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- ВОЕННЫЙ ИНЖЕНЕРНЫЙ СТРОИТЕЛЬНЫЙ ИНСТИТУТ

Номер посвящен Международной конференции “Энергосбережение в городском хозяйстве и промышленности” (Санкт-Петербург, 10-12 декабря 1996 г.)

Публикуются материалы основных докладов по технологическим, экономическим, нормативно-правовым аспектам энергосбережения

В порядке обсуждения. Новое технологическое оборудование на отечественном рынке

Информация о предстоящих конференциях

Реклама

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Codes and Standards of Building Energy Efficiency: A Regional Approach

Abstract

In this paper, we consider the problem of the development of regional building standards with an enhanced level of energy efficiency. It is known that all-Russian codes cannot reflect all regional particularities. Moreover, existing all-Russian codes do not have standards that set limits on the overall consumption of heat energy for space heating in buildings. In light of the increasing need for energy efficiency and the passage of the Russian Federation Law "On Energy Conservation", it has become necessary to develop new principles of regulation of the heat-energy indices of buildings.

In this paper we report on the collaborative development of a model regional standard by the Center for Energy Efficiency (CENEf) and the Natural Resources Defense Council (NRDC). This standard, entitled "Energy Efficiency in Buildings: Regional Norms for Thermal Performance and Heat Supply", is intended for application by regional administrations of the Russian Federation.

Among the basic principles of the proposed normative document are the establishment of general requirements based on the overall energy consumption of the building. The means for meeting these requirements are left to the building designer. Thus the designer has the freedom to achieve the designated energy targets more rationally, depending on climatic, energy, and construction particularities of the region where the building is to be located.

A new index is proposed as the basis of the model regional standard — the specific energy consumption of the building during the heating season. By means of this index, the overall energy efficiency of the whole building is defined, including both the thermal envelope and the heat supply system. Since there might be the risk of achieving the given energy-consumption level by lowering thermal comfort, this version of the standards foresees special requirements for thermal comfort.

A building design will satisfy the requirements of the given standards if the calculated specific energy consumption during the heating season does not exceed the values of a region-specific function, chosen for a region on the basis of local conditions. A building envelope in compliance with the model standard must be designed in correspondence with:

1. general energy-consumption requirements, or
2. either a. prescriptive requirements for the building envelope or
   b. requirements for the building envelope and the heat supply system.

The simultaneous design of the building envelope and the heat-provision system allows the possibility of achieving a balance between the level of thermal-envelope performance and the delivery of heat from the HVAC system, through adjustments either to the envelope or to heating systems, compensating through increased efficiency for excess heat losses elsewhere.

The model regional standard includes requirements for the verification of energy parameters during the design and construction stages, and also after one year of operation. To these ends, the model standard foresees the "Energy Passport" of the building, a certification system in the form of an Excel computer spreadsheet. We also propose the use of the Energy Passport for calculation of the monthly energy consumption of the operating building through regional weather-station data, by which payments for supply of heat energy may be determined if actual heat meters are absent.

In this report, we also describe the experience of the development of energy-efficiency standards in Moscow, which have been in force since 1994. We also discuss the restructuring of the construction industry of the city of Moscow through transition to construction of buildings with efficient insulating materials. Using the example of the city of Tula, we show the experience of finding the financial means for implementation of regional standards.

The authors present two primary advantages of these regional standards, which are especially important for regions.

• The first advantage lies with standardization based on energy-consumption properties of the building. This

advantage allows the achievement of energy efficiency via various technical possibilities, such as increased thermal-envelope performance, or improvements to the HVAC system.

• The second advantage lies with the use of the Energy Passport of the building. This advantage allows for more precise calculation of monthly energy consumption than current calculation methodologies now used in Russia. Thus regions and municipalities can more accurately determine their correct expenditures on demanded heat energy.

Such regional standards can be developed in response to the Russian Federation Law "On Energy Conservation" under the general name "Energy-Efficient Buildings".

The implementation of regional standards will yield energy conservation in regions of up to 40–50% and will bring about savings of budget resources for heat-energy subsidies of up to 40% over existing levels.

In the Federal Law on energy efficiency and in the Government Resolution of the Russian Federation from 2 November 1995 [1] on first-order measures on the realization of the potential for energy conservation, are such recommendations as the development of standards for the consumption of heat and electricity, and the creation and implementation of highly efficient thermal insulation materials and building components, which have prompted the initiation of the development of new normative requirements.

