

How to attain sustainability in energy supply?

A survey is given on the recent state of global energy supply and the possible scenarios for satisfying energy needs in future. As a basis two main facts that address energy problem are used, i.e. human population on our planet, H , registers a permanent increase, but the total quantity of raw materials RM spent worldwide increases by an accelerated rate. Equation $RM = k \cdot H$, expresses their dependance. Unfortunately, k is not a constant as reasonably expected, but is a parameter that increases with time. That means that man's average raw-materials need (per capita consumption) grows every year, decade and century. This trend is opposite to the quantity of raw-material's resources, both non-renewable and renewable, which decreases with time. There are two possible explanation of this conclusion. First, the spoiled members of consumer's societies do continue to expand their spending habits, thus ignoring the appeals for reasonable behavior. Second, the members of countries in economic expansion, which suffered poverty up to now, use the opportunity to satisfy their so far suppressed needs. On that way they contribute to a jump in increase of raw-materials exhaustion.

In a search for solution more scenarios are listed and their possibilities are analyzed. Next to the traditional concepts of saving mode and spending mode, which were propagated and checked in past, the new trend of glorifying the renewable energy sources is critically considered. It is shown that the renewable sources as, e.g. photovoltaic conversion, biomass, artificial photosynthesis, wind and ocean energies, and classical hydropower energy posses a number of hidden disadvantages and that they are not so green and an universal solution for our energy supply problem as recently presented. All of them contain some extra burden, as e.g. consumption of lot of raw-materials accompanied with emission of greenhouse gases in the step of their production or building, corresponding high price, limited life span and similar non-green properties.

As a result of the performed survey it is concluded that there is no recent energy that is completely renewable. There is no completely clean and recyclable technology in the energy sector. The invention of such an item will be proclaimed as wonder.

No alternative energy source is yet available that will satisfy our future energy needs. The only realistic solution is to reduce the per capita energy consumption to a level that will comply with the recent energy resources. When all the world regions will start to enjoy the benefits of modern life, the amount of needed energy will be so enormous, that the renewable energies will be only a tiny part of energy balance sheet. It is terrifying that the world, especially the countries with developed economies, is now far from lowering the individual energy consumption. The problem of providing sufficient energy is open.

Key words: Energy supply, Raw-materials, Renewable energies, Global attitudes, Illusions

INTRODUCTION

One of the major concerns today is how to attain sustainability in dealing with the natural resources, especially the ones that provide energy and materials. The concern is best visualized by means of these three (opposing) facts, i.e. (i) Global population increases, (ii) Raw material's reserves do deplete stubbornly at an increasing rate, and (iii) Despite of such a situation, *per capita* consumption of energy

and materials continuously increases*. This means that we do exhaust the renewable resources faster than the nature could replenish them, while the non-renewable resources we did deplete to the level of critical reserves [1, 2].

Admitting how serious is this problem, we do keep regularly the Sustainability on agendas of our

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* Even faster increase in per capita consumption of natural goods is expected with the advance of economies and life standard of population in today's underdeveloped countries, as e.g. in Africa, Asia and South America. They do outnumber the population in developed regions. Fig. 1 shows differences in energy consumption for lighting in different Earth's regions [4]. These differences will disappear soon.

gatherings, from Planet Earth Summits up to the family size meetings. We did prepare a number of documents (declarations and protocols, resolutions, framework conventions, etc.), where we do appeal to everyone's conscience for rational behavior. Wise solutions were offered (and accepted!), but their

realization did not satisfy the expected dynamics and globalism, especially as far as the key players in depleting the resources and generating the pollution, climate changes and similar indecencies are concerned [3]. So far, the effects are not satisfactory. Will they ever reach that level?



Figure 1 - World at night (satellite image) [4]

Differences in night illumination will not last forever.

TWO OPPOSITE APPROACHES

At first glance, there are two possible approaches.

The first one advocates the saving attitude, i.e. responsible spending of natural resources and an honest manipulation with natural resources both from recent and future generations. This is the *saving mode*. It is well known worldwide, because in last twenty or thirty years this concept was endlessly explained, recommended and favorized from top authorities. Unfortunately, it is not easy to convince the mankind to drop the consumption habits. Also, it is not wise to expect that the underdeveloped regions and continents will express their solidarity by further postponing of their entrance in comfortable life. Table 1 documents the latterclaim on a dramatic way, i.e. the developing countries in Asia Pacific recently do posses only one half of private cars compared with the Western Europe countries. Situation is fluid and changes in favor of Asia Pacific countries. It is estimated [5] that by the year 2026 there will be twice as much private cars in Asia Pacific compared to Western Europe!

