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ENERGY TRANSFORMATION – SUSTAINABILITY THROUGH EFFICIENCY

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Abstract. In this paper, we will look at how improving energy efficiency and switching to renewable sources (solar, wind, hydroelectric) can support long-term sustainable development. Worldwide, energy efficiency is becoming the central solution for reducing the carbon footprint, reducing pollution and preserving resources, in the context of climate change and the depletion of natural resources. Thus, energy efficiency contributes to minimizing energy losses in conversion and use processes, which leads to reduced costs and pollution. It also supports energy security and reduces dependence on fossil fuels such as oil, coal and natural gas, which are polluting and limited sources. Another crucial element is technological innovation, which includes the development and implementation of new technologies such as photovoltaic panels, wind turbines, geothermal power plants and energy storage systems. The shift towards a sustainable energy system is thus a key direction in mitigating climate change, preserving natural resources and improving quality of life, he said, while supporting the transition to a more secure and energy-sustainable future.

Keywords: *climate change, emissions reduction, energy efficiency, renewable technologies, sustainability.*

JEL code: *O33, Q55*

Introduction

The study aims to analyze the contribution of energy efficiency in optimizing resource consumption and in reducing the negative impact on ecosystems, aiming at a sustainable future from the energy perspective.

In the literature, the transformation of energy and sustainability through efficiency is widely approached by authors from various perspectives. Energy efficiency is the key to reducing carbon emissions and conserving natural resources, as it not only limits energy losses in conversion and use processes, but, but it allows cost savings and reduces environmental impact. Energy efficiency is "the largest energy resource" because it is easier to save energy than to generate new sources [3]. Another key issue is technological innovation, which includes the development and application of new technologies such as photovoltaic panels, wind turbines, geothermal power plants and energy storage systems. These technologies offer cleaner methods of obtaining energy and, by integrating them with digital solutions and IoT (Internet of Things), enable more efficient control and reduction of losses throughout the energy chain [2]. Emerging technologies (solar, wind, green hydrogen, etc.) optimize both energy production and distribution, which leads to a significant reduction in losses. Renewable sources, such as solar and wind power, are presented in the literature as the pillars of a sustainable energy economy. Their integration with energy efficiency methods provides a viable alternative to fossil fuels and contributes to reducing global greenhouse gas emissions. Investment in efficiency is essential not only for ecology, but also for the economy, generating opportunities in the field of green technology and enhancing economic competitiveness through job creation, reducing consumer costs and decreasing national energy dependence. Among the challenges that stand in the way of the effective implementation of sustainable technologies and energy efficiency, high initial costs, reluctance to change and the lack of uniform regulations could be mentioned [5]. Thus, it becomes imperative that policies are well defined, financial incentives and educational programmes lead to the adoption of energy efficiency measures and the transition to green energy [9].

A large part of the energy sources used globally come from fossil fuels (oil, natural gas and coal), generating large amounts of carbon dioxide and other greenhouse gases (GHG). These emissions contribute to global warming, which triggers extreme climatic events such as droughts, floods, forest fires and hurricanes. Energy efficiency can significantly reduce fossil fuel consumption, thus reducing emissions and climate impact. International agreements such as the Paris Agreement set targets for reducing carbon emissions. Oil, natural gas and coal reserves are limited and their continued exploitation at high rates leads to the rapid depletion of these resources. As resources run out, extraction costs increase and pollution associated with exploitation and transport becomes more serious. By increasing energy efficiency, we can reduce dependence on these resources by keeping them for a longer period.

The process of extracting resources has negative effects on ecosystems, destroying natural habitat and threatening biodiversity. Energy efficient technologies can reduce the demand for new resources, thus limiting the expansion of exploitations and the impact on natural ecosystems.

In addition to GHG emissions, fossil fuels also generate dangerous pollutants such as nitrogen and sulphur oxides, heavy metals and volatile organic compounds. They affect air and water quality, contributing to public health problems and biodiversity degradation. Energy efficiency reduces consumption and thus, implicitly, the volume of pollutants released into the environment. Conventional energy processes also generate hazardous waste and require large amounts of water for cooling and other processes. Lower energy consumption also reduces the impact on water resources, which are increasingly subject to environmental pressures. Energy efficiency brings considerable economic benefits, reducing production and operating costs for industries and households. Thus, the savings made can be invested in more environmentally friendly technologies. Dependence on energy imports is vulnerability for many countries. By improving energy efficiency, this dependence can be reduced, allowing more efficient use of local resources and reducing exposure to fluctuations in the global market.

