Reflections on the Power of Oil and Other Fossil Fuel Issues

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We live in a world powered by fossil fuels. Nowadays there is nothing - no thing - that is bought for money which is produced without using fossil fuels all along the production and distribution lines. Our food, clothing, transportation etc. is produced using fossil fuels. And fossil fuels are needed to build nuclear power plants as well as windmills.

For a minority of 1 billion people out of the world population soon reaching 7 billion fossil fuels have provided living conditions which our predecessors 200 years ago could and the billions of poor people today can only imagine to find in paradise: plenty of delicious food, plenty of clean and hot water in every tap, comfortable cars taking you anywhere at 100 kilometres per hour, Christmas holidays on other continents, etc. etc. - you name it.

Do we - the rich - rightfully enjoy the fruits of our ingenuity? No, not quite so. Rather we enjoy the entirely accidental occurrence of cheaply recoverable fossil fuels in the crust of the earth and we enjoy the divide between us, the rich minority, and the poor majority which historically is the result of the 500 years of Europe's gun-powder powered colonization of the rest of the world.

Now, as things fall apart, and we - the rich - are desperately, against all odds, seeking ways and means to sustain our paradisal living conditions, there is reason to reflect on the power of oil and some fossil fuel issues in general:

In the course of a century the abundance of physical power provided by fossil fuels has changed the world - the way we live and as importantly the way we think. As we now enter the final stages of this short era in the history of mankind where all physical technologies, infrastructures, etc. are based on the abundance of cheap fossil fuel power, there is reason to reflect on the magnitude of this power as compared with the physical power available to mankind before the fossil fuel era and the power mankind may have to make do with hereafter.

Also, to comprehend the bad omens and the multitude and magnitude of the tasks involved in the transition to the post-fossil fuel world, one must recapitulate the accidental historical and geological circumstances which led to the present, unprecedented, singular point in the history of mankind.

Moreover, as we seek from this historically exceptional point of departure to find ways and means to accomplish the transition to the post fossil-fuel world in a constructive manner, we must thoroughly review the basic concepts and literary stereotypes which constitute the specific intellectual framework of the fossil-fuel era, primarily the concept of energy as a commodity and the concept of never ending economic growth inherent in economic theory and the liturgy of the modern political economy.

The physical power of oil

First, a few examples may serve to visualise the physical power of oil as compared with the power which men or animals can yield.

We all have a feeling of the force of gravity and the power it takes to lift a heavy item. Building Stonehenge, the Egyptian pyramids, the Greek temples, the Roman aquaducts, and other great edifices around the world, men constructed leverage mechanisms which enabled hundreds or thousands of workers or slaves to lift huge blocks of stone or marble and place them in position high above the ground. Many tons of food were eaten to provide the men with the energy needed to carry out the heavy work. Nowadays a mobile crane powered by a diesel engine can lift a ten tonnes block 20 metres in less than a minute, burning only a spoonful or two of diesel oil to do the job.

The shifts in the orders of magnitude in the fossil-fuel world:
Imagine:
13 persons in a lift. Total weight, say, 1,000 kg = 1 ton
The work done lifting them 4 floors up, 10 metres, is 0.027 kWh.
About the same as the electric power used by a low-energy light bulb in one hour.

Surprising to the modern city-man, using 5,000 kWh of electric power a year: *Does it only take so little power to lift 13 persons 10 metres?*

Conversely surprising to an Indian peasant having his first electric lamp installed: *Does it really take so much work to keep a low-energy bulb alight for one hour?* He knows by experience how much work it takes to lift 1 ton 10 metres.

Or compare the power of a horse toilsomely drawing a single-furrow plough through the soil at slow walking speed with a diesel-powered tractor easily drawing a ten-furrow plough four times faster. Or the *six*-horse team royal carriages in the 19th century with today's common *sixty*-horsepower small European cars.

