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Faculty of Mechanical Engineering

10th International Scientific Conference

IRMES 2022

Research and Development of Mechanical Elements and Systems

PROCEEDINGS

"Machine design in the context of Industry 4.0 – Intelligent products"

ADEKO
Association for Design, Elements and Constructions

26 May 2022, Faculty of Mechanical Engineering, Belgrade, Serbia

10th International Scientific Conference - IRMES 2022

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PROCEEDINGS

Machine design in the context of Industry I4.0 – Intelligent products

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Dear Ladies and Gentlemen, Colleagues, Participants and Friends of IRMES 2022

The International Conference on Research and Development of Mechanical Elements and Systems – IRMES is organized under the auspices of the Association for Design, Elements and Constructions (ADEKO). The Conference has a long tradition of gathering scientists, researchers, academics, engineers and industry representatives, intending to exchange and share knowledge, ideas, experiences, innovations and research results in the field of engineering design, machine elements and systems.

So far, there have been nine editions, organized by several universities – members of the ADEKO association:

1995 – University of Niš, Faculty of Mechanical Engineering
1998 – University of Belgrade, Faculty of Mechanical Engineering
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2019 – University of Kragujevac, Faculty of Engineering

More than a thousand authors participated in previous IRMES conferences, with more than a thousand papers published in total. The current IRMES conference was supposed to be held in 2021. However, due to the COVID-19 epidemic, it was postponed to 2022.

The main topic of the IRMES 2022 conference is „Machine design in the context of Industry 4.0 – Intelligent products“. For sociologists and philosophers of science, the question remains whether the concept today, most commonly called Industry 4.0, is the true fourth technological revolution or the development/continuation of the third technological revolution – through further application of computers in production and logistics. It is indisputable that the essential question of this concept is the following: how do we introduce intelligent production in the industry? This consequently opens up new questions in the field of engineering design, theory and practice of technical systems and machine elements, and innovative product development – in the environment of the now global comprehensive Industry 4.0 concept or the Japanese answer to this concept – Society 5.0.

Teaching subjects and modules, such as Mechanical Elements, Machine Design, Innovative Product Development and others, has been the basis and generator of previous technological revolutions. Therefore, the question arises as to how to develop and improve the existing content of these subjects, but, also, what the best way for knowledge transfer is to keep the listed subjects as a driving force behind further development and improvement of philosophy and concept of Industry 4.0 (ie. how to implement new teaching methods, lessons, exercises, student projects, laboratory work, evaluation).

Taking into account the previously described facts, it is clear why an exchange of opinions, experiences and results between experts in the Industry 4.0 area is essential for social and industrial development. One of the best ways to do that is via public debate at international conferences, such as IRMES 2022, which we are very glad and proud to host and organize this year.

Belgrade, 26 May 2022

Prof. Dr. Radivoje Mitrović

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SAVING ENERGY THROUGH THE USE OF RENEWABLE ENERGY SOURCES TO LOW CARBON CITIES

Ana RADOJEVIĆ
Jasmina SKERLIĆ
Danijela NIKOLIĆ
Blaža STOJANOVIĆ

Abstract: *In the field of energy, Europe is facing challenges such as high import dependence, low diversification, high and volatile energy prices, growing global energy demand, security risks affecting producer and transit countries, growing threats from climate change, insufficient energy efficiency, as well as an increasing share of renewable energy sources (RES). Climate change has been identified as one of the biggest challenges, and European energy policy is increasingly focused on tackling this threat, advocating for reducing greenhouse gas (GHG) emissions, especially* CO_2 *emissions. The European Parliament wants the new energy policy to support the goal of reducing GHG emissions in the EU by 55% until 2030 and achieving a zero net emission rate by 2050. In the total world energy consumption, cities participate with over two thirds, and more than 75% of all GHG emissions come from cities. In the cities themselves, buildings are one of the biggest sources of* CO_2 *emissions. The EU directive on energy efficiency of buildings sets the goal that by 2050 the housing stock fund has zero* CO_2 *emissions. Thus, the goal is low-carbon cities, and the path to the goal may be the use of RES in cities. The paper uses examples from the world and Serbia to analyze how the use of RES leads to low-carbon cities.*