Energy efficiency stimulates the development of advanced technologies such as renewable energy sources, digitalization and automation of energy processes. This can lead to a more modern and competitive economy. As investment in energy efficiency increases, jobs are created in areas such as building renovation, renewable energy infrastructure and energy resource management, thus promoting a sustainable economy.

1. Connections between energy sources and conversion efficiency in the context of sustainable development

The link between the different types of energy sources and the efficiency of their conversion is crucial for the creation of sustainable energy systems. This connection affects not only the process of energy generation, but also its effects on the environment and the economy.

Energy sources fall into two broad categories: renewable and non-renewable. Renewable energy sources are those that naturally regenerate over relatively short periods of time, thus being considered sustainable. Non-renewable energy sources are those that do not naturally regenerate within an accessible human time frame, making them finite and unsustainable in the long run.

Table 1. Types of energy sources

Types of energy sources	Description	Examples
Renewable energy sources - Sources of energy that renew naturally in a short time		
Solar energy	Energy obtained from solar radiation	Photovoltaic panels, solar thermal plants
Wind energy	Energy obtained from the movement of the wind	Wind turbines, wind farms
Hydraulic power	Energy obtained from the flow of water	Hydropower plants, dams
Geothermal energy	Energy obtained from the heat of the earth	Geothermal plants, geothermal heat pumps
Biomass	Energy obtained from organic materials	Bio fuels (ethanol, biodiesel), wood burning
Tidal energy	Energy obtained from tidal motion	Tidal power plants

Non-renewable energy sources - Sources of energy that are consumed and not renewed in the short term		
Fossil fuels	Energy obtained from finite natural resources	Oil, coal, natural gas
Nuclear energy	Energy obtained through nuclear fission or fusion	Nuclear reactors

Source: author data processing according to the World Energy Outlook 2021 report

Energy transformation refers to the process by which energy from one form is converted into another form so that it can be used effectively in various applications. This process is fundamental in all areas of human activity, from electricity production to the operation of transport, heating and cooling systems.

In literature, energy conversion is frequently associated with the *principle of conservation* of energy, which stipulates that the total energy of an isolated system remains constant, even if it can be transformed from one form to another. Thus, the chemical energy of a fuel can be converted into heat energy by the combustion process, and then into mechanical energy by means of an engine.

Table 2. Types of energy conversion

Type of energy conversion	Description	Examples
Thermal conversion	The transformation of thermal energy into other forms of energy	Thermal power plants, steam turbines, solar thermal panels
Mechanical conversion	The transformation of mechanical energy into electrical energy or other forms	Wind generators, hydropower, gas turbines
Electrical conversion	The transformation of electrical energy into other forms of energy	Electric motors (transforms electrical energy into mechanical energy), electric heaters (transforms electrical energy into thermal energy)
Chemical conversion	The transformation of energy stored in the chemical bonds of substances	Batteries (chemical energy is converted into electricity), fuel cells (convert hydrogen and oxygen into electricity and water)
Nuclear conversion	Transforming nuclear energy into other forms of energy	Nuclear reactors (energy released by fission or fusion is used to produce electricity)
Solar conversion	Transforming solar energy into other forms of energy	Photovoltaic panels (transforms solar energy into electricity), solar thermal power plants (transforms solar energy into thermal energy)
Mechanical conversion to electricity	Use of mechanical energy to generate electricity	Generators (used in power plants and hydropower plants)

Source: author data processing according to the Global Energy Transformation: A Roadmap to 2050, 2019

These conversion methods play a role in the efficient use of energy, allowing it to be produced, distributed and stored in order to sustain the most sustainable global energy demand. Increasing efficiency and integrating renewable energy sources into these systems are fundamental to address environmental challenges and promote energy sustainability [1].

The interconnection between energy source types and the efficiency of the conversion process is essential for the improvement of energy systems. Renewable sources, while facing some efficiency challenges, bring considerable benefits in terms of sustainability and environmental impact. On the other hand, non-renewable sources, although they may be more effective in some respects, contribute to pollution and dependence on scarce resources [6].

