IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Sustainable Development and Planning
Vol. 18, No. 8, August, 2023, pp. 2411-2419
Journal homepage: http://iieta.org/journals/ijsdp

Tariff Financing of Biogas Projects at Wastewater Treatment Plants: A Comparative Study of Russian Federation

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https://doi.org/10.18280/ijsdp.180812

Received: 2 May 2023
Revised: 9 June 2023
Accepted: 14 July 2023
Available online: 29 August 2023

Keywords:
tariff, anaerobic digestion, wastewater treatment plants, financial tools, investing

ABSTRACT

Effective environmental and energy management is crucial in the wastewater treatment sector. This article examines the implementation of biogas projects, which use anaerobic digestion to convert sewage sludge into energy and biofertilizer, in the Russian Federation. These projects, while common in the European Union, are rare in Russia due to financial constraints. Currently, they are primarily funded by utility operator investment programs, supported by tariffs for wastewater services. It is estimated that funding these projects through a five-year investment program would result in an annual tariff increase of 6-20% in the first two years. Additional financial mechanisms, such as 'green' credits and government interest rate compensation, have minimal impact on tariff growth. Any increase, however, can be burdensome for the population, and regional administrations may hesitate to implement these projects due to tariff concerns. Regardless, these projects are essential for Russia's transition to a circular economy.

1. INTRODUCTION

Wastewater treatment plants (WWTP) play a substantial role in the environment and public health protection, preventing natural and biological ecosystems from entering pathogens and contaminants. Wastewater treatment (WWT) is a multistage technique, implementing physical, biological and chemical processes, to bring water quality to standard values making it safe for discharge into water bodies [1-3].

Sewage sludge is considered major and inevitable by-product of WWT that has to be subjected to special treatment and disposal procedure. Sewage sludge is originated throughout WWT, when pollutants are retained and concentrated into a conditionally solid fraction. Substantially, the sewage sludge is a complex multicomponent system consisting of hazardous organic and mineral matters: nitrogen, phosphorus, potassium, a large number of microorganisms, including pathogenic, toxic compounds, especially heavy metal ions. Moreover, sewage sludge is a strong greenhouse gas (GHG) generator due to the degradation of organics with the release of methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) into atmosphere [4-8]. For instance, methane is more than 21 times as potent as carbon dioxide at the atmosphere heat-trapping effect. The excess of GHG leads towards irreversible climate patterns change, spatial and quantitative growth of natural disasters, and ultimately negative threat to the humanity and wildlife [9].

Nowadays, sustainable environmental and energy management has become significant issue in WWT sector [10]. Anaerobic digestion (AD) is well established and recognized technique to convert sewage sludge into energy and biofertilizer [11]. Furthermore, it provides the transition towards the circular economy (CE) principles, including the energy independence, smart waste management, GHG mitigation and resource recovery [12].

The biogas, obtained through AD process, is a valuable energy resource that can be used in various ways: to produce thermal energy in boilers, to co-generate heat and electricity in combined heat and power (CHP) units, or to enrich it into biomethane for further import into the national gas transmission system. On the other hand, biogas can be used for resource recovery through the extraction of the useful substances, such as CO_2, which can be used in the chemical industry, metallurgy, food industry or elsewhere.

In terms of the sanitary and epidemiological situation, digested sewage sludge becomes stabilized: within the mesophilic mode of AD the number of pathogens in sewage sludge is significantly reduced, while thermophilic mode of AD makes sewage sludge completely safe [13].

Biogas projects are widespread in the European Union, in contrast to Russian Federation. The European Commission set a goal of 35 billion m^3 of annual biomethane production by 2030 according to its actual REPowerEU plan. Nowadays, total production of biomethane and biogas in the EU-27 is 3 and 15 billion m^3 respectively with maximum potential by 2050 at 95 billion m^3 [14]. According to the International Renewable Energy Agency (IRENA) report, current potential in Russia Federation for biogas production for all sources, including forestry, agricultural residues and organic waste, is 73.7 billion m^3 ($2*10^{18}$J), with half of that being in the South federal and Volga federal districts. In 2017, the biogas generation from sewage sludge in Russian Federation was 15 PJ ($15*10^{15}$J), which is obviously insufficient [15].

