

## ENERGY PERFORMANCE AND ENERGY SAVING OF LIFE-SUPPORT SYSTEMS IN EDUCATIONAL INSTITUTIONS

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### ABSTRACT

This article describes the results of energy consumption monitoring analysis in buildings of educational institutions. Relevance of resource-saving technologies use is substantiated in order to improve energy performance and energy saving.

The principal model is proposed. This model describes the impact of building automation systems (BAS) and utility systems management tools (USMT) on the accomplished level of energy performance. The method for determination of the minimum requirements for the aforementioned systems in respect of educational institutions is given.

Provisions for heat distribution stations upgrading in order to improve heat supply of a building are proposed.

The contemporary automation systems of buildings ensure the most efficient control automation for heating, ventilation, lighting, hot water supply systems. This leads to significant increase of operation efficiency and reduction of energy costs. The integrated energy saving processes and functions are optimized depending on the specific climatic conditions in a region, special considerations in respect of building operation and user requirements. It leads to significant reduction in energy consumption and greenhouse gas emission.

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## INTRODUCTION

Considering existing public, political and social tendencies, the relevance of energy performance improvement and implementation of energy saving activities currently becomes a very important and economically viable task.

To provide allowed and, preferably, optimal internal environment parameters in all classrooms, laboratories and auxiliary rooms is one of the conditions for successful process of education. This requires applying effective regulatory and technical documents for construction.

Energy saving options in public buildings are closely connected to heat supply systems operation modes. The modes are determined by regulatory requirements and by minimum heat losses thanks to use of energy efficient and cost efficient design and space-planning considerations.

For prediction and planning of energy costs and for resource-saving technologies efficiency evaluation, systematic approach in energy consumption monitoring must be used.

The following tasks are determined in the Government Program "Energy saving and energy efficiency improvement for the period through 2020": to improve the energy efficiency control (energy management introduction), to implement activities for promotion and education on energy efficiency issues, to ensure energy saving technologies design and application. In the course of this program, series of activities are implemented. These activities include energy certification of educational facilities and alignment of energy consumption metering and analysis. Based on the results of the investigation, the action plan is outlined. It allows it to increase energy performance of the guarding structures and reduce energy intensity as well as specific costs of energy and heating resources.

In some instances energy saving activities cannot be used for cost saving based on energy resources cost reduction due to lack of tools to measure these resources.

Replacement of doors and windows, heat insulation of front faces, floors of lift slabs in pediments and attics allows it to improve energy performance. Automated heating systems with weather-based adjustment ensure comfortable conditions, while reaching the best efficiency in energy saving. In the context of energy performance improvement of a heat supply system and maximum cost efficiency, it is important to ensure internal environment parameters close to optimal. It also has the most positive effect for health and learning capabilities of students.

State policy in the scope of energy saving and energy performance improvement in educational sector foresees all-round revamping of educational institutions and their engineering infrastructure based on the consolidation of efforts on different levels of authority in order to improve living standards of the population in regions and in the Russian Federation in general.

The series of actions are primarily aimed at upgrading of local general education systems. Energy performance improvement and implementation of energy saving activities in educational institutions are outlined [3].

Utility costs are currently fall within 10% of educational institution costs [5]. The main reasons of very high energy intensity in educational institutions, which prevent energy saving policy, include:

- substantial losses while consumption and transfer of electrical and thermal energy, high consumption of primary energy resources;
- significant obsolescence and physical wear of utility networks and power equipment;
- lack of funds for implementation of innovative and efficient energy technologies, installation of metering and control devices.

The important reason of unsatisfactory energy saving in educational institutions is low motivation in respect of energy performance of processes and technologies improvement.

Based on the advanced experience, flexible energy saving provides 2-10% of the whole amount of energy that potentially can be saved. Flexible energy saving model in educational sector can be implemented when an end user is involved into resources consumption reduction. It can be achieved by information support, sustainable promotion of energy saving approach, and instructing different groups of users on the most efficient ways of energy saving.

In the course of development and introduction of this program, the integrated database should be created. This database will include information on engineering support of all educational institutions as well as information on activities and technologies introduced and aimed at energy performance improvement and energy saving in a specific educational institution.

The systematic approach and integrated activities will be more efficient when the information on the different types of local educational institutions will be available. It can be achieved by means of an on-line information system based on expert evaluation and investigations in energy sector. This system can be implemented on a popular website. This web portal will provide information on the key issues of energy performance improvement in an educational institution and implementation of energy management system.

