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Economic realities and development perspectives of small-scale power generation in the Republic of Belarus

The article analyses the efficiency and economic feasibility of autonomous power supply by the example of several cogeneration plants (mini-CHPs) operating in the industrial and municipal enterprises of the Republic of Belarus. The article also focuses on some important features of the energy sector, in particular the problem of cross-subsidies and tariffs in the energy sector. The results and main economic indicators of the exploitation of a number of cogeneration plants, constructed in the Republic over the last eight years, are presented and analysed in detail. The article is based on the detailed study of the economy of each object in particular and on the comparison of the results by the parameters of economic efficiency of all of the objects under study in general. Certain disadvantages and advantages of this direction in the energy sector of the country are defined. A number of problems and tasks, revealed on the basis of a long-standing generalised experience in designing, construction and exploitation of cogeneration plants in the Republic, and requiring thorough investigation and resolution are identified.

Cogeneration plants, tariffs, gas turbine plants, energy, maintenance and servicing, electricity supply, electricity.

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During Soviet times, economic regions (districts), cities, large-scale industrial objects were mainly supplied with heat and energy centrally from large sources of the country's energy system. A large number (nationwide) of objects of the local energy supply (as a rule industrial and utility boilers, etc.), was built in the areas where connection to the 'central plant' was impossible due to technical, technological reasons and unjustified high cost. The vast majority of these plants are socialist construction objects, survived to the present day, which are physically, technologically, and morally obsolete and therefore, absolutely unprofitable. They either require modernization or decommissioning, or complete replacement by modern, effective sources of energy. In the current conditions of the serious transformation of the state economy and transition to market conditions of management, it became possible for enterprises to independently choose the options of energy supply.

It should be noted that the electric power industry of Belarus is the only one on the post-Soviet space that has preserved a vertically integrated model, where the state exercises centralized control over production and economic activities of power enterprises. The total installed capacity of power system of the Republic of Belarus on January 1, 2010 was 8261.68 MW and independent block-stations that are not in the national union Belenergo produced about 409.0 MW or 5% of the total capacity, which indicates a complete state control over the Belarusian energy market [1].

At the 17th Belarusian Energy and Ecology Congress, held in Minsk in October of 2012, Deputy Energy Minister of the Republic of Belarus Mikhail Mikhadiuk announced in his report ‘The state and the prospects of the Belarusian energy complex’ that the capacity of power plants of the Republic is more than 8300 MW, 7895 MW of which are produced by Belenergo power plants. So, the situation on the energy market of the country has not changed for the past three years: 95% of the facilities are still owned by the state, while individual enterprises have in their ownership only 5% of all existing in the Republic capacities.

Electricity and heat cogeneration plants have been used in recent years as autonomous power supply at industrial and municipal enterprises. Such equipment for production of supplementary electricity and heat energy at the industrial enterprises is commonly called cogeneration plants or installations of small-scale power generation [2].

When considering the small-scale power generation, it should be noted that there is a system of state regulation of electricity tariffs, which creates certain price opportunities for the construction of new generating facilities. At present, electrical energy pricing in Belarus has not changed since the planned economy of the Soviet period.

Since January 1, 2013, the Government of Belarus was going to reduce electricity tariffs for industrial consumers, as stated by Vice Prime Minister V. Semashko in May of 2012 at the Plenary Session of the Belarusian Industrial Forum. Energy tariffs for industrialists are planned to be reduced by the funds, released as a result of a gradual shift away from cross-subsidization in the power industry. Cross-subsidisation in the power sector is a harmful phenomenon, adversely affecting the economy of the whole country. It not only distorts the price targets for the population, leading to inefficient energy consumption, but is also hidden tax on business, as a result of which its competitiveness reduces.

Energy tariffs shall consider the economic interests of both producers and consumers of energy, as well as create the incentives to save energy at all stages of its production and consumption, which will ultimately enhance the efficiency of the national economy. The issue concerning the necessity to eliminate cross-subsidization between the commercial and the residential sector has been long discussed in the country, but significant results have not been achieved yet.

