Forty-Percent Savings and Beyond: Recent Advances in Code Implementation and Development of Super-Efficient Buildings in Russia and Its Neighbors

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ABSTRACT

The Russian Federation, the Republic of Kazakhstan, and Ukraine continue to make important advances in implementation of energy codes, market transformation, and design innovation in the building sector. Since 2003 Kazakhstan and other CIS[1] countries have been explicitly following Russia's lead in moving to adopt and implement energy-saving building codes. This paper begins by summarizing new developments, including passage and implementation of new codes and an ambitious incentive program in Moscow.

Now Russia and CIS countries are looking beyond their current building codes. Environmental sustainability has become a high-priority goal, as strongly articulated in policy documents of Russian agencies, most notably the Russian Academy of Architectural and Construction Sciences. Pursuit of this goal is taking several forms, including integrated planning of buildings and utility systems; development of new codes; research and investment in new technology; and the launch of a new initiative to develop experimental comfortable energy- and resource-minimizing residences (known by the Russian acronym as "KERM houses"), which would consume one-third to one-half the energy of buildings built in compliance with 2001 codes.

Recent Advances in Building Energy Codes

Russia and Kazakhstan

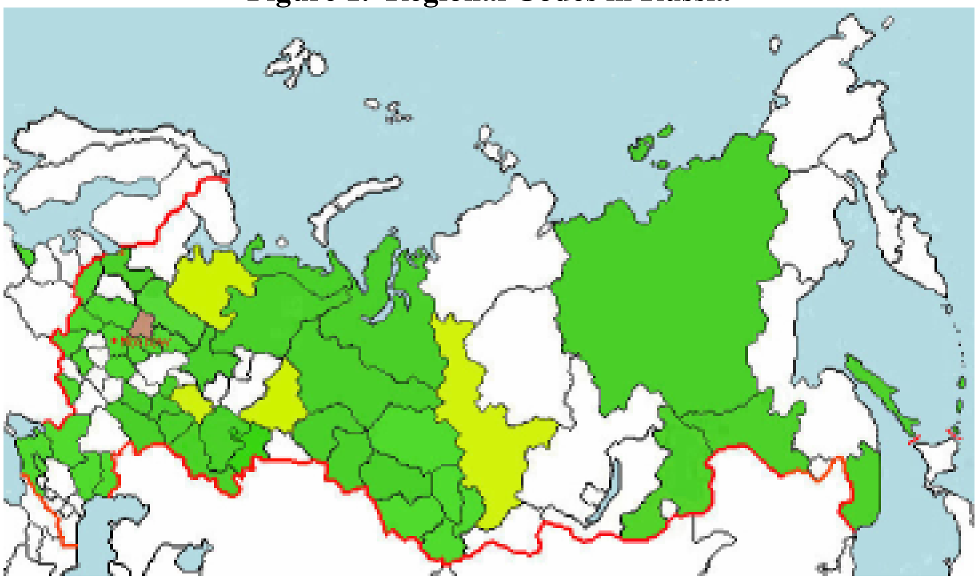
Since 1994, new building energy codes have been spreading across the Russian Federation and the Republic of Kazakhstan. These new codes are predominantly based on a model code developed jointly by the Center for Energy Efficiency (CENEf), the Research Institute for Building Physics (known by its Russian initials as NIISF), the Institute for Market Transformation (IMT), and the Natural Resources Defense Council, under the support of the U.S. Environmental Protection Agency (EPA). These new codes and the model code apply to all new construction or major renovations of residential and commercial buildings. This trend has culminated in the entry into force of the following codes predominantly based on the model code.

- New performance-based regional codes in 53 provinces (oblasts and krays) and autonomous republics of the Russian Federation (adopted 1994-2005);

[1] "CIS" is an abbreviation for the "Commonwealth of Independent States," an association of former Soviet republics that was established in December 1991 to help ease the dissolution of the Soviet Union and coordinate interrepublican affairs.

- A new performance-based federal code applicable across the whole Russian Federation (adopted 2003); and
- A new performance-based federal code in the Republic of Kazakhstan (adopted 2004).