State-financed institutions consume a significant amount of energy resources. Therefore, they have a very high energy saving potential. According to expert evaluation, it is possible to save 34% of consumed energy, 37% of heat energy, and 25% of natural gas [6]. Technically feasible energy saving for heat supply systems of those institutions equals to 50%. The estimated potential energy saving rate is given based on the analysis and comparison of energy performance characteristics for the most technically advanced buildings of state-financed institutions, which are operated in the Russian Federation.

Energy saving potential for an educational institution is closely connected to operation modes of heat supply systems. Modes are determined by regulatory requirements for internal environment parameters in classrooms and laboratories.

Specified internal environment and air motion parameters during operation of heating, ventilation and air conditioning systems in educational institutions determined in GOST 30494 are used in order to ensure parameters within the specified regulatory requirements in serviced area of premises:

- for winter period – the minimum allowed temperature in conditions of excess heat absence in premises;
- for summer period – in conditions of excess heat presence in premises – air temperature within the allowed temperature range but not higher than the designed temperature of outdoor air by 3°C and not higher than the maximum allowed temperature; in conditions of excess heat absence in premises – air temperature within the allowed temperature range.

In heated premises of educational institutions, during winter period when they are not used and in non-duty hours, temperature lower than specified but not less than 12°C can be set. The specified temperature should be ensured before start of work. In regulatory documents for buildings and structures of educational institutions, it is recommended to implement programmable control of internal environment parameters. It allows the further heat consumption reduction (according to expert evaluations at the average rate of 10% and more). The European Standard EN 15232: 2012 "Energy performance of buildings – Impact of Building Automation, Control and Building Management" is one of the contemporary regulatory documents for energy saving and provision of comfortable living environment by means of heating systems automation [8]. Functionality of indoor automation systems is determined based on the level of their impact on energy performance of a building. Herewith, the energy performance level is defined by the actual and calculated energy consumption ratio. Based on the EU Directive "On energy consumption in buildings", in energy

performance calculation costs for lighting, heating, cooling, ventilation, hot water supply, and other energy consumption types are considered.

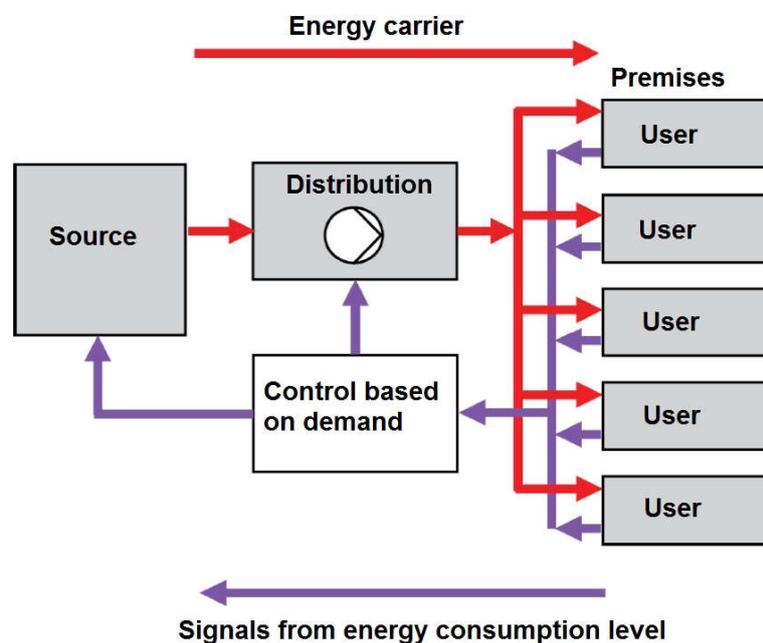
According to the European Union Standard [8], each EU country implements its own regulations to determine reference values for energy performance and methods of their calculation. In Germany, 920 TW·h per year is used for heating of buildings, while more than a half of this value accounts for non-residential buildings, where it is reasonable to implement automation systems. Based on the analysis carried out according to the Standard EN15232, 20% of energy was saved with the use of heating systems automation. It is as much as 10 TW·h and provides significant reduction in energy consumption. Approximately 80% of all expenses for a building are accounted for operating expenses (Fig. 1.1). In particular, energy costs are accounted for the largest fraction of expenses. Here great opportunities for optimisation exist. However, the cost efficient operation must not have an impact on comfortable working environment. No doubt, the negative impacts such as personnel and students feeling uncomfortable and affected by cold must not prevail while operating costs saving process implementation.



