**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE**

**Sumy State University**

*Academic and Research Institute of Business, Economics and Management*
(Institute/faculty)

*Department of Economics, Entrepreneurship and Business Administration*
(department)

"Defense allowed"

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24 06 2024 .

# QUALIFICATION WORK
## towards attaining a Master's Degree

specialty *073 Management,*
(code and title)

*educational-professional* program *Business Administration*
(educational-professional / educational-scientific) (program)

Topic: Managing renewable energy development at a water supply enterprise

Student BA.m-22ан Duan Wenjuan
(group code) (surname, name)

The qualification work contains the results of own research. The use of ideas results and texts of other authors are linked to the corresponding source.

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Supervisor Prof., Dr. Sc. (Econ.), Prof. Iryna Sotnyk
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**Sumy – 2024**

*Ministry of Education and Science of Ukraine*
*Sumy State University*

**DEPARTMENT OF ECONOMICS, ENTREPRENEURSHIP AND BUSINESS ADMINISTRATION**

APPROVED
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"24" 06 2024.

**ASSIGNMENT**
**for the qualification work**
**towards attaining a Master's Degree**

Student of group BA.m-22ан, 2 year of study ARIBiEM
(Institute)
Specialty 073 "Management"
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Managing renewable energy development at a water supply enterprise

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Initial data for research: textbooks, educational manuals, internet resources, scientific reports, company reports, and periodicals

Content of the main part of the qualification work (list of questions to be considered) Integrating renewable energy into water supply enterprises; strategic management and policy integration for renewable energy in water supply companies;

## Summary

Master's thesis consists of 50 pages, 3 chapters, 11 tables, 1 annex, and a list of 61 references.

The topic's relevance is the need for the implementation of energy-efficient measures and renewable power solutions at water supply enterprises to ensure the economic and environmental sustainability of these businesses, as their energy expenses can account for more than 50% of all production costs.

The *aim of the research* is to manage renewable energy development at a water supply enterprise by examining the strategies and implications of integrating renewable power into water supply operations to address high energy costs and promote sustainability.

The *research tasks* are: to identify and analyze various renewable energy sources applicable to water supply enterprises; to assess the role of water supply enterprises in the development and adoption of renewable energy; to examine case studies and best practices in managing renewable energy projects at water supply enterprises; to develop a conceptual framework for managing renewable energy development in water supply companies; to evaluate management mechanisms, strategies and approaches for integrating renewable energy into water supply operations; to analyze the regulatory framework and policy implications for renewable energy projects in the water sector; to substantiate and manage the renewable energy development at JSC “Water Supply Enterprise as a case study.

The *object of the research* is the water supply company. The *subject of the research* is management and economic mechanisms for renewable energy development at a water supply enterprise. The *research methods* are factor, structural, investment, sensitivity and strategic analyses, analytical approach and case study analysis.

The *scientific novelty of the research* is scientifically substantiated economic approaches and mechanisms to manage renewable energy development at a water

supply enterprise based on the investment and sensitivity analysis of a green power project. The *practical significance of the research* is the integral assessment of the economic and other benefits of the proposed solar power plant construction project that help substantiate the feasibility of implementing renewable power measures at the water supply company. The results of the research are published in the conference proceedings and a scientific article.

*The first chapter* offers an overview of renewable energy sources applicable to water supply enterprises, emphasizing their potential benefits and implementation. It explores the crucial role of water supply enterprises in adopting renewable energy solutions for sustainability and operational efficiency. Additionally, it presents case studies and best practices from different water supply enterprises, providing practical insights.

*The second chapter* outlines a conceptual framework for managing renewable energy development within water supply companies, detailing essential strategies and considerations. It discusses various management mechanisms and approaches for integrating renewable energy into water supply operations, focusing on practical implementation tactics. Additionally, it examines regulatory frameworks and policy implications for renewable energy projects in the water sector.

*The third chapter* covers the case study and provides an overview of JSC's "Water Supply Enterprise," including its operations, structure, and challenges in renewable energy management. It presents the technical and economic indicators of a solar power plant construction project at the enterprise, analyzing the project's feasibility and expected economic performance. The chapter also highlights non-economic advantages, such as environmental benefits and enhanced corporate reputation outlining the strategy for further development of the enterprise.

*Keywords*: MANAGEMENT, BUSINESS, STRATEGY, DEVELOPMENT, MECHANISM, RENEWABLE ENERGY, WATER SUPPLY ENTERPRISE, INVESTMENT ANALYSIS.

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# Introduction

The water supply business plays a crucial role in both national and local economies, providing essential needs for the population and businesses. A distinctive feature of this industry is its high dependence on electricity, as activities such as water extraction, pumping, purification, distribution through water supply networks, wastewater disposal, and disinfection require significant amounts of electrical energy to operate the corresponding equipment (Li et al, 2024; Zakariazadeh et al., 2024; Lako et al., 2024; Hong et al., 2023; Harasymchuk et al., 2024). Therefore, the search for and implementation of energy-saving measures in water supply enterprises is the top priority to ensure the sustainability of these businesses, as their energy expenses can account for up to 70% of all production costs (García-Valiñas et al., 2023; Reis et al., 2023; Zubrowska-Sudol et al., 2023; Meschede, 2019; Bhojwani et al., 2019).

In recent years, water supply companies have faced escalating energy costs, prompting them to seek innovative solutions to mitigate expenses and promote sustainability. The integration of renewable energy sources has emerged as a promising strategy to address these challenges while advancing environmental objectives (Glekas, 2008; Vieira & Ramos, 2008; Iskhakova et al., 2024; Jain & Khare, 2024; Bhatraj et al., 2024; García et al., 2022). Therefore, the development of optimal management strategies and considerations involved in harnessing renewable energy within water supply enterprises to reduce operational costs and enhance sustainability is extremely relevant.

Historically, water supply companies have relied heavily on conventional energy sources, such as fossil fuels, to power their operations. However, rising energy prices and environmental concerns have spurred interest in alternative energy options. Renewable energy technologies, including solar and wind, offer sustainable alternatives that can help water supply enterprises reduce their dependence on costly fossil fuels while lowering carbon emissions (Yang et al., 2022; Lee et al., 2018; Vieira et al., 2008; Coelho & Andrade-Campos, 2014).

The integration of renewable energy sources is of paramount importance for water supply enterprises seeking to alleviate the burden of high energy costs. By leveraging solar panels, wind turbines, and other renewable technologies, these companies can generate clean energy onsite, reducing their reliance on expensive grid electricity. This not only mitigates the financial impact of energy expenditures but also enhances the resilience of water supply operations by providing a reliable and cost-effective energy source.

Moreover, renewable energy integration aligns with broader sustainability objectives, positioning water supply companies as leaders in environmental stewardship. By transitioning to renewable sources, these enterprises can significantly reduce their carbon footprint and contribute to global efforts to combat climate change. Additionally, renewable energy projects can serve as valuable revenue streams, as excess energy generated can be sold back to the grid or utilized for other purposes, further offsetting operational costs.

