Energy Sector and the Global Economy

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The future of the energy sector is an urgent topic nowadays, as the survival of humanity and each of researchers depends on it. This sector is part of a larger whole, i.e., of the national or global economy, and it determines its growth. This became particularly obvious recently as it has become necessary to increase the share of renewable energy in the total energy balance to stop global warming, which is the source of climate change.

Keywords: energy transition ; solar energy ; solar communism

1. Introduction

Among the characteristic features of the present energy system, there is an increase in the share of prosumers in energy generation, a feature unknown before. Prosumption is a consequence of the ICT revolution and widespread digitalization of nearly all sectors of the economy and spheres of human life. It has led to the development of new business models, which have transformed previous economic systems. Traditional capitalism, known from economy handbooks and the scientific literature, has been replaced by a new system called prosumer capitalism.

Prosumer capitalism is regarded as the starting point for describing the future of the energy sector and the global economy. There is every indication that this system of management is now on the decline. Prosumer capitalism is not a stable form of economic process organization due to the externalization of the labor cost and synergistically double exploitation. Previous management systems—producer capitalism and consumer capitalism—also involved exploitation, although of a different kind. Producer capitalism should be classified as a singly exploitative economic system, as the exploitation of workers is its main feature. Consumer capitalism, in turn, is doubly exploitative, as it makes it possible to exploit both workers and consumers. On the other hand, a new and more intensive form of exploiting people emerged in prosumer capitalism, which permeates many areas of human activity at the same time [1][2]. Other flaws of this system include a self-propelled cycle of production and consumption, a constantly growing debt of work, microfascisms associated with power relations, and the robotization of prosumers and transforming them into a new type of commodity. Other threats may be associated with the emergence of huge multinational corporations, with considerable economic and political power given to them by social media users. All of this may lead to overproduction, overconsumption, social inequalities, ecological disaster, and climate change. Therefore, it becomes manifest that—on the one hand—prosumer capitalism facilitates the energy transition, as it accelerates the growth of the green energy sector and its integration with energy generation from fossil fuels, and—on the other—it can stimulate irrationality and excessive energy consumption. Thus, it is a temporary form of management, and it will have to be transformed into something different in future. Incidentally, proposed solutions to prosumer capitalism problems are, at the same time, strong stimuli for its transformation and improvement. From the futurology perspective, covering the period until the mid-21st century, one can list the successive systems of management, which include ecosocialism, dot-communism, and solar communism.

The visions of the future discussed are evaluated by means of a tool called terminology management, which is useful in knowledge organization and presentation and helps to imbue words with a sense. It helped to identify prosumer capitalism as the Fourth Wave in Toffler's civilization revolution pattern. It is also known as the Connected Society. The difference between individual waves arises from the importance of prosumption in the respective economic systems, i.e., switching cyclically between marketization and demarketization. This provided the basis for identifying the next two waves, which are consistent with the goals of the global energy transition and involve ensuring a compromise between the sustainable growth of the global economy and the need to eliminate global warming, which is responsible for climate change. The Fifth Wave of Computing is convergent with the socioeconomic agenda of ecosocialism, whereas the Sixth Wave of Technological and Energy Communism is associated with a new economic system called solar communism. The futuristic research horizon is restricted to the year 2050, as by this time—according to the optimistic scenario—mankind will have eliminated the anthropogenic greenhouse effect, and its whole energy needs will be satisfied with solar radiation.

