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Energetic Sustainability and the Environment: A Transdisciplinary, Economic–Ecological Approach

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Abstract: The paper combines original concepts about eco-energetic systems, in a transdisciplinary sustainable context. Firstly, it introduces the concept of M.E.N. (Mega-Eco-Nega-Watt), the eco-energetic paradigm based on three different but complementary ecological economic spaces: the *Megawatt* as needed energy, the *Ecowatt* as ecological energy, and the *Negawatt* as preserved energy. The paper also deals with the renewable energies and technologies in the context of electrical energy production. Secondly, in the context of the M.E.N. eco-energetic paradigm, comprehensive definitions are given about eco-energetic systems and for pollution. Thirdly, the paper introduces a new formula for the eco-energetic efficiency which correlates the energetic efficiency of the system and the necessary newly defined ecological coefficient. The proposed formula for eco-energetic efficiency enables an interesting form of relating to different situations in which the input energy, output energy, lost energy, and externalities involved in an energetic process, interact to produce energy in a specific energetic system, in connection with the circular resilient economy model. Finally, the paper presents an original energetic diagram to explain different channels to produce electricity in a resilience regime, with high eco-energetic efficiency from primary external energetic sources (gravitation and solar sources), fuels (classical and radioactive), internal energetic sources (geothermal, volcanoes) and other kind of sources. Regardless the kind of energetic sources used to obtain electricity, the entire process should be sustainable in what concerns the transdisciplinary integration of the different representative spheres as energy, socio-economy, and ecology (environment).

Keywords: M.E.N. (Mega-Eco-Nega) eco-energetic paradigm; eco-energetic efficiency; ecological coefficient; eco-energetic chains; energetic sustainability; circular resilient model; eco-energetic diagram

1. Introduction to the Transdisciplinary Pattern for Eco-Energetic Systems

Whenever the energetic impact upon sustainable development is analyzed, the positive and negative economic, environmental, and social implications should be considered [1–6]. The global demand for energy along with its potential disturbance to the environment in the context of resource shortages, requires both a local and international as well as a transdisciplinary method to educate the entire society [2,7–11], considering all sociocultural [5,12], administrative, and legal realities [12,13]. These aspects could solve the problem concerning the energetic impact over the environment (household technology), with a high awareness level of responsibility regarding the need for a clean, healthy environment [4,5,7,8,14–19]. Any approach regarding the actual matter of energy must also consider the socio-economic impact on all levels. Therefore, a modular systemic approach was introduced, with different representative spheres as necessary knowledge spaces to be analyzed: energy, economy, ecology (environment), with the main core of them, sustainable education [9,10,20,21]. Consequently, every 'E' component—energy, economy, ecology-environment, and education—has a well-established role and position within a balanced and natural state of a new kind of equilibrium that is desired to be achieved [8,22].

In this context, to explain the achieving advanced knowledge, the paper introduces the original DIMLAK (Data, Information, Messages, Learning and Advanced Knowledge) model of the knowledge integration [23,24]. Shortly, the DIMLAK model represents a holistic way of the knowledge integration management (KIM), with different heterarchical–hierarchic stages of knowledge integration represented by the transdisciplinary chains with five sequences, as follows: (a) Data (D), as statistical approach; (b) Information (I), as syntactic way to relate descriptions, definitions, or perspectives; (c) Synergistic contextual message (M), as semantics in order to give significance in a synergistic context; (d) Sustainable integrative all-life learning (L), as pragmatic pattern comprising strategies, practices, methods, or specific approaches; and (e) Advanced Knowledge (AK), as an apobetic level (top, highest level) embodying principles, insights, moral aspects, or archetypes, to attend the desired level of expertise (wisdom as top-down perspective, and skills as bottom-up perspective), in an emergent continuum flow. In this way, the new perspective of knowledge creates a better transdisciplinary understanding as a dynamic synergistic integrative process [23]. So, it is necessary to implement the sustainable integrative learning/teaching as a key factor for sustained, inclusive, and equitable economic growth to achieve all the Millennium Development Goals [8–10,14].

