E3S Web of Conferences 497, 01009 (2024) https://doi.org/10.1051/e3sconf/202449701009
ICECAE 2024

Advancements in renewable energy sources (solar and geothermal): A brief review

Abdugani Rakhmatov[1*], *Odil* Primov[2], *Maxammadjon* Mamadaliyev[3], *Shoyatbek* Tòrayev[3], *Utkir* Xudoynazarov[2], *Shoxboz* Xaydarov[2], *Elshod* Ulugmurodov[2], *Ilhom* Razzoqov[4]

[1]Department of Power Supply and Renewable Energy Sources, National Research University TIIAME, 100000 Tashkent, Uzbekistan
[2]Department of Automation and Control of Technological Processes, Karshi Institute of Irrigation and Agrotechnologies, 180119 Karshi, Uzbekistan
[3]Andijan Machine Building Institute, 170119 Andizhan, Uzbekistan
[4]Department of Algorithms and Programming Technologies, Karshi State University, 180119 Karshi, Uzbekistan

Abstract. This scientific article provides an in-depth review of recent advancements in renewable energy sources, examining their significance in addressing global energy challenges. The paper covers various types of renewable energy, including solar, wind, hydropower, geothermal, and biomass, emphasizing technological developments, efficiency improvements, and environmental considerations. Additionally, the article discusses the current state of renewable energy adoption globally and its potential impact on reducing carbon emissions. The analysis integrates findings from recent studies and research papers to present a comprehensive overview of the current landscape of renewable energy technologies.

1. Introduction

The 21st century has witnessed an increasing recognition of the limitations and environmental repercussions associated with conventional energy sources. The extraction, combustion, and utilization of fossil fuels have not only contributed significantly to global warming but have also led to geopolitical tensions and resource depletion [1, 2]. In this context, renewable energy sources have emerged as a promising alternative, harnessing the inexhaustible power of natural elements to meet the world's growing energy demands.

Motivated by environmental imperatives and the need for energy security, governments, industries, and research institutions globally have intensified efforts to explore and enhance the potential of renewable energy technologies. The quest for sustainable energy solutions has led to remarkable strides in the development of solar [3, 4], wind [5], hydropower [6-10], geothermal [11-13], and biomass [14-20] technologies. These advancements not only promise cleaner energy but also herald economic opportunities and increased energy independence for nations.

The energy potential of RES on a planetary and individual country scale is many times the current level of energy consumption, and therefore they can be considered as a possible source of energy production. Well-known prerequisites for the development of mankind suggest the need for a broad study of renewable energy sources already in management, both due to the inevitable increase in production and increase in the cost of oil, gas and coal, as well as for environmental reasons (CO_2 emissions and other harmful consequences of economic policy on the environment). The use of renewable energy sources, as a rule, does not have a serious negative impact on the environment; for the most part, they are environmentally friendly and widely available sources of energy.

Serious disadvantages of RES that limit their widespread use include the low density of energy flows and their variability over time and, as a consequence, the need for significant costs for equipment that collects, accumulates and converts energy [21]. For example, the flux density of solar radiation on the surface of the earth at noon on a clear day is only about 1 kW/m^2, and its average annual value, considering seasonal and weather fluctuations, for the sunniest regions of the globe does not exceed 250 W/m^2 [22]. The average specific energy density of a wind flow also, as a rule, does not exceed several hundred W/m^2 at a wind speed of 10 m/s, the specific energy density is approximately 500 W/m^2. The energy density of a water flow with a speed of 1 m/s is also is only about 500 W/m^2. For comparison, we point out that the heat flux density on the furnace walls of a modern steam boiler reaches several hundred kW/m^2.

*Corresponding author: arakhmatov@mail.ru

At the same time, technologies for using various renewable energy sources are actively developing in many countries of the world, many of them have reached commercial maturity and successfully compete in the energy services market, including in the production of electrical and thermal energy.