All of the discussions on the future of the energy sector should start with the second law of thermodynamics and with defining the Earth's heat budget. The concept of thermodynamic entropy was introduced to economics by Nicholas Georgescu-Roegen, which contributed to the emergence of a new trend in economic studies called ecological economics. It involves the following reasoning. Human economic activity consists of transforming the limited natural resources of low entropy into high entropy waste, which shows that there are physical limits to global economic growth. A constant increase in the physical throughput is not possible due to the exhaustion of the sources of energy, raw materials and space, and biosphere destruction. Future knowledge will not be able to eliminate those limitations. Thus, entropy sets the ultimate limits for economic growth processes and becomes the physical basis for many socioeconomic forecasts. Apparently, all this appears sensible and logical, but this reasoning does not lead to a correct outcome due to incorrect assumptions. Nicholas Georgescu-Roegen claimed that the Earth is a closed system, so it cannot exchange matter or energy with its surroundings. However, this is a definition of an isolated system in thermodynamics, whereas closed systems are systems that do not exchange matter with the surroundings, but they are open to energy exchange. The Earth meets these conditions. Correcting Georgescu-Roegen's error proves that the solar radiation which reaches the Earth can be a source of work whose recycling is infinite. Therefore, not only qualitative but also quantitative human growth is possible.

2. Is Solar Communism the Future of the Energy Sector?

2.1. The Origins of Communism as a Socioeconomic System

Schwartzman claims that the roots of communism lie in the Bible [3] (p. 16). It is also asserted that communism is synonymous with practical Christianity and that Jesus Christ was the first communist [4] (p. 593). As the well-known socialist theorist Karl Kautsky notes, Christian communism resulted from the desire of the poor to abolish all private property, and joint ownership was supposed to guarantee that misery and poverty would be eliminated. Their source is the same as in other forms of communism—the disenfranchisement of the popular masses. In early Christianity, the communist sphere encompassed articles of consumption, their distribution, and joint consumption. Furthermore, rural areas witnessed communism in production since jointly organized labor was possible there. In agriculture, consumption was directly linked to production, given that almost all production was intended for private consumption [5]. In other words, Christian communism essentially consisted of agricultural activity in the circumstances of Toffler's First Wave, which is why it occurred mainly in rural regions. Production was mostly undertaken to meet one's own consumption needs rather than to be sold. Using contemporary language, prosumption prevailed there. The factors which united Christian communities were communal suppers and the organization of mutual aid. As soon as wealthy individuals emerged among them, they gradually lost their proletarian character.

In the Middle Ages, monasteries were the primary form of technical and economic improvement since the cooperative mode of production, which was characteristic of those entities, dovetailed perfectly with the existing conditions of rural production. Unsurprisingly, monastic communism was the main form of Christian communism at the time. Within its framework, the Christian ideal of communal consumption and production, i.e., prosumption, could once again be reified. This structure of Christian monasteries has survived to the present day. However, monastic communism could not become the basis of the social economy because it required celibacy and conflicted with individual marriage. As such, it was limited to a minority. On the other hand, the conditions of production in the large urban centers resulted in the dispersion of proletarians [5] (pp. 345, 452, 455). The development of communism in the cities faced enormous obstacles from the very outset due to the separation of production and consumption, which, as Toffler noted, led to the gradual marketization of the world, and that trend deepened even further during the Second Wave associated with the Industrial Revolution. The shape of the economic system is not determined by how consumption is arranged but by the organization of production. The discrepancy between production and consumption was exacerbated by the division of labor, which, in turn, resulted from expanding industrial production. Hence, the cities saw only communism of consumption, confined to joint consumption of foodstuffs and other goods, so it operated within common households and families. In Kautsky's contemporary utopian communism, which functioned in the circumstances of the Second Wave, attempts were made to couple communism of consumption with the communism of production, but this led to its failure due to disputes and misunderstandings [5] (p. 454). The failure of utopian communism should be attributed to the separation of the consumption and production sectors for the sake of exchange, which resulted in the collapse of prosumption. It may therefore be concluded that communism and prosumption go hand in hand: what supports the former also sustains the latter.

Kautsky also underlines that religion was the primary factor in the development of Christian communism. As the author himself admits, there is no communism without religion. The strength of the Christian community lay in the propagation of messianic ideas, belief in the Christ Crucified and personal resurrection. Not only did it enable the group to survive as a secret organization inside the Roman state, but it also enabled it to become an unassailable power. Originating from the

proletariat, the Crucified Messiah accomplished what no one else before had, or has since been able to, achieve: he conquered Rome, coerced Caesars into obedience, and gained dominion over the entire world [5] (pp. 380–381, 451).