Taking into consideration the bio-economic representation of the economic processes, there is here an entropic transformation of valuable natural resources (low entropy) into valuable waste (high entropy), so it is necessary in every economic transition of the developing countries to follow a dynamic equilibrium regarding these two types of the entropic states [12,13,25,26]. Transdiciplinarity should solve the main dilemmas because the economic and social systems are consuming and transforming 'mattergy' (energy embedded in matter), as natural resources, and 'informaction' (information by intentional action) as non-material and non-consumable specific anthropic resources [24,27,28]. It is necessary to improve the natural dynamic equilibrium to achieve a desired sustainable dynamic in a socio-economic ecological system, so it can satisfy human needs, as well as the capacity of reducing entropy to its minimum possible level [13,26]. The economic-ecological needs are approached from the point of view of a dynamic equilibrium and natural development, necessary to find optimal evolving ways using local and global political, legislative, educational mechanisms to make this phenomenon happen [12,13]. Also, good synergies in achieving this objective come to be the main catalysts in developing higher technologies and innovation as well as higher responsibility for a rational consumption of goods and resources and environment protection, in the so called (3 + 1) Rs paradigm (reduce, reuse, recycle, and recombine) [16,27]. The consumerism with its "consume more energy to be more complex", known as "chemical imperialism", in which the harvested chemicals are stored as matter-embedded energy, is a false economic progress concept which cannot grow the level of complexity [25,26]. So, it is necessary to rethink the socioeconomic development strategies in the context of circular resilient economy with a knowledge based society/economy (KBS/E) [16,24,29–32], as a final goal of the advanced knowledge in the synergistic significant context (synergy, as $1 + 1 > 2$, and signification as $1 - 1 \neq 0$) [24,28]. Considering the chains of energy production, transportation, and processing—with electric energy as a final goal—it is necessary to make an extension of the well-known thermodynamics, in a new conceptual frame, that of the eco-energy, as sum and synthesis of what energy does mean for human life and for the planet, as well [9,10,25]. Therefore, an original definition for the eco-energetic efficiency e is introduced to explain the eco-energetic system with its final electrical energy product. Using the input energy, $W_{en,enter}$, the output eco-energy, $W_{ecoen,out}$, and energetic losses, $W_{en,loss}$, altogether with externalities $W_{eco,cost}$, as ecological impact on energetic costs, the classical energetic efficiency η, and the ecological coefficient τ, are put together in a comprehensive form.

2. An Integrative Synergistic Approach to Electrical Eco-Energetic Sustainable System

2.1. The M.E.N. (Mega-Eco-Nega-Watt) Transdisciplinary Paradigm

We begin by focusing our analyses on some known eco-energetic chains that have as final product electrical energy [14,33]. To better understand the issues of the energy–environment relationship, a new modular approach is proposed. The traditional models of energy production are working with wasteful by-products and collateral impairments (emission of CO_2, CO, NO_x, SO_2, HC, dioxin, thermal pollution, noise pollution, population illnesses, etc.), generating prohibitive costs, and causing environmental damages and imbalances, that need to be eliminated [34–38]. For these reasons, a new transdisciplinary triad was put together, M.E.N. (Megawatt, Ecowatt, Negawatt), as a paradigmatic concept, to better understand the quantitative–qualitative content of an eco-energetic system working in a sustainable way [10,13,14,20]. The common factor of these three components is life itself, having the human being as a determinant factor. The M.E.N. concept is introduced in order to offer a synergistic-generative overview on energetics with an original energetic 'projection' in planning the needs of energy—Megawatt [37,38]; clean energy—Ecowatt [24,39]; and finally, efficiency and preserving energetic resources, including alternative energies and technologies—Negawatt [40–42]. For a better understanding of the introduced M.E.N. systemic transdisciplinary original concept, it is necessary to define the content of every part of this conceptual construct, and the signification of the synergistic-generative combination M.E.N., as sustainable energy, presented in Figure 1. Firstly, it is necessary to define the sphere of Megawatt, considered as "*the joint need of energy*", where energy is distributed between different categories of final users, energy demands being related to the lifestyle, standard of living, demographics, existing resources, as well as the costs involved in transforming different types of energy into electric energy [14,37,38,42]. Secondly, there is a necessity of clean energy, the electrical energy as it is known, circumscribed in the term Ecowatt, as "*every kind of energy economically transformed into cleansed and low-polluting energy*", with the energy of pollutant fuels, equivalent in kWh_e, that sustains the economy and preserves the ecosphere; fuel energy that is transformed into energy savings in clean conditions; searching for higher efficiency in electricity production and use, searching for eco-megawatt. The increasing of the efficiency in using electricity does not imply adverse effects, replacing fossil fuels with electricity saves energy, even considering the production of electricity itself [10,39,42]. The third sphere of the M.E.N. paradigm is Negawatt, which is talking about "*the cheapest energy as one that is still not consumed*", the energy saving being the first and most important source of energy, which requires highly efficient facilities, energetic transport with minimal loss and controlled consumption, preserving resources, alternative energy sources and specific technologies, and increased efficiency of energy sources and consumption. The negawatt represents also saved energy, by reducing energetic losses within the system, and by limiting unnecessary consumption [12,31,34].