In Russian Federation there are only few biogas projects at WWTP. In 2009, Russia's first mini-thermal power plant, feed-in by biogas from sewage sludge, was put into operation at the Kuryanovsk WWTP of Mosvodokanal. Nowadays the total volume of digesters at Kuryanovsk and Lyubertsy

WWTPs is 280 ths m^3 [16]. In 2018, the biogas plant with 10 ths m^3 total digesters volume was put into operation in Yekaterinburg [17].

Several projects with landfill gas generation from municipal solid waste (MSW) were implemented during last decade. The Moscow district is one of the leaders in landfill gas generation and utilization. The pioneer renewable energy investment project was "Torbeevo" landfill, located in Lyubertsy area. In 2018-2020 the construction of 8 regional projects with combined heat and power (CHP) units started. The total energy output will be more than 100 million kWh per year [18].

The following factors hindering the implementation of biogas projects can be determined:

- the need to address more pressing challenges, e.g., failure to meet the standard quality of WWT or high deterioration of WWTPs' buildings and equipment;
- low energy prices;
- climatic features;
- unavailability of AD equipment and personnel;
- barriers for establishing "green" tariffs for energy, generated from biogas plant;
- lack of financial tools to support AD initiatives.

At the moment, practically the only mechanism for the implementation of biogas projects is an investment program of the operator of WWTP, financed by tariffs set up for WWT services for residential, commercial and industrial buildings. Tariffs are an important indicator of the socio-economic well-being of the population of the regions separately and of Russian Federation as a whole: they are closely monitored at different governmental levels. Every year the government sets a limit on the increase for payments made by citizens for communal services, varying by region. The average annual growth index is 4%.

To understand the prospects for the implementation of biogas projects in Russian Federation via the investment program and to assess the potential tariff growth, it is necessary to conduct an investigation. The analysis of domestic and foreign manuscripts on similar topics failed.

This article considers the implementation of biogas projects at WWTPs in Russian Federation applying "green" financial tools in terms of tariff dynamics.

2. MATERIALS AND METHODS

2.1 Anaerobic digestion and combined heat and power technology

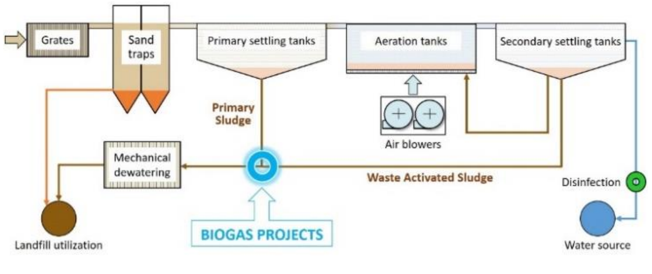

Figure 1. Typical WWTP treatment technique scheme

Wastewaters passes through the complex technological process (see Figure 1) to get rid of all harmful chemical, organic, mechanical, biological and other impurities.

The requirements of regulatory documents for the composition and content of pollutants and pathogens in discharged wastewater, as well as the qualitative and quantitative composition of wastewater inflow, determine the use of various treatment techniques. Generally, the two-stage treatment, including mechanical and biological techniques, is widely used at WWTP, operating in the large cities of Russian Federation.

Mechanical treatment facilities are the preliminary stage of treatment: they are designed to retain undissolved impurities. Grates are intended for detention of large pollution of an organic and mineral origin. Sand traps are used to isolate finely dispersed impurities of the mineral composition, mainly sand. Primary settling tanks retain settling and floating pollution, mainly of organic origin. During mechanical treatment of urban wastewater, up to 60% of suspended solids are retained, while biological oxygen demand (BOD) is reduced by 30%.