These requirements are analogous to those established in other countries and regions, and have proven very effective at reducing energy use while improving thermal comfort in buildings and reducing their overall cost.

It is known that all-Russian norms cannot reflect all regional particularities. Russia is the largest country in the world, and the range of winter heating season severity varies between different towns over a ratio of over 6 to 1 [2]. Therefore the national standards must contain only overall basic requirements. In accord with SNiP 10-1.94 "The system of normative documents in construction. General conditions", baseline requirements are set for the consumption properties of the building. The consumption characteristics reflect those qualities of the building that create agreeable living and working conditions for people. Related to these characteristics, from the point of view of thermal engineering, are parameters for thermal comfort on the building premises and the expenditure of heat energy on these premises for the maintenance of a given microclimate in the course of the heating period. Regional particularities must find reflection in regional norms for energy efficiency.

In accord with existing legislation, regional normative documents may be adopted by regional administrations without official permission from Minstroy of Russia, if they do not contradict all-Russian normative documents.

Existing norms on building thermal engineering (SNiP II-3-79 ed. 1996) do not have standards which limit the overall consumption of heat energy for heating the building. In connection with the strengthening of requirements for energy conservation, there has emerged a need to develop principles of standardization of the heat-energy indices of the building.

This situation is similar to that in the United States. U.S. national standards apply (or will apply) to the testing and labeling of heating, cooling and water heating equipment and to thermal insulating properties of components such as windows. The federal government also sets minimum levels of energy efficiency to which state standards must be compared. In the case of residential buildings, the state may choose to set lower standards than the national model; for commercial buildings (offices, schools, retail buildings, factories, civic buildings, etc.) the state standards must be at least as energy conserving as the national model. Actual standards for building energy efficiency are set regionally in the U.S., usually at the state level but sometimes at the municipal level.

CENEf (the Center for Energy Efficiency, Russia) in collaboration with NRDC (the Natural Resources Defense Council, USA) and NIISF, with the support of the U.S. Environmental Protection Agency, has developed a model of Regional Standards for the Russian Federation
on energy efficiency in buildings. The development of model regional normative documents should be based on the following steps of research and measures for realization after their adoption by the regional administration:

* Study of the structure of the energy balance and the construction industry of the region;
* Analysis of construction designs of the buildings of mass construction, which are or are capable of being widely implemented in the practice of construction of the region;
* Assessment of the level of energy consumption of different types of buildings of the region, as currently constructed and as they could be built with economically feasible improved components or designs;
* Development of the region's own norms on the basis of the planned level of energy supply to the buildings

sector and the particularities of the regional construction industry;

* Development of recommendations on construction designs of exterior envelope structures with an enhanced level of thermal performance;

* Development of principles of thermal engineering design of energy-efficient buildings including sections on "Energy Conservation," "Energy Passport," and "Comparison of Alternatives to Proposed Designs" in the contents of the design;

* Development of design documentation in correspondence with new requirements of the regional standard;

* Familiarization of product manufacturing with high thermal-engineering properties - wall panels, windows, thermal-insulation and waterproof materials, devices for automatic regulation, monitoring, and measuring heat energy, heat exchangers and other efficient equipment for the supply and delivery of heat;

* The carrying out of experimental construction of facilities with high indices of energy efficiency for the investigation and assessment of the quality of products and design decisions with subsequent correction of the design documentation;

* Transition in the region to mass construction of energy-efficient buildings and also to renovation of buildings in correspondence with the regional standard.

Two regions - Chelyabinsk and Rostov - have already expressed the desire to work with the CENEf/NRDC team on this model, adapting it to specific climatic, construction, and energy particularities of their regions. Moreover, Tula and Kostroma have included the development of similar norms in their programs for energy conservation.

The developed model of Regional Standards [3], as it currently exists in draft form, takes into account specific construction and climatic particularities of the regions, does not contradict the requirements of federal normative documents, and contains equal or more stringent requirements than federal standards. This document presents itself as a Draft of regional standards, which are intended for application to a concrete region and for subsequent adoption and implementation by a regional administration.

The basic principle of the structure of the given normative document lies with its establishment of main requirements, based on the consumption properties of the building. The means for meeting these requirements are left to the designer to choose. This gives him the freedom to achieve the specified target and to attain the final result by a more rational path, depending on climate, energy, and construction particularities of the region for which the building is being designed.

