up to a couple of hundred dollars for one ton of oil equivalent and almost 30 ¢/kWh.

2.3 Environmental effects

The environmental effect may not be as dramatic as the "Kyoto Protocol" people think. However, it is certain that some negative effects exist.

There are several excellent studies that have estimated these damages, as in the following.

13 scientists (Robert Constanza et al: "The value of worlds eco-system services and natural capital", Nature, Vol. 387, 15 May 1997, pp 253-260) estimate 17 global functions which serve the sustainability of life on earth. Among them: gases control, climatic controls, control of large disturbances of global systems, water control, water supply, erosion and precipitations, soil formation, nutrients circulation, waste handling, flower pollination, populated biological control, dwelling sites, food production, recreation, culture.

It has been definitely shown that the use of fuels and especially their burning has some effects on these recovery systems. A conservative estimate of the annual contribution of the 17 systems across the globe (16 different landscape units) is 3326 trillion dollars per year ($33X10^{12}$).

The maximum estimated value was $55X10^{12}$ $/year and the minimum estimated value was $16X10^{12}$ $/year.

Moreover, the estimate was that the system reacts in a non linear way. If the system tends to more extreme values away from the steady states balance condition, the damages rate tends to increase.

As an illustration, consider 1% change or about 0.33 trillion dollars per year. If this is caused due to the human production of 30 trillion kWh a year, this means a damage of about 1 cent/kWh.

Some estimates are that the actual damages are in the order of 2% and in some cases even more. The list of examples is very long.

I shall avoid getting into detailed arguments pointing very definite damages. One poetic expression is: "People passed a threshold from using the "interest" and started consuming the "capital" or the "principle". It would take a new leadership to meet the complex threats which can be predicted.

Reviewing many investigations concerning the "communal external costs" of using energy, I came up with the following range of values.

Table 1 - External cost of producing electricity

Fuel	Minimal external communal cost	Reasonable choice of external cost
Coal	1-2 cents/kWh	6-7 cents/kWh
Oil	2 cents/kWh	6-7 cents/kWh
Natural gas	1 cent/kWh	2 cents/kWh

Such values, if they are accepted, (and there are arguments that they are much higher, especially if we include defense expenses) can lead to an estimate of what is the permissible investment in order to avoid the communal external costs.

Table 2 - Permissible extra investment due to elimination of extra costs

Source of electricity	Minimal external communal cost [¢/kWh]	Extra investment per average kW for delivery	
		5% interest rate	10% interest rate
Coal	6-7	8078-9425	15770-18400
Oil	6-7	8078-9425	15770-18400
Natural gas	2	2693	5256

With such worthwhile investments, the problem to adopt alternative sources of renewable energy becomes easier. However, the best solar energy source for electricity is barely justified economically by these figures. The most advanced method to use solar radiation for electricity showed recently a production cost of 15.5 ¢/kWh. This is to serve 8 hours out of 24. The anticipated investment for 24 hours supply far exceeded the above values and at the bottom line we cannot replace about two thirds of the fuel use.

Alternatively we would have to invest in an expensive storage system and have a definite loss of energy in the transactions needed.

It is necessarily to warn the use of table 2 (as it is done sometimes from ignorance and sometimes with dishonesty). The load factor of the best solar technology is less than 0.3. this means that it replaces electricity from fuel only a third of the time or less. This is in addition to intermittency due to accidental cloudiness. Thus, the permissible investment due to the avoidance of pollution effect is less than one third of the figures on the right column of table 2.

2.4 The high cost of the fuel

Several years ago when the cost of a barrel of oil was less than 10 dollars, I was among those who predicted a rise in the costs (30-40 dollar per barrel in 2005). I didn't dare to suggest that it will reach over 70 dollars in the mid 2007, and these days, June 2008, it is around $140 per barrel. This is something that many countries cannot afford.

Note that if many of the cheaper fuel resources will be exhausted, the fossil fuel power stations that are being built today will become obsolete within few years. Also new methods to use renewable energy will become much cheaper. At least so we hope. So, why waste more money on the traditional fuel operated power stations?

2.5 Price fluctuations damage

It can be shown that fluctuations of oil prices cause an unbelievable economical damage (not necessarily a monotonic rise).

Assuming an economic function Y (for example the net domestic product N.D.P.) and Y is a function of the oil price P in some manner, Y can be expressed then by:

(1) $$Y = Y_{\bar{P}} + \left(\frac{\partial Y}{\partial P}\right)_{\bar{P}} \Delta P + \frac{1}{2!}\left(\frac{\partial^2 Y}{\partial P^2}\right)_{\bar{P}} (\Delta P)^2 + ...$$

a simple Taylor' series expression of Y as a function of P (subscript $\bar{P}$ reads "at average P"). One can now calculate the average Y by integrating equation 1 over the time t and divide by the total time period T.

(2) $$\overline{Y} = Y_{\overline{P}} + \left(\frac{\partial Y}{\partial P}\right)_{\overline{p}} \frac{1}{T}\int \Delta P dt + \frac{1}{2!}\left(\frac{\partial^2 Y}{\partial P^2}\right)_{\overline{P}} \frac{1}{T}\int (\Delta P)^2 dt + ...$$

$$= Y_P + \frac{1}{2!}\left(\frac{\partial^2 Y}{\partial P^2}\right)_p \sigma_P^2 + ...$$

Where:

$\overline{P}$ average value of oil price in this case around which one calculates the derivative and the integral;

The first term $Y_{\overline{P}}$ is a constant;

The second term vanishes as the sum of ΔP around $\overline{P}$ is zero.

The third term is

(3) $$\frac{1}{2!}\left(\frac{\partial^2 Y}{\partial P^2}\right)_{\overline{P}} \sigma_{\overline{P}}^{\;2}$$

Where $\sigma_{\overline{P}}^{\;2}$ is the variance of P around average $\overline{P}$.

The fourth term would be:

(4) $$\frac{1}{3!}\left(\frac{\partial^3 Y}{\partial P^3}\right)_{\overline{P}} \mu_P^{\;3}$$

The term μ^3 tends to vanish because the third power of the fluctuations is relatively small, and because the values are more or less evenly distributed around $\overline{P}$ with positive and negative values. We can write the final approximate result as:

(5) $$Y \cong Y_{\overline{P}} + \frac{1}{2}\left(\frac{\partial^2 Y}{\partial P^2}\right)_{\overline{P}} \sigma_P^{\;2}$$

In relative terms Y compared with $\overline{Y}$ at a fixed average oil prices $\overline{P}$ we get

(6) $$Y \cong 1 + \frac{1}{2}\left(\frac{\partial^2 Y}{\partial Pr^2}\right)\sigma_{Pr}{}^2$$

It is easy to show that the value of the second derivative near optimal economic operation is negative (a second derivative near a maximum). Moreover, it is easy to estimate that the absolute value of the derivative will be close to a unity, and possibly higher.

Calculating the variance of oil price relative value in the second half of the 20th Century, is several percents and over shorter periods even more than 10%. This means that the very fluctuations of the oil prices cause a reduction of functions like G.D.P. by several percents per year. This is a very high damage over and above the increasing fuel costs and the environmental damages.

2.6 The losses for defense

It has been estimated by a team in Princeton, U.S. in 1992, that when the cost of gasoline in the US was 30 cents per gallon, the weighed cost of defense, the preparations for war and spending for two actual wars directed to safeguard the fuel sources cost in addition about 70 cents per gallon of gasoline.