Keywords: *climate change; GHG emissions; RES; low-carbon cities; smart measurements*

1. INTRODUCTION

At the time of the energy crisis, we are witnessing the role of energy independence, ie the importance of a large share of the use of renewable energy sources and energy savings.
Today, more than half of the world's population lives in urban areas [1], and the number is constantly increasing. By the middle of the century, three-quarters of the global population is likely to live in urban areas, that is, in cities. Cities consume two-thirds of energy, generating more than 75% of global greenhouse gas emissions, which are a major cause of warming and climate change.
It undoubtedly follows from the above that cities are key actors and must be leaders in actively encouraging and enabling change, ie in facilitating the maximum use of renewable sources. The current trend of rising prices of electricity and other energy sources (gas, oil products, solid fuels) will become even more drastic with the worsening climate crisis. In order to ensure timely availability of energy and a better quality of life in local communities, in the future it is necessary for cities, ie. local self-governments, to take decisive steps towards the maximum use of renewable energy sources as soon as possible.
The cessation of the use of fossil fuels and the maximum use of locally available renewable energy sources is a crucial step in the fight against climate change.
The use of decentralized renewable energy sources is the primary tool for reducing the use of fossil fuels, mitigating the effects of the climate crisis and preserving nature and the environment. In addition, local renewable energy sources stimulate economic development, provide us with more choices in terms of our own energy production, and encourage local competition and innovation.

2. PLANNING for LOW-CARBON CITIES

Through the correct determination of strategic goals and planning the development of the city, the city administration defines the direction and speed of change and manages them in a coordinated manner, which enables real and systemic changes. This is an important advantage of cities.
Cities must know and plan what they need to ensure the low-carbon development of the city and enable everything

that citizens need for a quality life, not only now, but in 10, 20, 30 and more years.

The solutions we need must not trap us in new carbon emissions and further dependence on energy and energy imports, they must include investments in local sustainable energy.

Low-carbon cities have always been the subject of research by researchers around the world. All cities, especially those in low- and middle-income countries, are looking for solutions to control climate change. In order to achieve a city with low carbon emissions, participation and cooperation between governmental and non-governmental organizations and sectors has become more pronounced, so that all of them strive to achieve an integrated goal (low-carbon city).

One example of low-carbon city planning is Bangkok, where there is a planned decline in energy consumption and reduction of carbon emissions from 2000 to 2025. The year 2000 is used as the base year. The sustainability of the sixteen proposed policies and scenarios was analyzed using a multi-criteria decision-making approach. The results of this study provide insight into Bangkok's energy and carbon future and highlight the steps needed to promote a sustainable, low-carbon society. The most significant energy savings are in the transport sector, where the modal shift from private passenger vehicles to public transport systems has the potential to significantly reduce energy demand, carbon emissions and local air pollutants.

The Chinese government has been continuously developing several series of low-carbon city pilots since 2010. Research [2] shows how possible the goal of reducing carbon emissions can be achieved by building low-carbon pilot cities in different parts of China. The research showed that the effects of pilot policies vary significantly in different regions, depending on administrative power, GDP, carbon trade policy, use of new energy vehicles, energy structure, industrial structure and level of innovation.

Paper [3] shows that zero carbon buildings in Hong Kong can contribute to the creation of low carbon cities. In order to achieve the goals, it is necessary to raise public awareness of sustainable living, reduce energy use in other buildings and promote strategic urban planning. However, the most significant risks were identified as geographical barriers to domestic renewable energy production, high reliance on fossil fuels, and policy resistance by practitioners.

Empirical results in [4] have shown that pilot cities in China reduce carbon emissions by approximately 2.72% per year. In addition, the related loss of gross domestic product from 2013 to 2017 was approximately 1.19 trillion yuan. The analysis of the mechanisms clarified that the pilot cities reduced emissions by adjusting their industrial structure, promoting technological innovations of companies in order to increase their overall factor productivity and stimulating research and development of low-carbon technologies. The results of this study provide examples, supported by data, for the government to further promote its policy of building low-carbon cities.

