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Reshaping Development for Energy Sustainability in Permacrisis

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Abstract

The paper presents the transitions between different levels of the metacrisis (permacrisis, policrisis) identified, the main strategy in this context being to discover the possible “black swan” of energy, resource technologies, or solutions and to break the vicious circle of staying at the lower level of development which deters the creation of the right dynamic equilibrium, with real sustainability at all levels, in dynamic local and global processes. A new transdisciplinary pattern for permacrisis is introduced, with energy becoming a very important part of the problem. The M.E.N. energetic concept assures the integration of the circular economy in the global necessary model for a new sustainable economy, with a lot of risks, threats, and disasters, in a continuously changing way. It is important to keep reaching certain goals of the sustainable development ideology, but at the same time to create the desirable right dynamic equilibrium in the context of permacrisis aimed to provide up-to-date solutions to the environment, society, and economy problems as an ENSEC integrative transdisciplinary model. Some of the possible solutions for the searched “holy grail” of energy are also presented.

Keywords: Permacrisis; Sustainability; Transdisciplinarity; Energetic MEN Paradigm; ENSEC Model; Non-Resilient Transitions; Nuclear Energy; Hydrogen; Green Energy

Abbreviations

CCUS: Carbon Capture Utilization and Storage; SAR: Small and Advanced Reactors; SMR: Small Modular Reactors.

Introduction

It is of great importance to know the way in which the concept of sustainability could be available throughout the biggest crisis context associated with a globally extended period of instability and insecurity (paragraph 2, *Sustainability development. New adapted definitions and models)* [1,2]. Although there are a lot of local and international mechanisms for providing sustainable development and solving ecological issues, there are still a lot of challenges to the sustainability goals since the Rio Earth Summit in 1992 [3]. The dilemma of economic progress and environmental preservation is not solved only by the theoretic conceptualization of sustainability but practically by creating conditions for a sustainable economy, without any significant progress in achieving the international institutional goals [4]. These new challenges are creating the permacrisis, with five non-resilient transitions: climate, energetic, geopolitical, demographic/health, and technological transitions, and are associates as well with five types of crises that resilience is limited in tackling them [5]. These five unstable transitions have changed the world [2], making necessary some individual and viable global solutions to resist the change with these permanent unpredictable transitions. In this context, it is necessary to rethink the well-known relationship between resilience, viability, and subsistence to eliminate the risks of environmental and socioeconomic vulnerabilities [2,6]. To ensure sustainable development in a non-stable environment, with a lot of disturbance at all levels of an ailing economy, it is necessary to respond with resilient solutions and help the system *"jump"* in a secure way from the bottom level of the development to one of the top levels to ensure a dynamic equilibrium of the ENSEC systems, at every possible level [7].

The next step in the presentation of this study is *"The Transdisciplinary Approach of the Sustainability in Permacrisis"*, where we evaluate the context of the last years with the existing five transitions, as climate disturbance [8-11]; energetic challenges [6,12]; geopolitical reconfigurations [13]; demographic/health realities [14,15]; IT, automatic and technological development [16,17], being necessary individual and viable global and local solutions, as well [18,19]. The dilemma of economic progress and environmental preservation is still not solved both in terms of the conceptualization of sustainability and practically, by the creation of viable economies in a desirable permanent equilibrium, not in permanent crisis [2].

The section entitled *Energetical aspects of the transdisciplinary sustainable development and new perspectives of the energetic policies* starts from the necessity of a green, global energetic system without any disturbance of the natural ENSEC pattern [5], considering the two natural resources, solar and gravitational [6]. In today's dynamic world, the energy sector stands at a pivotal crossroads; as global demands grow and environmental concerns intensify, the search for sustainable energy solutions has never been more urgent. From rethinking energy access to embracing cutting-edge technologies, the landscape is filled with both challenges and opportunities. The energetic security of the environmental and socioeconomic systems in such permacrisis situation has to be reevaluated, reshaping the methods in a transdisciplinary way to integrate the energetic resources, specific technologies, even education at all levels, in the new ENSEC M.E.N. (Mega-Eeco-Nega) energetic paradigm [5,6].

Sustainability Development New Adapted Definitions and Models

The triple bottom line can be broken down into *"three P's"*: planet (environment), people (society), and profit (economy) with environmental, social, and economy governance (ESG) metrics [20]. These categories can be used to conceptualize environmental responsibility and to determine any negative social impacts to which they might contribute with those procedures, holding businesses publicly accountable to focus on more sustainable practices in addition to financial profit [5,21]. A definition is identified stressing the importance of justice as a broader aspect of social life by *"...living in harmony with social and environmental conditions based on the sense of equality and justice"*, or a solution-oriented definition as: *"Sustainability is an awareness of the relationship between the world and the implications of our actions. Finding solutions through innovation approaches, expanding future choices by practicing environmental care, build institutions that are constantly studying and cultivating values that promote justice"*. Although there is a variety of sustainability definitions, each of them has its connotation and a response to a certain historical period and socio-economic need.

A process-oriented approach was tackled in 1990, which came with the idea that development could ensure sustainability and economic efficiency for the residents of communities by creating a *circular economy* [5,22]. It means that each output of the production or sustainability was introduced as a policy concept, the document being concerned with the tension between the aspirations of mankind towards a better life on the one hand and the limitations imposed by nature on the other hand [3]. The concept of sustainability has been re-interpreted as encompassing three dimensions, namely environmental, social, and economic (ENSEC paradigm of life) [5]. A return is made to the original meaning, where sustainability is concerned with the well-being of future generations and, in particular, with irreplaceable natural resources - as opposed to the gratification of present needs, which we call now well-being, being necessary a balance between these two aspects presented here. Natural resources (environmental), at the expense of future generations (socially), have to be completed to generate capital (including knowledge) (economically), which raises future well-being [5,20].

