Selected problems of classification of energy sources – What are renewable energy sources?

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The contribution is dedicated to study of issues related to the classification of energy sources from the point of significance and interpretation accuracy. There are some aspects described and documented by examples that show the ambiguity of currently most used methods of dividing an energy source or their classification respectively to generally exerted categories and identifications, where relevance and exactness are not clear, but it depends on specific conditions. However, such conditions are generally not included in the classifications. For analysis, mostly physical, technical, environmental, regional and time aspects were taken into account. The increasing complexity of energy mixes, technologies, and legislative environment naturally leads to the need of perceiving broader aspects of reviewing and evaluation of individual sources. The correct interpretation is a prerequisite for communication between specialists, public and mainly in the field of legislation, which enables influencing of the implementation of individual sources and technologies in practice, mainly by regulation and support from decision-making and control bodies, from regional up to the global level. The findings point out to the fact that the road to orientation within the issue leads through identification and evaluation of representation of typical characteristics of individual sources, which, in a particular context lead to the classification of a source into a particular category. However, such position may be changed in time and place.

Key words: *renewable energy sources, alternative energy sources, traditional energy sources, sustainable energy, energy sources classification,*

Introduction

The use of energy source is part and also the condition of development of humans and human society. Since, in the broader understanding, the energy may be considered as the equivalent of change, and then also the development of human society into social and technically more complicated forms as well as the growth of human population means that human society must use more energy to cover its needs, from ever increasing portfolio of energy sources.

Currently, the world population is over 7.2 billion and energy demands per one person have increased, for example, in the EU; the energy demand is 125 kWh per person per day [1]. The increased energy demand, issues related to energy safety and environmental impacts related mainly to the use of fossil fuels brought up the need to use also other sources of energy, mainly the so-called renewable sources. Therefore, the current mix of energy sources required to meet the societal needs is covered by a large scale of sources. The representation of individual sources is related to a particular field of industry as well as the geographical location of surveyed area and time aspect.

The more complicated structure of sources and development of energy technologies (for acquisition, conversion and transport) into the large scale of forms lead to the fact that terminology and classification of sources fail to cover all parts of this issue, therefore, causing that there is no clear orientation and understanding. The clear understanding of terminology is a basic prerequisite for communication between specialists, public and for forming legislation regulating the use of individual sources and technologies in practice.

Methodology

Currently utilized energy sources in the context of their classification into existing and used classifications of energy sources with an emphasis to renewability used by relevant institutions (from the global point of view) were the subject of analysis. When examining the sources of information, the following aspects were evaluated: understanding explicitness, adequacy and correctness, argumentation and its presentation, time and location adequacy, versatility, sensibility to secondary aspects such as energy technology.

When evaluating the adequacy of the classification of individual energy sources, several aspects of understanding of renewability/non-renewability of sources in relation to the understanding of characteristics of individual sources or energy types respectively were taken into the account.

They are mainly the following aspects:

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- Understanding of renewability/non-renewability or exhaustibility/non-exhaustibility respectively in time and location scope.
- Primary source, form, and energy carrier.
- Energy technology (a technical aspect of the use of a source) and its effect on the position of a source.
- Understanding homogeneity of a source (combination or various or contradictory characteristics respectively).
- Understanding exactness - the existence of disputes.

During consideration and effort to define or redefine the position of an energy source, the principles analogical with principles used in pedagogy were used, according to [7] the visualization principle, methodology principle (justifiable hierarchy), uniformity principle (unity), scientism principle (scientific substantiation).

Analysis of understanding of the renewable energy sources in their definition

The subject of the analysis is energy sources and their classification into categories that are generally perceived (also by experts contributing to forming legislative framework regarding energy industry as well as education) as clear. It is related to the understanding of the following terms: renewable and non-renewable energy sources. Understanding the aspect of renewability of an energy source may be deduced from definitions presented and used by subject established in the particular field at various levels covering the broader area of activities (international organizations, national institutions, commercial subjects) and definitions used in dictionaries and literature.

