The Fruit Has Ripened: Energy Code Implementation and Market Transformation at the Federal and Regional Levels in Russia

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ABSTRACT

This paper reports on new developments in the implementation of regional and federal building energy performance codes in Russia. Since mid-2000, the number of regions with codes has more than doubled: now more than thirty regions have adopted codes and have received registration by federal officials. These regions have a collective population of more than 60 million people, and together account for some 70 percent of Russia's new construction and renovation. Buildings built in compliance with new codes consume forty percent less energy for heating than minimally code-compliant buildings built before 1995.

Almost all Russian regional codes are based on the same model code, developed by the authors and other Russian and American colleagues. The regional codes embody essentially the same energy-performance requirements, normalized per degree-day in the heating season. The regional codes do vary from each other in a number of ways, reflecting economic conditions, construction-industry particularities, and policy priorities.

The onset of codes has yielded significant market transformation, as new requirements have prompted manufacturers to develop new generations of advanced walls and windows. New technologies include porous lightweight concrete for one-layer walls, porous hollow bricks, and exterior insulation. The Russian market has also been witnessing ongoing advances in fenestration, including increased use of vinyl frames and selective coatings.

Introduction

The development of new building energy codes in Russia has been a long, complicated, and labor-intensive process. The development of building energy codes in Russia over the past decade may be divided into four stages, which reflect various degrees of implementation of a compliance approach based on whole-building energy performance.

Prescriptive codes are the *first* stage. In this stage, codes set requirements for the thermal resistance of exterior building envelope elements. Falling short of the requirements is not allowed. Whole-building energy performance is not considered. Federal Russian codes on thermal performance of buildings in force before 1995 (the code entitled "Thermal Engineering") followed the prescriptive approach. The code-stipulated levels of thermal performance in buildings failed to meet more ambitious energy-conservation policy objectives.

The *second* stage is the first step in the integration of the performance approach. In this stage the code sets requirements for the *average heat-transfer coefficient of the whole building envelope* under steady-state conditions of heat transfer. The first code in Russia to use this calculated average heat conductivity coefficient of the whole building as the key compliance parameter was the 1994 Moscow city code for energy conservation in buildings (MGSN 2.01-94 Energy Conservation in Buildings). This code also constituted an important step in the direction of energy efficiency – it provided for a 20-percent reduction in energy consumption per unit of newly constructed floor area, relative to pre-code levels.

In the *third* stage, codes set limits on the *total energy demand for heating during the heating season*. Compliance is based on calculated whole-building heat energy requirements. The methodology for codes in this stage and the ensuing fourth stage, as well as the model regional code developed for the regions of the Russian Federation, was developed by a team of Russian and American specialists (Matrosov and Goldstein 1996; Matrosov, Chao, and Goldstein 1998).

Based on this methodology, major revisions to the federal thermal-engineering code for buildings were developed and entered into force in 1994-95, providing for a 40 percent reduction in energy consumption for buildings built and renovated starting in 2000, in comparison with 1995. As a result of this code, a number of energy-efficient technologies new to Russia were introduced. Note, however, that although whole-building energy analyses were used in developing these revisions, the code itself reflects the first stage, since there is no performance-based compliance path for users.

Specific energy demand for heating was first introduced in 1994 in the Moscow city code, where the parameter was used as a checkpoint by plans examiners. In the new edition of this code in 1999 (Matrosov, Butovsky, and Goldstein 1999), this parameter became a required element of compliance; the code sets limits on specific energy demand for heating, and provides a detailed algorithm and computer code for performing compliance calculations. All Moscow construction is now being carried out in compliance with the 1999 code.