A major question is to what extent one compensates for the other, as a debate centered around the problem of substitutability, as a distinction between "weak" and "strong" sustainability, which are working complementary, not in opposition. The real contradiction exists between long-term sustainability and short-term welfare as a form of government in which the state, or a well-established network of social institutions, is protecting and promoting the economic and social well-being of its citizens, based upon the principles of equal opportunity, equitable distribution of wealth, and public responsibility for citizens [23].

Moreover, the distinction between three "pillars" of sustainability (environment, society, and economics) as it is presented in Figure 1 is conceptually a fuzzy problem, one without a perfectly clear goal, a path to success, or known solution, as a vague and imprecise information [24] because we have no scale to measure the equitability, bearability, and viability. A necessary definition has to revert the concept of the sustainability to the original sense in which the concept was intended, but acknowledgig the permacrisis context, with its five transitions: climate disturbance; energetic challenges; geopolitical reconfiguration; demographic/health reality; IT & automatic and technological development necessary individual and viable global and local solutions.

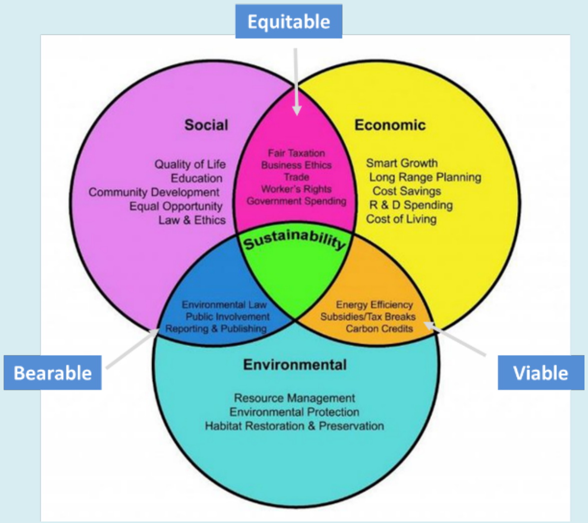

Figure 1: ENSEC Sustainable Development Model (Triple Bottom Line, PPP paradigm) [5,20,21].

The Transdisciplinary Approach of the Sustainability in Permacrisis

Although there are lot of local and international mechanisms for providing sustainable development and solving ecological issues, there are still dilemmas and challenges of the sustainability goals since Rio Earth Summit in 1992 [3]. There is no significant progress in achieving the international institutional goals; even more, new challenges are emerging creating a permacrisis. The main challenges and dilemmas of the current understanding of sustainability are as follows: (a) there is a discussion about the "strong" and "weak" sustainability; will the new generation inherit an *economic wealth* or a *preserved resource economy* [4]; (2) the dilemma of economic progress and environmental preservation is still not solved both in terms of its conceptualization of sustainability and, practically, regarding the creation of viable economies [5]; (3) None of the sustainability goals proved to have significant progress since Rio Earth Summit (three decades ago) [4]; (4) renewable energy technologies are more labor and material intensive, requiring rare natural elements [2,25]; (5) geopolitically speaking, energy security represents a risk for most countries and companies [2,26].

The discouragements and limitations of the sustainable development understanding is not expressed only by the scientific communities but by high officials of international organizations such as the UN Secretary-General António Guterres, who addressing the *UN Economic and Social Council* in 2022 said that *"Our world is suffering from the impact of unprecedented emergencies caused by the climate crisis, pollution, desertification and biodiversity loss, the COVID-19 pandemic, by new and ongoing conflicts, and by the ungoverned development of new technologies"* [27]. The same problem was addressed by international forums such as G20 Summits [28]: decarbonization, poverty, pandemic, and efficient use of resources remain a big unsolved issue. The efforts of the last decades to provide sustainable development seem to be geared more towards an ideology than progress or development that would bring society to the next level. This situation makes us raise the question of redefining the concept of sustainability and give new approaches to the solution of this complex challenge. The environment and geopolitics get more and more complex and unpredictable; because of these aspects, sustainable development must be discussed from a transdisciplinary point of view, to cope with the complexity and unpredictability of the world economy, environment, and geopolitics. In this sense, transdisciplinarity could help us understand and approach complexity and provide new level of understanding and solutions to the human needs and society's. Regarding sustainability and its 21st Century challenges, we consider transdisciplinarity as the right way to understand and approach them because [29]:

transdisciplinarity gives interpretive approaches, critical science, and grounded theory, this paradigm exploring the values in a new synergistic generative context, creating a new praxis through working pragmatically by a sustainable all-life learning, using integrative learning concepts, as a movement toward integrated lessons [30].

This new integrative approach helps people make connections, putting together skills and knowledge from multiple sources and experiences, applying the skills and practices in various settings, utilizing diverse and even contradictory points of view. This is the paradigm aimed to tackle system far from equilibrium, in transition/crisis, and chaotic [7]. The reality of the multiple crisis at all levels of the life is one of the fundamental reasons why we approach sustainability development in the view of the transdisciplinary way. The specific situations in the communities, countries, and around the world are of paramount importance, and these phenomena polycrisis, permacrisis, metacrisis with general integrative multiple crisis, have implications about worldviews, probabilities, and priorities, in the conditions of all risks (climate changes, wars, tsunami, corruption, energy, pollution, desertification, migrations), disasters, hazards and other such situations [31]. The term "crisis" is very used, including polycrisis, permacrisis, and metacrisis, as well.