According to the English dictionary [4], the renewable source is defined as "any naturally occurring, theoretically inexhaustible source of energy, as biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel". There is no condition of validity in the definition. The definition is facilitated by enumerative designation of sources, i.e. definition of properties or characteristics by defining members or examples. As the main characteristics, the "theoretically inexhaustible" is used; therefore, there is no clear understanding ("theoretically").

According to the dictionary, [5] the RES are defined as "another name for alternative energy", while alternative energy is defined as "energy, such as solar, wind, or nuclear energy, that can replace or supplement traditional fossil-fuel sources, as coal, oil, and natural gas". According to [6], the RES are then defined as "alternate energy", further explained as "alternative energy; energy derived from sources that do not use up natural resources or harm the environment; also called (renewable energy)". The definition above presents an equivalent relation between categories of "renewable" and "alternative"; however, the words are not synonyms. Alternative sources are then defined by naming and characteristics - ability to substitute fossil fuels. The above mentioned alternative sources also include nuclear fuel; it means that the nuclear fuel, according to the understanding of the definitions above, is classified to renewable sources by the dictionary.

Wikipedia (in English language) adapted the definition of RES from publication in a well-respected scientific publication [9]: "energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal heat" and the definition is supplemented according to [10] „Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services." The definition mentioned above includes a mix of relevancies; the first part includes a definition of the main characteristic - natural replenishment on a human timescale. The second part states that such renewable energy should replace conventional fuels in four distinct areas (energy industry sectors, in a broader meaning), i.e. more corresponding with the aspect of alternative position in individual sectors.

Companies established in the power industry, earth sources and use of renewable energy sources present definitions mainly adopted from the agenda valid in the region's legislative environment. According to the Texas Renewable Energy Industry Alliance (TREIA) adopted by the Texas legislature, the definition stated in [8] is "Renewable energy: Any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources." The ability of regeneration, i.e. renewability of the resource in a short time scale is an important characteristic of the definition. In the definition, the resources are specified in relation to their origin.

The Australian Renewable Energy Agency (ARENA) uses the following definition: „Renewable energy is energy which can be obtained from natural resources that can be constantly replenished" [11]. The definition is based on the characteristic of constant replenishment regarding natural origin, i.e. it should refer to the primary form of resources - the primary resource.

On its website [12], IEA defines RES in the following way: „Energy derived from natural processes (e.g. sunlight and wind) that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy. "According to [13] the IEA, the definition of renewable energy includes the following sources: "electricity and heat derived from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources". The definition includes the condition of a faster rate of replenishment than the consumption of a resource, at the same time, there is a restriction regarding biomass as well as hydrogen.

The International Renewable Energy Agency (IRENA) has, according to [13], a statutory definition ratified by 108 members (107 states and the European Union) as of February 2013: "renewable energy includes all forms of energy produced from renewable sources in a sustainable manner, including bio energy, geothermal energy, hydropower, ocean energy, solar energy and wind energy." The definition above is based on the characteristic of "sustainable manner of use of the source" and names the individual sources.

From the point of view today, there is an interesting definition of RES according to the Department of Non-conventional Energy Sources (India) [32] from 1982: Renewable sources of energy are those natural resources which are inexhaustible and can be used to produce energy again and again. Examples are solar energy, wind energy, geothermal energy, tidal energy, water energy and bio energy. Atomic minerals are inexhaustible sources of energy when used in fast breeder reactor technology. Apart from the usual characteristics and naming examples, there is an added technological condition valid for nuclear fuels, i.e. it considers another aspect that is not related to the origin of the primary sources, but it relates to a particular way of its using.

Similar to the definition in document [13], the presented overview shows that these definitions vary in the type of sources included and in whether sustainability considerations are explicitly incorporated. These differences illustrate the fact that there is no common or global definition of renewable energy resp. RES.