The thrust power of the jet engines of a 40-tonnes aeroplane taking off at 500 kilometres per hour is a hundred times the power of any machine seen before the

20th century. The millions of tons of bombs which devastated the European cities during World War II and Korea and Vietnam thereafter could not have been spread without the power of oil. Neither could the atomic bombs which razed out Hiroshima and Nagasaki have been carried over the Pacific Ocean without oil.

The power of oil and fossil fuels in general came very cheaply as compared with power from other energy sources. Wind power is relatively cheap as compared with other non-fossil power sources. Yet, it would be an enormous economic undertaking to replace fossil fuels by wind power, even if the energy needs of the presently affluent OECD countries were reduced to 1/3:

> World car production 2009: ~70 million cars* $10,000/car = ~$700 bn
> A global windmill industry with similar capacity could annually produce:
> 250,000 big 2 MW windmills of ~$3 million/windmill = ~$700 bn
>
> Imagine that in the OECD countries by 2050 the total amounts of
> - electric power
> - heat, and
> - motive power for transportation
>
> are reduced to 1/3 of the present amounts, and that
> - people in other countries by 2050 enjoy the same per capita amounts as people in the OECD countries.
>
> Were the resulting global power supply in 2050 to be achieved by wind power, using the most energy efficient conversion techniques, about 10 million 2 MW windmills should be erected around the world.
>
> At a production rate of 250,000 windmills per year, comparable to the present global automobile production, it would take 40 years to produce and erect these 10 million windmills.
>
> And along the way the costs of new electric grids plus the windmill maintenance costs would rise to about the same as the costs of producing and erecting the windmills.
>
> Moreover, the costs of new electric transportation infrastructures are to be taken into account.

This example may serve to visualize the magnitudes of the investments needed to construct a future world in which a population of 7 or 9 million live in way which is comparable with the way we live in the presently affluent societies, albeit with much lower per capita energy needs. Indeed, fossil fuel power came very cheaply as compared with anything else.

The ominous logics of the oil-based economy

All over the world cars, lorries, trucks and ships powered by oil have determined the development of cities and local, regional, national and international transportation infrastructures. Today no society can function without these ubiquitous vehicles.

There is a simple logic behind this development. Namely, that oil must be consumed at the same rate as it is extracted from the oil fields. At the beginning of the 20th century when abundant amounts of oil became cheaply available from the oil fields in Pennsylvania and Texas, there was little demand for oil. However, in 1876 the German engineer Nicolaus Otto had made his first four-stroke petrol engine and Rudolf Diesel had patented his diesel engine in 1892. Already in World War I these engines became essential sources of power in the war industry, powering military lorries and tanks, and cars for the high ranking officers.

After the war the proliferation of petrol and diesel engines in cars, lorries, trucks and tractors provided outlets for the equally rapid growth in the oil flow from the oil fields. Thus the profitable production of oil-powered vehicles made oil extraction profitable and vice versa. The vehicle industry and the oil industry went hand in hand, inseparably. The saving of oil by the construction of fuel-efficient engines was in nobody's interest as very cheap oil kept flowing in abundant amounts and powerful cars met the consumers' desires.

By this logic the world was transformed into the new shapes and dynamics one can see from the windows of an aeroplane circling over a city. The flows of cars on its motorways and roads and in its streets, like blood in its arteries and veins.

The future of this oil-based technology and economy holds an ominous perspective. As long as growing demand for oil, meaning more cars, trucks, tractors, and aeroplanes is met by growing amounts being extracted year by year, the world economy is becoming increasingly dependent on oil. Governments - building more motorways and airports - the motorcar industry, the aeroplane industry, and the oil industry all nourish the hope that this dependency on oil will continue to grow in the foreseeable future.

While the annual extraction capacities from existing oil fields are in decline, some new fields are still being found and by means of enhanced extraction techniques more oil can be squeezed out of what is called mature fields. However, some day the annual amounts which can be profitably extracted will decline - irreversibly. The sooner the better. Because the more oil the oil companies manage to squeeze out of the oil fields and sell at a competitive price, the steeper the fall in supply when the decline sets in. The more the world economy becomes dependent on cheap oil, the more cataclysmic the consequences when the demand can no longer be met.

