



AI applications in smart cities' energy systems automation

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ABSTRACT

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Artificial intelligence (AI) plays a significant role in energy systems transformations in smart cities. Climate change and environmental sustainability imposed utilities to shift toward renewable energy resources and technologies applications in recent decades. Renewable energy technology deployment is associated with high initial investment and integration with the existing supply and demand systems. Operation stability has been challenging to integrate renewable energy with the customary old systems. On the other hand, renewable energy ensures sustainable energy and future development with minimum loss and greenhouse gas emissions. Therefore, AI is the primary mover of power systems modernization with high accuracy of management and control. This study tried to evaluate the efficiency and performance of AI in the renewable energy sector, focusing on the European Union as the case study. This study analyzes the first renewable energy processes in the chain and energy from gross to final consumption. Afterward economic consequences of renewable energy using natural resources (solar, wind, etc.) in smart cities are discussed. Finally, the efficiency of AI in renewable energy is examined, followed by future work.

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1. Introduction

Topics related to advanced AI technologies and their integration with intelligent energy systems and networks require a multiplicity of computational, economic, and social considerations. This platform itself needs to define some domains and specifications. Smart energy management has been studied by many researchers to develop and sustain the community, academia, industry, etc. Smart energy management within a smart city concept offers an emerging techno-economic advantages, therefore this topic has received an increasingly attention in the recent decades.

Energy crisis in the early 1790s, when the danger of energy and resource shortages was felt around the world. The planet and the reduction of underground resources created the conditions for the discussion of ecological protection [1]. Recently, energy consumption has shifted the focus to renewable energy sources with low carbon emissions, highlighting the need for the continued protection of the environment and human health [2]. The integration and use of biodegradable energy in the smart energy

management sector has a major impact on reducing greenhouse gas emissions. In comparison with fossil and natural fuels, renewable energy can be regenerated naturally, which can contribute sustainable energy development. These energy resources are always available and can meet human energy consumption for a long run with a proper decision making to overcome the initial cost dilemma. All governments and manufacturers have always sought to create this smart grid of renewable energy. And there have been solutions that bring AI into this sector and use its capacity to meet these needs. AI and its wide range can be pointed to the possibility of high prediction and generalization and its reliability and ability to explain [3]. AI represents a new era in the knowledge society and the global development based on smart and adequate information and knowledge processing and application. With a surge increase in neural networks, cognitive computing, machine learning, etc. methods and techniques applications, it offers a new unforeseen capability for management, monitoring, and optimization of



energy systems such as the integration of AI with 5G networks and sensor networks that can create a novel and suitable context for the future services of smart cities. In recent years, the focus has been on creating intelligent machines that work more like humans and react, and AI can be a branch of computer science that adds intelligence to applications and is a kind of technological advancement that gives the computer-human ability. The reasons for the growth of AI, then it could imply in the heart of AI and the growth engine of this science is the Internet of Things (IoT) because it can manage data through cloud computing, when devices are connected to internet, they can make timely and efficient decisions [4]. The main discussion in the use of AI in the intelligent energy sector is related to the capacity of AI to activate optimization systems as well as personalization and parameterization of consumption and production. Intelligent energy systems require an in-depth analysis of social and economic factors. Various AI approaches, including structured data management, data mining capabilities, and machine learning techniques together can be used for the smart energy systems. An AI-enabled smart grid advances the development of intelligent renewable energy, AI must be added to all levels of energy networks [5]. The aim of this paper is to evaluate the World Union report considering the reduction of natural resources and non-renewable natural energy trends, which covers technical and economic studies. And the analysis of the facts has concluded that renewable energy can speed up the quality of life of citizens and help make cities smarter. As mentioned, AI with the science of machine learning, cognitive computing capabilities, etc. are one of the main factors in the field of intelligent energy networks. Analysis and discussion of the forementioned dimensions are the main objectives of the paper.

In this paper, it is stated how AI could foster renewable energy deployment, and evaluating whether it is economical to include AI or not. Enabling of renewable energy technologies into smart cities can be economic and environmental-friendly in long run. Literature finds that the use of economically renewable energy with its use of advanced AI technologies can be challenging due to many resources, but it can be an optimum socio-economic solution for designing future and healthy smart cities. Finally, in this study, an attempt has been made to use logical and generalizable AI for renewable energy development analysis by evaluating different intelligent networks that can be formed to be used in smart cities for future generations.

2. AI and biodegradable energies

Energy sectors in the world have undergone many changes that affect its growth and flexibility as the primary and powerful source for future global development. Due to climate change and the reduction of natural resources and increasing pollution, development of smart and renewable energy cannot be ignored. In this trend, each country has its own exploiting energy plans, depending on the internal and external potential. An increasing trend towards renewable energy deployment in Giga scales system requires antral production and distribution [6]. Energy production using its renewable resources has remain problematic depending on the environmental and climate change limitations that requires an adequate planning meeting ecological and socio-economical aspects.