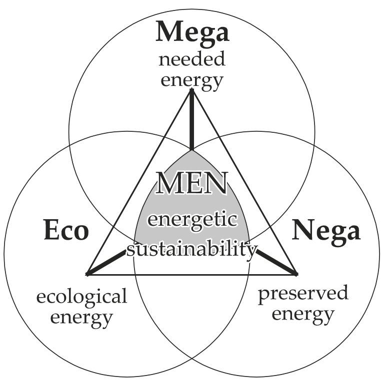

Figure 1. A transdisciplinary representation of the M.E.N. eco-energetic sustainability (Megawatt, Ecowatt, Negawatt).

In this way, the eco-energetic system becomes more efficient preserving and processing efficiently the energy [12,31,34]. Renewable energies and technologies are very important to be considered as a special category, making the negawatt cheaper, cleaner, and more reliable than a conventional megawatt [24,40,41]. Any energetic system produces—besides thermal, mechanical, or electrical energy—a multitude of other polluting byproducts that increase the cost of life that can equivalently be quantified and estimated as "energetic costs" [14,33,36–38,42,43]. As is presented in Figure 1, the common space M.E.N. of the superposition of megawatt, ecowatt, and negawatt spheres, can be considered the synergistic-generative space of the sustainability in the eco-energetics domain. M.E.N. energetic sustainability is considering that life, at all its stages, must circumscribe the multitude of factors that determines it, by minimizing, as much as possible, the risk factors, in the context of an increasing globalization and natural imbalances, of constant growth of energy needs, and life-style improvements. This standard of living with associated risks and constraints, in a sociocultural context in which "natural" education at all institutional levels must become a *modus vivendi*, condition, and purpose for protecting and preserving life and natural planetary equilibrium [8,20,33,38]. In order to achieve these standard goals by a qualitative-quantitative approach, the eco-energetic system has to be re-defined, in a new synergistic-generative way, as "*an energy processing system, which produces, transports, consumes, stores, converts energy from one form to another, etc, in the conditions of a continuing growth of vital needs of energy (megawatt), considering the ecologic costs with minimum energetic loss, by eliminating pollutant energy sources (ecowatt), by introducing renewable and alternative energies, preserving the resources and perfecting the technologies, and related techniques (negawatt), with a high level of efficiency that ensures an energetic sustainable development, locally, regionally, and globally (as mega-eco-nega-watt)*" [14,33].

2.2. The Efficiency and Ecological Coefficient as Indicators for Sustainable Eco-Energetic Systems

In order to make the introduced M.E.N. paradigm efficient, in studying the eco-energetic systems it is necessary to give a more extensive definition for pollution putting together the global and local aspects of the sustainable development, as follows: "*pollution is considered as a modification of the natural system properties, by adding or subtracting qualitative-quantitative entities due to the transfer of material, energy or information, through natural and anthropic actions, resulting an imbalance in a system with local, regional and global consequences*" [14,24,33].

