Review paper

UDK 621.311.24:620.92(091)
DOI 10.7251/COMEN2502129DJ

ENERGY TODAY AND TOMORROW

Momir Đurović

Montenegrin Academy of Sciences and Arts, Podgorica, Montenegro

* Corresponding author: momirdj@ac.me

Abstract: This paper provides an overview of current and future global energy challenges, focusing on the dynamics of energy demand, environmental impacts, and technological transformations that are shaping the transition toward more sustainable energy systems. Although fossil fuels continue to dominate the world's energy mix, rapid developments in technology, efficiency, and policy are driving significant shifts in how energy is produced, delivered, and consumed. The study examines the factors influencing rising global energy demand, the role of energy security and geopolitical considerations, and the environmental consequences of continued dependence on fossil resources. Special attention is given to emerging renewable technologies, decentralization, digitalization, and the increasing importance of consumers within the evolving energy ecosystem. The analysis highlights that, despite progress in renewable energy and innovation, fossil fuels will likely remain central through mid-century, creating a pressing need for feasible carbon mitigation strategies. The paper concludes that future energy systems will depend on large-scale technological innovation, new digital infrastructures, and coordinated global policy efforts to ensure sustainability, reliability, and equity in the decades ahead.

Keywords: energy transition; global energy demand; renewable energy; fossil fuels; energy security; environmental impact; decarbonization; digitalization; emerging technologies; energy policy.

1. INTRODUCTION

Most of the energy we capture for use on Earth comes from the nuclear reactions on the Sun. Historically, changes in energy systems have resulted due to different periods of technological, economic, and social advancements taking place by many actors at diverse locations. It is certain that the changes of the energy systems during the next few decades will be such that they will be fully different in many issues from what they are today.

Energy systems are structured by many resources, technologies, end users, and infrastructure [1]. They are driven by economics, resource availability, public policies, and social behaviors. The relationships between those actors are very complex.

At present fossil fuels like coal, oil and natural gas provide around 80 percent of the world's energy mix, which warms homes, charges devices and power transportation. It is, at the same time, the primary human source causing the greenhouse gas emissions.

At the beginning of the twenty-first century energy systems are changing [2] fast due to: the costs and availability of specific energy resources, technological advancements, the environmental considerations, and need to provide energy services to billions of people in developing countries. The energy consumption will increase drastically in the coming decades [3] what will result in many environmental problems.

Energy transitions which occur at different places with different speeds, aiming to fulfill specific societal functions, represent complex socio-technical transformations.

2. ENERGY DEMAND

Since the commercial oil drilling began (1850s) it has been drawn more than 135 billion tons of crude oil. At the same time around 1.2 billion people in the regions like Asia, Latin America and parts of Africa still do not have access to modern energy services. It is forecasted that the world's energy consumption will increase by almost 50% by 2050.year.

The growth or decline in energy demand, as well as its efficiency use, is primarily result of the state-policies. The energy demand is mostly affected by a need for a better, and more sophisticated ways of meeting people's needs [4]. The energy can be treated as service activity since consumers are buying warmth, lighting and power. It's important for energy to become part of the circular economy, keeping resources in use for as long as possible by recovering, regenerating and re-using them wherever possible [5]. This will result in a shift away from buying energy in kWh or BTU towards buying energy as a service, what means that consumers have to pay a company for energy at the best price, while actively improving the efficiency of their homes so they use less.

With energy being a service, consumers have bigger influence and more choice on its production and use. At present around 80% of the world's energy demand to warm and mostly cool homes, charge devices and provide transport comes from fossil fuels what has become the primary human source of greenhouse gas emissions. Along that line in many situations proper solution might be reached by generating and using energy locally [4] instead having centralized energy systems.