At the present, the US spends huge sums of money to overcome the arbitrary regime that was in Iraq. In April 2006, the American Congress estimated that the cost of the war in Iraq has reached 280 billion dollars. It also gets huge sums to maintain a strong army in Saudi and in other countries. The US government spends huge sums to support the potential allies. This has cost about $ 1,000 per person in the U.S.A. If this fine is related to electricity use, it amounts to over 7 ¢/kWh. However, the government is still afraid to embargo Iran's oil export to prevent it from producing atomic bomb because the blockage of Iran's oil will increase the fuel prices even more than they are now.

2.7 Loss of possibilities to exercise freedom and the battle between cultures

Countries undertook all kinds of means to ascertain the supply of fuel. Therefore, they have built fuel storages, made long term fuel buying contracts, which both are very costly.

For many years Europe has yielded to Islamic culture demands and gave preference to Islamic infiltration of population. In fact, Europe risked the freedom of its life. It is now being threatened by very large populations full of hate, superstition and with low values of human life and human dignity, telling the truth, and other indicators. The oil fields, which finance global terrorism, are run by corrupt and cruel leaders who speak in the name of God.

Oil merchants accumulated trillion of dollars by which they can buy the economical elements of the western countries. They can even buy simply foreign currency and inflict economical blows whenever they fill like it.

2.8 Another criterion for deciding if a technology for renewable energy is economically viable

It is difficult to settle the debate on the extent of damages to the environment and the probability that it is manmade due to the use of fuel. It becomes most difficult if we want to include secondary efforts in our modern world with such expenses such as security, economical stability, etc.

We can define a ratio R as follows:

$$R=\frac{P(D)}{(1-P)E}>1 \quad ,$$

Where:

P the probability that there will be a damaging change in climate or any other change;

D the estimated damage we shall have to face;

E the extra cost of an alternative energy source which is clean and will prevent the damage.

In order to justify a change to use an energy source without fuel, R must be larger than a unit. In other words, the extra cost of another energy source which, in all probability, will eliminate the damage by using fuel, must be smaller than the probable anticipated damage.

The main struggle should be to obtain sources of very small E and possibly even negative.

I cannot see P and D being agreed upon. However, in a simplistic way, one can say that if the alternative energy source is cheaper than energy source that use fossil fuel - then who cares if P is high and D is high or not? We shall prefer the alternative. **We have to leave the Stone Age not necessarily because we are out of stones or because stones are expensive.**

2.9 How much renewable energy is available and how expensive is it

Providing alternative sources of energy which are renewable and which are better distributed around nations will create a movement towards another age, like coming out of the Stone Age by ancient people. There are many reasons to do it even if we are not convinced that there is going to be disastrous change in climate, just as it was justified to leave the Stone Age.

The industrial revolution was a transfer to a new age. It came along with learning how to use very high concentration of energy sources brought very conveniently by fossil fuel. It is the time to try and move into a new age.

The questions are:

1. **What are the available sources today?**

2. **How much renewable energy is available and how expensive is it?**

3. **In what directions do we have to develop more new sources of renewable energy?**

4. **Can we, or should we, delay the exhaustion of cheap fuel sources by better solutions right away? Or do we have to wait until we have still better solutions?**

We can come up with practical criteria where the environmental can justify the change to renewable. However, using the other reasons mentioned above, maybe we do not have to wait until everyone is convinced by the environmental argument alone. And - if we find a cheaper source, cheaper than using present methods - why not changing right away?

The following discussion enumerates the methods that can be applied almost immediately or very soon. It does it very briefly without going into many details.

It is amazing how many attractive possibilities exist. It is even more amazing why these possibilities are not used.

3. Alternative ways to reduce our dependence on fossil fuel

3.1 Source groups

There are 7 groups of ways to consider in order to reduce the burning of fossil fuel and thus improve the situation not only as far as the "greenhouse gases" are concerned, but for all other reasons that are very real here and now and briefly described in the above.
We certainly do not wish to wait and see who was right in the debates on pollution and global warming. Is global warming man-made? Can it be reversed? What is the damage involved?

Group 1 - Improve efficiency of energy use
Group 2 - Use the fruits of the sun to produce electricity
Group 3 - Use solar radiation to supply heat
Group 4 - Adaptation to demand and supply time fluctuations. This could be, for example, by storing energy to meet peak demands and by change of the demand distribution
Group 5 - Use solar radiation to supply electricity
Group 6 - Other sources
Group 7 - Some miss-concepts

There are all kinds of other ideas. We limit our discussion here mainly to massive replacement of energy sources for three main uses: electricity, transportation and heating. It seems that the first four groups can do most or all of what is needed. The fifth one has good chances to be achieved hopefully after some more development that will take time, possibly decades. The fifth group can be used also for applications not necessarily to replace large masses of fossil fuel. It may help solving some special local needs. At the moment, there seems to be no justification to apply them right away on a large scale.

3.2 Efficient use of energy

In Israel it has been shown that 20% or more of the energy can be easily saved in all uses with an investment that will be paid back in less than 5 years. This is true in electricity use, in transportation, in agriculture, industry and in power production.
In Western Europe the average use of electricity is about 6000 kWh per capita per year. In the US it is closer to 14000 kWh per capita per year. How come? There is no real difference of this magnitude in the standard of living. The difference is simply a result of waste. So, in principle, the U.S. can possibly reduce the use of electricity to half - 50% reduction in burning of fuel to produce useless energy!
There is absolutely no doubt that a tremendous amount of fuel can be saved also in transportation.

There are dozens of tricks to save. Among them: a new technology such as efficient lamps; slimmer cars; hybrid cars; better municipal transportation, and possibly by electricity; better building isolation; modern and more efficient air conditioners, the use of natural light, etc.
All electrical facilities with remote control waste energy continuously even when they are not in operation. Heat that comes off refrigerator is then picked up by air conditioning. It is possible to save a lot of energy in obtaining uniform water distribution, it is possible to recover large parts of the energy used for desalination.
A lot of energy saving can be achieved in India where the worst losses are due to stealing of electricity, high losses of transmission lines and non realistic prices for the energy use.
These are just few examples by which a dramatic effect can be achieved and no negative economical impact as the American Congress is afraid of.
The effort to privatize the Israeli Electric Corporation to start competition is to a great extent an illusion. All it will do as it did in almost all other cases abroad is to raise the cost of electricity and to cause supply failures. The Israeli case would lead to a government loss of nearly 50 billion N.I.S. Probably the most important regulatory change is to allow relatively fast depreciation of investment to be recognized for the tax deduction to replace tax deduction by wasting fuel. The other one is setting realistic electricity prices. Finally, the Government must support commercialization efforts, however, these should not be turned into subsidies to fashionable trends that have no near present economical justification.

3.3 The use of the fruits of the sun

Throughout history men used the fruit of the sun using basically three sources:
- Wind energy;
- Hydro-power;
- Burning of bio-mass.