Discussion

When considering the base for the division of energy sources to renewable and non-renewable, the criterion of "renewability" or "exhaustibility" of energy source seems to be the decisive criterion. Such criterion seems to be unanimous and represent a common characteristic.

For a closer examination of the energy source renewability or exhaustibility criterion, it is necessary to make provisions for physical, time and location aspects (e.g. the first and second law of thermodynamics, geologic time scale, the dimension of a region, the Earth, space). Due to the above mentioned, the perception of exhaustiveness/non-exhaustiveness of a source should be in relation to time and place dimensions related to behavior and activities of human and human society linked with the use of energy sources and its intensity. The distribution should be therefore based on the criterion taking the extent of the source exhaustibility from the point of view of place and time dimensions and uses of human society into the account.

Upon the above mentioned, it is possible to define the definition of renewable and non-renewable sources in the following way:

Renewable energy sources are in place and time dimensions of human society within the context of social process non-exhaustible.

Non-renewable energy sources are in place and time dimensions of human society within the context of social process exhaustible.

The definitions include the main characteristics in the practically usable meaning of understanding the renewability criterion.

To enable further considerations, it will be necessary to supplement the basic distribution by further levels (mainly upon the origin of sources/energies) and add specific examples. The further distribution is mainly related to the fact that individual energy sources from both main categories may be very diversified by their nature and without a closer characteristics, mainly in case of fuels, it would not be possible to come to relevant conclusions.

According to their origin, the renewable source may be distributed to:

- Exogenous sources, including solar energy and its derivatives (e.g. wind, water energy, biomass and tidal power, which is a result of gravity interaction between Earth, Moon, and Sun.
- Endogenous sources, including mainly geothermal energy as well as osmotic power or salinity gradient power, i.e. the energy available from the difference in the salt concentration between seawater and river water [27].

Non-renewable sources may be divided according to their origin:

- Organic, including fossil fuels (such as coal, oil, natural gas).
- Mineral, including nuclear fuels.

Fossil fuels are sources of solar energy originally deposited into the shape of chemical bonding of organic compounds. Such organic matter had been gathering for long periods of time and in a geological environment in favorable conditions it underwent changes that resulted in increasing the energetic density of the resulting material and at the same time, a gathering of such material in the earth's crust - the creation of deposits. Chemical fuels comprise of combustible material and ballast [28]. During the process of oxidation, the combustible material releases heat and comprises of active elements (providing heat) and passive elements. Active elements of fossil fuel combustible material are mainly carbon (Q_C = 33.8MJ.kg^{-1}), hydrogen (Q_H = 140 MJ.kg^{-1}) as well as sulphur. The passive elements are oxygen and nitrogen. The ballasting elements, for solid and liquid fossil fuels, are ash materials (mineral components, mainly SiO_2, Al_2O_3 a $CaCO_3$) and water [28]. The representation of individual components in the fuel determines its characteristics, which directly influence the possibility to release energy and consequently the way of its use (according to [15], for coal 10-31.5 MJ.kg^{-1}; oil 28-42 MJ.kg^{-1}; natural gas 33.2-42 MJ.m^{-3}, which at the density of 0.76kg.m^{-3} represents 25.23-31.92 MJ.kg^{-1}).

Active elements of fossil fuel combustible material, mainly carbon (so-called fossil carbon) and emerging compounds (mainly CO_2) are the cause of currently the most important negative environmental phenomenon, such as anthropogenic climatic changes as multiple data published in studies such as [29], [30] point out to such anthropogenic effect. This way, the whole principle of current global renewable/non-renewable issue is based on fossil fuels.

