Implementation of thermonuclear fusion platforms as the foundation of energy efficiency for the global social and economic sustainable development

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Abstract. This article gives an overview of the state and private projects in such domains as promising technologies of the controlled thermonuclear fusion. Topical energy and economic issues (uncertainties) and threats have been studied, including the requirements applied to existing and future energy economics in order to achieve energy efficiency and sustainable global development. Results of the research of multiple international and private projects dedicated to nuclear power show their inner correlations and scopes of application. The article also aims to confirm the idea that state and corporate support of innovative energy startups is much more efficient than the monopolization and direct administration of the energy domain. Additionally, it shows that trending information technologies have laid the foundation for the development and implementation of controlled thermonuclear fusion, which in future will become a source of energy compatible with all requirements of global development. And those innovative technologies will support a long-term sustainable development of international innovative network economies.

1. Introduction
The existing social and economic system is only possible due to the achievements in the energy domain. Power supply and its efficiency are crucial both to sustain the achieved results, and to continue further development in its broad sense. Implementation and development of innovations, scientific and technical, social and economic progress demand sufficient technological level in the energy domains as one of several mandatory conditions.

In compliance with the estimates of the potential input from the energy systems into the Agenda for sustainable development, adopted by the UN in 2015 [1], and in addition – the requirements of post-industrial economy, modern and propitious energy technologies should:

- be compatible with higher safety standards;
- be flexible and adapt to the changes in energy consumption rates (including sharp load fluctuations);
- facilitate the reduction and minimize the environmental and climate footprint;
- be economically efficient and readily available to the consumer.

Unfortunately, both “traditional” and modern technologies of energy production to some extent all fail to meet the abovenamed requirements. As a result, much is expected from a number of auspicious technologies associated, first of all, with the issues of the controlled thermonuclear fusion. This
domain of research recently has been heavily invested both by state governments and private sector startups. With this research paper we aim to show the ways how thermonuclear fusion technologies can be implemented to achieve global sustainable development of the mankind; their advantages and methods of implementation, as well as successful operation by means of artificial intelligence, as only one of the examples.

2. Uncertainty and prospects in global energy production

In order to achieve sustainable energy consumption and its further growth in the conditions of physical and social restrictions (including environmental concerns) a development and implementation of the new sources of energy is required. At the same time, at any given moment in time the prospects of sustainable development of energy systems depend on a number of objective and subjective factors, including energy prices volatility on global markets, the state of research and development progress, political, social and macroeconomic environment on the level of countries and macroregions of the world. The majority of these factors suffer from a higher degree of uncertainty [2], which makes businessmen, politicians and researchers analyze the current situation, find and isolate the tendencies, predict and anticipate future changes in an attempt to prepare for the introduction of new technologies and exploration of new markets.

At the present time, according to the established opinion shared by a number of researchers, the highest potential among all promising technologies of energy production in the sustainable energy domain belongs to the controlled thermonuclear fusion [2] (hereafter – CTF). The research in this field of knowledge is quite active, despite the fact that its commercial use can only be expected in the medium- or rather long-term planning. It is also worth noting that the scale and financial expenses of the required scientific research are massive, and nevertheless this work is done both on state and corporate levels (energy innovation startups).

On top of that, there are other promising technologies of energy production from a number of alternative, renewable and practically “unlimited” sources, including water (tides and geothermal heat), wind (wind turbines), sun light (solar energy) and biomass (bioenergy, i.e. production of energy from bio products by means of combustion or fermentation, extraction of spirits and gases) [3]. All of these energy sources have certain technical, geographical and other restrictions, which limit their ability to replace global consumption of coal, oil, gas, hydroelectric and nuclear power plants. If the CTF technology succeeds, these sources will forever remain local alternative energy sources.

Finally, to complete the picture we would like to add that since the CTF has been at the research stage so far, the improvement of “traditional” methods of energy production, construction and technical upgrade of hydroelectrical power plants, as well as the development of nuclear energy based on nuclear fission (nuclear power plants, NPP) is still important. In all of these areas the Russian Federation has significant achievements on global level.