The term poly-crisis indicates that there are many intersecting crises with generally different causes [26], whereas permacrisis indicates that these are no longer unusual periods of time [32], while metacrisis indicates that there are some deeper crises relating to most of the individual aspects of the crises [33]. Very often most individuals even do not understand that there is a crisis or what kind of crisis they are going through, the multiple crises the world is suffering from, leads to the state of continuous crisis that makes it very difficult to perceive and cope with it. There are identified five *non-resilient transitions, the climate transition, energy transition, geopolitical transition, demographic/ medical transition, as well as technological transition* meaning five types of crises that *resilience* is limited in tackling these transitions [2,32] with individual and *viable* solutions, being unable to resist the change and the transition (Figure 2). We need to rethink the relationship between resilience, viability, and subsistence to eliminate the risks of socio-economic and environmental vulnerability. To ensure sustainable development in an unsustainable and unstable environment, we must respond with viable solutions and help the system "jump" to the next level of development and create the state of a *dynamic equilibrium* [7]. The creation of a dynamic equilibrium is the way to cope with the permacrisis and lay the foundation for the sustainable development when instability take place and the development adapts and finds the right equilibrium and positioning to respond to the permacrisis. Considering these non-resilient transitions, we can identify more sustainable development strategies with classical parameters and new introduced, as well, such as: a) equitable development, fair society, energy security/ free access to energy and resources; b) viable economy with cost optimization and economic efficiency; c) bearable development; and d) net-zero emissions/efficient waste management. This approach helps us to identify at least 3 levels of development and 9 strategies that will respond to the above-mentioned parameters in time. The stagnation in development means energy consumption with high carbon emissions, an unfair society, the weak economy in a meta crisis [2].

Figure 2: Five non resilient transitions [2].

The new non-resilient transitions open a whole spectrum of opportunities to grow to the next level and to benefit from a new form of equitable, bearable, and viable society and new level of sustainable development. So, we consider that transdisciplinary sustainable development could be defined as developments aimed to cope with the climate, energy, geopolitical, demographic/health and technological transitions in a viable, bearable and in an equitable way to create the right dynamic equilibrium and jump to the next level of human development. The efforts of the last decades to provide a sustainable development look to be more an ideology than a progress or development that would bring society to the next level. This situation makes us raise the question of redefining the concept of sustainability and give new approaches to the solution of this complex challenge. The environment and geopolitics get more and more complex and unpredictable. Transdisciplinarity could help us to understand and approach complexity and provide new level of understanding and solution to the human needs and society [29]. Regarding sustainability and its 21st Century challenges, we consider transdisciplinarity is the right way to understand and approach it because (1) transdisciplinarity gives interpretive approaches, critical science, and grounded theory; (2) this paradigm explores the values in a new synergistic-generative context; (3) it is created a new praxis through working pragmatically by a sustainable all life learning; (4) is working as a movement toward integrated lessons with integrative learning concepts; (5) this approach helps people to make connections, putting together skills and knowledge from multiple sources and experiences [18,34]; (6) it applies skills and practices in various settings, utilizing diverse and even contradictory points of view; (7) this paradigm aims to tackle system far from equilibrium, in transition/crisis, and chaotic states even disasters [26]. The permanence of the multiple crises is one of the fundamental reasons why we need to approach sustainability development in the view of the transdisciplinary way.

Energetical Aspects of the Transdisciplinary Sustainable Development and New Perspectives of the Energetic Policies

This chapter has four sections: MEN energetic concept; Green energy, alternative energetic solutions and technologies; Hydrogen; Fission and fusion energy.

MEN Energetic Concept

It is very clear that energy is an essential element for economic stability, functioning as the backbone of nations, and a power source for sustainable economies. To ensure energy security is one of the most critical goals for countries seeking sustainable economic development. The concept of energy security refers to the ability of an economy to guarantee the supply of energy in a sustainable and timely manner at an affordable price without adversely affecting its economic performance, many studies identifying energy security as one of the most critical indicators of an economy's stability [35]. The recent Russian-Ukrainian conflict has affected energy production and supply, resulting in unprecedented increases in energy prices, especially in Europe. In addition to a large number of people having been displaced, the military conflict has also created hyperinflation, which has contributed to a high level of interpersonal violence and an increase in the cost of living. So, it is necessary to bring new theoretical and empirical evidence for studying the nexus between energy security risk and economic stability in an era of permacrisis [2]. The promotion of electricity generated from renewable energy sources (RES) has gained a high priority in the energy policy strategies of many countries in response to concerns about global climate change, energy security, and other reasons. Renewable energy sources (RES) supply 14% of the total world energy demand. RES are biomass, hydropower, geothermal, solar, wind, and marine energies. The renewables are the primary, domestic and clean or inexhaustible energy resources. The percentage share of biomass was 62.1% of total renewable energy sources in 1995. Large-scale hydropower supplies 20 percent of global electricity. Wind power in coastal and other windy regions is promising as well.