The State programme for the development of the Belarusian energy system until 2016, approved by the Decree of the Council of Ministers of the Republic of Belarus No.194 of February 29, 2012 entered into force in Belarus on March 20, 2012. The Programme stipulates that the level of reimbursement of the cost of electricity production and supply by the population is expected to reach 47.9% in 2013, 72.7% in 2014, and 100% in 2015.

While the government prepares the population to the full payment of energy tariffs, heat tariffs are expected to increase gradually, and 100% recovery is not an issue in this case. It is planned that the level of heat supply costs reimbursed by the population will amount to 19% in 2013, 23.6% in 2014, and 30% in 2015.

On the whole, the level of cost recovery electricity and heat tariffs should reach 32.4% in 2013, 45.9% in 2014, and 61.7% in 2015. In 2011, 38.5% of electricity costs and 21.4% of heat costs were recovered by the population of Belarus. Previously it was expected, that the Law "On electric energy" would be adopted in Belarus in 2012, the Law "On state regulation of electric and thermal energy tariffs" in 2013, the Law "On Heat Supply" in 2012.

Some Belarusian sources state that energy tariffs in the Republic are distorted in comparison with neighbouring countries: the average electricity tariff for industrial consumers amounted to 3.73 cents per 1 kWh, while for the population it made up 25.9 cents per 1 kWh. By comparison: in the EU countries, the average electricity tariff for industrial consumers in the first half of 2011 was 12.8 cents per kWh, for the population – 2.56 cents per kWh. For example, in Poland the tariffs made up 11.8 and 21.3 cents per kWh respectively, in Lithuania – 14.6 and 17.6, in Latvia – 12.9 and 16.9, in Ukraine – 9.2 and 3.1, in Russia – 8.3 and 7.2 [3].

However, in order to make comparisons by certain EU countries, let us depart from Belarusian sources, statistics, statements of officials and turn to the following data. Thus, according to "Europe's Energy Portal" (www.energy.eu), the tariffs for industrial enterprises and for the population as of May 2012, for example, in Austria amounted to 10.47 eurocents per 1 kWh for the industry, and 17.98 eurocents per 1 kWh for the population; in Bulgaria – 5.22 and 8.23 respectively; in Germany – 10.24 and 24.06 respectively; in Denmark – 9.13 and 25.62; in the UK – 8.82 and 12.65; in Poland – 8.37 and 14.19; in Lithuania – 10.17 and 12.01; in Estonia – 6.81 and 9.48; in Finland – 6.78, and 13.69; in France – 7.42 and 12.79; in Belgium – 8.71 and 19.40. So, as follows from the data of "Europe's Energy Portal", energy tariffs for the population 1.5–2.5 times higher than for the industry in the EU countries.

At this stage, such important social factor should be taken into account, as the need for a substantial increase in population real incomes, which could provide full energy cost recovery of residential customers in the process of energy pricing in Belarus. Significant costs of power connection, cross-subsidization of population at the expense of industrial consumers, electricity transmission tariffs, undoubtedly, form incentives of industrial consumers to establish their own generation.

At present, the economic essence of cogeneration equipment implementation is reduced to alleged energy cost-cutting, which is defined as the difference between the set tariff per 1 kWh and the prime cost of electricity produced by cogeneration plant, while fuel economy is defined respectively as the difference between brake specific fuel consumption per 1 kWh of energy, produced by Lukomlskaya SDPS and Berezovskaya SDPS, considering the fuel equivalent consumption of 320 g/kWh [4]. Due to technical re-equipment of the Lukomlskaya SDPS in 2007, the brake specific fuel consumption for electricity production decreased to 312.8 g c.t. per 1 kWh (in 2006 – 316.3 g c.t. per 1 kWh). At the Lukomlskaya SDPS this indicator is significantly lower than at the thermal power stations of OAO MOSENERGO, where in 2006 the brake specific fuel consumption in the condensation mode amounted to 377.9 g c.t./(kWh), for electricity – 252.6 g c.t./(kWh); in the Republic of Belarus this index amounted to 274.6 g c.t./(kWh), i.e. higher by 22 g c.t./(kWh).