Yet, the countries currently concentrating on fossil fuels (production and export) at the expense of sustainable energy sources (nuclear and alternative energy) and trending technological research and development are in the risk group. With the development of alternative energy production and the CTF the demand for “traditional” energy supply will critically drop down. It is also possible that the decrease in the demand for nuclear energy will follow immediately or in the near future. This drop will also eliminate the financial funds required for the implementation of new energy sources, unless this issue is handled with due attention.

The Russian Federation is among those countries in the risk group, which face the potential threat of using decades-old technically outdated energy industries in the mid-term planning. Research shows that revolutionary changes to global energy markets can lead the economy of those countries to degradation in an instant; Russia, to be exact, might repeat its own history of the first half of the 19th century, when the invention of a steam engine depreciated Russian “strategic reserves” of shipbuilding timber [4].

To conclude our sketchy review of the global energy tendencies and threats for the countries which do not invest enough in the research and development of the innovative energy projects, we would like
to add a few words about nuclear energy. Nowadays the technology itself and construction of nuclear power plants is not something of a breakthrough or innovation, to the contrary – these technologies have become quite common long time ago. The nuclear industry is sometimes referred to as “traditional” along with wood, coal, oil and gas energy sources, in contrast with “alternative” sustainable energy. The time will pass and modern energy sources will in their turn be replaced by some accumulation of thermonuclear or other new, “alternative” methods of energy generation. In this respect the following theoretical analogy can be proposed: if nuclear energy and nuclear power plants are a “steam boiler”, then the CTF is an “internal combustion engine”, in other words, a quality step forward in the energy (economic) efficiency.

Next, we will study the main state and private sector projects dedicated to the CTF technology development, with the common goal of search for answers to global energy challenges, including access to modern, cheap, reliable and sustainable energy, growth of energy efficiency on a global scale.

3. State and international CTF projects
Thermonuclear energy is currently in the field of interest of all the countries claiming to take the lead in global economy. The research has started in the US, European countries, and of course in China. Russia, along with other developed countries, tries to conduct its own research, as well as take part in the international CTF projects.

In this regard the biggest collaboration is of special interest – International Thermonuclear Experimental Reactor, ITER. Its theoretical planning started back in the 80s of the 20th century in the USSR, the USA and France, while actual construction took place only thirty years later in 2010 in France [5].

According to the available publications in academic literature, recent decades showed a noticeable progress in the implementation of the CTF concept, primarily based on the use of tokamaks – magnetic confinement devices [6]. It took joint efforts from the European Union, Japan, the USA, Russia, India, China and Korea (participants of the ITER project) and their consolidated financial and intellectual resources in order to achieve success on the next level. The project in its turn is based on the “multiyear research of a magnetic thermal insulation for the hot plasma with the preservation of thermonuclear fusion reaction in steady state” [6].

The scale and complexity of the ITER project were the reason why it not only remained at the stage of theoretical planning for decades, but also significantly extended its deadlines and budget at the stage of construction. According to the accessible information at the moment, the budget of this project has grown to 19 billion Euros, and the deadline for facility construction has been shifted from the initial 2016 to 2025. Nevertheless, this project must be completed, because it is crucially important for the fundamental research in thermonuclear physics. To be specific, ITER will allow us to estimate economic efficiency and reliability of the CTF technologies which, if successful, could be applied in the next generation power plants.

In general, state and international projects aim to achieve and confirm the results of fundamental scientific research, put to test scientific theories and concepts. The results of fundamental research funded by the state budget also prepare the ground for private initiatives – energy startups including the CTF. Obviously, the discussion concerns introduction of a method that would facilitate the commercial implementation of fundamental research in those countries where private sector initiative is rewarded, and innovative entrepreneurs have the creative, scientific and financial freedom to fulfill the interests of the society.

4. Privately funded projects in the CTF domain
The USA (and its close neighbour Canada) is the leading country where state and corporate companies encourage transition of fundamental research results to private innovative startups and that way stimulate innovation. It is no accident that Microsoft, Apple, Tesla and other landmark companies emerged in the US. And it is only natural that all private CTF projects that draw public and academic
attention also turned up in the North America. We are speaking of these companies – thermonuclear fusion startups:

- General Fusion (Canada);
- Helion Energy, Inc. (USA);
- Lockheed Martin Corporation (USA);
- Tri Alpha Energy (TAE Technologies, USA).