When it comes to mineral sources, they are mainly of ore character comprised of uranium or thorium compounds. Actually, they are not real fuels. Therefore, they are not sources of chemical energy (energy of chemical bonding) as from such sources, and the energy is not gained by the process of oxidation - burning. The natural uranium, obtained from the uranium ore, the portion of atoms of ^{235}U is 0.7 %, and a portion of atoms of ^{238}U is 99.3 %. The core of ^{235}U is fissile due to the subversion of internal core stability by binding and kinetic energy of captured neutron. This is a chain process and regulated in an active zone of the nuclear energy reactor. The released energy is mainly in the form of heat (app. 85 %) created by conversion of kinetic energy of fission products during their slow-down in a thick environment of nuclear fuel (solid fuel) [31]. The rest of energy is released in the form of γ radiation. The result of those above would mean that the content of fissile isotope in mineral fuels is the equivalent of combustible material in fossil fuels. On the other hand, the analogy above is not absolutely correct due to the fact that mineral fuels include the so-called breed material that may be considered as a secondary fuel. However, the secondary fuel is not produced from the primary, but from the non-fissile components, being ^{238}U (app. 99.3 % content in the natural uranium) for the uranium fuel, from which, after neutron capture and two β decompositions, there is fissile ^{239}Pu, which is an artificially created element - transuranium (nuclear conversion).

The situation is similar for thorium, from its ^{232}Th non-fissile isotope after neutron capture and two β decompositions, there is a fissile ^{233}U. That means that thorium as a mineral fuel is an incoming primary source to make the ^{233}U "fuel". Generation of ^{233}U takes place in a generation reactor; the use takes place in an energy reactor. Such process may be compared to the process of fossil fuel refining.

Contrary to the generation of secondary fuels for fossil sources, such as the production of petrol from oil, during generation of nuclear fuels, there are some fuel components used that in their primary form, do not constitute any fuel whatsoever.

If, for evaluation, we take time as well as the source use intensity factor into account, we come to the fact that "renewability" and "non-exhaustiveness" of energy source are basically not synonyms, they express different characteristic. A renewable source, providing low or zero intensity of its drawing should show the ability of quantitative growth, i.e. its stock may increase in time. That is the characteristic feature of the solar energy derivative - biomass. If, on one hand, biomass is an exhaustible source (in the case of high intensity of use in a time frame under consideration) that due to the systematic renewability (given the meeting of certain conditions) it is also a renewable source. That means that the criterion of "renewability" and "non-exhaustiveness" may be perceived in an opposite way, i.e. renewability $\neq$ non-exhaustiveness.

To be able to make a conclusion from the consideration above, it is necessary to examine the physical basis of individual energy sources (forms of energies) being currently used in the global energy industry. The subject of examination is the natural form of an energy source from the view of its origin, form and conditions of its existence, in binding to a carrier, time and place framework.

The first group of sources are sources, which are a form of energy alone - electromagnetic radiation. Solar radiation is such energy source. It is energy that in the global scale, continually arrives at the earth's surface from an external source – the Sun (in local scale, the supply of solar energy to the earth's surface shows great differences and variations upon latitude, a period of year and day, atmospheric conditions, etc.). Such source/form of energy is not bound to substantial particles (the photon's invariant mass is zero). Upon the brief characteristic of particles and their properties mentioned in [20], [21], it is possible to say that photons are elementary (indivisible) field particles (belonging to a group of bosons). Their lifetime is endless. They are created and cease to exist by many ways (for example by annihilation during the passing of electron between orbitals or during particle annihilation).

From those above, we may come to the conclusion, that the solar energy is renewable and non-exhaustive to the intent that its source (Sun) and its thermonuclear reactions are non-exhaustive. Its renewability is provided by continuous incoming radiation from the Sun (time scale of source lifetime at the level of 10 Ga. This is a time scale greatly exceeding the possibilities to meet the conditions for the existence of life on the Earth (therefore the existence of human beings). The solar energy is the renewable and non-exhaustive energy source.

The second group of energy sources are sources bound to a physical carrier; they utilize the mass and heat transfer principle, mainly wind, water energy, however, there are no transformations at the level of chemical or nuclear reactions. The carrier (air, water) represents a working substance, of which substantial property is its weight or density. The amount of transmitted energy then depends on the speed of movement of such substance or the used pressure gradient respectively. The renewability of such sources depends on the supply of energy from the primary source only. Such energy puts substances - carries into movement (solar energy).