Table 1 - Number of personally owned cars, in thousands, (past, present and forecast) [5]

Year	Western Europe	Asia Pacific	Western Europe vs. Asia Pacific,
2008	204	87	234 %
2010	207	99	209 %
2012	212	121	175 %
2014	217	147	148 %
2016	221	178	124 %
2021	231	270	86 %
2026	244	417	58 %

The alternative approach is quite opposite. It advocates unrestricted spending of resources in a belief that further expanding of production activities will create new resources that will replace the exhausted ones. This is the *spending mode*. It is of rather adventurous nature because is based on a hope, not on firm arguments. Practically this is a kind of search for completely new: (i) sources of energy, (ii) materials, that will successfully replace the exhausted ones, (iii) technologies (iv) economies, etc.

Such an approach seems attractive, but it contains a hidden risk: What if the search fails in providing the new resources and in meantime we further and deeply deplete the existing ones? Mankind will face serious shortages, which could eventually turn to global catastrophes, wars, fame, etc.

In the past such approaches were checked in few occasions and did prove to be successful [6]. They did generate a belief that science and technology, using the genius of scientists and engineers, will perform successfully again and again. Their believe is that the hidden risk of further depleting the natural resources must be accepted because there is no better solution.

This reasoning calls, e.g.: *'Forget the spending and similar sound and rational behavior! They won't solve the problem. Instead, continue to spend as much as you need, and start a search for solution in finding new possibilities, new ways to the desired precursors for mankind's civilization based on materials, a lot of materials. Do not worry, technology creates new resources! It is an illusion that all the 7 billion humans on the Earth will behave honestly and fair, and spend as low as agreed. Expect selfishness and dirty game'*.

SAVING AND RATIONAL SPENDING – NO! NEW SOURCES – YES!

When accepting the spending attitude as a must for prolongation of recent mankind's well-being, one has to keep some reserve that the whole Earth's population will be equally honest and fair to slow down the raw materials consumption. This is the reason why further modification of the described two modes (saving and spending) are elaborated and offered.

One of these efforts is the program document of the European Association for Chemical and Molecular Sciences, EuCheMS, titled *Chemistry – Developing Solutions in a Changing World* [7]. It contains a list of priorities in planning the further breakthroughs, i.e.:

1. Energy
2. Resources
3. Health
4. Food
- Etc.

There is no need to explain why *energy* is positioned as the top priority. Energy is the key factor in maintaining the modern life, no matter if used as fuels, heat or electricity. The energy consumption increases permanently and its price goes the same way. It is believed that in 2050, the global energy demand will double the present value, no matter that the Earth's population will reach 'only' something above 9 billion, and not the double figure of 14 billion. It is obvious why the energy demand will outnumber the demographic increase: Man will further increase its *per capita* energy consumption! This increase will be especially high in the developing countries. It is also expected that until the 2050, fossil fuels and uranium minerals, the dominant energy sources, will be further depleted. This imposes today's science to start the search for tomorrow's energy sources.

Normally, we will continue to rely on the Sun energy, today's dominant or exclusive energy source on Earth [8]. But in future that will not be the Sun energy captured thousand years ago and stayed in the Earth's crust, but it will be a recent Sun energy, from 'yesterday eventually today'. This one belongs to the category named *renewable energy*, and will continue to renew and appear for millennia on. These energies are transformed by means of photovoltaic conversion, via biomass, by artificial photosynthesis, by wind and ocean energies, etc.

THE MANY FACES OF SUN ENERGY

The first energy, the one transformed by *photovoltaic conversion*, is an electrical energy generated directly from the sunlight by means of semi-

conductors that possess the photoelectric property, i.e. the ability to convert directly the sunlight into electrical energy. Such devices were already innovated and are permanently improved, but nevertheless recently they perform with only 15 percent efficiency, while in future we do expect them to be more effective and to convert even 80 or 90 percent of sunlight energy into electrical one. They are robust, without moving parts and silent, that makes them reliable and durable energy converters. Today their market share is only some 0.5 percent, and for 2050s the expectation is that they will participate in global electricity production with 11 percent [9]. In order to achieve such a performance, man should rationalize the fabrication of future photovoltaics, i.e. to develop next generation of converters based on less expensive ultra-refined silicon, or even non-silicon one, together with some other improvements [7].

