9.3 Considerations about energy.

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Abstract.

As in any branch also in nuclear reactors there are attempts to forecast future as from the technology point of view so from the amount and economic effectiveness of planned capacities.

It is frequently forgotten that electricity and maybe further products from nuclear energy cannot be easy stored and that there is strong feedback among overall economy and energy in its different forms and general decrease of production leads to the decrease of electricity (oil, gas) use and even to the greater decrease of its prices. This altogether is leading to the demand of deeper understanding of the energy flow, including cross-frontier trade and supply and R&D planning including very long time intervals to keep industry and life standard, which may need new technology development and bringing to the functioning new industry branches. There are described various aspects of the problem and possible conclusions for us in the situation of growing public demands and decreasing raw material base.

Material is based on works and presentations from the INPRO collaborative project RMI "Meeting energy needs in the period of raw materials insufficiency during the 21st century" and older works.

Let us start from the historical review of works, concerning profile of energy used from different raw materials during the mostly last two centuries [1]. Starting from wood energy was used also from coal, gas and oil. Doing statistical analyzes of historical data you can derive following curves.

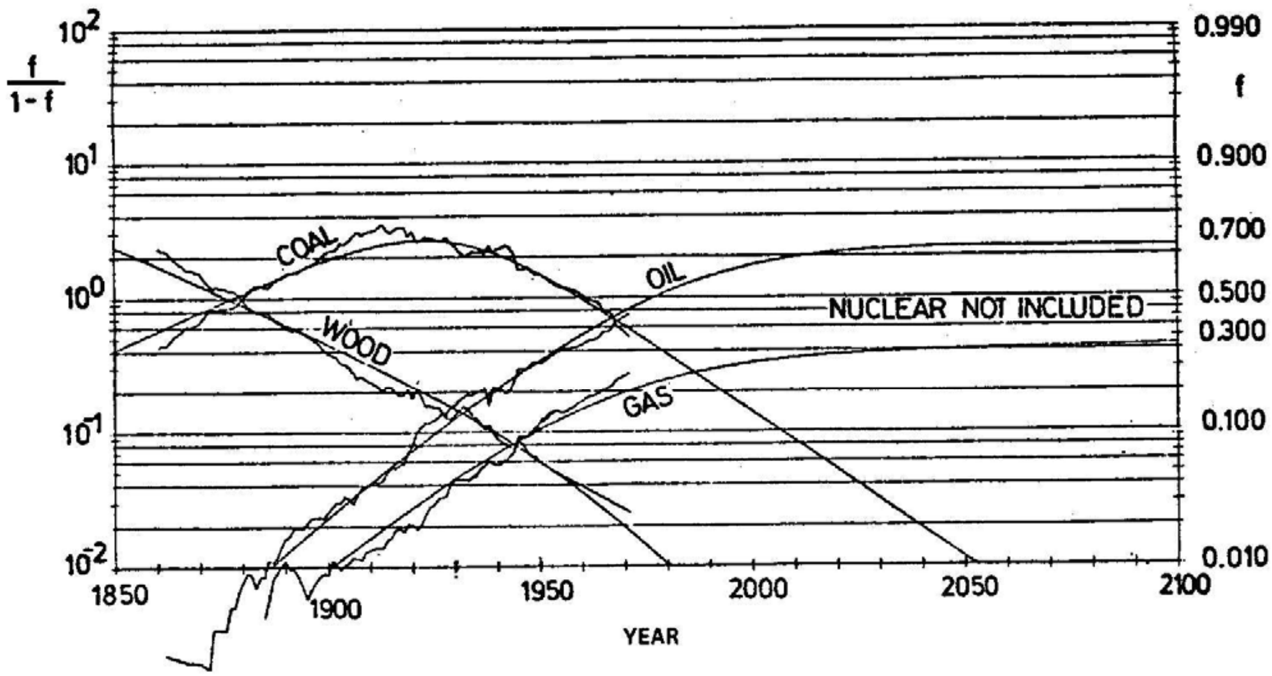
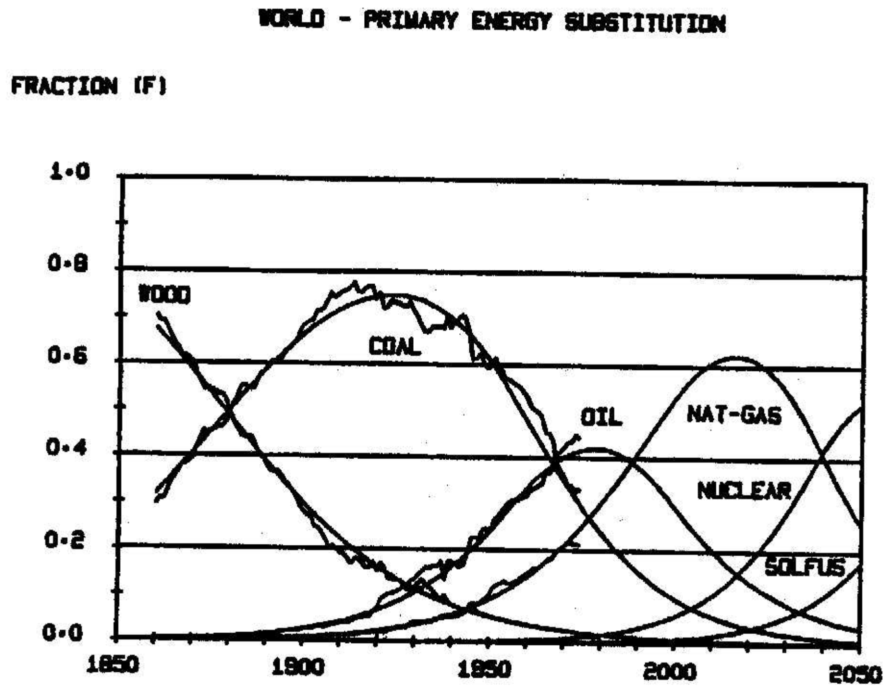