There are a lot of studies about the energy in a number of countries in Europe, United States, as well as Japan to promote renewable energy resources (RES), identifying the most successful specific, locally and globally policies [36]. In our study, economic stability is defined as people having access to the services and resources essential to living a healthy life in good and bad times (e.g., financial resources, quality food and housing, and employment that provides a living wage). We employ GDP growth as a measure of economic stability, as it reflects a country's overall economic performance and is generally associated with the availability of essential services and resources. The recent volatility of world energy markets and prices as a result of multiple crises (COVID-19, the Russian invasion of Ukraine, hyperinflation, and others) has caused macroeconomic and fiscal instability, with other big problems, as fluctuations in the energy markets affect economies that are highly dependent on energy imports. There is a particular relevance of geopolitical events and inflation associated with energy insecurity to energy-exporting countries that intend to use energy deliveries to further their political objectives. Energy security is also a concern for developing countries which continue to be dependent on foreign technical expertise for a variety of reasons, including the inability to adapt imported energy technologies to suit their local demand. Additionally,

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power stations, pipelines, refineries, and transmission lines can be targeted easily in civil wars, domestic uprisings, and international conflicts. Increasing commodity, energy, and food prices have led to inflation reaching a historical high due to an uncertain economic climate and rising operating costs. Consequently, there is a concern about economic stability.

Previously was introduced and used the M.E.N. (MegaEcoNega) concept [5,6] as a basis of sustainable solutions in terms of energy production and consumption. Megawatt (need for energy consumption), with green energetic economy through what is recognized as Ecowatt (cleen energy without wastes), correlated to Negawatt (preservation of the energy through specific methods, technologies, even education at all levels (all life sustainable integrative learning). An innovative way to foster efficient gains by negawatt markets would treat saved electricity as a commodity. The actual technologies and state policies are oriented all to megawatt markets (chemical imperialism) aiming to gain indirectly from the green economy. In this context, Lovins says and Prisac with his coauthors [2,37] reaffirm the following statement: *"perhaps the strongest incentive to create negawatt markets is their win-win solutions to many environmental problems…it's now generally cheaper to save fuel than to burn it, global warming, acid rain and urban smog can be reduced not at a cost but at a profit."* In terms of energy management, MEN (Mega-Eco-Nega) paradigm is one of the basic models that served to elaborate ENSEC sustainable development concept for energy [6,38] (Figure 3).

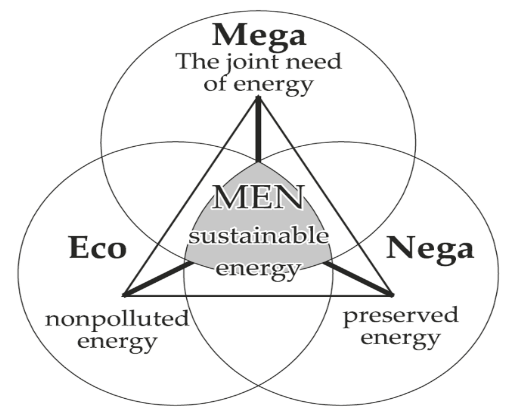

Figure 3: MEN Concept of sustainable energy consumption [6].

This does mean an increasing need for energy (Megawatt) (socioeconomic development), but the challenge is that its consumption and its sources need to be ecological (Ecowatt) (associated to green energy) with a Negawatt consumption or efficient and preserved energy, because its sources are limited [2] (special IT and automatic technologies, produces, systems [39], a high level of all-life sustainable education [29], in transdisciplinary schools of innovative networking as advanced knowledge transdisciplinary spaces [18,40]. In the last years, important advances have been made in the storage of thermal energy by using salt, stone, or sand batteries. It is not always evident when a resource can be considered renewable. We propose that a resource is non-renewable if it cannot be recovered or replenished with today's technology neither at a practicable cost nor within a reasonable time [41]. It will be clear that renewable or non-renewable is often a matter of degree-some renewable resources are replenished more easily than others, affirmation not true in an absolute sense. It is not possible to produce (or indeed to live) without any natural resources we need to study only those situations where such substitution is possible.

Green Energy Alternative Energetic Solutions and Technologies

Developing renewable green energy sources is one of the most critical topics in material- and energy-related fields nowadays, due to the growing demand for energy and increasing concerns regarding environmental pollution problems. About green possible energies there are many discussions, every solution being available strictly in a very narrow fashion. The energetic problem has to be approached from the perspective of the natural resources presented in the diagram from figure 4, sustainable energy future as part of the green energy solution [6]. Rapid and deep reductions in greenhouse gas emission are needed to avoid dangerous climate change. This will necessitate low-carbon transitions across electricity, transport, heat, industrial, forestry, and agricultural systems. But despite recent rapid growth in renewable electricity generation, the rate of progress toward this wider goal of deep decarbonization remains slow. From the presented diagram is seen the electrical possible global hub, where off it is possible to obtain all specific energetic needs, as: thermal energy, mechanical energy, radiant energy, frigotechnic energy, chemical energy, electromagnetic energy, and other energetic utilization (Figure 4).