The growing influence of renewable energy in the energy sector emphasizes the need for accurate forecasting of variable resources [7]. AI supposed in the 1771s, and advanced in the recent decades. AI has gained confidence after IBM Computer defeated a chess champion in a match and ALPHAGO defeated an Asian Games champion and many of these systemic behaviors that have been able to overcome human powers. It is used in many fields, AI can be introduced to the following three features [8]:

- 1- Learning (knowledge and algorithms that are based on data collected, improve and increase automatic efficiency)
- 2- Cognition (potential for identifying scars and processes based on similarity to previous periods)
- 3- Actions (action and autonomy of AI in timely and systematic decisions)

Researches report that AI is an activity dedicated to intelligent machines and it is a quality intelligence that enables the entity to function appropriately and with foresight in its environment [9]. AI refers to the computational study that enables understanding, reasoning, and action that must be defined in terms of these goals:

- In engineering (seeks to solve real-world problems as the final stage of AI)
- In scientific analysis (identifying ideas which solve problems and serves as an incentive to use AI in major activities and studies).

AI can make predictions, recommendations, and decisions about a specific set of goals defined by humans and affect the real or virtual environment [10]. Relying on the analysis of observing, collecting, and

analyzing large data sets, AI systems can change their behavior without reprogramming. They provide an overview of processes, and algorithms can provide valuable information. When the systems and data become more complex, AI needs a system and support for decision-making process [11]. With the presence of AI in the energy sector, a huge change is taking place that the whole world is involved in this issue and they must plan their macro-administrations in such a way as to create space for AI and smart grids in their programs. Today, climate change has raised concerns about the development of these intelligent systems [12]. As a result, before starting anything, experts need to assess the weather and climate conditions and calculate how much energy enters the smart grids, for example, into the power grids [12]. For this purpose, AI intelligent algorithms are created and produced that produce, control, and transfer these energies to the network. These new algorithms require less computational time and are more accurate [13]. The complexity of these networks is constantly increasing and AI should use automated algorithms along with weather forecasting to use the

full potential of investing in renewable energy and forecasting the energy produced by all components of the network. Creating a network in renewable energy requires a lot of initial capital, which is one of the main problems. Therefore, to reduce costs by using AI, systems receive and analyze large volumes of data from the smart grid. The use of AI destroys traditional science and creates intelligent networks that lead to economic growth and reduce environmental pollution. Developed countries in the world of this used the subject and are witnessing prosperity and investment in their labor market [13].

Importance of human presence in AI activities, which shows in Figure 1, outlines the goals and importance of human presence. AI can indeed be a substitute for human activities, but the fact that a human being as an expert brain should be the actions and behaviors of AI monitors are not far-fetched. This diagram demonstrates a set of activities that humans can manage in AI environment. In general, it can be implied that the integration of AI and renewable energy can help increase jobs and quality of life within smart cities applications.