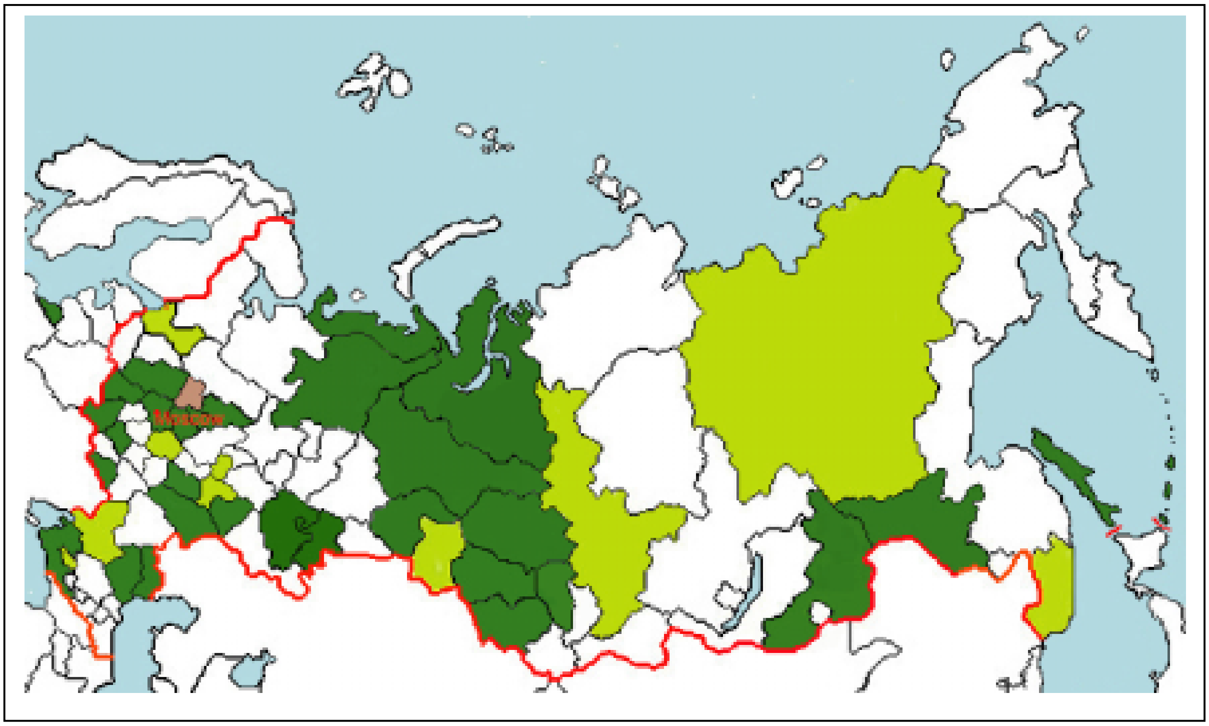
Furthermore, the new federal code “Single-Family Homes” from 2001 uses the parameter as an alternative compliance path. A different new federal code document – the code of practice (or guidance manual) “Building Thermal Performance Design” — contains an officially required Energy Passport (energy performance statement) and an algorithm for calculating whole-building heat energy requirements.

And finally, in the *fourth* stage of integration of the performance approach into Russian codes, requirements for the thermal performance of the building and for the efficiency of the heat supply system are unified by *limits on the primary fuel used to heat the building*. An analogous methodology has already been in use in the United Kingdom, France, Italy, and Germany; now, this approach is prevalent among Russian regions with their own codes, except Moscow.

Results of Implementation of Regional Codes in Russia

Regional codes have met with huge success in Russia — and their impact continues to ripple through the country. From 1999 to 2002 more than 30 regional codes have been adopted in Russia, from the Kaliningrad Oblast to the west and the Sakhalin Oblast in the east, and from the Krasnodar Kray to the south up to the Nenets Autonomous Region to the north, with a total population of more than 60 million people. See Figure 1 (Matrosov, Butovsky, and Goldstein 2000). Normalized per degree-day, the regional codes across Russia embody essentially similar requirements (see Table 1). All the regional codes have been approved by the heads of regional government, entered into force in these regions, registered by the Russian State Committee on Construction with assignment of a registration number, and included in the official list of code documents, in force on the territory of the Russian Federation. No fewer than 70 percent (and in some regions, such as the city of Moscow, 100 percent) of newly built and renovated buildings are being designed and built in accordance with these regional codes.