The model standards regulate the energy efficiency of the whole building, including thermal performance and the heat-supply system, and allow the designer great flexibility in deciding what components to use to meet the whole building goal. But since complete flexibility would carry with it the risk of achieving the given energy-consumption at the expense of reduced thermal comfort, the conception of the standard foresees special requirements for thermal comfort.

Following these two basic requirements - the limitation of overall energy consumption of the building and the provision of adequate thermal comfort - normative requirements have been established for the thermal-performance of the building by means of two alternative methods of demonstrating compliance:

* the SYSTEMS (performance) approach, which considers the building as a single energy-consuming system [5] with a given target energy consumption; and

* the ELEMENT-BY-ELEMENT (prescriptive) approach, in which various elements and assemblies of the building envelope provide the required comfort.

Standards offering the choice of these two methods have been very effective in the state of California, and have been adopted by ASHRAE in Standards 90.1 and 90.2.

To implement the SYSTEMS approach, a new index has been placed into the basis of the model regional standards - the specific energy consumption of the building during the heating season. From this, it is possible to set up standards of specific energy use for heating or cooling the building, which the thermal-protection properties of the aggregated building envelope or shell of the building define. The specific energy consumption of heat energy for heating the building, measured in $Wh/m^2 \cdot {}^{\circ}C.day$, is defined as the quantity of heat required during the heating season for one square meter of usable floor area of the building and design values of degree-days, calculated as the temperature differences between indoor air and the average temperature of outdoor air during the heating period's duration. Evidence of the universality of this index in Russia is provided in works [6, 7].

Analysis has shown that around Russia, on average, 425 kWh/m².yr is demanded for the needs of heating residential buildings from central sources of energy, which includes 80% of buildings. If one carries this index to the average degree-day level for Russia, around 5000, then one receives 85 Wh/m².°C.day). Analogous data on foreign nations appear thus: Germany - 260 kWh/m².yr, 3163 degree-days, 82 Wh/m².°C.day; USA - 120, 2700, 44.4; Sweden 135, 4017, 33.6 respectively. It is evident that in comparison with the data for the USA and Sweden, Russia lags behind by more than twice as much.

The effectiveness of the proposed index can be shown in an example. The 9-story residential building of the 60-030 series, designed in compliance with the first stage of the SNiP II-3-79 (ed. 1995) and connected to a system of centralized heat supply in the cities of Verkhoyansk, Yakutsk, Omsk, Samara, Astrakhan, and Krasnodar, will consume heat for heating during the heating season at levels of 467, 393, 256, 195, 139, and 100 kWh/m².yr respectively, but units with degree-days, 38, 37, 39, 39, 41, and 40 Wh/m².°C.day respectively. (Table 1.) The stability of this index is evident.

Table 1

Specific Energy Consumption of Buildings q During the Heating Season. An Example for Typical 9-story Multifamily Building (60-030)

City	Specific heat energy consumption kWh/m²	Wh/(m².°C.day)
Verhoynsk	467	38
Yakutsk	393	37
Omsk	256	39
Samara	195	39
Astrakhan	139	41
Krasnodar	100	40

SNiP II-3-79 (ed.1995) - I stage of implementation

Toward the goal of defining the correspondence of the proposed norms with existing normative requirements, calculations [11] were carried out using required values for heat-transfer resistance and air-penetration of building envelopes according to the first stage of the implementation of SNiP II-3-79 (ed. 1995). Ten typical multi-story building designs were chosen for these calculations: two 5-story, three 9-story, and one each of 12, 14, 16, 17, and 22-story buildings. We received 3020 quantities for specific heat energy use. The received results were subjected to statistical analysis in an IBM computer in the following manner: An interval of 5 Wh/m².°C.day was chosen, the figures of specific energy consumption were grouped in order of size, on the basis of which was generated a histogram (fig. 1) of the distribution of the number of cases of specific energy consumption.

