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An Economic-Ecological Transdisciplinary Approach on the Binomial Relationship between Energetic Sustainability and the Environment

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Abstract. The paper combines two new original concepts about eco-energetic systems. The first one is related to the M.E.N. (Mega-Eco-Nega-Watt) paradigm, which is based on three different but complementary ecological economic spaces: *MEGAWATT*, as needed energy, *ECOWATT*, as ecological energy, and *NEGAWATT*, as preserved energy, even the renewable energies and technologies, in the context of electrical energy production. The second concept presented in this paper is the eco-energetic efficiency, introduced in order to facilitate a correlation between the energetic efficiency of the system and a necessary, new defined ecological coefficient. The proposed formula for eco-energetic efficiency enables an interesting form of reporting to the 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 economy model. Finally, is presented an original diagram of the energetic chains to produce electricity in a resilience regim, with high eco-energetic efficiency from originating in different primary energetic sources as external (gravitation & solar sources), fuels (classical & radioactive), internal sources and others. Even what kind of energetic sources are used to obtain electricity, as coals, gas, wood, hydropower, nuclear power, wind power, biomass, solar systems, and others, the entire process should be sustainable in what is the transdisciplinary integration of the different representative spheres as energy, socio-economy, ecology (environment), with the main core, sustainable education, inclueding the law and administrative aspects, as necessary fields of the knowledge based society/economy.

Keywords: M.E.N. (MEGA-ECO-NEGA) ecoenergetical paradigm; eco-energetic efficiency; ecological coefficient; eco-energetical chains; sustenability; circular economy model; ecoenergetic diagram

1. MEN Eco-ecological sustainable energetic paradigm

In analyzing the energetic impact on sustainable development, the economic, environmental and social impact must be considered, on both, the positive and negative sides [1-6]. The educational aspects, which assume the actual transdisciplinary education [7-11] of all social-cultural components [5,12] **,** as well as the administrative and legislative issues [12,13], can solve the problem concerning the energetic impact over the environment (household technology) [4,5,7,8,14-17]. However, the most effective way is proper education, awareness of responsibility regarding the need for a clean, healthy environment [18, 19]. Any approach regarding the actual matter of energy must also consider the socio-economic impact on all levels. The need for energy, the environmental disturbance, as well as the energetic resources crisis requires, all together, and each individually, a unified approach at a community level and from an educational perspective, also including administrative and legislative aspects. Therefore, a modular systemic approach was introduced, with different representative spheres as necessary sequences to be analyzed: energy, economy, ecology (environment), and the main core of them, sustainable education [9,10,20,21].

Every paradigmatic component, every *E* (energy, economy, ecology-environment, and sustainable education), has a well-established role and position within a balanced and natural state of a new kind

