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ORCID: https://orcid.org/0000-0002-6584-5851

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Mini Review

Roadmap for Renewable Energy Development

Penjiyev Ahmet Myradovich*

Doctor of Technical and Agricultural Sciences, Academician of the International Academy of Sciences Environmental Safety (IAELPS), Turkmen State Institute of Architecture and Construction, Ashgabat, Turkmenistan

***Correspondence:** Penjiyev Ahmet Myradovich, Doctor of Technical and Agricultural Sciences, Academician of the International Academy of Sciences Environmental Safety (IAELPS), Turkmen State Institute of Architecture and Construction, Ashgabat, Turkmenistan, Email: ampenjiyev@gmail.com

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Annotation

The article examines the priorities and prospects of the road map for the development of renewable energy using the example of Turkmenistan. The main scientific conditions of the goal, objectives, principles of public policy, a heterogeneous class of renewable technologies, the main scientific conditions of the road map for sustainable development, the environmental aspect of climate change, mitigation potential, and costs are presented. The compiled roadmap for the use of renewable energy sources outlines the expected energy, economic, and environmental effects from the use of renewable energy technologies in remote areas from the centralized power line. The author believes that the outlined development roadmap for the use of renewable energy sources will become the basis for drawing up programs in other countries, depending on natural, climatic, and geographical conditions. Thus, the road map for the development of renewable energy sources, the use of local renewable energy resources, can reduce the need for fossil fuels in some cases by up to 80% and will significantly reduce the anthropogenic load on the environment. The introduction of renewable energy sources is one of the most relevant and promising for the development of the desert and the fight against desertification in the Karakum.

Introduction

According to scientists, global economic losses from climate change amount to more than 300 billion US dollars per year for the period 1976-2020. On average, the global air temperature has risen by 1.3 ˚C.

Renewable energy sources (RES) can be called the main contender for the status of the energy resource of the future and can significantly contribute to climate change [1-3].

The uneven distribution of the world's fossil resources, the rapid growth of the planet's population, and political conflicts have led to the fact that most countries are striving for energy independence. This can be achieved in part through the production of electricity based on renewable energy sources. At the same time, there is an urgent issue of reducing anthropogenic loads on the environment, in particular, minimizing emissions of greenhouse gases into the atmosphere leading to the greenhouse effect.

For example, Life Cycle Assessments (LCAs) of electricity generation show that greenhouse gas (GHG) emissions from renewable energy technologies are generally significantly lower than emissions associated with fossil fuels and, under certain conditions, lower than emissions from fossil fuels using carbon capture and storage (CCS). Average values for all RES range from 4 to 46 g CO2e/ kWh, and averages for fossil fuels range from 469 to 1001g CO2e/ kWh (excluding emissions from land-use change). This is another advantage of RES because, in the process of generating electricity and heat, there are no greenhouse gas emissions [3].

Based on this, the world community is creating all the necessary conditions for preventing global warming is the structural restructuring of the world energy sector with an increase in the share of renewable energy sources.

At the end of 2022, the world produced more than 7655.8 TWh, in percentage terms, the total electricity generation is: 55.0% or 4213 GW, while at thermal power plants running on: gas -19.7%; coal -16.7%; nuclear reactor -19.0%; [https://www.statista.com/statistics/267358/world-installed-power-capacity/]. Of these, the energy generated on the basis of renewable energy sources is wind power station - 11.7% (898.9 GW); solar power plant - 13.9% (1061.6 GW); biofuel power plant - 1.7% (150.7 GW); geothermal power plant – 0.2% (14.6 GW). The total based on RES without hydroelectric power plants is 40.3 % or 3381.7 GW; hydroelectric

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power stations - 18.2% (1392.5 GW); nuclear power plants - 5.4% (415 GW) [4,5].

It should be noted that the expected share of energy produced using renewable energy sources in the world at the end of 2023 will be 4970 TWh, in Europe - 1200.0 and in some countries, in TWh will be: USA - 800.0; China – 1600.0; Great Britain – 155.0; Germany - 280.0; Japan – 250.0; Brazil – 185.0; Spain – 110.0; Australia – 85; Italy – 80.0; Türkiye – 75.0; Canada – 60.0; Russia – 15.0. [4,5].

According to the World Bank, the share of financing of renewable energy from total capital investments in 2020 was 69% (FPP - 27 %, WPP - 24%, HPP - 13%, other - 5%), and the share of financing of fossil fuel power plants - 31% (coal - 12%, atom - 9%, gas - 10%).