The existence of such energy sources depends not only on the supply of primary energy (solar energy) but also on the presence of effective substance, which must be in a suitable environment (e.g. for water, in a suitable temperature range for gaseous and liquid phase). From the geologic point of view, there are situations when it is not necessary to meet some of the necessary conditions for functioning of the effective substance in a certain time interval and place (glaciation), even in the case of preserving the supply from the primary energy source. Such sources may be in ultimately, from the point of dimensions of human society needs, identified as renewable and non-exhaustive.

The next type of energy source is a source, for which the transfer of energy is bound to a physical carrier or more precisely, environment. Such source is a geothermal energy. When it comes to geothermal energy, the origin of heat is various, however, ultimately, the final heat is bound to a physical carrier (transport medium) such as water/steam or a mass of rock and chemical elements of which such carriers are made of, do not enter any of chemical reactions. The exhaustibility of such sources may be evaluated from two aspects. First, for hydro geothermal sources, static and used by an open way (no reinjection used), the depletion of transport media means that the source is exhausted. For dynamic sources (naturally or technically by using reinjection), the source may be exhausted within a certain period of time in case that the rate of use exceeds the rate of the ability of renewability of the source. However, after the consolidation of conditions the source is regenerated again. For such consideration, the period of tens of years may be considered as sufficient enough (exhaustion, as well as regeneration, depends on intensity and conditions).

From those above it is clear that such sources are more complicated, and even its characteristic requires more specific interpretation within a certain context. Essentially, the exhaustiveness of geothermal energy is, similar to the Sun, determined by the lifetime of the cosmic body of the Earth and is provided with the time frame of the source lifetime, being at the level of Ga. The Earth disposes of partially active and partially accumulated forms of energy. As presented in [22], currently, the total heat capacity generated within the Earth is estimated to 44.2 ±1 TW, when taking the calorimetric data [23] into consideration and 31 ±1 TW when utilizing the chemical analysis [24]. The heat capacity generated during the breakdown of radioactive isotopes of ^{238}U and ^{232}Th, according to [25] represents $20^{+8,8}_{-8,6}$TW and by the breakdown of ^{40}K, the output of 4 TW is generated. Therefore, the main part of heat comes from the breakdown of radioactive elements in geospheres. To the contrary from the Sun's output, which is increasing (depending on the amount of material in which the thermonuclear fusion takes place), the output of the Earth is decreasing with time by radiating the accumulated heat into the outer space and reduction of material being subject to radioactive breakdown. The cooling process is still very slow. The temperature of the mantle has decreased no more than 300 to 350 °C in three billion years, remaining at about 4000 °C at its base [26]. Such sources may be, ultimately, from the point of dimensions of human society needs, identified as renewable and non-exhaustive.

A next group is a group of energy sources, in which the process of storing and release of energy takes place by wandering of elements within forming of molecules. They are sources of chemical energy. The base alone - elements - remain unchanged and are continuously recycled. The energy is supplied during formation of chemical fuels and is released during their expiration (burning). On one hand, the renewability of chemical energy sources depends on the supply of energy required for the course of chemical reactions (mainly solar energy), on the other hand, it depends on presence of energy saving agent, i.e. live organisms (for hydrocarbon fuels such as methane we will consider with biogenic way of creation of organic matter decomposition, even though methane is also formed by other, abiogenetic processions that require specific and complex conditions of existence, affected by a number of factors. The fossil fuel source renewability also depends on geological factors. For assumption of some aspects of the cyclic character of the alteration of geological eras (mainly analogue climatic conditions) and providing we would consider the time interval of $10 - 10^2$ Ma (diametrically exceeding the dimensions of human society), the fossil fuels would be renewable energy sources, while carbon and hydrogen are in their natural cycle of storing the solar energy into the chemical compound bindings (by photosynthesis). Such idea was presented in [18], [19].