All three lead today to energy sources which are economically competitive to the use of fuel.
Wind energy can provide in many countries in the order of 20% of the electricity supply and more. It can be very widely extended by relatively slight subsidy.
Hydro-power is available in some areas, but overall it is far from enabling a revolution in energy sources. The global potential is estimated to be less than 6-7% of the electricity consumption. It has one by-product which is quite important. This is a way to conform the supply of electricity to the demand without the need to build very expensive power stations operated by fuel which are active only few hours during the year. The cost of electricity from such additional power station can become even 5 folds the baseline supply. This can be prevented by hydro power which is naturally available or by pumped storage which can be installed. (The energy loss in pumped storage is about 30%).

The bio-mass is a very important source in developing countries. The municipal and agricultural waste in Israel can provide up to 10% of the electricity (about 5 million tons a year and 4% annual increase), however, the use of this waste has several very important by-products, such as:

a. Preventing groundwater pollution;
b. Preventing the emission of greenhouse gases. In Israel, these are about 1/4 of all the greenhouse gases;
c. Saving land, transportation load and birds that endanger aviation.

The use of bio-mass can now be extended into a new dimension. A lot of experience has been collected in using Ethanol to replace car gasoline. Certain oil crops can serve to produce oil that replaces diesel fuel. However, there are limits to these possibilities due to shortage of irrigated land shortage of water and relatively high costs. Today where it is applied it negatively affects the classical agricultural supply and some times replaces natural vegetation.

The third type of the fruits of the sun is the wind. The wind and bio mass may provide each not less than 10% of the electricity at low production costs, and in some countries even twice that.

In the following I am going to show a way to break these limits and possibly turn some new methods into an unbelievable combination of very cheap electricity from renewable sources and huge volumes of relatively cheap desalinated water and irrigated land that will provide in turn, very large dimensions of replacement also to fuel for transportation.

Note that we can replace in Israel at least 20% of fuel for electricity which amounts to some 7% of the fuel used. We can replace also 30% of fuel for heat supply and easily 20% in turning the use more efficient.

The total replacement of energy can thus reach nearly 60% of the use of fuel, and this is an economically attractive way and almost immediately!

3.4 Other fruits of the sun

There are other fruits of the sun such as temperature differences in the ocean water, wave energy and the use of underwater streams with underwater turbines similar to wind turbines.

So far, none of the above could be proven as economically viable for large scale electricity sources.

In the next part of this report we are going to describe a revolutionary new source of the fruits of the sun.

3.5 The use of solar radiation for heat

This group of technologies has very good chances to supply much of the energy that uses fuel today. Using heat at home and in industry is some 30% of the energy use.

In Israel, about 3% of the energy is supplied so far by solar water heating. Much more can be supplied to industry for process heat and for direct house heating. The technology is practically available.

By using heat storage and some heat pumps, one can cover peak demands of energy at times of extremely high need for cooling and heating. It not only saves fuel, but also high investments for peak demand situations.
As an example - the technology of "parabolic mirrors" which has been used first by "Luz" and now "Solel" in Israel, has no more than 10% efficiency from solar radiation to electricity. However, it could have better than 50% efficiency from solar to heat with temperatures up to 400 centigrades. It is much cheaper to store heat than electricity.

3.6 Solar energy technology for electricity

The two most advanced technologies in that sense are:
(1) Parabolic mirrors that concentrate solar radiation on an oil pipe. Oil heated to 400^0 C is used to boil steam and move turbines.
This method was demonstrated by the Israeli company "Luz", replaced by by "Solel". However, as was already stated, the cost was recently calculated to be 15.5 ¢/kWh, and this is only for 6-8 hours a day.
(2) The Solar Tower by the Weizmann Institute is predicted to have a similar cost and has the same basic limitation like the "Luz" technology. Both require several times, about 15 to 25 fold the area needed by the Energy Towers (to be described later) to produce one million kWh per year.
(3) The most popular solar energy for electricity is the photo-voltaic cell. Towards the end of 2005, the lowest cost was about 3 dollars per Watt peak output. Translating it into a cost per kWh brings it to 30-40 ¢/kWh.
In order to reduce the cost of electricity from photo-voltaic cells, two main concepts were suggested in recent reviews:

a. Concentrate the solar radiation and improve the overall efficiency;
b. Utilize the heat that is absorbed.

However, so far, no one has proved yet these by providing a new product that will cross the economical limit line. The rest is speculation.
On top of the photo-voltaic cells, which are as yet very far from economical, there came the concept of "distributed sources". Basically, this special term tries to place photo-voltaic sources on each roof, and then connect them into an overall electricity supply system.
At least two basic things must be remembered:
a. The local instantaneous installed output is directed by temporary high demand. When large power stations supply electricity day and night to a diversified population of consumers, the overall installed capacity is about twice the capacity that could supply all the need on the average. If we install photovoltaic cells without a huge and a very expensive storage, this ratio would be not less than 5 times the average consumption, and possibly even 10 times - an extremely inefficient and expensive investment!

b. The individual cells are still connected to a large net of transmission lines. The overall result is that we have an impossible expensive system with no horizon to become economically attractive with the exception of very special rare cases. Still, huge sums are spent on photovoltaic systems and it is very heavily subsidized.

3.7 The energy efficiency and economy of hydrogen fuel cells remain unproven

This is an unbelievable story. The use of hydrogen and other gases could be reached in special "fuel cells" and produce electricity at relatively very high efficiency. However, electricity or another source of energy is necessary in order to produce the hydrogen. Today the overall efficiency is not high. The process is extremely expensive because of the need for energy transactions and hydrogen storage.

There are some local and small scale uses of stored energy where hydrogen could be the agent. There are some very interesting ideas to use fuel cells and recycled gas to form a revolutionary type of large scale "battery". However, so far, nobody proved the practical viability of hydrogen cells as such for any large scale source of energy.

3.8 There are several other sources that are not exactly of the same type

Among them is the use of geothermal sources that can be very useful in some countries. An Israeli company - "Ormat" installed around the world about 1000 MW geothermal power using especially an Israeli development of a turbine operated by an organic fluid that boils at relatively low temperatures.

The ocean tide which is affected by the moon and can be used in some places by capturing sea water during the high tide and releasing it at a low tide.

Finally, nuclear technology can supply energy, but it has its problems of nuclear waste. There exists a serious security problem and the electricity is not necessarily cheap. It brings with it all kinds of other sensitivities which highly depend on security requirements.

In summary, we can replace the use of fuel to a very high extent 50-60% or more (depending on the conditions in each country). This is with very attractive known technologies.

A lot can be done in order to move consumers away form the peak of demand and combined with storages. We can save very large sums in building new power stations and delay them for many years. The new power stations operated by fuel will become absolute long before they are really needed.

In the following we shall describe a new technology that uses a new form of the fruits of the sun. this new technology would revolutionize not only the electricity supply, but also eliminate water shortage and replace fuel for transportation.

4. A new technology using the fruits of the sun

4.1 "Energy Towers" - A new revolutionary form of the fruits of the sun

The "Energy Tower" is a technology which was developed in Haifa, at the Technion--Israel Institute of Technology. This technology enables electricity production in arid and warm environments, utilizing the abundance of hot dry air of such climatic zones as a source of potential energy.

According to the analysis of the "Energy Tower" concept, this technology should be the most economically promising, to date, of all renewable technologies which are being developed to produce environmentally clean electricity. An Energy Tower outperforms hydro, solar, wave and wind turbine sourced electricity, in terms of cost per unit, and also in terms of the ability to provide an uninterrupted power supply. Unlike previously designed solar chimneys, which required solar collectors to heat air to generate an updraft, Energy Towers cool warm atmospheric air, and generates a downdraft, which is present 24/7/365. In addition to supplying electricity, Energy Towers also offer further major by-products.