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of *equilibrium* that is much needed and desired to be achieved [8,22], as follows: *Energy* <–> *Economy* <–> *Ecology (Environment)* <–> *Education.* In this context to achieve advanced knowledge through the original DIMLAK model of the knowledge integration [23], where sustainable integrative learning/teaching is a key factor for sustained, inclusive and equitable economic growth to achieve all the Millennium Development Goals [8-10,14]. Taking into consideration the bioeconomic representation of the economic processes from a semiophysical perspective 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 in the developing countries to follow the right dynamic equilibrium regarding to these two types of entropic states [13,24,25]. It is impossible to renounce totally on the production of goods to be economically strong (that brings a high entropic state) and concentrate all effort on providing services and intellectual work (low entropic processes). The transdiciplinarity has to solve the main dilemmas because the economic and social systems are consuming and transforming mattergy (matter and energy), as natural resources, and informaction (intention action and information) as nonmaterial **nonconsumable** specific anthropic resources [27,28]. There is necessary to be improved a natural dynamic equilibrium in order to achieve a desired sustainable dynamic in a socio-economic ecological system, able to satisfy the human needs as well as the capacity of reducing entropy to its minimum possible level [13,25]. The ecological economy needs are approached from the point of view of dynamic equilibrium and a natural development, necessary to find optimal evolving ways using local and global political, legislative, educational mechanisms in order to improve this phenomenon happen. Also, good synergies in achieving this objective come to be the main catalyst in developing higher technologies and innovation as well as higher responsibility for a rational consumption of goods and resources and environment protection, in so named (3+1) R paradigm (reduce, reuse, recycle, recombine) [16,26]. The consumerism with its "consume more energy in order to be more complex", known as "chemical imperialism", in which the chemicals harvested are stored matter-energy, is a false economic progress concept which cannot grow the level of complexity, so, it is necessary to rethink the socio-economic development strategies, in the context of the circular economy in the knowledge based society/economy [16,27,30-32], as a final goal of the advanced knowledge represented through the hetero-hierarchic levels of the semiophysical synergistic signification pattern, synergy (1+1>2) and signification ($1 - 1 \neq 0$) [28]. Considering the chains of energy production, transportation and processing, with electric energy as a final link, the supplementation of the system of known and general accepted concepts is required – the principle of thermal equilibrium, the principle of conservation (non-creation energy) and the principle of entropy with a new conceptual frame, that of eco-energy, as sum and synthesis of what energy means for human life and for the planet [9,10,24]. Therefore, a new, original concept should be introduced, the *eco-energetic efficiency e* of an energetic system, alongside with its final electrical energy product, with its *energetic efficiency* η, and the *ecological coefficient* τ of the system was also introduced. From this perspective, the paper is focused on the analysis of some known energetic chains that have as final product electrical energy [14,33]. In order to better understand the issue of energy-environment relationship, a new modular approach of this relationship is suggested. In most cases, one part of the processed energy does not reach the consumer, or it bears a large load on ecological costs (emission of CO_2, CO, NO_x, SO_2, HC, dioxine, thermal pollution, noise pollution, population health, etc.) causing local, regional and global imbalances [35-38]. For these reasons, were put together, in a transdisciplinary triad M.E.N. (Mega, Eco, Nega-watt) as a new paradigmatic concept, to a better understanding of the quantitative-qualitative content of an eco-energetic system working in a sustainable way [10,13,14,20]. The common factor of the three components is life itself, having the human being as the 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* [27,39], and finally efficiency and preserving energetic resources, including alternative energies and technologies – *Negawatt* [40-42]. Because of the novelty of the introduced the M.E.N. systemic transdisciplinary concept it is necessary to define the content of every part of this concept, and the signification of the synergistic-generative combination M.E.N., as sustainable energy, presented in figure 1. First of all it is necessary to define the shere of *Megawatt*,

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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]. At the second level is the necessity of clean energy, the electrical energy as it is known, circumscribed in the term *Ecowatt, as „every kind of energy economically transformed into unpoluted energy"*, with the energy equivalent in kWh_e of pollutant fuels that sustain 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-megawatts; increasing the efficiency in using electricity does not imply adverse effects, and 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, that 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 the resources, alternative energy sources and specific technologies, and increased efficiency of energy sources and consumption. Negawatt represents saved energy, by reducing energetic losses within the system and by limiting unnecessary consumption, thus increasing energy system efficiency, by energy preservation and processing it efficiently. Renewable energies and technologies are very important to be considered as a special categories, making the negawatt cheaper, cleaner and more reliable than a conventional watt [27,40,41].