The abovementioned companies conduct a number of physical processes research and find technological solutions for the CTF, publishing some of the achieved results in the open sources with free access. Both startup enterprises and industrial “veterans”, including Lockheed Martin apply for financial support from the state government and corporate investment funds, use access to NASA technical and research database, and can also attract private investors and conduct private research and development. In other words, in the US and Canada private companies (entrepreneurs) have the opportunities to design, build and test private thermonuclear plants. This is not only impossible in Russia, but even in the EU countries as well.

General idea of the private research companies is to create a compact thermonuclear reactor, with the dimensions which make it possible to place it inside a standard shipping container. We are speaking about a compact, and at some point, a mobile reactor, which can be shipped to any destination on Earth. In near future we can see construction of relatively compact and safe thermonuclear reactors, capable to supply with energy cities and rural areas, including remote locations where the demand for energy resources is especially high.

5. Modern technologies and the CTF

In case of a successful development of the fundamental and applied technologies in the CTF domain, construction of several thermonuclear reactors (where they are needed) is expected to become a reality. This trend will boost the post-industrial and future economies, partially due to the fact that the reactors based on thermonuclear fusion will meet the requirements listed in the beginning of this article. This needs a detailed explanation:

1) Safety – will be achieved almost “automatically”, since a thermonuclear reaction requires uninterrupted preservation, and once stopped, it will only last a few minutes, and then the reactor will shut down.

2) Flexibility. Compact thermonuclear plants can be built in the city suburbs, on the outskirts, etc., united by a single “smart” power network (“smart grid” concept) controlled by the artificial intelligence. The AI, if necessary, will be able to schedule the operation of a network with hundreds and thousands of reactors, taking into account daily and seasonal energy consumption fluctuations, and reserve power supplies to provide energy, if needed in case of failures and force majeure situations.

3) Reduction and minimization of environmental footprint. The CTF does not rely on the combustion of wood, coal or hydrocarbons, i.e. it produces zero emissions. The CTF is also free from radiation footprint (although this issue will have to be settled); nuclear accidents similar to Chernobyl and Fukushima with the subsequent massive environmental pollution are absolutely not possible thanks to fundamental differences between these two nuclear technologies.

4) Economic efficiency and hence availability for the consumer from the very beginning has been prioritized in the economic model for its commercial implementation. Otherwise this technology will remain a theoretical model without any practical application.

It is worth noting that the AI technologies are to be used not only for the management of energy distribution from the thermonuclear power plants to the consumers, but also for the precision control
of magnetic fields, confining plasma inside the fusion reactor. The AI will manage a list of certain parameters depending on the type of the implemented CTF technology.

A number of the CTF startups suggest using modern laser technology to conduct the fusion reaction. In general, it is clear that the CTF accumulates all readily available and future technologies from different domains of knowledge, starting with mathematics and IT, and finishing with physics, chemistry and ecology.

6. Conclusion

The future of world economy and human society directly depends on the success of energy projects. Implementation of the “alternative” energy sources and the CTF technologies will help humanity enter a new level of social and economic relations, improve the rate and efficiency of innovations application, development of the network, post-industrial economy and following it social, technological and economic establishments and principles.

The foundation for the successful study and implementation of the thermonuclear energy has been already laid by the achievements of fundamental science and development of information technologies, including the AI, digital networks and much more. Obviously, we are on the brink of the next revolution in the energy domain, which logically follows recent information and communication breakthroughs. At the same time, the countries that want to keep their avant-garde positions in science, technology and resulting social and economic progress, need to invest now in the development and testing of new energy technologies, instead of blindly relying on “traditional” and common economic models. Current state of affairs is no secret in the North America, Europe and some advanced Asian countries; it is also evident for the Russian government (at least it might seem so from the official statements), but only time will tell, if this understanding will be converted to actual achievements in sustainable innovative development.

7. References

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