**Fig.1.1.** Cost relationship on different stages of a heat supply facility life cycle

The European Standard EN 15232: "Influence of automation on energy performance of buildings" [30] is a Standard of the European Committee for Standardization (CEN) implemented within the unified standardization project. The project is aimed at execution of the Energy Performance of Buildings Directive (EPBD), energy performance improvement, and energy saving activities implementation in the countries, members of the European Union. The Standard EN15232 defines the evaluation method for the impact of Building automation systems (BAS) and Utility system management tools (USMT) for the accomplished energy performance as well as the method for the minimum requirements determination for the aforementioned systems in respect of different types of buildings.

The contemporary automation systems of buildings ensure the most efficient control automation for heating, ventilation, lighting, hot water supply systems. This leads to significant increase of operation efficiency and reduction of energy costs. The integrated energy saving processes and functions are optimized depending on the specific climatic conditions in a region, special considerations in respect of building operation and user requirements. It leads to significant reduction in energy consumption and greenhouse gas emission. Building automation systems and, above all, utility network control systems provide all necessary information for operation and maintenance of buildings and energy management. According to EN 15232, functions of building automation system are based on the energy demand and supply model for a specified building.



**Fig.1.2.** Energy demand and supply model for a building of an educational institution

Lighting as well as ventilation and air conditioning equipment must ensure comfortable conditions in premises of a building and provide the specified values of temperature, humidity and intensity of illumination. Power supply is provided in compliance with time-varying parameters of end users. It ensures maximum reduction of losses in the course of energy generation, distribution and transportation.

AUTOMATIC CONTROL			
1	HEATING CONTROL		SN Energy saving basis
1.1	Control of supply		1
	<i>Control system is installed on a heat source or premise level. In the first instance, one system can be used to control several rooms.</i>		
0	<u>Without automatic temperature control in a room</u>		Maximum value of generated heat is constantly supplied to heat exchangers. As a result, in case of partial load, excess heat is generated.
1	<u>Central automatic control</u> Only central automatic control is used for heat distribution and generation. It can be performed, for example, by a device for outdoors temperature control according to EN12098-1 or EN12098-3.		Heat supply is controlled, for example, based on outdoors temperature (according to the probable requirements of users). Energy losses in case of partial load are reduced but heat output in premises cannot be separately metered.
2	<u>Separate room control</u> <u>Thermostatic valves</u> or electronic control devices are used.		Heat supply is controlled based on temperature in a room (variable, controlled). Heat output in a room (heat from sun, humans, animals and equipment) is taken into account as well. Comfortable conditions in a premise can be maintained with reduced energy consumption. Note: Electronic control devices are more efficient than thermostatic valves (higher accuracy, different control actions for all valves in a premise are coordinated).
3	<u>Separate room control with communication</u> of control devices and central system (for example, time schedule)		Centralization advantages are added to the above mentioned feasibility demonstration: - time schedules reduce generation at time of absence of people, - <u>control</u> and monitoring functions allow additional process optimization.
4	<u>Separate room control with communication</u> of control devices and central system, and <u>presence control</u> The demand is based on presence of people.		The following advantages are added to the above mentioned feasibility demonstration: - efficient presence control allows additional energy saving in a room while partial load, - <u>energy</u> is supplied based on demand (energy generation) that allows it to minimize losses while heat generation and distribution.