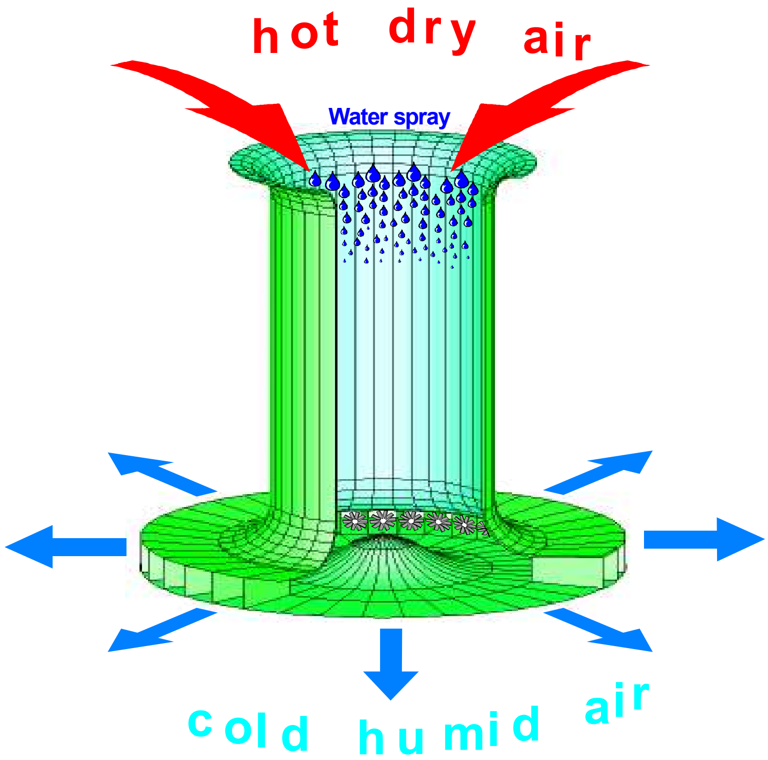

Figure 1 - The Energy Tower principle

4.2 The principle of the "Energy Towers"

For this technology to be cost effective the construction of a vertical tube is necessary, with characteristic optimal dimensions of: 1000-1200 m in height, and 400-500 m diameter. (See figures 2 & 3). (The efficiency comes very near to a maximum with Tower's heights, passing about 700 m). Water is pumped up the tower top and sprayed into the shaft. As the water falls, it partially evaporates, and thus cools the air. This cooler air is denser and falls.

In effect, the chimney is a controlled vertical wind making machine. It uses a well known natural phenomenon which is often called "wind shear" and closes it inside a tall cylindrical shaft.

The air in such an Energy Tower can reach high velocities, close to 80 km/h. The kinetic energy developed will reach over 2.7% of the used heat. It will be converted to another mechanical energy, driving turbines at the tower base, which will then convert this energy into electrical energy. A certain part will be used for pumping (about 0.9%) and some will be lost by friction or by throwing kinetic energy outside (about 0.6%). A little above 1.2% will be turned to deliverable electricity. Even at night there is usually sufficient heat in the atmosphere to allow airflow through the tower. A typical division of the mechanical engineering is given in fig. 4 at a 1200X400 m cylinder, about 40 km North of Eilat, in Israel and 80 m above the sea level. The efficiency of producing electricity is proportional to the cylinder height. For every 100 m increase in the elevation of the Tower's base, some 5% are subtracted by the net electricity supply.

An ***Energy Tower can again be conceptualized as a machine for producing wind on-demand, 24 hours a day, 365 days a year.***

4.3 Proof of the physical principle and the underlying technology

The basic principles utilized by the "Energy Tower" have been repeatedly reviewed by independent consultants and reviewing committees. These reviews have indicated that the physical principles patented by the company called "Sharav Sluices" are feasible, as are the projected economic benefits. An Energy Tower can be built using proven technologies. While a tower of 1200 m in height may seem improbable to some, or at least untested, all engineers consulted have indicated that the concept lies well within current engineering capabilities found in text books. An 800 m office building which is being under construction is far more complicated.

The development required the use of several independent disciplines. They were all tested theoretically in more than one way and by scale experiments.

4.4 Economy

The Israeli Ministry of Energy nominated an expert review committee to investigate the project. This committee found that an Energy Tower is an economically attractive method of electricity generation. A considerable economic margin is present when

electricity from an Energy Tower is compared with electricity generated from conventional fuel sources (coal, oil, nuclear or natural gas). (See tables 3 & 4). The R & D Department of the Israeli Electric Corporation had participated in the review and confirmed the results, and so did others. **Furthermore, this cost-benefit analysis did not include the ecological accounting of externalities, which would further increase the Energy Towers' margin of utility compared to a conventional generation scheme. This estimate also omitted consideration of the by-products such as economical sea water desalination, etc. that further contribute very significantly to the benefit side of "Energy Towers". Finally, the estimate was done before the large hike of fuel costs.**

Table 3 - Characteristic electricity production costs (¢/kWh) by major electricity suppliers, for years 2005-2010 (1996 US dollars) (75% load factor, 30 years); costs before the big rise of fuel prices

Replaced technology	**Cost extreme range**		**Representative average costs**	
	5% discount rate	10% discount rate	5% discount rate	10% discount rate
Nuclear	2.47-5.75	3.90-7.96	3.31	5.05
Coal	2.48-5.64	3.74-7.61	4.07	4.99
Gas	2.33-7.91	2.36-8.44	3.98	4.47
Energy Towers	1.68-3.93	2.51-6.42	2.47 (in Eilat)	3.88 (in Eilat)

The first and second column on the left of table 3 show the estimated costs range. The bottom line shoes the range for Energy Towers. The third and forth columns show typical average costs of products. At the bottom line again in the Tower in the Arava, North of Eilat.

Another comparison can be made with a much more recent review. Let's take a look at the following table which is taken from: "Contribution of Renewables to Energy Security" , OECD/IEA Information Paper - April 2007 ; written by: Samantha Ölz, Ralph Sims & Nicolai Kirchner.

Table 4 - Energy costs

Technology based on	Investment costs ($ US/kW) in 2005	Electricity generation costs (¢/kWh)
Large hydro	1,500-5,500	3-12
Small hydro < 10 MW	1,800 - 6,800	6-15
Wind onshore	900 - 1,100	3-8
Wind offshore	1,500 - 2,500	7 - 22
Geothermal	1,700 - 5,700	3 - 9
Solar PV	5,000 - 8,000	18 - 54
Solar thermal	2,000 - 2,300	10.5 - 23
Biomass	1,000 - 2,500	3 - 10
Ocean (current, tidal, wave)		5.5 - 16
Coal	1,000 - 1,200	2 - 6
Coal with CCS	1,850 - 2,100	4 - 6
Natural gas	450 - 600	4 - 6
Nuclear	2,000 - 2,500	2.5 - 7.5

It must be stated that the lower limits of solar PV, solar thermal and nuclear are not at all realistic. They are far too low compared with examined data. Hydrogen is not even mentioned as an energy source and rightly so. Furthermore, the estimated investment is per installed kW. The investment to compare with is per average kW, and is considerably higher. It is easy to show that the practical load factor of supply from photo-voltaic cells is certainly less than 0.3 and, in all probability, closer to 0.1 and this even if the figures in the above table 4 are acceptable, the investment per average kW is between 3 times to 10 times the figure there or between $ 15,000 to $ 80,000.