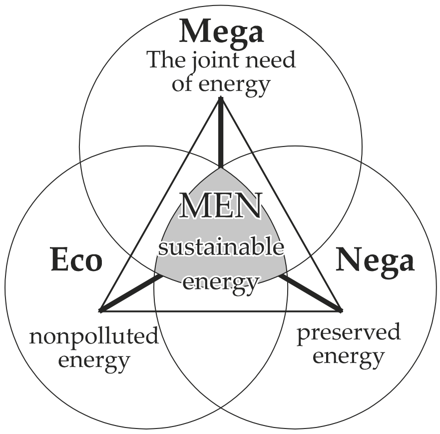

Figure 1: A transdisciplinary representation of the MEN ecoenergetic paradigm

Any energetic system produces, besides the proper energy that can be thermal, mechanical or electrical, a multitude of other polluting products that raise the cost of life that can equivalently be quantified and estimated – energetic costs [14,33,36-38,42,43]. As is presented in figure 1, the commun space M.E.N. of the superposition of Megawatt, Ecowatt and Negawat spheres, can be considered the synergistic-generative space of the sustainability in the eco-energetics domain. Life in all its stages, in a perfectly natural initial equilibrium must circumscribe the multitude of factors that determine it, by minimizing, as much as possible, the risk factors, in the context of an increasing globalization and natural imbalance, of constantly increasing energy needs, and life-style improvements (standard of living with associated risks and constraints, in a socio-cultural context in which the "natural" education at all institutional levels must be a "modus vivendi", condition and purpose for protecting and preserving the life and natural planetary equilibrium) [8,20,33,38]. In order to achieve these goals by a qualitative-quantitative approach, the *eco-energetic system* has to be defined 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, considering the ecologic costs with minimum energetic loss, with an efficiency that ensures locally, regionally and globally sustainable development by introducing renewable and alternative energy, by eliminating pollutant energy sources, preserving the resources and perfecting the technologies and related techniques"* [14,33].

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2. The ecoenergetic efficiency and ecological coefficient in energetic electrical systems

In order to make efficient the MEN paradigm is necessary to give a definition for pollution putting together the global and local aspects of the sustainability, as follows: *„pollution is considered as a modification of natural system properties, by adding or subtracting qualitative-quantitative entities due to the transfer of material, energy or information, resulting in a system imbalance with local, regional and global consequences, including anthropic actions"* [14,27,33]. In this context it is necessary to introduce the eco-energetical sustainability as a very transdisciplinary concept, a complex relationship between environment, economy, and society [14,27] An eco-energetic system that processes energy must ensure a clean energy output, un-polluting and un-pollutant, easily accessible, storable, that has a cost-efficient production, as electricity seems to be at this moment. This has the aim to reduce energy losses, $W_{en,loss}$ and to decrease ecologic costs $W_{eco,cost}$ considered as externalities [1,16,27,30,43-45], which will express altogether the eco-energetic loss from the system, with input energy $W_{en,enter}$ and $W_{ecoen,out}$ as output energy in the ecoenergetic process. Therefore, adding the principle of thermal energy to that of conserving energy in thermal processes (non-creation), and adding to the principle of the enthropic increase of thermal energy loss, we will be able to incorporate the new concept of the ecological processing of energy within a unitary formula, the MEN concept previously described with one of the efficient eco-energetics system that produces ecologically rehabilitated energy, defining the *eco-energetic efficiency e, as* follows

$$e = W_{ecoen,out} /(W_{en,loss} + W_{eco,cost}), \qquad (1)$$

instead of *the energetic efficiency*

$$\eta = W_{ecoen,out} /W_{en,enter}, \qquad (2)$$

with the energetics balance of the eco-energetics system

$$W_{en,enter} = W_{en,loss} + W_{ecoen,out} \qquad (3)$$

After a little algebra results the formula for the ecoenergetic efficiency as follows:

