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LOW-CARBON ECONOMY: MODERN VIEW ON ENERGY CONCEPT OF SERHIY PODOLYNSKY

The article focuses on expediency of transformation of humanity to the paradigm of the low-carbon economy as a result of restrictions or unavailability of carbohydrates, the ongoing global energy and environmental crisis. In this context, the energy concept of an outstanding thinker of the XIXth century Serhiy Podolynsky, a scientist who was ahead of his time, is relevant in modern times.

It has been established that S. Podolynsky focused his attention on four issues: nature of energy, its movement and transformation; consideration of fossil fuels and efficiency of their use in the conditions prevailing at that time; studying energy as a major factor in agriculture; essence of human labour as a means of energy storage.

In his fundamental work, S. Podolynsky draws attention to a need to increase efficiency of the basic fuels at that time - coal and wood, as for getting the later leads to deforestation resulting in environmental degradation. History has confirmed expediency of the major part of Serhiy Podolynsky's ideas, particularly, ecosafety and cost-effective energy production using solar energy, wind energy, hydro energy of small rivers, geothermal energy, plant and animal waste, biofuels, etc., which are the basis of modern concepts of low-carbon economy.

Introduction. Energy is usually called a queen of the world. Due to existence of the energy conservation law, the category of "energy" binds together all natural phenomena. Physical increasing of energy amounts used by mankind has been an important precondition for economic, scientific and technological progress for a long time.

Over the past two centuries, qualitative changes have taken place in various branches of energy production accompanied by alternating jumps and evolution: the steam engine - internal combustion engine – electric motor. This has determined the growth of rates of replacement of manual labour with machine one. Obviously, energy-saving of manual labour is directly dependent on the level of mechanical engineering development and rates of growth of energy availability per worker.

A universal historical trend is a relative decline in the use of directly available natural potential, particularly hydrocarbons. However, the type of scientific and technological progress focused on permanent increase in production of fossil energy resources is limited in volume, accessibility and quality of their reserves.

Restrictions or unavailability of natural resources, including hydrocarbons, permanent global energy and environmental crisis of the late XX - early XIX century have led to an objective need for reorientation of material production to an energy-saving type, transition to the low-carbon development paradigm.

Review of researches. Numerous scientific publications of researchers released recently have been devoted to the problems of the low-carbon economy. In particular, development of the low-carbon economy in G20 countries has been highlighted in the article by He Ge [He 2012], prospects and opportunities for further spread of the low-carbon economy in the regions of Ukraine have been considered in details in the scientific paper [Shevtsov, Barannik, Zemlianyi, Riauzova 2013].

The monograph by I. Haidutsky [Haidutsky 2014] has been devoted to theoretical, methodological and practical aspects of investing in the low-carbon economy, the article by N. Karaieva and N. Bereznytska [Karaieva, Bereznytska 2014] has been devoted to use of expert methods to support the low-carbon strategy for economic development. The above-mentioned set of problems has been studied in numerous books and articles by scientists from leading universities of Poland [Lis, Mazurkiewicz, Pająk 2015, pp. 181-202; Pająk, Dahlke, Kvilinskyi 2016, pp. 109-122; Pająk, Mazurkiewicz 2015], other European countries, discussed at scientific conferences.

In this context, the energy concept of an outstanding thinker of the XIXth century Serhiy Podolynsky (1850-1891) attracts our attention. The French scientist Debirre named Serhiy Podolynsky an author of one of the newest theories of thermodynamics. A famous Belgian explorer and Nobel laureate Illia Prigozhin pointed out that his discovery had been prompted by this precisely concept by Serhiy Podolynsky. Developing his ideas, Volodymyr Vernadsky, Konstiantyn Tsiolkovsky and others created the theory of the noosphere. In particular, V. Vernadsky called S. Podolynsky a scientist who was ahead of his time: "we find short but absolutely clear instructions, opinions and facts about energy difference between of the living from the dead - already in the writings of the founders of thermodynamics - R. Mayer, W. Thomson (Lord Kelvin), H. Helmholtz. These instructions had been neither understood nor appreciated. Later and independently, the predeceased S. Podolynsky understood all the importance of these ideas and tried to adapt them to study economic phenomena" [Vernadsky 1954; Vernadsky 1991].