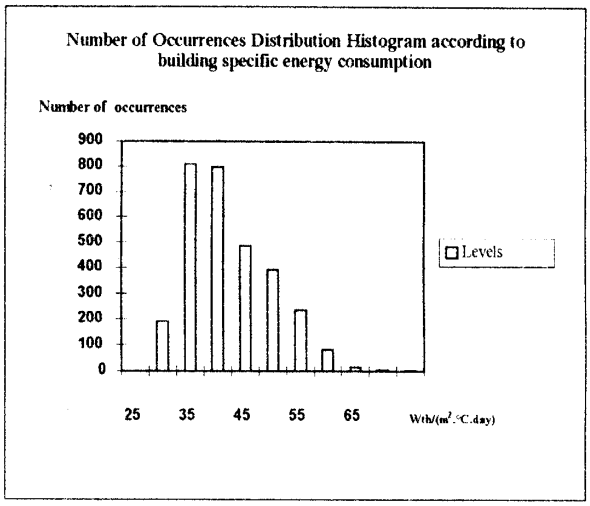
As a result of the analysis of data for buildings of different heights, values of maximum values of specific energy consumption were calculated and tested, corresponding to the first stage of implementation of thermal performance according to SNiP II-3-79* (ed. 1995) (Table 2). A building design that complies with the model Regional Standards will satisfy the requirements of the given standards if the calculated specific energy consumption during the heating period will not exceed the values of a target function. The target function based on the SNiP II-3-79* document and draft targets for heating system efficiency are shown in Table 2.

Table 2

Maximum level of building specific energy consumption q_o

Number of floors	1 -2	3 - 4	5 - 9	10 and more
Specific energy consumption $q_o <$ Wth/m².°C.day	85	70	55	50

The standard value of this target function may be established by a balance of energy resources of the region according to conditions in 1995 and forecasted conditions for 2000. The calculations are conducted according to the methodology of least-cost planning, economic impact, and technical potential of the construction industry. In connection with this, the values set forth in table 2 may be changed in the adjustment of the standard to a specific region.



In table 3, an analysis of this index is presented based on the example of three climate zones of the United States according to the data of the research of [8], conducted in 1978. The data reflect the results of energy demand in 1975-1976 in 125,000 single-family and 45,000 multi-unit buildings in three climate zones with average values of degree days equal to 3889 °C.day for zone I, 3472 °C.day for zone II, and 1667 °C.day for zone III. Just as in the conditions of Russia [7], the independence of this parameter of climate conditions of the USA is also evident.

Table 3

Specific energy consumotion for heating for the USA 3 climate zones

Type of the building	Specific energy consumption for climate zone (Wth/ m²°C.day)		
	I	II	III
Multi-flat buildings	47,1	50	49
One flat buildings blocked together	52,7	49	53,8
Individual buildings for one family	75,4	65,4	77,7

In table 4, a classification of German buildings according to energy efficiency is presented, as proposed in work

Table 4

Classification of German buildings according to energy efficiency

№	Type of the building	Specific energy consumption for heating, Wt.h/(m².°C.day)
I	Old buildings	95-126
II	New buildings according to German standarts currently in force	47-63
III	Energy effective buildings today	16-25
IV	Energy effective buildings in future	6,5-12,5

[9].

Through comparison of the proposed standards for specific energy consumption (table 2) for the model Regional Standards, it can be seen that the proposed figures have the same values as the United States and Germany. One should note that in Russia, on average, 85 Wh/m2.degC.day of energy from centralized sources are expended on the heating needs of existing residential buildings, which is somewhat better than old buildings in Germany.

The requirements for the comfort microclimate for normal human living activities, in the interior zone of occupancy as well as on its margins [10, 11], are provided for by a corresponding combination of the levels of heat energy supplied to the building and its thermal-envelope performance. Therefore the building is viewed as a single energy system, providing the specified expenditures of energy for heating while also providing for comfort conditions.

The choice of the level of energy consumption may be regulated by performance and prescriptive standards of thermal performance of the building and by the efficiency of systems of microclimate maintenance.

In figure 2 the structure of the model Regional Standard is presented. The shell of the building must be designed in compliance with:

- the general energy-consumption requirements, or either
- the prescriptive requirements for the building shell or
- the SYSTEMS approach, which integrates requirements for the building shell and systems of heat supply, laid out in article [12].

The first possibility defining requirements for the building shell, general energy-consumption requirements, is presented above. This procedure makes it possible to satisfy the requirements of the standard according to the specific energy consumption q0 when the resulting heat-transfer resistance R0r of one group of the envelope (including the separate parts of the aggregate of walls, windows, floor construction, roofing, and lighting) may be reduced (that is, may have reduced thermal insulation), as long as of another group of the envelope, including the remaining parts of the entirety of the envelope, may be improved, providing as a result equivalent overall heat losses for the whole exterior envelope of the building. The allowable reduction is limited by comfort requirements.