The same must be said about the solar thermal. The cheapest kWh known from this source was found to be ¢ 15.5. It cannot supply more than one third of the day without the use of fuel. In wind farm seems to be right, however, the average kW cost is three times as much. The calculated investment for an Energy Tower of the dimension of 1200X400m, North of Eilat (40 km from the sea and 80 m above the sea level) was found to be $ 2300 per average KW.

The committee nominated by the Minister of Energy investigated the potential cost benefit of setting up an Energy Tower in the Southern Arava Valley, which runs on a North-South axis between Israel and Jordan. The projected production cost of electricity in this region was found to be 2.47 ¢/kWh at 5% discount rate and 3.88 ¢/kWh with 10% discount rate over 30 years, including operations and maintenance and 4 years construction period. Thus, the electricity costs from an Energy Tower are slightly less than the average electricity costs of oil, coal and natural gas combined cycle power stations with the old prices. When considering the economics of power generation alone, the range of possible costs for conventional power sources widely overlaps those obtained from an Energy Tower. However, as it was stated, electricity generation is not the only direct economic benefit to accrue from running an Energy Tower. The fringe benefits would vary from site to site and are estimated to range from 4 to 14 ¢/kWh, depending on the situation.

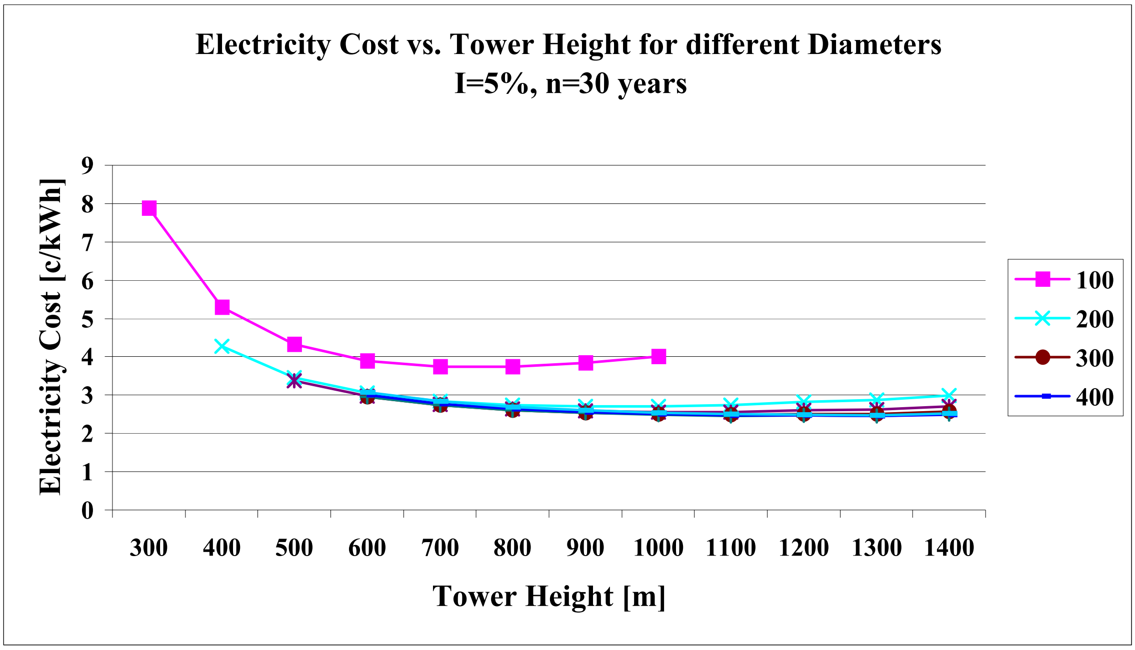

Figure 2 - Electricity production cost from Energy Towers with 5% discount rate, in the Arava Valley in Israel

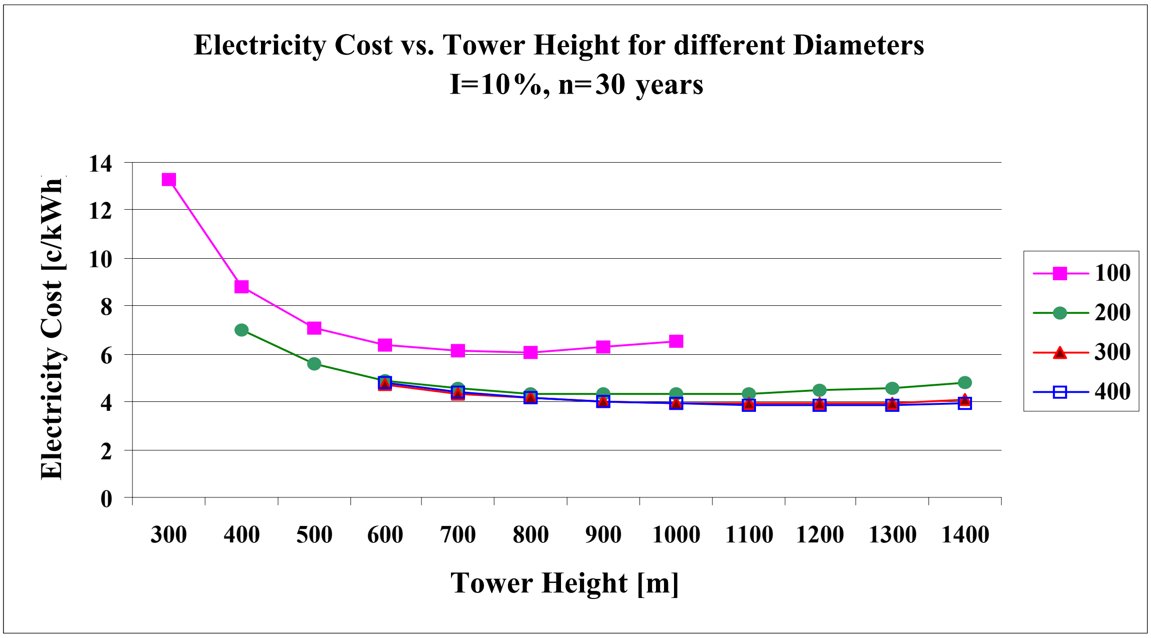

Figure 3 - Electricity production cost from Energy Towers with 10% discount rate, in the Arava Valley in Israel

4.5 Few points to compare solar technologies with the "Energy Towers" technology

An Energy Tower's projected cost of electricity production is the lowest of all current renewable sources, with the exception of some very large hydro-power stations under very favorable conditions.

For example, electricity generated from photovoltaic cells costs today is in the order of 30-40 ¢/kWh (and not the number quoted in table 4). The investment /average kW from photovoltaic is in the order of $50,000. For an Energy Tower in the Arava Valley in Israel, the investment is $2,300/kW - over an order of magnitude less. The projected cost of electricity from the best solar thermal technology by Solel was found to be 15.5 ¢/kWh. The investment in a Kilowatt output that works one third of the day would be way over 15000 dollars.