2. Development of renewable energy sources in the world

The development of renewable energy sources on a global scale has witnessed a dynamic and transformative trajectory, driven by a confluence of environmental, economic, and technological factors. This section outlines the key facets of the development of renewable energy sources worldwide, elucidating the progress, challenges, and future prospects. The past two decades have seen a substantial surge in the deployment of renewable energy sources across the globe. Solar and wind energy, in particular, have experienced exponential growth, supported by declining costs, favorable policy frameworks, and increased public awareness of environmental issues. Countries on every continent have made significant strides in expanding their renewable energy capacity, with concerted efforts to diversify energy portfolios. One of the pivotal drivers of renewable energy development has been the remarkable decline in the costs associated with technologies such as solar photovoltaics and onshore wind. Economies of scale, technological innovations, and increased competition have collectively contributed to making renewable energy increasingly cost-competitive with conventional fossil fuels [23]. This economic viability has accelerated the adoption of renewable energy across both developed and developing nations. Governments worldwide have played a pivotal role in fostering the development of renewable energy. Robust policy support mechanisms, including feed-in tariffs, tax incentives, and renewable energy targets, have incentivized investments in clean energy projects. International collaborations, such as the Paris Agreement, have further catalyzed a global commitment to transitioning toward low-carbon and sustainable energy systems [24]. Continuous advancements in renewable energy technologies have been instrumental in overcoming barriers and expanding the potential of clean energy sources. Breakthroughs in energy storage, improvements in the efficiency of solar and wind technologies, and the development of innovative solutions like floating solar farms contribute to the resilience and versatility of renewable energy systems. The increasing share of variable renewable energy sources poses challenges related to grid stability and energy intermittency. To address these challenges, countries are investing in smart grid technologies, energy storage solutions, and grid management systems. Integrating renewable energy into existing infrastructure requires a holistic approach to ensure a reliable and resilient energy supply.

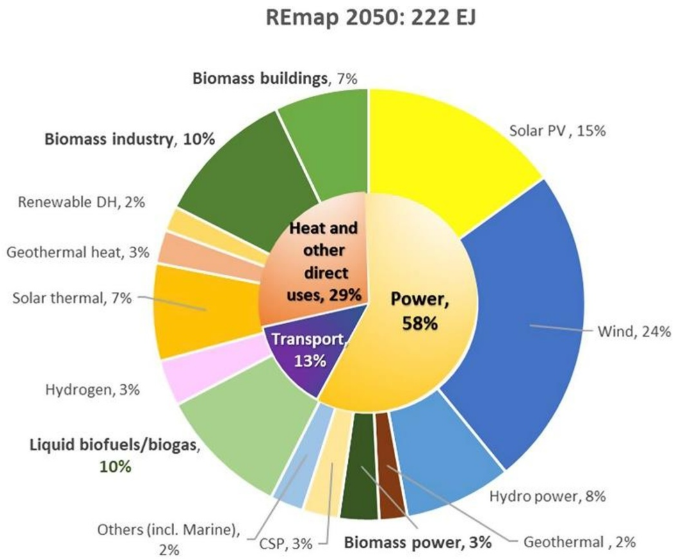

Fig. 1. Breakdown of renewables use in total final energy consumption terms, REmap 2050 (source: IRENA 2018) [25]

Similar to 2021, 38% of the world's electricity was provided by carbon-free generating sources in 2022, including hydropower, nuclear power, and integrated renewables. The majority of the world's electrical grid is still fueled by fossil fuels, although change is happening more quickly now. This is the second year in a row that solar photovoltaic (PV) systems have accounted for more than 50% of new electricity generating capacity, despite persistent supply chain and trade challenges worldwide. Presently, solar photovoltaics (PV) is the generation technology that is expanding the fastest; in 2022 alone, 25% more PV power capacity was installed. The percentage of PV power generated globally increased from approximately 3.6% in 2021 to approximately 4.5% in 2022.
According to the IRENA (2018) study, 222 EJ (energy equivalents) of renewable energy are used in final energy terms. 58% is accounted for by the power sector. This includes an increase in the use of renewable energy for electrification

(particularly for heat pumps and electric cars). One might also credit this kind of renewable energy deployment to the end-user sectors. Particular attention should be paid to the significant contributions of wind (24%) and bioenergy (32%, including district heating) to the deployment of renewable energy overall (see Figure 1) [25].

