

THE EFFICIENCY OF USING RENEWABLE ENERGY SOURCES IN THE GREEN ECONOMY: THE CASE OF SURKHANDARYA REGION

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Abstract

The transition towards a green economy has become an important priority for sustainable economic development, environmental protection, and energy security. Renewable energy sources, particularly solar, wind, and hydropower, offer opportunities to reduce dependence on fossil fuels, improve energy efficiency, and support regional economic growth. This article examines the efficiency of renewable energy utilisation in the green economy, focusing on the natural, economic, and infrastructural conditions of Surkhandarya Region, Uzbekistan. The study considers the region's solar energy potential, the economic feasibility of renewable energy projects, their environmental benefits, and their contribution to employment and local development. A qualitative analytical approach is employed, combining the principles of sustainable development, regional economic analysis, and renewable energy assessment. Particular attention is paid to investment requirements, electricity storage, grid infrastructure, financing mechanisms, and institutional support. The analysis suggests that solar energy represents a particularly promising option for Surkhandarya because of the region's favourable climatic conditions. Nevertheless, the long-term efficiency of renewable energy projects depends on appropriate technology selection, reliable infrastructure, financial viability, and effective public policy. The article proposes measures to strengthen renewable energy development and improve the region's contribution to Uzbekistan's green economic transition.

Keywords: Green economy, renewable energy, solar energy, wind energy, energy efficiency, sustainable development, Surkhandarya Region, Uzbekistan, investment, environmental sustainability, regional economic development.

Introduction

The development of a green economy has become one of the major priorities of contemporary economic policy. Increasing energy demand, environmental degradation, climate change, and the limited availability of conventional energy resources have encouraged governments and businesses to seek more sustainable models of economic development. In this context, renewable energy sources play an essential role in transforming energy systems and improving the environmental sustainability of economic activities.



A green economy can be understood as an economic model that seeks to improve human well-being and social equity while reducing environmental risks and ecological pressures. Its implementation requires coordinated action in energy production, industrial development, agriculture, transport, construction, and public administration. Among these sectors, energy occupies a particularly important position because electricity and heat are essential inputs for almost all economic activities.

Renewable energy technologies, including solar photovoltaic systems, solar thermal installations, wind turbines, and hydropower facilities, can contribute to the diversification of energy supply. Their application may reduce greenhouse gas emissions, improve energy security, and create opportunities for technological innovation and employment. However, renewable energy development also requires substantial investment, appropriate infrastructure, effective regulation, and careful economic assessment.

Uzbekistan has significant opportunities to expand renewable energy production, particularly through solar power. The country's climatic conditions, growing electricity demand, and commitment to energy-sector modernisation provide a basis for further investment in clean energy technologies. At the regional level, however, the effectiveness of renewable energy development depends on geographical conditions, existing infrastructure, patterns of energy consumption, and the structure of local economic activity.

Surkhandarya Region is an important case for investigating these issues. Located in the southern part of Uzbekistan, the region has climatic conditions that make solar energy an attractive option for electricity generation and selected thermal applications. Renewable energy technologies may support households, agricultural enterprises, public institutions, commercial facilities, and industrial consumers.

At the same time, the development of renewable energy in Surkhandarya should not be assessed solely in terms of installed generating capacity. A comprehensive assessment must also consider the cost of electricity production, equipment lifetime, maintenance expenses, grid integration, seasonal demand, financing conditions, environmental impacts, and the contribution of projects to regional employment and productivity.

The purpose of this article is to analyse the economic and environmental efficiency of renewable energy utilisation in the green economy, using Surkhandarya Region as a regional case study.

The main research objectives are:

To examine the theoretical relationship between renewable energy and green economic development.

To identify the principal natural and economic conditions influencing renewable energy deployment in Surkhandarya.

To assess the economic, environmental, and social dimensions of renewable energy efficiency.

To identify the principal barriers to renewable energy adoption in the region.

To propose practical measures for improving renewable energy investment and utilisation.

The article approaches efficiency as a multidimensional concept encompassing financial performance, energy productivity, environmental benefits, and social outcomes.



2. Theoretical Foundations of the Green Economy and Renewable Energy Efficiency

The concept of a green economy is closely connected with sustainable development, resource efficiency, and the reduction of environmental externalities. Traditional economic models often evaluate production primarily through output, revenue, and profitability. A green economic approach expands this perspective by considering the environmental and social consequences of economic activity.

Renewable energy contributes to this approach by providing electricity and heat from resources that are naturally replenished. Solar radiation, wind, and flowing water can be used to generate energy without the continuous combustion of fossil fuels. Although renewable technologies have environmental impacts associated with manufacturing, transportation, construction, and disposal, their operational greenhouse gas emissions are generally lower than those of fossil-fuel-based electricity generation.