In this context, it is necessary to introduce the eco-energetic sustainability as a transdisciplinary concept, as a complex relationship between environment, society, and economy, in a dynamical correlation with the M.E.N. paradigm [14,24]. An eco-energetic system that processes energy must ensure a clean energy output, un-polluted and unpolluting, easily accessible, storable, with cost-efficient production. Until now, only electrical energy seems to fulfill these conditions, being easily accessible, partially storable (for a while this in an inconvenience), convertible efficiently with acceptable costs from every type of energy. Electricity is transformable into another kind of energy by physical processes and special techniques and technologies, with a better efficiency, and lower costs. In every eco-energetic chain, there is an energetic balance of the energies as follows

$$W_{en,enter} = W_{en,loss} + W_{ecoen,out} \quad (1)$$

with input energy, $W_{en,enter}$, output energy, $W_{ecoen,out}$, and energetic loses, $W_{en,loss}$. To these energies involved in an eco-energetic chain, it is necessary to add the term $W_{eco,cost}$, as ecological impact on energetic costs, well known through externalities [1,16,19,24,30,43,44]. Because externalities are not considered part of the energetic balance, the M.E.N. eco-energetic transdisciplinary paradigm reconfigures a new ecological-economic way to express this new pattern, by introducing the eco-energetic efficiency e, as follows

$$e = W_{ecoen,out} / (W_{en,loss} + W_{eco,cost}) \quad (2)$$

instead of the energetic efficiency

$$\eta = W_{ecoen,out} / W_{en,enter} \quad (3)$$

So, it is putting together $W_{en,loss}$ and $W_{eco,cost}$, as a sum $W_{en,loss} + W_{eco,cost}$, of every eco-energetic system considered to be 'eco-energetic damages'. In every eco-energetic process, the permanent aim is to reduce the 'eco-energetic damages', reducing energy losses, $W_{en,loss}$, increasing so classical energetic efficiency η, and decreasing externalities in the system, $W_{eco,cost}$, make the system more ecological.

After a little algebra is obtained, the comprehensive formula for the eco-energetic efficiency as

$$e = \eta / (1 + \tau\eta) \quad (4)$$

where τ, the ecological coefficient, is defined as

$$\tau = W_{eco,cost} / W_{ecoen,out} - 1 \quad (5)$$

with values between $\tau = -1$ (no, or very low ecological loses, with $W_{eco,cost} > 0$), and $\tau \geq 0$ (with a lot of vulnerabilities, identified with the ecological disaster, or "ecological emergency" situation, where $W_{eco,cost} = W_{eco,out}$). The situation identified by $\tau > -1$ and $\tau < 0$ represents the situation when $W_{eco,cost} > W_{ecoen,out}$.

2.3. Sustainability, Resilience, and Vulnerability within Eco-Energetic Systems

As presented before, the ecological parameter τ has values between $\tau = -1$ ($W_{eco,cost} > 0$), defining resiliency with no loss, or with very low ecological losses, and $\tau \geq 0$ ($W_{eco,cost} = W_{eco,out}$), associated with the vulnerabilities of the eco-energetic systems. These situations are considered as risks and ecological disaster or 'ecological emergency' situations, where ecological losses are comparable with the electrical energy at the end of the chain. The situation identified by $\tau > -1$ and $\tau < 0$ ($W_{eco,cost} > W_{ecoen,out}$) represents the viability of the eco-energetic systems. The most efficient eco-energetic systems ($e \geq 1$) assume for ecological coefficient τ values in the interval [−1,0), and energetic efficiency η more than 0.5. A system with large ecological losses must have a low energy loss to compensate the high ecological expenses, with the best possible efficiency, expressing an unstable balance. On the other hand, if τ is very small (close to −1), the systems have a better efficiency, even though the energetic losses could be at high levels. Overall, if the denominator of e, $W_{en,loss} + W_{eco,cost}$, should be made as small as possible, for the same value of the $W_{eco,out}$, the energetic efficiency e increases. If the value of the energy loss $W_{en,loss}$ becomes less then $W_{ecoen,out}$, and the ecological costs $W_{eco,cost}$ represents less then $W_{ecoen,out}$, both values of the energetic efficiency η and of the eco-energetic efficiency e are increasing, the quality of the eco-energetic system increases to high performance levels, evolving to energetic quality with $\eta \rightarrow 1$, the correspondent ecological coefficient attending its highest level, the two extreme situations indicating peaks of both energetic and ecological quality as well.