Figure 8. World energy data and fit to substitution model. Only data from time period 1930-1950 used for parameter estimation.

where ***f*** is relative market share of the given technology.

Sum of the all technologies (wood + coal + oil + gas = 1) is one. The approach was further developed and tested curves are from the book [1], where is also described economical explanation based on considerations about market and how new and better production can entering into it. Two component market was generalized for the energy interpretation to the several component market. There are also something like balance equation from which you can have analytical expressions. Natural condition is statistically independent behavior of component. This is not fully fulfilled for the nuclear energy entering the market in the last several decades. There were too many public and political influences, so that it is not quite clear how to prepare independent data. During the studied data there were practical no influences from the decreasing of material reserves and raw materials for energy were practically infinite (decisive were using and transportability) and conditions on the market were changing smoothly. The only exception was so called oil crises started in October 1973, but it was relatively short period of several months. Stormy development of nuclear energy was one of the consequences.

It could be of interest also next form of the former graph, containing also already 30 years old views on the technology development.



Here the contributions of the various primary sources are shown as fractions of the total market. The smooth curves are two-parameter logistics assembled in a system of equations as described in the text. *The fitting appears perfect for historical data.*

Prolonging of the graph was possible due to analytic form of dependence. There was huge idealism, at that times (around 1980), about the technology development. It is remarkable that oil was expected to reach maximum of mining before 2000. Simple imaginings about energy dependences was definitely broken after 1990, when developing countries rapidly entered the world market.

If you thoroughly look on the graph you can see that there are no abnormalities there, as if there were no crisis during the studied periods. This is due to relative norm of energy – if activity is smaller also energy needs are smaller and relative profile is kept. Really absolute industry production was much smaller and as a consequence absolute energy needs and production was correspondingly lower. During oil crisis 1973 problem was different – only oil was in short supply, but probably due to short time several months it was out of attention to try to find how decrease of oil supply will influence shortages in transport and as a final consequence shortages in industry production and lower GDP. At that time there were drastic limitations – private cars were not allowed in the given days to go on the streets etc., there were main streets from western cities shown in television practically without any cars on the places of former traffic jams. It is a strange that there is no influence on the production evaluated. On the other side oil embargo was applied only to the so called western countries, so that main influence was only in the part of the world. Contemporary situation is not far from the scarce of oil - there are declarations, that the oil is only question of money, that we have enough oil (IAEA), but if price will be multiplied by two or three (and it already was the case), where is the limit of direct influence of transport limitations and the feedback on GDP? We have now existing experience with so called “financial or hypothec” crisis which has limited production and as a consequence also needs for raw materials including oil – and amount of oil on the market is sufficient in the prices of about 80$ and slightly growing due to industry growing production and vast increase in development countries, which are taking ready technologies and want to bring their population to the same standard of living as the developed countries. Some attempts to catch it and interpret world as two-component economy are in the work [2]. Energy needs are proportional to GDP growing, which is now in the developed world more or less stagnating and in the developing countries like China and India is nearly 10%.

We shall try in the next part formulate out main questions – how will develop nuclear energy and if nuclear energy development could be studied without other energy resources. We need also more understand local energy planning in smaller countries and which outer information we need. For the future covering of our needs we also need answer on the technological questions – have we in our disposal all technologies needed for successful development or in which time we can have them.