The exhaustiveness of chemical energy sources is in relation to the intensity of utilization, original amount and time frame. For example, in case of intensive using of dendromass sources in the volume that exceeds the ability of regeneration of vegetation in certain evaluated area and time, when production of carbon and hydrogen from using the wood material exceeds the amount that the plants can include into the chemical compounds within this period of time (rate of renewability) of which their bodies are made, the dendromass is characterized as an exhaustive energy source negatively entering the greenhouse gases balance. Such consideration is also related to the source renewability alone as factors entering the process exceed the energy balance evaluation framework. They are called "non-energy" factors, such as water and wind erosion, water balance changes, exhaustion of the soil, changes in the composition of plant and animal species, changes of microclimate, changes of use of the soil fund, etc. The factors mentioned above may cause, as stated in [18] that there is no source (vegetation) renewal in a manner and to the extent that could be anticipated, upon the static vegetation balance containing a quasi-constant amount of mass being renewed.

Ultimately, from the point of view of dimensions of needs of human society, the group of chemical sources - biomass - may be considered as the exhaustive and conditionally renewable source (due to the continuous creation of biomass in real time, upon meeting the conditions of renewability). The second group of chemical sources - fossil fuels - are, due to the same aspect - non-renewable and exhaustive.

The last group represents nuclear fuels, where the process of energy release is bound to a nuclear fission reaction, during which the original element is destroyed, and other elements are developed (fission products). In this case, it is not possible to say that the input material remains as its base is changed in a very dramatic way. Because the "fuel" is destroyed in the process of energy utilization, it is not possible to consider renewability (energetically active fuel compound - fissile isotopes of heavy elements cannot be created by natural processes in the Earth's conditions. Such heavy elements were created by a neutron capture during nucleogenesis during the evolution of space, and they got into the Earth's geosphere during its formation).

On the other hand, such sources have a "breeding" potential of transforming the originally non-fissile elements into fissile elements. That could mean a certain aspect of renewability, ability to produce new fuel. Nuclear energy sources (by fission) may, therefore, be identified as exhaustive and non-renewable sources with the breeding potential.

From the point of energy production to one fission of ^{235}U core, there is approximately 3.2 $\times 10^{-11}$ J on average (for further deductions, we can express such value for the amount of 1 kg of ^{235}U, i.e. 79 TJ). If we compare it with the energy released during the total oxidation of a carbon atom to CO_2, it is 6.5 10^{-19} J. Therefore, it is clear that there are massive differences in energies for both, very different ways of energy release, for evaluation of the elementary process. The difference of energy for the elementary process is even more apparent for the expression of energy in eV (200,000,000 eV vs. 4 eV) [28]. If the energy production made from individual fuels/sources were expressed in the amount of energy produced during the specific elementary process only, it would not make provision for physical, technological and practical aspects of energy "obtaining" and that could lead to incorrect interpretations and misleading simplifications. That may be described in the example of nuclear fuel use, where the impact of technology used to fuel energy yield, due to the high energy density of the fuel, is the most significant.

In case of closer analysis of the position of individual energy sources in the categories of renewable/non-renewable, we will come to the conclusion that even despite a clear interpretation of primary energy (primary energy source) position in a particular group, if we would consider technical way of use we could come to unclear or mixed meanings or more precise results.

In some classifications of energy sources, as presented for example in [32], nuclear fuel is also considered as non-exhaustive and, therefore, renewable source of energy when used in fast breeder reactor technology. This is a technological aspect directly related to the fact how much energy may be yielded from nuclear fuel, i.e. with the fuel energy yield.

In a nuclear reactor using natural uranium as fuel (containing 0.71 % ^{235}U), according to [28], the energy yield is less than 0.86 $TJ.kg^{-1}$ (10 $MWd.kg^{-1}$). The energy yield of reactors utilizing the enriched uranium to the level of 3 % ^{235}U is 2.9 $TJ.kg^{-1}$ (33 $MWd.kg^{-1}$), while, for a higher rate of enrichment, it is possible to consider the values of 4-8.6 $TJ.kg^{-1}$. (46.3-99.53 $MWd.kg^{-1}$) [28].