As a result of OAO MOSENERGO restructuring, specific consumption for electricity is reduced through the increase in the share of cogeneration electricity and the decrease in the share of condensation generation [5].

It is important to note that the justification of investment of the projects do not include the comparisons of brake specific fuel consumption per 1 kWh of energy and 1 Gcal of heat with the existing CHPs of the Republic of Belarus that are much closer to cogeneration equipment by their technical specifications as the base of comparison. Cogeneration is defined as a combined production of electricity and thermal energy, CHPs of the power system of the Republic of Belarus perform a similar function.

According to Belenergo, brake specific fuel consumption for electricity and heat production on the individual CHP of the country is lower, in comparison with gas reciprocating and gas turbine units, where the estimated fuel equivalent consumption amounts to 160 and 170 g/kWh.

The calculations of industrial enterprises and design organizations in the justification of investment show that the cost of own production is 2–3 times lower in comparison with the electricity tariff, and indicate 2–2.5 times reduction in the consumption of fuel and energy resources, in comparison with brake specific fuel consumption when producing 1 kWh of electricity at Lukomlskaya SDPS and Berezovskaya SDPS. According to the authors, it is impossible to compare objects, incompatible in functions and tasks, as well as the various constituent levels by total costs for generation of 1 kWh of electricity. The tasks and functions of the Lukomlskaya SDPS are much more large-scale for resolving the issue of providing the country with energy and are not of local character. In addition, the power supplying companies (SDPS, CHP) contain the reserve of capacities, in case of emergency failure and periodic maintenance, current and capital repair of mini-CHPs.

Business entities, owing cogeneration plants and denying the reservation of capacities in the power system, are forced to put into operation additional amount of gas reciprocating and gas turbine units, in order to provide continuous technological process of energy production. In this context, the volume of capital investments in mini-CHPs is increased by 35–40%, operating costs increase correspondently. Moreover, the number of backup units is not taken into account in the justification of investments, and the efficiency calculation is adjusted to the maximum output of each unit by generated energy in total. Obviously, it distorts the real costs in the justification of investments in the construction of mini-CHPs, and accordingly the indicators of economic efficiency in the course of maintenance. Therefore, it is very important to consider maintenance costs in operating costs, as their share in total costs is about 30%.

Maintenance costs should be determined on the basis of repair cycle regulations. Planned repairs, usually vary in the volume of repair works, therefore, they are divided into certain groups. The repair works of certain types and volumes in practice for specific gas reciprocating and gas turbine units of different manufacturers are performed on the basis of actual technical condition of the equipment, determined by periodic technical inspections with the use of diagnostic tools.

The structure of repair cycle is a sequence of certain types of repair between the moment, when the product had been put into operation and the first major overhaul. Repair cycle is calculated in actually worked hours, therefore, it is necessary to keep record of the operating time of the details for objective repair works planning in the operating conditions of gas reciprocating and gas-turbine units. Constant efficiency of gas reciprocating and gas turbine engines up to their depreciation and write-offs must be maintained through current and capital repairs. Interrepair maintenance is carried out in the intervals between routine and periodic maintenance, the purpose of which is to reduce equipment failure rate in this time period to the greatest extent possible and quickly eliminate any failures.

It should be noted that downtime during periodic maintenance and repairs is 720–760 hours per year. The current repair is carried out at the place of installation of cogeneration equipment, and capital repairs are performed at the base of the plant-manufacturer. On average, the labour-intensiveness of one operating repair of 8–10 calendar days makes up 200–220 people per hour, a repair is made within 8–10 months. For example, after four years of operation of gas turbine unit GTU-15c, owned by the Republican unitary production enterprise Belarusian Cement Plant (Kastsyukovichy), with total run of 26700 hours (average annual operating time amounted to 6675 hours, that is by 17% lower than the design one) had been dismantled and sent to the overhaul to the factory Zorya-Mashproekt (Nikolaev, Ukraine). The cement plant acquired another installation as a backup, due to the long repair period of GTU–15c. However, it is not taken into account, when justifying the investments in the volume of capital investments, therefore the effectiveness of the technical and economic indicators of the construction of cogeneration plants is distorted. The capital investments payback period increases by 50–60%, when the acquired standby unit is included in the investment volume. Therefore, given the high share of expenditures for the maintenance in total operating costs, it is necessary to follow common maintenance and repair standards, set in accordance with the repair cycle regulations, when substantiating the investments for the construction of mini-CHPs. In the absence of normative documents and materials, the average ratios by type of repair for the entire repair cycle period must be developed, based on operational observations and statistical data. The example above confirms that the enterprise that owns a mini-CHP (gas turbine unit), also should have a standby unit of a gas turbine or a reserved capacity in the power system.