This is illustrated by the US Department of Energy in Figure 1 below. In this figure it is assumed that 'Ultimate recovery', i.e. the total amount of oil recovered from oil fields in the 20th and 21st century, is 3,000 billion barrels, equal to the areas under the two curves (US Geological Survey's mean value estimate). If the annual oil extraction (production) = annual global consumption peaks in 2016 the decline rate could be 2 percent per annum. Should the oil companies find it profitable to make the huge investments needed to prolong the period of growth another 20 years, the world economy would in 2037 be much more dependent on oil (twice as many oil powered cars, lorries, tractors, airplanes, etc.) when the dramatic decline sets in. This scenario is, however, unlikely because the high oil prices needed to make the investments profitable would curtail demand and thus extraction.

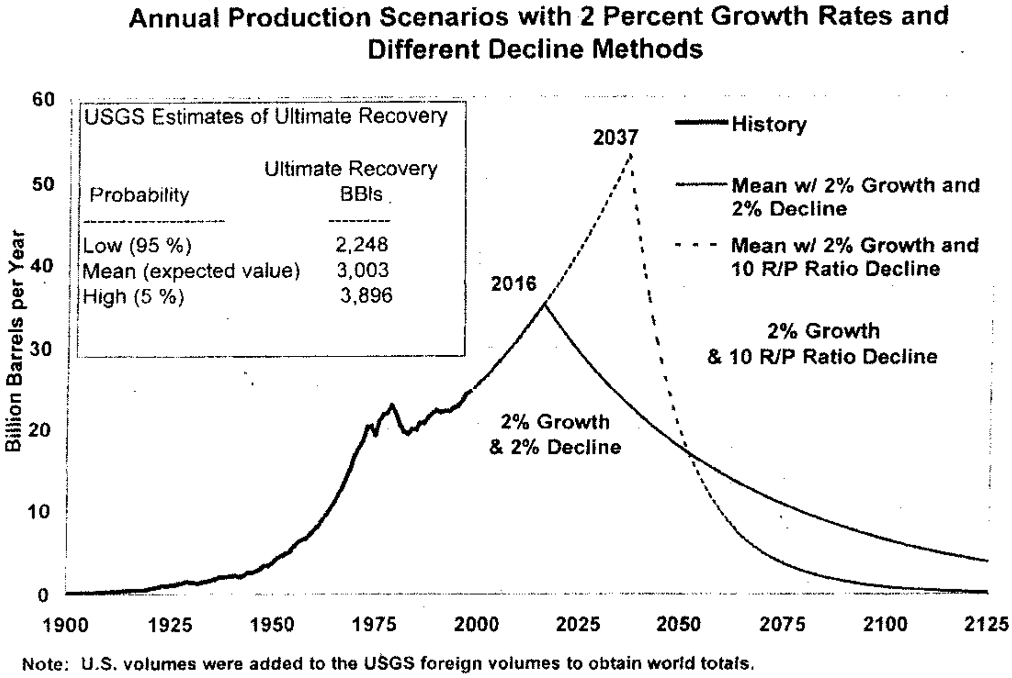
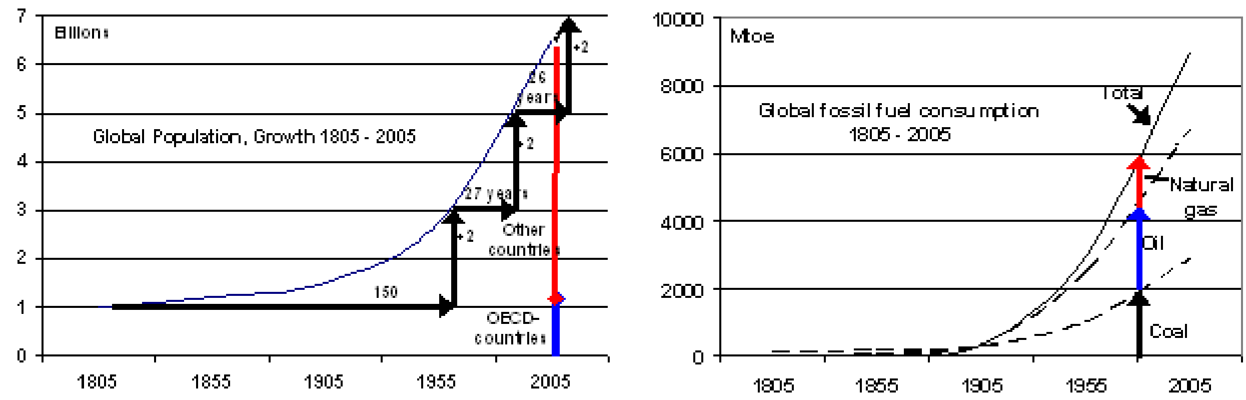