In the context of sustainable development, the role of energy transformation can be analyzed through several perspectives:

a) One of the most important objectives of sustainable development is the reduction of greenhouse gas emissions. Transforming energy to renewable sources such as solar, wind or hydraulic

power helps to reduce dependence on fossil fuels that contribute to air pollution and climate change. By improving the efficiency of conversion processes, carbon emissions are reduced and environmental impacts are limited [4].

b) Diversification of energy sources by integrating renewable sources into the energy mix reduces the vulnerability of economies to fluctuations in fossil fuel prices and geopolitical instability. This diversification contributes to economic stability and to ensuring a continuous supply of energy for consumers and industry.

c) Ensuring access to energy for all communities, particularly in underdeveloped regions. Renewable energy projects (solar panels or wind turbines) provide local energy solutions that are often more affordable and easier to implement than traditional fossil fuel infrastructure. This contributes to improving quality of life and reducing energy poverty [12].

d) Innovations in renewable energy technologies and energy efficiency generate economic opportunities by creating jobs in research, development, construction and operation [8].

e) The implementation of policies supporting the use of renewable sources and energy efficiency reduces the negative impact on ecosystems and natural resources [7].

f) Raising awareness of the impact of energy choices on the environment and the economy can empower consumers, which contributes to achieving sustainability goals.

In order to increase conversion efficiency, investment in research and development as well as the adoption of energy policies that facilitate the transition to sustainable sources must be made. Here you can exemplify some strategies: creating new conversion technologies, such as more efficient wind turbines or high-performance photovoltaic panels; development of mixed energy systems combining renewable sources with traditional ones, thus maximising efficiency and minimising environmental impact and last but not least implementing measures to encourage energy efficiency and the use of renewable sources (fiscal subsidies or credits for green energy investments) [11].

2. Significance of energy efficiency in reducing emissions

The most important factor in reducing greenhouse emissions is undoubtedly energy efficiency with an impact on air quality and, implicitly, global warming. Society can reduce fossil fuel consumption and associated emissions by using energy more efficiently, thereby contributing to international environmental goals and protecting ecosystems.

In the table below, we exemplify the distribution of fossil fuel consumption by sectors of activity at European Union (EU) level.

Table 3. Distribution of fossil fuel consumption at EU level by sector

Sectors of activity	Percentage of total consumption Fossil fuels (%)
Electricity and heating production	35
Industry	25
Transport	30
Residential and commercial sector	8
Agriculture	2

Source: estimated values taken from Eurostat databases, 2021-2022 reports

Most global carbon dioxide (CO₂) emissions come from burning fossil fuels for energy production, including electricity, transport and industry (about 35%). It can be seen that industry also represents one of the largest consumers of energy (about 25%), but by optimizing production processes and adopting equipment and materials with high energy efficiency, emissions from this sector can be significantly reduced. With the help of efficient industrial equipment, the implementation of energy consumption monitoring systems and the optimization of construction and production processes can contribute to reducing emissions and increasing the competitiveness of companies [10].

Another sector responsible for consuming 25% of energy-related CO₂ emissions is transport, and increasing energy efficiency by improving vehicle fuel efficiency, using hybrid and electric vehicles and implementing more efficient transport management practices can substantially reduces

the impact on the environment. Energy efficiency programs in transport are essential for the transition to more sustainable mobility and the reduction of air pollution, especially in urban areas.

Buildings are responsible for 8% of the EU's energy consumption and related emissions. Thermal insulation measures, use of efficient materials, modernization of heating, ventilation and lighting systems lead to improved energy efficiency and can reduce CO₂ emissions by up to 50%. In cities, where the population and building density is higher, the energy efficiency of buildings is essential for long-term emission reductions.

Reducing energy and industrial emissions, together with energy efficiency measures, helps to improve air quality and protect the health of the population, thus reducing expenses related to the treatment of conditions caused by pollution. Combining energy efficiency with the use of renewable sources will generate, in the long term, an energy system capable of meeting the increase in energy demand, while contributing to the reduction of carbon emissions.