Biological treatment facilities provide the main wastewater treatment stage. With the help of special microorganisms that form activated sludge, wastewater undergoes deep cleaning. Organic particles of nitrogen and phosphorus are eliminated, and the purified liquid is mineralized. In this case, suspended organic matter settles to the bottom, after which sediment and floating contaminants are removed from the tank.

Sewage sludge, originated through the process of wastewater treatment, is averaged, thickened and transported to mechanical dewatering workshop. Finally, sewage sludge is utilized at landfills.

Before entering the water bodies, discharged wastewater goes through disinfection process. The most common methods include the use of gaseous chlorine, UV disinfection or ozonation [19-23]. The point for the potential biogas project applications is presented at Figure 1.

Anaerobic digestion is the most widely applied technique for the treatment of sewage sludge, produced at WWTPs. Anaerobic digestion is the process of microbiological decomposition of organic matter in the absence of oxygen with the release of biogas –a mixture of methane (CH_4) and carbon dioxide (CO_2) [24-27]. Generally, several methods of biogas energy utilization can be applied, including the combustion in boiler room, combined heat and power (CHP) generation via CHP-units and direct use as a fuel through biogas enrichment to biomethane. Finally, sewage sludge contains phosphorus, nitrogen and potassium and can be used directly or via composting as organic fertilizer [28, 29].

Anaerobic digestion process must proceed strictly in anaerobic environment together with controlled activity of microorganisms. The efficiency of the anaerobic digestion process is assessed by the degree of decomposition of organic matter, the amount and composition of the resulting biogas. There are two main temperature zones of vital activity of anaerobic microorganisms: mesophilic digestion with temperature ranges from 20°C to 40°C, and thermophilic one with temperature range from 50°C to 70°C. Thermophilic digestion differs from mesophilic one by greater intensity and ends about 2 times faster, due to which the required volume of utilities is halved and the sanitary and hygienic indicators of precipitation are improved, but it requires almost twice as much heat consumption. Anaerobic digestion is carried out in special digesters – methanetanks, where required temperature and environment are maintained (see Figure 2).

To increase the degradation rate and, therefore, biogas yield, the digestion process can be improved by the application various pre-treatment techniques, which includes chemical (e.g., oxidizing, acid, alkali), biological (e.g., microbes, enzymes), physical (e.g., mechanical, thermal, ultrasonic) methods and co-digestion (digestion of a mixture, e.g., sewage sludge + food waste) [30].

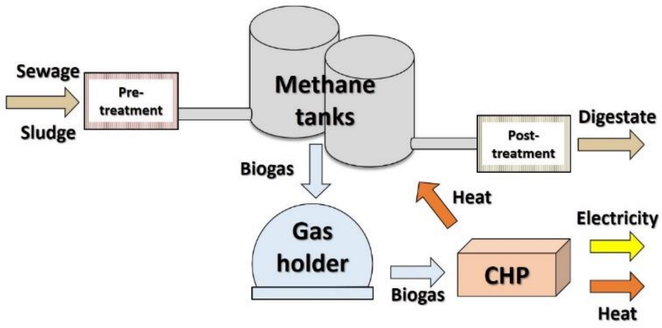

Figure 2. Typical technological process of anaerobic digestion (prepared by authors using data from source [29])

Digested sludge is transported for mechanical dewatering for subsequent disposal at landfills. However, in circular economy paradigm, sewage sludge can be used for agricultural needs after post-treatment activities. For example, mixing sewage sludge with wood waste by composting allows you to get organic fertilizer [31-34].

2.2 Case study area

The current investigation of the prospects for the implementation of biogas projects using "green" financial instruments in terms of tariff dynamics was carried out at the wastewater treatment plant (WWTP) of the city of Yekaterinburg. Yekaterinburg is one of the largest metropolitan areas in the Russian Federation with a population of 1,544,376 citizens. It is located on the eastern slope of the Ural Mountains right on the border of Europe and Asia. The features of the relief of the city determined two main sewage basins - northern and southern ones, where 2 WWTP operate. The authors examined in detail the features of the operation of the Northern WWTP and used its main performance data in the study [35].