Figure 1. This figure was presented in 2000 by the US Department of Energy, Energy Information Administration (EIA). It shows in principle the dire consequences of continued efforts to defer the downturn of the annual supply of a limited resource, in casu oil: The higher the rise, the steeper the fall. In reality we will hardly see a pointed peak but rather an undulating plateau for some years before the irreversible decline sets in.

The accidental circumstances

The modern - physically speaking - powerful world is generally considered to be the result of the continual progression in science and technology, a progression which will change its direction towards other power sources when oil becomes scarce. But that is not the case.

The history of mankind may in all respects be accidental. However, the accidental circumstances which resulted in exponential growth in populations and production, beginning in the 18th century and gaining unprecedented momentum in the 20th (see Figure 2) are unique. In the first place, the climatic and biological events about 150 millions of years ago which resulted in the deposition of organic material in deep waters, poor in oxygen, were accidental. So were the later tectonic upheavals which buried some of these organic masses deep in the crust of the Earth where the conversion to oil and gas took place under high temperatures and pressures. Most of the oil and gas escaped to the surface but some was trapped in pockets under impenetrable layers - the oil and gas fields. The estimates of the amounts of oil which at reasonable costs can be recovered from the oil fields range from 2,000 billion to 4,000 billion barrels. Presently about 1,100 billion barrels have be recovered and burnt. The amount is accidental. Had there been only 1,000 billion barrels, our world had been very different from what it is today.



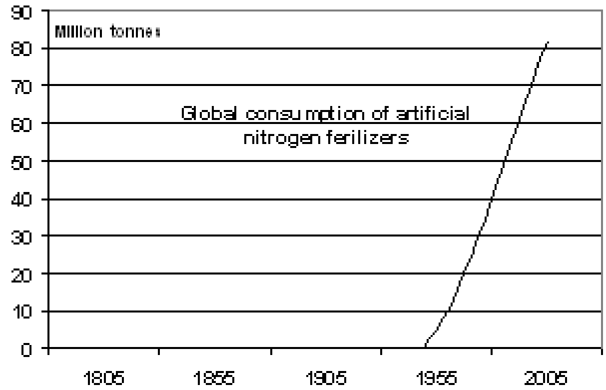


Figure 2. The exponential growth in the world's population could not have taken place without the concurrent exponential growth in the consumption of fossil fuels and the consumption of artificial fertilizers, produced, transported and spread by means of fossil fuels (natural gas for the production of artificial nitrogen fertilizers).

As regards the natural sciences, it was the discovery of the atmosphere and the pressure of air in the 16th and the 17th century that blazed the intellectual trail which enabled Thomas Newcomen to foster the idea of a steam engine and in 1712 to build an engine that actually worked. From then on, the development of powerful machines driven by coal, oil or gas was primarily the result of the symbioses between the fossil fuels and the machines, brought about by a few key inventions made by a few ingenious engineers.