According to Kautsky, modern communism is altogether different in its nature from Christian communism. By definition, the former is a macroeconomic system encompassing the entire society whereby the proletariat must acquire state power in order for it to become a reality, whereas the latter is inherently a microeconomic system. Modern communism should be the communism of concentration of wealth and concentration of production [5] (pp. 467–468).

An elaborate paradigm of modern communism was envisioned by Lenin, who emphasized that the basic trait of this socioeconomic system is the complete withering away of the state. In his view, the state is an organization of violence which is brought to bear for one social class to exercise oppression over another. Social classes are in evidence when the members of society differ in their relation to the social means of production. Since under communism, society will be classless, the state as an instrument of oppression will also prove dispensable. A similar fate is destined to befall democracy since, to Lenin, the term denotes a state that presupposes subordination of the minority to the majority, which is tantamount to the systematic oppression of one part of the population by another. It is only in a communist society that democracy may become complete and thus unnecessary, withering away along with the state in consequence. Only then will it be possible to realize the principle of “from each according to his ability, to each according to his needs”. The state will wither away during the transition period from the proletarian revolution to the consummation of communism. Under this new system, everyone will be able to partake in the management of socioeconomic life and take over functions previously held by the state [6]. As Engels notes, as social classes disappear, society “will put the whole machinery of state where it will then belong: into the museum of antiquities, by the side of the spinning wheel and the bronze axe” [7] (p. 160). These notions turn out to coincide with the ideas of political prosumerism and correspond to what one understands today as digital prosumer capitalism [8]. In addition, Lenin would have certainly approved of the present-day energy transition based on prosumer electricity markets, given that he fully appreciated the importance of electricity for the socioeconomic development of humanity. In his opinion, “communism is Soviet power plus the electrification of the whole country since industry cannot be developed without electrification” [9] (p. 419).

Priddat and Jansen elaborate on the idea of virtualization of the state, which consists of enhanced political prosumerism, a goal achieved by increasing citizen participation in the political planning process. This translates into delegating responsibility through society to society so that citizens may take control, assume greater responsibility for their own affairs, and focus on local problems. It is the citizens who should run the state, not the other way around. The development of eGovernment will make it possible to tackle the three challenges of civil society: the integration of the citizenry, co-opetition, and policy networks, as well as the virtual production of public goods. As a result, the size of the state will be reduced by half while its influence will grow twofold. The government’s use of citizens’ advice may allow it to solve problems to better effect. The paradox of the withering state is also present here: as globalization advances, local politics (glocalization) gains increasing significance. The production of multiple public goods (with the exception of law, infrastructure, and, in part, education) can be outsourced to civic organizations or private enterprises, which can simultaneously cooperate and compete with one another. Another matter of interest is the concept of the zero-gravity state, which utilizes virtual production structures and value-adding networks to optimize its state quota [10].

2.2. The Essence of Global Solar Communism

It is not economic, social, and political ideas which lie at the core of solar communism, but the laws of physics. Prior to discussing this issue, the basic concepts involved have to be defined. According to the second law of thermodynamics, the entropy of an isolated system, i.e., one which does not exchange energy and matter with its surroundings, must increase insofar as any changes occur in it. An increase in entropy is tantamount to decreased ability to perform work, which results from the transformation of low-entropy energy into waste heat. Consequently, thermodynamic entropy can be defined as a randomized state of energy that cannot be utilized to perform work (being unavailable). Thermodynamics also defines closed systems which do not exchange matter with the environment but are open due to the energy flow [11].