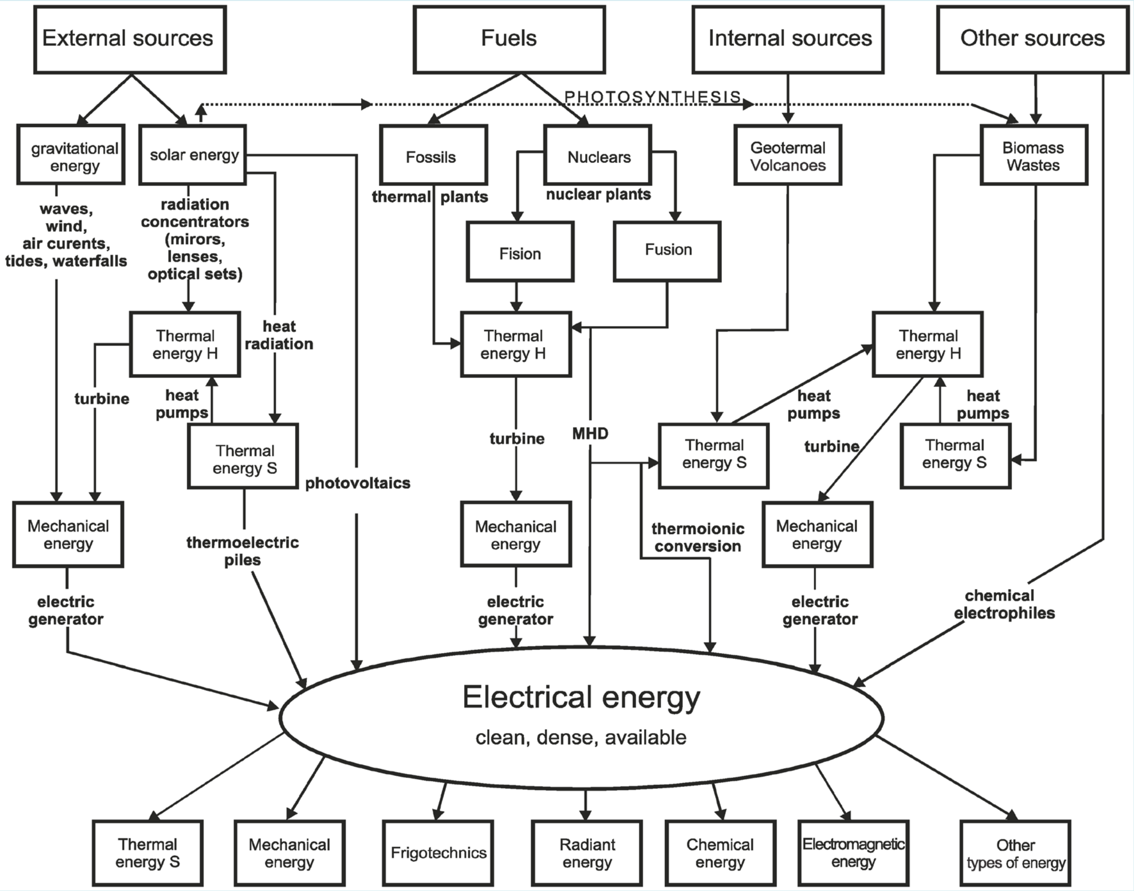

Figure 4: The diagram of the main transformations into electricity of the primary energies (S: "Soft thermal energy" with low temperature; H: "Hard thermal energy" with high temperature; MHD: magnetohydrodynamic) [6].

Embracing renewable energy sources, leveraging technological innovations, and fostering collaboration are key to overcoming the challenges posed by climate change and energy security. The journey toward a sustainable energy future demands collective action and steadfast commitment from all sectors of the economy at all levels, tailored to diverse regional needs, through high innovation level, with progressive policies, prioritizing sustainable solutions, so the course toward a resilient and equitable energy system that meets the needs of present and future generations will be a reality. The permacrisis, associated with a globally extended period of instability and insecurity, especially in the many wars as a geopolitical problem associated with climate change and the global energy crisis is of most importance regarding the political decision to begin the transition from the dependence on fossil fuels to renewable energy and/or decarbonization, through a diversification of the energetic resources to create a real, sustainable green energy politics, even circular economy [38,42].

The big dilemma of these aspects remains the quality of the energy resources, especially of nuclear energy, which seems to be the "Holy Grail" of decarbonization and energy source distribution, to be used in combination with renewable sources of energy. Wind and solar energy green resources, with some possible disadvantages, require reliable storage of electricity on a large scale, which causes it to become extremely expensive [2]. The paper presents a very optimistic perspective on the energetic analysis of the long-term trend for energy consumption and generation as a case of the big players in carbon emission searching for the *"black swan"* of energy [2,43]. We have to transform challenges into opportunities to pave the way toward resilient, stable, and predictable energies. Even the uncertainties underlie the future path of the energy system, electrification will continue with energy storage associated systems, including lithium-ion battery cell and others rare earth manufacturing markets for penetration of renewable energy and system resilience even the general energy storage, with small and large-scale renewable integration, grid support and behind-the-meter storage; low-carbon gas (hydrogen technology and renewable gas), solar and wind energy will grow, driven by specific contextual guides, dominating global power economy; charcoal, oil and gas will remain essential complementary components of the energy mix, with carbon sequestration, with global coverage on carbon capture utilization and storage (CCUS) even specific technologies for decarbonization solutions [44].

