UNIVERSITY OF BELGRADE
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

Research and Development of Mechanical Elements and Systems

PROCEEDINGS

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

Editors
Prof. Dr. Tatjana Lazović
Doc. Dr. Žarko Mišković
Prof. Dr. Radivoje Mitrović

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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
2000 – University of Podgorica, Faculty of Mechanical Engineering
2022 – University of East Sarajevo, Faculty of Mechanical Engineering
2004 – University of Kragujevac, Faculty of Mechanical Engineering
2006 – University of Banja Luka, Faculty of Mechanical Engineering
2011 – University of Niš, Faculty of Mechanical Engineering
2017 – University of Montenegro, Faculty of Mechanical Engineering
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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CONTENTS

PLENARY LECTURES

INVITED LECTURES

INDUSTRY 4.0

MACHINE ELEMENTS AND SYSTEMS

ENGINEERING DESIGN, NEW TECHNOLOGIES

10th International Scientific Conference
IRMES 2022
"Machine design in the context of Industry 4.0 – Intelligent products"
26 May 2022, Belgrade, Serbia

MAINSTREAMING LOW CARBON URBAN DEVELOPMENT – DECARBONIZING CITIES

Jasmina SKERLIĆ
Danijela NIKOLIĆ
Blaža STOJANOVIĆ
Ana RADOJEVIĆ
Aleksandar MIŠKOVIĆ

Abstract: *For decades now, the climate changes have required great attention in sustainable development of the planet, and, same as reducing carbon emissions in the environment, they have become an absolute imperative for the future of the human civilization. Compliance with the Paris Agreement requires the transformation of national economies in order to meet net zero carbon emissions by the middle of the century. To achieve this, countries need to define long-term decarbonisation strategies with short- and medium-term actions to determine their ideal future scenario, while maximizing socio-economic benefits. Identifying new roads and fostering urban development with very low or neutral carbon content is a new challenge for government, industry and the community. Providing the capacity to generate and trade carbon credits in urban development could potentially help decarbonise cities. Carbon certification has also been identified as a way of recognizing and rewarding progressive urban development, which can show a true reduction in carbon. This paper describes the procedures that followed in order to support the creation of a decarbonisation trajectory for the transport and energy sectors. In this paper, we will discuss the technological path of deep decarbonization that supports reaching zero emissions by 2050. Certainly, innovations in decarbonisation will be the main source of wealth in the future. So far, it has been shown that technologies are available, the principles of urban design for decarbonisation are well understood, but management systems to facilitate and manage development at the municipal level are still largely lacking. If we succeed in developing such systems, processes, and mechanisms that target the built environment and reward positive behavior, we could begin to radically decarbonize our cities.*
Keywords: *Energy policy; smart measurements; decarburization of cities; greenhouse gas emissions;*

1. INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) is an international agreement established in 1992. The convention's objective was to stabilize greenhouse gas (GHG) emissions across the world in order to respond to the global threat of climate change. The subsequent Kyoto Protocol established legally binding obligations for countries to reduce their emissions. Most recently, in 2016, the Paris Agreement was adopted to govern GHG emission reductions from 2020. These international treaties are designed to catalyze appropriate mitigation action across the world.
At the same time, European energy policy is increasingly becoming a significant tool in the fight against climate change, advocating for the reduction of GHG emissions. The European Parliament is in favor of stronger commitments to EU targets, and stresses that the new energy policy must support the goal of reducing GHG emissions by 55% in the EU by 2030 and achieving zero net emissions or climate neutrality by 2050. With the adoption of the latest amendment to the Directive on energy efficiency of buildings, in 2018, EU countries will have to establish stronger long-term renovation strategies, with the goal of the housing fund having zero CO2 emissions by 2050.
Two of the five main objectives of EU energy policy relate to decarbonisation: the decarbonisation of the economy and the transition to a low-carbon economy under the Paris Agreement, and encouraging the development of new and renewable forms of energy to better align and integrate climate change-related targets into the new market model.
The current policy agenda is based on the comprehensive integrated climate and energy policy adopted by the European Council on September 24, 2014 and revised in December 2018, which envisages achieving the following targets by 2030: reducing greenhouse gas emissions by at least 40 % compared to 1990. On November 30, 2016, the European Commission presented the Proposal for a Regulation on the governance of the Energy Union as part of the "Clean Energy for All Europeans" package [1].