Figure 1. Regional Codes in Russia



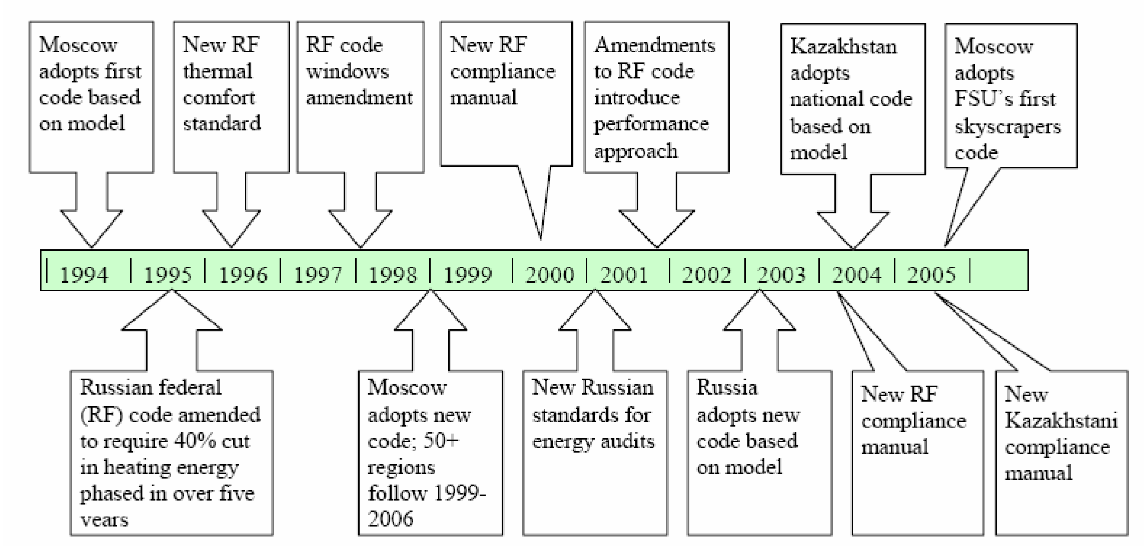
Note: Regions that have adopted codes show dark shading;
those with codes undergoing final editing show light shading.

The new codes are accompanied by various technical standards and compliance guides for building designers. Figure 2 summarizes the chronology of new codes and accompanying documents in Russia and Kazakhstan.

The new federal and regional building energy codes in Russia and the new federal code in Kazakhstan require approximately 40-percent reductions in energy consumption for heating compared to existing buildings built under previous codes. The new codes require efficiency comparable to western European codes (Matrosov & Goldstein, 2005). Required performance levels are set for various building categories based on number of stories, building type, floor area, and heating degree-days. These stipulated levels are determined based on calculation models for typical buildings designed with materials compliant with prescriptive requirements. The same algorithm is used to calculate performance of the actual building being designed. Designs whose calculated energy consumption exceeds code-stipulated levels are not granted permits.[2] Calculated consumption is recorded in a code-stipulated document standard known as the Energy Passport.

[2] In May 2006, the head of the city of Moscow's building plan review office personally communicated to the author that his office is now rejecting about 15% of all permit applications for this reason and that the rejection rate has gradually fallen to the current level from about 25% a few years ago.

Figure 2. Timeline of Building Energy Codes and Standards



Progress Toward a New Code in Ukraine

As of spring 2006, Ukraine too is rapidly progressing toward a new national code for energy efficiency in residential and commercial buildings. This process is under the direction of the Ukrainian Ministry of Construction, Architecture and Communal Residential Services and Ukraine's Institute for Building Construction. CENEf, NIISF, and IMT, under the support of the U.S. EPA, have offered consultation and training to assist this process.

Ukrainian authorities have integrated many of the resulting suggestions into the draft code. Because of these recommendations, the new Ukrainian code is expected to include a performance-based compliance option, a calculation methodology similar to that of the Russian and Kazakhstani codes, energy-performance rating systems, and an Energy Passport documentation system. Expected energy savings relative to existing building stock will be about 40 percent, as in Russia and Kazakhstan.