The efficiency of renewable energy utilisation can be examined through several complementary indicators.

2.1. Economic efficiency

Economic efficiency concerns the relationship between the resources invested in a renewable energy project and the economic benefits generated throughout its operational life.

Relevant indicators include:

Initial capital expenditure.

Operation and maintenance costs.

Levelised cost of electricity.

Payback period.

Net present value.

Internal rate of return.

Electricity savings and avoided energy purchases.

The levelised cost of electricity (LCOE) represents the average cost of generating a unit of electricity over the lifetime of a power facility, taking account of investment, operating costs, output, and discounting assumptions.

2.2. Energy efficiency

Energy efficiency refers to the extent to which energy resources are converted into useful output. In renewable energy projects, relevant indicators include electricity generated per unit of installed capacity, system availability, conversion efficiency, and the proportion of generated electricity that is actually consumed or delivered to the grid.

For solar photovoltaic installations, the capacity factor is particularly useful. It measures actual electricity generation relative to the output that would occur if the system operated at its rated capacity continuously throughout the assessment period.

A high level of solar radiation does not automatically guarantee a financially successful project. Performance also depends on equipment quality, panel orientation, temperature, dust accumulation, shading, inverter efficiency, maintenance, and electricity demand.



2.3. Environmental efficiency

Environmental efficiency concerns the environmental benefits achieved relative to the resources used and the impacts generated by a project.

Relevant indicators include greenhouse gas emissions avoided, reductions in local air pollution, water consumption, land use, and the environmental impacts of manufacturing and disposing of equipment.

The quantity of avoided emissions depends on the electricity source displaced by renewable generation. For this reason, estimates should use an appropriate emissions factor for the relevant electricity system and period rather than assuming that every renewable kilowatt-hour produces the same environmental benefit.

2.4. Social and regional efficiency

Renewable energy projects may create employment, improve electricity access, support rural development, and reduce the vulnerability of households and enterprises to energy supply disruptions.

Their social effectiveness depends on the distribution of benefits. A project that produces electricity at a competitive cost may still have limited local development effects if equipment, technical services, and skilled labour are sourced almost entirely from outside the region.

Consequently, the evaluation of renewable energy in Surkhandarya should combine financial, technical, environmental, and social indicators rather than rely on a single measure.

3. Natural and Economic Conditions for Renewable Energy Development in Surkhandarya Region

Surkhandarya Region is situated in southern Uzbekistan and has a predominantly continental climate, with hot summers and comparatively mild winters in many lowland areas. These conditions make solar energy an important option for regional energy development.

The region's geographical position, agricultural activities, settlement patterns, and growing demand for electricity create opportunities for the use of renewable technologies. Nevertheless, the technical and economic suitability of individual projects must be determined through site-specific assessments.

3.1. Solar energy potential

Solar energy is particularly relevant to Surkhandarya because of its generally favourable solar conditions. Photovoltaic systems can convert sunlight directly into electricity, while solar thermal technologies can provide heat for water, buildings, and selected agricultural processes. Potential applications include rooftop solar installations on residential buildings, schools, hospitals, administrative facilities, warehouses, and commercial premises. Larger photovoltaic installations may also be developed where land availability, grid access, and environmental considerations permit.

For agricultural enterprises, solar energy can support irrigation pumps, water supply systems, refrigeration, storage facilities, and processing operations. These applications are particularly relevant where electricity demand coincides with periods of strong solar radiation.



However, solar generation varies throughout the day and across seasons. High temperatures and dust accumulation can reduce photovoltaic performance, making appropriate equipment selection, panel cleaning, ventilation, and maintenance important components of project management.

A regional solar development strategy should therefore combine resource assessment with analysis of electricity demand, available roof or land area, grid capacity, and investment costs.

3.2. Wind energy opportunities

Wind energy may provide an additional source of renewable electricity in suitable locations. Nevertheless, the presence of open land or strong seasonal winds does not by itself establish the economic viability of a wind project.

Wind development requires detailed measurements of wind speed, direction, seasonal variation, turbulence, and extreme weather conditions. The technical characteristics of the proposed turbines, access to transmission infrastructure, transport costs, and environmental constraints must also be considered.

For Surkhandarya, wind power should therefore be treated as a location-dependent opportunity requiring systematic resource assessment. It may complement solar energy where suitable wind conditions and cost-effective grid connections are demonstrated.

3.3. Small hydropower and other renewable technologies

Hydropower may be feasible in locations with suitable water flows, elevation differences, and infrastructure. However, its development must take account of water availability, seasonal variation, irrigation requirements, ecological conditions, and competing uses of water resources.