Taking into account the relevance of implementing green energy solutions for water supply enterprises, this *research aims* to manage renewable energy development at a water supply enterprise by examining the strategies and implications of integrating renewable energy into water supply operations to address high energy costs and promote sustainability.

The *research tasks* are:

- to identify and analyze various renewable energy sources applicable to water supply enterprises;
- to assess the role of water supply enterprises in the development and adoption of renewable energy;
- to examine case studies and best practices in managing renewable energy projects at water supply enterprises;
- to develop a conceptual framework for managing renewable energy development in water supply companies;
- to evaluate management mechanisms, strategies and approaches for integrating renewable energy into water supply operations;

- to analyze the regulatory framework and policy implications for renewable energy projects in the water sector;
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The information base of the research includes textbooks, educational manuals, internet resources, scientific reports, company reports, and periodicals.

# 1 Integrating renewable energy into water supply enterprises

## 1.1 Overview of renewable energy sources applicable to water supply enterprises

The overview of renewable energy sources applicable to water supply enterprises encompasses a diverse array of sustainable options aimed at powering various aspects of water supply operations. These sources offer environmentally friendly alternatives to traditional fossil fuels, contributing to reduced carbon emissions and enhanced sustainability. Key renewable energy sources applicable to water supply enterprises include (Sotnyk & Duan Wenjuan, 2023; Sotnyk et al., 2024):

1) solar energy: solar power, derived from sunlight, is one of the most widely utilized renewable energy sources. Water supply enterprises can harness solar energy through photovoltaic (PV) panels or solar thermal systems. PV panels convert sunlight directly into electricity, while solar thermal systems use sunlight to heat water or other fluids for various applications within water treatment plants, pumping stations, and distribution networks (Tawalbeh et al., 2021; Shrestha, 2005);

2) wind energy: wind power is generated by harnessing the kinetic energy of wind through turbines. Water supply enterprises situated in regions with consistent wind patterns can benefit from wind energy to supplement their electricity needs. Wind turbines can be installed on-site or in nearby locations to generate clean and sustainable power for water pumping, treatment, and distribution processes (Ramos, et al., 2011; Vieira & Ramos, 2008);

3) hydroelectric power: hydroelectric power utilizes the energy of flowing water to generate electricity. Water supply enterprises located near rivers, streams, or other water bodies with suitable hydraulic conditions can leverage hydroelectric turbines to produce renewable energy. These turbines can be integrated into existing water infrastructure, such as dams or water treatment facilities, to generate power while ensuring efficient water management (Vieira & Ramos, 2008);

4) biomass energy: biomass energy is derived from organic materials such as agricultural residues, forestry waste, or wastewater sludge. Through processes like anaerobic digestion or combustion, biomass can be converted into biogas, biofuels, or thermal energy. Water supply enterprises can utilize biomass-derived fuels to generate heat and electricity for various operational needs, including heating water, powering boilers, or generating electricity (Kurbatova et al., 2023; Cherchi et al., 2015);

5) geothermal energy: geothermal energy harnesses heat from the Earth's subsurface to produce electricity or provide heating and cooling services. While less commonly applied in water supply enterprises compared to other renewable sources, geothermal energy can still offer sustainable solutions, especially in regions with accessible geothermal resources. Geothermal heat pumps can be utilized for heating water or spaces within water treatment facilities, contributing to energy efficiency and cost savings (Lee & Younos, 2018; Reis et al., 2024; Lourenço et al., 2024).

Overall, the diverse range of renewable energy sources available to water supply enterprises presents opportunities for reducing reliance on conventional energy sources, lowering operational costs, and minimizing environmental impact. By strategically integrating renewable energy technologies into their infrastructure and operations, water supply enterprises can enhance their sustainability and contribute to global efforts towards combating climate change.

## 1.2 The role of water supply enterprises in renewable energy development

Water supply enterprises play a pivotal role in renewable energy development by serving as catalysts for the adoption and integration of sustainable energy solutions. While their primary function is to provide safe and reliable water services to communities, these enterprises can leverage their infrastructure, resources, and influence to promote the transition toward renewable energy. The role of water supply enterprises in renewable energy development encompasses several key aspects:

1. Demand generation. Water supply enterprises represent significant energy consumers due to the extensive energy requirements of water treatment, pumping, and distribution processes. By embracing renewable energy technologies, these enterprises can reduce their dependence on fossil fuels and contribute to the growing demand for clean energy solutions. Through their procurement policies and investment decisions, water supply enterprises can stimulate market demand for renewable energy technologies, driving innovation and cost reductions over time (Meschede, 2019; Reis et al., 2023, 2024).

2. Project implementation. Water supply enterprises have the capacity to initiate and implement renewable energy projects within their operational footprint. Whether through on-site installations of solar panels, wind turbines, or hydroelectric generators, or through partnerships with external energy providers, these enterprises can directly contribute to the expansion of renewable energy infrastructure. By investing in renewable energy projects, water supply enterprises can diversify their energy sources, enhance energy security, and mitigate the risks associated with fossil fuel price volatility and supply disruptions (Sotnyk et al., 2021, 2022; Glekas, 2008; Ávila et al., 2022).

3. Collaboration and partnerships. Collaboration between water supply enterprises, government agencies, research institutions, and private sector stakeholders is essential for advancing renewable energy development. Water supply enterprises can engage in partnerships with renewable energy developers, technology providers, and financial institutions to leverage expertise, access funding opportunities, and overcome barriers to project implementation. By participating in collaborative initiatives and knowledge-sharing platforms, water supply enterprises can accelerate the deployment of renewable energy solutions and maximize their impact on sustainability goals (Reis et al., 2023; García et al., 2022; Lee & Younos, 2018).

4. Community engagement and education. As trusted institutions within their communities, water supply enterprises have a unique opportunity to raise awareness and promote the benefits of renewable energy adoption. Through outreach programs, public events, and educational initiatives, these enterprises can engage with customers, stakeholders, and local residents to foster a culture of sustainability and environmental stewardship. By demonstrating their commitment to renewable energy development and showcasing successful projects, water supply enterprises can inspire community members to embrace clean energy technologies and support future initiatives (Kurbatova et al., 2020; Prokopenko et al., 2021; Sotnyk et al., 2014).

In summary, water supply enterprises play a multifaceted role in advancing renewable energy development, serving as drivers of demand, facilitators of project implementation, collaborators in partnerships, and educators in their communities. By leveraging their influence and resources, these enterprises can accelerate the transition to a more sustainable energy future and contribute to global efforts to combat climate change.

## 1.3 Case studies and best practices in managing renewable energy projects at water supply enterprises

Case studies and best practices in managing renewable energy projects at water supply enterprises provide valuable insights into the successful implementation of sustainable energy solutions within the water sector. By examining real-world examples and learning from best practices, water supply enterprises can identify strategies, overcome challenges, and maximize the benefits of renewable energy integration. Let us consider a few illustrative case studies and best practices.