From the data above, it is clear that the development of renewable energy has become a global endeavor, with countries collaborating on research, technology transfer, and investment initiatives. International financial institutions, private investors, and multinational corporations are actively contributing to the financing and implementation of renewable energy projects, fostering a collaborative approach to address the shared challenges of climate change. The transition to renewable energy sources is intrinsically linked to mitigating the impacts of climate change. By reducing greenhouse gas emissions and lessening dependence on finite fossil fuels, the development of renewable energy contributes significantly to global efforts to achieve a more sustainable and climate-resilient future.

Hence, the development of renewable energy sources on a global scale reflects a paradigm shift in the way societies generate and consume energy. While substantial progress has been made, continued efforts in technological innovation, policy evolution, and international collaboration are essential to realizing the full potential of renewable energy and addressing the challenges posed by climate change and energy sustainability.

3. Solar Energy

Solar energy occupies a leading position among renewable energy sources and is widely available. Solar radiation, due to the fact that it comes from a source with a brightness temperature of about 6000 °C, from a thermodynamic point of view is a high-quality primary source of energy, allowing the fundamental possibility of its conversion into other types of energy (electricity, heat, cold, etc.) with high efficiency. However, its significant disadvantages from a technical point of view are instability (daily, seasonal, weather) and relatively low energy flow density [26, 27]: outside the atmosphere about 1.4 kW/m^2, on the earth's surface on a clear afternoon about 1 kW/m^2, and on average per year (taking into account nights and cloudiness) from 150 to 250 W/m^2, which nevertheless corresponds to the annual supply of energy equivalent to 150–250 kg of equivalent energy per 1 m^2 of the earth's surface (1 kg of standard fuel = 7 Mcal). These properties of solar radiation make it difficult to create efficient energy devices, since a large area is required for solar radiation receivers and the creation of energy storage devices. As a result, despite the "free" nature of solar radiation itself, the cost of solar installations turns out to be high, which reduces their competitiveness in relation to traditional power plants using cheap fossil fuels.

Among the wide variety of technologies and devices being developed for the energy use of solar energy, solar heating, electricity generation and refrigeration technologies are the most mature and are finding increasingly widespread competitive practical application [28]. Photovoltaic (PV) converters are becoming increasingly used in different countries. More than 90% of the market is solar cells based on poly- and monocrystalline silicon (see Figure 2), the modules of which have an efficiency of 15-17%. In mid-latitude environments, such grid-connected PV installations can produce between 900 and 1500 kWh/kWp per year, equivalent to 120 to 200 kWh/m^2 per year.

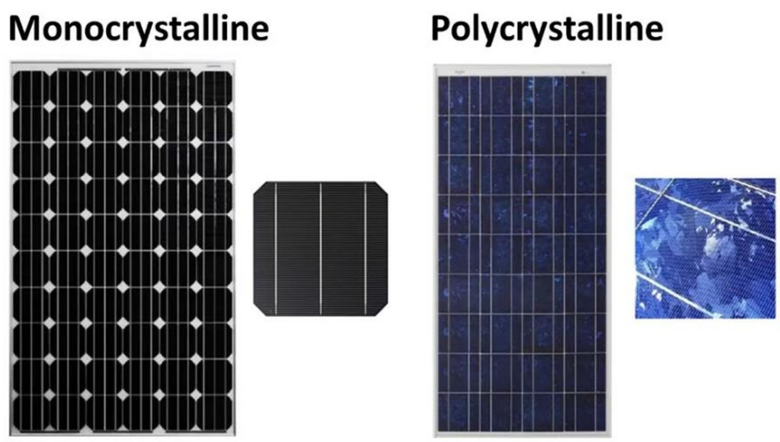

Fig. 2. Differences between monocrystalline and polycrystalline solar panels (source: prostarsolar.net)