Limits of energy raw materials.

Maybe there are also other works, but we shall follow Russian analyses done in RRC “Kurchatov institute”. Data about energy resources concerning fossil materials are more or less known. There were repeatedly analyzed based on the fitting of the balance equations and yearly published data about extracting, specially, oil and gas are not published and represent knowledge and companies secrets. Such a way you can have time dependent curves of oil and gas pumping and supplies. World is subdivided into several regions and after fitting old data through coefficients dependent on investments you combine world data. Concerning oil market price already reached nearly 150 USD and than suddenly fallen down, when also the whole world GDP has fallen down due to the last crisis. It is over our study this global market features, for us is serious that also need for oil and transport has fallen down and as a consequence price of oil fallen down to about 25% and from that time it is smoothly growing to the existing 50% of that maximum price. Prognosis done in the Russian works obtained maximum of the world oil supply about 2015 and decrease slightly more than 1% among 2020 – 2030. The same result was reached from Czech analyzes using US data about maximum of the world Hubert oil curve, but result was obtained through the very much simplified way. There is no serious approach to estimate consequences of such development – there are only naïve “green” ideas use wind and sun to produce electricity and savings and believe that it can save us.

Much better looks the situation with gas, which is more or less sufficient for this century. World curves could be also taken from Russian works published within IAEA INPRO. But there are some complications to use it – the greatest gas deposits are in the solid form under low temperature and pressure, and such solid, cristallic methane can suddenly under different conditions expand about more than 150 times greater volume and explode – corresponding mining technology is not yet ready.

As conditions for mining oil and gas are getting to be more complicated and also prices will be higher. Argument is also the last accident in the Mexico gulf and consequences on the US coast there.

Problem is how to digitalize such quantitative considerations and how to estimate corresponding influence to the world and local GDP. It should also underlined, that mutual energy resource connections can lead to the feedbacks which are completely unknown.

Situation looks better with coal, but only in the world measure. Coal is local source and its transport for the long distances is too expensive – here is Russia good example, having coal in the very east regions and being scarce of it in the western part and as a consequence using gas and nuclear there. But anyway it is supposed that there is plenty of coal up to about 200 years.

Quite different is the situation with nuclear. At first nuclear development could be hardly denoted as statistical process and that is why it will probably not be possible to include it into the old energy raw materials considerations with wood, coal, oil and gas. There are also technological aspects – contemporary reactors can use enriched uranium as the main energy resource and with such fuel and existing lifetime (up to 100 years) we need to use fast breeding starting from approximately 2050. The upper limit of this technology could be prolonged using MOX fuel with plutonium from the burned fuel – it is not very recommendable operation; destroying the only resource of fuel for fast breeders. Some prolongation we can expect also from using uranium from low content uranium deposits. But some declarations, that we can mine uranium from sea water are fairy tales – to reach yearly production we need to process so much water, which is comparable with the year income. So that it is the only way to start fast breeders, close fuel cycle with actinides maybe also to use thorium, which is about more than four times more frequent in the earth crust comparing with uranium. This is taking into account contemporary knowledge and experience possibility to multiply uranium resources about 200 times and with thorium to come to approximately 1000 years raw material resources. This is time interval out of any contemporary considerations and people mankind societies, which can also generate another human philosophy and population density.

As a summary we can conclude that earth has time about ten years to find support for the oil and transport market – the only bigger reserves are in nuclear and partially in coal.

Technology needs and time.

Mostly we need electricity and from this point of view there are no principal objections to go forward, even fast breeders have now enough experiences to start industrial period. We can also expect that reprocessing of spent fuel will be enlarged and that dry technologies and electrochemical separations will come from laboratories to the workshops and industry.

Reprocessed fuel is no more waste but set of materials with different lifetimes and radioactivity – actinides are the same source of fission energy as enriched uranium and must be used for the aim – produce temperature and electricity and give as a result the same fission products, but already without actinides. Fission products after some time will consist of radioactive elements strontium and cesium with half-lifetime about thirty years (after three hundred years activity will be about 1% and we can store it we will not find direct use) long live fission products like technetium and iodine are week beta active and their danger is very small and how much they can be harmful is under question mark. New reprocessing methods are not conditions for future works; we expect simplified, cleaner and cheaper work. Problem for future will be capacities, because all fuel for the new fast breeders will have to be reprocessed.

