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The reclassification of energy sources for electrical energy

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1 Introduction

To fulfill energy demand, especially electricity, the world is moving toward the usage of clean and sustainable energy sources. The market share of fossil fuels is diminishing year by year, and for renewable sources, it is *vice versa*. This transition's main focus is zero emission and sustainability. The present carbon emissions of the world based on reliable sources account for 57 giga tons of carbon equivalents ($GtCO_2e$) (Olivier et al., 2017). At present, the power sector emissions account for around 20 $GtCO_2e$, or 34% of the total emissions. This is associated with a growth rate of 10% since 2010 and a target to decrease by at least 50% by 2030 with around an 8% annual fall rate. This is followed by the steel and industrial sector with 14 $GtCO_2e$ or 24%, which has risen by around 15% since 2010. These need to decrease by around ¼ by 2030. Global average direct emission intensity of steel production needs to decrease by around 30% by 2030. Furthermore, the agricultural sector adds about 13 $GtCO_2e$ or 22%. Of these, about 7 $GtCO_2e$ come from direct, farm-gate emissions with an annual growth rate of 0.6% per year since 2000. These are set to decrease by around 20% by 2030. Emissions by internationally traded agricultural products are about 27%. The transport sector accounts for around 8.7 $GtCO_2e$, or 15% of the total emissions, which has risen by 13% since 2010. These need to decrease by nearly 1/3 by 2030. This can be achieved by 100% zero emission vehicle (ZEV) sales policies by 2035 along with a 10-fold public charging infrastructure by 2030. Carbon emissions are not only limited to commercial sectors but also to buildings and other residential areas of 6% or 3 $GtCO_2e$ per year. Although renewable energy sources also emit carbon, their total contribution to carbon emissions is only about 6% or 3 $GtCO_2e$. This confirms the necessity of renewable source adoption for sustainability. The International Renewable Energy Agency (IRENA) aims to become the main driving force in promoting a transition toward the use of renewable energy on a global scale. Also, hydrogen production (which is used as a fuel for IC engines) and use accounts for around 0.9 $GtCO_2e$ of emission, or 1.5% of the total emissions. Renewable and low-carbon hydrogen production currently accounts for less than 1% of the total. Targets and commitments to use low carbon and renewable hydrogen are equivalent to 3% of the current total hydrogen demand. This shift of energy production from conventional to sustainable sources explores new methods and sources for producing decarburized energy. Also, the perception toward solar and wind energy as a non-conventional source of energy in this present century may not be right. The emergence of alternative and waste energy recovery technology motivation is reasserting the importance of understanding the present energy scenario (Kapitonov, 2019), (Quaranta and Muntean, 2023). Hence, the new sources and methods are explored to be regrouped necessarily based on their characteristics. This aids in better understanding the nature and role of energy sources. This perspective reclassifies and characterizes energy sources into three main types and newly coined the terms discharged energy source, declining/depleting energy source, and sustainable energy sources. This opinion proposes four criteria for classifying energy in a particular classification. They are carbon neutrality,

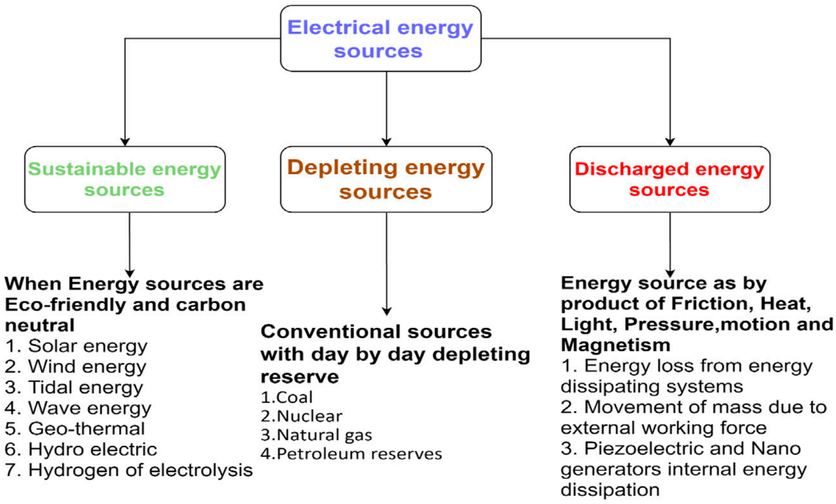

FIGURE 1
Reclassification of electrical energy sources.

eco-friendly, nature of availability, and usage at present. The choice of these four criteria is considered because of its crucial role in making energy sources sustainable.

2 Classification and discussion

Figure 1 shows the newly coined terms for energy source classification along with regrouping current technologies based on the proposed criteria.