Although intensive research and development in the field of photovoltaics in all leading countries of the world has led to serious successes both in terms of increasing the efficiency of photovoltaic converters and in terms of reducing the cost of their production, the cost of electricity obtained from solar cells is still much higher than the cost of electricity generated by conventional power plants. For example, even in sunny California, where the annual number of hours of use of solar cells exceeds 3000, the cost of electricity produced is not less than 20 cents per kWh. Thus, electricity obtained from solar power plants should not be considered in the next decade as an alternative to traditional electricity, but as an opportunity to supply electricity to consumers who are remote from existing power grids or who want to have a backup source in case of power failure. Most often, we are talking about installations of relatively low power, which include a rechargeable battery for power supply at night.

3.1 Application of Solar Photovoltaic converters

Photoelectric converters are increasingly used in autonomous power supply to consumers not connected to electrical networks:

Communication systems (repeaters, mobile radio systems, telephone networks, autonomous monitoring and control systems). The power of photovoltaic installations used in this area ranges from several watts to several kilowatts.

Recharging batteries. It is known that if batteries are not used for a long time, their capacity decreases. The use of solar cells makes it possible to solve the problem of self-discharge of batteries in the cheapest, most reliable and simplest way [29].

Cathodic protection. PV cells have found wide application as an autonomous power source for corrosion protection systems of telecommunication towers, pipelines, underground metal tanks and underground building structures exposed to aggressive environmental influences. As a rule, their power for these purposes does not exceed 10 kW.

Signaling devices. Power supply using PV converters for signal navigation lights on rivers, at sea, safety lights installed on power lines, high-rise buildings, light and sound signaling devices on railways and roads, etc.

Lighting. Tens of thousands of solar cells in combination with rechargeable batteries are used in different countries to illuminate billboards, road and parking signs and signs, etc., including inside large cities.

Electric refrigerators. Electric refrigerators powered by solar cells have become widespread, especially in countries with hot climates, making it possible to store valuable perishable products, primarily medicines, vaccines, etc.

Remote monitoring. This direction of using PV converters is also one of the most common. Today, there are more than 100,000 photovoltaic installations in different countries that provide power to autonomous weather stations, stations for autonomous control of temperature and water level, liquid flow in pipelines, control of air pollution levels near industrial enterprises, etc.

Water pumping installations. Photovoltaic installations are used for lifting drinking water from wells and wells, for irrigation purposes in agriculture. The units operate in the presence of solar radiation, accumulating water in a tank. Such installations are characterized by a simple design and are relatively inexpensive, since they do not require the use of rechargeable batteries.

Energy supply of residential buildings. One of the challenges associated with the use of PV in residential and administrative buildings is that PV modules can replace traditional building elements or cladding materials. At the same time, they must satisfy architectural solutions and be attractive from an aesthetic point of view.

3.2 Development of solar power plants

In a number of countries, there are several dozen demonstration photovoltaic stations with a capacity of several hundred kW each, which are prototypes of future large solar power plants. They are still far from self-sufficiency, but are important for accumulating operating experience and demonstrating promising environmentally friendly energy technologies.