The Northern WWTP has undergone a global modernization over the last decade and is currently one of the most modern facilities in Russian Federation with a maximum performance of 100,000 m^3/day. Drum-type grates and aerated sand traps are applied for wastewater mechanical treatment stage, while nitri- and denitrifier aerotanks are used for biological one. Wastewater is treated with UV exposure before being discharged. The sewage sludge treatment facilities include 2 digesters (see Figure 3), each with a capacity of 5,000 m^3, and a mechanical sludge dewatering workshop with chamber filter presses. The digesters operate in a mesophilic mode, and the biogas generated in the volume of almost 3,000 Nm^3/d is used in the boiler for own heating needs [7, 36].

The WWTP under consideration is operated by a municipal enterprise that satisfy the sanitary needs of the population of the northern part of Yekaterinburg at regulated tariffs set by local authorities.

The following scenarios are under consideration within the current investigation:

Scenario 1: the generated electrical energy is sold to the grid via green tariff.

Scenario 2: the generated electrical energy is used for self-consumption (thus decreasing the energy consumption from the grid).

Figure 3. Methane tanks at Northern WWTP

These scenarios are considered under the following conditions:

- Basic conditions suggest the use of credit on common market terms.
- Advanced conditions suggest the use of:

·special "green" credits for environmental and renewable energy projects.

·budget support through subsidized interest rate of the credit.

The codes for the scenarios, mentioned above, are presented in Table 1.

Table 1. Scenario codes for the case study

	Basic Conditions	"Green" Credit	Subsidized Interest Rate
Scenario 1	V1 basic	V1 green	V1 subsid
Scenario 2	V2 basic	V2 green	V2 subsid

2.3 Assessment of tariff dynamics for implementation of biogas projects

The methodological approach consists of the followings steps, including: i) calculation of the capital & operational expenditures for the case study; ii) evaluation of the project benefits for the case study; iii) finding ROI & Payback period indicators; and iv) calculation of the investment component in tariff for implementation of biogas project.

2.3.1 Calculation of the capital and operational expenditures

Total capital expenditures (CAPEX) include the capital costs of all fixed assets (biogas plant and CHP-unit) and non-fixed assets (design and commissioning costs). Operational expenditures (OPEX) include employee salaries, cost of maintenance, supplies, rent, utilities, insurance, depreciation and taxes [37].

2.3.2 Evaluation of the project benefits

Speaking about project benefits of biogas projects at WWTP, the authors consider the potential income and savings, which are achieved through the project implementation. These entities are examined under basic dimensions – economic, environmental & social, and are expressed in monetary terms. In addition, the budgetary, market and production dimensions can be under consideration.

The basic benefits for biogas projects implementation are presented at Figure 4.

Social dimension grants the positive company's image (or prestige), however these benefits are quite difficult for assessment. In this research, the authors focused on the benefits that give the greatest weight for project performance, and are easy for evaluation: environmental and social factors does not taken into account under current methodology.

Figure 4. Basic advantages for the implementation of biogas projects

The project benefits are calculated, using the following equation:

$$Project\ benefits = Savings + Income \quad (1)$$

where, Savings (€) include the savings on self-energy consumption of WWTP, savings on environmental payments; Income (€) include the income from resource extraction, income from the use of digested (post-treated) sewage sludge as fertilizer and income from energy supply to the grid.

2.3.3 Finding ROI and Payback period indicators

Biogas project implementation grants the initiator a multiple effect: the detailed benefits were presented at Figure 1. However, when considering financial instruments for project implementation, the economics of the project is a crucial issue. Speaking about the use of various financial tools, Return on Investment (ROI) and Payback period (PP) indicators were applied to assess the efficiency of the projects [38].