1. Case study of solar PV installations.

The Los Angeles Department of Water and Power (LADWP, 2024) implemented a large-scale solar PV project across its water treatment and distribution facilities to reduce energy costs and carbon emissions. By installing solar panels on rooftops, parking structures, and unused land, LADWP generated renewable energy on-site and offset a significant portion of its electricity consumption. The best practices of this case study include:

1) conducting comprehensive feasibility studies and site assessments to identify suitable locations, assess solar potential, and optimize system design;

2) collaborating with experienced solar developers and contractors to ensure the quality, performance, and reliability of solar PV installations.

2. Case study of hydroelectric power generation.

The Portland Water Bureau in Oregon, USA, utilized its existing water infrastructure to generate hydroelectric power through the installation of turbines in gravity-fed pipelines and water supply conduits. By harnessing the potential energy of flowing water, the bureau generated clean electricity while maintaining water supply operations (Portland, 2024).

The best practices of this case study include:

1) integrating hydroelectric power generation into water supply infrastructure upgrades and capital improvement projects to maximize efficiency and cost-effectiveness;

2) engaging with regulatory agencies and stakeholders to navigate permitting and environmental compliance requirements for hydroelectric projects.

3. Case study of energy efficiency and demand management.

The Sydney Water Corporation in Australia implemented a comprehensive energy efficiency program aimed at reducing energy consumption and optimizing operational processes across its water treatment plants and pumping stations. Through measures such as equipment upgrades, system optimization, and behavioral changes, Sydney Water achieved significant energy savings and cost reductions (Sydney, 2024).

The best practices of this case study include:

1) implementing energy management systems and monitoring tools to track energy usage, identify opportunities for improvement, and measure performance against established benchmarks;

2) providing training and capacity-building initiatives to empower staff and stakeholders to actively participate in energy conservation efforts.

4. Case study of innovative financing and funding mechanisms.

The Water Authority of Fiji leveraged public-private partnerships and international funding sources to finance the development of renewable energy projects, such as solar-powered desalination plants and wind-powered pumping stations, to improve water supply resilience and sustainability in remote island communities (Water, 2024).

The best practices of this case study include:

1) exploring innovative financing models, such as energy performance contracting, third-party ownership, and green bonds, to overcome budget constraints and mobilize investment capital for renewable energy initiatives;

2) collaborating with financial institutions, development agencies, and donors to access grants, loans, and incentives for renewable energy projects.

In conclusion, the considered case studies and best practices demonstrate the diverse approaches and successful outcomes of managing renewable energy projects at water supply enterprises worldwide. By sharing lessons learned and replicating proven strategies, water supply enterprises can accelerate their transition to clean, renewable energy sources, enhance operational efficiency, and contribute to environmental stewardship and resilience.

# 2 Strategic management and policy integration for renewable energy in water supply companies

## 2.1 Conceptual framework for managing renewable energy development in water supply companies

The conceptual framework for managing renewable energy development in water supply encompasses key principles, strategies, and considerations aimed at effectively integrating renewable energy solutions into water supply operations. This framework provides a structured approach to guide decision-making, planning, and implementation processes, ensuring alignment with organizational goals, technical requirements, and sustainability objectives. The essential components of the conceptual framework are presented in Table 2.1.

Table 2.1 - The key components of the conceptual framework for managing renewable energy development in water supply companies of local communities (Sotnyk et al., 2021; Zakariazadeh et al., 2024; Lako & Çomo, 2024; García-Valiñas et al., 2023; Reis et al., 2023)

| Stage of the conceptual framework | Characteristics of the stage |
|---|---|
| 1 | 2 |
| 1 Needs assessment and goal setting | - a comprehensive assessment of energy needs, consumption patterns, and operational requirements within the water supply system of the settlement and the water supply company;<br>- definition of clear goals and objectives for renewable energy integration, considering factors such as cost reduction targets, environmental sustainability goals, and energy security priorities of the water supply company and local communities. |

Continuation of Table 2.1

| 1 | 2 |
|---|---|
| 2 Resource assessment and technology selection | - evaluation of available renewable energy resources, including solar, wind, hydro, and biomass potential, through site assessments and feasibility studies that can be potentially applied to the water supply company and local communities;<br>- selection of appropriate renewable energy technologies based on resource availability, site-specific conditions, technical feasibility, and economic viability to implement on-site. |
| 3 System design and integration | - design of renewable energy systems and infrastructure to meet specific energy demand profiles, operational constraints, and regulatory requirements of the territory and the company;<br>- integration of renewable energy generation components seamlessly with existing water supply infrastructure, such as treatment plants, pumping stations, and distribution networks. |
| 4 Financing and investment | - development if a financing strategy to fund renewable energy projects, considering capital costs, operational expenses, financing options, and return on investment;<br>- exploration of various funding sources and mechanisms, including grants, incentives, loans, public-private partnerships, and innovative financing models. |
| 5 Regulatory compliance and permitting | - compliance with relevant regulatory frameworks, standards, codes, and permitting requirements governing renewable energy development and water supply operations;<br>- obtaining necessary permits, approvals, licenses, and environmental assessments for renewable energy installations, addressing legal, environmental, and social considerations. |
| 6 Stakeholder engagement and capacity building | - engagement of stakeholders, including staff, management, government agencies, local communities, and industry partners, throughout the renewable energy development process; |

Continuation of Table 2.1

| 1 | 2 |
|---|---|
| | - building internal capacity through training, awareness campaigns, knowledge sharing, and skill development initiatives to support effective renewable energy management and operation. |
| 7 Monitoring, evaluation, and continuous improvement | - establishment of monitoring and evaluation mechanisms to track the performance, efficiency, and impact of renewable energy systems over time;<br>- regularly review and data analysis, identification of opportunities for optimization and improvement, and implementation of corrective actions to enhance system performance and reliability |

By adopting the considered conceptual framework, water supply enterprises can effectively manage the development and integration of renewable energy solutions, optimize energy utilization, reduce operational costs, and contribute to environmental sustainability and resilience in the water sector.

## 2.2 Management mechanisms and approaches for integrating renewable energy into water supply operations

Integrating renewable energy into water supply operations requires careful consideration of various models, mechanisms and approaches to ensure optimal utilization of resources, cost-effectiveness, and sustainability. The most popular management mechanisms, models, and approaches commonly used for integrating renewable energy into water supply operations are as follows (Szpak et al., 2024; Coelho & Andrade-Campos, 2014; Kurbatova et al., 2021, 2024; Yu-Xia Tu et al., 2022; Sotnyk et al., 2019, 2022; Cherchi et al., 2015; Lee & Younos, 2018; Melnyk et al., 2023):

1. On-site renewable energy generation.

This approach involves installing renewable energy generation systems directly at water supply facilities, such as treatment plants, pumping stations, and distribution networks. For this, common technologies include solar PV panels, wind turbines, micro-hydro turbines, and biomass energy systems.On-site generation allows water supply enterprises to produce clean energy locally, reducing reliance on grid electricity and mitigating energy costs and environmental impact.