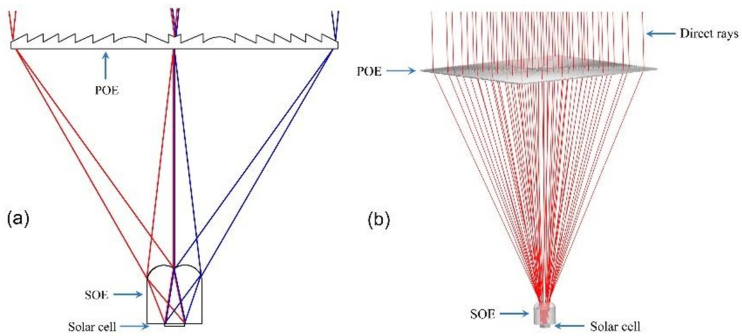

Fig. 3. (a) Schematic showing edge-ray mapping in an ideal Fresnel concentrator, (b) Layout of the eight-fold Fresnel-based CPV system with ray-tracing sowing how rays uniformly illuminated the cell [31]

Along with the transition to thin-film elements, there is an opportunity to reduce the cost of an installed kilowatt by using PV cells with solar radiation concentration. This approach is based on the fact that the cost per unit area of a solar radiation concentrator is lower than the cost per unit area of a solar cell. By irradiating a solar cell with solar radiation concentrated n times, it is possible to reduce the size (area) of the photocell by approximately the same amount to obtain the same power [30]. In addition, when using concentrated radiation, the efficiency of solar cells increases slightly. Studies consider concentration levels ranging from ten to several hundred. For relatively small concentrations, fairly cheap Fresnel lenses can be used. Figure 3 demonstrates the schematic showing edge-ray mapping in an ideal Fresnel concentrator, (b) Layout of the eight-fold Fresnel-based CPV system with ray-tracing sowing how rays uniformly illuminated the cell [31]. At high concentrations, an additional problem arises associated with the heating of the solar cell, at which its efficiency decreases [32, 33]. They are trying to get around this difficulty either by using PV cooling, or by using selective concentrators that direct a concentrated radiation flux to the PV only in the wavelength range that is effectively converted into electricity. At the same time, the rest of the spectrum, primarily the long-wavelength part, which actually heats the solar cell, is not concentrated.

4. Geothermal Energy

Geothermal energy can make a significant contribution to the energy supply of various regions of the country. Geothermal energy refers to the physical heat of the deep layers of the Earth, which have a temperature higher than the air temperature on the surface. Both liquid fluids (water and/or steam-water mixture) and dry rocks located at the appropriate depth can act as carriers of this energy. From the hot interior of the Earth, a heat flow constantly flows to its surface, the intensity of which, on average over the Earth’s surface, is about 0.03 W/m2. Under the influence of this flow, depending on the properties of rocks, a geothermal gradient arises. In most places it is no more than 2-3 °C/100m. However, in places of young volcanism, near faults in the earth’s crust, the geothermal gradient increases several times and already at depths of several hundred meters, and sometimes several kilometers, there are either dry rocks heated to 100 °C or more, or reserves of water or a steam-water mixture with such temperatures.

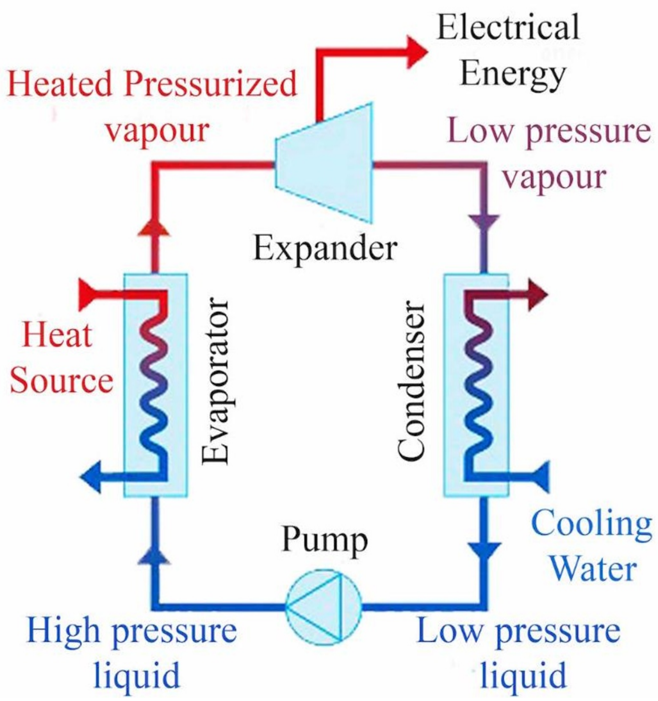

Fig. 4. The organic Rankine cycle produces energy by expanding an organic working fluid through a turbine [34]