According to the “Declaration on the level of tariffs for 2008” the fee for the capacity reserve maintenance increased by 12.3%, as compared to 2007. The inclusion of expenses for reserve capacity increases the total amount of operational costs of the mini-CHP by 30–35%.

It should be noted that for the four years of gas turbine unit operation at the Republican unitary production enterprise BCP (Kastsyukovichy), the costs only for maintenance, current and capital repairs exceed 2.4-fold the initial cost of the purchased equipment. When the cost of the capacity reserve maintenance is included, the costs incurred in this period under the above-stated article reach fourfold value relative to the cost of the gas turbine unit.

Based on observations and calculations, scientists and production workers in their publications express different points of view on the issue of capacity reservation. Some authors believe that the non-inclusion of the cost of reserve capacity maintainance from the prime cost of electricity produced by own local energy sources may lead to nonoptimal decisions for the national economy in terms of economic effect [6]. Others believe that the consumer can minimize the amount of electricity consumption from the power station, or refuse to use it, in case the own capacity is sufficient, and in force majeure circumstances to reserve power from the power system and to reimburse the costs of the reserve maintenance. These costs should consider the part of the cost that is directly relevant to the consumer [7].

According to the authors, it is unreasonable to set individual tariffs on the maintenance capacity reserve for each consumer, because the comparability of capacity reservation costs will not be observed. A single average rate for the Republic is to be set. That will enable the planners to get the initial data for calculations and the equivalent approach to feasibility study.

In 2007, the gas turbine unit (GTU-15c) at the Republican unitary production enterprise BCP (Kastsyukovichy), worked off 7900 hours and approached the preliminary estimate of 8000 hours, the most effective economic indicators have been achieved, and the running time time increased by 83%, as compared to 2004 [2, 8, 9, 11]. Then all values will be presented in convenient units (in US monetary units in prices of the year specified for the calculation). Annual electricity production amounted to 119 million kWh, at the prime cost of 4.13 US cents/kWh, excluding the costs for reserve capacity maintainance. When the cost of reserve capacity is included, the cost of 1 kWh of electricity increases by 1.35 US cents.

Currently the construction of mini-CHP gas reciprocating and gas turbine units is mainly financed by the Republican and local budgets, innovation funds – their equity participation is 65–75%, and own means of the enterprises – 25–35%. Therefore, you first need to determine the economic effect from the implementation of the above activities. In order to do this (by power system), let us compare the power production cost of Mogilevenergo and the local source of energy at the Republican unitary production enterprise BCP. The cost of 1 kWh of electricity of Mogilevenergo amounted to 6.72 US cents, and of the BCP, taking into account the cost of reserve capacity maintainance was equal to of 5.48 US cents in 2007, when the dollar exchange rate was equal to 21.50 Belarusian rubles. The economic effect for the national economy is calculated by the following formula:

$$Eef = (Cps - Cle) \times Vle, \qquad (1)$$

where *Eef* – annual economic effect, US dollars;

Cps – prime cost of 1 kWh of electricity by the power system (Mogilevenergo), US dollars;

Cle – cost of 1 kWh of electricity by local energy source (BCP), US dollars;

Vle – annual electricity volume generated by the local energy source, kWh.