Without coal the proliferation of the steam engine could not have taken place and without the steam engine, coal could not be mined and transported.

Without the steam engine as a forerunner, the petrol and diesel engines could not have been constructed within a few years because the industrial manufacturing of the engine parts - cylinder blocks, pistons, crank shafts, connection rods, etc. - would not have been in place.

And without the oil-powered engines the exploration of oil fields and the extraction of their contents would have been neither technically nor economically feasible to the extent we have seen since the 1930s.

Nevertheless, as oil becomes scarce and fossil fuels in general must be abandoned because of their impact on the global climate, it is generally believed that other energy technologies can provide the same abundance of power which was accidentally provided by oil, gas and coal. It's believed that unsustainable economic growth, based on fossil fuels, can be transformed into sustainable economic growth, based on the so-called 'renewable energy sources'. That without fossil fuels sufficient food can produced to feed a global population which may grow to 9 billion people by 2050.

However, there is no factual evidence to support such wishful thinking. It may appear that the accidental occurrence of fossil fuels is a curse rather than a blessing as metaphorized by the following little allegory:

> On an island far out at sea a flock of hens, roosters and chickens live very well. Their number is limited by the annual recuperation cycle of the grass, other vegetation, worms, and insects on which they feed. But one day a hundred barrels of grain are washed ashore from a wrecked ship. Suddenly there is plenty of food. Within a short time they grow in numbers. They grow big and fat from the ample supply of food and their excrements pollute the soil. The island's natural life cycles are disrupted. After a while most of the grain has been consumed and what is left has been trampled down into the soil. Now they are too many to live from the vegetation, much of which has been laid waste.
>
> Had they found only a few barrels of grain, they would not have been led into such disarray.

Visions of change

In the so-called developed world the access to abundant amounts of cheap fossil fuels has not only led to overweight economies. It has also brought about the economic surplus needed to develop the multitudes of new technologies which might provide ways and means to develop viable post fossil-fuel societies.

However, the analysis of ways and means to accomplish the transition to the post fossil-fuel world has been left mainly to economists, visionary greens, politicians, journalists, authors and some industrialists who find profitable prospects in the marketing of green technologies. Even though the combined technological, societal, and economic challenges involved in the transition call for comprehensive, multi-disciplinary analyses of feasible strategies.

In his widely quoted report *The Economics of Climate Change* - The Stern Report - the economist Nicolas Stern wrote in 2007, two years ago:

> "If economics is used to design cost-effective policies, then taking action to tackle climate change will enable societies' potential for well-being to increase much faster in the long run than without action; we can be 'green' and grow. Indeed, if we are not 'green', we will eventually undermine growth, however measured".

If economics provides guidance on the way to green prosperity, why then did mainstream economists lead us into the present economic and environmental calamities? Since 1987, when the Brundtland report *Our Common Future* introduced the concept of 'sustainable development' and warned about the risk of climate change, economists have dismissed the ever-growing evidence that the liturgically praised economic growth is unsustainable. The policies they designed are cost-effective only as long as fossil fuels are very cheap and the environmental costs of burning them are paid by those not enjoying their power or, regarding the affluent societies, are deferred a decade or two.

As we have seen, the exponential economic growth in the 19th and the 20th century was accidental - based on the power provided by cheap fossil fuels. Current conventional economics are based on economic growth theories and models emanated from the fossil-fuel powered economy. Without the abundance of fossil fuel power they would hardly have come into existence.

Regarding technology, the most salient vision of changes which the cost-effective, new economic conditions should bring about is conveyed by the notion of 'energy efficiency' - meaning that in future the use of fossil fuels should be less wasteful than it has been hitherto. What the notion of 'energy efficiency' tacitly implies is the lamentable fact that because fossil fuels, oil in particular, have been so cheap, the depletion of the resources and the accompanying CO2 emission has taken place at a much faster rate than would have been the case if the economic measures now advocated had been adopted twenty years ago.