In the case of breeder reactors and repeated fuel cycle, it is possible to expect the total energy yield of 52 $TJ.kg^{-1}$ (600 $MWd.kg^{-1}$). In the case of making provision for the thermal cycle efficiency, being around 30-40 % of the power plant (reactor) heat output, then when using the natural uranium without repeated use of regenerated fuel, it is possible to yield 0.21 $TJ.kg^{-1}$ (2.4 $MWd_e.kg^{-1}$). From the enriched uranium, for the repeated fuel cycle in the breeder reactor, it is possible to yield 21.6 250$TJ.kg^{-1}$ (250 $MWd_e.kg^{-1}$) [28].

The aforementioned suggests that the technological aspect may also influence the conditions of source classification into a certain category. Such factor is of a qualitative nature, and it may involve in time, it may also be influenced by regional aspects.

The next aspect of the evaluation of the source position in a particular category is interpretation homogeneity. The example of energy source, which is not possible to clearly classify into a renewable or non-renewable category, and which was, and still is subject to required legislative modifications and clarifications, is the environment energy utilized via a heat pump. Heat pumps are quoted in the European Directives on the use of Renewable Energy (RES), on the Energy Performance of Buildings (EPBD) and the Energy related products (ErP). In addition, heat pumps are also referenced in the Directive on the promotion of the use of energy from renewable sources (2009/28/EC, RES Directive, Article 2) [33].

In the Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 [34] on the energy performance of buildings (EPBD) recast, Article 2 point 18, 'heat pump' means a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings. [34] The definition above is based on the physical nature of the heat pump functioning principle, and it does not take the nature of individual types of energy and equipment's energy balance into account.

In the European Directives on the use of Renewable Energy (RES), point 31: Heat pumps enabling the use of aerothermal, geothermal or hydrothermal heat at a useful temperature level need electricity or other auxiliary energy to function. The energy used to drive heat pumps should, therefore, be deducted from the total usable heat. Only heat pumps with an output that significantly exceeds the primary energy needed to drive it should be taken into account [33]. From those above, it is clear that such wording fails to clearly define conditions, for which it is possible to clearly consider heat pumps as renewable energy sources, or more precisely, what portion of energy supplied by the heat pumps comes from renewable energy sources.

Actually, to be able to evaluate what is the portion of the renewable heat produced by the heat pump, it is necessary to consider the number of factors (heat pump structure, COP, SPF, composition of energy sources in the region, their allotment, electricity production efficiency, and so on). It is necessary to define clearly and describe the parameters above to achieve clarity for expression of individual aspects being subject to examination. The Coefficient of Performance (COP) expresses the ratio of thermal energy taken away from heat pump condensers with the ratio of (electric or heat) energy powering the heat pump operating cycle. It is a parameter, which is determined under laboratory conditions, according to STN EN 14511.

The Seasonal Coefficient of performance (SCOP) expresses the average heat factor for the prolonged period of time, typically being the heating season.

SCOP also includes energy necessary for delivery and distribution of heat energy for set thermal loads and climatic conditions (according to EN14825) and also reflects energy demand at times, when the heat pump is not in operation (e.g. stand-by) [36] (according to the EU Commission Decision No. 813/2013).

Seasonal Performance Factor (SPF) according to EN 15316-4-2, also called the Heat Pump Average Seasonal Efficiency Factor (according to the EU Commission Decision No. 813/2013), [35] SPF is evaluated for real conditions in relation to a building, climatic conditions [36].