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

where τ, the ecological coefficient, is defined as

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

with values between $\tau = -1$ (resiliency with no ecological loses, $W_{eco,cost} = 0$) and $\tau = 0$ (ecological disaster, or "ecological emergency" situation, with ecological losses comparable with the electrical energy at the end of the chain, $W_{eco,cost} = W_{eco,out}$). The situation identified by $\tau < 0$, represents the viability of the ecoenergetics systems, where $W_{eco,cost} > W_{ecoen,out}$. Most efficient eco-energetic systems ($e \geq 1$) assume values for ecological coefficient in the interval $\tau \in [-1,0)$, and energetic efficiency values η more then 0,5 (see figure 2). A system with large ecological losses must have a small energy loss in order to compensate the high ecologic expenses, with the best possible efficiency (e ≥1). On the other hand, if τ is small (close to -1), we can have a system with a better efficiency, even though the energetic losses are higher. Overall, if the denominator of *e*, $W_{en,loss} + W_{eco,cost}$, can 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 $W_{en,loss}$ is 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, so the quality of the eco-energetic system is increasing to a high level of performance, which can evolve to increase the energetic quality η tends to 1, the correspondent ecological coefficient is attending its highest level, the two extreme situations indicating the peak of both, energetic and ecological quality. The optimum balance of such an ecoenergetic system is found in a compromise between minimal energetic losses (η tends to its maximum possible value, and τ is represented by minimal ecological costs) [33,43,44]. In this context, externalities represented by the equivalent energetic term $W_{eco,cost}$ are related to social welfare, to ecology, and also to the economy. Firstly, it is necessary to measure the social damages, which are not paid for by its main actors; secondly, to translate these damages into a monetary value; and thirdly, to explore how these *external costs* could be charged to the producers and consumers [43,44]. If the market takes into consideration the private costs, policy-makers should try to take account by quantifying ***the***

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external costs [43,45], models for pollutant dispersion being developed and a lot of case studies have been performed [46-48]. Electricity and transport are key factors for economic and socio-economic development, the produced air pollutants (particles, oxides of nitrogen, sulphur dioxide, etc) provoking damages like morbidity or premature mortality (chronic bronchitis, asthma, heart failure) [14,49-51]. 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 [18,50] in a transdisciplinary sustainable development context [1,2,23,27,52,53].

3. Sustainability and circular resilience for eco-energetic systems

The research is interested in energetic systems that have electricity as the final link of the chain and that are dense, clean, available, partially storable and easily convertible into any other type of energy, with high yield. There are enough reasons to believe that electrical energy has no other competitor in the current stage at this moment. 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 are considerably reduced [3,54]. 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.) [14,37,42]. All these costs are related and expressed to kWh_e as the easiest way to compare relative costs, various ways of producing electricity even when it is considered a co-generative process [55]. The worldwide consumption after fuel type is varying annually, with a sensible 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 [10,20,38,56,57]. 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 [43,44]. The estimated external costs include several components correlated with noise, poor visibility (example smog), risk of major accidents (especially for nuclear plants) [49,50], emissions and health risks during the operation of power plants and during different stages regarding fuel processing and transportation, as well as risks during constructions and related technologies [16,40,48]. 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 [14,17]. The incorporation of the external costs ("externalities") [4,43,19,45] into energy prices is important to sustainable energy policy, as a key challenge, and an important step towards "getting the prices right" [16,24,44,48,55,50]. 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 bio-diversity from loss of habitat, and new forms of inequality associated with changes in technologies and production patterns [18,50,54,59]. Because a significant part of the energy is yet produced using fossil fuels 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 [18,48], so it is necessary to implement alternative energy sources as wind energy, solar energy, nuclear energy, hydraulic energy, and others, known as renewable energies with

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a very small polluting effect, using the new circular economy model as a key for boosting European economy [31, 32,55].

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 [65]. 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% of efficiency levels using the best available technologies, and cogeneration methods combine heat and power offering efficiency rates of 80-90% [3,52,53,59]. 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 the circular economy to solve the waste problem [19,24,31,49,56]. Life cycle analysis (and assessment) (LCA) process seeks to identify and assess the environmental, economic and social impacts associated with a product, process or activity, and it provides a conceptual framework for a detailed and comprehensive, comparative evaluation of energy supply options in the context of the sustainable development using the circular economy model, as an opportunity to rethink the idea of progress, of an economy renewing constantly itself, in order to create products with a „second life", from consumer to user. The question is if the linear economy could or not work in the long term, in the connection with prices of resources and energy becoming increasingly volatile [6,19,31,32,65, 56,60-62].