The investment in a wind turbine is usually over $ 3000/kW average. Again, intermittency is a problem that limits the use of wind-turbine generated power as an overall renewable solution. For a continuous supply, one must add an alternative source or a storage system.

An Energy Tower is an additional source of energy that is obtained indirectly from solar radiation, similar to wind, hydro and bio-mass, rather than directly the solar radiation.

Another interesting comparison is that of the land area needed to produce 1,000,000 kWh/year. The area needed with the Energy Towers is not more than 250 m^2/1,000,000 kWh/year for the main structure. It does not exceed 750 m^2 when we include some of the by-products and extra safety in collecting the salt spay. The area needed for the best solar technology today is about 25 times larger for the main structure and 8 times compared with the extra area used. The area needed to produce 1,000,000 kWh/year with the updraft solar tower is about 300 times larger.

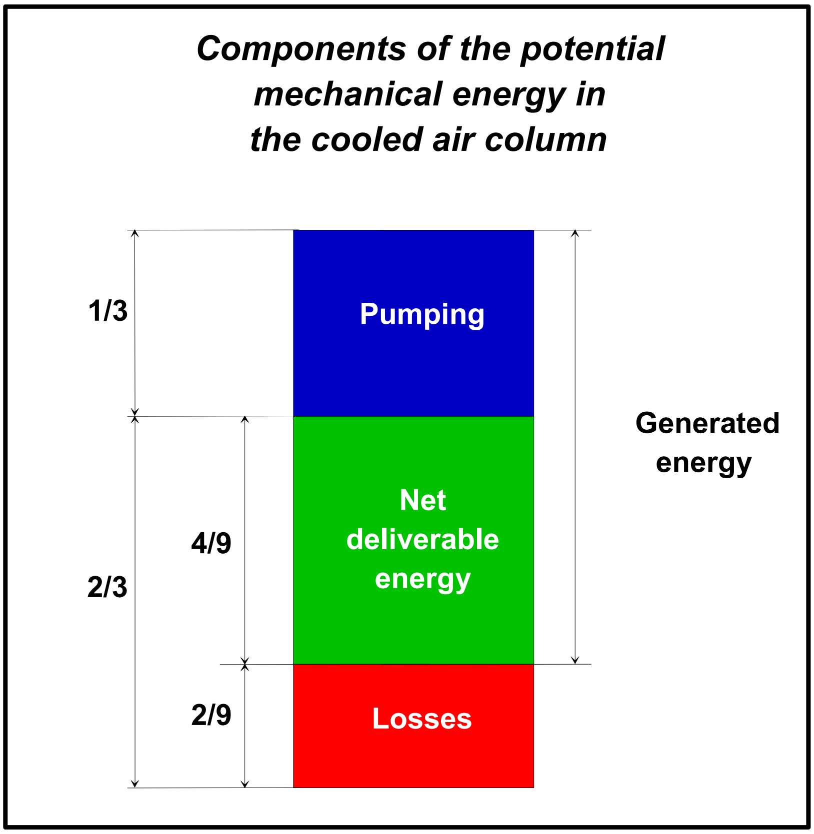

Figure 4 - Components of the mechanical energy (North of Eilat)

4.6 The potential of Energy Towers

At the above cited cost, the potential for power generation using Energy Towers in Israel has been analyzed and found to be more than twice Israel's projected future energy consumption. The cost per unit is calculated to remain cheaper than electricity produced from fossil fuels. (See figure 5).

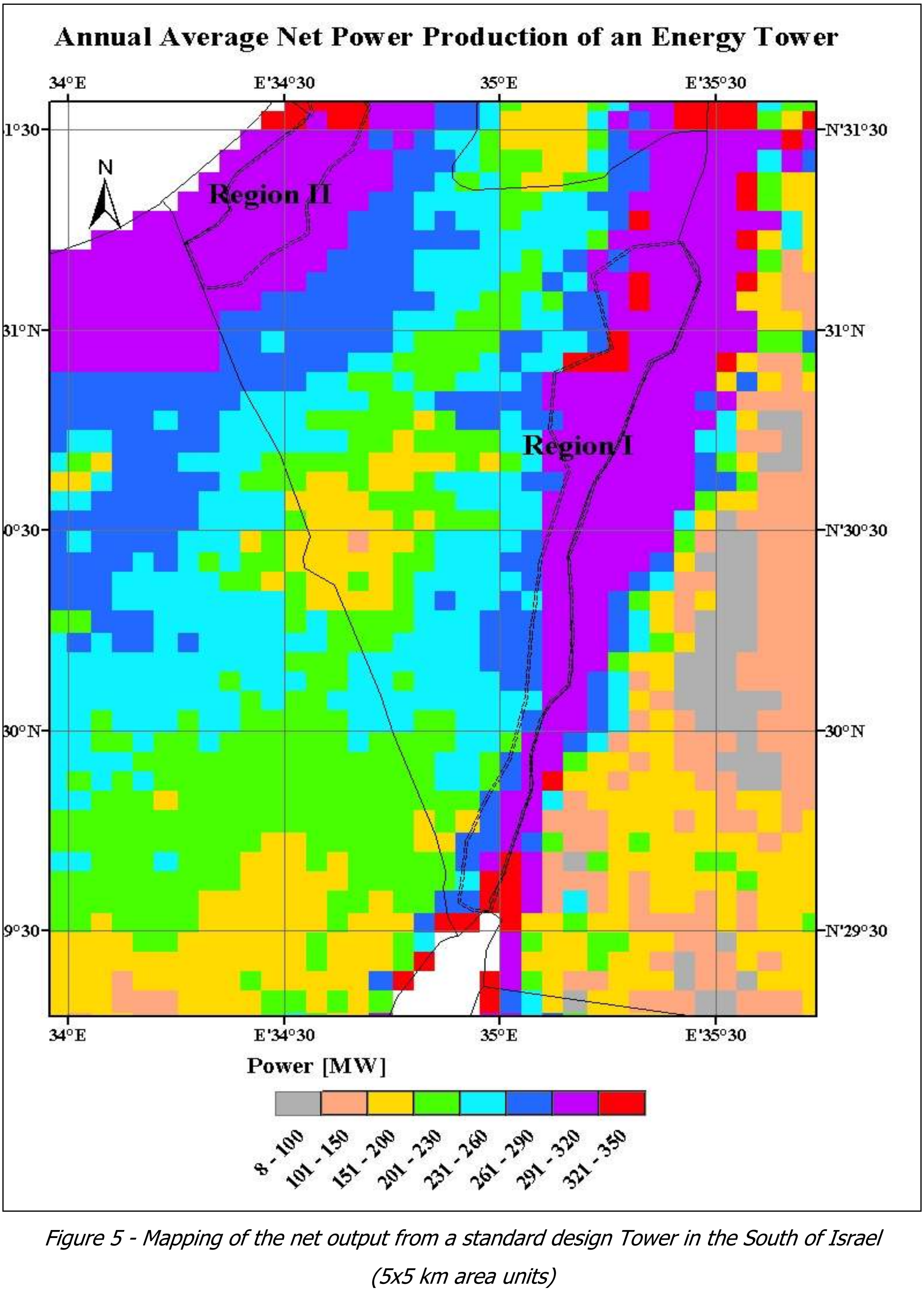

Figure 5 - Mapping of the net output from a standard design Tower in the South of Israel (5x5 km area units)

The theoretical global potential of Energy Towers was recently calculated, as an academic exercise, and under very conservative assumptions. A net average output per

Tower was conservatively assumed to range from between 200 and 600 MW average output. Areas where the climate and topographic conditions lead to an output lower than 200 MW average were excluded from the survey. The minimal diameter of sky space was assumed to be 400 km^2 per Tower (so that sufficient descending hot air is available for each Tower).