The optimum balance of such an eco-energetic system is found in a settlement between minimal energetic losses (η tends to its maximum possible value, and τ represented by minimal ecological expenditures) [19,33,43]. In this situation, externalities represented by the equivalent energetic term $W_{eco,cost}$, are correlated even to social welfare, to ecology, and also to the economy. However, we must first measure the social damages, which are not paid for by its main actors; secondly, translate these damages into a monetary value; and thirdly, explore how these external costs should be properly allocated to both the producers and consumers, thus influencing future behavior [19,43]. If the market takes into consideration the private costs, policy-makers should try to take account by quantifying the external costs [43,44], developing models for pollutant dispersion [15], and performing a lot of case studies, as well [45–47].

Electricity and transport are key factors for economic and socioeconomic development. The produced air pollutants (particles, oxides of nitrogen, Sulphur, dioxin, and others) provoke damages like morbidity or premature mortality (chronic bronchitis, asthma, heart failure) [14,15,48–50].

The health impacts of air pollution, the monetary valuation of these impacts ("value of statistical life"), accidents in the whole energy supply chain, and the assessment of other impacts like global warming, acidification, and eutrophication are parts of the externality costs with social, economic, and ecological contributions in a transdisciplinary sustainable development context [18,49]. Disaster risk reduction measures need to be integrated in development programs related to sustainable development, natural resource management, the environment, poverty reduction, urban development, and adaptation to climate change [1,2,23,24,51,52].

The research is interested in energetic systems that have electricity as the final ring of the chain. There are enough reasons to believe that electrical energy has no other competitor at this moment, being clean, appropriate, partially storable, and at hand, usable in a lot of ways and tools, with a very low pollutant level. The efficiency with which electricity is used is higher than the inefficiency of producing it, being considered analogous to "cutting butter with a chain saw" [40,42]. So, the myth that electricity is wasteful stems from ignoring the efficiency with which electricity is used and the inefficiency with which fuels are used in the marketplace. In other words, due to its indispensability, the costs no longer seem to matter that much, therefore even an environmental factor of $\tau = 0$ (vulnerable states), or close to that value is preferable to the lack of electricity, the price paid for it never being too big [33,42].

However, there are still enough resources to increase the efficiency of using electricity in various technological processes. Thus, the steel produced with electro-technologies based on fossil fuels requires less energy consumption and lower CO_2 emissions than steel coke. Energy savings are estimated at 70% and the emission of CO_2 as well as other pollutants being considerably reduced [3,53]. The production of electricity requires three categories of costs: investment and maintenance costs (CI), fuel costs (CC), and external costs (CP) (air pollution, noise, greenhouse effect etc.) [14,15,37,42]. All these costs are related and expressed in kWh_e as the easiest way to compare relative costs, various ways of producing electricity even when it is considered a co-generative process [54]. Worldwide consumption based on different fuel types is changing continuously with a sensible and constantly increase of the renewable contributions, and a decrease for coals and oil, with a specific distribution in the global economy from a sustainable point of view [10,20,38,55,56]. Externality costs expressed by $W_{eco,cost}$ are referring mainly to emissions of SO_2, SO_3, NO_x and others, as well as to the greenhouse effect (CO_2, N_2O, and CH_4), ionizing radiations and to other pollutants [19,43]. The estimated external costs include several components correlated with noise, poor visibility (e.g., smog), risk of major accidents with long term consequences (especially for nuclear plants) [48,49], emissions and health risks during the operation of power plants and during different stages regarding fuel processing and transportation, as well as risks during construction and from related technologies [16,18,40,47]. Burning fossil fuels for electricity generation also releases trace metals such as beryllium, cadmium, chromium, copper, manganese, mercury, nickel, and silver into the environment, which also act as pollutants [14,15,17]. The incorporation of the external costs ('externalities') [4,19,43,44] into energy prices is important to sustainable energy policy, as a key challenge, and an important step towards "getting the prices right" [16,19,24,47,54,57]. The economic growth is the measure of increasing human welfare, with consumption possibilities as major component of this, as welfare is understood by the public, aware that economic growth alone cannot fully describe its needs and wants. It is necessary to be mindful of this, given some of the negative consequences of uncontrolled economic activity—health risks from transport emissions and ozone depletion, declining biodiversity from loss of habitat, and new forms of inequality associated with changes in technologies and production patterns [18,49,53,58]. Because a significant part of the energy is yet produced using fossil fuels such as coal, oil, and gas, a lot of associated environmental problems are exceeding human activity as greenhouse effect, acid rains, air pollution, and ozone layer depletion [18,47]. So, it is necessary to implement alternative energy sources such as wind energy, solar energy, nuclear energy, hydraulic energy, and others—known as renewable energies with a very small polluting effect—using the new circular resilient economy model as a key for boosting European and other developed economies [32,38,41,55].