Alongside the prospects of 'energy efficiency', progress in the development of 'renewable energy sources' should mitigate climate change and pave the way to the post fossil-fuel world. It should be noted, however, that 'renewable energy' is not a technological category of energy sources. It is a popular notion which encompasses every earthly energy source except fossil fuels and nuclear power. The amount of 'renewable energy' being utilized is unmeasurable and in any case an irrelevant quantity. What matters is the amounts of fossil fuels being burned and the amounts of radioactive waste being produced in nuclear power stations and there is no simple relationship between these quantities and the quantities of renewable energy, however measured .

The fossil concept of energy as a commodity

These reflections on the concepts of 'energy efficiency' and 'renewable energy' lead to the question: What, in the minds of economists, politicians, public servants, and other laymen in the field of thermodynamics, does the word 'energy' actually mean?

Etymologically the word stems from the Indoeuropean word 'uergon' which - as one can hear - is the origin of 'work'. In classical Greek it became 'érgon', 'en-érgon', and 'enérgeia' meaning the ability to perform work. Until the 19th century the word was rarely used in literature. Nowadays it is commonly used in expressions like "he is very energetic", "one uses a lot of energy when jogging", "I don't have the energy to do the job", etc.

That 'energy' is lost in the carrying out of any kind of work and has to be renewed is well known. Life is incredibly complex organizations of unstable chemical and electro-chemical states constantly decaying into entropy and renewed by recuperating energy flows. The technological aids to human life are very simple imitations of biological organizations: Machines which utilize the chemical energy potentials of fuels and free oxygen (in engines and boilers); the gravitational potentials (in hydro power stations); the kinetic potentials of the atmosphere (in windmills); and finally the electric potentials generated by the machines (in electric motors, lamps, etc.).

All potential energy sources decay into entropy sinks of low-temperature heat. Thermodynamic engineering is about the design of machines which control the decay in such a manner that the decay processes yield useful energy, viz. the loss of potential gravitational energy in a waterfall as against the generation of electric power by means of a turbine which controls the water flow; or the loss of potential chemical energy when oil is burned in a simple boiler as against the generation of mechanical power when the combustion is controlled in an engine.

Energy is lost in all processes and must be replenished or renewed. Biology and technology is all about organization and control of the flows of energy towards the low-temperature entropy sinks in such a manner that useful power is obtained along the way.

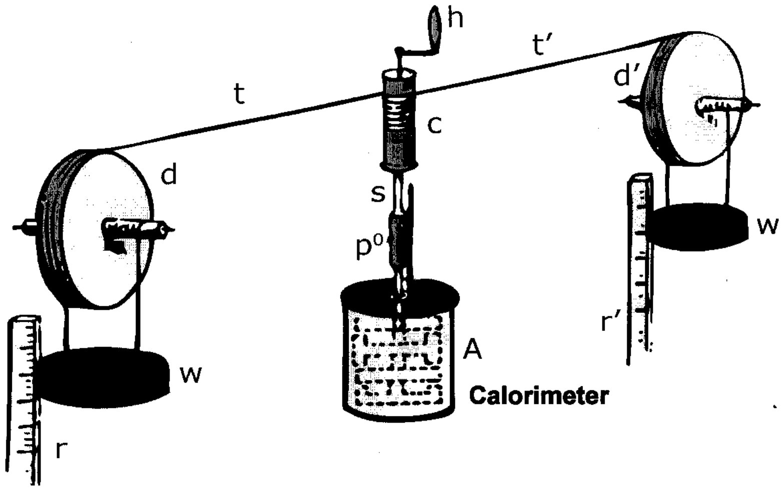


Figure 3. Joule's experiment: The work performed by the force of gravity when the two weights move downwards is not lost but converted into heat (calories, the imaginary substance) by the propeller rotating in the calorimeter. However, the small rise in temperature is of no useful value. What is potentially useful is lost. Likewise, the potentially useful power from the electric grid or from oil - which can move trains and lift heavy items - is mostly lost when converted into low-temperature heat for room heating or warm water.