According to the Directive [33], for the heat pump, the heat from environment fed from the heat pump evaporator may be considered as the renewable energy source. Such energy is generally designated as $E_{RES,}$ and it is determined according to the following relation: $E_{RES}=Q_{usable}*(1\text{-}1/SPF)$, where Q_{usable} being the total usable heat delivered by the heat pump (conjunction of installed capacity and number of hours, according to the type of heat pump at full power in a particular climatic area). It is valid that only heat pumps, for which $SPF > 1.15 * 1/ \eta_e$, where η_e is a ratio between electricity made and primary energy used for the production of electricity calculated as the EU average, according to Eurostat data, may be considered as renewable energy sources. From those above, it is clear, that the value η_e with time and depends on a specific country or more specifically region. For example, according to EUROSTAT, in 2007 the value was η_e=43.8 %. Electric heat pumps need to achieve a minimum seasonal efficiency (SPF) of 2.63 or better [37].

In 2013, the EU issued harmonized guidelines (Commission Decision No. 2013/114/EU), under which conditions the heat production by heat pumps installed within the EU countries may be included in the national statistics and commitments of renewable source development if using the Earth's heat, outside air, and water.

The heat pumps powered by electricity must achieve the minimum yearly efficiency of SPF of at least 2.5. For heat pumps in which heat is the power energy, the efficiency of input energy equals to 1, meaning the minimum value of SPF is 1.15 [35].

For the SCOP value of 2.5 it is considered that the heat pump substitutes production of the same amount of heat in gas or solid fuel boiler operating with the average yearly heat production efficiency of 85 %. The electricity consumption calculation of primary energy is a 2.5 multiple (taken from the SPF calculation) [35].

The heat pump is a typical example that important role for source evaluation and its classification in practical cases is played by technical aspect of energy source application, which is related to the design of the energy equipment alone, conditions of its operation, output energy parameters, place where such equipment will operate and time (period) for which the equipment will be operative. The form of primary energy alone (e.g. solar energy via environment energy), which is undoubtedly renewable may (by the course of several energy conversions as well as accompanying energy processes) reach only a small portion of the total energy balance, which is ultimately reflected in the total assessment/classification of the machine.

To emphasize the complexity of examined environment, it is necessary to say that, as stated by, for example [38], also such energy source saving the primary (fossil) energy sources is considered as the renewable energy source, and it is classified as economic energy saving. They are such energy savings where investment costs spent for execution of such savings are covered by profits from saved energy consumption (due to the higher efficiency of energy conversion) over the economically accepted period of time.

Therefore, the designation of "renewable energy source" may also be used for a virtual source without any physical form, however, being expressed by a certain energetic, economic and social effects.

Conclusion

When executing a deeper analysis within the effort to classify some source into a certain category, several issues arise pointing out to the fact, that individual sources have no reciprocal antagonistic position, however, they more or less carry characteristics of one or another side depending on conditions, contemplated period of time, position, etc.

The presented analysis also showed that currently used source classification used for the creation of an agenda as well as for education of future specialists fails to reflect some important properties or aspects of the use of such sources, which might lead to incorrect interpretations of the wording of regulations and the necessity of their constant revisions. Due to those above, it is necessary to perceive mainly the fact that what might have been understood clearly until not long ago may these days seem very differently, in the opposite way, depending on the context. The presented analysis focused more on the identification of the problems and ambiguities and showed some direction when evaluating and classifying sources.

The analysis showed that energy sources should not be classified into certain categories upon enumeration, they should be more likely classified upon some justifiable prevailing reasons and for which it is necessary to obtain further information regarding utilization of the source from the technical, regional and time point of view, etc.

Due to the fact that energy mixes are getting more complicated in various countries, more sophisticated technologies, more complex legislative frame from the point of environmental demands and limited and supporting tools, it is possible to expect that currently valid categories and meaning of classification will be substituted by a more flexible and more appropriate classification describing the most important meanings and characteristics that will enable better orientation in this issues of more effective application of regulation mechanisms.

The facts presented herein point out to the fact that without stipulation mainly time, place as well as capacity data, the consideration about renewability/non-renewability of energy source would not have practical meaning and it is possible to expect that in future, there will be a new method for evaluation and distribution of sources created, based on principles including criteria such as form of carrier, possibility of accumulation, thermodynamic quality, location binding, etc.

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