The Ukrainian Ministry is currently taking account of expert recommendations, with plans to upload a final review draft to the website of the Ministry for public discussion. This step is planned for April 2006. After this, the draft should be presented for discussion and adoption in a special technical session of the Ministry. The Ministry plans to finish this process in July 2006.

Seven CIS Countries Move to Adopt the Russian Federal Code

On September 20, 2004, the CIS's Interstate Scientific-Technical Commission on Standardization, Technical Norms and Certification in Construction voted to adopt the Russian Federal building energy code as an "Interstate Building Code." Seven CIS countries participated: Russia, Kazakhstan, Armenia, Tajikistan, Kyrgyzstan, Moldova, and Uzbekistan. The latter five must each must take further action to officially adopt the code but the vote was an important step toward that goal.

Improvements in Moscow's Building Code

The city of Moscow, where approximately 11 percent of new residential construction in Russia takes place, has drafted revisions to its own city energy code, MGSN 2.01-99*. It is expected to officially adopt the changes this year and many of the changes have already been made administratively. Revisions include new tables of input data for degree-days and solar radiation; new tables of requirements for whole-building energy performance (including a 12-percent reduction in allowed energy consumption by buildings 4-5 stories tall, relative to the prior edition of the code); new requirements for thermal resistance of individual building-envelope elements; a new section on increasing energy efficiency of existing buildings; and appendices on verification of energy performance of buildings entering into operation, including selective thermographic assessment and testing of air infiltration of noncompliant buildings.

A New Code on Skyscrapers in Moscow

NIISF has drafted two chapters and three sections of supplemental information regarding thermal performance and related energy and indoor-environment issues to a new Moscow code on skyscrapers, MGSN 4.19-05, entitled "Design of Multifunctional High-Rise Buildings and Building Complexes in the City of Moscow." This document is the first of its kind in the former Soviet Union. Its requirements have already been applied to the design of 16 high-rise buildings. It was also used in the design of a four-building complex of skyscrapers in Astana, the capital of Kazakhstan; in the case of these buildings, use of the Moscow code material and approaches has resulted in a design plan that calls for energy performance that beats Kazakhstani code requirements by at least 10 percent.

Estimated Energy Savings to Date from New Codes

The onset of new codes and accompanying market transformation are especially timely given recent rapid growth in construction volumes in the former Soviet Union. In Russia in 2003 housing starts totaled 36 million square meters, in 2004 41 million square meters, and in 2005 almost 44 million square meters – see table 1 (Yakovlev 2005). All the new construction referenced above is subject to the new codes. (For comparison, Russia's existing housing stock as of spring 2006 is about 2.8 billion square meters according to Russian government figures.)

Table 1. Volumes of Residential Construction 2002-2005, Thousand Square Meters

Type of building	2002	2003	2004	2005
Multifamily	19,566	21,092	24,854	26,038
Single-family	14,210	15,174	16,145	17,571
Total	33,776	36,266	40,999	43,609

Ukraine's residential construction volume in 2005 was at about 15 percent of Russia's according to figures from the two governments. In Kazakhstan in the five months from January through May 2005, 8,794 buildings with a total area of 1,951,400 square meters were built. The vast majority of that construction (1,609,500 square meters) was residential (Datacom LLP 2006).

With the growth of residential building stock, there has been an inevitable growth in energy consumption for heating. The concurrent development of the new generation of energy-conservation codes has slowed this growth. Between 2002 and 2004 annual consumption of fuel for the generation of heat in Russia only grew by 116 petajoules (PJ), compared with a baseline growth of 181 PJ had buildings been constructed in accordance with prior codes. Over the period from 2002 to 2005, the overall energy savings totaled more than 215 PJ. These energy savings have led to an almost 15-million-tonne reduction in carbon dioxide emissions. In the period from 2002 to 2010, the cumulative reductions are anticipated to rise to almost 1,200 PJ and more than 80 million tonnes of carbon dioxide in Russia alone.[3] This curtailment of emissions of greenhouse gases into the atmosphere is particularly important given Russia's adoption of the Kyoto Protocol in February 2005.