Annual economic effect of the enterprise is defined on the basis of the electricity price (tariff) for 1 kWh by the formula:

$$Eefe = (Sp - Cle) \times Vle, \qquad (2)$$

where *Eefe*– annual economic effect of the enterprise, US dollars;

Sp – sale price of 1 kWh of electricity by the power system (Mogilevenergo), US dollars;

Cle – cost of 1 kWh of electricity by local energy source (BCP), US dollars;

Vle – annual electricity volume generated by the local energy source, kWh

Let us substitute the original data in the formula (1) and obtain the results of the annual national economic effect that will amount to 1.071 million US dollars. BCP spent about 15.4 million US dollars in capital investments on the construction of a cogeneration plant. The simple payback period of the investments makes up 10.4 years, and it increases to 14.3 years, when the prime cost of 1 kWh of electricity generated by BCP certain suppliers is taken into account in the calculations. The service life of a gas reciprocating unit GTU–15c is defined by the manufacturing factory as 100000 hours, respectively, with the annual operating time of 7500–8000 hours a physical life of the unit will make up 12.5–13.5 years. The authors draw as an example a mini-CHP, which is one of the best by operational and economic indicators in the Republic and the initial data in the calculations are assumed with regard to the most effective year out of the four years of operation. It should be noted that even under these most favourable payment conditions, the mini-CHP (GTU-15c) is paid off only within physical life limits in the context of national economy [2, 8, 10].

Let us estimate the economic effect for the company and substitute the value of the tariff for 1 kWh of active electric energy in formula (2). The 2007 tariff level amounted to 7.79 US cents per kWh, and as a result, the economic effect of the company made up 3.884 million US dollars. Physical payback period of the mini-CHP (GTU-15c) at the Republican unitary production enterprise BCP was defined as 5.6 years, assuming that the work is not less than 7900 hours per year.

The analysis of calculations show that, if the annual operating time of GTU–15c is below 5500 hours, the economic benefit for the company will be sharply reduced and the payback period will exceed the physical lifetime of the installation, and this means that the exploitation of the unit in this mode is economically inexpedient.

Consider anorther example on defining the economic effect, when designing and constructinng a mini-CHP with an electric capacity of 21 MW at JSC Polymir. When determining the comparative economic efficiency, the indicators of the Novopolotsk CHP are adopted as a comparison base, as it provides electricity and heat energy to JSC Polymir. The cost of 1 kWh of electricity at the Novopolotsk plant was 5.17 US cents at that time, and thermal energy per 1 Gcal made up 28.9 million US dollars respectively. The prime cost of 1 kWh of electricity cogeneration plant with the annual output of 160 million kWh within 3 US cents without considering spare capacity, while taking into account the sum of 1.48 US cents and will make up 4.48 US cents. Let us substitute the original data in the above formula (1) and get the result of the economic effect in the amount of 1.104 US million dollars. The project cost of the local energy source at JSC Polymir is estimated in the range of 22 US million dollars. Physical payback period of the implementation of this project in terms of national economy will make up 19.9 years. When determining the economic effect, the efficiency of the steam of 40 t.a. generated by the own cogeneration plant, is not given in the calculations, as the share of 40 t.a. in the thermal balance of the energy of the enterprise is 8–9%.

At the same time, brake specific fuel consumption for producing 40 t.a. of steam production is almost the same: CHP – 171 kg/Gcal, and the cogeneration unit – 170 kg/Gcal, and it will not affect the final result of efficiency [2, 10].

In order to reduce energy expenses, OAO Mogilevkhimvolokno within two years planned and built an energy complex with a capacity of 14.7 MW in total consumption of 67 MW of electricity. Power consumption is provided by CHP-2 (Minsk cogeneration plant-2) and the closing energy system of condensing power plant, with the share of 7–10% provided by the power plant-2 and the rest supplied by the condensing generation (CPP). In the structure of annual energy resources consumption, the largest share is constituted by electricity – 40–42%; steam – 31–33%; while fuel for heating high-temperature organic heat transfer agent accounts for the smallest share (6–8%). The state spent about 17.6 million US dollars on the construction of the energy complex, including 5.6 million US dollars out of OAO Mogilevkhimvolokno own funds, which accounted for 31.5% of the total amount. The prime cost of 1 kWh of electricity generated by local energy source will amount to 2.86 US cents, and taking into account the cost of maintaining the reserve power it will increase by 1.43 US cents correspondingly at an annual electricity production of 116 million kWh and the running time of each unit (4 units by 3.7 MW) of 8,000 hours per year and the prime cost of 1 Gcal of heat – 26.81 US dollars. The calculation of costs on the production of 1 kWh of electric energy according to the economic method for 2008 in Minsk cogeneration plant-2 was 5.48 US cents, with the brake specific fuel consumption of 328 g/(kWh) and, accordingly, the costs of thermal energy per 1 Gcal made up 21.37 U.S. dollars. The prime cost of 1 Gcal of heat energy in 2007 at the Republican unitary production enterprise Mogilevenergo amounted to 28.17 US dollars.