According to the Regulation, each Member State should present an "integrated national energy and climate plan" by 31 December 2019, and every ten years thereafter. These long-term national strategies will set out a political vision for 2050, in order for member states to achieve the goals of the Paris Agreement. These integrated national energy and climate plans will include national objectives, contributions, policies and measures for each of the five dimensions of the energy union: decarbonisation, energy efficiency, energy security, the internal energy market, as well as research, innovation and competitiveness. The European Parliament also calls for stronger commitments to EU targets, and stresses that the new energy policy must support the goal of reducing EU greenhouse gas emissions by 55% by 2030 and achieving a zero net emission rate or climate neutrality by 2050.

2. WHY CITIES?

Today, close to 55% of the global population live in urbanized areas. By 2050 it is expected that this number will increase to over 65% [2]. In Europe, the level of demographic urbanization is approaching 74%. Because of all this, the European Commission's long-term strategy [3] recognizes cities as ideal places for transformative and sustainable solutions. Urban renewal and better spatial planning, including green spaces, can be the main ways to achieve the goal of net-zero GHG emissions by 2050 [4]. Cities consume over two-thirds of the total amount of energy consumed worldwide. Over 70% of all GHG emissions originate from cities [5].

The impact the urban environment has on contributing to the root cause of climate change cannot be understated.

Carbon dioxide (CO2) is the most prevalent GHG emitted by human activity. CO2 is the most commonly-used term when describing accounting for harmful GHGs. National and international carbon emissions accounting shows carbon as carbon dioxide equivalent (CO2e). This includes the conversion of other GHGs, such as methane from landfill, into their equivalent CO2 emissions based on their relative global warming potential. This form of accounting aligns with national and international measurement of CO2 emissions) [6].

The application of low-carbon technologies for sustainable energy production and use requires the active involvement of local and regional communities. The reason for this is that cities around the world consume 78% of the world's energy and are responsible for more than 70% of global CO2 emissions [7], due to energy production, transport, industry and the use of biomass [8]. Urban activities affect the environment both negatively and positively [9], leading to the need for cities to address climate change, reduce energy consumption and increase the use of renewable energy sources (RES) through the development of holistic plans based on environmental, social and economic aspects. To do so, city authorities need the support of appropriate methods throughout the value chain of urban development that address the growing demand for energy, changing demographic data, and creating infrastructure [10]. This is even more relevant given that a recent review of climate plans of 200 EU cities reveals that climate change planning in EU cities is largely determined by their local organizational capacity [11].

The EC strategy points the way forward to a carbon-neutral economy by referring to a set of joint actions:

- improving energy efficiency in buildings, which today are responsible for 40% of energy consumption;
- maximizing the deployment of renewables and the use of electricity to fully decarbonize Europe energy supply;
- embracing clean, safe and connected mobility, currently responsible for around a quarter of the GHG emissions in the EU;
- fostering circular economy as a key enabler to reduce GHG emissions, starting from reducing the input of materials through reuse and recycling, and significantly modernizing or replacing existing installations;
- developing an adequate and smart infrastructure ensuring optimal interconnection, especially to support the major developments framing the energy transmission and distribution landscape of tomorrow;
- reaping the full benefits of bio-economy enhancing capacity of agriculture and forestry to provide sufficient food, feed, and fibers as well as to support the energy sector and various industrial and construction sectors.
- enforcing carbon sinks, as important as reducing emissions, by maintaining and further increasing the natural sinks of forests, soils, and agricultural lands and coastal wetlands;
- tackling remaining CO2 emissions with carbon capture and storage previously seen as a major decarbonisation option for the power sector and energy-intensive industries [12].

Several programs and voluntary initiatives such as the EU Covenant of Mayors Pact (CoM) [13] renamed as Covenant of Mayors for Climate & Energy, or the UN Global Compact of Mayors for Climate and Energy [14] or the C40 Cities Climate leadership group [15] strive to lead their partner cities towards sustainable development achievements, low carbon future design and improved quality of life of their citizens.