The global potential power generation using Energy Towers was conservatively estimated to be 230,000 billion kWh/year. This figure assumes an electricity production cost for the Tower not higher than 3.93 ¢/kWh, or 6.42 ¢/kWh at 5% and 10% interest rates, respectively. This mapped global potential is at least 15 times the present electricity global consumption. The climatic data was obtained from satellite global mapping. Concrete distances from the sea and elevation differences were used for the calculation. A very similar result was obtained by estimating the heat transfer by the Hadley Cell Circulation from the equatorial zone to the two desert belts around the globe to be $2\text{-}4X10^{16}$ KWh/year. (The maximum estimate was an order of magnitude higher). The efficiency of turning it into electricity was assumed to be 1%. The result was then 200,000 to 400,000 billion kWh/year.

<u>Following is a table of the possible regional energy supply and the possible number of people served.</u>

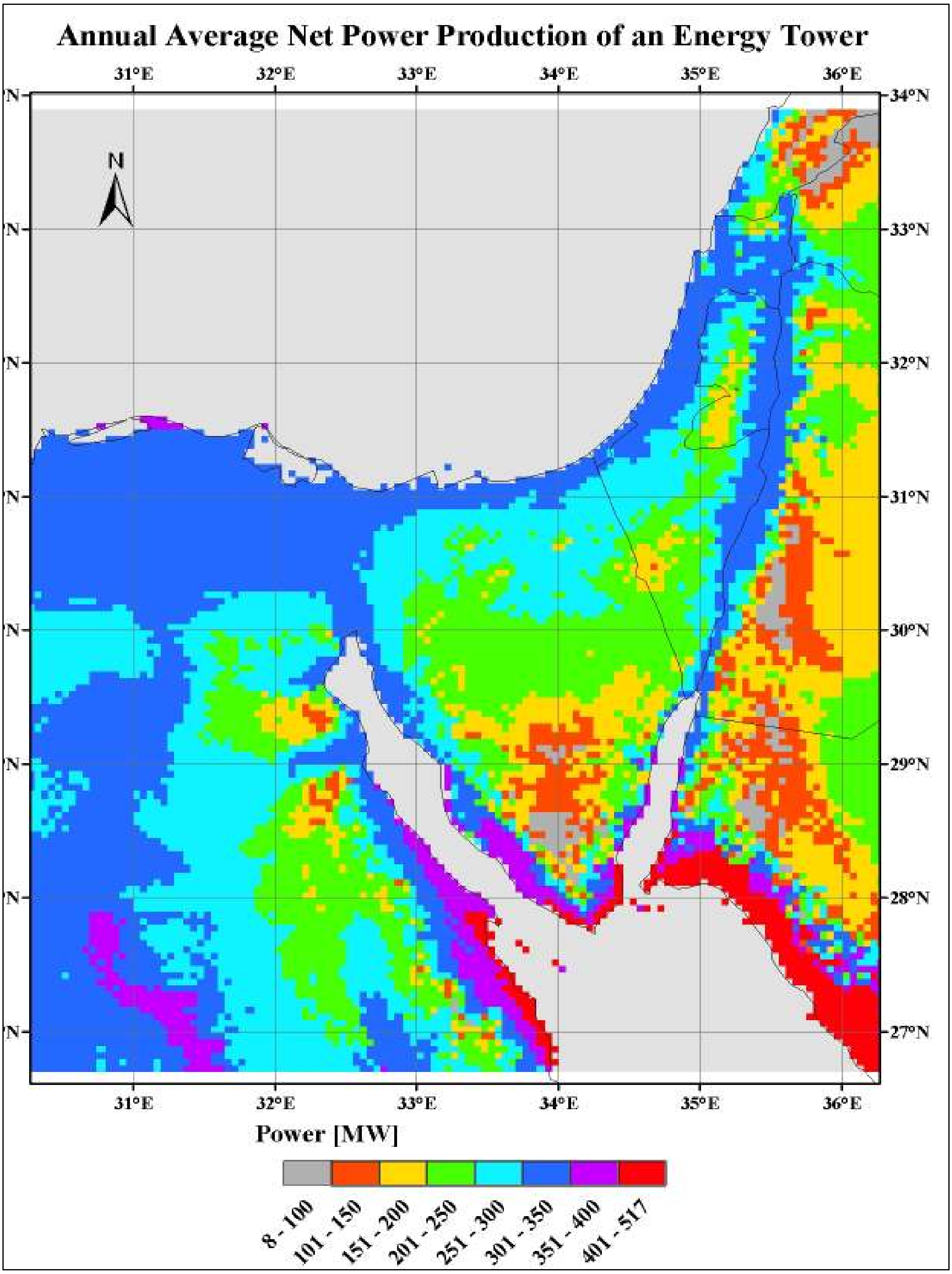

Figure 6 - Mapping of the net output from a standard design Tower in Israel and its neighbors (5x5 km area units)

Table 5 - Regional potential from Energy Towers producing more than 300 MW average

Region	**Number of people served, including units between 200 & 300 MW**	**Electricity /capita /year**
	[billions]	[kWh/year]
North Africa	3.58	6,000
South Africa	1.37	6,000
India	1.19	6,000
U.S.A., Canada & Mexico	1.22	10,000
Chile & Peru	2.77	6,000
South Europe	0	6,000
Australia	0.71	6,000
Saudi Arabia	1.25	6,000
Persian Gulf	1.12	6,000
TOTAL	**13.21**	**------**

Consider the high result despite the fact that we have neglected all Towers with less than 300 MW average (and not 200 MW). The global output is doubled when adding the areas between 200 and 300 average MW.

It might be of interest to Iran that using the technology of "Energy Towers" they could, in all probability, supply to 400 million people electricity at a Western European level and they could have very cheap desalinated water at the amount equivalent to twice the Nile River by using just 20% of the electricity. This alternative should be passed to them to replace their nuclear "games". Moreover, it is far more attractive than the nuclear energy offered by some from any point of view, except for devoted terrorism.

In the Southern part of Europe: Spain, Italy, Greece and Turkey, Energy Towers could be built, in all probability, with an average power of less than 300 MW, totaling a supply of electricity to about half a billion people at West European standard. Europe can thus supply the majority of its electricity consumption with no need to depend on North Africa that could supply electricity to several billions people. Adding some 20% of the electricity from wind farms and 10% from bio-mass in waste, the whole electrical supply in Europe would not need a drop of fuel.

4.7 Additional benefits of the "Energy Towers"

There are over nearly twenty additional benefits that devolve from the installation of an Energy Tower. About half of these are tangible-material by-products; the other benefits are of an intangible macro-economic environmental or political nature.

1. Adaptation of supply to demand

There are time fluctuations in the electricity production and fluctuations in the demand. There are several ways to overcome these discrepancies.