4. The main transformations in electricity of the primary energies

The eco-energetic resilience [4,29] is referring to the ability of a system producing electricity in the context of all its transdisciplinary components as socio-ecological, eco-ecological, and socio-technical networks working across semiophysical time-wise, space-wise, and act-wise scales to maintain or rapidly return to equilibrium in the face of a disturbance, to adapt to change, and to quickly transforming systems to limit current or future adaptive capacity [14,27,29,35,63,64]. As a guaranty of the sustainability, with a resilient pattern, semiophysics is valuing information in a context of the existence of hetero-hierachic levels reciprocally irreducible of the advanced knowledge in the knowledge based economy [17,23,28,61,63,64], searching for multi-perspective systems approaches in a synergistic way [23,66,67,]. The model could be improved with results for other chains, as plasma physics, geothermal plants, MHD, thermoionic conversion, biogas, solid waste, biofuels, hydrogen, all of them having electricity as the final goal as is presented in figure 3. Energy losses determine a low energetic efficiency and the pollution is evaluated using the ecologic coefficient, τ , corresponding to different types of pollution (mechanical, chemical, thermal, by production technologies and recycling). In the context of an input energy $W_{en,enter}$, every ring of every chain of the eco-energetic derived from main energetic resources, gravity, solar energy, fuels, and others, could be affected by loss energy, $W_{en,loss}$, by ecologic costs $W_{eco,cost}$ as externalities, with output electrical energy, $W_{ecoen,out}$ in a considered specific ecoenergetic process [18,44,45]. The levels of the polluting and losing process are different at every transformation being improvable methodologically and technologically, so the possibility to calculate the global eco-energetic efficiency *e* is possible with formula (4) $e = \eta / (1+\tau\,\eta)$.

The diagram of energetic chains demonstrates the way to obtain electricity in a resilience regim from different primary energetic sources as external (gravitation & solar sources), fuels (classical & radioactive sources), internal sources and others. The ways to obtain electricity are specifically presented as a direct process from a primary source without mechanical step (photoelectricity, solar thermopiles, chemical electropiles), or from thermal intermediary energy states (thermoelectricity, MHD, thermoionic conversion, etc), through mechanical transformation without thermal channel (wind energy, hydroenergy), transforming soft thermal systems into hard thermal systems using heat pumps, in order to increase the efficiency of the energetic process. The biomass and wastes are processed in many different technologies, the final goal being a cheep, cleansed, and disposal electricity. Even what kind of energetic sources are used to obtain electricity, as: coals, gas, wood, hydropower, nuclear power, wind power, biomass, solar systems, and others, the entire process should be sustainable in what is the

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transdisciplinary integration of the different representative spheres as energy, socio-economy, ecology (environment), with the main core, sustainable education, even the law aspects, as necessary sequences in the knowledge based society/economy. At every level of transformation there are specific pollutant processes incorporated as externalities, and loss energy, both of them responsable on the level of the 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 $W_{eco,cost}$ as well.