ROI is calculated using the following equation:

$$ROI(\%) = \frac{Annual\ net\ profit}{CAPEX} * 100\% \quad (2)$$

Annual net profit is calculated, using the following equation:

$$Annual\ net\ profit = Project\ benefits - OPEX \quad (3)$$

PP is calculated using the following equation:

$$PP(years) = \frac{1}{ROI} \quad (4)$$

The *ROI* and *PP* indicators are used within the current investigation to give the economic performance overview: some scenarios can have zero and even negative *ROI* due to low electricity prices, and (or) high capital costs.

2.3.4 Calculation of the investment component in tariff

The vast majority of WWTPs in Russian Federation are managed by municipal or state enterprises. The wastewater treatment services are under regulation of local authorities through tariff setting. The activities of companies responsible for wastewater treatment are divided into operational and investment; so, tariffs may include a production and investment component, respectively. In other words, the tariff is calculated using the following equation:

$$Tariff\ for\ WWTP\ services = T_O + T_I \quad (5)$$

where, T_O (€/m^3) is operational component of the tariff; T_I (€/m^3) is investment component of the tariff.

The implementation of biogas projects is predominantly carried out through investment program where tariffs are the main source for financing. The number of other implementation methods, including energy service contracts and public private partnership, is negligible.

The first step for biogas project implementation via investment program is the adjustment of water supply and sanitation scheme – a strategic planning document for municipalities. After the investment program is approved, tariffs are calculated and established.

Tariff is calculated using the following equation:

$$T_I(€/m^3) = \frac{RGR}{Q} * 100\% \quad (6)$$

where, *RGR* (€) is Required Gross Revenue; *Q* (m^3) is total volumetric inflow of wastewaters at WWTP.

The RGR is calculated as follows:

$$RGR = CAPEX - Annual\ net\ profit \quad (7)$$

3. RESULTS AND DISCUSSIONS

In 2018 [39] biogas project was put into operation at the Northern WWTP as a part of the sewage sludge treatment and utilization workshop. The project was implemented according to the investment program adopted by local authorities. According to the investment program reports [40], the actual CAPEX for biogas project is amounted to €6.23 million. Hereinafter, this value was obtained by transition the capital cost in 2018 prices into the price level, actual for 2022 [41], using the Rub/€ exchange rate from august 2022.

When the biogas facility was put into operation, biogas was utilized in a heating boiler for heat energy generation. However, this disposal method has limited use only during the heating season; the rest of the time the biogas was burned in a gas-candle. The CHP-unit as an alternative method of biogas utilization was designed to improve the efficiency of biogas use. Currently, due to lack of funding, the project has not yet been implemented, but authors will consider project data. The project included the following set of works: supply, installation and connection of a CHP-unit based on the Jenbacher JGS 312 GS-B.L generating complex with maximum electric performance of 635 kW. The project cost was €1.00 million.

Thus, the total cost of implementing a biogas project (CAPEX) for WWTP with a maximum inflow performance of 100,000 m^3/day was €7.23 million.

Actual operational expenditures (OPEX) for biogas infrastructure and CHP-unit at Northern WWTP are €0.20 million and €0.08 million respectively. These costs include the personnel wages, the cost of maintenance, current repairs and spares. The total OPEX is €0.28 million.

The project benefits under considered scenarios were calculated, using the Eq. (1). The results are presented in Table 2.

Despite the fact that the scenario v1 looks quite efficient in terms of project benefits, it is much more difficult for implementation. Nowadays in Russia Federation there are a number of regulatory documents for establishing the special "green" tariffs for electricity produced at qualified generating facilities operating as renewable energy sources, has been approved. However, by the beginning of 2021, in Russia there was the only one qualified generation unit, that use biomass [42]. The qualification of generating unit for renewable energy facilities according to the official requirements is too complex and possible only if self-generation exceeds the self-consumption.

The energy, generated from biogas project at Northern WWTP, covers more than 70% of self-energy consumption. Thus, the implementation of scenario v2 will not only reduce the self-energy consumption, but also improve the reliability of power supply by creating an alternative energy source.