Hydrogen and renewable gas production need new transportation patterns and market outlooks; similar things are necessary for solar PV, as a global PV market with end-to-end supply chain insights [45]. The projections and trends of the International Atomic Agency about nuclear energy are 6% to 12% of global energy by 2050 because of the high energetic potential and low carbon emission of fission nuclear sources. An alternative to giant fission plants is Small Modular Reactors (SMR) or Small and Advanced Reactors (SAR) [46] installed in a shorter time at the place of consumption (such as plants, factories, or towns). In case of the occurrence of a natural disaster or a military conflict, these will be more reliable but also will ensure an easier and quicker cooling of a reactor in case of emergency. Renewable sources have quite a bright future, representing 62 % of all power generation by 2050 [2,47]. Solar and wind sources alone are estimated at 48% in 2050, whereas oil and coal are predicted to decrease dramatically, which is due to halve in their use of generating power. Hydropower will continue as a stable energy source, but the investment will be kept at a similar level due to high costs, environmental problems, and geographical issues, even the low level of the water stock. Fossil fuels, nuclear, and hydro energy will continue to be used in the next 30 years because of geopolitical considerations and because of technical existent problems with other energy sources. The production of solar panels, wind generators, and batteries for storage implies the increased demand for rare earth elements to be used, such as graphite, lithium, cobalt, indium, vanadium, nickel, silver, neodymium, lead, molybdenum, aluminum, zinc, copper, manganese, chromium, with high costs. The World Bank forecasts a low-carbon future, which will be very mineral intensive because clean energy technologies need more materials than fossil-fuel-based electricity generation technologies. By 2050, the increase in demand for graphite, lithium and cobalt will be around 500%, comparable to 2018 [48]. Most of the critical elements required in producing clean energy technologies are found concentrated in select regions of the world, 78% of graphite is produced by China and Brazil [49], and 70% of cobalt is produced in the Republic of Congo [50], while 70% of lithium is produced by Australia and Chile [49]. One of the desired energy is fusion a large-scale energy source with no carbon emissions which could help countries reduce their reliance on fossil fuels, even nuclear fission, leading to much-reduced carbon emissions, avoiding the dangers from fission plants and thus helping us tackle the specific crisis. The nuclear fusion reaction, would be a possible “holy grail” which transform hydrogen plasma into helium under enormous heat and pressure, releasing huge amounts of clean, renewable energy.

Hydrogen

Hydrogen energy technologies are considered as the cutting-edge clean energy technologies all over the world [51]. One of the most important aspects analyzed in this sequence is the hydrogen energy resource instead of methane, with a very important industry adjacent to the production of hydrogen. The water electrolysis as a solution to produce hydrogen is completed with photo-catalitic and electro-catalitic technologies [52,53]. Germany is attempting to solve the problem of lack of energy by developing hydrogen green energy, as it plays a central role in implementing the Paris Agreement on climate and in the development of the chemical industry [54]. The only way to replace coal in the metallurgical sector (which is responsible for around 10% of the carbon emissions) is by using hydrogen. One of the ambitious projects is shown by the agreements between Canada and Germany focused on producing and supplying hydrogen in Europe [49]. Canada has vast experience and possesses advanced technologies in producing green and clean hydrogen by electrolysis using renewable energy [53]. Nevertheless, 95% of today’s hydrogen is sourced from fossil sources. Research and development of hydrogen production is needed to make renewable hydrogen cost competitive against fossil hydrogen. This generates demands for fundamental research on new concepts and materials in electrolysis [52]. There are three major challenges for using hydrogen: production, storage, and end-use. All of these are parts of a bigger system and processes that are highly intensive in terms of material consumption, which contributes to the pollution of the environment. Electrolysis itself needs electricity, which is likely to be sourced from either solar and wind, plants which is much more expensive to generate than the electricity which is produced from fossil fuels or nuclear. The benefits of utilizing hydrogen as an energy source in transportation, household and industrial environments would come mainly from (a) a potentially unlimited supply due to its highest mass abundance on Earth compared to other chemical elements, (b) its significant energy storage capacity, nearly three times higher per volume unit than those of other classic sources such as methane, and c) the control of carbon-related emission and pollution, which can take place at the initial step of the generation of the fuel and not when energy is released (zero-emissivity). Independently of its final use, green hydrogen is expected to be produced massively in the near future from carbon-neutral and environmentally benign processes [54]. Catalysis plays an essential role in a significant number of processes that consider green hydrogen generation. The green generation of hydrogen using conventional catalysts and molecules from bio-resources, such as water, alcohol, acetic acid, and others, appears as a hot research field subjected to intensive research [55]. Building up a commercial technology will require a significant improvement to compete with the well-established (and gray but not green) methane dry reforming process. The more environmentally benign energy-intensive water-electrolysis would also be a benchmark reference if combined with a solar (photovoltaic) energy supply [56]. Nevertheless, at present, the water electrolysis economic viability is restricted by the need for more efficient and stable membranes as well as working around the clock, which in turn would require other energy sources in addition to the sun. Within the context of hydrogen production from natural resources, photocatalysis would be an attractive possibility as it works at room temperature and pressure. Ideally, hydrogen can be produced photo-catalytically from water but independently of catalytic aspects, the separation cost of hydrogen and oxygen could make the cost of the technology prohibitive. Unless newly developed efficient (not currently achievable) photocatalysts can produce the two gases separately at two different physical locations even from the initial stage of the reaction, the use of water as the hydrogen source may not find application as a competing technology. Therefore, the use of broadly available and cheap bio-resources such as methanol, ethanol and others in water as the primary target(s) of the process appears as a rather convenient alternative. However, as is well-known, the efficiency of the corresponding hydrogen production photocatalytic processes is limited, restraining their industrial application. Meanwhile, the generation and conversion efficiency of these renewable energy systems largely depend on the effectiveness of the catalysts. Actually, new 2D materials have boomed since the successful fabrication of graphene from graphite in 2004 [57]. The unique physical, electronic, and chemical properties of these 2D materials mean that they can be expected to have rich and exciting structural and physio-chemical properties, making them promising for numerous applications in electronics, sensing, photonics, catalysis, bioengineering, energy harvesting, flexible electronics etc. Furthermore, based on the unique assembly properties of 2D materials, they can be easily combined with other functional materials to form heterostructured hybrids that would give rise to intriguing features, such as integrating the merits and overcoming the weaknesses of the individual counterparts and even generating new properties or functions. EU also adopted the 'Hydrogen Strategy' in 2020 and put forward a vision for the creation of a European hydrogen ecosystem for research and innovation to scale up production and infrastructure to match that of the international dimensions [47].