Figure 1. Drafting and Adoption of Regional Energy Codes in the Russian Federation



Note: Regions with dark shading have adopted codes. Regions in light shading have completed final draft codes, which are now awaiting approval.

Table 1. Maximum Allowed Energy Consumption for Heating(q_h^{req}), kJ/(m^2·°C·day) [kJ/(m^3·°C·day)], Over the Heating Season

Types of buildings	Number of stories				
	1-3	4-5	6-9	10-12	More than 12
Residential	115	85	80	75	70
Office buildings	[32]	[27]	[23]	[21]	[20]
Education facilities	[36]	[30]	[29]	[27]	[25]
Medical facilities, clinics, and long-term care	[34], [33], [32]	[31]	[30]		
Pre-schools	[45]	--	--		

Note: Values for q_h^{req}, kJ/(m^3·°C·day) are shown in square brackets. Building types to which these values apply often have tall windows and high ceilings because of increased natural-light requirements; thermal-performance requirements are therefore normalized per unit of building volume, rather than floor area.

The Moscow code provides some perspective on the energy-conservation impact of new codes in Russia. Applicable to all new construction and major renovation of residential buildings in Moscow, the code has covered about 3.2 million square meters of floor area per year since it entered into force; last year construction volume was 3.8 million square meters, and in the current year, 4.2 million square meters are planned. Construction in compliance with the code in Moscow has led to the cumulative savings of heat energy of more than one TWh (which makes up 4 percent of overall heating energy demand of the city), and has reduced carbon dioxide emissions by 120,000 tonnes for each year's stock of new and renovated buildings.

Table 2 shows figures for heat energy demand for representative building designs implemented widely in Moscow, which meet the requirements of the regional code. More than a million square meters of floor area has been constructed in Moscow based on these designs. The cost of a square meter of the modernized P44T and P3M series is about 5 percent higher than their predecessor series P44 and P3, which were developed in compliance with the code in force prior to 1995. The Russian government council that awards prizes in science and engineering honored the modernizing of the P44T and P3M series in 2001.[1]

Table 2. Calculations of Energy Consumption for Heating for Representative Buildings in the City of Moscow

Series	Number of apartments	Specific energy consumption for heating, MJ/m^2 (per heating period)	
		Calculated	Required by code
P44T/17	272	342	342
P3M-1/17	264	317	342
P3M-4/17	408	310	342
P55M/14N1	181	335	342
P3M-4.9	216	335	396
P46M/9	125	392	396
P46M/5 8 sections	108	439	468

[1] Building series numbers in Moscow designate types of buildings and the identity of the wall-panel prefabrication plants that produce them. For all these series numbers shown, "P" means that the building is made from precast concrete panels. Numbers after slashes in Table 2 designate the number of stories.

How Do Regional Codes Differ from Each Other?

Although Russian regional codes have all been developed from the same model, follow the same basic principles, and embody essentially similar energy-performance requirements when normalized per degree-day, they can still differ substantially from each other.

The first area of variation involves climate data and outdoor air parameters.

The second area of variation is in the contents themselves, since some regions wanted to develop sections in their own codes, dealing with energy efficiency in domestic hot water systems, district-wide heating and water supply, electric supply, and electric equipment. Examples of such codes include TSN 23-304-99 of the city of Moscow, TSN 23-306-99 of the Sakhalin Oblast, and TSN 23-328-2001 of the Amur Oblast. *(Ibid.)*

The third area of variation is in the boundaries, for which the required energy-demand values are set – at the site of primary fuel consumption (for example, a district heating plant, or in the case of electric heat, the power plant), or at the building. In both cases the calculation of specific energy demand for heating is carried out for the building, with subsequent adjustments for calculations of primary fuel use, as necessary.