Trends in Approaches to Performance-Based Compliance

Whereas previous codes were purely prescriptive, the new codes in Russia and Kazakhstan introduce a performance-based compliance option, in which designers meet a specified whole-building target for specific energy consumption by whatever means they wish, subject to minimum comfort requirements. The onset of the performance approach in codes has meant that designers have free hands to design buildings with greater creativity and expanded flexibility to seek cost-optimal solutions, while still attaining energy performance equivalent to prescriptive requirements. While it has not been feasible for us to collect and analyze large numbers of building designs to quantify trends in compliance approaches, still we can confidently offer our sense of preferred methods, based on a number of actual building designs.

Building geometry. Unlike American performance-based codes, the Russian and Kazakhstani codes present a fixed budget for energy consumption for heating per unit of occupied floor area, not a custom budget based on the building location and overall footprint and dimensions. This means that building designers in Russia and Kazakhstan can reduce energy consumption not only by choosing high-performance materials and building elements, but also by designing wider buildings with relatively low surface-area-to-volume ratios. Thus, for example, buildings developed by the Russian Academy of Architecture and Construction Sciences with a widened frame lead to an 18-20 percent reduction of energy consumption while still maintaining indoor comfort conditions.

Windows. In many regions, multifamily residential buildings are still made almost entirely from concrete wall panels prefabricated at factories dating back to the Soviet era. Retooling of these plants to generate more efficient panels has been happening in some areas, with some success, but in many others, technical and financial barriers limit the wall-panel plants to continued

[3] These figures conservatively count only residential construction volumes and do not include commercial construction, which is also subject to the new codes. Carbon dioxide calculations use the following coefficients: natural gas 50 tonnes CO_2/terajoule (TJ), heavy oil [mazut] 77.3 tonnes CO_2/TJ, and coal 99.1 tonnes CO_2/TJ. Russian thermal stations and boiler plants' weighted fuel mix is about 50% natural gas, 30% heavy oil and 20% coal. Most Russian buildings rely on district heating. Based on limited field tests, we assume a 50% average energy efficiency of these centralized systems of heat supply. The 2010 savings are conservatively estimated based on the current heating fuel mix and the growing residential construction volumes in the above cited Russian government projections. The authors' last ACEEE summer study paper (Matrosov, Chao, Goldstein & Majersik 2004) describes the estimation methodology.

production of less thermally-efficient products. The window market, on the other hand, has been far more nimble from the point of view of technical development of more efficient products, manufacture of these products, and financing, including widespread aggressive market participation by European firms. We examined compliance documentation for four buildings in Krasnodar and Novorossisk, and found that in all four cases, designers compensated for wall panels with less thermal resistance than prescriptively stipulated, by using windows that were far more efficient than prescriptively required. We believe that similar conditions prevail in many other regions.

We can infer from the Krasnodar/Novorossiisk cases that the performance approach is probably dramatically reducing the cost of compliance relative to the prescriptive approach alone because it would be impossible to find more efficient wall panels in the area, and impractical to ship them in. The success of new windows under the new code requirements suggests that in the next round of codes, regulators should strongly consider more stringent prescriptive thermal-resistance levels for windows, with accompanying adjustments to required whole-building performance targets.

Other areas. Use of external insulation, added insulation in attics and under ground floors, and other strategies have also been widely applied to achieve compliance.

Overall compliance trends and market transformation. It is too early to state with confidence the degree of compliance with the newest codes, such as the new federal code in Kazakhstan. But for codes that have been in effect for a few years or more, such as in Moscow, enforcement agencies note full compliance, at least on paper with submitted applications. Possibilities exist, of course, for noncompliance stemming from corruption or incompetence among designers or enforcement agencies. But evidence of compliance on paper is largely supported by direct evidence of changes in wall and window manufacturing, dealer inventories, and actual buildings. Over the past several years, throughout Russia and now in Kazakhstan, we have had direct observations of efficient building designs, construction practices, and sale and installation of efficient building materials, leaving no doubt that the former Soviet construction sector has undergone a market transformation to greater efficiency over the same period that the new building codes have entered into force. The codes have been an important factor in this transformation (Matrosov et al. 2004).