As a result, the capacity of power plants based on renewable energy sources (excluding hydroelectric power plants) in 2021 increased by 16.3% (FPP - 22.8%, WPP - 13.4%, BioPP - 7.5%, GeoPP - 2.1%).

As can be seen from the above indicators, the rapid development of energy based on renewable energy sources is expressed in the improvement of existing technologies and the reduction of capital costs and the cost of generated electricity, first of all, solar and wind energy are still a priority.

Modern Turkmenistan is a dynamically developing state in the Central Asian region, possessing rich natural resources, infrastructure, and human potential. Our country is actively pursuing comprehensive reforms and transformations that can ensure sustainable growth for many years to come.

Today, new tasks are being put forward for sustainable economic development, which is based on the use of modern and innovative technologies in production structures.

The widespread use of renewable energy sources (RES) corresponds to the high priorities and objectives of the energy strategy of Turkmenistan.

It should be taken into account that 80% of the country's territory is occupied by the Karakum Desert. Consequently, a significant part of the population lives in areas of unreliable centralized electricity supply.

The energy potential of renewable energy sources on the territory of Turkmenistan is: the technical potential of low-potential solar energy is $4 \cdot 10^{15}$ kJ or approximately $1.4 \cdot 10^{11}$ t. t. per year; wind energy potential - 6.4 10^{11} kWh per year; the total heat and energy productivity of thermal waters is $2.5 \cdot 10^{10}$ tce. t. per year or 2.03 10^{10} kWh per year with a debit of 1.3 million m^3 per day; biomass energy; the energy of small rivers - research is required to obtain the latest data [3,6-8].

At the 28th session of the UN Framework Convention on Climate Change (COP28) in December 2023 in the United Arab Emirates in Dubai, in his speech, the President of Turkmenistan Serdar Berdimuhamedov noted with accession to the Paris Agreement a number of relevant national programs have been adopted, a number of specific initiatives have been put forward aimed to consolidate and approved a roadmap for international cooperation on adaptation and mitigation of climate change, and announced adherence to the Global Methane Commitment. In general, Turkmenistan is taking steps to introduce low-carbohydrate technologies. Among the promising vectors within the framework of the "green" economy, the implementation of projects for the production of hydrogen from natural gas is being considered. In addition, Turkmenistan is actively working to ensure environmental food security, healthcare, rational use of natural resources, waste processing and disposal.

In addition, Turkmenistan plans to reduce greenhouse gas emissions by 20% in 2030 relative to 2010 and also plans to achieve zero growth in greenhouse gas emissions in the medium term, starting in 2030, and in the long term, significant annual reductions.

On the issue of "green" energy, the National Strategy for the Development of Renewable Energy until 2030 and the new Law of Turkmenistan "On Renewable Energy Sources" have been adopted. The law defines the legal, organizational, economic, social, and financial framework, and mechanisms for regulating relations between the state, producers, suppliers, and consumers of renewable energy sources, production equipment, installations, and technology for the use of renewable energy sources [1-3,6-8].

Goals and objectives of the RES law

The purpose and objectives of the RES Law are the development and use of RES, improvement of the energy system and structure, diversification of energy resources, improvement of social and living conditions in hard-to-reach settlements (Karakum desert, mountainous areas, etc.), ensuring the energy security of Turkmenistan, environmental protection, rational use of natural resources and achieving sustainable development of the country's economy.

The main objective of the law is the organization of energy supply. This means management of work aimed at the economical use of fuel and energy resources:

- Analysis of the structure and volume of consumption, identification of energy losses, establishment of the causes of their occurrence, and determination of ways to eliminate or reduce them;
- Development of energy-saving measures;
- Introduction of energy-saving technological processes and equipment;
- Carrying out work to forecast the demand for agricultural products that require the least amount of energy resources;
- Carrying out calculations of production fuel reserve standards; collecting information on the availability of local and secondary energy resources and developing proposals for their use;

- Determination of the list of energy-intensive machines and equipment subject to write-off as irrational;
- Application of accounting for consumed energy resources on farms, in teams, and at each workplace; accounting for overconsumption of energy resources caused by the inadequate quality of raw materials and other products received, as well as low quality of manufactured products.

