For a Clear View of Traditional and Alternative Energy Sources

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Abstract: ***We list a number of criteria which have to be considered in order to make meaningful decisions about possible energy sources. At the same time we list pros and cons of some alternative energy sources. One of the reasons for putting down these lines can be traced to the following fact: it is often possible to find statements about practically infinite energy resources, which are inexhaustible and available for almost free, and can be used without any side effects. The intention of these notes are to shed some light on the effects of energy production and consumption on the global climate, the nature of available energy resources, and some of the effects of their exploitation.***

Keywords: *global climate, energy resources, realistic overview, future prospects*

I. INTRODUCTION

Criteria for using one energy source over another, or using a combination of them are manifold. To set the context: Energy consumption has an ever growing, in fact accelerating trend, thus in spite of increase in energy savings and gain in energy efficacy new energy sources need to be found, [2,4,7]. Most, in fact striking 86.4% in 2007 , of the world's energy supply comes from fossil sources, which is unsustainable at the time scale much shorter than the availability of the energy resources would suggest. Because of soaring energy prices, the trend is increasing, as coal regains attention as a primary energy source. As fossil fuels are used in oxidative processes, their consumption results in carbon-dioxide production, most of which is finally released into the atmosphere, resulting in increased carbon footprint. An operational definition of carbon footprint is "A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO_2e) using the relevant 100-year global warming potential (GWP100)." [23]. The increased amount of carbon-dioxide changes the thermodynamic properties of the atmosphere. Increase of the CO_2 concentration in atmosphere is often depicted in what is known as “Keeling curve”, one is depicted in Figure 1, from [22]. Via direct and indirect mechanisms the increased concentration of carbon-dioxide generates the process of global warming, which refers to the rising average temperature of Earth's atmosphere and oceans and its projected continuation [9,13]. Increasing global average temperature trend is known as global temperature anomaly, Figure 2. Spatial variation of the global temperature anomaly is shown in Figure 3., [13]. In fact, carbon-dioxide in only one of greenhouse gases released into the atmosphere, the most important naturally occurring gases being water vapour, which causes 36-70% of the greenhouse effect, methane which causes 4-9%, and ozone, which causes 3-7%. The concentrations of CO_2 and methane have increased by 36% and 148% respectively since 1750, [5]**}**. These levels are much higher than at any time during the last 800,000 years, the period for which reliable data has been extracted from ice cores.[16,17,11,14] Less direct geological evidence indicates that CO_2 values higher than this were last seen about 20 million years ago, [24]. Ever since the human race exists, Earth had its polar caps. It is right now, at the very beginning of the 21-st century that the possibility of loosing the Arctic ice cap may become a reality. The domino effect on other ice-caps (Greenland, Antarctica, mountain glaciers) can not be excluded.

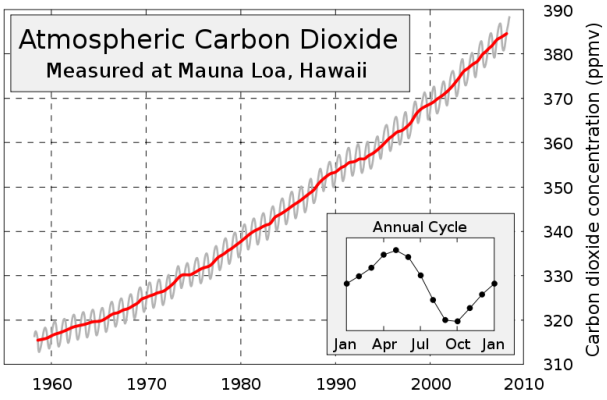

Figure 1. Rise in the atmospheric concentration of CO_2, source of figure [21].

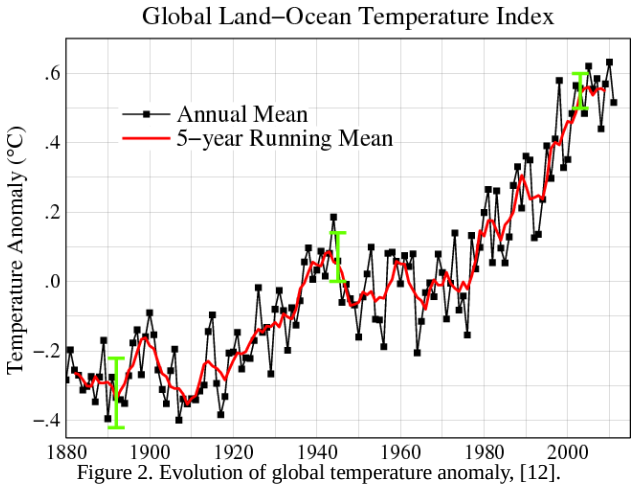

Figure 2. Evolution of global temperature anomaly, [12].