Existing geothermal power plants (GEPs) are plants that operate from a thermodynamic point of view according to the Rankine cycle [34-37]. Figure 4 shows that the organic Rankine cycle that produces energy by expanding an organic working fluid through a turbine. The working fluid in a steam turbine can be either water vapor obtained directly from geothermal fluid (in this case, the installation is called single-circuit), or, especially at low fluid temperatures, double-circuit (binary) with a low-boiling working fluid in the second circuit. The unit capacity of such GeoPPs ranges from hundreds of kW to hundreds of MW.

To produce electricity with acceptable technical and economic indicators, the temperature of the geothermal fluid should, as a rule, not be lower than 150 °C, while for the purposes of direct heat supply, deposits with lower temperatures (30-100 °C) are suitable. Under certain conditions, shallow thermal waters with a temperature of 20–30 °C can be effectively used as a source of low-grade heat in heat pump heating systems [38].

The main problems of geothermal heat supply are related to salt deposition and corrosion resistance of materials and equipment operating in aggressive environments [39]. In this regard, the implementation of double-circuit heat supply systems using efficient and corrosion-resistant modern heat exchange equipment is of great practical interest. In order to

avoid pollution of the environment, rivers and reservoirs with mineral compounds extracted from the bowels of the earth, modern technologies for the use of geothermal energy provide for the reinjection of spent geothermal fluid into the formation.
Priority areas for further research and development are the development of binary geothermal power plants using low-boiling working fluids, solving problems associated with scale deposits and corrosion of geothermal equipment, and developing technologies for extracting valuable chemical components from geothermal fluids.

5. Conclusion

The section devoted to solar PV technology included improvements in solar cell efficiency, the emergence of novel materials, and breakthroughs in thin-film technologies. Furthermore, the integration of solar energy into the grid, advancements in energy storage solutions for solar installations, and innovations are thoroughly explored.
The section on geothermal energy provided insights into advancements in enhanced geothermal systems, drilling technologies, and reservoir management. The paper explored the potential for direct use applications of geothermal energy and assessed the environmental viability of geothermal power generation.
In conclusion, this brief review synthesized recent advancements across various renewable energy sources, especially solar and geothermal energy. By examining the technological, environmental, practical and theoretical dimensions, this paper provided a valuable resource for researchers, policymakers, and industry stakeholders working towards a sustainable and resilient energy future.

