Calculation of the economic and environmental efficiency of introducing advanced technologies in the energy supply of buildings

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Abstract. This article discusses the use of advanced cogeneration technologies at existing combined heat and power plants, regulating the supply of thermal energy in a building using an individual heating point. For Uzbekistan, an urgent problem is the serious study of the use of energy-saving technologies, in particular in the heat supply systems, for the efficient use of investments. The achieved effect of reducing specific energy consumption for the production and consumption of thermal energy to the level of world standards will ensure the energy and environmental security of the country, which urgently requires accelerating the implementation of these projects. The search for large and small projects for the technical and technological renewal of production to ensure the competitiveness of products, as well as the means and sources for this should first become the most important task and responsibility of the manager and engineering staff of each heat supply enterprise. The article provides calculations on the basis of which the payback, investment, efficiency of measures in the field of renewable energy sources for electricity and heat supply are determined, as well as the calculation of thermal energy savings when installing an individual heating point.

1 Introduction

For Uzbekistan, an urgent problem is the serious study of the use of energy-saving technologies, in particular in the heat supply systems, for the efficient use of investments (on the strategy of Actions for the further development of the Republic of Uzbekistan 2017 Decree №PF-4947). The achieved effect of reducing specific energy consumption for the production and consumption of thermal energy to the level of world standards will ensure the energy and environmental security of the country, which urgently requires accelerating the implementation of these projects. The search for large and small projects for the technical and technological renewal of production to ensure the competitiveness of products, as well as the means and sources for this should first of all become the most important task and responsibility of the manager and engineering staff of each heat supply enterprise (Resolution of the President of the Republic of Uzbekistan On the priorities for the development of industry of the Republic of Uzbekistan in 2011-2015 RP-1442 15.12.2010). High-energy

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intensity still dominates in all sectors of the republic’s economy [1]. Uzbekistan is among the 25 most energy-intensive countries in the seven main sectors of economic activity: agriculture, hunting and forestry; construction, manufacturing industry; transport and communications; wholesale and retail trade, restaurant and hotel business and other activities.

According to the practice of increasing energy efficiency at the enterprises of the republic, about half of the energy-saving measures are implemented on production lines, and the rest - on energy equipment. As a result of the implementation of modernization programs for industrial sectors, including fuel and energy sectors, it is possible to realize up to 46% of the planned amount of energy resource savings.

Currently, the republic's production and technical enterprises are provided with some of the largest energy subsidies in the world, estimated at approximately $4 billion per year (Asian Development Bank. Project “Technical Assistance to the Republic of Uzbekistan in Assessing Energy Needs” 2004. Conceptual provisions and directions for the development of the use of renewable energy sources for the production of electrical and thermal energy in Uzbekistan for the long term. The document was developed by "Uzbekenergo" 2011). The Government of Uzbekistan recognizes the need to increase domestic prices for electricity and gas to cover the real level of costs of energy supply companies necessary to directly meet demand, maintain the level of reliability and maintain fixed assets. Enterprises will be able to maintain competitiveness only by increasing labor productivity and efficient use of energy resources. Projects for modernizing equipment at industrial enterprises of the republic, implemented within the framework of World Bank Group programs, led to a significant increase in energy efficiency of production and a reduction in specific energy consumption by 40-70%, as well as an increase in operating profit by 5-7% even in non-energy-intensive industries. Despite these advances, many industrial enterprises are ignoring potential investments that could improve energy efficiency. At least 20% of enterprises do not take operating and maintenance costs into account when purchasing new equipment, and another 22% prefer less efficient, but cheaper models. Limited financial capabilities lead to the fact that technical problems that arise at enterprises are often solved according to a temporary scheme, without technical and economic study, and this leads, in the long term, to large financial losses [2].

The purpose of the work is to show by calculation the economic and environmental efficiency of introducing advanced technologies in the energy supply of buildings in the republic.

In view of the above, a comprehensive assessment of energy saving measures, the introduction of modern technologies, and energy resource consumption metering systems is necessary.

2 Materials and methods

Analysis of the situation in Tashkent, as well as a comparative analysis of organizational and technical aspects of centralized heat supply and solving similar problems in developed countries, made it possible to identify a set of measures aimed at increasing the energy efficiency of existing boiler houses and heating networks [3].

In the heat supply of residential and industrial facilities, the main technological measures, the implementation of which is necessary in the republic:

- after measures at combined heat and power plant (CHP), the greatest savings can come from measures to increase the efficiency of thermal energy production at gas industrial and municipal boiler houses and to increase the efficiency of heat distribution in centralized heat supply systems based on gas turbine units with a capacity of up to 1 MW - mini-CHP;
- use of heat pumps in centralized heating: for transfer of low-grade heat;
replacement of physically and morally outdated boilers with new ones using modern technologies. (condensation boilers for buildings);
- introduction of a regulated heating regime for housing and industrial buildings by equipping them with individual heating points (IHP) in the first place, because taking measures to improve their thermal efficiency will only have the effect of increasing the temperature in the room and will not affect the reduction in energy consumption at heat sources;
- introduction of variable-frequency electric drive (VFD) in water recycling systems of boiler houses. Savings in consumed electrical energy can reach 25÷40% with a payback period of up to two years [4,5].