It is forecasted that the global energy demand will grow in average about 0.7 percent per year through 2050 year (versus an average of more than 2 percent from 2000 to 2015). It has been registered that global GDP doubles over the period whereas energy demand increases only by 30%. Lower global energy demand growth in the future will be result of many factors like: new technologies, greater efficiency, fall of energy intensity (the energy used for each unit of gross domestic product - GDP), global economic shift toward services, slower population and economic growth, lower demand in Europe and North America, and possible pandemics. This decrease in demand will be followed by lower "global energy intensity". It has been suggested (Goldemberg et al.) that around 1 kW per capita can provide "basic needs," for energy demand, while, recently, it was proposed (Spreng) a "2000-watt society". Modern technologies allow much greater well-being at low levels of energy consumption. By 2050 year the demand for electricity will reach a quarter of all energy demand (18 percent in twenties). Oil, gas and coal will remain the dominant sources, accounting for more than 75% of energy supplies in 2035 (down from 85% in 2015). Obviously, the climate change and energy security issues will determine the energy mix in the future. [6,7]

The main factors that affect energy demand include: economic structure and it's effect on industrial and commercial energy [8]:

– residential energy in electricity and natural gas affected by state policies, and

– energy used in transportation as the result of total miles traveled and vehicle efficiency.

Market trends suggest that the demand for new energy resources [9] will rise dramatically over the next 25 years since it is expected that:

– Global demand for all energy sources to grow by 57 % over the next 25 years.

– By 2030, 56 percent of the world's energy use will be in Asia.

– Nearly new 300 power plants (1,000MW) will be needed to meet electricity demand by 2030.

– Currently, most of greenhouse gas emissions comes from electrical generation which relies on coal and a fossil fuel.

Due to increased demand and limited supply in the coming time energy prices should rise dramatically what will result in the business impacts, like:

– Drop in profits due to high operating costs.

– Reduction of sales of energy, and disruption of supply chains.

– Loss of competitiveness in energy intensive, businesses.

The demand is related to energy mix. The energy mix means the specific combination of different energy sources used to meet energy consumption needs, generally, on the country level. The energy mix should not be mixed up with the power generation mix (the electricity mix), which describes the breakdown of energy sources used specifically to generate electricity. The energy mix depends on the energy resources being national or import available to a country, standard of living and level of development. The adjusting energy demand to energy mix,

as well as integrating storage and demand flexibility within country, requires automation, machine learning and real-time price signals, what will result in the energy market becoming largely digital. Today, most of the world is dependent on electricity. It has radically influenced and changed human life, in homes, architecture, communications, transport. It has been the main power in Industrialization, too. One has no to neglect that electricity can be fatal to human and animals in its raw form, too.

The key concept for energy demand is energy security, what is ability of a country to secure sufficient, affordable and consistent energy supplies for its domestic, industrial, transport and military requirements. It has to be met regardless of economic or political conditions. It should include a high level of government control, and a number of geopolitical concerns. On the world's level it is often concern in the need for stability and security in the country producing and exporting the oil. Equally, it concern might be the diplomatic relations within certain countries. An energy-secure country can be considered to be that which has accessible use of a variety of energy sources.

The energy security can be achieved by a variety of strategies, such as by:

– Exploiting own resources to achieve full self-competence.

– With less dependency on imports.

– Supplementing own energy resources with reliable imports from a wide range of suppliers.

– Reducing domestic demand for energy. Increasing efficiency.

Energy security has become the main force in the geopolitical landscape in the world. The countries with large oil reserves are still largely dictating energy security. With a new technologies developed it will happen a shift in the geopolitics of energy security.

The Energy Security is related to Energy Dependency, a issue that take in consideration the consumption dependent upon imported energy. A low Energy Dependency results in higher Energy Security.

One of the biggest changes that will take place is that consumers will become the important part of the energy sector, ensuring that the energy does not have a destructive impacts on the Earth. In that sense The Internet of Things will be used to provide a greener approach to energy use. Furthermore, the 'Internet of energy' will make use of connected digital systems to control how we satisfy demand, use and store energy

3. ENERGY AND ENVIRONMENT

Increase of global energy production and consumption will result in a massive environmental degradation. Burning coal, oil and gas has been manifested in the rising levels of greenhouse gases in Earth's atmosphere. Thus, the problem is how to use energy efficiently(10) such to improve human well-being, while controlling environmental and consequently its public health impacts. This will depend on human ability to identify and control the consequences of: technological and economic developments, public policy, cultural preferences, and many environmental impacts such as climate change.