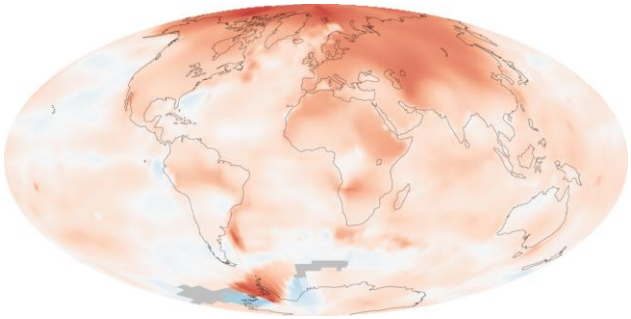

Figure 3. 10-year average (2000–2009) global mean temperature anomaly relative to the 1951–1980 mean. The largest temperature increases are in the Arctic and the Antarctic Peninsula, [13].

Global warming, if no decisive action is taken, will in itself have grave consequences for stability of the climatic patterns worldwide [8,9], e.g. via changing the thermohaline circulation in the world ocean. Predicted temperature rise based on the Hadley Centre Coupled Model, version 3 is shown in Figure 4. Global temperature is a bifurcation parameter in global climate models, so it its variation needs very close monitoring and appropriate actions are needed to conserve stable climatic patterns. Any change, especially human related rise, in global temperature will have far reaching consequences which will materialise in food supply, stability of global economy, social unrest and the future of human civilisation as we know it.

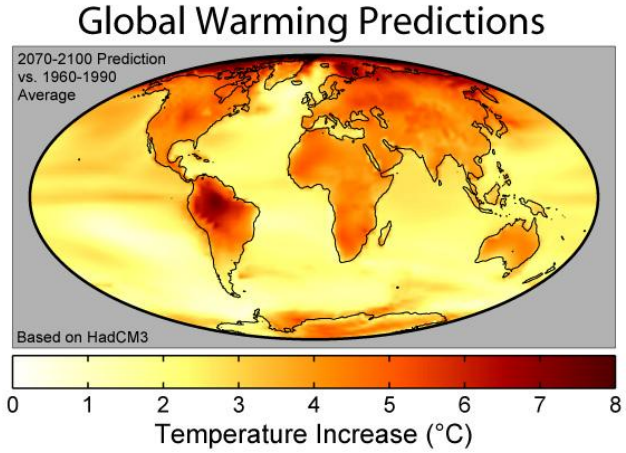

Figure 4. Predicted temperature rise for the 21st century, based on the HadCM3 climate model, figure from [6].

These, and many other facts turned the attention towards so called alternative energy resources.

Before we proceed any further, we have to notice the importance of the nature of energy consumers. Roughly, the energy consumers can be divided into mobile and static. It is much simpler to solve the energy supply in terms of alternative energy resources for static consumers than mobile ones.

Mobile energy consumers can be traced to traffic, which is to a great extent powered by fossil fuels, with the exception of some trains, trolley buses and electric cars, lately. One notable exception being reintroduction of wind energy in a form of combined fossil-fuel wind propulsion of large marine vessels. Mobile consumers need fuels which have very high energy content, more precisely energy density. None of the alternative sources is such. For the time being, only fossil fuels and their derivatives have sufficient energy densities at affordable prices. Therefore at present, as long as there is no fundamental breakthrough in storing electrical energy and coal chemistry or an industrial scale alternative to some version of photosynthesis is found, alternative energy sources are viable for static energy consumers only.

II. TRADITIONAL VS. ALTERNATIVE ENERGY SOURCES

Traditional energy resources are fossil resources and hydroelectric resources. Because of their long history, to some extent uranium fission power plants can also be considered as traditional energy sources. Out of this list, only hydroelectric resources can be treated as sustainable, though for a variety of causes, in the long-term, they need not be. A point should be made, historically, oil *was* an alternative to coal, say.

Alternative resources cover a wide range of existing, exploitable resources, or resources being developed. An incomplete list would definitely include the following energy sources: wind, sun, geothermal sources, biomass, biofuel, biological hydrogen production, waves, oceanic tides, oceanic currents, oceanic thermal and haline gradients. One immediately notes, that not all the energy sources are always and everywhere available. Use of solar energy is determined with the number of sunny days at each and every location. Windy weather is not guaranteed. Intermittency is an important feature of alternative energy resources. It means, that sufficient backups are needed, in most cases backups are guaranteed from the centralised energy supply system.

At best, ocean can be regarded as energy resource for coastal areas only. Biofuel was meant to be an eco-friendly and seemingly sustainable candidate for a future energy resource, but its overal energy balance turned out to be negative, and its ecological and economical effects, via affecting global food prices, turned out to be devastating.