References

1. Perera F, Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist, *Int J Environ Res Public Health* **15**(1), 16 (2017)
2. Xu Y, Zhao F, Impact of energy depletion, human development, and income distribution on natural resource sustainability, *Resour Policy* **83**, 103531 (2023)
3. Turaev A, Muratov K, Tursunov O, Comprehensive analysis of the change of pop solar power station output parameters in relation to ambient temperature, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012003 (2020)
4. Kodirov D, Tursunov O, Ahmedov A, Khakimov R, Rakhmataliev M, Economic efficiency in the use of solar energy: A case study of Agriculture in Uzbekistan, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012031 (2020)
5. Safarov A, Tursunov O, Izzatillaev J, Mammedov R, Study on the possibilities of using wind energy in the northern areas of the Bukhara Region, *AIP Conference Proceedings* **2741**(1), 050013 (2023)
6. Kodirov D, Tursunov O, Modeling and analysis of a reactive low-pressure hydraulic turbine, *IOP Conf. Ser.: Mater. Sci. Eng*. **883**, 012085 (2020)
7. Kodirov D, Tursunov O, Calculation of Water Wheel Design Parameters for Micro Hydroelectric Power Station, *E3S Web of Conferences* **97**, 05042 (2019)
8. Kodirov D, Tursunov O, Parpieva S, Toshpulatov N, Kubyashev K, Davirov A, Klichov O, The implementation of small-scale hydropower stations in slow flow micro-rivers: A case study of Uzbekistan, *E3S Web of Conferences* **135**, 01036 (2019)
9. Kodirov D, Tursunov O, Karimova K, Akramova N, Parpieva S, Shafkarov B, Application of hydro energy in small power supply systems, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012037 (2020)
10. Kodirov D, Tursunov O, Khushiev S, Bozarov O, Tashkhodjaeva G, Mirzaev S, Mathematical description of water flow quantity for microhydroelectric station, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012032 (2020)
11. Sharmin T, Khan R, Akram MdS, Ehsan MM, A State-of-the-Art Review on Geothermal Energy Extraction, Utilization, and Improvement Strategies: Conventional, Hybridized, and Enhanced Geothermal Systems, *International Journal of Thermofluids* **18**, 100323 (2023)
12. Greco A, Gundabattini E, Solomon DG, Singh Rassiah R, Masselli C, A Review on Geothermal Renewable Energy Systems for Eco-Friendly Air-Conditioning, *Energies* **15**(15), 5519 (2022)
13. Anderson A, Rezaie B, Geothermal technology: trends and potential role in a sustainable future, *Appl Energy* **248**, 18–34 (2019)
14. Kalandarov P, Tursunov O, Abdulloev H, Karimov I, The effect of biomass moisture on the intensity of the fermentation process in biogas production, *AIP Conference Proceedings* **2741**(1), 050014 (2023)
15. Abduganiev N, Tursunov O, Kodirov D, Erkinov B, Sabirov E, Kilichov O, The use of thermal technologies for the recovery of value-added products from household solid waste: A brief review, *IOP Conf. Ser.: Earth Environ. Sci.* **614**, 012005 (2020)
16. Tursunov O, Dobrowolski J, Zubek K, Czerski G, Grzywacz P, Dubert F, Lapczynska-Kordon B, Klima K, Handke B, Kinetic study of the pyrolysis and gasification of Rosa multiflora and Miscanthus giganteus biomasses via thermogravimetric analysis, *Thermal Science* **22**, 3057-3071 (2018)