Table 2. Project benefits under considered scenarios

Scenario	Energy Generated, ths. kWh*y	Tariff, €/ths. kWh	Project Benefits, ths. €
v1 (Income)	4,642.8	171.3333	795.47
v2 (Savings)	4,642.8	61.3333	284.76
ths. – thousand			

Tariff for selling the energy, obtained from renewable sources, to the grid (The equivalent tariff is established for Luchki biogas power station, located in Belgorod region, Russian Federation), source: [43]
Tariff for energy, consumed from the grid, established for Sverdlovsk region, Russian Federation, source: [44]

Concerning ecological payments in Russian Federation, companies, responsible for water supply and sewerage, pay fee for negative environmental impact for sewage sludge disposal: the rates depend on the hazard class of the waste [45]. In common, sewage sludge belongs to waste hazard class IV, less often – to V waste hazard class. The process of AD does not directly affect the transition from hazard class IV to V – the application of post-treatment techniques is required, e.g. composting of digested sludge. However, in this case, this technology is not used. It should be mentioned, that the effect of preventing GHG from being released into the atmosphere by application of AD, doesn't influence a particular WWTP in terms of environmental payments.

In the current case study, techniques for valuable substances (e.g., phosphorus) extraction are not applied. These techniques, in general, have limited use in Russian Federation due to the availability and low cost of traditional extraction methods.

The use of sewage sludge in Russia without any post-treatment technique may be relevant for non-agricultural applications such as quarry and landfill remediation. At present, the market for purchasing the sewage sludge for agriculture has not been established yet, so no benefits are considered.

The annual net profit, ROI and PP for basic conditions were calculated, using Eqs. (2)-(4). The outputs are presented in Table 3.

Table 3. Project performance for considered scenarios

Scenario	Annual net Profit, Million €	CAPEX, Million €	ROI, %	PP, Years
v1	0.51	7.23	7.08%	14.12
v2	0.00		0.02%	>5000

The obtained results for v1 correlate with similar indicators from other investigations [46, 47]. However, the economic performance of v2 is good for nothing. The biogas project without the approval of special "green" tariffs will be unprofitable: it can only be implemented for environmental, energy and prestigious goals. As we examined above, scenario v1 currently has a significant number of barriers to implementation.

To calculate the investment tariff component, the authors used Eqs. (6)-(7). Standard five-year period for the implementation of investment program was considered, with the credit, taken on market conditions: according to the data from Central bank of Russian Federation [48], the average interest rates for industrial enterprises in August 2022 is approximated for 13%. The terms of the loan provide for annuity payments and a 12-month delay of the principal debt payment (for design, construction work and commissioning).

Table 4. Inputs and outputs for calculation of investment tariff component

Years	1	2	3	4	5	Total
Credit payt., million €	0.95	2.34	2.34	2.34	2.34	10.31
RGR v1, million €	0.95	1.83	1.83	1.83	1.83	8.26
RGR v2, million €	0.95	2.34	2.34	2.34	2.34	10.31
Q, million m^3	20.72	20.72	20.72	20.72	20.72	-
T_I (v1), €/ m^3	0.05	0.09	0.09	0.09	0.09	-
T_I (v2), €/ m^3	0.05	0.11	0.11	0.11	0.11	-

The inputs and outputs for calculation of investment tariff components are presented in Table 4.

The RGR for scenario v2 is equal to the credit payments: this means that the effect of savings due to the use of energy from CHP-unit generation for self-consumption is completely leveled by OPEX. In addition, this fact has a strong correlation with the zero ROI for considered scenario.

To evaluate the investment tariff component for advanced scenarios conditions, it is necessary to duplicate the procedure described in Table 5 with alternative input data. According to representatives of the banking community [49], the rate on "green" loans for projects of sustainable development in the Russian Federation is lower than the usual market rates by 0.4-0.5 percentage points, while at international markets this value is 0.2 percentage points less than market one. However, these projects must meet certain criteria, defined in the Russian government decree from 21.09.2021, number 1587 (biogas projects with energy generation are included under these criteria). One of the leaders in "green" credit market is Sber bank: the total amount of transactions with "green" credits in Russian Federation exceeds €3 billion [50].