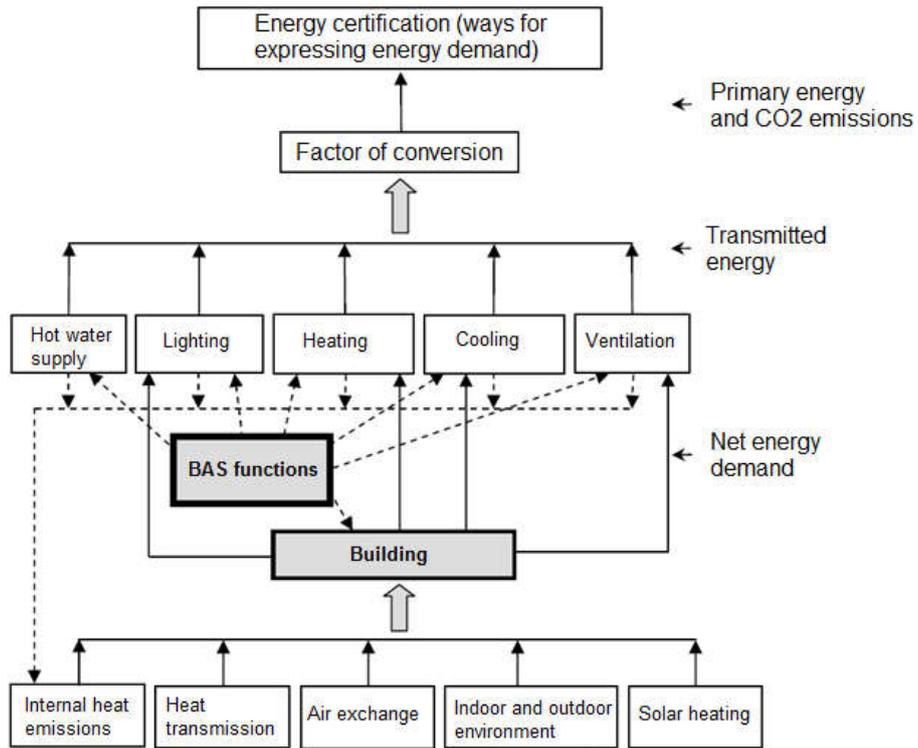
Fig.1.3. Functions of heat supply automation systems according to EN15232: 2012 [8]

Four energy performance classes for BAS (A–D) are defined in EN15232 [8].

		Definition of classes							
		Residential				Non-residential			
		D	C	B	A	D	C	B	A
AUTOMATIC CONTROL									
1	HEATING CONTROL								
1.1	Generation control								
	<i>Control system is installed near a heat source or on premise level. In the first case one system</i>								
0	Without automatic control								
1	Central automatic control								
2	Separate room control								
3	Separate room control with communication								
4	Separate room control with communication and presence								
1.2	Generation control for TABS								
0	Without automatic control								
1	Central automatic control								
2	Enhanced central automatic control								
	Enhanced central automatic control with intermittent control								