Based on these data, the cost of production of 1 Gcal at the Minsk cogeneration plant-2 was estimated to be by 21% lower than in the energy sector of OAO Mogilevkhimvolokno, and according to the system of the Republican unitary production enterprise Mogilevenergo the excess is only 5%. Therefore, in determining the economic effect for the national economy and enterprise by the specified position the calculations are not held, because the impact is insignificant and almost reduced to zero. Let us substitute the original data in the formula (1) and see that the economic economic effect will amount to approximately 2.8 million US dollars.

The simple payback of the cost of 6.3 years is ensured by high level of the prime cost of 1 kWh of electricity at the Republican unitary production enterprise Mogilevenergo, which greatly exceeds the costs of the power system of the Republic of Belarus, in comparison with the Minsk cogeneration plant-2 excess of 22.6%. When calculating the economic effect, if the prime cost of 1 kWh of electricity at the Minsk cogeneration plant-2 is taken as a comparison base, the economic effect of the energy complex is reduced to 1.38 million US dollars and the payback will amount to 12.8 years.

Therefore, it is possible to say that the main type of the energy produced by the Minsk cogeneration plant-2 is thermal energy and a small amount of electric power. As the Minsk cogeneration plant-2 is located two kilometres away from OAO Mogilevkhimvolokno, the calculations show that if capital investments, spent on the construction of a local energy source, were focused on the reconstruction of Minsk cogeneration plant-2, the effectiveness of the pay-off could increase 3–4 times. Only savings on thermal energy would amount to 5.5 million US dollars per 1 Gcal. When providing thermal energy for OAO Mogilevkhimvolokno, even within 50% of the total demand, the annual economic effect for this position will be approximately 2.8 million US dollars [2, 10].

The economic analysis and calculations on other objects, including the complex for submicron production at the unitary enterprise Semiconductor device factory of Minsk Scientific Production Association Integral, have been carried out in the similar way. The energy technological complex should provide the enterprise not only with power, and heating, but with cooling as well (CCHP). Specific capital investment makes up 1512 US dollars per 1 kW of power that is higher by 57% as compared with the equipment installed at the Republican unitary production enterprise BCP in Kastsyukovichy. The recoupment of capital investments in terms of the economic effect will amount to 16.1 years. It should be noted that the share of project works in the total cost of construction makes up 3.7–4.9%, while in relation to the installation and construction works it amounts to 14–20%, and that is higher than in the countries with the developed economies like France, Germany, etc.

In addition, the engineering company during the planning usually reviews the estimated cost of the works in the direction of increasing the original value 2.5–3.5 times. When determining the design documentation cost for the calculation, the design capacity, which remains practically unchanged from the initial design and until the end of the construction, is used as the basis. For example, the initial cost estimate for the architectural and construction projects "The energy technological complex of the polyester yarn plant of OAO Mogilevkhimvolokno" increased 2.44 times for two years. At the same time, during the construction of a similar object with the value of over 10 million US dollars in Germany, the share of the design work made up 2.1–3.6%; while at that, the salaries of the design engineers are 6–7 times higher than the salaries of our design engineers. The high cost of design and construction works in our country depends on many factors: the qualifications, performance and productivity.

For the 2006–2008 period design and construction of the energy technological complex for submicron production at the unitary enterprise Semiconductor device factory of Minsk Scientific Production Association Integral, held about 70 production meetings with design engineers and construction companies.