3. INTERNATIONAL CASE STUDIES

The UK government has committed to reduce its greenhouse gas (GHG) emissions by 80%, from 1990 levels, by 2050. Decarbonisation of transport and heat supply to buildings is recognized as a fundamental step in achieving this target. With cities being the largest producers of GHG emissions, they provide the biggest opportunity for climate change mitigation. Two contrasting visions of a 2050 target-compliant scenario are assessed against each other. One is based on higher usage of nuclear power and renewables, and the other is based on predominantly gas with carbon capture storage (CCS). An impact assessment is done on both scenarios to see how each scenario might perform over four evaluation criteria. The evaluation criteria provide insight into each scenario regarding: security of supply, costs, sustainability and feasibility of deployment. While both scenarios raise some issues on the feasibility of deploying certain technologies, the more favorable scenario, in terms of the study results, is the nuclear and renewables option. The renewable energy generating technologies included as part of the study – from largest to smallest in terms of capacity – are wind, solar photovoltaic, tidal and river hydro. [16] The results of the study provide an important contribution to academic debate on what might be the most effective approach to achieving the 2050 decarbonisation target.

Results for the city of Sao Paulo show that district cooling is cost-effective in the highest linear cooling density zones, with full penetration in zones with over 1100 kWh/m by 2050. This threshold diminishes with tighter carbon constraints. Heating is electrified in all scenarios, with electric boilers and air-source heat pumps being the main supply technologies for the domestic and commercial sectors respectively by 2050. In the most carbon constrained scenario with a medium decarbonized electricity grid, ground source heat pumps and hydrogen boilers appear as transition technologies between 2030 and 2045 for the commercial and domestic sectors respectively, reaching 95% and 40% of each sector's heat installed capacity in 2030. In the transport sector, ethanol cars replace gasoline, diesel, and compressed natural gas cars; compressed natural gas buses replace diesel and electric buses; and lorries continue using diesel. In carbon constrained scenarios, higher usage of electric cars and buses are envisioned, while no change is observed for lorries. Finally, the most expensive scenario was only 6% more expensive than the reference scenario, meaning that achieving decarbonisation targets is not much costlier when comparing scenarios from a system-wide perspective [17].

In Ireland, decarbonisation technologies' pathways were researched as to which of them may aid in meeting national decarbonisation targets, and their potential role at local administrative area scale was evaluated. Application of this method resulted in a small number of larger industrial and commercial buildings, representing only 4% of the sector's buildings, were found to account for 38% of its decarbonisation potential. Future carbon emission scenarios identified that electricity demand may be expected to increase for the industrial and commercial sector by 2030, and that the technological potential for current photovoltaic systems have the potential to reduce GHG emissions by 4% more than currently planned Irish grid-scale decarbonisation trajectories. The method may be adopted at European scale, using local data on climate and building attributes, and is applicable at national, regional and local scales. The paper concludes with a review of technologies which may aid further decarbonisation studies, which include improved data availability for 3D building generation, and enabling technologies such as machine learning algorithms applied to satellite imagery [18]. This paper describes a framework for estimating the effectiveness of photovoltaic and rainwater harvesting technology deployment on industrial and commercial zoned buildings to facilitate reducing national GHG emissions.

There is a number of examples around the world on how the parts of cities have been transformed into low-carbon places. BedZED - UK is one of them, as well as Vauban, in Freiburg - Germany and Hammarby Sjostad, in Stockholm - Sweden.

BedZED is small, dense, mixed-use eco-development located in the southern suburbs of London. It is built on a brownfield site and situated close to a rail station. From its inception, it pushed the boundaries, testing and showcasing several new low-carbon technologies and urban design elements. Completed in 2002, BedZED is one of the original and hence most well-known global examples of a grass roots sustainable development. The name BedZED originates from Beddington Zero (Fossil) Energy Development and was originally designed to be a carbon-neutral precinct [19].

The aim was to generate enough zero-carbon energy onsite to meet the electricity, heating and hot water needs of the development, while feeding excess energy into the grid.