In [5], the following solutions for achieving a low-carbon city in Tehran were identified with the help of Scenario Wizard software: Implementing urban green spaces such as local community gardens to enhance local participation and green employment, availability and density of pedestrian areas in order to develop non-motorized transport and reduce pollutants, conversion of the public buildings of the city into green buildings in order to move towards low carbon Tehran, creating the space for participation with the help of citizens to informing them, creating the national network for information sharing of urban projects and plans, financial supports for micro and creative industries in order to economic prosperity and increasing domestic production, implementing environmental plans to improve the ecological balance of the city, creating rooftop gardening on the roofs of public buildings, creating cool white ceilings (sealant coating with light colour) and installation of solar panels on the roofs of public buildings. Research has shown that Tehran's best scenario for moving to a low-carbon city would be the first scenario.

Paper [6] has shown that population size, household size and built - up land concentration are most responsible for carbon emissions. In this study, an integrated assessment method was used to assess the spatial carbon emissions, carbon sequestration capacity, emission-sequestration balance, and carbon resilience capacity of a Himalayan city using the ecological support coefficient.

The study [7] aims to analyze the CO_2 emission characteristics and spatial distribution in megacities among different countries, which is important for climate change mitigation. In this study, 12 megacities from China, Japan, and South Korea were selected as typical case studies for analysis. Results show that Chinese cities' CO_2 emissions are among the top four cities studies and are much higher when compared to the other sample cities in Japan and South Korea. Chongqing, Incheon, Tianjin, and Shanghai were the top four cities with the highest carbon intensity. The spatial distribution of urban carbon emissions varies widely. In Seoul, Tokyo Metropolis, and Beijing, 90% of carbon emissions are concentrated on 74.17%, 55.95% and 8.93% of the land area, respectively. The results of the driving forces and emission reduction targets analysis indicate that the three countries face different challenges and there are different action plans in each city accordingly. This study proposed the carbon emissions reduction targets and countermeasures in different industrial sectors, including an increased rate of the standardization of city CO_2 emission accounting systems and the decarbonization of the power industry, among others. These countermeasures will not only contribute to the analysis of CO_2 emissions but will also promote to the low-carbon city development and encourage the realization of urban sustainable development goals.

The paper [8] examines the roles of local governments that are in the early stages of a transformation from centralized to decentralized energy, while drawing on the lessons learned from the experience of three municipalities in Japan. This study found that the effective transitions to renewable energy in Japanese towns result largely from conflict-free policy coordination, which the author argues was produced by forward-looking local mayors.

This paper explores challenges that power sector faces in order to meet the decarbonization targets, and identifies certain modifications that should be made during the transition process. [9] Urban electrification with renewables is a crucial strategy for achieving low-carbon and climate-resilient communities. Given the different types of power customers (e.g., residential, commercial and industrial), this work develops a systematic and straightforward framework for the optimal planning of urban solar/wind/biomass (/natural gas) systems at neighbourhood scale using the actual real-time hourly electric loads. This study can help decision-makers in developing more effective policies and mechanisms to support the urban hybrid renewable energy systems.

3. EXAMPLES OF THE USE OF RES IN CITIES IN THE PROCESS OF DECARBONIZATION

There are different ways to achieve the goal of low-carbon cities, and most of them involve the use of renewable energy sources. The process of producing electricity, district heating systems, urban transport, the concept of a smart city, as well as the use of biomass, can be some of the ways to achieve climate-neutral cities.

When taking into account the general terms on which the global green and low-carbon transition takes place, it can be affirmed that the use of clean and renewable energy, including wind, hydro, solar, etc., is an alternative to the traditional energy sources. The renewable energy industry possesses considerable potential, and has recently become the center of the global energy landscape. Therefore, this article refers to the rolling-window Granger causality test, in order to explore the role of renewable energy (RE) in reducing the GHG emissions. By studying the interactions that take place between RE consumption and carbon dioxide (CO_2) emissions, we find that the negative impact of RE on CO_2 indicates that the replacement role of RE has become increasingly prominent, for it to effectively contribute towards the realization of carbon emission reduction. The results in this regard are consistent with the energy-environment model, suggesting that RE has an excellent performance in achieving carbon neutrality. In fact, CO_2 usually exhibits a negative effect on RE, which indicates towards the predictability of environmental quality to the development potential of renewable energy. [10]