According to V. Shevchuk, S. Podolynsky formed principles of the essential economic paradigm, the fundamental nature of which is to open sources of economic life and social progress. He demonstrated that solar energy is such a source [Shevchuk 2002].

Podolynsky S. is considered a founder of the school of physical economy, promoter of the energy approach to human capital [Zlupko 2000; Maksymenko 1995; Rudenko 1998; Shevchuk 2005].

As L. Vorobyova points out [Vorobyova, 2008]:

1) S. Podolynsky created an original doctrine which surpassed the previous achievements of economics and laid the foundation for a new school - physical economics. If physiocrats borrowed from William Petty one part of his definition of value (i.e. land) and Adam Smith and David Ricardo – the other (i.e. labour), S. Podolynsky combined them. He stated that not only land and labour but also solar energy, which is largely accumulated on the Earth through human labour, are a source of value;

2) S. Podolynsky developed a new paradigm of civilizational development. He relates the progress of society with increasing energy budget of every person and mankind as a whole, with energy saving and accumulation. Energy saving and accumulation occur due to conscious, creative human labour;

3) S. Podolynsky gave a new natural scientific definition of labour. He was the first in the world of science who linked the concept of "labour" and "development" with an increase of free energy flows. The scientist first proved that with his labour, a human being is able to increase accumulation of solar energy on the Earth and reduce its dissipation in the universe;

4) S. Podolynsky laid the foundation of an integrated system of "nature - society - human being".

Modern scientists think that S. Podolynsky's discoveries are outstanding discoveries for all the mankind's science and call them "Podolynsky's law" [Kuznetsov 2003]. The study guide prepared and published by O. Kuznetsov and B. Bolshakov [Kuznetsov, Bolshakov 2002] has been based on the thinker's ideas.

Serhiy Podolynsky was born in Kyiv province of what was then the Russian Empire (now Cherkasy region, Ukraine) in a noble family: his father Andrii Ivanovych was a civil servant, famous poet; his mother Mariia Serhiiivna had Polish and French roots (she was Count Octaviy Choiseul-Hufye's granddaughter and Count Stanisław Szczęsny Potocki's great-granddaughter).

Podolynsky S. graduated from the Natural Department of the Physics and Mathematics School of St. Volodymyr Imperial University (the city of Kyiv) with honours (a gold medal), continued his studies at medical departments in Paris and Zurich. In Breslau (now Wroclaw), he worked at Rudolf Heidenhain's laboratory where in 1876, he presented his doctoral thesis in medicine. After that, he passed an appropriate examination at the Medical Department of the University in Kyiv (because foreign diplomas were not recognized in Russia according to the decree of 1873) and got "a doctor degree".

Podolynsky S. started publishing his works at 23. Articles about development of the labour movement, an issue of health of the rural population, philosophical and economic works were issued from his pen. In 1877, he emigrated to France and settled in Montpellier and in 1880, he published his work "Human Labour and Saving Energy" in the journal "Slovo" (Word) [Podolynsky 1880], which was also published in France, Italy and Germany.

Nowadays, this most important Podolynsky's work has been reprinted in Montreal [Podolynsky 1990], Moscow [Podolynsky, 1991], Kyiv [Podolynsky, 2000]. He was elected a member of the French Society of Science Development.

Setting objectives. In our opinion, nowadays, considering a number of environmental issues of power engineering, researches related to ecologization of energy production are important because we do not have scientists' well-established views on the energy strategy, in particular expediency of nuclear power plants, development of alternative ecological safe energy sources. Studying S. Podolynsky's scientific heritage allows to take into consideration his methods of approach to the energy concept based on the paradigm of low-carbon economy. Considering the mentioned above, we have attempted to analyze Serhiy Podolynsky's views on four issues (energy, its motion and transformation; fossil fuels and efficiency of their use; energy as a main factor in crop and livestock production; human labour as a means of energy accumulation), their relevance to modern conditions of global development.