The introduction of thermodynamic entropy into economics is credited to Nicholas Georgescu-Roegen, who made it a measure to determine the ultimate limits of the development of economic processes and a physical foundation employed in social predictions [12]. The processes of production and consumption consist of transforming low entropy into high entropy, resulting in waste [12] (p. 18). Since the resources of low entropy in the human surroundings are limited and become gradually depleted, as is the case with fossil fuels, there must exist physical limits to further growth of the world economy. The continued increase of the physical throughput will sooner or later become impossible due to the depletion of energy, materials, and space, with concurrent destruction of the biosphere. Future knowledge will not be capable of removing the strictures imposed on the world economy by finitude, entropy, and ecological dependence [13] (p. 199). The

concept of entropy generated by economic processes was expanded by Jeremy Rifkin, who approached entropy as pollution, a marker of cosmic disorder, and a primary cause of environmental destruction [14][15]. Járosi and Kovács attribute the shape of the modern energy transition in Europe to the catastrophic visions and intellectual influence of Jeremy Rifkin, who continued the work of Georgescu-Roegen. The Hungarian authors are skeptical of the European Union's energy policy and emphasize that its efforts have minor significance for global climate protection and cannot prevent the rise of anthropogenic greenhouse gas emissions in emerging economies [16].

To Georgescu-Roegen, a closed system does not exchange matter and energy with the environment [17] (pp. 7–8). He further observes that a closed system cannot ceaselessly perform work at a constant rate [18] (p. 304). However, this is how thermodynamics describes an isolated system as opposed to a closed one [19] (pp. 3–4). If the Earth is an isolated system, then there must indeed be physical limits to the development of the world economy since, under the second law of thermodynamics, matter and energy are irrevocably dissipated [17] (p. 8). However, this is not the case, since the Earth is a closed system and thus does not exchange matter with space (except for space vehicles and meteorites), but remains open to solar energy transfer. David Schwartzman notes the mistake Georgescu-Roegen made and demonstrates that the conversion of low-entropy, high-temperature energy into high-entropy, low-temperature heat can be a source of work whose recycling is infinite. An elucidation of the differences between isolated systems and closed systems helps one understand why Georgescu-Roegen took a pessimistic view of the use of solar energy in the economy—he considered all solar systems known in 1981 to be parasites of fossil-fuel-based energy technologies [20] (pp. 70–71, 198). This confusion of concepts is also crucial in solving the problem of optimizing humanity's relationship with nature, since it supplies the physical foundation for the development of solar communism [11]. Thus, the vision of an entropic apocalypse culminating in the annihilation of civilization proved erroneous.

Given the energy budget at the Earth's surface, the solar energy flux reaching the surface/atmosphere is equal to the flux radiating back into space. The natural greenhouse effect is due to the absorption of heat radiation by water and carbon dioxide molecules in the atmosphere which reradiate heat to the surface. Any economy which does not rely on direct solar flux but uses fossil fuels, as well as nuclear and geothermal energy, affects the heat budget of the Earth because the emission of heat radiation exceeds the natural flux from the surface. This also involves the enhanced greenhouse effect, whose principal source is anthropogenic carbon dioxide and methane. The global economy would not have an impact on the Earth's surface heat budget only if the use of solar energy were not associated with net transfers of these greenhouse gases to the atmosphere and ocean systems [11].

The physical underpinning for the development of solar communism is staggering. The world economy could increase its energy consumption tenfold using only 1% of the solar radiation reaching the Earth's surface without changing its current heat budget. This means that anthropogenic greenhouse gas emissions and direct waste heat production can be avoided. The annual flux of solar radiation is ten times the total energy stored in the global coal resource or in one million billion (10^{15}) barrels of crude oil. The energy payback time, or the number of years it takes for photovoltaic panels to generate the amount of electricity needed to produce them, is 1–4 years (as of 1994). The U.S. demand for electricity could be fully met by installing silicon-based photovoltaic panels in an area equal to a square with a side measuring 140 km, which is much smaller than the area currently occupied by U.S. military installations. The introduction of solar communism will not be possible without optimal relations between the technosphere and the ecosphere and, therefore, adherence to the principle of maximizing the containment of the technosphere [11].