The fourth area of variation is in requirements for building envelope elements, which satisfy calculated federal prescriptive requirements. This area allows for the possibility of accounting for the particulars of the regional construction industry and local products. Several regions have developed recommendations on selection of insulation levels based on economic criteria (TSN 23-305-99 of the Saratov Oblast, TSN 23-318-2000 of the Republic of Bashkortostan.

The fifth area of variation lies with sample calculations. Sample calculations and Energy Passports may be provided for typical multi-family and/or single-family buildings in the region.

The sixth area of variation is in fire-safety requirements.

The seventh area of variation is in required performance levels. For example, TSN 23-323-2001 of the Khanty-Mansiisk Autonomous Region, starting in 2003, has established required levels for specific energy consumption for heating that are 20 percent more strict than those shown in Figure 2. This is for now the only case where the administration of a region has on its own initiative decided to achieve greater energy efficiency in buildings than in other regions.

New Technologies Emerging in Response to Federal and Regional Codes

Stringent energy-performance requirements require the use of efficient thermal insulation materials. The demand in the Russian residential sector alone for thermal insulation materials is projected to reach 25-30 million cubic meters by 2010. Mineral wool is the most widely used type of insulation, with more than 65 percent of the Russian market, followed by synthetic foam at 20 percent, fiberglass at 8 percent, and thermal-insulating concrete at no more than 3 percent. Demand for thermal insulation products has stimulated a competitive market on the supply side, but high customs tariffs and transport costs have caused market expansion to be restricted to in-country Russian production only.

Two examples are most revealing. The first is a Russian-German factory called URSA, run by an open joint-stock company called Pfleiderer-Chudovo, that manufactures thermal-insulation products made of glass-staple fiber. Located not far from St. Petersburg, the plant uses equipment and technology from the Pfleiderer company. Products from URSA are being used mostly for attic insulation. The second is a Russian-Danish factory not far from Moscow, run by the closed joint-stock company Rockwool Russia, which makes insulation from basalt rock. Rockwool products are used mostly in exterior wall systems. All products of these factories are certified, based on design heat-conductivity coefficients.

While there have emerged no difficulties in meeting new regional code requirements in the design of roofs and attic ceilings, new requirements for exterior walls have been met only through the development of major new design approaches. Obviously, from a thermal engineering point of view, there are significant differences among the various types of walls: single-layer, triple-layer with insulation in the middle, and two-layer with insulation on the outside. The possibility for the use of one or another type of building elements is limited by the greatest number of heating degree-days for which a given element provides the necessary thermal performance at a prudent thickness level.

According to the data of the Russian State Committee on Construction, 72 percent of Russian enterprises produce wall elements and materials that comply with increased performance requirements of the latest federal prescriptive codes. In the different regions of Russia, the compliance rate is significantly higher: in the Northwest, 89 percent; in the Central, 82 percent; in the Volga region, 86 percent; and in the Urals and the Far East, 77 percent. There are also those that lag behind — for example, the North Caucasus, at 44 percent. Different construction types also show variation in compliance rates: 68 percent for the building envelopes of fully prefabricated buildings, 87 percent for those made of bricks or other small blocks, and 92 percent for buildings made with frames or mixed systems.

New technologies for the creation of external walls have begun to see wider use: light or porous concrete for walls of buildings with frames made of reinforced concrete, three-layer load-bearing panels with flexible fiberglass and metal ties and an insulation layer of polystyrene inside, bricks made of "warm" porous ceramics, and facade systems with two-layer walls with insulation on the outside.