The circular resilient economy model is considered a development strategy that entails economic growth without increasing consumption of resources, deeply transforming production chains and consumption habits by redesigning industrial systems to reduce waste, and integrating these systems through the specific (3 + 1) Rs paradigm at the system level in a context of resilient eco-energetic development [16,24,26,31,32,54]. In this context, the question is if the linear economy, in opposition to the circular resilient economy, could work or not on long or middle term, in correlation with mattergy (energy incorporated in matter) as a limited resource, with continuously increasing cost prices [6,19,31,32,55,59–64]. To this approach is associated the rehabilitation tendency to use methods to burn gas and coal with increasing efficient energy production, and relative benefits of gas compared to coal [61,63,64]. In this way, the levels of energy efficiency of coal-fired plants built have increased to 46–49% efficiency rates, compared to coal plants built before the 1990s (32–40%). However, at the same time, gas can reach 58–59% efficiency levels using the best available technologies, and cogeneration methods combine heat and power offering efficiency rates of 80–90% [3,51,52,58]. The efforts to balance the various aspects of the M.E.N. triad assumes interlinked actions of all responsible factors regarding social, economic, and environmental positions from the very new model of circular resilient economy in a knowledge based economy/society to solve the waste problem [4,19,24,29,31,32,48,54,55].

The life cycle analysis (LCA) and assessment process [19,44] seeks to identify and assess the environmental, economic, and social impacts associated with specific products, processes, or activities. It would provide a conceptual framework for a detailed and comprehensive, comparative evaluation of energy supply options in the context of the sustainable development using the circular resilient knowledge based economy/society model, as an opportunity to rethink the idea of progress, of an economy renewing constantly itself, to create products with a "second life", from consumer to user [16,20,23,29]. Energetic sustainability [21,34,52,59,61] is a desirable state that refers to the robustness and effectiveness of the eco-energetic systems in the context of the transdisciplinary M.E.N. paradigm. The eco-energetic resilience [4,5,29] refers to the capability of a system producing electricity to maintain or rapidly return to equilibrium in the face of a disturbance, to adapt to change, and to quickly transform systems to limit current or future adaptive capacity [14,27,29,35,62,63]. These are analyzed in the context of the socio-ecological, eco-ecological, and technical networks working transdisciplinary in a semiophysical networking context [24,28]—on time-wise ("*think long-term and act now*"), space-wise ("*think globally and act locally*"), and action-wise ("*be aware that your actions produce consequences globally and your thoughts are rooted locally*") scales [12,24,28]—as a guaranty of sustainability, with a resilient pattern in the knowledge-based society/economy [17,23,28,60,62,63]. Such systems are searching for multi-perspective approach models in a synergistic way [23,28,64–68].