The Paris climate agreement (December 2015), which means having global warming "well below" 2 Celsius, while limiting the temperature rise to 1.5 degrees Celsius, is accepted to be the way to reach a sustainable future for mankind. Basically, it implies fundamental transformations of the energy mix by 2050 year, i.e. how much hydrogen, biomass or renewables-based synthetic fuels can substitute fossil fuels. Such energy transformations will be followed by many technical issues. On top, the cost will be one of the most crucial problems. The Paris agreement understands that by 2030 year there would be ensured universal access to affordable, reliable and modern energy. This should be achieved by significantly increase in the share of renewable energy [11] in the global energy mix and doubling the global rate in energy efficiency. It understands implementing more of international cooperation such to facilitate access to clean energy and technology. That will be equally important all around the world, in particular in developing countries, as well as in small island developing States.

Energy generation and consumption, particularly from fossil fuels, have influence on environment by threatening public health and effecting wildlife habitat and biodiversity. To accomplish this, we have to come up with new ways to tackle the energy challenge. But, due to the superior energy intensity and reliability of fossil fuels they will play significant role in energy mix through 2050, what will result, as forecasted, in rise of energy-related greenhouse-gas emissions by 14 percent in the next period.

The trends which can provide the flexibility of energy systems allowing for a higher, cost-effective, environmentally efficient use of renewables are electrification, decentralization and digitalizing. By decentralization of energy production - locally produced energy- it is enabled more flexible management of the energy and technologies in the system what will enable that **c**onsumers have more choices in how energy is produced, and how it effects environment. By decentralization the losses in transmission are minimized while production of wasted heat in power stations is reduced. Decentralization of energy production by renewable energy sources is challenging the security of the global energy supply.

Energy is the most important in preventing diseases and fighting pandemics. It enables tools for healthcare facilities, such as clean water, communications and IT services to provide social distancing, and many more. Access to energy is essential to respond to the COVID-19 crises (The Special Representative of the UN Secretary-General for Sustainable Energy for All). The energy industry, these days, is experiencing the problems due to the COVID-19. There are oil and other market disruption as the result of a collapse in demand while having a surplus of supply.

It has to be noted that democracy does not improve sustainability, either it does not do worse than non-democracies, although democratization can reduce environmental damage. At the same time democracy does not have to result in more efficiently energy consumption while promoting well-being.

The environmental sustainability is significantly influencing the energy industry, too. Thus, it is very important to move focus from selling electricity to selling grid infrastructure and energy services what is in line with a free-market of energy.

4. SOLUTIONS FOR A RENEWABLE -POWERED FUTURE

The greatest challenge in energy sector is to reduce use, or even eliminate, fossil fuels from many activities such as from aviation, freight and long-range transportation, as well as from certain industrial processes (. Around a fifth of the world's primary energy supply already comes from renewable sources (wind, solar, hydro and geothermal), and it is expected to grow by 2.6% each year until 2050. Traditionally the main source of renewable energy used to be hydroelectric power but wind and sun are becoming the fastest growing renewable sources, today. Research into renewable energy sources, batteries, carbon capture and storage are helping to move the world to a more sustainable future.

It is possible to list many promising new technologies when concerning alternative energy sources of the future and environment. They might happen on the market in different time periods. Some of them look as science fiction from the point of today. In that sense listed are some of the most promising alternative energy sources of the future. Some of them may be long shots, but some may also play a crucial role in the energy mix of the future [12].

- Space-based solar, what requires a satellite to orbit, as well as the conversion of electricity into microwaves to transmit energy to the Earth's surface.
- Human power, means using the energy generated by the movement of people to power devices.
- Tidal power, which is very high and it is already in use in some cases**.**
- Hydrogen power, which is one of the most clean energy source accounting for 74% of the mass of the entire nuclear fuel, or around 5% of universe.
- Magma power, which is already used at Iceland.
- Nuclear waste, means better use of nuclear fuel.
- Embeddable solar power, such as solar windows which can harvest the part of the light spectrum that eyes can't see.
- Algae power, that relays on energy-rich oils which can provide up to 9,000 gallons of biofuel per acre.
- Flying wind power, means harvesting wind power at higher elevation.
- Fusion power, might be solution of all problems.