Nuclear Energy Fission and Fusion Sources

Another dilemma is that a nuclear reactor could produce a massive quantity of energy, but there are significant problems associated with nuclear power plant: the classic nuclear reactors are very expensive whilst also time-consuming to build. The biggest threat posed by nuclear energy is radiation polluting the environment in the instance of a leak, or an explosion in the reactor, even the wastes. This may happen because of a number of reasons such as damage during war, loss of control at the power plant, overheating, lack of the reactor coolant, or a natural disaster. Such examples are the two catastrophes, in Chernobyl (1986), Fukushima (2011), and the very closed is Zaporozhie in Ukraine, the largest nuclear power plant in Europe, as part of the military action in this region in the context of the Russian Ukrainian war [2]. In the context of the permacrisis, with energy representing one of the five challenging transitions, the analysis of this paper is focused on the energetic options and solutions in the large global crisis. The biggest energy security question is now, how could be used alternative sources of energy with the goal of decarbonization (which is one of the EU goals) in order to assure reliable, economically feasible, and geopolitical safer energy, because gas is no longer a reliable long-term option because of permacrises. EU and entire world need climate-neutral energy and more autonomy in this respect, and, according to long-term strategy, with an economy of net-zero greenhouse gas emissions [58]. One of the most radical decisions for a green energy strategy was taken by Germany in June 2011 to phase out all nuclear stations by 2022, because of the energy crisis, this goal was not fully achieved by 2022 [59]. On April 15, 2023 Germany stopped producing any electricity from nuclear power plants [60]. The projects and international partnerships could be a good example of green and energy independence.

As a transitional solution faster fission reactors mean more reactions, squeezing more energy out of the same volume of fuel. Fast reactors can even get energy out of fuel already spent by conventional reactors. The nation's existing nuclear waste contains enough energy to power the entire country for hundred years with fast reactors. Because of their efficiency, fast reactors can operate for longer periods before needing to be refueled. Fast reactor designs also tend to use coolants other than water, influencing reactor construction. Medium-sized reactors are well suited to replace aging fossil fuel plants because they aren't as expensive and don't take as much time to build as conventional, full-size reactors [61].

Nuclear fusion, the physical reaction that powers the stars, is a potentially unlimited source of energy that could end our energy worries and dependence on fossil fuels. The construction of industrial plants to produce electricity from fusion is one of the greatest scientific challenges of our time. In this sense we have ITER, the largest nuclear fusion reactor of its kind in the world in the world, called tokamak, which demonstrates the feasibility of fusion as a large-scale energy source with no carbon emissions [62]. Other such experiments are two prototype for the external heating of the ITER plasma, called the 'MITICA' and 'SPIDER'. Once completed, ITER will be used to conduct scientific research into fusion power, with the hope of being able to demonstrate the viability of building a nuclear fusion reactor. The facility is scheduled for completion in 2025, and the hope is that the first plasma generation will be achieved by the end of 2025 year. If successful, nuclear fusion could well help countries reduce their reliance on fossil fuels, even nuclear fission, leading to much-reduced carbon emissions, avoiding the dangers from fission plants and thus helping us tackle the specific crisis. Nuclear fusion reaction, as a possible *"holy grail"* transform hydrogen plasma into helium under enormous heat and pressure, releasing huge amounts of clean, renewable energy. This virtually limitless source of energy faces a lot of technical insurmountable challenges at this moment. ITER is the biggest, most powerful fusion device ever devised, which will finally show that fusion power plants can really be built. After the first plasma will be produced, in 2025, it will probably take until 2035 to achieve full fusion power, when the sun will come on the earth. The principle of the fusion is quite simple, two light nuclei, hydrogen isotopes, deuterium and tritium, combine to form a heavier nucleus and energy. Deuterium is abundant in sea water and tritium can be produced from lithium, thus a fusion plant would have no shortage of fuel, so, it would not produce pollutants or radioactive waste and would be intrinsically safe, because fusion is not a chain reaction, the fusion promises clean and sustainable energy. The production of energy from fusion reactions has already been demonstrated in both tokamaks and stellarators, the two possible designs for a fusion reactor, but only in small research reactors that consume more energy than they produce. The next step is demonstrating that fusion can generate energy at the power-plant scale [63,64]. Because of the high magnetic fields that they need to generate (up to 13 Tesla), all ITER's magnets are made of superconducting material-depending on the magnet, NbTi, Nb3Al or Nb3Sn-and will operate at liquid-helium temperatures [65].

Discussions, Conclusions, and Further Research

The economic and consequently, energetic security of the environmental and socioeconomic systems in permacrisis situation has to be reevaluated, reshaping the methods in a transdisciplinary way integrating the energetic resources, specific technologies, education at all levels, in the new ENSEC Mega-Eeco-Nega energetic paradigm. In the context of the permacrisis, with energy representing one of the five challenging transitions, the analysis of this paper is focused on the energetic options and solutions for entire world in the large global crisis, with some commandments, zero carbonation, with a green natural energy, resilient energetic resources, using only natural intelligent solutions and technologies, in order to assure reliable, economically feasible, and geopolitical safer energy.