Principles of state policy in renewable energy sources

State policy in the field of renewable energy sources to achieve the objectives is to strengthen energy security through increasing the share of renewable energy, developing competitive energy systems, and ensuring environmental protection within the framework of national and regional programs. And also in the rational use of natural resources, public health, and labor protection in the implementation of measures aimed at developing the renewable energy sector with the help of state support for the use of renewable energy sources.

This includes the creation of a system of legal, financial, and economic mechanisms that ensure the economic interest of producers (consumers) of renewable energy sources, with the aim of including renewable energy sources in the fuel and energy balance.

Of no small importance is attracting investment and supporting entrepreneurship, guaranteeing the sale of generated RES energy, and creating the competitiveness of systems using RES. Information support for technical and technological achievements in the field of renewable energy sources and broad involvement of the public and scientific and technical potential in the process of development of renewable energy sources is also one of the priorities of state policy in this area [1].

Heterogeneous class of renewable technologies

RES constitute a heterogeneous class of technologies: Direct solar energy conversions use solar radiation energy to produce electricity using photovoltaic cells and concentrating solar energy to produce thermal energy (heating or cooling by either passive or active means), to supply direct lighting needs and for potential production of fuel that can be used for transport and other purposes.

The extent of solar technology development ranges from research and development (R&D) (e.g., solar-derived fuels) to relatively field-ready and off-the-shelf (e.g., passive and active solar heating and silicon wafer-based solar cells) technologies.

Many, but not all, technologies are modular in nature, allowing them to be used in both centralized and decentralized energy systems.

Solar energy is variable and, to some extent, unpredictable, although the time profile of solar energy output correlates relatively well with energy demand under some circumstances. Thermal energy storage offers opportunities to improve energy output control for some technologies, such as concentrating solar energy and direct solar heating.

Wind power uses the kinetic energy of airflow. The main application relevant to climate change mitigation is the production of electricity using large wind turbines located on land (onshore) or in seawater or freshwater (offshore). Onshore wind technologies are already being produced and applied on a large scale. Offshore wind technologies have great potential for continued technical improvement. Wind power is variable and, to some extent, unpredictable, but experience and detailed studies in many regions of the world have shown that the integration of wind power does not generally pose insurmountable technical barriers.

Bioenergy can be produced from a variety of biomass feedstocks, including cotton biomass and agricultural and animal waste; forest plantations with short-cutting rotation; energy crops; organic components of municipal solid waste and other types of organic waste. Through a range of processes, these raw materials can be used directly to produce electricity or heat or can be used to create gaseous, liquid, or solid fuels. The range of bioenergy technologies is wide, and their level of technical development varies considerably. Some examples of commercially available technologies are small and large boilers, residential pellet heating systems, and ethanol production from sugar and starch.

Lignocellulose-based transportation fuels are examples of technologies that are in the pre-commercial stage, while algal liquid biofuel production and some other bioconversion methods are in the research and development stage.

Bioenergy technologies are used in centralized and decentralized installations, with traditional biomass currently the most widely used in developing countries. Bioenergy typically offers continuous or controlled energy production. Bioenergy projects typically depend on the availability of local and regional fuel supplies, but recent developments indicate that solid biomass and liquid biofuels are increasingly being traded internationally.

Geothermal energy uses available thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are sufficiently hot and permeable in nature are called hydrothermal reservoirs, and reservoirs that are sufficiently hot but enhanced by hydraulic stimulation are called enhanced geothermal systems (EGS).

Once at the surface, the fluid at various temperatures can be used to generate electricity or more directly in areas where thermal energy is required, including district heating or using lower temperature heat from shallow wells for geothermal heat pumps used for heating or cooling. Hydrothermal power plants and thermal applications of geothermal energy are technically developed technologies, while UGS projects are at the demonstration and pilot testing stages, also going through the R&D stage. When geothermal power plants are used to generate electricity, they typically provide a constant output.

Marine energy is extracted from the potential, kinetic, thermal, and chemical energy of seawater, which can be converted to provide electricity, thermal energy or potable water. A wide range of technologies are possible, such as dams for tidal currents, underwater turbines for tidal and ocean currents, heat exchangers

for converting ocean thermal energy, and various devices for harnessing wave energy and salinity gradients. Ocean energy technologies, with the exception of tidal dams, are undergoing demonstration and experimental testing, and many of them require additional research and development. Some technologies have variable energy output profiles with varying levels of predictability (e.g., wave, tidal range, and current), while other technologies may be capable of nearly constant or even controlled operation (e.g., ocean thermal energy and salinity gradient).