The *biomass* (from specially grown plants or different organic wastes) could be used for heat or electricity generation or as fuel. Possibilities are great, but there are some limitations, such as e.g. the biomass usage must be sustainable, economically and energetically sound, without generation of greenhouse gases and without endangering the food production. Biomass could be directly combusted, or converted into fuels (gas or liquid) or other compounds. In order to realize such a goal it is necessary to invent new (bio)catalysts, improve the separation techniques, etc. To prevent the competition with food production, biomass could be produced from genetically modified plants able to grow on soils not convenient for food production, even at the harsh environments, such as oceans.

Artificial photosynthesis is a set of processes where direct conversion of sunlight into stable compounds occurs. As a result hydrogen, methanol and similar compounds with high content of energy are generated from cheap and abundant raw-materials as e.g. water and carbon dioxide. This photosynthesis is not as complex as the natural one, no matter that in principle it copies the same conditions but in a simpler, smaller and more efficient way. An important advantage of the artificial photosynthesis is that produced fuels could be stored for later use, what is not the case with electricity produced via photovoltaic conversion. Other benefit is that this photosynthesis consumes carbon dioxide, thus lowering the amount of the greenhouse gas. Unfortunately, the reduction of carbon dioxide is an extremely complex process that requires special catalysts.

The steps of the artificial photosynthesis are now recognized, but the whole process is not yet integrated in a unique operation. It is mainly based on capturing of sunlight that causes excitation that is

further transformed into an electrochemical potential. Catalysts are needed for both oxidation and reduction step of this synthesis, as well as a membrane that will separate their products, e.g., hydrogen and oxygen [7].

Electricity is already produced by means of the *wind and ocean energies*, i.e., waves, tide and salinity gradient, but in near future this production is expected to intensify further. Wind energy utilization leads in this group, while the rest ones are applied only on convenient locations. Possible expansion on offshore locations is expected, together with new developments, such as light and persistent composite materials for such application, lubricants, long-lasting protective coatings, etc. The exploitation conditions in this case are quite different and they require new types of materials, technologies and maintenance.

THE RENEWABLES *ALTER EGO*

This was a short and simplified introduction into the field of renewable energy sources and their possibilities, recent and expected in future. The main feature of these sources is that they provide energy without carbon dioxide emission and its negative consequences. In short, these energies (technologies, etc.) could be named *green*, the brand that is very popular and desirable nowadays. This gives hope that our future in energy supply is properly directed.

But, some other aspects do interfere and oppose to such a conclusion.

If we thoroughly analyze all the aspects of these ideal (rather, idealized) technologies, some doubt will arise about their perfection leading to a conclusion that the real situation is a bit different [10].

Here are some of these 'buts'.

By definition, renewable energy origins from sources that will never exhaust. It will last forever and, somehow, resembles to the engine that will run forever – without consuming energy! This appeals to precaution, even skepticism, because long time ago we did erase from reality the concept of *perpetuum mobile* gadgets.

Next, even if we succeed to arrange the renewable energy to become unique (or at least dominant) type of used energy, our supply problem is yet not solved. Namely, we do not need energy only, but we need also many other and different materials, natural or man-made, that are used in providing us with cloths, homes, roads, vehicles and other needs. Only if we do agree to have only strictly elemental leaving, we could survive on the above listed derivatives of Sun energy. But we are not ready to give up the benefits that are provided by use of the variety of raw-materials. In our usual lifestyle we do need items

of non-renewable nature, that are mined or drilled in mines or oil fields, then transported to the factories and transformed in the goods that make our living so reach and pleasant. Times when we were satisfied only with goods that are harvested or picked up (i.e. the fruits of renewable kind) are long ago forgotten. So, let me conclude: *Without non-renewable raw-materials there is no reach and diversified life!*

Some less known data that illustrate how idealized are the contemporary green innovations are given in the next section.

THE GREEN ILLUSION

Energy from the Sun will be delivered to our planet until it exists, probably another four or five billion years. This gives us the basis to claim that the Sun will last forever. But, even if Sun will be 'forever', and his energy is renewable, the panels that convert the sunshine in electricity – are not renewable. The panels should be kept clean (without dust and other deposits) so that water is needed for that purpose. In deserts, the most suitable location for solar panels installation, the water is very scarce. Next, much more water is needed for cooling of auxiliary equipment and installations, for turbines and condensers operation, etc. So, it is true that photovoltaic panels are non-consumable, but the rest components need maintenance.