3. The Eco-Energetic Diagram to Transform the Primary Energies into Electricity

This section focuses on the diagram of energetic chains and demonstrates the way electricity can be obtained in a resilient regime from different primary energetic sources: external (gravitation and solar sources), fuels (classical and radioactive sources), internal, and others. The transdisciplinary sustainable eco-energetic M.E.N. model could be applied to a lot of chains—such as plasma physics, geothermal plants, MHD (magnetohydrodynamic), thermionic conversion, biogas, solid waste, biofuels, hydrogen, and others—all of them having electricity as the final goal as is presented in Figure 2. There are some chains where the electricity can be produced without a mechanical ring, like photoelectricity, solar thermopiles, chemical electrophiles, or from thermal intermediary energy, as thermoelectricity, magnetohydrodynamic (MHD), thermionic conversion etc. Some of the eco-energetic chains present a transformation from mechanical energy into electricity without thermal sequence, like wind energy, hydro-energy, and ocean waves systems. The soft thermal systems with low temperature (STS) are transformed into hard thermal systems at high temperature (HTS) using heat pumps, to increase the efficiency of the eco-energetic processes, as it is defined in Section 2.2 by Equations (2) and (4). The biomass and waste by-products are processed in many different technologies [54,58,60,64,65]. The final goal of all these transformations is the electrical energy, considered as a dense, clean, available and partially storable [65,67,68]. Regardless of the kind of energetic sources used to obtain electricity (coals, gas, wood, hydropower, nuclear power, wind power, biomass, solar systems, and others), the entire process should be sustainable in what concerns the transdisciplinary integration of different representative spheres as energy, socio-economy, ecology (environment), including sustainable education, even law, as necessary sequences in a knowledge-based society/economy [13,30,37,38].