State programs for subsidizing interest rates on loans aimed at the implementation of environmental projects are already being used in the Russian Federation. However, for the projects in the field of renewable energy, they have not yet become widespread due to the availability of own cheap traditional generation. In Russia, due to budged limitations, only few state programs with budget financing and subsidies for renewable energy projects, are adopted. Local authorities are predominantly implementing municipal and state programs aimed at developing communal services and increasing its energy efficiency for buildings and machineries. These programs are aimed at ensuring the standard quality of wastewater treatment or preventing serious accidents at WWTPs due to high wear and tear. In common, in developing countries, renewable energy targets are abandoned or progress in achieving them is slow [51].

Speaking about best practices, the European Commission has established special financing mechanism to support the development of renewables. It has been in force since September 2020. This mechanism links countries that voluntarily pay (contributing countries) with countries that agree to have new projects built on their soil (hosting countries). EU supports the financial contributors with grants, which cover either the installation of a renewable-production facility (investment support) or the actual production of renewable energy (operational support) [52, 53]. However, high tariffs for energy supply as well as the need to ensure energy security make biogas projects in EU attractive to investors.

Substantially, financing of biogas projects in Russian Federation from the budget is possible in the form of interest rate compensation when using bank loans. According to the mentioned above the state decree of Russian Federation number 1587, the initiators of biogas projects may be subsidized to reimburse up to 60% of green loan interest payments [54]. Until 2020, there was a state program for the development of the water management complex, which provided the compensation up to 6 percentage points from the key rate, set up by the Central Bank of the Russian Federation [55].

Based on the information provided, for the purposes of this study, for advances conditions (scenarios “v1 subsid” & “v2 subsid”), the market interest rate was reduced by 6%. The results for advanced conditions for scenarios under consideration are presented in Table 5.

Finally, to evaluate the tariff increase in dynamics for various scenarios, the tariffs for WWT services were calculated using the Eq. (5). The outputs are described in Table 6. The basic tariff, established for 2022 without investment component, is 0.37 €/ m^3 (presented in column with year #0).

Table 5. Results for advanced conditions of investment tariff component calculation

Years	1	2	3	4	5
T_I (v1 green), €/ m^3	0.04	0.09	0.09	0.09	0.09
T_I (v2 green), €/ m^3	0.04	0.11	0.11	0.11	0.11
T_I (v1 subsid), €/ m^3	0.02	0.08	0.08	0.08	0.08
T_I (v2 subsid), €/ m^3	0.02	0.10	0.10	0.10	0.10

Table 6. Total tariff (with investment component) under various scenarios

Years	0	1	2	3	4	5
T (v1 basic), €/ m^3	0.37	0.42	0.46	0.46	0.46	0.46
T (v2 basic), €/ m^3	0.37	0.42	0.48	0.48	0.48	0.48
T (v1 green), €/ m^3	0.37	0.41	0.46	0.46	0.46	0.46
T (v2 green), €/ m^3	0.37	0.41	0.48	0.48	0.48	0.48
T (v1 subsid), €/ m^3	0.37	0.39	0.45	0.45	0.45	0.45
T_I (v2 subsid), €/ m^3	0.37	0.39	0.47	0.47	0.47	0.47

The obtained in Table 6 results allow to create a tariff growth diagram for scenarios under consideration. The adoption of the investment program with the biogas factory with CHP-unit construction will lead to the next tariff growth in 5-year dynamics (see Figure 5).

The annual indexation of citizens' payments for utilities is limited by the law within the framework of the housing codex of the Russian Federation [56]. The index depends on the district of Russian Federation: for the Sverdlovsk region in 2022 it is 2.9% [57]. The results obtained through the study show that the implementation of biogas project at Northern WWTP will lead towards the necessity of significant tariff growth: these values exceed the established limit index for the citizens' payments for communal services. The use of “green” loans has an insignificant impact on the tariff growth, since the rate has no differ from the market one. Despite the legislative initiatives on “green” loans, these transactions are carried out by commercial banks that are not ready to give a significant discount and lose their own profits. So far, such a financial instrument is more of a prestige product for banks. Even under the most favorable conditions, when scenario “v1 subsid” is implemented, using of state subsidies for the interest rate on the loan, the total tariff growth will amount to 120.45%. In contrast, the worst score is for scenario “v2 basic”, when the total tariff growth will amount to 130.50%.