Results of the research. Energy, its motion and transformation. In their time, scientists believed that energy was the sum of all natural forces contained in the system of bodies and could be in the form of seven different physical forces: heat, light, electricity, magnetism, chemical affinity, partial forces and universal gravitation. Guided by the scientific researches of that time, Serghiy Podolynsky drew his attention to the fact that the total energy of a system, including the universe, has a completely unchanged value, and the energy conservation law is, in fact, no more than a generalization of the long-known law of mechanics.

The researcher divides energy into kinetic and potential: in cases when we have kinetic energy, motion is directly available to our senses (e.g., flowing water, a falling avalanche, working steam engine, shell fired from a cannon, motion of the Moon around the Earth, etc.). Conversely, even though motion of a matter exists in its potential energy, it has not entered into forms accessible to our sense yet, although it can get it under certain circumstances. An avalanche hanging over a cliff, a heated but still not working steam engine, a loaded cannon, human food that has not been converted into a muscle contraction at work yet are examples of potential energy.

He writes that planets and satellites derive energy from stars (the Sun) and this will eventually lead to widespread energy levelling. Transfer of energy is accompanied with transformation of one kind of energy into another. But not all the forms of energy can be equally easily transformed into others. And every time such a transformation takes place, there is a tendency of energy to move, at least, partially, from easy convertible forms (e.g., movement) to a form modified with great difficulties, (e.g., heat). Thus, energy of the Universe is constantly moving from easily convertible forms to more stable ones, therefore its opportunity to transform is constantly decreasing.

Referring to W. Thomson, the scientist concludes: in a long lapse of centuries, all the energy will take a form incapable to transform which will consist

of heat evenly distributed throughout the Universe. In this case, every life and every movement that we feel, obviously, have to stop because we know that it is necessary to have bodies with different temperatures to transform heat into another form of energy. Trend of energy of the Universe to its general balance is called by S. Podolynsky dissipation of energy (entropy) and the energy distribution law is as proven as the energy conservation law.

The researcher points out that energy of the Sun and own energy of the Earth, which gradually decreases, are energy sources on our planet. He analyzes how people use energy produced in the result of rotation of the Earth around the Sun and around its axis by applying it for mills using tidal energy. People also use internal heat of the Earth (hot water sources) for heating homes, cooking. According to S. Podolynsky, economic use of wind, which in fact is nothing more than a result of striving to balance temperatures, is important.

Force of water currents is not disregarded by him. He notes that water falling, for example, to a mill wheel from height provides the percentage of useful work which is not made by a steam or electromagnetic machine, or even a more favorably arranged working animal or human body. That is why it is no accident that the researcher saw the wind and water engines as the best ones, as they are notable for extremely high percentage of provided work because their energy is already in the stage of higher, convertible energy.

The scientist's attention is attracted by invention of the "solar car" - a device that heats water and turns it into steam with special mirrors using sunlight. He believes that in terms of energy conservation, the solar car may be the best machine invented at that time. Any work done by this machine is including an excessive amount of solar energy into mankind's budget without simultaneous dissipation of saved energy as it often happens when a steam engine or domestic animals work. His estimations show that whatever a number of people was on the Earth, all energy needs would be fully met, as not less than one half of horsepower from the accumulated solar energy would be accounted for each person.

The researcher concludes: solar energy obtained by the Earth gradually decreases. Obviously, in order to accumulate convertible energy in conditions of its decrease on the Earth surface and the closest layers beneath it, a process of energy-saving should take place, a process that is opposite to dissipation. It should even be a process of converting sustainable energy (heat) into its highest form, more convertible into mechanical motion, potential or kinetic.

The scientist pointes out that on the Earth, we receive solar energy that is not too much convertible but its form is not stable too much. High temperature, light, chemical rays are all such forms of energy, which, however, with a great loss to dissipation, are still partially transformed on the Earth's surface into more convertible, higher kinds of energy such as mechanical work of a machine, muscle contraction, and, probably, mental activity.

The scientist notes considerable difficulties of transition of lower forms of energy into higher ones. He indicates that known methods by which solar energy

can be converted into mechanical motion are very few, and reserves of convertible energy are not accumulated in the air. This is due to the fact that nature does not have tanks that could be filled by themselves with "condensed" air, energy of which could be consumed to the necessary extent.

According to the scientist, although the total amount of energy received by the Earth surface from the inside and from the Sun gradually decreases, at the same time the total amount of energy accumulated on the Earth surface and available to mankind is gradually increasing. This increase is influenced by human labour and that of workstock.