The adoption of green technologies together with efficiency measures is of particular importance for an efficient transition towards a sustainable energy system which contributes to the reduction of energy losses and, at the same time, to the increase of production capacity from renewable sources.

The transformation of the energy system implies the need for significant investments, and well-coordinated multi-year planning, together with the efficient use of financing funds, are essential. By acting promptly, savings can be realized. It is crucial that funding is efficiently allocated to investments that take into account domestic particularities and adequately respond to the needs of the energy system in a timely manner.

The investments represent concrete opportunities for improving the quality of services for consumers and for revitalizing local industry, by generating jobs and stimulating the economy. Increasing energy efficiency throughout the energy chain, which includes production, transport, distribution and end-use of energy, will benefit the environment, reduce greenhouse gas emissions, increase energy security, help fight energy poverty and it will contribute to increasing competitiveness in all sectors of the economy.

In terms of responsible behaviour in the use of energy resources, this is a key element in addressing the energy crisis and combating climate change. To change the mentality and behaviour of consumers, we need to adopt sustainable practices in everyday life. The citizen must be educated through information campaigns about the impact of inefficient energy use on the environment. These campaigns are designed to explain how reducing energy consumption can save money and protect the environment. At the same time, a responsible behaviour is that of minimizing waste (e.g.: extinguishing light and unused appliances, reducing the temperature in homes, using energy-efficient appliances-class A+++ , etc).

Responsible behaviour must also be experienced by companies in reducing energy consumption by adopting responsible and sustainable business practices. Companies can adopt policies to reduce energy consumption through short and long-term energy saving objectives (e.g., measures to optimize energy consumption in factories, office buildings, the use of energy-efficient technology and the promotion of responsible behaviour among employees). Photovoltaic installations or wind turbines can help companies significantly reduce energy consumption from conventional sources and reduce their carbon footprint. Upgrading equipment, recycling waste energy and optimizing production processes to reduce energy consumption can improve energy efficiency in the industrial sector. In the transport sector, the most important steps to reduce energy consumption and greenhouse effect emissions are to optimise routes and choose energy efficient vehicles. Responsible behaviour can be supported by Governments through fiscal policies, such as financial incentives (for the purchase of energy-class home appliances A+++ , for example, solar panels for homes or electric vehicles) regulations (imposing standards for buildings, home appliances and vehicles) and support programmes for implementing more efficient energy practices. Another responsible behaviour in the use of energy resources also involves adopting a more sustainable lifestyle through the use of public transport, reducing the consumption of natural resources and choosing more environmentally friendly consumption options. By reducing the carbon footprint of food by choosing local and seasonal

products, it can help save resources. Choosing reusable products, such as water bottles or fabric shopping bags, helps conserve energy and resources. Therefore, at individual and collective levels, small changes in behaviour can have a particular impact on energy consumption and greenhouse gas emissions.

Conclusions

Energy efficiency is a special element in reducing emissions and in the fight against climate change. By reducing the carbon footprint and optimizing energy consumption in various areas, energy efficiency helps to protect the environment and improve quality of life. The implementation of these measures brings many benefits, from the conservation of natural resources to the reduction of pollution and the promotion of public health. In the current context, where global objectives aim to limit global warming, energy efficiency is becoming an essential tool for building a sustainable and resilient future.

Efficiency in energy transformation is a key factor in the sustainable use of resources. Renewable sources play a fundamental role in ensuring a sustainable energy future by providing clean and inexhaustible alternatives, unlike non-renewable sources, which are not only limited but also harmful to the environment. Energy efficiency is not only a method of reducing emissions, but also a driver for sustainable economic development. Investments in this area not only bring financial savings and lower emissions, but also support the construction of a sustainable future by implementing effective solutions and innovations in various industries, including, promoting a greener and more resilient economy. Consistent education and awareness efforts are also crucial to ensure that these measures are applied on a large scale. Investments in energy efficiency have a multiplier impact on the economy, contributing to job creation, improving quality of life and ensuring a more sustainable future. Therefore, the implementation of energy efficiency can bring many economic, social and environmental advantages. However, it is necessary to address the challenges of initial costs, lack of awareness and inadequate regulation in order to maximise the positive effects of these measures. An integrated approach, including education, favourable policies and investment in infrastructure, is crucial to overcome these obstacles and support the transition to a more sustainable future.

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