Despite an overarching focus on operational energy, the designers of the development integrated a variety of sustainability measures and initiatives that targeted emissions from a wide range of areas, including water, waste, materials and transport. The development's broad focus on sustainability made it an outstanding example of what is possible at a small-scale and very local level. Some of the initial low carbon, sustainability features included the following:

- highly energy-efficient three-story townhouses that use solar passive design, including passive ventilation and daylighting to reduce the need for artificial heating, cooling and lighting;
- low-carbon materials sourced locally where possible;
- energy- and water-efficient appliances;
- grey water-recycling facilities onsite as well as rainwater tanks;
- solar photovoltaic panels on roofs;
- biomass-fuelled, combined heat and power (CHP) plant providing zero-carbon electricity and district heating to the development (later changing to a gas district-heating system);
- mixed use, combining office space and residential dwellings, to reduce transport emissions from commuting;
- transit-oriented (i.e. situated next to a train station to promote low-carbon transportation) to reduce personal transport emissions; and
- provision and encouragement of local food production (including rooftop gardens), reducing food miles and associated emissions.

In addition to the numerous low-carbon initiatives, many other broad sustainability features were included such as affordable housing and a range of other housing tenures [20], community facilities and open space, and the preservation and promotion of biodiversity in the surrounding area [21], [22].

Vauban is another relatively compact, sustainable neighborhood development located on the southern edge of the city of Freiburg, in Germany. Redeveloped on a former military base, Vauban is largely residential, designed to meet rising housing demand [21]. It is connected by a light rail, providing residents with a short commute to the city center and is virtually car free, with limited parking provided at each house and full walking and cycling orientation. The development is renowned for its passive and active integrative solar design onsite, biomass co-generation plant, integration of nature and car-free or shared-zone streets. The houses are also surrounded by plants and gardens designed and built between 1995 and 2008, with considerable community consultation; this development demonstrates what is possible when citizens and residents are involved and empowered through the planning process.

Vauban is often referred to as an eco-village, sustainable urban district or 'model sustainable neighborhood' [23]. While it does not make any specific carbon claim, studies have shown that Vauban has reduced carbon [20], noting that Vauban residents produce around 0.5 tons CO2/per person/year compared to the average 8.5 tons CO2/per person/year for typical Freiburg residents. The list of initiatives below offers insight into how they were able to achieve this.

Vauban's low-carbon features include the following:

- energy-efficient houses (with all buildings meeting at least the low-energy standard, though 200 are passive houses/units and 59 Energy-Plus houses);
- expansive solar photovoltaic systems on roofs of houses, public and commercial buildings and car parks;
- biomass-fuelled co-generation plant (together with solar supplying 25% of districts electricity needs);
- heavily restricted car parking facilities deterring car ownership (with only 16% of Vauban residents owning a car);
- a mix of car-free and shared-zone streets (with the majority of travel being by foot or bike);
- light-rail connection to the city;
- adoption of housing cooperatives and associations, which allows residents to have responsibility for the management of their building, and thereby increases their awareness around issues such as energy consumption; and
- mixed-use development (around 600 jobs and 5000 residents).

While it is unclear which measures were included in the carbon footprint, it is likely that the low-per capita footprint would be largely attributable to the buildings in Vauban - all of which meet high energy efficiency standards. Although the houses are extremely energy efficient from an operational perspective, it is unclear whether the embodied emissions in materials used in the construction of the buildings have been accounted for this result. Another reason for the low-carbon footprint in Vauban would be related to the energy system supplying the precinct's electricity. Described by Williams (2012) [20] as low or zero-energy system (LZE), co-generation using biomass and solar photo - voltaics supplies one quarter of the district's electricity.

B001 is an eco-development built in the Western Harbor district of Malmo in Southern Sweden. It is a mixed-use, high-density precinct, currently home to 3000 residents as well as some light rail, commercial and tourism businesses. By 2020, the development is anticipated to house between 15 000 and 20 000 residents and attract several eco-businesses to the district [20].

It was previously an industrial precinct and thus in need of decontamination renewal. It is now a popular and attractive residential and tourist location.