Organic fuel and efficiency of its use. Serhiy Podolynsky notes that the source for fossil fuels formation (coal, oil, peat) are plants that covered the Earth surface in different periods by means of energy delivered by the Sun. In fact, the energy stored in coal is only saved solar heat.

Considering extraction of coal and peat, the scientist points out that energy contained in coal exceeds energy spent on its extraction in both heat and work in 20 times. But he doubts whether coal extraction and consumption is useful work or whether it is dissipation of energy in space. The researcher is concerned about the fact that deposits of coal and peat being ready stockpiles of solar energy have both been extracted uneconomically and consumed wastefully without returning all the saving of energy that they could give either while heating or machine working.

The scientist is worried with some incorrectness of existing at that time methods of calculating energy efficiency because coal is a deposit of solar energy collected over a long period of time. Utilizing coal in large quantities, we introduce accidentally collected profits of previous years to our budget and conduct a calculation as if we really make ends meet. He believes that use of this kind of fuel would only be effective ("useful labour") if annually we could fix such an amount of solar energy on the Earth surface which is equal to the energy of the extracted coal by means of all the work spent to extract it. The researcher notices that humans look with fair fear at the use of combustible material done on such principles.

The scientist examines effectiveness of technology use, believing that it is not a mechanical tool (working machine) that is it's the main component but an engine. Considering the work of steam engines and other thermal machines, the researcher suggests the following data. First of all, the economic equivalent of almost all the thermal machines is much lower than the economic equivalent of driving force of water and air (no more than 1/6 - 1/5). Secondly, their real industrial equivalent is even less than the theoretical economic equivalent as mostly a part of the heat derived from fuel combustion is absorbed by a steam engine. The scientist believes that the main reason for inefficiency of steam engines is the fact that when we consume coal, loss of energy is always similar to saving, and this makes us fear as we watch the spread of steam engines.

He notes a destructive effect of steam engines in areas with no coal and routes for its transportation (as it was in the areas of sugar industry). And he asks his contemporaries a sharp questions: whether sugar production provided deforestation is energy-saving, i.e. is useful labour, or it is rather dissipation of energy in space, that is ridiculous predation.

Therefore, S. Podolynsky's conclusion is not accidental: if the steam engine is not quite profitable even now, its activities will be not effective at all in some distant future. The scientist realizes that people cannot abandon it now because their needs are growing so fast that they cannot be removed from their satisfaction to save for the future. In addition, consciously or unconsciously, deep down, everybody has a hope that in case of an extreme hardship, there will be a new invention that will save everything or, at least, delay a trouble for an indefinite term.

The researcher believed that until humans find such an engine for their machines which will provide them with energy for a longer time without confusion of rapid depletion, all calculations of an amount of technical work, which are at the disposal of mankind, should be considered erroneous because an amount of energy that supports this work may eventually cease to exist. At the same time, to some extent, he justifies the situation noting that a need for coal is so inevitable and its reserves are so big and an opportunity to have new inventions before their exhaustion is so probable that humans cannot behave differently as did previously, i.e. trying to increase their reserve of unconvertible energy with coal mining whenever possible.

Energy as a main factor in crop and livestock operation. Serhiy Podolynsky concludes that under present conditions, all the people who eat products of plant growing and animal husbandry satisfy their need for food almost exclusively with solar energy introduced in exchange of human labour on the Earth surface because plants mostly keep only solar energy.

So far, as plants have increased and continue to increase a reserve of converted energy on the Earth surface, the scientist believes that plants are the worst enemies of world energy dissipation. In fact, functioning of the mechanism of raising the solar energy from the lower level to the highest one takes place in plants. However, the energy, stored by plants and accumulated inside the Earth, does not result by itself in production of new higher energy.

The researcher notes that since the emergence of mankind, productivity of nutrient material containing a reserve of converted energy on the Earth surface has been increasing. Thus, according to his estimations, in France, each thermal unit applied as human or horse labour to cultivate an artificial meadow produces an excess accumulation of solar heat which equals to 41 thermal units, and cultivation of wheat equals to 22 thermal units. He explains that this excess of energy is derived from labour of humans and workstock.