2. Power Purchase Agreements (PPAs).

PPAs enable water supply enterprises to procure renewable energy from third-party developers or energy service providers without upfront investment in equipment and infrastructure. Under a PPA, the water utility agrees to purchase electricity generated from renewable sources at a predetermined rate over a specified contract period. This model offers financial flexibility, risk mitigation, and access to renewable energy without the burden of ownership, maintenance, or operational responsibilities. It is quite convenient for water supply companies, however, the price of such services and benefits can be high.

3. Energy storage and microgrid systems.

Energy storage technologies, such as batteries and pumped hydropower storage, complement renewable energy generation by storing excess energy for use during periods of high demand or low renewable resource availability. Microgrid systems integrate renewable energy sources, energy storage, and conventional grid connections to create resilient and self-sufficient energy networks. Water supply enterprises can deploy microgrid systems to optimize energy supply, enhance reliability, and minimize disruptions, particularly in remote or off-grid locations. The main drawback of this solution is the high value of energy storage technologies, preventing their wide use at different water supply companies.

4. Energy efficiency and demand management.

Improving energy efficiency and implementing demand management measures are critical components of renewable energy integration in water supply operations. Water utilities can reduce energy consumption through equipment upgrades, process optimization, leakage reduction, and energy-efficient technologies. Demand management strategies, such as peak shaving, load shifting, and demand response programs, help balance energy supply and demand, optimize energy use, and reduce utility costs.

5. Collaborative and community-based models.

Collaborative models involve partnerships between water supply enterprises, local communities, government agencies, non-profit organizations, and private sector stakeholders to develop and implement renewable energy projects. Community-based models prioritize community engagement, ownership, and benefit-sharing, empowering local stakeholders to participate in renewable energy initiatives and gain social, economic, and environmental benefits. This scheme is the most promising to implement for depressed or low-income territories where water supply companies belong to or are subsidized by the municipalities.

By leveraging these models, mechanisms and approaches, water supply enterprises can effectively integrate renewable energy into their operations, optimize energy management, reduce carbon emissions, and contribute to sustainable development and resilience in the water sector.

### 2.3 Regulatory framework and policy implications for renewable energy projects in the water sector

The regulatory framework and policy implications play a crucial role in shaping the landscape for renewable energy projects in the water sector. Table 2.2 presents an overview of the regulatory framework and policy implications for such projects.

Table 2.2 – The regulatory framework and policy implications for renewable energy projects of water supply companies (Sotnyk et al., 2014, 2017, 2021; Hong et al., 2023; Bhatraj et al., 2024; Reis et al., 2023; Yang et al., 2022)

| The regulatory framework | Policy implications |
|---|---|
| 1 | 2 |

| | |
|---|---|
| 1 Government regulations and standards | - Governments establish regulations and standards governing the deployment, operation, and safety of renewable energy systems in the water sector. |

Continuation of Table 2.2

| 1 | 2 |
|---|---|
| | - These regulations encompass technical specifications, environmental standards, grid connection requirements, and safety protocols to ensure compliance and mitigate risks. |
| 2 Renewable energy targets and mandates | - Many governments worldwide set renewable energy targets and mandates to promote the adoption of clean energy technologies, including those in the water sector.<br>- Renewable energy targets aim to increase the share of renewable energy in the overall energy mix, reduce greenhouse gas emissions, and enhance energy security and resilience. |
| 3 Feed-in tariffs and incentive programs | - Feed-in tariffs and incentive programs provide financial incentives to encourage the deployment of renewable energy projects, including those in the water sector.<br>- Feed-in tariffs offer guaranteed prices for renewable energy generation, incentivizing investment and facilitating project development.<br>- Incentive programs may include tax credits, grants, rebates, and low-interest loans to offset upfront costs and improve project economics. |
| 4 Net metering and interconnection policies | - Net metering policies allow water supply enterprises to offset their electricity consumption with on-site renewable energy generation and receive credit for excess energy exported to the grid.<br>- Interconnection policies govern the technical and procedural requirements for connecting renewable energy systems to the grid, ensuring safety, reliability, and grid stability. |
| 5 Environmental and permitting regulations | - Environmental regulations and permitting requirements govern the environmental impact |

| | |
|---|---|
| | assessment, site approval, land use, water rights, and other aspects of renewable energy projects in the water sector. |

Continuation of Table 2.2

| 1 | 2 |
|---|---|
| | - Permitting processes ensure compliance with environmental laws, protect natural resources and mitigate potential adverse impacts on ecosystems, biodiversity, and water quality. |
| 6 Market mechanisms and trading platforms | - Market mechanisms, such as renewable energy certificates and carbon markets, create additional revenue streams and incentives for renewable energy projects.<br>- Renewable energy certificates certify the environmental attributes of renewable energy generation, allowing water supply enterprises to sell or trade them to meet regulatory compliance or voluntary sustainability goals. |
| 7 Research and development funding | - Governments allocate funding for research, development, and innovation in renewable energy technologies and applications relevant to the water sector.<br>- Research funding supports technological advancements, pilot projects, demonstration initiatives, and knowledge sharing to accelerate the deployment and scale-up of renewable energy solutions. |

Overall, a supportive regulatory framework and policy environment are essential for unlocking the full potential of renewable energy projects in the water supply sector, driving investment, innovation, and sustainable development while addressing energy challenges and climate change mitigation goals.

# 3 Case study: renewable energy development at JSC "Water Supply Enterprise"

## 3.1 Overview of the water supply enterprise

The municipal JSC "Water Supply Enterprise" encompasses all activities and infrastructures involved in sourcing, treating, and delivering water to end-users, including households, industries, and agricultural sectors on the city territory of the enterprise's location. This essential service plays a critical role in maintaining public health, supporting economic activities, and ensuring environmental sustainability in local communities.

Due to the specifics of the city's water resources, the company uses groundwater as the main resource. Because of the elevation changes in the city, water is supplied to different parts of the city using pumping stations at three levels, which requires significant electricity consumption for each level. In addition to extracting and supplying water, the company carries out the full cycle of water drainage. Water treatment at the company includes the following stages:

- primary treatment: involves the removal of large debris and sediments through processes like screening and sedimentation.
- secondary treatment: biological processes are employed to remove dissolved and suspended organic matter.
- tertiary treatment: advanced filtration and disinfection methods (e.g., chlorination, UV radiation) ensure water is safe for consumption.

Distribution systems of the company incorporate:

- infrastructure: a complex network of pipes, pumps, storage tanks, and treatment facilities that deliver water from sources to consumers, and
- maintenance: regular monitoring and maintenance are essential to prevent leaks, water contamination, and ensure reliable water supply.

Regulation and quality control systems of the enterprise include:

- standards and compliance: regulatory bodies establish water quality standards to ensure safe drinking water. Regular testing and compliance are mandatory;
- public health: ensuring the microbiological, chemical, and physical quality of water is crucial for preventing waterborne diseases.

The technological processes of JSC “Water Supply Enterprise” are quite energy-intensive. The energy resources consumed include electrical energy, natural gas, and solid fuel. Solid fuel and natural gas are used in building heating systems. Electrical energy is used to power electric motors of technological equipment, lighting, and for performing auxiliary processes.