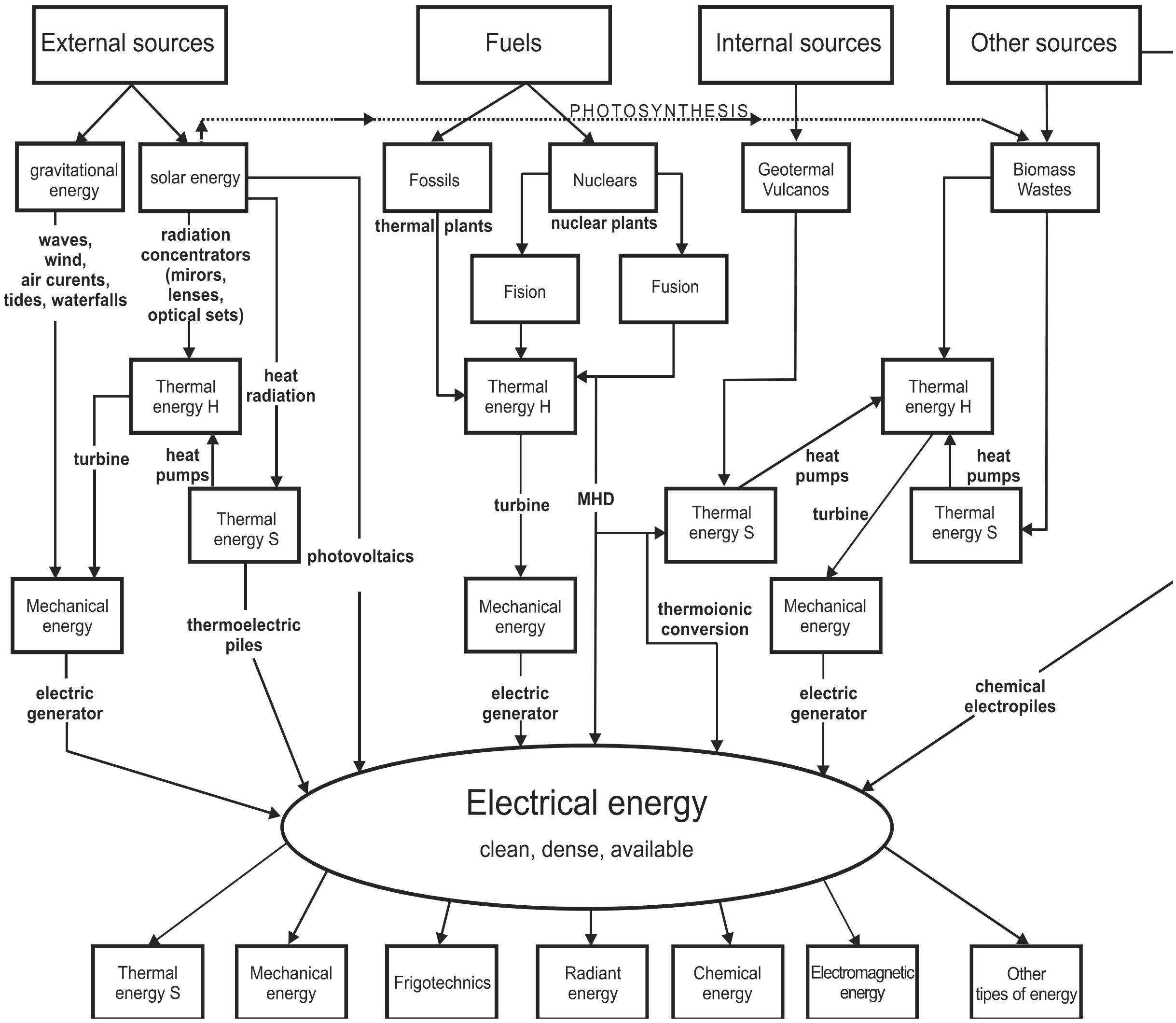

Figure 2 The main transformations in electricity of the primary energies of the external & internal sources, fuels, and other kind of sources

Conclusions

In the context of high-level demands for energy as *megawatts*, especially clean and cheap energy, the search for *ecowatts* and *negawatts* represents the most important preoccupation for electricity as the most clean energy, associated with saving energy, replacing the fossil fuels by alternative energies and associated technolohies. One of the most important reasons to save energy and convert it into electricity is to reduce emissions of carbon dioxide generating global warming, as well as, to avoid other kinds of eco-energetic problems (as acid rains, heavy metals pollution, radioactive illness, and other damages on population and environment). The way energetic efficiency works is configured through the MEN concept allows to use a combined eco-economic transdisciplinary approach with a new formula for eco-

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energetic efficiency, combining through it the classic energetic efficiency with the ecological coefficient. Some electric energetic chains are analyzed to establish the most efficient, ecological and energetic transformations from different energies in electricity. High-efficiency eco-energetic transformation in electricity represents the sustainable way to search the MEN transdisciplinary sustainable pattern (*megawatt*, *ecowatt, negawatt).* Energy loss determines a low efficiency and pollution should be evaluated using the introduced ecological coefficient, corresponding specifically to the different types of pollution (chemical, physical, combined, etc), by production technologies and recycling processes in a circular economy with a minimum waste, as the greatest challenge of these times for the required alternative way of thinking, valuing and acting. The research could be developed calculating the eco-energetic efficiency for every chain of the energetic transformation in electricity.

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