Considering agriculture as a scope of human labour, the scientist notes that productivity of an acre of land is increased by ten, twenty or more times when a

human being makes it their work. Efficient agriculture is the best use of useful labour, i.e. labour that increases saving of solar energy on the Earth surface.

The researcher describes functioning of agriculture from energy point of view. In particular, he considers a ready energy reserve in the form of seeds and an energy reserve in the form of fertilizer as a precondition that plant life is able to make that significant saving of solar energy which is the immediate goal of agriculture.

But, it is the scientist's opinion that all of the following agricultural works as well as plant products processing do not only retain the converted energy, increase its quantity, which is in exchange on the Earth surface, but rather dissipate energy accumulated in the human body. However, all these expenses are compensated by consumption of the convertible energy reserve accumulated in crop production.

The researcher calculates that to return to humans all the energy spent on plant growing in full, solar energy saving in crop production should not exceed 20 times an amount of human mechanical work spent on plant growing. To the scholar's mind, in plant growing, as in some other fields of material production, the energy conservation law is quite obviously applied.

Considering animal husbandry, the scientist notes that the work on breeding domestic animals facilitates transition of energy saved by plants to the highest form. Despite the fact that this agricultural sector is not accompanied with saving of a new, excessive amount of solar energy, the role of nomadic life and animal husbandry is extremely beneficial in the development of labour. He motivates this with improving human food supply and saving time for leisure and observations. We know that partly energy goes to animal food. More or less, all animals turn a part of saved energy to its highest form, mechanical work; and completing that, animals, though, dissipate the energy stored by plants again.

Studying animal husbandry, the researcher notes that the main purpose of keeping livestock is to use working domestic animals as a means of increasing human capabilities. The scientist points out that livestock should be used as draft power for three reasons. First of all, livestock eats plant food that mostly does not need any special cooking. Secondly, the economic equivalent of most workstock is higher than the economic equivalent of humans. Thirdly, because of its small size, mechanical work done by humans is simply insufficient to do all the necessary actions.

However, according to the researcher, in energy distribution benefits obtained with working domestic animals cannot be very big because the economic equivalent of working livestock is not big. To support this thesis, he cites the data that when a steam engine works, one hour of steam horsepower costs 3 pence but when horses work, it is 5½ pence, that is almost twice as much. Besides, domestic animals eat the same food that humans do, i.e. land under meadows (grassland) could provide food for humans as well.

Further, the researcher says it is obvious that if the purpose of animal husbandry was only desire to get more mechanical work, a huge amount of work done by animals would be subsequently modified with machines. But since keeping domestic animals is for another purpose (to produce meat, leather, wool, manure, etc.), the matter cannot be resolved with such simplicity. The scientist notes that consuming meat, we cannot avoid losses inevitable in transition of solar energy saved by plants into animal meat used as human food and losses related to cooking.

Speaking of energy stored by plants and animals in the materials used as food and for making clothes, the researcher says that an amount of energy is limited and directly dependent on quality characteristics of plants, it stands on an amount of human labour applied in agriculture. And he concludes: if a volume of mechanical work constantly grows, crop volumes can constantly increase.

The scientist draws attention to another means of increasing nutrients in proportional ratio to applied mechanical work: it is direct synthesis of substances used as human food from inorganic elements that constitute them. His calculations show that synthetic production of nutrients using solar energy can save half horsepower of engine power for capita. The scientist concludes that use of solar energy as a direct engine and production of nutrients from inorganic materials are the main issues standing in line to continue the most favorable energy saving on the Earth surface.

Human labour as a means of energy-saving. Analyzing F. Quesnay's, A. Smith's, J. Sismondi's, J. Stuart Mill's views, Serhiy Podolynsky indicates that the purpose of labour is to meet needs. He understands needs as awareness of desire for energy exchange between a human body and external nature. The researcher concludes: labour is manifestation of energy of a human body through which a human being produces the amount of energy which, without his intervention, lacks in nature for exchanges necessary for a human being.