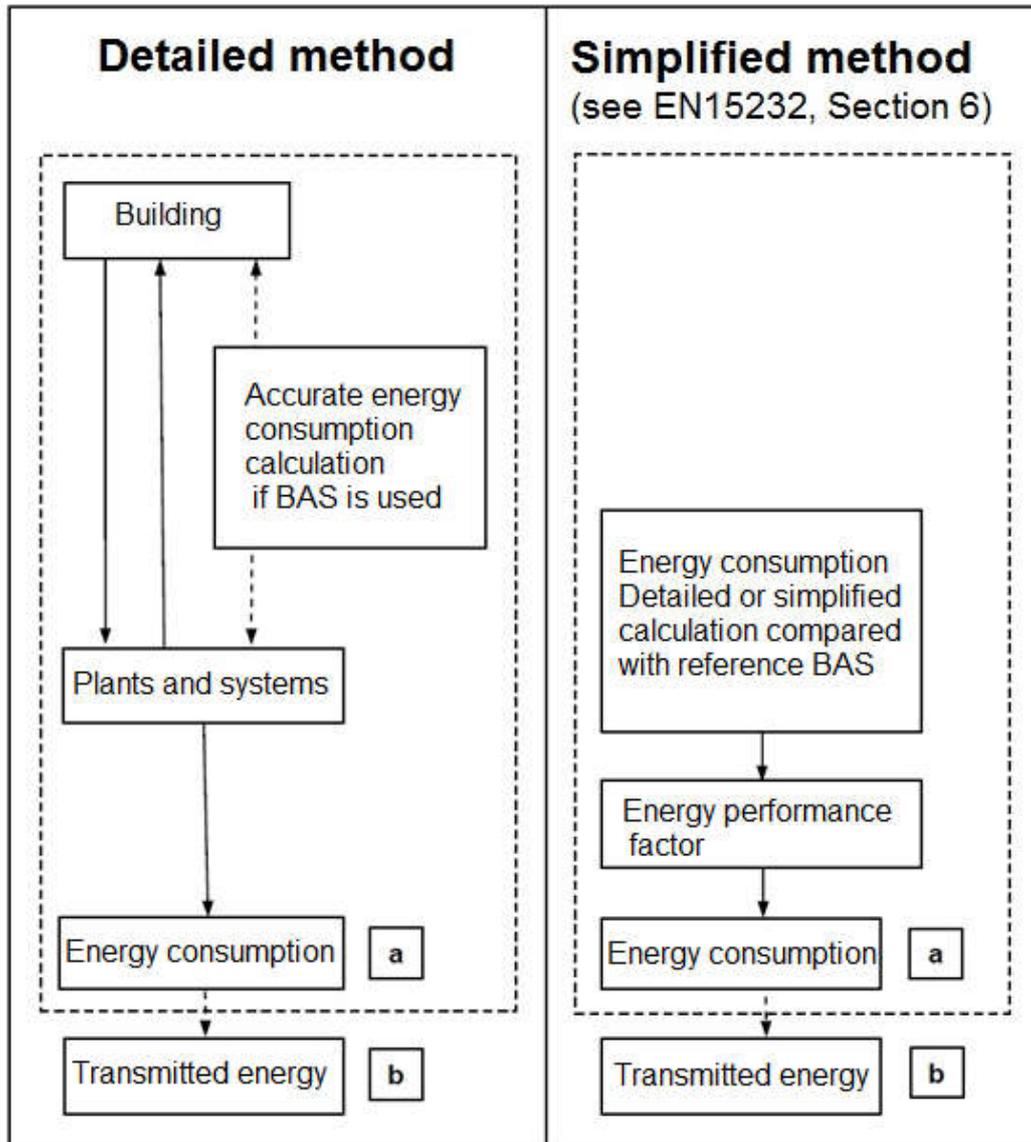
1.3	Hot water temperature control (direct or reverse) in a distribution network							
	<i>Detailed functions can be applied for direct electrical heating control of a network.</i>							
0	Without automatic control	■				■		
1	Outdoors temperature compensation control	■	■			■	■	
2	Control based on demand	■	■	■	■	■	■	■
1.4	Control of distribution network pumps							
	<i>Controlled pumps can be mounted on different levels of a network</i>							
0	Without automatic control	■				■		
1	On/off control	■	■			■		
2	Multi-stage control	■	■	■		■	■	■
3	Pump variable speed control	■	■	■	■	■	■	■
1.5	Generation and/or distribution intermittent control							
	<i>One control device can control different rooms/zones using one presence model</i>							
0	Without automatic control	■				■		
1	Automatic control with constant time program	■	■			■	■	
2	Automatic control with optimal start/stop	■	■	■		■	■	■
3	Automatic control with demand evaluation	■	■	■	■	■	■	■
1.6	Control of combustion generator and supply from the centralized supply system							
0	Constant temperature maintenance	■				■		
1	Variable temperature maintenance based on outdoors	■	■	■	■	■	■	■
2	Variable temperature maintenance based on load	■	■	■	■	■	■	■
1.7	Heat pump control							
0	Constant temperature maintenance	■				■		
1	Variable temperature maintenance based on outdoors	■	■	■		■	■	■
2	Variable temperature maintenance based on load and demand	■	■	■	■	■	■	■
1.8	Sequential activation of different generators							
0	Priority is only based on time of operation	■				■		
1	Priority is only based on load	■	■			■	■	
2	Priority is based on load and demand	■	■	■		■	■	■
3	Priority is based on generator efficiency	■	■	■	■	■	■	■

Fig.1.4. Energy performance classes for BAS



**Fig.1.5.** Calculation stages to determine BAS and USMT impact on the energy performance level of a building

Considering the factors, detailed and simplified calculation of BAS functions impact on energy performance of a building can be performed (Fig. 1.6).



**Fig.1.6.** Detailed and simplified calculation of BAS functions impact on energy performance of a building according to EN15232: 2012

BAS and USMT impact on energy performance for many buildings can be determined using the simplified method with sufficient accuracy, and complex calculations are not required. The application of the simplified method is limited: it can be used for energy performance classes A, B, C and D. This method does not provide classification that is more accurate. Significant energy saving due to use of BAS can be achieved by installation of presence sensors, airflow control devices and heating, cooling, ventilation and air conditioning systems activation and de-activation control devices.