2.3. Conditions Necessary for the Implementation of Solar Communism

It follows from the laws of thermodynamics that economic development on the Earth's surface may be continued by humankind even in the relatively distant future, provided that it relies on solar energy. Direct utilization of its minor proportion by humans would mean connecting the world economy to an immense flux of energy capable of performing inconceivable work. This portion of solar energy would eventually be converted into waste heat in any case, as evidenced by the natural heat budget. If the world economy were based solely on solar energy, it would increase the physical throughput (industrial processing) in the technosphere without a negative impact on the biosphere, provided that the production–consumption cycle is closed. This would enable the export of entropy flux into space in much the same way as it happens with the natural biosphere powered by solar energy. However, before these possibilities can be made a reality, the basic principle of communism—"from each according to his ability, to each according to his needs"—has to be reinterpreted in a manner which will render it applicable not only to humans but also to the Earth's ecosystem [21]. For this to be accomplished, the thermodynamic processes taking place in nature must be supported by appropriate socioeconomic policies on a global scale.

As Schwartzman observes, the transition to solar communism requires gradual application of that modified principle already in the near future, i.e., in a mixed social formation referred to as ecosocialism, which should be situated on the timeline immediately after prosumer capitalism. In his view, ecosocialism—a combination of ecological and socialist movements—is a prerequisite for the reification of the ultimate system: a global solar community. Since ecosocialism does not presuppose the occurrence of the phenomenon known as synergistically double exploitation, it must inevitably be clearly distinguished from prosumer capitalism. The end of the era of prosumer capitalism confronts humanity with the great bifurcation: the choice between relegating global capitalism to prehistory or a climate catastrophe of unimaginable consequences caused by unsustainable capital reproduction processes [22].

The notion that future civilization should rely on the solar radiation flux reaching the Earth's surface stems from the fact that it is the most abundant and most easily accessible source of energy, while its negative impact on health and the environment is negligible compared to fossil fuels. In addition, solar energy technologies are developing globally at a nearly exponential growth rate [3]. Today, the global anthropogenic energy flux (waste heat) equals only 0.03% of the solar flux on land surfaces. This is equivalent to saying that one hour of solar flux reaching the Earth's surface supplies an amount of energy equal to the annual consumption of energy by the global population. In this case, the second law of thermodynamics does not limit economic development. The impact of converting solar energy into useful work poses much less of a threat to ecosystems than the current hazards since the resulting waste heat is discharged into space and does not actually increase the natural flux [23]. In this way, humans may adapt their economic undertakings to the entropic flow from the Earth's surface and take advantage of the existence of a heat sink in outer space, which guarantees ecological balance and biospheric self-organization [24] (pp. 161–172).

The sufficient and necessary conditions for the attainment of solar communism include material and political requirements as well as the demilitarization of the world. The material requirements are as follows: the existence of a global and highly efficient solar energy infrastructure; containment and precautionary measures in environmental policy; demilitarization of technologies and propagation of state-of-the-art information technologies around the world; concentration of the population in green cities and the establishment of large biospheric reserves. Among the political requirements, one should list a transnational workforce organized bottom-up, accelerated democratization of the global society, a transnational ecosocialist political movement, and partial achievement of the material requirements cited above. Further indispensable elements include social governance of production and consumption at all levels (from local to global), universal equity among people, communal ownership of land, and termination of the production of value based on labor time [22] (pp. 483–489).

It has previously been argued that one of the preconditions for the realization of communism is increased labor productivity under capitalism. With respect to solar communism, the list may be supplemented with state-of-the-art information technologies, renewable energy, and organic agriculture based on agroecology [21].

The main goal of ecosocialism is the global class struggle for ecological sustainability [21]. In their quest to end the domination of the big capital, the working class, middle strata, and indigenous peoples represent a countervailing force to the national and transnational ruling classes [22]. Specifically, ecosocialists have targeted the nuclear military industrial fossil fuel complex as the guardian of the interests of the transnational capital class and thus one of the greatest threats to the transformation of current prosumer capitalism into solar communism. In 2015, total defense outlays amounted to USD 2.03 trillion. Ecosocialists consider this sector to be the reproduction center of global capital due to the fact that it exerts a powerful influence on the internal and external policies of the major capitalist powers and seeks to control the world's oil reserves. In addition, the fossil fuel and nuclear industries are closely associated with this sector, which translates into the ability to use the threat of nuclear attack to achieve imperial policy goals. The complex is also seen as a major obstacle to the emergence of a global multiclass alliance striving to reduce global greenhouse gas emissions and transition fully to solar energy [3].