I will concentrate of alternative energy sources which can be an option in a continental region, without significant wind potential or too big number of sunny days. The alternative options are biogas, and geothermal energy. Biogas, in most cases methane, can be efficiently produced in sewage plants and animal farms to reduce their operational costs via decreased external energy consumption. In spite of some carbon-dioxide release, the net effect from the carbon footprint perspective is positive, as methane is much worse greenhouse gas than carbon-dioxide, not to mention other environmental advantages, such as highly improved quality of processed sewage water. One should note that biogas is used immediately at the production site, because of its scarcity and low energy density. Geothermal energy will have big future in heating technology, though because of transportation costs, this form of energy is also used locally. These two examples illustrate an important feature of alternative energy sources: they are produced and used locally, transport is practically absent. This

results in geographically distributed alternative energy sources, which may have an advantage, and that is fault tolerant property of distributed systems. One should note another feature of the examples, these energy sources need an external energy resource in order to operate. Thus, they can reduce the energy consumption from the external source, but generally, they can not replace it. A further remark has to be made. Geothermal energy is believed to be practically inexhaustible. In fact it is not, as long term exploitation (25 years, say) depletes the amount of thermal energy which can be used from from a well. The lifetime of a well can be greatly prolonged, if during summer the heat is pumped back to the well, i.e. if the well is used for cooling.

III. REALISTIC FUTURE OPTIONS FOR CENTRALISED ENERGY SUPPLY SYSTEMS

Future of centralised energy supply systems will follow a different route. For a centralised energy supply system new, long term, carbon footprint neutral solutions are needed, we just briefly summarise some possible future alternatives. In countries located at the Atlantic coast, wind energy is the source of 20% of all the energy consumption already. Large solar plants in north west Africa can in principle produce enough energy to cover 20-30% of EU's annual energy need [19]. Note, that these sources with current technologies operate intermittently. New solar technologies are already operational, based on salts (60% sodium nitrate and 40% potassium nitrate) for heat storage, which offer constant, or at worst, prolonged energy supply [1] during the whole day-night cycle. Three Andasol plants provide sufficient energy for half a million people in southern Spain. Nevertheless, future of solar energy lies not only in electrical energy production, but to large extent in heating. Combinations of wind and solar plants, in the form solar updraft towers [16] are also being developed with projected 200 MW capacity. This technology uses solar energy to heat large volume of air, which by its upward motion through a large chimney speeds up and propels a wind turbine to produce electrical energy.

I will conclude this section with mentioning two further possibilities, which may be realised within 20-30 years. One being thorium based nuclear fission. Uranium fission results in radioactive waste, which needs costly post-processing and long term storage. Uranium suitable for commercial exploitation can be found only at few sites. On the other hand thorium based fission does not produce long-lived (compared to uranium fission) radioactive waste. The amount of commercially available thorium amount is much larger (thorium is three to four times more abundant than uranium in the Earth's crust, [20]) and its distribution is much more even when compared to uranium, not to mention prices. Countries with largest known thorium reserves are India, Australia and USA. Notably, in case of thorium there is no need of isotope separation. Energy released in thorium reactors is much more suitable for thermal conversion than the energy released in uranium reactors. In fact, thorium reactors can be used to incinerate high-activity nuclear waste and produce energy. Being rich in thorium deposits, India already made advances towards an exploitable thorium reactor.

Nuclear fusion can resolve many problems with energy supply, once the technologies are available. The advantages of nuclear fusion compared to nuclear fission are numerous. The energy yield in fusion is larger than in fission. The amount of radioactive waste is incomparably smaller, in fact, there is no direct waste from the reactor itself, the neutron flux from the fusion reaction activates the reactor's shielding material. The reactor will burn tritium, and in future possibly a light isotope of helium, ^{3}He. For its operation fusion reactor needs lithium. Based on the present estimates, the amount of lithium available is sufficient ensure global energy production. A prototype fusion reactor, ITER (International Thermonuclear Experimental Reactor) [10] is under construction, it is expected to become operational at the end of the decade. Once it is built, it will be a prototype for future commercial fusion reactors. The ITER fusion reactor itself has been designed to produce 500 megawatts of output power for 50 megawatts of input power. It worths mentioning in this context, that the renewed interest in Lunar programmes is related to the fact that the Lunar surface is covered with regolith, which is rich in Helium-3, which is expected to play an important role in future fusion reactors, [3].

IV. CONCLUSION

Energy production and consumption affect the environment, whatever the energy source is. Present energy production and consumption trends are likely to continue in the near future, though they are to change, either because of organised global effort or for another reason. It can not be overemphasised, that the realistic option in future and present energy supply policies is the reduction of energy consumption, and increasing the gain in energy efficacy, whatever the available energy source is. We argue that alternative energy resources have a potential to reduce the strains on centralised energy supply systems, and can increase their fault tolerance. Alternative energy solutions can be applied locally, though their widespread application will have global effects. Large scale energy supply systems will change the primary sources of energy, we hinted some possible future resources. We just note that alternative energetic solutions need consideration of installation, maintenance and operational costs, locally and globally, important issues which we have not discussed. It needs to be stressed, that any solution of future energy supply needs a societal perspective, which neither technology nor economy can bypass.

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