The first one is built-in pumped storage. Observing fig. 4, one can see that in the example in North of Eilat, the pumping energy makes about 3/9 and the electricity supply 4/9 of the overall mechanical energy. This means that if we temporarily stop the pumping, we can add about 75% to the electricity delivery. All that is needed is water storage at a high enough elevation.

It is a built-in capacity with no energy loss and minimal additional investment it will improve the economics of an Energy Tower by more than 30% (in the order of 2 ¢/kWh over and above the average tariff that can be obtained in many sites).

If one does not find a nearby elevated ground, then it is possible to build a reservoir on the top of the Tower if we turn from a steel structure to a reinforced concrete.

One can adjust the installed capacity. It is also possible to use a special product, such as desalination which will be operated at different times.

2. Desalination

Another way of adaptation to fluctuations can be achieved by using electricity for a certain product, such as desalination, and stop it periodically.

Another way of eliminating at least the production fluctuation is by lowering the installed power. The electricity cost reduces, reaches a minimum and then becomes more expensive. An annual uniform supply has been obtained when the cost of electricity increased about 25%.

Desalination of sea water / brackish water / sewerage waste water can be incorporated. This capacity can be added in a modular fashion. The projected investment saving for desalination using this technology, Reverse Osmosis in association with the "Energy Towers" technology, is over 50% and the energy outlay is 33% less when compared to conventional Reverse Osmosis. The cost savings for sea water desalination was calculated to reach 45%, when contrasted with current methodologies. Utilizing approximately about 20% of the Tower's energy, calculated according to base line dimensions, it is possible to desalinate 200 million m^3 water/year. As the electricity from such a Tower North of Eilat is sufficient for half a million people at a West European standard (3.1 X 10^9 kWh/year at 6000 kWh per capital per year). This means additional water of about 400 m^3 /capita/year comparing to only 300 m^3/capita/year today in Israel.

This water would cost 25 ¢/m^3 or less. This is a major benefit - indeed, it is conceivable that an Energy Tower might one day be built for the sole purpose of desalination - allowing human habitation of previously unviable desert regions. At this cost per cubic meter, water is cheap enough for industrial applications, and for a broad range of agricultural applications including food production and fuel supply through bio-mass.

3. Replacing fuel for transportation

Having huge volumes of cheap desalinated water in huge desert areas can provide for irrigating oil plants. The extracted oil can replace diesel fuel. Other plants and agricultural waste can be used to produce Ethanol to replace gasoline and bio-gas to replace natural gas. Can we imagine North Africa providing electricity to the whole of Europe (see table 4 above), and also having for its own use both electricity and fuel for transportation? At the same time, North Africa will have water addition like 20 times the Nile River.

4. Aquaculture

By using the water en-route to the Tower, each Tower of standard design has the potential to provide facilities for the production of 160,000 tons of sea fish per year. All it takes is to retain the sea water on-route to the Tower for a day or two. The total water spray North of Eilat was calculated to be 600 million cubic meters per year. One day average retainment means about 1.6×10^6 m^3 of ponds. Experience shows that about 100 kg fish could be grown per 1 m^3 of pond, or the figure of 160,000 tons.

This would provide income that is well above the cost of water supply to the Tower and would eliminate the environmental pollution problems associated with sea-based aquaculture.

Aquaculture could add nearly another cent per kWh profit to the added area for ponds that could surround the Tower and will add no more than 500 m^2 per million kWh per year, totaling about 750 m^2 per one million kWh per year. Fish growing could easily provide another cent additional profit.

Note that 1 kg fish requires only 1 kg dry food. This compares to 2 kg for poultry, 3 kg for hog meat and 5kg for cattle. Thus, fish farming makes possible providing meat to the population and saving a lot of land and water.

The potential has been estimated to be possibly twice - 130 million tons per year, and this is compared with present value of 90 million tons from both sea fishing and ponds at present.

The first two benefits of running an Energy Tower are expected to range from between 2 and 3 ¢/kWh in all or most sites. We have not estimated the benefit of producing fuel for transportation.

5. Salinity elimination

Salination is presently destroying some of the largest irrigation projects and is affecting irrigated agricultural land in many locations world-wide. **The drainage water, left after irrigation accumulates salts, eventually turns ground water and rivers more and more salty. Using the collected drainage water to produce electricity in an Energy**

Tower, produces a more concentrated brine that is much cheaper to dispose. The overall result is that the expensive disposal of the salty drainage water is reduced to about 5%. An additional benefit of 10 kWh electricity is produced for each cubic meter of evaporated water in the Energy Tower. Studying the Indira Gandhi Canal in the North of India (Rajasthan district) it has been found that about six Energy Towers could be built disposing of about 3.5 billion cubic meters of brackish water, producing in the order of 30 billion kWh per year. it has also been found that for the interception of one cubic meter of brackish water, half a cubic meter of fresh water could be gained towards the Canal end closer to the sea. This is by removal of salinity from the water stream.

Since much available surface water on earth is brackish, there are other benefits in water aquifers, or drainage water. This water can be used to produce electricity, desalinated and the brine can be pumped into the ocean, producing approximately10 kWh for each cubic meter of evaporated water.

6. ***From the end brine, having twice the salinity of sea water and from the sea water itself - it is possible to recover a significant amount of energy (close to 10% addition).***

7. ***Cooling water for thermal stations, including solar thermal.***

8. ***Air cooling for gas turbines (cooling the air by one centigrade improves the turbine efficiency by about 1%).***

These are the main material tangible by-products. Some of the others are:

9. ***Zero-emission electricity generation.***

10. ***Avoidance of reliance on imported fuel.***

11. ***Immunity from future fuel price instability and the inevitable cost rises.***

12. ***Immunity from cost fluctuations.***

13. ***No need for costly strategic fuel reserves.***

14. ***Improved balance of payments both by saving and by industrialization.***

15. The use of clean zero-emission renewable energy will avoid the penalty of greenhouse gas emissions (the Kyoto Protocol) and might be materialized into some income.

16. Potential benefits, savings on defense costs and alleviating the blackmailing capacity by oil merchants.

4.8 Other important gains

Thus Energy Towers could turn out to be the democratic world's most effective weapon with which to maintain political freedom and to prevent irreversible environmental degradation of the planet. Energy Tower technology addresses the following global problems:

1. **Pollution and greenhouse gas emissions due to fuel burning both for electricity and for transportation.**

2. **Shortage of good water, over pumping and salination of agricultural land.**

3. **Preservation of marine ecosystems, by encouraging sustainable aquaculture.**

4. **Avoiding wars, reducing military spending.**

5. **A major political change and more equitable distribution of richness among nations.**

5. Final notes

It seems that the "Energy Towers" technology is today by far the most attractive method to supply most of the global need for electricity and indirectly by producing very cheap desalinated sea water and replacements for fuels for transportation. In Israel, these two consist of 2/3 of all the energy consumption. The other third is heat that can be obtained directly from solar radiation, or indirectly from the first two. These come along with extremely attractive and revolutionary by-products. The technology can be applied with no delay. ***There are three conditions:***

I - People who make decisions and provide the means should understand what they are talking about;

II - The so called "experts" should be honest and describe truthfully the real conditions, not being afraid to loose their status;

III - There are people who become insulted by the fact that someone else made a suggestion they did not think about. These people should be kept away from positions of public making decisions or as advisors.

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