Tidal power, Space-based solar, Human power, Algae power, Flying wind power, Fusion power and many others are still in development stage. At present, wind and solar are increasingly popular sources of energy, although they only have made a fractional part in the energy mix so far. But, the problem is that the sun does not always shine, and the wind doesn't always blow. In the last decades, wind and solar power had "explosive average annual growth" (23 percent and 50 percent) resulting in renewable sources of power now representing around 30 percent of the world's total capacity and 23 percent of total global electricity production (A

recent report from the World Energy Council found).

The problem with the hydrogen, the most needed power source, is since there are no natural reservoirs of pure hydrogen. It is an energy carrier but not a primary source of energy. Although its extraction from natural gas or water requires significant amount of energy, the hydrogen fuel cells might be an important power source in the near future. Another promising energy source the biofuel is predominantly currently in use by grain-based ethanol, which production is energy-intensive while requiring a large amount of land and water.

Nuclear energy today provides over a third of the world's low-carbon electricity. For nuclear energy technical and institutional innovations are needed, what includes a new generation of reactors, such as small modular reactors, fast reactors, and the fusion energy. Storing carbon dioxide underground or turning it into clean fuel are still far from commercial solution. None of the possible solutions is without challenges. Storing energy to satisfy demand is not yet cheap and powerful enough. Batteries to store energy are still expensive and not much efficient.

Many energy scenarios predict a growth in renewable energy installations, especially in expansion of offshore wind capacity, and a widespread uptake in domestic electric vehicles. On top biogas and biofuels are often seen as the most viable alternatives to fossil fuels.

To achieve reliable, efficient power systems using large shares of renewables (solar and wind) should imply the following: (IRENA's 2019 Innovation Landscape study) :

– More flexible generation, including interconnections and regional markets.

– Renewable energy production using advanced weather forecasting

– Renewable energy generation and demand over large distances using supergrids.

Optimization of operation between distribution system and distributed energy sources such to provide demand on site management.

The significant decarburization of the fuel mix will happen since renewables, nuclear and hydroelectric power are going to reach half of the growth in energy supplies with investment by 2030 globally over $1.2 trillion annually, more than five times into fossil fuels.. Some work (McKinsey) suggests that new cap``acity in the future will come from wind and solar (77 percent), from natural gas (13 percent), and the rest from everything else. In particular wind and solar are expected to grow four to five times faster than any other source of power up to 2050 year. This transition in energy supply and demand will result in a new global energy mix and security order.

There is, still, no rational and efficient way to store the electricity produced by renewables. Capacitors and flywheels can stored/provide energy for a few minutes or hours. Using new hydroelectric dams for that purpose has become controversial issue. It might happen that the solution for storing energy come in the form of fuel. (Robert Armstrong). But, due to o the superior energy intensity and reliability of fossil fuels they will play still significant role in energy mix through 2050, what will result, as forecasted, in rise of energy-related greenhouse-gas emissions by 14 percent in the next period. One major advantage fossil fuels have over renewable energy sources is since they are very easy to store and transport (Credit: Getty Images)

The shift towards renewable energy sources is resulting in reshaping energy industry [13]. This shift is affected as well by the convergence of the energy and power industries.

5. CONCLUSION

The most important energy issue is: will there be enough available energy in the near future (14) appreciating increase of population and increase of standard of living? These problems have to be solved by technologies which are still in the research or under development. Furthermore, having in mind that by 2050 year we will, still, be getting most (75%) of energy from fossil fuels the question is how will be possible to obtain carbon capture storage and its utilization? It cannot be achieved only by a new mix or by developing new technologies, but in a shift of the geopolitics of energy.

The energy consumption in the countries with lower levels of economic development is linked to well-being, what is not the case with high-income nations. The level of development affects human well being via negative externalities, too. Thus, the question is how to minimize energy consumption while maximizing well-being? The solution might be in connecting the energy grids of several countries (creating "supergrids"), what will result in sharing energy mix and services over a wider area.

In solving these problems energy companies may control more precisely use of our home appliances by turning them on and off depending on (Credit: Getty Images) fluctuations in the weather or the time of day. It would mean a move from the "power-on-demand" way of consuming energy. Thus, it is certain that in future will happen the biggest change in the area of energy market and services, i.e. in consumers control over energy sources, and on energy consumption as well as in control of its cost, what will enlarge management activity.