B001 is most often cited as an eco-district, but has also been labelled as carbon neutral, climate neutral and energy neutral [24]. Interestingly, there appears to be little information about, or comparison of, the residents' carbon footprints, which seems to be a common metric used by other eco-developments. Most literature on B001 discusses the various initiatives in place, particularly focusing on the energy efficiency standards of the buildings and the low-carbon energy system employed [20].

Some of the low-carbon initiatives implemented at B001 include the following:

- 100% locally generated sustainable energy;
- a wind turbine in the harbor, 3 km from the development, supplying energy to houses;
- solar PV embedded into the development;
- green roofs;
- heating/cooling systems using a local aquifer as storage;
- high energy efficiency standards of buildings (105 kW/m2); and
- a waste to energy system.

Hammarby Sjostad is a 200-ha site located in a close proximity to the city center of Stockholm. Previously contaminated municipality-owned land with poor transport connectivity, Hammarby Sjostad has now become a vibrant, desirable and celebrated eco-district within Stockholm. The district houses 20,000 residents in a relatively dense area (50 units/ha) and boasts one of the most celebrated and discussed 'closed-loop' systems for integrating energy, water, waste and transport at the local level. This has contributed considerably to the reduction in the district's emissions, and Hammarby's prime location (waterfront and close to the city) has been optimized by the extension of a light rail to the development. Hammarby Sjostad is known as an 'eco-district' with its eco-claim predominantly centered on its innovative eco-cycle model or closed-loop resource management system. The development sets the goal of reducing per capita emissions to 2.5–3 tons CO2/per person/year compared with the average Stockholm citizen's emissions of 4 tons CO2/per person/year [20].

Some of the low-carbon initiatives implemented in Hammarby Sjostad include the following:

- a closed-loop system that utilizes the waste products from various processes such as waste water and municipal solid waste to create energy (biofuel, biogas and waste heat), which is used for electricity generation, district heating and fuel in cars;
- micro-generation, i.e., from solar PVs and solar collectors;
- energy-efficient buildings;
- vacuum waste collection;
- light rail connected to city;
- a car share scheme; and
- an Environmental Advice Centre to inform and educate residents about living a low-carbon lifestyle [25].

As Stockholm residents already have one of the lowest per capita carbon foot-prints for a developed city (largely

because of the low-carbon energy grid, district heating network supported by relatively high density, and thermally efficient buildings), it was difficult to find and implement further reduction measures.
All of these examples (BedZED-UK, Vauban, Freiburg-Germany and Hammarby Sjostad, Stockholm-Sweden) are described in detail in the book [26].

4. CONCLUSION

Given that 70% of total GHG emissions come from cities, they are becoming places where action is inevitable in the fight against climate change. Some of the possibilities for reducing CO_2 emissions, as the most widespread greenhouse gas emitted by human activities, are: improving energy efficiency in buildings, which today are responsible for 40% of energy consumption, greater use of renewable energy sources, maintaining mobility, because traffic is responsible for about a quarter of EU GHG emissions, the use of the circular economy, the use of the smart city concept, increasing the capacity of the bio-economy, agriculture and forestry, as well as the implementation of carbon sinks.

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CORRESPONDENCE

Dr Jasmina SKERLIĆ, Assistant Professor ,
University of Priština
Faculty of Technical Sciences
temporarily settled in Kosovska Mitrovica,
Knjaza Miloša 7,
38220 Kosovska Mitrovica, Serbia
jasmina.skerlic@pr.ac.rs

Dr Danijela NIKOLIĆ, Associated Professor ,
University of Kragujevac
Faculty of Engineering,
Sestre Janjić 6,
34000 Kragujevac, Serbia
danijelan@kg.ac.rs

Dr Blaža Stojanović, Associated Professor ,
University of Kragujevac
Faculty of Engineering,
Sestre Janjić 6,
34000 Kragujevac, Serbia
blaza@kg.ac.rs

Ana RADOJEVIĆ, Mech. eng.
City Energy Manager
City of Kragujevac
Trg Slobode 3
34000 Kragujevac, Serbia
aradojevic@kg.org.rs

Dr Aleksandar MIŠKOVIĆ, Professor of vocational studies
Academy of Professional Studies Sumadija,Department in Kragujevac,
Kosovska 8, 34000 Kragujevac, Serbia
amiskovic@asss.edu.rs

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