Electrically driven heat pumps can provide low-temperature heat using less than a third of the power spent in a simple electric heater, even though losses because of temperature differences within the device also occur in heat pumps. However, if the electric power is generated in fossil fuel-driven power stations with an efficiency of about 40 percent, the fuel consumption for low-temperature heating is only about 20 percent smaller than the fuel consumption using an oil or gas boiler. By means of an oil or gas fired engine driving a heat pump the fuel consumption can be reduced to less than 50 percent as compared with an oil or gas boiler because the heat from the engine's cooling circuits is added to the heat from the heat pump. Thus the amounts of electric power or fuels needed to provide low-temperature heat strongly depends on the technique being used.

In classical physics, however, energy is something else. The conservation of energy is one of the basic principles, like the conservation of mass and the conservation of electric charge. It was discovered by James Joule (1818-1889). His famous ground-breaking experiment - see Figure 3 - showed that when the weights moved down, the work transferred to the propeller in the cylinder vessel - the calorimeter - was converted into heat. Something is conserved: the mechanical work is not lost but converted into an equivalent amount of heat. That 'something' Joule - unfortunately - called 'energy'. Later, as the theory of thermodynamics matured, 'energy' was defined as a thermodynamic state function - something very abstract and entirely incomprehensible to laymen.

Thus, the word 'energy' has two very different meanings. The one is the original, intuitively comprehensible meaning: the energy of unstable states driving all biological processes and machines and lost in the process. The other is the physical meaning: the thermodynamic state function which is constant (conserved) but incomprehensible to laymen who nevertheless believe that they know what it means.

Strangely, many believe that they comprehend the 1. law of thermodynamics, which states the conservation of energy in a closed (adiabatic) system, although the 1. law is a corollary (an immediate implication) of the definition of energy, which very few are acquainted with. There against, the 2. law of thermodynamics is believed to be difficult to comprehend although it essentially states the well known experience that any system when kept in isolation without renewal of its internal unstable states will decay into a stable (dead) state.

'Energy' found its way into the political vocabulary during the oil crises from 1973 to 1980. Few of the politicians, economists and bureaucrats who adopted the word pondered on its meaning. Most had learned in school that 'energy' is something which can be measured by means of a calorimeter: some substance - calory - which exists in different forms: fuels, electricity, heat, and mechanical power. An understanding which allows energy bookkeeping accounts to be kept in the same manner as monetary bookkeeping accounts. Disregarding the fact that the sum of the energy values of a quantity of oil, a quantity of electric power, and a quantity of low-temperature heat from a solar absorber is a number which is no more relevant than the sum, measured in litres, of a bottle of water, a bottle of whiskey, and a bottle of milk.

It is true that
* 1 litre of water + 1 litre of whiskey + 1 litre of milk makes 3 litres.
Likewise,
it is true that
* 1 GJ of oil + 1 GJ of electric power + 1 GJ of heat from solar collectors makes 3 GJ.
But the summations are irrelevant for any practical purpose.
Nevertheless, the energy statistics upon which energy policies are based consist of such irrelevant summations, e.g. gross energy consumption, renewable energy totals, etc.

Moreover, the concept of energy as a tradeable commodity is readily derived from the concept of energy as a substance.

In particular, electric power, conceived of as an energy commodity, is traded on electricity markets where all sorts of different means of power generation: coal-fired power stations, gas-fired power stations, hydropower, nuclear power, biomass fired power stations, windmills, and photovoltaic panels compete although they generate electric power under very different economic and operational conditions. This is clearly irrational because market competition implies that producers whose costs are higher than others loose their market share. But we need windmills, solar power, biogas-fired cogeneration plant, etc. even though these power sources may be more expensive than power stations fired by cheap coal.