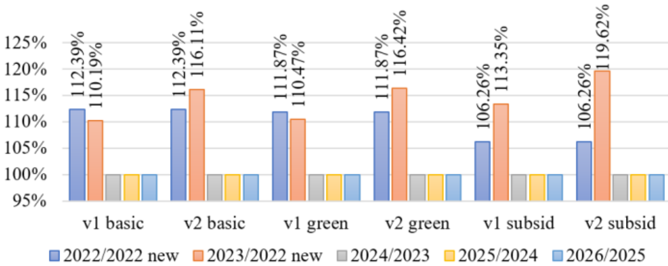

Figure 5. Tariff increase rate for various scenarios (year/previous year)

The tariff growth above the established index is the prerogative of local authorities. However, this decision may affect the political and economic stability of the region. Therefore, the regional leaders are not ready to use this option. Furthermore, there are a number of problems associated with high physical and moral depreciation of WWT facilities, problems with the quality of wastewater treatment, which have a much higher priority in the implementation.

The low energy prices compared to developed countries [58, 59], the predominance of traditional generation, the presence of higher priority goals for investment at WWTPs, give the implementation of biogas projects in Russian Federation limited prospects.

4. CONCLUSIONS

The present study considers the comparative analysis of implementation of biogas projects at WWTPs in the Russian Federation through the procedure for approving the investment program and the investment component in the tariffs for WWT services, which is paid by the consumer.

Two main scenarios applied to biogas plant were determined, including the sale of generated energy to the grid via green tariff and the use of generated energy for self-consumption of the utilities. The authors came to the conclusion that the former scenario is unrealistic due to the bureaucratic obstacles in the approval of the green tariff, while the latter one does not provide tangible financial benefits for the WWTP (the savings are offset by the operating costs of the biogas facility). However, the biogas projects still have benefits for implementation: safe stabilization of sewage sludge, reduction of GHG emissions and the provision of an independent backup source of electrical energy. Moreover, these projects allow the consistent transition towards circular economy principles.

Considering the results of the study, it is worth saying that the implementation of biogas projects through a five-year investment program will lead to an annual tariff increase of 6-20% in the first two years, providing that other investment projects could not be implemented. Additional financial tools to support the development of biogas projects, including "green" credits, or compensation of interest rate by government budget, could not give tangible results, allowing only a slight restraint on the growth of tariffs for WWT services.

Nevertheless, even such a small increase in tariffs is quite sensitive for the population, and regional administrations are unlikely to decide to increase the tariff for the implementation of biogas projects. Moreover, there are more pressing issues on the current agenda The present quality of WWT in most cities and towns of Russian Federation needs improvement. According to Russia's Ministry of Natural Resources, more than 70% of the approximately 9,000 WWTPs in operation today (within centralized sewerage systems) were built 30 to 50 years ago and 80% of them should be upgraded. Furthermore, some of it cannot be upgraded, but rather must be completely rebuilt. According to the Ministry of Natural Resources, the national modernization of WWTPs will require about $20 billion, while the Ministry of Construction consider the required annual investment rate for each of the next five years for "bringing the water supply and sanitation systems into conformity with standards" at $1.5 billion [60]. In this situation, the implementation of biogas projects at WWTP is the second step in the development of the utilities. However, for consequent transition towards circular economy in Russian Federation, the implementation of biogas projects is of a great importance.

ACKNOWLEDGMENT

The research was supported by the Russian Science Foundation, Grant No.: 22-28-01740, https://rscf.ru/en/project/22-28-01740/.

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