3 Introduction of individual heating points in buildings

Investments are financially attractive if the cost of saving a unit of energy (for example, 1 kWh) is less than the cost of purchasing an additional unit of energy. The cost per unit of energy savings depends on the initial capital cost, possible additional operation and maintenance costs to achieve the energy savings, and the investor's options beyond energy efficiency improvements (accounted for through the investor's discount rate). In this study, the discount rate for consumers was 10%, and for institutional investors – 12%.

The cost of purchasing an additional unit of energy is determined by the tariff or market price of the energy resource (depending on whether energy prices are regulated) for these investors [6].

Investments are economically feasible if the cost of saving a unit of energy (for example, 1 kWh) is less than the cost of the state for the construction of new generating capacity (for example, 1 kW) or the value of lost profits for the country from exporting a unit of gas - depending on, which of these values is greater. When determining cost-effectiveness, this study calculated the cost of energy saved using a discount rate of 6% in the case of government investment. The basis for the calculations was the assumption that the state's requirements for return on invested capital are lower than those of private investors, however, it can also attract capital on more favorable terms. Cost-effective investments also differ from financially efficient investments in that they take into account external effects, both positive and negative. The largest externality, discussed in the following sections, is the reduction in carbon dioxide (CO₂) emissions that often accompanies energy efficiency investments.

We will consider an assessment of the economic efficiency of changes in the centralized heat supply scheme associated with the introduction of individual heating points (IHP) using the example of a two-section residential building. This building has 17 floors (the first floor is non-residential) and 128 apartments, it is located in Tashkent on Hamid Olimjan Square; the specific consumption of thermal energy for heating is 102 kWh/m²; the heated area is 7200 m².

We take the service life of the IHP to be 20 years ($T_{S.L.} = 20$ years). We accept the value of the discount rate $r = 0.10$ (10%). The cost of thermal energy is equal to 0.015 $/kWh (converted to the current exchange rate).

We assume for calculation that the transition to IHP leads to a reduction in thermal energy consumption for heating by 30%, and, thus, the specific thermal energy consumption for heating the building is 71.4 kWh/m².

The reduction of the thermal energy costs in value terms (that is, the annual average additional income due to savings in energy resources and energy-saving measures throughout the entire service life) is
\[
\Delta D = (102 - 71.4) \cdot 0.0015 = 0.448 \ \text{\$ m}^2 \cdot \text{year}
\]
The cost of the IHP, including installation, is $14 thousand, hence the amount of investment per 1 m² of area is

\[ K = 14000 \div 7200 = 1.94 \frac{\$}{m^2} \]

Let us determine the economic efficiency for two schemes for using incoming income: discounting them (using them as working capital) and increasing them (capitalization - accretion them at interest, for example, by lending them).

To assess the economic efficiency of investments in energy-saving measures, it is necessary to determine the following criteria for economic efficiency, taking into account discounting and accretion:

The total income is determined by saving energy resources over the entire period of operation of energy-saving measures. The total discounted income due to energy savings for the entire period of operation of energy-saving measures \( DIT_{S,L} \), $/m², is determined by:

\[ DIT_{S,L} = \frac{\Delta D \cdot [1 - (1 + r)^{-T_{S,L}}]}{r} = 4.08 \frac{\$}{m^2} \]

The total income due to saving energy resources for the entire period of operation of energy-saving measures with the accretion (capitalization) of incoming income \( AIT_{S,L} \), $/m², is determined by:

\[ AIT_{S,L} = \frac{\Delta D \cdot [(1 + r)^{T_{S,L}} - 1]}{r} = 27.5 \frac{\$}{m^2} \]

Determination of the payback period of investments. The non-discount payback period \( T_0 \), years, is determined by the formula:

\[ T_0 = \frac{K}{\Delta D} = \frac{1.94}{0.48} = 4.08 \text{ years} \]

The payback period of investments, taking into account discounting of incoming income due to energy savings \( T_d \), years, is determined by the formula:

\[ T_d = \frac{\ln(1 - T_0 \cdot r)}{\ln(1 + r)} = 4.93 \text{ years} \]

The payback period for investments during the accretion (capitalization) of incoming income due to energy saving \( T_a \), years, is determined by the formula:

\[ T_a = \frac{\ln(1 + T_0 \cdot r)}{\ln(1 + r)} = 3.6 \text{ years} \]

The calculation results showed that the transition to IHP is quite effective from an economic point of view. Low payback periods allow us to classify this method of energy saving as low-cost and quickly payback.