A conclusion of this paper is that solar, gravitational, energetic nuclear fusion, without any nuclear fission energetic, hydrogen instead methane, with alternative green technologies, the storage solutions for the electrical energy (batteries), even for the thermal energy (liquid and sand storage rooms). The "black swan" solution is a complex one in a transdisciplinary way, in very unstable dynamics with viable, unpredictable, non-resilient solutions for decades. Regarding green energies, there are a lot of discussions, every solution being available strictly in a very narrow fashion. The problem has to be approached from the perspective of the natural energetic resources, as presented in the energetic diagram, which has to be completed in the future with new energetic challenges. Unlike wind and solar, which only produce power when the wind is blowing and the sun is shining, nuclear plants run 24 hours a day, seven days a week, generating electricity without producing greenhouse gas emissions, making them an appealing alternative to natural gas and coal power plants as a clean source of always-on power but with a very latent danger, so the role of the nuclear decarbonizing global economies would be not available, technology, funding, regulation and even geopolitical concerns making unclear if next-generation nuclear will have a meaningful impact in the near-term. Fast reactors, as a possible fission energetic alternative, do not slow down the fission reaction. There are some important questions for the future research to reestablished the equilibrium in the energetic sector: how can this component of a resilient economy speed up the shift from fossil fuels to renewable energy sources to stop climate change; how can innovations in renewable energy technologies and energy storage systems improve efficiency and affordability; what kind of policies and regulatory frameworks are most effective in promoting investment in clean energy infrastructure to create a competitive market; what do investors prioritize when evaluating funding opportunities in sustainable energy projects, and how can innovators tailor their proposals to meet these criteria effectively; what innovative strategies can ensure equitable access to reliable electricity, especially in regions where it lacks; what impact do successful implementation of energy projects have on local communities and economies, and how can these successes be effectively communicated to encourage broader adoption; how can stakeholders collaborate across sectors and regions to expedite the adoption of sustainable energy solutions to avoid permacrisis consequences, for a new sustainable energy and economy.

The puzzle of decarbonization and energy security and sustainability, both for the final consumer and for the national scale, can only be solved if science and new technology will find the energy *„black swan"* which is a fully autonomic energy source that provides a certain independence from external sources. In this case, each country has its own independent way of energy production, considering the natural resources and technologies available. In the long run, nuclear energy will stay yet in use, even it is a very dangerous energetic sources (see Chernobyl, Fukushima, Zaporizhia, and now, possible Kursk) and will make up between 6-12% of all energy production by 2050, Germany denies the major role of this kind of energy. The nuclear fusion is a possible clear energy source through tokamak and stellarator technical specific solutions associated with supperconductivity. The new ENSEC (environment, society, economy) transdisciplinary pattern needs a crisis approach about the necessity of the very important role of the implementation of the circular economy studied by the author. It means that all waste must be reused and recycled at all levels of the economic value chain in a very intelligent and pragmatic way. This open a vast area for research, technologies and educational progress. In this sense hydrogen could be a very challenging renewable source for the future decades.

Finally, the challenges and perspectives in this research area will be expounded based on the current research status.

Author Contributions

The present research is the result of the collaboration between Emanuel University of Oradea (Ioan G. Pop & Carmen Fagadar) and Divitia Gratiae Chisinau (Igor Prisac) and other universities (Bogdan Voda Cluj, Technical University Cluj) with 5 articles in the last 4 years: 1) Prisac I., Pop I.G., 2023, Redefining Sustainable Development in the Context of Transdisciplinary Paradigm; 2) Prisac I., Pop I.G., Fagadar C., The Energy Security of Eastern Europe in the Context of the Russian Ukrainian War. In: Journal of Waste Management & Xenobiotics. Medwin Publishers, 2023; 3) Pop Ioan G., Codruta Badea Manuela, Jaradat Muhammad Hadi, Vaduva Sebastian, Prisac Igor, Talpos Mihai-Florin, Pop Izabella Eugenia, Considerations about Sustainable Development of the ENSEC (Environmental-Social-Economic) Systems. Transdisciplinary M.E.N. (Megawatt, Ecowatt, Negawatt) Eco-Energetic Paradigm. In: Modern Perspectives in Economics, Business and Management; 4) Pop I.G., Jaradat M.H., Fagadar C., Pop I.E. and Prisac I., Pollution, Waste, and the New CE-CBE Integrative Recycling Paradigm in the Knowledge Based Society/Economy, 2022, Review Article, Open Access Journal of Waste Management & Xenobiotics; 5) Prisac I., Pop I.G., Fagadar C., Transdisciplinary Approach on the Energy Security of Eastern Europe in the Context of the Russian Ukrainian War, to be published.

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Contribution to the paper of the authors is a specific collective one, with major contributions on chapters 2 & 3 by Ioan G Pop & Igor Prisac and on chapter 4 as follows: MEN energetic concept- Ioan G Pop; Green energy, alternative energetic solutions and technologies-Igor Prisac, Carmen Fagadar, Ioan G Pop; Hydrogen-Igor Prisac, Ioan G Pop; Fission and fusion energy Ioan G. Pop, Carmen Fagadar. The coordination of the research was done by Ioan G Pop.

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Conflicts of Interest

The authors declare no conflicts of interest.

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