2.1 Sustainable energy source

The United Nations Brundtland Commission coined the term and concept of sustainable development in its 1987 report Our Common Future, where it is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Kreith, 2014). From then, sustainable development has since been stated and explained from multiple perspectives. Similar to sustainable development, here, this perspective is limited to defining and elucidating the sustainable energy sources which can be converted to electrical energy. Most of the renewable energy sources are claimed to be sustainable due to their nature of replenishment. These sources are, namely, solar energy, wind, hydro, geothermal, bioenergy, and marine energy sources such as tidal and wave energy. However, the replenishment nature is not the only criterion to call it a sustainable energy source; it must necessarily satisfy the current economic, environmental, and ecology requirements (Bhuiyan et al., 2022). The environmental requirements include low/null carbon emissions from sources when converting into electrical energy since the installation and commission work of these sources to electrical conversion require the use of fossil fuel for transportation and workplace management. These result in net carbon generation rate improvement from a particular conversion system. When coming from an ecological perspective, the installation of these energy systems in particular locations will never be eco-friendly if that particular location has a rich biodiversity. This case is particularly attributed to wind energy systems in remote hill areas, hydroelectric stations, and geothermal plants (Kati et al., 2021). Furthermore, water, when converted into hydrogen through water electrolysis, has very low-carbon emissions and has the potential to replace conventional gasoline that will come under this aspect. Hence, based on these insights here, sustainable energy sources are redefined based on the aforementioned four-point criteria. A sustainable energy source is defined as "A source that can be convertible into electrical energy and by virtue of its nature able to replenish itself without adversely affecting the environment and biodiversity of its location." Apart from this, another key aspect in this source is the economic feasibility. Since a high-cost energy conversion solution can never be sustainable, hence these source conversions must be affordable. However, this case is not applicable to newly explored energy sources because of its initial struggles for development and marketing (Nahak et al., 2021). This source offers the following features: 1. This source converts into electricity that produces null/very low-carbon emission; 2. the risk to biodiversity is null/very low when this source transforms into electricity; 3. ideally, this source never depletes; 4. the infrastructure for converting this source into electricity must also possess a low-carbon emission profile; and 5. the source must be a cost-effective solution for producing electricity.

2.2 Depleting energy source

As addressed in the previous literature, like the fossil fuel whose reserve strength is decreasing day by day, these sources also possess a similar nature but it is not only restricted to fossil fuels but also applicable to other sources such as nuclear energy. As per empirical estimation and countries' pledge, many fossil fuels, including coal and natural gas utilization, will be reduced to 50% of their present strength as of COP-21-2016 by 2030 and become completely carbon neutral by 2060–70. Moreover, the time to generate these sources is never as fast as the depletion of these sources. Hence, even though humanity needs its use, these sources cannot run the global energy needs for more than half a century. Hence, its place in this classification is similar to conventional fossil fuels and non-renewable energy sources even though it is carbon neutral and economical (Prior, 1980). The newly coined term depleting energy source can be defined as "Energy sources available on earth either in abundantly or limited volume, either preserved or unpreserved but cannot be replenished even though these are carbon neutral." Coal is available abundantly in the Earth's crust, whilst nuclear sources are quantitatively less but able to generate more electricity. Both these sources are classified in the depleting energy category even though they are completely different in terms of carbon emission, type of preserve, and quantity. The other energy sources here are along with coal, nuclear, natural gas, and petroleum reserves. Based on the proposed four-point criteria, coal, natural gas, and petroleum show clear characteristics of the depleting source's property, whilst nuclear energy possesses contradiction in terms of energy reserves. Since nuclear energy has a very high potential for electricity conversion, the risk to biodiversity and its reserve characteristic in nature pull it into this classification. The present world is depending upon these sources as fuels for transport, electricity generation, and heating and cooling applications (Abas et al., 2015). The phase-out from these and transition into sustainable energy sources will provide the benefit of reduced global warming, improved public health, reduced pollution, and reinstated biodiversity.

2.3 Discharged energy sources

Apart from the classification of energy sources based on the previous methods and conventional techniques, still the generation of electricity is possible when the energy source is a byproduct of the process. In better terms, during the energy conversion or in the process results in the dissipation of energy from the system in the form of heat, light, wind and friction, and this can be converted into electricity by either direct conversion techniques or indirect techniques (Bani Hani et al., 2022). The heat energy dissipated from radiators, hot air from exhaust fans, draught fan air mass movement (Pancholi, 2022), (Akram and Butt, 2022), and friction between rolling materials can be converted into electrical energy using direct energy harvesters known as thermoelectric, triboelectric, piezoelectric, thermoelastic, and thermomagnetic harvesters (Eryganov et al., 2022). Most of these techniques use liberated heat, induced stress due to elongation, and electron liberation for electrical energy conversion. Unlike the previous two cases where sources are well defined and known to the world, these discharged energy sources have not yet come into limelight. Hence, almost most of the waste energy recovery system's energy sources are annexed to this classification, given the discharged energy source. A discharged energy source is described as "When the energy source is the result of a process in any form of friction, heat, light, chemical, pressure, and magnetism and air mass movement to subsequently either convert electrical energy or stored for energy generation." The air mass movement due to the motion of vehicles and draught fans, heat dissipated from heat exchanges and radiators. This also extends to heat dissipated from boiling and another furnace, and heat absorbed by thermal conductive energy storage elements through conductive, convective, and radiative heat transfer can be classified under these energy sources. These systems, despite low popularity, are proven effective and have the potential to emerge as energy sources (Ivanova et al., 2022). Utilization and conversion of these sources can further help in energy efficient operation of energy systems. Figure 1 shows the tree diagram of all these three types of source classification.

3 Conclusion

The necessity of this taxonomy investigation is to address the need and role of emerging sources in the energy sector. Unlike co-national classification, this investigation uses a three-tier model to address the group energy sources. The characteristics of depleting energy sources and sustainable energy sources are similar to conventional and renewable energy sources, but the strategic four-point criteria that are carbon neutrality, eco-friendly, nature of availability, and usage at present distinguish these from others, while the discharged energy sources are unclassified sources placed under emerging and explored source taxonomy.

Author contributions

AR: concept and writing. RM: investigation and proof reading.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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