The main production and technical units that ensure the water supply technological process are pumping stations, which integrate the processes of raising drinking water from underground aquifers (First lift), transporting and storing it in clean water reservoirs, and transporting drinking water from these clean water reservoirs to consumers through the city’s water supply system (Second lift). Supplying consumers with drinking water in buildings higher than five floors is organized using Third-lift pumping equipment. Such equipment is located in central heating points or in the buildings themselves.

The drainage system includes sewage pumping stations and a system of pipelines (both pressure and non-pressure collectors). The main equipment of the sewage pumping stations consists of pump units with a nominal capacity of 100-800 $m^3$/h and a nominal head up to 60 m. The average annual electricity consumption by the drainage system’s current receivers is about 10,000 thousand kWh per year.

City treatment facilities are one of the largest consumers of electricity at JSC “Water Supply Enterprise”. The main consumers are the pumping equipment of wastewater treatment and disinfection systems, air blowers of the biological treatment system, and auxiliary equipment for lighting, heating, and control operations.

Among the main challenges that the company faces at the current stage of its operations, it is appropriate to highlight the following (Table 3.1).

Table 3.1 – The main challenges of the water supply company (Ramos et al., 2011; Reis et al., 2023; Sotnyk, 2017; Tawalbeh et al., 2021)

| Challenges | Characteristics |
|---|---|
| 1 Resource scarcity | - **Overexploitation**: Excessive withdrawal of groundwater and surface water can lead to depletion and environmental degradation.<br>- **Climate Change**: Alters precipitation patterns, leading to droughts and water scarcity in many regions. |
| 2 Infrastructure | - **Aging Systems:** Many water supply systems are outdated and require significant investment for upgrades and repairs.<br>- **Urbanization:** Rapid urban growth increases demand, often outpacing the development of necessary infrastructure. |
| 3 Financial constraints | - **Investment Needs:** Upgrading and expanding water infrastructure requires substantial financial resources, which are often limited.<br>- **Affordability:** Balancing the cost of water supply with affordability for consumers is a persistent challenge. |
| 4 Contamination risks | - **Pollution:** Industrial discharge, agricultural runoff, and improper waste disposal can contaminate water sources.<br>- **Natural Contaminants:** Issues like arsenic and fluoride in groundwater pose significant health risks in some areas. |

Given the analyzed challenges, we can propose the following directions of innovations and solutions to implement at the enterprise in order to react effectively to the existing problems:

1) technological advances, including:

- energy efficiency improvements: application of energy-efficient and renewable power technologies to reduce the energy cost of the firm;
- smart water management: utilizing the Internet of Things and data analytics for efficient water management and leak detection;

- advanced treatment technologies: innovations like membrane filtration, advanced oxidation processes, and nanotechnology improve treatment efficiency and water quality;

2) sustainable practices:

- integrated water resources management (IWRM): promotes the coordinated development and management of water, land, and related resources;
- water recycling and reuse: encouraging the use of treated wastewater for non-potable purposes to reduce demand on freshwater sources;

3) community engagement:

- education and awareness: promoting water conservation practices among consumers;
- participatory planning: involving communities in decision-making processes to ensure that water supply systems meet local needs.

Overall, the water supply enterprise is a critical sector for the municipality that requires a multidisciplinary approach to address its numerous challenges. Ensuring sustainable and safe water supply involves not only technological and infrastructural advancements but also regulatory frameworks, financial strategies, and community involvement. By addressing these aspects comprehensively, the enterprise can continue to provide this indispensable resource for future generations.

Given the fact that the company spent more than 50-60% of its total costs on electricity, let us consider the investment project on implementing solar energy generation technologies at the enterprise to ensure the self-production of electricity to satisfy its own needs in energy.

## 3.2 Key technical and economic indicators of the solar power plant construction project at the enterprise

Given the technical setup, existing power supply schemes for electrical equipment, geographical location, and logistical conditions, as well as the company's energy costs and anticipated electricity price increases, it is advisable to consider installing a pilot solar power plant at JSC "Water Supply Enterprise." The enterprise has sufficient space for a solar panel field and the necessary electrical equipment for connecting solar plant inverters and energy storage systems with the pump station equipment. The technical capabilities of supplying water consumers isolated from the water supply network and clean water reservoirs directly from the well, equipped points for filling mobile tanks (tank trucks), and the ability to organize water supply in the event of a complete shutdown of the pump station due to the lack of power from the electrical grid, severe accidents in the wastewater or water supply system of the city, indicate the appropriateness of choosing this option.

Based on technical and economic feasibility, it is proposed to implement a pilot project for the construction of a 120 kW solar power plant. The estimated monthly electricity generation volumes of the solar power plant for its first year of operation are provided in Table 3.2.

Based on the data in Table 3.2, in the first year, the solar power plant will generate 174.8 thousand kWh of electricity, while the enterprise's annual consumption is 1112.4 thousand kWh, corresponding to an average electricity substitution rate of 15.6%. In subsequent years, the electricity generation by the solar power plant will decrease by 0.8% annually due to technically objective degradation of the solar panels (annual decrease in the productivity of solar panels). The operational lifespan of the solar power plant is assumed to be 25 years. The monthly electricity consumption volumes are assumed to remain constant for all 25 years of the plant's operation. The calculation of the annual electricity production volumes by the solar power plant for the next 25 years and the average share of substituting purchased electricity with self-generated electricity for these years is presented in Table 3.3. It is assumed that the annual volume of green electricity generation, which compensates for part of the enterprise's annual electricity consumption, is taken into account, and monthly electricity flows are not considered since they are reserved for the enterprise by default through the net-metering or net-billing system.

Table 3.2 – Average forecasted monthly generation, consumption, and substitution of electricity at the solar power plant of JSC "Water Supply Enterprise"

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume of generation, thousand kWh/month | 1.78 | 5.28 | 13.3 | 18.89 | 24.19 | 26.31 | 26.25 | 24.28 | 16.89 | 11.5 | 4.4 | 1.73 |
| The share of monthly generation in the annual volume, % | 1.02 | 3.02 | 7.62 | 10.81 | 13.84 | 15.05 | 15.02 | 13.89 | 9.66 | 6.56 | 2.52 | 0.99 |
| Consump-tion volume, thousand kWh/month | 96.4 | 91 | 92 | 90.4 | 89.2 | 88 | 101 | 102 | 92 | 91.6 | 94 | 94.8 |
| Share of replacement of purchased electricity with own one, % | 1.9 | 5.8 | 14.5 | 20.9 | 27.1 | 29.9 | 26 | 23.8 | 18.4 | 12.6 | 4.7 | 1.8 |

The incomes of the project are determined by the savings obtained from reducing the volume of electricity purchased by JSC "Water Supply Enterprise" for powering equipment, due to the use of solar energy for these needs. Investment costs for the project include the cost of purchasing equipment, conducting installation and commissioning works, designing, and expenses for dismantling and decommissioning the equipment after the solar power plant's operational life ends. Annual operational costs for maintaining the solar power plant will include annual depreciation charges and other expenses for the ongoing maintenance of the solar power plant.