Electricity generators powered by wind possess generator blades and concrete tower of enormous dimensions (over hundred meters high, resp. long). It is true that these generators provide electricity without emission of carbon dioxide and other environmentally harmful consequences. But, it is also true that in building of these giant structures enormous quantities of materials were consumed. These materials, e.g. cement and steel reinforcing bars are produced by technologies that use coal and emit enormous quantities of carbon dioxide. Again we have a controversy – yes, the wind is a renewable energy, but the scarce reserves of incorporated rare earth metals are further depleted and never will be renewed.

Further increase of the land use for crops aimed at biomass production will reduce the available fields for agriculture plants and other traditional land use purposes. The regions where biomass production in the past did advance already experienced severe forest degradation and air pollution [10].

Production of electricity based on hydropower is not at all a new in the energetics. For the newly types of hydroenergy, e.g. ocean currents, waves and tides, the search for the most convenient exploitation mode is still on, while the exploitation of hydroaccumulations is well established and standardized. Today

some 16 percent of total electricity is produced from hydroenergy and this is more than the sum of all other renewable energies [7]. No matter that it is already well established, this resource suffers too some of the incomplete renewability disadvantages.

In building the concrete dams cement and reinforcing bars are used in a larger quantities compared to the new power plants on alternative energies. Other disadvantage is that the dams kill the river's ecosystem by stopping the established water flow. They prevent fish free movement as well; raise the ground-water level (with all the *pros* and *cons* consequences); reduce irrigation of downstream agricultural land; gradually loose their capacity due to sediments deposition; settlements have to be displaced from flooded area and greenhouse gases are formed from rotten plants. Finally, building a dam is an extremely expensive operation. As a summary of all these disadvantages in Figure 2 a drawing is given with a clear message to reconsider again the decision to build a dam [11].

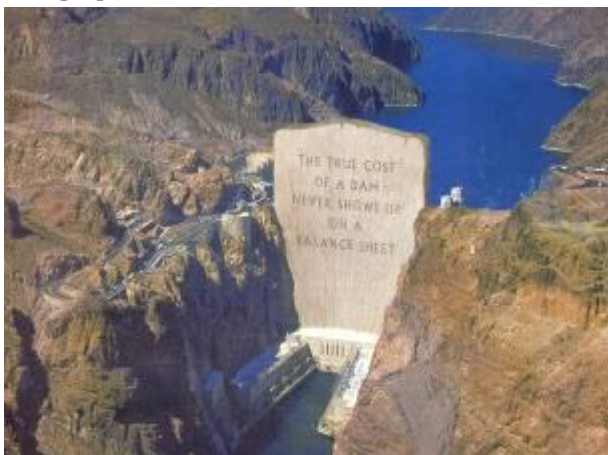


Figure 2 - A warning to be cautious before dam erecting decision is final

The message is: 'Dams. Think again' [11]

Most frequently the plants that use alternative energy sources are positioned in virgin rural areas, while the produced energy is consumed in densely populated urban areas. The energy is transported by means of power-lines. Unfortunately, wilderness will never recover after power-lines and corridors did fragment it.

ATTRACTIVE IDEA BUT BRUTAL REALITY

Despite the habit to present the alternative energy power plants as items that deliver free electricity forever, the reality is different. The life expectancy of a solar panel or wind turbine is actually shorter than that of a conventional power plant. Even the hydro-power plants are designed for a modest period of fifty years.

If the real situation is as explained, than what is the difference between the power plants on renewable energies and the conventional ones that run on coal, oil, natural gas or nuclear energy? The only confirmed advantage is that the renewable energy technologies cause less climate changes and generate fewer toxic waste.

In absolute figures, if we plan to achieve energy supply exclusively on alternative energy plants, we should completely change the structure of our power plants, i.e. build millions of photovoltaic systems on our roofs, millions of wind turbines, a lot of turbines powered by ocean waves and tide, thousands of hydropower plants, etc. This is an exclusively large and expensive investment, even for the richest world economies [12].