For modern energy-performance requirements it is most appropriate to use walls made of porous concrete blocks, prepared via various technologies. Where the density of this material is not greater than 500 kg/m^3, with a thickness of 500 mm and a heat conductivity not greater than 0.15 W/(m·^{o}C) the material may be used in regions with up to 6000-6500 heating degree-days. The expansion of the area of use of porous concrete materials into regions with more than 6500 heating degree-days is also possible, but only with an increase in wall thickness up to 700-750 mm.

The production of structural insulating blocks of porous concrete is located in the Tobolsk, Orenburg, and Golitsin factories, the Kaluga Building Construction Plant and others, and blocks from especially light concrete mixed with polystyrene beads (with a total density of 150-550 kg/m^3) are at 10 enterprises of the construction industry.

For single-layer walls, it is also appropriate to use different concrete materials with a density not greater than 600-700 kg/m^3 (light concretes, foam concretes and so on.), but their use in walls with thicknesses of 500 mm or less is limited to regions with 2000 heating degree-days or fewer — that is, southern regions.

The use of new light concrete products necessitated the development of new design and construction approaches for multi-story buildings - the establishment of a reinforced-concrete frame for the building, the erection of load-bearing walls made of light concrete resting floor by floor on the horizontal ceiling elements, with essential protection against outside atmospheric influences (facings made of brick, a plaster layer, and the like). Under this approach it is critical to select the correct type of facing. Its vapor permeability must not be less than the part of the wall made of light concrete, but its water-repellency must reliably protect the porous light concrete wall material from exposure to moisture.

Such design and construction approaches have found widespread use in the Yaroslavl, Samara, Orel, and other oblasts, and also in the city of Moscow.

Development and implementation of new technology is also proceeding in a traditional sphere — brick manufacturing. So it is, for example, at the factory of the closed joint-stock company Victory Knauf, which has been built in Russia thanks to the investment of the Knauf company. This plant has mastered the production of hollow bricks made of a porous ceramic material; production in 2001 reached almost 40 million bricks (based on standard brick measures). A wall made of these bricks is laid with conventional masonry techniques with a facing made of regular bricks, and are joined to each other by anchors made of stainless steel. According to the firm, the thermal resistance of such a wall is 3.19 $m^2 \cdot {}^oC/W$, which permits their use in regions with as many as 5100 heating degree-days, as in the central region of Russia.

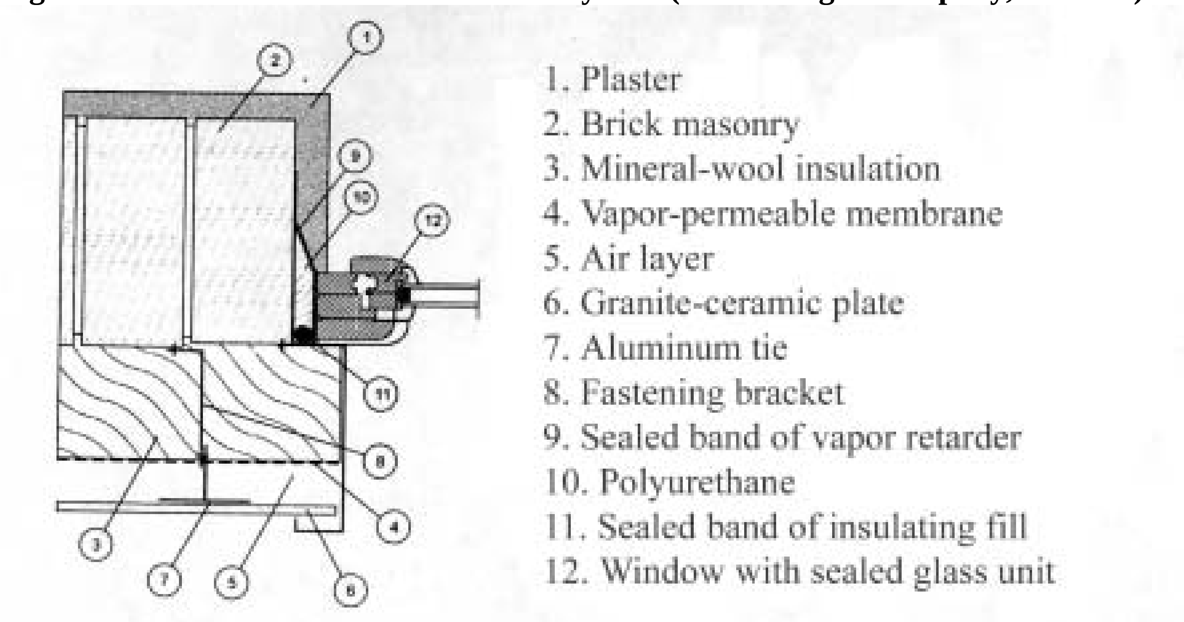
Wall systems with exterior insulation have an array of real advantages — high thermal homogeneity, amenability to convenient repair, variety of architectural options for façade design, and suitability for thermal upgrades to existing walls. Essentially, two variants of this system are used: *the first variant* is a system with a plaster layer; *the second variant* is a ventilated façade system with an air layer between the insulation and the protective outer layer of the wall.