Had the development of the industrialized societies not been powered by fossil fuels, this obviously irrational concept of energy as a substance and a tradeable commodity would not have prevailed. It is inherently associated with the unique properties of coal and oil and partly natural gas: high energy intensity and easy to transport and store.

Towards a future world without fossil fuels and nuclear power

In a future world without fossil fuels and nuclear power there'll be no consumption of energy. A forest, a green field, a windmill and a photovoltaic panel does not consume energy. These biological subsystems and technological artefacts will all be integral parts of complex energy systems, designed and operated so as to provide the energy in the form of food, fuels and electric power needed to support life in human habitats. Economic management will have been restored to its original objective: namely to ensure that available resources are efficiently used in a sustainable manner.

The term 'renewable energy' will be relegated to the chapters in history books which tell about the late fossil-fuel era. 'Renewable energy' is a meaningless concept in a world where energy technology is all about the organization of energy systems which make efficient use of the many different energy flows in the atmosphere, the hydrosphere, and the biosphere.

In the search for ways and means to accomplish the transition to the post fossil-fuel world in a constructive manner we must abandon the conceptual stereotypes which are rooted in the fossil-fuel economy. In particular, we must reinstall the original concept of 'energy' as a useful property of unstable states in complex systems, as against the fossil-fuel world's concept of 'energy' as a substance and a tradeable commodity.

As Albert Einstein said: "No problem can be solved from the same level of consciousness that created it". We will not find feasible solutions to the climate problem created by fossil fuels as long as we think in terms and stereotypes which have their origin in the economy and technology of the fossil-fuel world.

In conclusion

Oil, natural gas, and coal are power sources external to the biosphere. They have exceptional energy intensities as compared to the energy sources originating from the annual life cycles of the biosphere and the aero- and hydrodynamics of the atmosphere. They are easy to transport and store, and they have been cheaply recoverable.

In symbiosis with the oil-powered-vehicle industries the oil industry has created a global industrial production system in which trans-national companies can move their factories to countries where, for the time being, labour is cheapest. On satellite photos of the globe at night one can see the electric light radiating from the cities of the affluent countries but not the smoke from the mostly coal-fired power stations which provide cheap electricity to high-rise city centres and suburbs, built with fossil fuel and heated with fossil fuels. At daytime the satellite photos show the scars where rainforests have been cut down by means of oil-powered machinery and replaced by soya fields delivering feedstock to distant animal farms or palm trees delivering palm oil to the world growing motorcar fleets. Also, one can see the glaciers and polar ice sheets, which are retreating as the temperature rises because of the greenhouse effect of the billions of tonnes CO2 emitted by the burning of fossil fuels and the burning of forests. However, one cannot see the extinction of life in the oceans caused by the globally operating trawler fleet's depletion of fish stocks and the heating of the water.

Thus the unrestricted use of fossil fuels - power sources external to the biosphere - has rendered unprecedented wealth to a minority of the worlds population and caused havoc in the planets life cycles. In the economic-growth theories of the fossil-fuel era the destructions are included as the so-called 'externalities. In the Stern report *The Economics of Climate Change* (2007) Nicolas Stern writes: "Climate change is an externality that is global in both its causes and consequences. Both involve deep inequalities that are relevant are relevant for policy" (op.cit.p.33). That does not make sense because outside the infected biosphere there is the empty space. Climate change with its associated calamities are not external but internal to the biosphere. It causes internal dysfunctions of the life cycles of the entire biosphere. Particular externalities may be repaired by specific economic remedies. Internal dysfunctions of the global economic system as a whole call for a thorough revision of the economic principles governing the behaviour of people: an economy for the common good which serves to utilize the planet's natural resources in manners which preserve them for future generations.

A peaceful, constructive transition to the post fossil-fuel era is not only a matter of new technologies. It entails a revolution in the way we conceive of ourselves as party in the life cycles of the biosphere. We must acknowledge that the unprecedented external physical power of fossil fuels, which for a short while in history has rendered exponential growth in populations and production possible, has not enabled us to control the basic conditions for life on Earth.