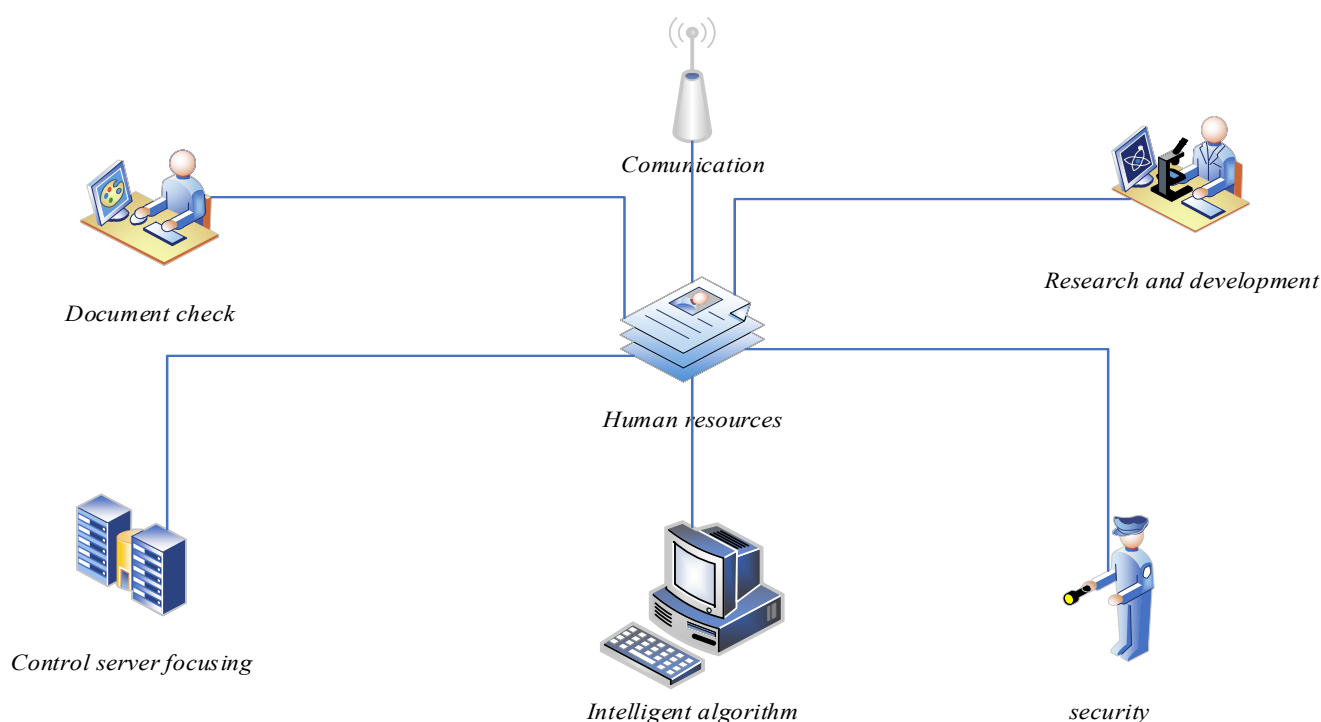


Figure 1. The importance of human presence in artificial intelligence activities.

3. Integration of AI and renewable energy in smart cities

With regard the fact that the amount of data in smart networks is very abundant, AI is widely used in these

networks. In this case, AI could be used especially are monitoring, exploitation, maintenance, and storage of renewable energy. By integrating AI and renewable energy technologies, the following items can be created:

- Production of renewable energies according to the variety of demand and supply fluctuations.
- Investigation of safety and reliability requirement of smart grids in renewable energies.
- Supply, demand, climatic characteristics, etc.
- Performance management.
- Energy storage.
- Design and market operations.
- Connection between network components and subnets that further investigation.

Intelligent matching of supply and demand: At the time of supply of artificial energy, using advanced algorithms, it determines that energy, which network does the supply belong and directs it to the same network.

- Intelligent storage: The energy produced by storing renewable energy sources such as wind, solar, etc. is stored in predetermined locations, which is one of the tasks of AI.
- Centralized control system: The general management system is an intelligent network that is designed in a smart city and has the task of controlling resources.

4. Methodology and analysis

This paper deals with the following methodologies:

- Establishment and macroeconomic partnerships in the field of smart grids and renewable energy.
- Integration of AI in research models and recognition of AI as a research field with a key impact on its efficiency and performance in the network smart and renewable energy.
- The impact of AI projects in smart cities and the economic viability of this study.

Due to the increasing use of fossil fuels and renewable resources utilization in the world, developed countries al relied to renewable energy technologies in the context of their economic capabilities. According to the World Energy Commission renewable energy refers to sources such as wind, solar, water, bio-fuels, and renewable waste. European and American countries are among the leaders that seek to create a global climate for the use of renewable energy [14].

In 2019, a new directive was issued by the American and European Union stating that by 2031, at least 32% of the energy supplied by these countries must be from renewable energy sources. Some of these countries have achieved their goal before 2024.

Countries with smart energy management and countries have even exceeded the goal of this indicates that European and American countries have special planning on this and have an upward trend [15]. Due to the performance of renewable energy, many countries also consider their economic interests in the planning and deployment of these resources, and before starting any work, they measure their costs by using AI science, they can reduce their costs to the lowest possible cost. There are many fields of study in this regard in American and European countries that studies are recommended to refer future work [16].

Table 1 shows the change in renewable energy generation relative to the previous years of some nations with smart energy management in the field of renewable energies development (from 2006 to 2019), measured in terawatt-hours. This is the sum of energy from hydropower, solar, wind, geothermal, wave and tidal, and bioenergy, which data have achieved from artificial intelligent science.

Table 1: Annual change in renewable energy generation [17].

Nations	2006(TWH)	2019(TWH)	Changes
United States	30.643	51.04	60%
Europe	69.97	246.73	352.76%
Germany	19.43	45.11	233%
Japan	-1.14	45.14	380.12%
China	122.9	229.45	180%
India	11.2	64.08	538%

Renewable energy has grown between 2006 and 2019 [17,18]. However, renewable energy has increased its share of final energy consumption over the years. This growth of renewable energy has occurred with the help of AI. The new technologies are available, traditional energies (biodegradable and non-renewable) are still widely used. Possibilities are able with the presence of AI and the establishment of smart cities [17]. Analyzing data and studies, it was found that AI with smart energy management is being widely used worldwide with economic advantages.

5. Conclusion

Renewable energy deployment has increasingly grown worldwide to reduce the impact of climate change and global warming. Renewable energy is not only an important part of research in smart cities but also an effective solution for today's socio-economy

that can be looked at in terms of resource depletion. AI is also an integral part of the intelligence of any system and any part that renewable energy sector is no exception to this rule. AI helps to manage energy production, supply and consumption in a changing environment and market context. In this regard, it was found that the use of AI in the renewable energy industry causes great economic benefits. On the other hand, it should be noted that smart energy management is the heart of a smart city and this infrastructure should be part of the infrastructure. AI with smart energy management is a solution that must be used at the microeconomic level to optimize renewable energy technologies applications and performances by analyzing, forecasting, pattern identification, reducing storage costs, and better connecting networks and users. Therefore, AI with smart energy management changes the energy sector and improves sustainability nationally and globally.

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