Global prosumer capitalism prioritizes the reproduction of capital over the needs of humans and nature. This results in a reduction in global biodiversity and habitat destruction, which some believe may contribute to pandemics [3]. Therefore, the emergence of solar communism spells the ultimate end of the reproduction of the militarized fossil capital, and the consequent cessation of value creation. In such circumstances, the pursuit of class power will no longer be feasible [23]. A global solar communist society will be founded on a steady-state biophysical economy [3] (p. 22).

By consuming fossil fuels and using nuclear energy, humankind has incurred an entropic debt with the environment and, therefore, with space. Powering the global economy with solar energy will lead to the repayment of that debt in the form of nonincremental waste heat, which is impossible with unsustainable equivalents of such energy [3].

It is usually asserted that nuclear power does not affect climate change. However, environmentalists see it as a threat not only because of its ties to the military–industrial complex, but also because the existing fossil-fuel-based energy infrastructure powers all subsystems of the nuclear fuel cycle. Realignment of the global economy to solar energy may be delivered in sufficient time to avoid catastrophic climate change and prevent irreversible changes. Environmentalists emphasize that the transition to solar communism will be possible within the next 30 years if 1–2% of the current annual energy consumption, including the 85% involving fossil fuels, is allocated to solar and wind energy production each year [22] (pp. 491–492). The extant fossil fuel reserves will suffice to meet the needs of the global solar community, provided that they are not consumed as fuel. Moreover, solar energy tallies with the decentralized, democratic model of governance and control befitting a future global solar community [21]. Moreover, the current mean harmonized EROI (energy return on energy invested) values for solar photovoltaic systems range from 8.7 to 34.2, depending on the technology used, which is very promising, and these values could be even higher in the future [25].

2.4. The Exemplification: Possibilities of Developing Solar Power Plants in Poland

Solarization of the world—if it indeed takes place—will most likely begin with grassroots efforts by individual regions and countries. The use of solar radiation to produce electricity will be particularly important in this respect. The entire surface of the territory of Poland has similar solar energy resources, ranging from 980 to 1100 kWh/m^2 per year. Under standard test conditions (STC), an optimally located photovoltaic system can approximately yield 1000 kWh annually from each kilowatt of capacity installed. Depending on the technology used, this rate is usually in the 950–1025 kWh/kWp range [26] (pp. 132–133).

In recent years, the market for electricity involving direct solar radiation has grown rapidly. In late April 2022, the total installed capacity of the photovoltaic systems in Poland reached 9998.2 MW, in excess of double the figure for April of the previous year (4739.6 MW). At present, the prosumer share of installed capacity is almost 80%, and the number of devices they use exceeds 1 million. In the first four months of 2022, solar radiation generated 1782.6 GWh of electricity, which accounted for 2.8% of the national production. In the equivalent period last year, it amounted to 760.9 GWh and 1.3%, respectively [27].

In Poland, potential investors can estimate the overall cost of a photovoltaic system based on the following linear function [28]:

$$C(p) = 5845p + 3897, \quad (1)$$

where *C(p)* represents the cost in PLN, while *p* stands for the nominal power expressed in kWp. The calculations show that without external financing, the expected payback period of the system is 16 to 24 years.

At present, one of the most serious obstacles to the development of solar power in the country is the limited availability of connection capacities for new prosumers. Even so, forecasts concerning further development of solar power plants are very optimistic, but they do not appear likely to replace conventional power plants within a reasonable time horizon. Thus, the achievement of solar communism would indeed have to be global and involve the transmission of electrical power from the regions of the world with the highest solar exposure to the rest.

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