In an agricultural region, water has substantial economic and social value. Hydropower projects should therefore be evaluated within integrated water and energy planning rather than assessed exclusively in terms of electricity generation.

Other technologies may include solar water heating, biogas production from suitable organic waste, and selected forms of biomass energy. Their viability depends on the availability and quality of feedstock, conversion technology, logistics, and environmental safeguards.

Overall, solar photovoltaic technology appears to be a particularly promising option for further investigation in Surkhandarya, while wind, hydropower, and bioenergy require more specific assessments of local conditions.

4. Economic Efficiency of Renewable Energy Utilisation

The economic efficiency of renewable energy projects in Surkhandarya depends on the relationship between initial investment, operating expenditure, energy output, and the value of electricity supplied or saved.

4.1. Investment and lifecycle costs

Renewable energy projects often require substantial initial expenditure for equipment, installation, electrical connections, engineering, and commissioning. These costs may be offset by relatively low fuel expenditure and predictable operating costs over the system's lifetime.



Nevertheless, a project should not be considered economically efficient merely because sunlight or wind is freely available. The complete cost of converting a natural resource into usable electricity must be evaluated.

For rooftop photovoltaic systems, the principal financial considerations include panel and inverter costs, installation, roof suitability, electrical protection, maintenance, and possible battery storage. For larger projects, land preparation, grid connection, transmission upgrades, financing, and project development costs may represent important additional expenses.

The lifecycle approach is particularly useful because it prevents decision-makers from focusing exclusively on initial purchase prices.

4.2. Electricity cost savings

Households, agricultural enterprises, and public institutions can potentially reduce their expenditure on purchased electricity by generating a portion of their own demand.

The financial benefit depends on the amount of electricity consumed directly, the applicable electricity tariff, the rules governing exported electricity, and the timing of generation and consumption.

For example, an agricultural enterprise operating irrigation pumps during daylight hours may be able to use solar electricity directly. This can reduce the amount of electricity purchased from the grid. By contrast, an enterprise whose greatest demand occurs at night may require storage, grid electricity, or another complementary source.

Consequently, matching renewable generation to the demand profile is an important determinant of economic performance.

4.3. Investment payback and financial risk

The payback period is frequently used to communicate the financial attractiveness of small renewable energy systems. It estimates the time required for accumulated net savings to recover the initial investment.

However, the simple payback period does not fully capture the time value of money, equipment replacement, changing electricity tariffs, or uncertainty in future savings. More comprehensive investment decisions should use discounted cash-flow analysis and sensitivity testing.

The principal variables affecting project profitability include:

Equipment and installation costs.

Financing interest rates.

Annual electricity generation.

Self-consumption and electricity export arrangements.

Maintenance and inverter replacement.

Inflation and electricity price changes.

Equipment degradation and system lifetime.

For Surkhandarya, improving access to affordable long-term financing could help households and businesses overcome high initial investment barriers. Credit guarantees, carefully designed concessional loans, and transparent investment rules may support project implementation where financial and technical assessments demonstrate viability.



Conclusion

The efficiency of renewable energy utilisation is an important component of the transition towards a green economy. In Surkhandarya Region, favourable solar conditions, growing energy needs, and opportunities for agricultural and commercial applications create a basis for expanding renewable energy technologies.

The analysis suggests that solar photovoltaic systems are a particularly promising option for further regional development, especially where electricity demand coincides with solar generation. Wind energy, hydropower, and bioenergy may also contribute where site-specific assessments demonstrate technical, financial, and environmental viability.

The economic efficiency of renewable energy depends on lifecycle costs, electricity generation, financing conditions, maintenance, and the relationship between generation and demand. Environmental benefits depend on the electricity displaced, equipment lifecycle impacts, and appropriate management of land and water resources. Social benefits are influenced by employment, technical training, and the extent to which local enterprises participate in the renewable energy sector.

Several measures can strengthen these outcomes, including regional resource assessment, rooftop solar development, improved financing, electricity network modernisation, integration with efficient agricultural systems, and investment in technical education. A consistent monitoring framework is also necessary to evaluate project performance and guide future investment.

The principal conclusion is that renewable energy should be treated not simply as a technological alternative to conventional electricity generation but as an instrument of regional economic transformation. Its contribution to the green economy in Surkhandarya will depend on the integration of energy policy with economic planning, environmental protection, water management, education, and infrastructure development.

Future empirical research should use verified regional data to quantify electricity generation, investment returns, emissions reductions, and employment effects. Such evidence would provide a stronger foundation for determining the most effective renewable energy strategies and supporting sustainable economic development in Surkhandarya Region.

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