The main point of all the issues can be reduced to presenting mutual claims (i.e. the customer submits a claim to the design engineer that high-quality construction and project documents have not been given within the time limits set, and the designer, in turn, presents a claim to the null initial data for designing, etc). In addition, about two dozen of various meetings on the specified object have been additionally held at the Ministry of Industry, Ministry of Energy and in the Council of Ministers of the Republic of Belarus in order to facilitate the construction of this energy complex. All of this suggests that there is no qualified general contractor, who would be able to build such objects on a turnkey basis. The construction of turn-key facilities would reduce the construction period and the expenditures on design works, construction and installation works 2–3 times [10].

It is not only domestic design and construction organisations, but also foreign companies that are engaged in the planning and construction of mini-CHPs with natural gas applications in the country.

In order to compare the results in terms of efficiency indicators, the example on modernization of local boiler house in the city of Zhlobin is given in the article. The conversion of the boiler house of the Zhlobin power networks into a modern CHP was somewhat a unique project for Belarus. The delivery of complete equipment is the peculiarity of this project. The Finnish company Wärtsilä, a world renowned manufacturer of gas and diesel powered electrical generators, had won the competitive tendering for its maintenance.

Equipment turnkey projects are not typical for Belarus. A modern power plant is a whole complex of complex units and aggregates. In order to cut costs, the equipment is often purchased in parts, from different manufacturers. However, this approach is not always economically beneficial. Various inconsistencies and discrepancies appear during the equipment installation, to remove which, the engineering solutions, requiring additional investment, are to be found.

When implementing the project in Zhlobin, all major equipment was supplied by Finnish company, which was responsible for warranty service of units and aggregates, and their design. Three gas reciprocating units with a capacity of 8.7 MW each were assembled on the Zhlobin-based CHP and were launched into operation less than in 4 months. Finnish experts argue that the standard period of such construction is 6 months. In January, 2009 the power plant was officially launched. Now all three installations function nominally [11]. The Finnish company Wärtsilä has put into operation the object with the 1.7-fold exceeding capacity, reduced the construction time 8-fold, in comparison with the design and construction terms of the power complex of OAO Mogilevkhimvolokno presented by domestic organizations. Specific capital investment has been reduced by almost twice. A similar pattern is observed, when comparing and analyzing other objects. The operation of gas-engine installations practically does not provide any savings of imported gas, when compared to the existing CHPs in the Republic of Belarus.

In the production costs of electricity generated by local sources, it is necessary to consider not only the operating costs, but also the costs of capacity provisioning. The economic effect from the implementation of gas-engine cogeneration plants is determined as the difference of the prime cost of 1 kWh of electricity in the region (oblast) and the costs of local sources, and respectively as the difference between the tariff and the cost of electricity produced by the local source in terms of the enterprise. The results of the economic efficiency of certain gas-engine cogeneration plants in the Republic of Belarus are presented in the *table*.

A reasonable economic approach at all stages of design, construction and operation of mini-CHP allows the invested funds, presented on an example of two upgraded mini-CHPs (rather significant 2–3-fold decline in specific capital investment and 3–4-fold decrease in payback period of capital investments) to be used accurately, scientifically sound, and ultimately, most effectively [12]. According to the results of the analysis of the operation of mini-CHPs, built over the last decade, one can conclude that they do not affect the reduction of electricity tariffs (prices) for consumers. At the same time it should be noted that the operation of gas-engine installations practically does not provide any savings of imported conventional fuels – natural gas, when compared to the CHPs, operating in the Republic of Belarus. In addition, the results of the construction and operation of a number of mini-cogeneration plants on the base of gas-engine installations did not affect the fulfillment of the task of reducing the country's dependence on imported energy, formulated in the "Concept of Energy Security of the Republic of Belarus", approved by Presidential Decree No. 433 dated September 17, 2007 that stipulated the provision of at least 25% of the overall production of electric and thermal energy through the use of local fuels and alternative energy sources for the period until 2012, as well as the conversion of the existing boiler-houses into mini-CHPs. The development of new technological processes and new technical equipment was required to fulfill the target programme.