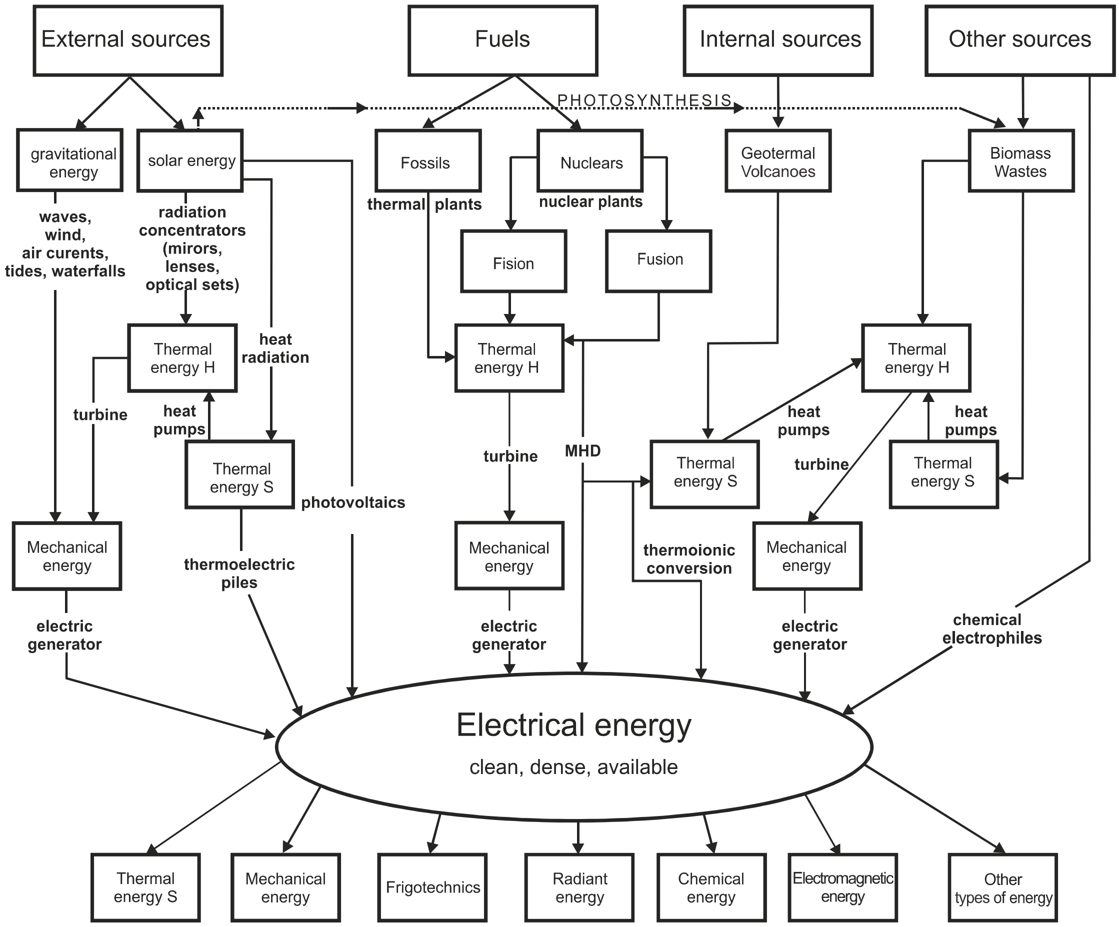

Figure 2. The diagram of the main transformations into electricity of the primary energies (S: "Soft thermal energy" with low temperature; H: "Hard thermal energy" with high temperature; MHD: magnetohydrodynamic).

At every level of transformation, there are specific pollutant processes incorporated as externalities, and energy loss, both of them having effects on the level of efficiency, the most important aspect of the eco-energetic process being the maximization of the $W_{ecoen,out}$, in the context of the minimization of the $W_{en,loss}$, and $W_{eco,cost}$, and of the sum $W_{en,loss} + W_{eco,cost}$, as well. Energy losses determine a low energetic efficiency, and the pollution is evaluated using the ecological coefficient, τ, corresponding to different types of pollution (mechanical, chemical, thermal, by production technologies and recycling, etc). In the context of an input energy $W_{en,enter}$, every ring of every chain of the eco-energy derived from main energetic resources—gravity, solar energy, fuels, and others—could be affected by energy loss, $W_{en,loss}$, by ecological costs $W_{eco,cost}$ as externalities, with output electrical energy, $W_{ecoen,out}$ in a considered specific eco-energetic process [18,19,44]. The pollution level and loss process are different with every transformation, but are improvable methodologically and technologically. By using specific forms of energy involved in a resilient or in a vulnerable eco-energetic chain producing electricity in the energetic processes—$W_{en,enter}$, $W_{ecoen,out}$, $W_{en,loss}$ and $W_{eco,cost}$—there is the possibility to calculate the global eco-energetic efficiency e with formula $e = \eta/(1 + \tau\eta)$, with potential of calculating η and τ.

4. Discussion, Conclusions, and Future Areas of Research

In the context of high-level demands for energy (megawatt), especially clean (ecowatt), and cheap (negawatt) energy, the original transdisciplinary M.E.N. eco-energetic paradigm enables a search for eco-energetic sustainability to obtain electricity. The cleanest energy, associated with saving energy, could be obtained by replacing the fossil and even nuclear fuels through alternative energies and associated technologies. One of the most important reasons to save energy and convert it into electricity is to reduce the emissions of carbon dioxide which generate global warming, as well as to avoid other kinds of eco-energetic problems (acid rains, heavy metals pollution, radioactive illnesses, and other damages to the population and environment). The M.E.N. paradigm enables an eco-economic transdisciplinary approach with a new formula for associated efficiency, combining in an original formula the classical energetic efficiency with the ecological coefficient, corresponding specifically to different types of pollution (chemical, physical, combined, etc.) by specific technologies and recycling processes in a circular resilient economy with minimum waste, as the greatest challenge for the required alternative way of thinking, valuing, and acting. The new given definitions for pollution and eco-energetic systems, associated with the holistic integrative diagram with different channels to obtain electricity from the main sources (external and internal sources, fuels, and others) and derived forms of usable energies, make it possible to integrate the circular resilience eco-energetic systems, to overcome the vulnerabilities of such systems with global and local solutions, for the short-, mid-, and long-term. Electro-energetic chains could be analyzed to establish the most efficient, ecological, and energetic transformations from different energies in electricity, where the eco-energetic M.E.N. spheres—Megawatt, Ecowatt, and Negawatt—are working together in a synergistic way. For the foreseeable future, it remains a big challenge to apply the M.E.N. transdisciplinary sustainable eco-energetic model to determine the eco-energetic efficiency, along with ecological coefficients for a lot of chains (plasma physics, geothermal plants, magnetohydrodynamics (MHD), thermionic conversion, biogas, solid waste, biofuels, hydrogen, and others), all of them having electricity as final goal based on the proposed eco-energetic diagram.

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