The prescriptive requirements for the building envelope present an easier way to achieve the required energy efficiency. If each of the different envelope components satisfies specified requirements for thermal resistance and air penetration, then the design will satisfy the requirements of this Standard. When one or more envelope components does not satisfy the element-by-element requirements, then a different possibility must be chosen.

Structure of the Regional Standards

Municipal codes: Moscow

The third possibility is simultaneous design of the building envelope and mechanical systems, where energy efficiency may be achieved by means of a balance of the level of thermal-envelope performance and heat delivery from the heating and ventilation system: either on account of the envelope of the building, or on account of those systems which compensate for excess energy losses by the efficiency of the systems.

The model Regional Standard contains requirements for the verification of energy parameters during the design and construction stages, and after a year of operation. In order to achieve these requirements, the energy parameters are documented and certified. This certification also provides the basic for establishing economic incentives based on energy conservation and of encouraging the efficient use of heat and energy resources in the construction industry at all levels. Certification can accomplish this goal in a variety of ways. First, it may be possible to establish incentives from the heat supply utility or another institution for meeting lower certified energy consumption levels. In Moscow, this incentive has taken the form of qualification for lower tariffs for efficient buildings; in California the incentive has been rebates of money from the local utility for more efficient designs. Second, if the real estate market believes the energy certification, buildings with higher certified levels of energy efficiency will be more valuable.

For the practical realization of this proposal, it is best to have a document that unites the three key aspects of implementation of energy efficiency: evidence of correspondence of the design to normative requirements, monitoring of energy efficiency in the process of construction and operation, and incentives for energy efficiency for building owners. Moreover, the most important point about implementation of energy efficiency of buildings is the assessment of a significant part of the stock of existing buildings. It is known that at present such data do not exist for operating residential and public buildings in Russia. With this goal, the model Regional Standard foresees the Energy Passport of the building, which is developed in the form of electronic tables of the software Excel. A description of the Energy Passport is given in article [14].

Existing practice of monthly payment for heat energy in residential buildings for the preceding period by municipal organs is carried out in accordance with the Methodological Instructions of the Russian Federation Committee for Municipal Affairs by means of a calculation path based on average monthly data on measured temperatures of outdoor air at a meteorological station of the region or the city. The calculation methodology set forth in the Instructions yields inflated values of heat energy (V. I. Samolyuk). An analysis of the data measured by heat meters of actual energy consumption in buildings of different regions of the country has shown that the divergence between calculated and measured values of heat demand is more than two times. Because of this, payments are made for heat energy not actually delivered. Insofar as residents, in their dependence on the region play from 25 to 40 percent for their heat energy, the remaining part is paid for from the regional budget. It is natural that municipal organs have become interested in the cessation of this subsidized part of the regional budget, and these are not small sums of money. For example, in the budget of the city of Chelyabinsk expenditure on heat energy makes up 80%.

In the model Regional Standard a calculation methodology has been developed for monthly energy consumption of operating buildings with the use of data of the regional weather station, a methodology which generates by its calculation method figures that are closer (divergence not more than 20%) to measured data. With the adoption of the Standard in the region and the use of this methodology will come very large economic savings.

A good example of the realization of proposed standards is the Moscow standards for energy conservation in buildings (MGSN) [16], adopted in 1994, where a standard for specific energy expenditures was established on the basis of the balance of energy resources of the city of Moscow, taking into account a five-year forecast by means of the American methodology of least-cost planning, taking into account the possible economic and environmental consequences and the technical potential of the Moscow construction industry. The numerical values of the standard of specific energy expenditure for heating of buildings in the course of design values of the heating season were equal to 275 kWh/m^2 for multi-story buildings and 400 kWh/m^2 for single-family buildings. On the basis of these values, for the first time in the practice of the country were established normative values for the derived coefficient of heat transfer of the building, equal to 0.7 W/m^2.°C for multi-story buildings and 0.6 for low-rise buildings with efficient insulation.