Even if electricity covering for the coming century has probably no problems, it is only a part of the demands. All transport (with very limited part on the electrical railways) is dependent on oil supply. Contemporary attempts to declare electromobils as ready thing maybe may be used to movement on golf grass but not to drive trucks at lest in the next decades – moreover cars are huge market and it was estimated in the US transport study that to modify it at least from one third will need ten years and also huge money and as the only way out was recommended to support liquid fuel market. There are also some suggestion and attempts to drive cars directly by hydrogen – it was realized, but effectiveness is small because you at first produce electricity from hydrogen cells and than drive car by this electricity. It is necessary to understand that we are speaking about the amount of energy equivalent at least to the 10 – 20 % of the existing oil supply and in the future even more. All such consideration is leading to the same conclusion – support existing liquid fuel market and for future try somehow develop new engine directly for hydrogen or for something produced externally to keep existing roads and cities and villages.

The only resource is nuclear and technology of water splitting. More or less known are heavy oil resources from oil shells and sands which, using hydrogen could be transformed into the liquid fuel and using coal and hydrogen from water we can produce standard liquid fuel. It is (without nuclear hydrogen) known procedure for example applied in greater amount in Czech chemical companies during the second word war to have fuel for German troops, Contemporary production is in operation in South Africa. Process produce great amount of CO_2 and is generally not recommended. Use of “nuclear” hydrogen is without such complications. Problem is that to start catalytic water splitting we need temperature about 850^oC and due to possibility of hydrogen to be explosive, save distance of chemical workshop from the reactor – distance estimated up to several hundred meters and maybe kilometer.

The very first idea is use of already tested pebble bed reactor cooled by helium. But deeper study is showing (see GIF) that helium has too low specific heat and cannot construct such heat exchanger for the heat transport from the reactor to the chemical workshop. It is about ten years known idea, erased probably in ORNL, to cool high temperature reactor by fluoride molten salts as analogy of original ORNL molten salt reactor in which uranium salt was diluted in the mixture of $LiF+ BeF_2$. Use of solid fuel is surely simpler idea than homogenous fuel mixture, which needs continues use of chemical reprocessing.

There is at first thorough description of such new type of semi-molten salt reactor in the GIF materials, together with the effectiveness of potential electricity production and rough comparison of prices comparison declaring that high temperature reactor cooled by molten salt should be from 30 – 50 % cheaper than helium cooled ones, which is comparable with already classical water cooled reactor with solid fuel -so high effectiveness is reached due to greater temperatures.

Concerning hydrogen production there are long time attempts, started from the period after the first oil crisis, when was recommended more than hundred chemical ways. It seems that now in greater amount it is studied only in US laboratories and yearly published documentation on www.doe.gov pages is about two thousand of standard paper pages with the sequence of concise summaries. Several processes are studied, ways to store hydrogen, material problems, distribution, etc. Year information is subdivided into the short files corresponding works on one place (up to about eight pages) and all together about several hundred files, which must be rearranged by higher versions Acrobat writer software, full one year file of reporting post more than 100MB. We do not know about any analogy of such works in EU, Russia or anywhere. We can only learn it and maybe try to join it, if being admitted.

Conclusion is that the best way should be so called sulfur iodine cycle. Basic environment is diluted sulfur acid. Process is fully closed and, specially, it does not produce any CO_2. Result is pure hydrogen and oxygen. Details are described in US public available materials.

It should be also commented sequence of steps and their possibility to expected energy needs. Following US GIF materials it is expected to have first of a kind (FOAK) realization (HTR cooled by MS) about 2025. But FOAK is not yet industry – it needs several years to collect industrial experience and maybe start of more massive investment, which can influence world or at least local energy balance. Effects on GDP cannot be expected sooner than 2030. This will be already period, when by existing estimations there will be lack of about ten percent of oil. It is also not yet clear what will be the future price of artificial liquid fuel using “nuclear” hydrogen and how to compare it with future potential losses due to lack of transport. This is, by my view, key question and it should be estimated including feedbacks in the not yet done economic analyses.

Maybe it not ideal way to produce additional liquid fuel to support transport vehicle, but up to now we do not know another way having sufficiently great raw material reserves. it will show us future and feedback of expensive transport to GDP growths or decrease.

It should be also noted that HTR, producing hydrogen in the described technology is not long time sustainable, because it is thermal reactor with enriched uranium, but technology modification is not complicated to have faster spectra or directly full molten salt reactor with any liquid nuclear fuel.

Author understands that such texts are no mathematical forecast, but hope that it can help to show complexity of such mixed technological, economical and sociological problems, which are over the forces of small countries but maybe can initiate broader common works.

Literature was prepared as a separate CD altogether about 603MB and will be given to the symposium organizers and AER Scientific Council.

Literature.

[1] Haefele W., Anderer J., McDonald A., Nakicenovic N.: Energy in a Finite World – Paths to a Sustainable Future, International Institute for Applied Systems Analysis, Cambridge, 1981