According to the authors, in order to maximize the efficient use of the budget (innovation) sources of financing and funds of the enterprises, not only domestic enterprises

Results by certain indicators of economic efficiency from the implementation of a number of gas-engine cogeneration plants at the industrial enterprises of the Republic of Belarus

Indicators	Gas-engine cogeneration plants					
	I-stage of BCP, Kastsyukovichy (Mogilev Voblast)	JSC Polymir, Navapolatsk (Vitebsk Voblast)	OAO Mogilevkhimvolokno, Mogilev	Scientific Production Association Integral, Minsk	Modernization of the associated gas CHP of the production Association Belorusneft	Zhlobin CHP following the modernization of the local boiler-house
1. Installed capacity , MW	16	21	14.7	17.4	24.4	26.1
2. Annual electricity production, million kWh	119	160	116	139	191	206
3. The prime cost of electricity, US cents/kWh	5.48	4.48	4.29	4.12	4.02	3.87
4. Specific consumption of fuel equivalent for production of electricity, G/kWh	197	164.5	160.9	161.7	163.1	158.1
5. Specific capital investment, US dollars/kWh	961	1051	1195	1512	510	654
6. Payback period of capital investments, years	14.3	19.9	12.8	16.1	8.6	4.4
7. National economic effect, thousand US dollars	1071	1104	1380	1626	1446	3605
8. Economic effect of the enterprise, thousand US dollars	3884	6432	5162	7260	7201	8075
9. Payback period of capital investments, considering the economic effect of an enterprise, years	5.6	3.4	6.3	3.6	2.9	2.1
10. The share of project works in the total cost of construction, %	3.7	3.9	4	3.8	4.9	3.8

are to be involved in the implementation of projects, but also prestigious foreign companies, which, having rich experience in this field, could put similar objects into operation in the shortest possible time. However, it is necessary to consider the possibility of involving various national specialists (designers, constructors, etc.) in undertaking an internship (training) in well-known foreign companies, which will obviously not only allow saving a lot of resources during the construction of such objects, but also permits training highly qualified specialists in the energy sphere.

The construction of mini-CHPs at the base of gas reciprocating and gas turbine units by domestic organizations is not sufficient for the economy of the Republic is only a financial assistance from the state to individual organizations (sometimes losing) for the maintenance and possible recovery of their economies due to the allocation of investment and later due to the possibility to pay for the consumed electric and thermal energy input, already generated by own source, at cost price and not as per tariff.

Obviously, national energy requires systematic and long-term development policy and a more thorough approach in terms of design, construction and operation of such facilities. This approach should be accompanied by profound, scientifically based and comprehensive researches of economic efficiency at all stages of creation of a small-scale power generation object and further stages of its ‘life’. It is not enough to implement a list of investment programmes in this area, oriented at the individual enterprises, and sometimes aimed only for a short-term facilitation through a set of financial measures provided to their economies. As a result, these investment projects become, in fact, a complex of ‘resuscitation procedures’ provided by the state in order to rescue the economy of a particular enterprise by building a mini-CHP at its base. Thus, the funds are withdrawn from other, perhaps, more important and effective programmes on the development of the Belarusian energy system.

Obviously, it is not reasonable to abandon the implementation of gas-engine cogeneration plants completely. The effectiveness of such stations increases significantly, when they are deployed at oil wells with associated gas, oil refineries, agricultural enterprises, where they are maximally close to the heat energy consumers, that considerably reduces the losses during transportation of [10, 13].

The authors consider that the more efficient spending of budgetary and other resources from multiple investment sources, as well as own funds of enterprises, requires the development of the package of normative and technical documentation, describing in detail and taking into account all aspects and specific features of the designed objects of small-scale energy, when justifying investments and setting forth a clear procedure for including these or that costs of the CHP operation in the calculations. These measures will allow scientifically, economically balanced and optimal decisions concerning the direction of the budget (innovation) funds to be chosen: either for the creation of a mini-CHPs, effective, indeed, not only for the economy of the enterprises, but for the economy of the whole country; or for the reconstruction and modernization of the existing CHP; or other key programs on the development of the energy complex of the Republic of Belarus.

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