So, forget even the notion of renewable energy - the way how they are presented today. The truth is that none of today's energies is completely renewable. The modern technology is still far from having an energy that is completely clean and recyclable. We are ready to proclaim such a source as a real wonder.

THE RESPONSIBLE CONSUMER AS THE CORE OF THE SOLUTION

So let us get rid of the wide spread illusions and look straight in the center of truth. No alternative energy source is today available that could satisfy mankind's energy needs in future. The only realistic solution is in our hands. We must reduce our per capita energy consumption to a level that will comply with recent energy resources. Furthermore, we have to accept the reality that tomorrow practically all the world regions will enjoy equally the benefits of modern life, and that the man of tomorrow also deserves his portion of world's energy reserves. Our primary assignment is to lower the *per capita* energy consumption. If we fail in doing this, the amount of needed energy will be so enormous, that the renewable energies could satisfy only a tiny part of it and will be positioned at the lowest position in tomorrow's energy balance sheet.

The world, especially the countries with developed economies, is now far from the idea of lowering the individual energy consumption. This means that the problem of providing sufficient energy, at least in the next 20 or 40 years is open and terrifying.

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IZVOD

KAKO POSTIĆI ODRŽIVOST U SNABDEVANJU ENERGIJOM ?

Dat je globalni pregled sadašnjeg stanja snabdevanja energijom, kao i mogućih scenarija kako će se to vršiti ubuduće. Naglašena su dva osnovna fakta koja karakterišu sadašnje stanje problema energije i to: humana populacija, N , na planeti koja je u stalnom porastu, dok ukupna količina sirovina neophodnih za egzistenciju ljudskog roda, RM , raste još bržim tempom. Jednačina $RM = k \cdot H$ prikazuje vezu između ova dva parametra. Nažalost k nije konstanta, kao što bi se očekivalo, već parametar koji raste sa vremenom. To znači da prosečna potrošnja sirovina po čoveku na Zemlji raste iz godine u godinu, iz decenije u deceniju, itd. Ovakav trend je u suprotnosti sa promenom količina zaliha sirovina, kako neobnovljivih, tako i obnovljivih. Dva su uzroka za ovakvo stanje. Prvo, pripadnici potrošačkog društva produžavaju da troše više i više, ne mareći za pozive na racionalno ponašanje. Drugo, pripadnici zemalja koje doživljavaju ekspanziju ekonomije, a dosad su živeli u bedi, ubrzano zadovoljavaju svoje potrebe za bogatijim životom i time doprinose skokovitom rastu iscrpljavanja planetarnih zaliha.

U potrazi za rešenjem nude se različita scenarija, čije su mogućnosti analizirane. Pored već tradicionalnih koncepta štednje i potrošnje bez ograničavanja, koji su ranije bili predlagani i provereni, kritički se analizira savremeni trend glorifikovanja obnovljivih izvora energije. Ukazano je da obnovljivi izvori energije kao što su fotonaponska konverzija, biomasa, veštačka fotosinteza, energija vetra i okeana, kao i klasične hidroelektrane, poseduju nedostatke i da nisu tako zeleno i univerzalno rešenje, kao što nam se prikazuju. Svaka ima neki nedostatak, kao što je neumerena količina potrošenih sirovina i odgovarajuća emisija staklenih gasova tokom gradnje tih elektrana, visoke cene, ograničenog veka trajanja i druge loše osobine.

Kao rezultat analize zaključeno je da zasada ne raspoložemo energijom koja je potpuno ili bar prihvatljivo obnovljiva. U sektoru energetike ne postoji kompletno čista i reciklirajuća tehnologija. Takav izum biće dočekan kao istinito čudo.

Za sada nemamo izvor energije koji bi mogao da podmiri potrebe za energijom ubuduće. Zato je i jedinstveno rešenje da se potrošnja energije per capita smanji do nivoa u skladu sa sadašnjim zalihama energenasa. Kada svi regioni sveta počnu da uživaju blagodete modernog života, biće potrebno toliko mnogo energije, da će mogućnosti obnovljivih energija predstavljati samo neznatni deo u bilansu energija. Zastašujuće je da smo danas daleko i od pomisli da smanjimo potrošnju energije. Ovo se posebno odnosi na stanovništvo ekonomski razvijenih zemalja. Konačno, problem snabdevanja dovoljnom količine energije je daleko od svog rešenja.

Ključne reči: snabdevanje energijom, sirovine, obnovljive energije, globalne navike, iluzije

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