The first variant is based on the use of insulation material that complies with special requirements, with a thickness up to 150 mm for mineral wool batts and up to 250 mm for polystyrene plates, affixed to the wall with rivets made of steel thrusts and polyamide braces. The insulation is protected from external atmospheric effects by an undercoat of adhesive, which in turn is shielded by a fiberglass net, and by a decorative outer layer (plaster or paint). One peculiarity of the first variant is the necessity of the use of safe, durable, and compatible elements, which prevent the partial or complete cracking or rupture of the insulation layers of building facades. In this light, materials, components, and products used all must undergo an engineering assessment of their suitability.

A system with the commercial name Dryvit has become widespread in Russia, produced by the manufacturer Infokosmos, with the use of Tigi-Knauf polystyrene plates or Rockwool batts as insulation. However, for certain regions this system has turned out to be very expensive. At outdoor air temperatures of -5 ºC and lower, to make installation of external insulation possible, it was necessary to create temporary heated enclosures and to make additional outlays for extra heating. The development of a cheaper system was necessary, to allow for wintertime work to proceed normally. A successful example is the "Shuba Plus" ["Fur Coat Plus"] system, developed in the city of Yaroslavl by the Everest company, which has received technical certification from the Russian Ministry of Construction. At present 20 foreign and Russian firms have passed necessary testing requirements and already possess technical certifications from the Construction Ministry for field application and are working in various regions of the country with up to 6000 heating degree-days.

The second variant differs from the first in that the thickness of the insulation (stiff mineral wool panels, also affixed to the wall with rivets) is not limited. But the insulation layer is protected by an outer surface layer made of various materials, installed on light metal elements (steel, aluminum alloy, or a combination) attached to the wall.. In addition, the insulation is protected by Tyvek film, which is added either at the factory or at the construction site. Moreover, there is a very small air space (thickness of 60 mm) between the outer surface layer and the insulation; the movement of air in this layer keeps the insulation dry (see Figure 2).

Figure 2. Ventilated External Insulation System (Stroitransgaz Company, Moscow)



The safety and durability of this variant depends on many factors, including providing for required anticorrosion protection for the metal rivets and their joints. In Moscow, for example, corrosion of a zinc roof occurs at a rate of about 5-7 μm per year.

Where rivets 400-450 mm in length are used to affix the mineral wool plates to the wall, variant 2 may be used in regions with up to 9000 heating degree-days.

Systems with external insulation are being implemented in the majority of buildings being built with a reinforced concrete frame, as well as in renovated buildings made of concrete panels or bricks.

At present, 22 organizations have received technical certifications for ventilated façade insulation systems and 12 organizations have presented the State Committee on Construction with materials for testing the suitability of the system.