According to S. Podolynsky, labour is such a use of mechanical and mental work accumulated in a body which results in increase of an amount of convertible energy on the Earth surface. He points out that its increase can occur in two ways: directly - through transformation of a new amount of solar energy into a more convertible form, or indirectly – through keeping from dissipation which is inevitable without intervention of labour, a certain amount of convertible energy that has already existed on the Earth surface.

The researcher proves that the instances of mechanical work manifestation in the inorganic world given by him (i.e. wind, water currents, tides) will never transform solar energy into a more convertible form and never prevent dissipation of higher forms of energy without intervention of humans consuming their mechanical work. Energy accumulated by plants goes to raise a new amount of energy to a higher level only if this reserve is a part of human food or that of a working animal, or serves as fuel for machines.

The scientist believes that physical work should not be confused with useful labour. To his mind, a savage worked a lot but his work was almost not useful labour because a savage increased a reserve of convertible energy on the Earth surface in a very limited way. On the contrary, a worker running a plough or reaping machine strains his muscles very little compared to usefulness of his labour in the sense of increasing a total energy reserve.

The scientist indicates that human labour productivity increases with decreasing its economic equivalent; with development of human needs, majority of them is met with labour. Human labour productivity significantly increases with use of work to transform lower forms of energy into higher ones, for example, using workstock, machines and others.

Considering a human body presented as a thermal machine, Serhiy Podolynsky estimates that the economic equivalent of a human machine (i.e. a quantity of heat per cent converted into mechanical work) is 1/5. Given the fact that on average, humans spend on food about half of their profits, housing, clothing, meeting mental needs make up the other half of their expenses.

The researcher concludes: if the economic equivalent of a human body calculated by an amount of eaten food or inhaled oxygen is 1/5, this equivalent should be reduced to 1/10, as a part of human life is spent inefficiently, e.g., in childhood, old age or diseases and so on. To summarize this, the scientist states that a human being has a certain economic equivalent which decreases as human needs increase.

Analyzing various human needs, the scientist concludes that an amount of labour and increase of energy exchange on the Earth surface caused by it must constantly grow not only because a number of people increases, but also because each person's energy budget grows. The modern human being must save 10 times more, and possibly in the future, they will have to save 12-15 times more.

Serhiy Podolynsky uses the term as "energy misappropriation" which is understood as phenomena, opposite to labour, all human acts leading to a reduction of the budget, an increase of energy dissipation with certain human acts. Thus, according to the researcher, the war with all its attributes, i.e. regular troops, navies, arsenals, etc., is nothing else than energy misappropriation available to mankind. To his mind, a special kind of energy misappropriation is production of luxury goods and unproductive consumption.

The scientist claims that improvement of human life should mainly consist of quantitative increase of everyone's energy budget, not just qualitative transformation of lower energy into higher one. So, only the society longing for quick energy accumulation can quickly move forward. In this case, stagnation is almost an equivalent to dissipation of energy savings because without development, public life looses any value and any meaning of existence. Therefore, the scientist believes that the main goal of mankind in labour should be an absolute increase in energy budget.

Conclusions. In his fundamental work, S. Podolynsky draws attention to the need to increase efficiency of the basic fuels at that time – coal and wood, as for getting the later leads to deforestation resulting in environmental degradation. History has confirmed expediency of the major part of Serhiy Podolynsky's ideas, particularly, ecosafety and cost-effective energy production using solar energy, wind energy, hydro energy of small rivers, geothermal energy, plant and animal waste, biofuels, etc., which is the basis of modern concepts of low-carbon economy.

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ECONOMIC TRANSFORMATION IN UKRAINE:

COMPARATIVE ANALYSIS AND EUROPEAN EXPERIENCE

Composite scientific work edited by Piotr Glowski & Oleksii Kvilinskyi

Warsaw 2017

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Proof-reader
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Cover designer
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ISBN **978-83-944739-0-7**

Published by **Consilium Sp. z o.o.**
00-545 Poland
Warsaw, Marszalkowska 58
Tel. (0048) 730 74 48 84
E-mail: office@clmconsulting.pl
http://clmconsulting.pl/

Printed by **Kunke Poligrafia Sp. z o.o.**
88-100 Poland
Inowroclaw, Magazynowa 27
Tel. (0048) 667 66 80 00
E-mail: bok@kunke.pl
http://www.kunke.pl/

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