17. Tursunov O, Zubek K, Czerski G, Dobrowolski J, Studies of CO_2 gasification of the Miscanthus giganteus biomass over Ni/Al_2O_3-SiO_2 and Ni/Al_2O_3-SiO_2 with K_2O promoter as catalysts, *J Therm Anal Calorim* **139**, 3481-3492 (2020)
18. Tursunov O, Zubek K, Dobrowolski J, Czerski G, Grzywacz P, Effect of Ni/Al_2O_3-SiO_2 and Ni/Al_2O_3-SiO_2 with K_2O Promoter Catalysts on H_2, CO and CH_4 Concentration by CO_2 Gasification of Rosa Multiflora Biomass, *Oil & Gas Science and Technology – Rev. IFP Energies Nouvelles* **72**(6), 37 (2017)
19. Tursunov O, Isa KM, Abduganiev N, Mirzaev B, Kodirov D, Isakov A, Sergiienko SA, A succinct review of catalyst dolomite analysis for biomass-msw pyrolysis/gasification, *Procedia Environmental Science, Engineering and Management* **6**(3), 365-374 (2019)
20. Tursunov O, Abduganiev N, A comprehensive study on municipal solid waste characteristics for green energy recovery in Urta-Chirchik: A case study of Tashkent region, *Materials Today: Proceedings* **25**(1), 67-71 (2020)
21. Ang T-Zh, Salem M, Kamarol M, Das HS, Nazari MA, Prabaharan N, A comprehensive study of renewable energy sources: Classifications, challenges and suggestions, *Energy Strategy Reviews* **43**, 100939 (2022)
22. Haas KA, Fritz HM, French SP, Smith BT, Neary V, Assessment of Energy Production Potential from Tidal Streams in the United States, Georgia Tech Research Corporation, Georgia (2011)
23. Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R, The role of renewable energy in the global energy transformation, *Energy Strategy Reviews* **24**, 38-50 (2019)
24. Aydos M, Toledano P, Brauch MD, Mehranvar L, Iliopoulos Th, Sasmal S, Scaling Investment in Renewable Energy Generation to Achieve Sustainable Development Goals 7 (Affordable and Clean Energy) and 13 (Climate Action) and the Paris Agreement: Roadblocks and Drivers, Columbia Center on Sustainable Investment, Columbia (2022).
25. IRENA, Global Energy Transformation. A Roadmap to 2050, IRENA, Abu Dhabi (2018)
26. Hassan Q, Algburi S, Sameen AZ, Salman HM, Jaszczur M, A review of hybrid renewable energy systems: Solar and wind-powered solutions: Challenges, opportunities, and policy implications, *Results in Engineering* **20**, 101621 (2023)
27. van der Wiel K, Stoop LP, van Zuijlen BRH, Blackport R, van den Broek MA, Selten FM, Meteorological conditions leading to extreme low variable renewable energy production and extreme high energy shortfall, *Renewable and Sustainable Energy Reviews* **111**, 261-275 (2019)
28. Kabeyi MJB, Olanrewaju OA, Sustainable Energy Transition for Renewable and Low Carbon Grid Electricity Generation and Supply, *Front. Energy Res*. **9**, 743114 (2022)
29. Kebede AA, Kalogiannis T, Mierlo JV, Berecibar M, A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration, *Renewable and Sustainable Energy Reviews* **159**, 112213 (2022)
30. Scharf K, Photovoltaic Effect Produced in Silicon Solar Cells by X- and Gamma Rays, *J Res Natl Bur Stand A Phys Chem*. **A**(4), 297-307 (1960)
31. Ullah I, Development of Fresnel-based Concentrated Photovoltaic (CPV) System with Uniform Irradiance, *Journal of Daylighting* **1**, 2-7 (2014)
32. Jing L, Liu H, Wang Y, Xu W, Zhang H, Lu Zh, Design and Optimization of Fresnel Lens for High Concentration Photovoltaic System, *International Journal of Photoenergy* **2014**, 539891 (2014)
33. Wang L, Teles MPR, Yu H, Silva BVF, Arabkoohsar A, Waste incineration and heat recovery hybridized with low-focus fresnel lens solar collectors for sustainable multi-generation; A thorough techno-economic-environmental analysis and optimization, *Chemosphere* **346**, 140409 (2024)
34. Shaligram A, Improving Efficiency of ORC Power Generation, Tech Briefs Media Group, New York, NY (2016)
35. Ziółkowski P et al., Different design aspects of an Organic Rankine Cycle turbine for electricity production using a geothermal binary power plant, *Energy Conversion and Management* **246**, 114672 (2021)
36. Atia D, Farghally H, Ahmed N, El-Madany H, Organic Rankine Cycle Based Geothermal Energy for Power Generation in Egypt, *Energy and Power Engineering* **9**, 814-828 (2017)
37. Hijriawan M, Pambudi NA, Biddinika MK, Wijayanto DS, Kuncoro IW, Rudiyanto B, Wibowo KM, Organic Rankine Cycle (ORC) in geothermal power plants, *J. Phys.: Conf. Ser*. **1402**, 044064 (2019)
38. Glassley WE, Geology and Hydrology of Geothermal Energy, In: Bronicki L (eds) Power Stations Using Locally Available Energy Sources. Encyclopedia of Sustainability Science and Technology Series, Springer, New York (2018)
39. Kaya T, Hoşhan P, Corrosion and Material Selection for Geothermal Systems, Proceedings World Geothermal Congress, Antalya, Turkey (2005)