Table 3.3 – Annual electricity production volumes of the solar power plant and the share of substituting purchased electricity with self-generated electricity at JSC “Water Supply Enterprise” during the project implementation

| Project year | Own electricity generation volume, thousand kWh/year | Share of substituting purchased electricity with own electricity, % |
|---|---|---|
| 1 | 174.8 | 15.6 |
| 2 | 173.4 | 15.4 |
| 3 | 172.0 | 15.3 |
| 4 | 170.6 | 15.2 |
| 5 | 169.3 | 15.1 |
| 6 | 167.9 | 15.0 |
| 7 | 166.6 | 14.8 |
| 8 | 165.2 | 14.7 |
| 9 | 163.9 | 14.6 |
| 10 | 162.6 | 14.5 |
| 11 | 161.3 | 14.4 |
| 12 | 160.0 | 14.3 |
| 13 | 158.7 | 14.1 |
| 14 | 157.5 | 14.0 |
| 15 | 156.2 | 13.9 |
| 16 | 155.0 | 13.8 |
| 17 | 153.7 | 13.7 |
| 18 | 152.5 | 13.6 |
| 19 | 151.3 | 13.5 |
| 20 | 150.1 | 13.4 |
| 21 | 148.9 | 13.3 |
| 22 | 147.7 | 13.2 |
| 23 | 146.5 | 13.1 |
| 24 | 145.3 | 12.9 |
| 25 | 144.2 | 12.8 |

Information on the cost of equipment and installation works was provided by the equipment supplier and the service provider for the installation and maintenance of solar power plants. Decommissioning costs after the solar power plant's operational life were calculated as 5% of the initial investment costs according to the recommendations (European Commission, 2015). Annual depreciation charges over the entire equipment usage period were calculated using the straight-line method. The discount rate was set at 15%, considering the project's risk level and assuming that the project's investment costs are formed in a 50/50 ratio of own and borrowed resources. All calculations were conducted in US dollars (USD). The initial data for the solar power plant installation project are presented in Table 3.4.

Table 3.4 – Initial technical and economic data for the solar power plant installation project at JSC “Water Supply Enterprise” (formed based on vendors' prices)

| Indicator | Indicator Value |
|---|---|
| **Investment costs, thousand USD** | **169.33** |
| - Cost of equipment purchase (hybrid power plant of 30 kW + grid power plant of 90 kW), thousand USD | 149.99 |
| - Installation and commissioning costs, thousand USD | 8.25 |
| - Design costs, thousand USD | 3.03 |
| - Decommissioning cost, thousand USD | 8.06 |
| **Annual operational costs, thousand USD/year** | **7.49** |
| - Annual depreciation charges, thousand USD/year | 6.77 |
| - Annual maintenance costs, thousand USD/year | 0.72 |
| Purchase price of electricity for the enterprise, USD/kWh | 0.21 |

Since the generated electricity will be used for internal needs and will not be sold externally, this activity is not subject to state taxation.

### 3.3 Justification of the economic efficiency of the solar power plant project and sensitivity analysis

To assess the economic feasibility of implementing the pilot project, we will perform an investment analysis, calculating the following indicators:

- Net Present Value– *NPV*;
- Internal Rate of Return– *IRR*;
- Discounted Payback Period – *DPP*;
- Profitability Index– *PI*.

The calculation of these indicators was based on the methodological approaches described in (Sotnyk, 2021, Sotnyk et al., 2020, 2022, 2023) and presented in Annex A. The project's incomes and expenses by year are provided in Table 3.5.

Table 3.5 – Incomes and expenses for the solar power plant project at JSC “Water Supply Enterprise”, thousand USD

| Project implementation year | Discounted project incomes | Discounted project investment costs | Discounted depreciation charges | Discounted maintenance costs |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 0 | - | 161.27 | - | - |
| 1 | 31.92 | 0.00 | 5.89 | 0.63 |
| 2 | 27.53 | 0.00 | 5.12 | 0.54 |
| 3 | 23.75 | 0.00 | 4.45 | 0.47 |
| 4 | 20.49 | 0.00 | 3.87 | 0.41 |
| 5 | 17.67 | 0.00 | 3.37 | 0.36 |
| 6 | 15.24 | 0.00 | 2.93 | 0.31 |
| 7 | 13.15 | 0.00 | 2.55 | 0.27 |
| 8 | 11.34 | 0.00 | 2.21 | 0.24 |
| 9 | 9.78 | 0.00 | 1.93 | 0.20 |
| 10 | 8.44 | 0.00 | 1.67 | 0.18 |

| | | | | |
|---|---|---|---|---|
| 11 | 7.28 | 0.00 | 1.46 | 0.15 |
| 12 | 6.28 | 0.00 | 1.27 | 0.13 |
| 13 | 5.42 | 0.00 | 1.10 | 0.12 |
| 14 | 4.67 | 0.00 | 0.96 | 0.10 |
| 15 | 4.03 | 0.00 | 0.83 | 0.09 |
| 16 | 3.48 | 0.00 | 0.72 | 0.08 |
| 17 | 3.00 | 0.00 | 0.63 | 0.07 |

Continuation of Table 3.5

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 18 | 2.59 | 0.00 | 0.55 | 0.06 |
| 19 | 2.23 | 0.00 | 0.48 | 0.05 |
| 20 | 1.93 | 0.00 | 0.41 | 0.04 |
| 21 | 1.66 | 0.00 | 0.36 | 0.04 |
| 22 | 1.43 | 0.00 | 0.31 | 0.03 |
| 23 | 1.24 | 0.00 | 0.27 | 0.03 |
| 24 | 1.07 | 0.00 | 0.24 | 0.03 |
| 25 | 0.92 | 0.24 | 0.21 | 0.02 |
| **Total:** | **226.53** | **161.51** | **43.78** | **4.65** |

Table 3.7 demonstrates the calculations of NPV, IRR, DPP, and PI for the solar power plant project at JSC "Water Supply Enterprise".

Table 3.7 – Indicators of the economic efficiency of the solar power plant project at JSC "Water Supply Enterprise"

| Indicator | Indicator value |
|---|---|
| NPV, thousand USD | 60.37 |
| IRR, % | 21.35 |
| DPP, years | 8.38 |
| PI | 1.37 |

Thus, the project to implement a 120-kW solar power plant at the enterprise is profitable, with an NPV of 60,370 USD. The IRR is over 21% at a discount rate of 15%. Therefore, the project has a financial safety margin and remains viable even with a slight increase in the discount rate, but not exceeding 21.35%. The discounted payback period of the project is up to 8.5 years, which is acceptable for energy investment projects of this scale.

Next, we will conduct a sensitivity analysis of the investment project to understand how the project's efficiency indicators might change under the influence of external factors such as changes in the economic situation, which may potentially alter the discount rate, and changes in electricity prices. For changes in the economic situation and, accordingly, the discount rate, we will consider, all other things being equal, an increase in the discount rate to 18% and a decrease to 10%. For changes in prices, we will consider an increase in electricity prices by 15%, 30%, 50%, and 100%. In these scenarios, we will examine how all project efficiency indicators change. The calculation results are presented in Table 3.8.