4 Introduction of solar attachments to boiler heat supply systems

When reconstructing and modernizing the heat supply systems of the republic, solar installations for preheating water can be integrated into existing centralized heat sources. This option is the most economical and reliable, since trained personnel will ensure the correct operation of the equipment. At the same time, emissions of harmful substances from thermal power plants and local boiler houses can be significantly reduced [7].

A quick return on investment in this technology can be achieved by releasing significant volumes of gas from domestic consumption for export needs. 65 billion m³ of natural gas is produced in Uzbekistan, of which 60% is consumed within the country. About 12 billion m³ are exported at a price of approximately $200 per 1000 m³, while on the internal market it is sold for $50 with the state subsidizing 40% of heat supply costs. The solar heat source allows you to save up to 200 m³ of natural gas with specific indicators of 0.12÷0.15 tons of standard fuel per 1 m² of solar collector. The required specific capital investments, taking into account
the necessary equipment and the cost of construction and installation work, will amount to $450 per 1 m² of solar collector area.

According to the State Statistics Committee of the Republic, 36,396.4 thousand Gcal were supplied in heat supply at the end of 2020. 4116.2 thousand tons of standard fuel were consumed for its production. On average, for boiler houses the hot water supply (DHW) load is about 30% of the total (including heating). If we ensure the introduction of solar attachments into existing boiler houses at a rate of replacement of the DHW load in the heat supply of the republic at 4%, then capital investments in solar collectors with an area of 50,000 m² will be required in the amount of about $22.5 million. Gas savings volumes will be 10,000 thousand m³ with potential export revenue

$$\frac{200 - 50}{10000} = 1.5 \text{ million}$$

CO₂ emissions (1000 m³ = 1.8977 tons CO₂) will decrease by 19 thousand tons. The payback will be

$$\frac{22.5 \text{ million}}{1.5 \text{ million}} = 15 \text{ years}$$

This indicator will ensure the return of invested funds over the allotted service life of energy-saving equipment [8].

In the future, this will make it possible to create a green construction industry and give impetus to the development of the use of renewable energy sources for heat supply systems.

Projects that lead to improvements in energy efficiency, especially on the supply side, depend on technology transfer to help in their implementation. Moreover, the potential for energy efficiency policies exists in countries with both monopolized and liberalized energy markets, although the scope and effectiveness of energy efficiency policies may increase as market mechanisms are introduced. It is predicted that, in the absence of any major changes in current policy, CO₂ emissions in the republic could increase by more than 50% by 2030, and by 100% by 2050. At the same time, the total volume of energy consumption will increase by 53% by 2030 and up to 109% by 2050.

Figure 1, based on the above study, shows the cost of measures to reduce emissions by sectors of the economy of Uzbekistan. Reducing emissions to zero by 2050 would require measures costing up to US$600 per ton; a 50% reduction would require measures costing up to US$1,000 per ton of CO₂ based on current technology developments. However, with the development of technologies, their cost can decrease by 2.5 times [9].

![Figure 1](https://example.com/fig1.png)

**Fig. 1.** Cost of measures to reduce emissions under the green scenario of economic development of Uzbekistan by 2050.
In figure 2, areas are highlighted by color, which classify measures for the development of energy-saving technologies in the republic:

- **Yellow**: refers to the oil and gas sector, which, due to the possibility of exporting resources, is the most economically attractive for energy saving in the republic. Activities in this sector have the greatest effect, up to 70% of the potential for reducing emissions in the medium term;

- **Green**: directly affects the area of thermal energy production and consumption in the housing and communal services sector. However, due to the fact that the consumption of thermal energy, which is the main type of energy resource for buildings, in the overall energy balance of the republic is up to 5%, the corresponding increase in emissions reduction also does not exceed 5%. The activities, as shown in Figure 2, are mostly financially attractive for consumers of the republic;

- **Red**: the need to modernize the electrical energy production sector, given the high cost of measures for the energy security of the republic.

The energy efficiency is more relevant for the republic today than ever before. An instrument simultaneously contributes to the achievement of three main goals of energy policy:

- Improving energy security;
- Reducing harmful environmental impacts;
- Improving the competitiveness of industry.

In the area of energy efficiency, significant results can be achieved in a short time, using existing technologies and with high profitability, especially on the demand side.

**Fig. 2.** Specific cost curves for reducing CO2 emissions for activities planned in the Republic of Uzbekistan.

**5 Conclusion**

The results of calculations for assessing the economic efficiency of changing the centralized heat supply scheme associated with the introduction of individual heating points showed that the transition to IHP is quite effective from an economic point of view. Low payback periods
make it possible to classify this method of energy saving as low-cost and quickly payback. Calculation of the implementation of a solar heat source showed that CO₂ emissions would decrease by 19 thousand tons. The payback period will be 15 years. This indicator will ensure a return on invested funds over the allotted lifespan of energy-saving equipment.

References

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