One of the biggest problem is how to cope with the rise in energy demand(20). In that sense there should be implemented shift in where we get our energy such to cope with the immediate raise in energy demands expected in the coming decades.

The new supply chain technologies are emerging what significantly improve visibility across the end-to-end supply chain. The traditional linear supply chain model is transforming into digital supply networks (DSNs). In such way it is enabled end-to-end visibility, collaboration, agility, and optimization. Whether there are events like COVID-19, trade war, terrorism, regulatory change, labor dispute, sudden changes in demand, or supplier bankruptcy, organizations that deploy DSNs being able to deal with the unexpected.

The future landscape of the energy industry will be transformed by technological innovations that drive towards a more convenient, efficient and ecological infrastructure. Transition to the new energy ecosystem [15] is going to be dominated by digital technologies from "visualization, analytics and machine learning to cloud-based technologies, artificial intelligence and digital twins".

Energy is one of the clearest examples of a geopolitical issue. Whilst intended to hurt the economies of the embargoed countries, this also forces importing countries to look elsewhere for their energy supplies.

New energy technologies (16) with digital possibilities will provide that the energy systems of the future will be more clean, cheap and efficient.

6. LITERATURE

[1] https://www.nbcnews.com/mach/powering-the-future

[2] https://tomorrowenergy.com

[3] https://widgets.weforum.org/eapi-2016/" \

[4] https://www.shell.com/energy-and-innovation/the-energy-future

[5] https:// dfgets.weform,org/capi,2016

[6] https://www.sciencedirect.com/book/9780080994246

[7] https://theecologist.org/2019/jan/04/what-future-energy.

[8] K. Mudruy., S. Werle, (ditors), Sebastian Renewable energy sources, Springer 2016

[9] K. Mudruy., S. Werle, (ditors), Sebastian Renewable energy sources, Springer 2016.

[10] https://www.iied.org/sustainable-energy-for-all-initiative

[11] www.un-energy.org

[12] https://www.visualcapitalist.com/alternative-energy-sources-future

[13] D.Yogi Goswami, Frank Kreith: Energy efficienct and Renewables Handboo, 2016 CBS Pres, s

[14] Future energy**,** ISBN 978-0-08-099424-6, 2014 Elsevier Ltd.

[15] M. Djurovic: The fututе has no history, Scholar press, 2019.

ЕНЕРГИЈА ДАНАС И СУТРА

Сажетак: Овај рад пружа преглед савремених и будућих глобалних енергетских изазова, са фокусом на динамику потражње за енергијом, утицаје на животну средину и технолошке трансформације које обликују прелазак ка одрживијим енергетским системима. Иако фосилна горива и даље доминирају свјетским енергетским миксом, убрзани развој технологија, повећање енергетске ефикасности и промјене у јавним политикама подстичу значајне помаке у начину производње, дистрибуције и потрошње енергије. У раду се анализирају фактори који утичу на раст глобалне потражње за енергијом, улога енергетске безбједности и геополитичких разматрања, као и еколошке посљедице континуиране зависности од фосилних ресурса. Посебна пажња посвећена је развоју обновљивих технологија, децентрализацији, дигитализацији и све значајнијој улози потрошача у еволуирајућем енергетском екосистему. Анализа указује да ће, упркос напретку у области обновљивих извора енергије и иновација, фосилна горива вјероватно остати кључна компонента енергетског система до средине вијека, што намеће хитну потребу за примјењивим стратегијама ублажавања емисија угљеника. Рад закључује да ће будући енергетски системи зависити од технолошких иновација великог обима, развоја нових дигиталних инфраструктура и координисаних глобалних политичких напора како би се у наредним деценијама обезбиједили одрживост, поузданост и праведност.

Кључне ријечи: енергетска транзиција; глобална потражња за енергијом; обновљиви извори енергије; фосилна горива; енергетска безбједност; утицај на животну средину; декарбонизација; дигитализација; нове технологије; енергетска политика.

Paper received: 9 April 2025 **Paper accepted: 17 November 2025**