Hydropower uses the energy of water moving from higher to lower horizons, primarily to generate electricity. Hydropower projects involve reservoir dam projects, natural river and stream projects and are carried out continuously at the project scale. This diversity gives hydropower the ability to meet large, centralized urban needs as well as decentralized rural needs.

Hydropower technologies are developed technologies. Hydropower projects use a resource that varies over time. However, the controlled energy output provided by reservoir hydropower structures can be used to meet peak electricity demands and help balance power systems that rely heavily on renewable energy sources. The exploitation of hydropower reservoirs often reflects their multiple uses, such as for drinking water, irrigation, flood control and drought control, as well as navigation and power supply [2,3,6-8].

Basic scientific conditions of the road map for the use of renewable energy sources for sustainable development

Determine the main types of use of renewable energy sources for sustainable development:

- Solar energy: determine - Resource potentials and their feasibility for economic and environmental reasons of using solar energy installations to convert solar radiation energy into electrical and thermal energy and the volumes of their economic use and environmental priorities at the current level of development of science and technology in the regions of Turkmenistan.

- Wind energy: determine - characteristics of wind energy, energy, operational and economic parameters of wind electric installations.

The amount of economically and environmentally feasible use of wind energy in the region in competition with traditional types of fuel and energy, and justify some requirements for the use of wind power plants imposed by the socio-ecological conditions of their use and the population's need for these power plants.

- Geothermal energy: Assess the forecast resources , energy efficiency , operational reserves of thermal waters and the cost-effectiveness of using geothermal energy, taking into account the thermal energy potential and technology for their extraction from the depths of the earth's crust in specific regions of Turkmenistan.

- Small hydropower: Calculate the energy potential for individual economic regions of the country, operating in conditions of developing market relations and the growing importance of socio-economic factors. At the same time, there is a need to take into account the possibilities of decentralized energy supply , different forms of ownership and sources of financing.

- Biotechnology: Bioresources, the potential for biomass and bioenergy production must be assessed, taking into account the task of environmental safety of the environment and pollution of the ecosystem and reducing the anthropogenic impact on the climate by using priority areas that are beneficial for both Turkmenistan and the region [2,3,6,7].

Environmental aspect

The rational use of fuel and energy resources is one of the global world problems, the successful solution of which will be of decisive importance not only for the further development of the world community, but also for the preservation of its habitat - the biosphere.

One of the promising ways to solve this problem is the use of new energy-saving technologies using non-traditional renewable energy sources. Despite the fact that modern energy is mainly based on non-renewable energy sources (about 80% of the world energy balance is oil, gas and coal), interest in renewable energy sources is steadily growing.

The main arguments for their use are the high price of traditional fuel, energy security for oil and gas importing countries, as well as environmental problems. In this context, it should be noted that an obligatory component of the course towards industrial and innovative development is the environmental aspect. The creation of new industries in all sectors of the economy will be carried out taking into account the rational use of natural resources, the introduction of environmentally friendly, harmless and waste-free production technologies.

Turkmenistan is an active supporter of cooperation on environmental issues within the UN and other international organizations. The country has created a modern regulatory framework that regulates the organization, management and planning of nature conservation, as well as the rational use of natural resources, the transfer of production processes to "green" technologies that require less fuel and energy resources per unit of production.

It seems effective to create a special incentive system for saving energy resources, introducing additional bonuses and benefits to engineering and technical workers of farms for economical consumption of fuel, electrical and thermal energy [1-3,6-8].

The economical and environmental use of energy resources, taking into account local conditions, is called eco-energy. It solves problems such as the study of local energy resources and methods for their effective development, determines the patterns of influence of local factors on the design of power plants using

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local energy resources: their parameters, economic and energy characteristics. The use of local energy resources can reduce the need for fossil fuels in some cases by up to 80%. Significant energy savings can be achieved by introducing innovative technologies, from primary energy production to final consumption.

Mitigation potential and costs: A significant increase in the use of renewable energy sources by 2030, 2050 and beyond is noted in most of the scenarios considered in 2008. The total volume of renewable energy production was approximately 64 EJ / year (12.9% of total primary energy supply), more than 30 EJ / year came from traditional biomass. More than 50% of scenarios assume a level of renewable energy use in 2050 of more than 173 EJ /year, in some cases reaching a level of more than 400 EJ /year.

Given that the use of conventional biomass decreases in most scenarios, the corresponding increase in the level of renewable energy production (excluding conventional biomass) is projected to range from about three to more than ten times.