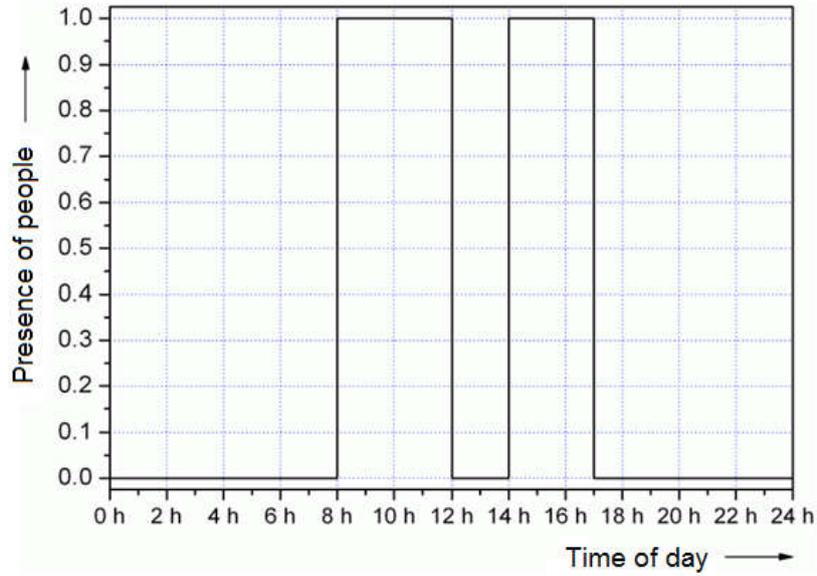


Fig.1.7. Operational profile for an educational institution

BAS energy performance factors for thermal energy (heating and cooling) are classified depending on type of a building as well as USMT and BAS energy performance class. Factors for class C are equal to 1 since this class is used as a standard class for USMT and BAS evaluation. Introduction of classes B and A causes BAS factors reduction, thus, energy performance of a building increases.

Non-residential buildings	BAS energy performance factors for thermal energy			
	D	C	B	A
	No energy performance	Standard (basic) energy	Advanced energy	High energy performance
Office building	1.51	1	0.80	0.70
Concert or conference hall	1.24	1	0.75	0.5 <sup>a</sup>
Educational institutions (schools)	1.20	1	0.88	0.80
Hospitals	1.31	1	0.91	0.86
Hotels	1.31	1	0.85	0.68
Restaurants	1.23	1	0.77	0.68
Retail or wholesale businesses	1.56	1	0.73	0.6 <sup>a</sup>

Other types of buildings: • Sports facilities		1		
<sup>a</sup> The values to a great extent depend on the demand in ventilation during heating and cooling				

**Fig.1.8.** BAS energy performance factors (for thermal energy) in public buildings

The growing requirements for heat supply quality set out new engineering policy. It implies recession of central heat distribution stations (CHDS) and users are connected to the heat supply network using local heat distribution stations (LHDS) installed directly in buildings. LHDS provide hot water preparation for hot water supply systems (HWS) using closed circuit [9].

A contemporary heat distribution station includes a complex of heating and pumping equipment with integral electrical and hydraulic automation devices. They maintain comfortable parameters of internal environment in heated premises of educational buildings and maintain water temperature in the hot water supply system. They ensure utility systems operation in fault-free mode, heat consumption metering, energy saving and improve energy performance [10].

According to the regulatory documents, a heat distribution station has the following main functions:

1. performs conversion of heat carrier type and parameters;
2. controls heat consumption rate in heating and ventilation systems;
3. maintains hot water temperature in the hot water supply system;
4. ensures differential pressure on control valves and upstream heat consumption systems;
5. limits maximum water flow rate in a network at the user side;
6. fills and feeds heat consumption systems, independently connected to the heating network;
7. controls circulating and boost pumps;
8. meters heat and water consumption.

Heating systems in buildings of educational institutions must be equipped with automated control devices to control temperature of heat carrier supplied into the system based on

outside air temperature. In buildings, where the heating system uses pipelines made of polymeric materials, heat carrier temperature must not exceed 90°C or threshold limit values for material of the used pipelines. In this case, automation schemes are implemented using electronic temperature control devices with weather-based adjustment.

Revamping of heat distribution stations is carried out in order to improve heat supply in a building of an educational institution in compliance with contemporary requirements.

Revamping of a heat distribution station in an educational institution provides:

1. optimization of thermal load distribution in a heating network;
2. adequate control of hydraulic and thermal modes of the internal heat consumption system in a building of an educational institution;
3. heat carrier flow rate reduction in the heating network;
4. saving of energy resources;
5. reduction of negative impact on the environment, compliance with regulatory requirements for energy performance and energy saving.

An automatic control system of a local heat distribution station in addition to weather-based adjustment also allows it to take into consideration heat "oversupply" due to overestimated heat transfer surface of heating equipment, and to take into consideration utility heat output. In case of use of frontal control for the heating system, heat from solar radiation can be considered. Additionally 5-10% of thermal energy in a building can be saved.

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