Windows provide another example of the proliferation of new technologies. The new generation of windows is based on the use of one-and two-chamber sealed glass units, the use of which has made it possible to achieve a real increase in energy performance relative to previously available products. The use in sealed glass units with selective coatings increases thermal resistance of windows to as high as 0.6 to 0.65 $m^2 \cdot {}^oC/W$. Thanks to the transition to windows with vinyl or wood-and-aluminum frames, airtightness problems have also been appreciably reduced.

In 2000, about 8 million square meters of windows were produced in Russia; of this quantity, about 4.8 million had wood frames, 2 million vinyl, and 1.2 million aluminum. The construction volume of windows has persisted through 2001. In vinyl- and aluminum-framed windows, only sealed glass units are used. Thus, close to 40 percent of windows produced in Russia embody new technologies. However, the incorporation in Russia of high-performance vinyl-framed windows has led to an array of problems in thermal-engineering design of the facades of buildings and in actual installation of windows into wall openings. Other problems are linked to insufficient consideration of air-infiltration requirements. In such cases, humidity levels may rise, leading to the formation of mold and mildew on interior building-envelope surfaces.

Special systems, which provide for a controlled flow of air through the occupied areas of residential buildings via natural ventilation, are rapidly filling a niche in the Russian market. Among the best performers in this area are special automated, acoustically insulated intake structures mounted directly on an airtight vinyl-framed window. These structures provides for an automatically regulated quantity of fresh and dry air to enter, controlled by humidity sensor in the living space, thus solving the problem of increased indoor humidity. As a rule, foreign firms, such as the French company Aereco, make such equipment, but Russian research and development is also occurring in this area.

Regarding new architectural approaches and building geometry, the regional codes have stimulated design and construction of wider, more compact buildings. Instead of previous designs that called for building widths of 11.5-12 m, buildings 22-24 m in width have become more widespread. Solely by virtue of geometry, these buildings may achieve a 40 percent reduction in energy consumption. These buildings are being introduced in the city of Moscow and in the Orel Oblast.

A draft of a new federal code, "Energy-Conserving Thermal Performance in Buildings," has been developed based on mounting experience with regional codes. In the new code, the thermal-performance level of the heated building will be defined based on a fundamentally new parameter: the specific demand for heating the building, per degree-day in the heating season. These requirements are being established on the basis of calculations of model buildings, designed in compliance with the second stage of energy-conservation levels contained in energy codes in force now. If energy-saving opportunities unavailable under previous codes are used (such as the influence of building geometry, accounting for natural and forced ventilation, internal heat gains, solar radiation, the degree of controls in heating systems, and so on) then the requirements for the thermal performance of individual building elements may be loosened somewhat, relative to the requirements of the second stage of the current code. In the end, the same energy-saving result will be achieved by virtue of improved building design, and the building designer will have more freedom to choose among various options in thermal-engineering design. Regions with new codes are using actual building designs as a preliminary basis for setting and refining their code requirements.

More information in English may be found by visiting http://www.cenef.ru/, at the section on "Energy-Efficiency Standards and Certification."

Conclusion

In conclusion, we note that:

- a new principle of building codes, based on the integrated parameter of specific energy demand by the building over the heating season, which grants significant freedom in the selection of design options and makes possible the monitoring of energy consumption during building operation, has for the first time been successfully applied in more than 30 regional government entities in Russia, and is contained in the new draft federal code for energy conservation and thermal performance of buildings.
- new code requirements have stimulated regional industries to produce new advanced construction materials and products comparable with those elsewhere in the world, and, in particular, to improve the production of high-quality efficient insulation, energy-efficient building envelope elements, and new types of energy-efficient windows.
- analysis of new building-envelope designs representing the newest technology, including external insulation systems, ventilated envelopes, three-layer panels with flexible ties, and the cumulative experience of regions in developing these new approaches in actual practice, confirm that these codes are being manifested in real buildings.

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