The share of RES in global primary energy supply varies significantly across scenarios. In most scenarios, the share of renewable energy is more than 17% of primary energy supply in 2030, increasing to more than 27% in 2050. Scenarios with the highest share of renewable energy consumption reach about 43% in 2030 and 77% in 2050.

The eco- energy indicators of solar energy in the Central Karakum are as follows: the reduction in emissions of various harmful substances into the environment when using a solar photovoltaic station will amount to 242.44 kW · h for annual electricity production per 1 m^2, annual savings in fuel consumption - 96.96 kg.T, the reduction in emissions will be, kg per year: SO_2 – 2.0; NOx – 1.1; CO – 0.14; CH_4 – 0.29; CO_2 – 155.0; solids – 0.21; when converted into thermal energy from 1 m^2 and an annual production of 1256.4 kW · h, the annual fuel economy is 502.6 kg of fuel equivalent ; emission reduction will be, kg per year: SO_2 – 10.4; NOx – 5.6; CO – 0.73; CH_4 – 1.53; CO_2 – 803.5; solids – 1.1 [3,6-10].

Strategic objectives

Among the strategically important tasks on the agenda of modern development, issues of energy, economics, ecology and social development of the country are of particular relevance and importance. Neutral Turkmenistan, being an active supporter of a consolidated approach to solving these problems, considers environmental safety as a fundamental principle of sustainable development.

The task of introducing non-traditional renewable energy sources is one of the most relevant and promising for the national economy of Turkmenistan. Its solution will improve the efficiency of use of fuel, energy and material resources in the production of a wide range of industrial and agricultural products, reduce energy consumption of fossil fuels and mitigate anthropogenic loads on the environment.

The presence of unique hydrocarbon reserves in our country is not an obstacle to the development of the use of renewable energy sources. Large energy resources allow us not to make strategic mistakes in choosing optimal technologies and directions for the development of renewable energy sources, and to create, taking into account the experience of Western countries - China and Japan, our own innovative technologies and large-scale projects for the use of renewable energy sources.

Using the potential of renewable energy resources will make it possible to solve the energy and socio-economic problems of regions remote from centralized energy systems, and will also make it possible to maintain their environmental safety.

Currently, Turkmenistan has ratified the Kyoto Protocol and is actively participating in international cooperation in the field of reducing greenhouse gas emissions. In this regard, there are serious economic prerequisites for becoming a leading seller in the market for greenhouse gas emission quotas. The proceeds can be used to solve a number of important environmental problems. The irrational use of fuel and energy resources is one of the global world problems, the successful solution of which will be of decisive importance not only for the further development of the world community, but also for the preservation of its habitat - the biosphere. One of the promising ways to solve this problem is the use of new energy-saving technologies using non-traditional renewable energy sources.

Turkmenistan's climate change strategy: Turkmenistan is taking practical steps in the field of climate change: the introduction of modern technologies in all areas of the economy is reducing the volume of greenhouse gas emissions; the National Strategy on Climate Change, the National Strategy for the Development of Renewable Energy until 2030 and the new Law of Turkmenistan "On Renewable Energy Sources" were adopted; Millions of trees are planted in the country every year.

Is underway to fulfill obligations under the Paris Climate Agreement. The commitments proposed in it are confirmation of Turkmenistan's ambitious goal to reduce: greenhouse gas emissions by 2030 in key sectors of the economy. Particular attention in this context is paid to reducing methane emissions. In this regard, the Turkmen side welcomes the new initiative on the "Global Methane Commitment" and expresses interest in its detailed study with a view to possible substantive participation [3,8].

Turkmenistan plans to achieve zero growth in greenhouse gas emissions in the medium term, starting from 2030, and in the long term, a significant annual reduction. Our country expects to achieve these indicators both through its own financial resources and with technical and financial support from international organizations and financial institutions.

Conclusion

Thus, the roadmap for the development of renewable energy uses local renewable energy resources to reduce the need for fossil fuels in some cases by up to 80%. Significant energy savings can be achieved by introducing innovative technologies, from primary energy production to final consumption. The task of introducing renewable energy sources is one of the most relevant and promising

for the development of desert territories of Turkmenistan. Its solution will improve the efficiency of use of fuel, energy and material resources in the production of a wide range of industrial and agricultural products, reduce energy consumption of fossil fuels and mitigate anthropogenic pressures on climate change.

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