The increasing level of carbon emissions is one of the most serious concerns in human history facing in today's world. Different countries adopt different policies and approaches to mitigate climate change severity. The current study evaluates the effect of carbon emissions, renewable energy sources, ICT, governance, and GDP in Morocco employing a time-series dataset over the period of 1985–2020. In this paper, we utilized the dynamic ARDL simulations model to explore the association among carbon emissions, renewable energy sources, ICT, governance, and GDP. The ARDL bounds test reveals a long-run connection among the variables. The findings suggest that renewable energy sources (i.e. solar, wind, hydroelectric), ICT, and effective governance are the key indicators to reduce carbon emissions. In addition, we utilized the Granger causality test to probe a causal connection between the study variables. The outcomes have long-run implications for carbon emissions degradation and Morocco's policy towards the fight against climate change. [11]

A transition towards long-term sustainability in global energy systems based on renewable energy resources can mitigate several growing threats to human society simultaneously: GHG emissions, human-induced climate deviations, and the exceeding of critical planetary boundaries. However, the optimal structure of future systems and potential transition pathways are still open questions. This research describes a global, 100% renewable electricity system, which can be achieved by 2050, and the steps required to enable a realistic transition that prevents societal disruption. Modelling results show that a carbon neutral electricity system can be built in all regions of the world in an economically feasible manner. This radical transformation will require steady but evolutionary changes for the next 35 years, and will lead to sustainable and affordable power supply globally. [12]

When we talk about the process of decarbonization in Serbia, several authors first dealt with the decarbonization of electricity production, at the level of the whole country. The results of the [13] reveal that hydropower and biomass have the highest potential among available renewable energy sources in decarbonization of electricity production. The paper [14] shows that, in the longer term, technologies that would most influence the market model will be distributed energy sources, demand response and energy storage, but it is also obvious how very important adequate policy measures are for the configuration of the decarbonized future. Interactions among technologies, system rules and market codes will trace the path of market model development. Serbia plans to shut down eight coal-fired power units with a capacity of 622 MW and a production of 1717 GWh per annum by 2024, but also to build a new 350 MW with a planned production of 2200 GWh.

3.1. Production of electricity from renewable energy sources

The paper [15] analyzes the use of renewable energy (RE) for electricity in 45 Indian cities within the Smart Cities Mission and its results. The analysis shows that the penetration of RE in cities is low. In addition to producing electricity in cities, those with the best performance could successfully use renewable energy outside city limits through regulatory incentives. The potential and strategies for exploiting more RES in cities were presented. The challenges of greater adoption of renewable energy sources in cities and necessary policy recommendations are also discussed.

3.2. Use of natural gas in district heating systems

Air pollution, caused by the use of fossil fuel, has been an environmental plague in China. It has a strong negative impact on human health. Since the costs of damage to health are not born by the pollution producers, these costs translate to social externality. Policies have an important role in optimizing resource allocation, such as penalizing the pollutant producers and incentivizing clean energy development. Among others, replacing coal with natural gas for heating represents an important example of air quality improvement measures. This paper presents a study that evaluates the health impacts from air pollution and the external cost of the "Coal-To-Gas" policy in district heating using Changping District (Beijing, China) as an example. Four scenarios were considered based on the historical and standard PM2.5 concentration. Results show that PM2.5 is responsible for causing an increase of 40% premature deaths in 2015 and that the monetary value of damage to health is higher than 1.2 billion CNY. In 2016 and 2017, the reported air quality was better than that in 2015. As a result, 13.3% and 26% premature deaths caused by air pollution were avoided in 2016 and 2017 compared to 2015 respectively. If the PM2.5 concentration level were to be reduced to national standard, the number of premature deaths attributed to PM2.5 could further decrease to 47.7% compared to 2015. Overall, the Coal-To-Gas policy in district heating reduces 0.017%~0.45% of premature death caused by air pollution each year. Air pollution reduction policies, which are expected to improve air quality together in the future, and the specific policy of Coal-To-Gas in district heating, could make great contribution to reducing the premature death caused by environmental problem and need more attention from the government and the public. [16]