Table 3.8 – Results of the sensitivity analysis of the investment project for the construction of a solar power plant at JSC “Water Supply Enterprise”

| Indicator | Indicator value | | | | | |
|---|---|---|---|---|---|---|
| | Discount rate | | Electricity price increase | | | |
| | 10% | 18% | +15% | +30% | +50% | +100% |
| NPV, thousand USD | 145.65 | 27.36 | 94.35 | 128.33 | 173.64 | 286.91 |
| IRR, % | 21.35 | | 24.83 | 28.28 | 32.86 | 44.26 |
| DPP, years | 6.46 | 10.71 | 6.48 | 5.32 | 4.31 | 2.93 |
| PI | 1.9 | 1.17 | 1.58 | 1.79 | 2.08 | 2.78 |

According to the results of the conducted sensitivity analysis, an increase in the project’s discount rate, which corresponds to the rising cost of money needed for investment in the project, negatively impacts the profitability of the solar power plant, reducing the project’s NPV by more than half – from 60,370 USD down to 27,360 USD. Conversely, a decrease in the discount rate to 10%, i.e., by 5 percentage points, increases the project's NPV by more than double – from 60,370 USD up to 145,650 USD. Moreover, an increase in the discount rate significantly lengthens the project's discounted payback period (by 2.5 years), while a decrease in the rate shortens the payback period by almost 2 years. The change in the discount rate does not affect the IRR; however, an increase in the rate reduces the project's PI to 1.17, while a decrease raises the PI to 1.9.

An increase in the purchase price of electricity positively influences all indicators of the project’s investment efficiency. The higher price leads to greater cost savings for JSC “Water Supply Enterprise” at the same investment and running costs, significantly increasing the project's profitability. For example, a 15% increase in electricity prices shortens the project’s payback period by nearly 2 years, increases NPV from 60,370 USD to 94,350 USD, raises PI from 1.37 to 1.58, and boosts the IRR from 21.35% to 24.83%, indicating enhanced financial strength of the project. Further increases in the purchase price continue to enhance the project's profitability. For instance, a 50% price hike increases NPV by 2.87 times, IRR by 1.54 times, shortens the discounted payback period almost by half, and raises PI by 1.5 times. If the price doubles, NPV grows by 4.75 times, IRR by 2.08 times, the discounted payback period shortens almost by three times, and PI increases by more than 2 times. Thus, in conditions of inflation and economic instability, the project of implementing the solar power plant at JSC “Water Supply Enterprise” becomes more profitable, indicating the economic feasibility of investing in it.

## 3.4 Non-economic benefits of the solar power plant project

A significant technological advantage of the project is ensuring the reliability of the technological process of transporting drinking water from the well to the consumer, with the possibility of storing water in clean water tanks. In the hydraulic water supply system, the clean water tank acts as a flow break and buffer capacity, allowing submersible pump units and pump units supplying water to the city network to operate independently. This enables stable operation with the highest efficiency of submersible pumps (operating in base mode) and regulation of the operating parameters of the second lift pump unit. Integrating the solar power plant into the existing energy infrastructure of the enterprise according to the proposed technical solutions requires minimal effort.

The social impact of the solar power plant construction project is determined in two interrelated directions: positive impact on water supply/sewerage tariffs and free delivery of sanitary-quality water for the population and critical infrastructure facilities.

The environmental impact of the solar power plant project implementation involves reducing CO2 emissions by replacing traditional electricity produced using fossil fuels with green electricity generated from solar radiation. The volumes of green electricity generated by the solar power plant over its 25 years of operation, which will be entirely used for the enterprise's needs, will replace the corresponding volumes of electricity that would potentially be produced using natural gas or lignite. The calculations of the environmental effect of the solar power plant construction and operation project are presented in Table 3.9.

Table 3.9 – Evaluation of the environmental effect of the investment project for the construction of the solar power plant at JSC "Water Supply Enterprise"

| Indicator | Indicator value |
|---|---|
| Average annual generation of green electricity by the solar power plant, thousand kWh | 159 |
| Total generation of green electricity by the solar power plant over its operational period (25 years), thousand kWh | 3975 |
| Specific $CO_2$ emissions, kg/MWh during electricity production using (Technical, 2023): | |
| - natural gas | 277 |
| - lignite | 433 |
| Reduction in $CO_2$ emissions on an annual basis when replacing traditional generation with solar power, tons/year, for: | |
| - natural gas combustion | 44 |

| | |
|---|---|
| - lignite combustion | 69 |
| Reduction in $CO_2$ emissions over the operational period of the solar power plant (25 years), when replacing traditional generation with solar power, tons, for: | |
| - natural gas combustion | 1101 |
| - lignite combustion | 1721 |

Thus, the project for the construction of a solar power plant at JSC "Water Supply Enterprise," in addition to economic benefits, has positive social, technological, and environmental consequences, including improving the quality and reliability of water supply and sewage systems in the city, reducing atmospheric pollution by decreasing the carbon footprint, and more. Its implementation will allow the enterprise to start transitioning to the use of green energy from autonomous sources, managing renewable power development in the water supply sector of the territory.

# Conclusions

Renewable energy has already become a global trend: in recent years, investments in it have consistently surpassed investments in traditional energy technologies. Many countries, particularly developed ones, are refraining from investing in new energy projects that involve fossil fuels. Progressive societies have come to realize that sustainable development is key to the stable future of national economies, and a just energy transition is one of the pathways to achieve it.

Alongside municipal energy companies, a substantial portion of production costs for water supply enterprises is allocated to electricity for water extraction, purification, transportation, and other associated processes. Therefore, optimizing energy consumption for water supply enterprises through the application of innovative renewable energy technologies is a significant contribution to their stable operation and the development of their production capacities. Managing renewable energy development at a water supply enterprise presents both significant challenges and substantial opportunities. Throughout this paper, we have explored how integrating renewable energy sources can enhance the sustainability and operational efficiency of water supply systems.

Key challenges include the intermittency and reliability of renewable energy sources, high initial investment costs, grid integration complexities, land use concerns, and regulatory hurdles. These obstacles necessitate strategic planning and innovative solutions, such as advanced energy storage technologies, smart grid systems, and supportive policy frameworks.

Conversely, the opportunities offered by renewable energy are considerable. Technological advancements are reducing costs and improving efficiency, creating economic growth and job opportunities. Renewable energy can enhance energy independence and security while delivering profound environmental benefits by reducing greenhouse gas emissions. Additionally, the development of decentralized energy systems can empower local communities and improve resilience.

By addressing these challenges with a proactive and informed approach, water supply enterprises can harness the full potential of renewable energy. This involves not only investing in the latest technologies but also fostering a culture of sustainability and innovation. Policymakers, industry stakeholders, and communities must collaborate to create an enabling environment for renewable energy adoption.

In its practical part, our study examines the prospects of implementing a 120-kW solar power plant project to meet the energy needs of an urban water supply enterprise. The investment analysis conducted on the JSC "Water Supply Enterprise" project demonstrates its profitability, with a net present value of 60,370 USD and an internal rate of return exceeding 21% at a 15% discount rate. The solar power plant project's payback period is estimated at 8.5 years, which is deemed acceptable.