The developed standards called for structural overhaul of the construction industry of Moscow as a means of transition to the construction of buildings with efficient thermal-insulation materials and to the current time, a positive experience of implementation has been received. In each Homes Manufacturing Combinat (abbreviations in Russian DSK) of Moscow, measures were adopted at various respective times for transition to building envelope components with improved thermal-performance characteristics. In particular, DSK-4 in the construction of wall panels for the PD-4 building, changed over to three-layer panels. DSK-1 began to produce experimental three-layer panels, also in compliance with MGSN. For DSK-3, one-layer panels were developed with the use of porous keramzit-vermiculite concrete. In the Moscow region of Zhulebino the construction of cottages with lightweight panels from peno-polystyrol concrete has begun. Also in Zhulebino, construction is being completed of three low-rise residential buildings with the use of exterior insulation from mineral wool.

Analysis has shown that the transition to multi-layer construction is doubly profitable if one compares the thermal-performance characteristics and the current Moscow prices of materials for one square meter of wall, produced according to the former and current Moscow standards. In the case of transition to multi-layer construction with efficient insulation thermal performance is increased two times in comparison with single-layer walls, and the cost of consumed materials in this case is lowered by almost two times.

A method has been approved for the raising of funds in regional for the implementation of regional standards. For example, in Tula, on the basis of the federal law on energy conservation, with the goals of raising the efficiency of the use of heat and energy resources and of creation of necessary conditions of transfer of the regional economy to an energy-conserving development path, a program of work has been developed for energy conservation. In accord with this plan shares of the energy-conservation complex were issued. The means from the sales of these shares were directed to work on energy conservation and in particular, were directed to two reinforced-concrete plants for transition to production of three-layer panels with improved thermal performance.

In conclusion, one should note that the authors propose two chief advantages of the proposed standard that are most important for regions:

The first advantage lies with standardization of the energy-consumption properties of the building. This advantage makes it possible to achieve a reduction in energy consumption, using various technical possibilities such as improvement of building-envelope performance as well as the improvement of heating and ventilation systems. The envelope improvements, especially, increase comfort for the residents. And full implementation of the efficiency improvements will better match the capacity of the heat supply system and its fuel to the demand, reducing or eliminating underheating in the middle of winter.

The second advantage consists of the use of the energy passport of the building. This advantage makes it possible to calculate more precisely the monthly energy consumption of an operating building, from which the outlays for the consumption of heat energy are generated.

The authors have much experience in the development of regional standards and offer their collaboration to regions for the development of draft regional norms and standards for thermal performance of buildings and systems for their heat supply. These regional standards may be developed as a response to the Russian Federation law "On Energy Conservation" under the general name "Energy-Efficient Buildings".

The use of regional standards offer energy savings in regions of up to 40-50% and bring about up to a 40% savings in budget resources in comparison with existing levels, for the subsidization of heat energy.

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КОМБИНИРОВАННОЕ ПРОИЗВОДСТВО ЭЛЕКТРИЧЕСТВА И ТЕПЛОТЫ В МАЛОЙ ЭНЕРГЕТИКЕ - ВЫСОКОЭФФЕКТИВНОЕ НАПРАВЛЕНИЕ СОВЕРШЕНСТВОВАНИЯ ЭНЕРГОСНАБЖЕНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ

При развитии общей энергетики, теплофикации и централизованного теплоснабжения в СССР и за рубежом считалось, что одним из главных преимуществ создания мощных централизованных энергосистем, кроме экономии топлива за счет высокого коэффициента полезного действия крупных паротрубных электростанций (ПТЭС) и теплоэлектроцентралей (ТЭЦ) и их работы в базовом режиме, является возможность эффективного использования твердого топлива с минимальными затратами ручного труда при его сжигании с очисткой дымовых газов и уменьшением загрязнения окружающей среды.

Вместе с тем, в современных условиях по экологическим требованиям, сложности и высокой стоимости перевозки угля, для большинства регионов Европейской части страны основным топливом стало газообразное и частично жидкое. В этих условиях, учитывая и низкую надежность централизованного энергоснабжения из-за износа его основного оборудования и теплотрасс, все большая роль отводится малой энергетике (МЭ) на основе традиционных энергоисточников, работающих на газообразном и жидком топливе с достаточно высоким КПД, вне зависимости от агрегатной мощности.

Малая энергетика РФ - это около 50 тыс. дизельных электростанций (ДЭ), приблизительно 180 тыс. котельных (КУ) и несколько тысяч малых гидравлических, геотермальных станций, ветро-, гелио- и других нетрадиционных источников. Традиционные энергоисточники (ДЭУ и КУ) малой энергетики потребляют при этом ежегодно более 150 млн. т у.т., вырабатывая на ДЭС 45 млрд.