3.3. Smart cities

Among the main components of a smart city, the energy system plays a key role, while the use of renewable energy sources has proven to be a significant contribution to reducing pollutant emissions and improving the quality of the environment. The use of renewable energy technologies very much, as part of the smart city concept, could make a significant contribution to a society with a low-carbon economy. The paper [17] fully presents the main components and roles of renewable energy sources (such as solar energy, wind, geothermal energy, hydropower, ocean and biofuels) used for smart city. In addition, the integration of forms of renewable sources into the energy systems of smart cities has been analyzed in detail on the basis of technical and economic criteria. Finally, existing challenges and future scenarios were discussed in detail to clarify the progress and perspective of smart renewable energy systems for a smart city. In general, the integration of renewable energy sources into the energy systems of a smart city is an insightful perspective and a solution aimed at achieving a cleaner process and more sustainable development.

3.4. Public transport

It is essential to understand the types and characteristics of urban transport CO_2 emissions and propose differentiated CO_2 emission reduction measures and formulate renewable energy use strategy, with a view to sequentially achieving the peak of urban transport CO_2 emissions. Based on the analysis of driving factors of urban transport CO_2 emission, this paper establishes a classified index system and then adopts the Gaussian mixture model (GMM) and expectation–maximization (EM) algorithm to cluster the trends of transport CO_2 emissions peak in 672 municipal cities in China. The results show that the model can effectively identify the differences between different cities and divide them into five types, namely the types of public transport demonstration, emission pressure, low carbon potential, population loss, and high carbon pressure, the proportion of urban transportation carbon emission in these five cities is 44.39%, 22.19%, 18.21%, 7.66% and 7.55%. Moreover, by analyzing different energy endowment characteristics and geographical features, optimization suggestions are put forward for the transportation energy consumption of different cities to realize the efficient utilization of renewable energy. [18]

3.5. Use of biomass

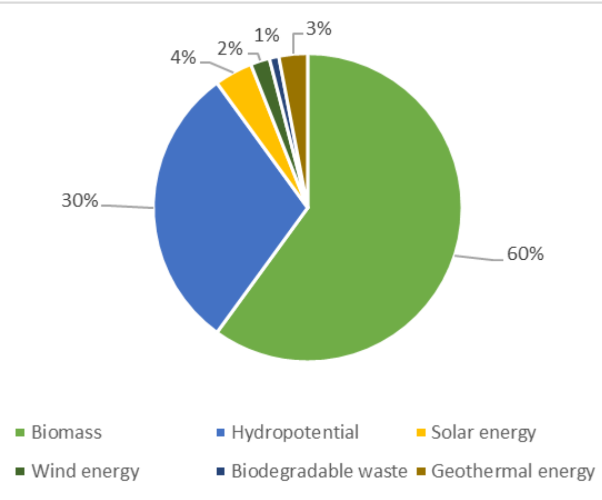

Fig.1. Potential of available renewable energy sources in Republic of Serbia

The available range of renewable sources in the Republic of Serbia shows that biomass has the greatest potential - 60%, out of which 32% is currently used. [19] Research shows that replacing fossil fuels with biomass in public buildings can lead to a reduction in CO_2 emissions of up to 94%, according to an analysis in the Serbian cities of Priboj and Pirot, where wood chips and biomass have been used for heating of the public buildings for the past six years.

4. CONCLUSION

At the time of the energy crisis, we are witnessing the role of energy independence, ie the importance of of the use of renewable energy sources and energy savings.
Today, more than half of the world's population lives in urban areas, and the number is constantly increasing. By the middle of the century, three-quarters of the global population is likely to live in urban areas, that is, in cities. Cities consume two-thirds of energy, generating more than 75% of global greenhouse gas emissions, which are a major cause of warming and climate change.
There are different ways to achieve the goal of low-carbon cities, and most of them involve the use of renewable energy sources. The process of producing

electricity, district heating systems, urban transport, the concept of a smart city, as well as the use of biomass, can be some of the ways to achieve climate-neutral cities.

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