Sensitivity analysis indicates the project's resilience even with a discount rate increase to 18%, maintaining the financial strength of the project with a discounted payback period of up to 10.71 years. Moreover, escalating electricity purchase prices significantly bolsters project profitability, rendering the investment in the solar power plant economically justified. Specifically, a 50% increase in electricity prices results in a 2.87-fold increase in net present value, a 1.54-fold increase in internal rate of return, nearly halving the discounted payback period, and a 1.5-fold increase in profitability index. Doubling electricity prices leads to a 4.75-fold increase in net present value, a 2.08-fold increase in internal rate of return, nearly tripling the discounted payback period reduction, and more than doubling the profitability index. Therefore, amid inflation and economic instability, the implementation of the solar power plant project at JSC "Water Supply Enterprise" becomes more profitable, indicating the economic viability of investing in it and the strategic importance of the project for the enterprise's further development.

Furthermore, the project offers technological advantages by ensuring reliable water transport processes and environmental benefits by reducing CO2 emissions through the substitution of traditional energy sources with solar energy.

Mechanisms for green energy development require the active participation of all stakeholders in processes aimed at rationalizing and greening energy systems, introducing cutting-edge renewable energy technologies, and improving energy efficiency in production and consumption. Implementing such initiatives at the enterprise level is crucial, especially in the municipal sector. The latter represents a significant consumer of energy resources, where savings can have powerful positive economic effects (in terms of reducing costs for sector enterprises), social benefits (potentially lowering utility tariffs for the population while maintaining or even enhancing utility quality), and environmental advantages (reducing the environmental footprint and decreasing environmental pollution).

In conclusion, the transition to renewable energy within water supply enterprises is not only feasible but also essential for long-term sustainability. The integration of renewable energy resources can transform water supply operations, making them more resilient, efficient, and environmentally friendly. As such, the management strategies outlined in this paper provide a roadmap for successfully navigating the complexities of renewable energy development, ultimately contributing to a sustainable future for both the water supply sector and the broader community.

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## Annex A

**Overview of indicators of investment analysis (adapted based on (**Melnyk, 2012; Sotnyk, 2021, Sotnyk et al., 2020, 2022, 2023**))**

Investment analysis indicators such as net present value (NPV), profitability index (PI), internal rate of return (IRR) and discounted payback period (DPP) are applied to justify the economic expediency of renewable energy projects in the business sector.

NPV, IRR and PI are the key indicators for decision-making regarding the investment projects' implementation in global practice. They evaluate the degree of a project's profitability within its lifecycle.

DPP is a secondary indicator for decision-making as it does not consider income obtained beyond the payback period. Therefore, the information quality for a balanced management decision is reduced. However, investors pay significant attention to DPP under the unstable economy and high risks of doing business. The smaller DPP is, other things being equal, the more attractive and less risky the project is for the investor.

The calculation of NPV, USD is carried out according to the formula:

$$NPV = \sum_{t=t_f}^{T} Inc_t \times (1 + r)^t - \sum_{t=0}^{t_l} C_t \times (1 + r)^t, \quad (A.1)$$

where $Inc_t$ is the project income (less running (operation and maintenance – O&M) costs) in the t-th year of the project's lifecycle, USD;

$C_t$ is investment costs (including initial investment and decommissioning costs) for the project in the t-th year of its lifecycle, USD;

$t_f$ is the year of receiving the first income;

$t_l$ is the year of the end of investment;

r is the discount rate bringing income and costs to a single time point;

T is the project lifecycle duration, years (NPV, 2022; Melnyk, 2012; Sotnyk et al., 2022).

If NPV > 0, the project's income exceeds the costs for the entire lifecycle. That is, the project is profitable and worth implementing. If NPV < 0, the project is unprofitable. If NPV = 0, the project is break-even. In case of high risks of investing, the projects' owners are not inclined to implement break-even measures as the latter do not provide sufficient financial security and may bring losses at the slightest deviations in the economic conditions.

The profitability index PI is calculated by the ratio of the present value of project cash flows to the present value of the investment costs (Melnyk, 2012; Profitability, 2022; Sotnyk et al., 2023):

$$PI = \sum_{t=t_f}^{T} Inc_t \cdot (1+r)^t \Big/ \sum_{t=0}^{t_l} C_t \cdot (1+r)^t . \quad (A.2)$$

If PI is equal to 1, the project is break-even. If PI < 1, the project's income is less than the investment costs. As the PI value increases, the profitability of the project grows.

IRR is the most complex to calculate and one of the most important indicators for evaluating the effectiveness of investment projects. It reflects the discount rate $r$ at which the sum of discounted incomes of a given investment project equals the sum of discounted investment costs. In other words, IRR is the discount rate at which the NPV of an investment project equals zero:

$$NPV = \sum_{t=t_f}^{T} Inc_t \times (1+IRR)^t - \sum_{t=0}^{t_l} C_t \times (1+IRR)^t, \quad (A.3)$$

The IRR indicator is widely used for comparative evaluation of investment projects, as well as for assessing the profitability of various types of investment activities (such as purchasing securities, placing deposit funds, etc.). When making management decisions regarding the implementation of investment projects, the minimum IRR can be used as a criterion. If the IRR of a specific investment project does not exceed the specified minimum rate, the project is rejected as inefficient. Projects with IRRs higher than the minimum established rate are considered feasible for implementation. The most effective project, according to the IRR indicator, is the one with the highest IRR among all proposed projects, exceeding the minimum established rate (Melnyk, 2012).

DPP, years, is determined by the formula outlining the period during which present incomes would cover the project's initial investment costs:

$$\mathrm{DPP} = \mathrm{m} + \frac{\mathrm{C}_{\Sigma} - \mathrm{SInc}_{\mathrm{m}}}{\mathrm{Inc}_{\mathrm{m+1}}} \cdot (1 + \mathrm{r})^{\mathrm{m+1}}, \qquad \text{(A.4)}$$

where $C_{\Sigma}$ is the total amount of discounted investment costs for the project, brought to the investment starting point, USD;

$SInc_m$ is the total discounted income, calculated cumulatively until the inequality is satisfied: $SInc_m < C_{\Sigma} < SInc_{m+1}$ , USD;

m is the number of full years in which the cumulative discounted income is less than the amount of discounted investment costs;

(m+1) is the year in which the cumulative discounted income will exceed the discounted investment costs;

$Inc_{m+1}$ is the project's income in the (m+1)-th year, USD (Melnyk, 2012; Project-Management.info, 2021).

Along with the initial investments, formula (A.4) considers all investment costs made in other than 0-th years of the project lifecycle and affecting its payback. The shorter DPPs, the more attractive projects are to investors (Sotnyk, 2021). The longer the DPP, the riskier the project with acceptable NPV, IRR and PI values. In the last case, the risks associated with unstable political, economic, and social environments are much higher than NPV, PI, IRR and DPP calculations indicate.