Energy Auditing and Field Testing of Energy Performance

Our project team has field-checked the energy performance of one operating code-compliant building against the design calculations made by the code-stipulated algorithm. This building is a two-section 11-story residential building. It was built in 2002-2003 to replace razed 5-story buildings in the city of Moscow. The building was built with Swiss “Plastbau” system technology, which is new to Russia. The building is considered experimental because of its new technology.

Field testing was carried out in winter of 2004, using a method for energy auditing of existing buildings (GOST 31168) developed by the Research Institute for Building Physics, in conjunction with the Moscow Architecture Committee. Researchers measured consumption of heat energy for heating, average indoor and outdoor air temperature, and average intensity of solar radiation on a horizontal surface over the heating seasons at defined intervals of time. Values for overall heat losses through the building envelope, average measured consumption of heat energy, and overall heat gains (internal gains and solar gains through fenestration) were calculated for these intervals of time.

The consumption of energy to heat the building over the design heating season, Q_h^y, was 2,917 GJ. The specific consumption of heat energy for heating the building over the heating season q_h, kJ/(m^2·^{o}C·day), was 70.33 kJ/(m^2·^{o}C·day). In accordance with the Russian federal code, the maximum permitted specific consumption of energy for heating a 10- or 11-story building is 72 kJ/(m^2·^{o}C·day). This exercise confirms that the building, in actual operation as well as in design calculations, complies with code requirements. It also confirms that the compliance calculation algorithm was precise relative to actual performance in this case.

Ratings and Financial Incentives

New codes in both Russia and Kazakhstan call for a five-tier building energy rating system, based on energy consumption relative to code requirements. The rating system is designed to be applied to both projected energy consumption and the measured performance of existing buildings. Buildings that beat code-stipulated energy-performance requirements by 50 percent or more get a rating of "A", and by 10 to 50 percent a "B". Buildings in minimal compliance get a "C" rating. Building designs that are projected to consume more energy do not comply with the new codes and are not eligible for building permits. Most buildings erected before the onset of new codes fall well short of current code requirements and would get a "D" or "E."[4]

The rating systems are a recommended framework for financial incentives for efficient buildings. But no codes require such incentives and no jurisdiction has yet actually created such incentives for privately funded buildings. Notably, however, the categories are apparently finding use among building owners, who specify desired categories for planned buildings in technical instructions to designers and builders.[5]

The ratings system has been used as the basis for efficiency incentives for publicly financed buildings. In May 2005, the Moscow city government adopted a new policy directive calling for major financial incentives for the creation of energy-efficient buildings in the city. Applicable only to contractors designing city-financed buildings, the rule calls for the city to pay proportional bonuses to architectural and engineering agencies that deliver building designs that consume significantly less energy than required by code, with short simple payback times for the incremental cost of energy-efficiency measures. Table 2 below shows multipliers applicable to standard design fees. In the case of the most efficient buildings (those that consume 30 percent less energy than required by code, with simple payback times of less than three years), responsible building-design agencies get a 50-percent bonus in addition to their usual design fees (Department of Civil Construction Policy, Development, and Renovation of the City of Moscow 2005).

[4] Based on extensive field observations by NIISF.

[5] See, for example, Technical Conditions for the Design of a Multifunctional Residential Complex on ulitsa Zheltoksan 2A in the city of Astana [Kazakhstan], 2005.

Table 2. Bonuses for Design of Energy-Efficient Buildings in Moscow (Multipliers Applicable to Standard Design Fees as a Function of Building Efficiency and Payback Time)

Category	Simple payback time		
	Up to 3 years	3 to 5 years	5 to 7 years
Increased (15-29 % less energy consumption than permitted by code)	1.35	1.3	1.25
High, Very High (30-50 % less energy consumption than permitted by code)	1.5	1.45	1.4

Looking Ahead: Strategic Policy Emphasizing Sustainability

Russia's energy policy is defined by the 1995 document "Basic directions of energy policy in the Russian Federation in the period up to 2010," which was confirmed by decree of the President of the RF starting on May 7, 1995, No. 472, and in which one of the main tasks set forth is the execution "of the realization of the potential of energy conservation by means of the creation and implementation of highly-efficient fuel- and energy-consuming equipment, thermal insulation materials, and construction." Russia's energy policy is realized at the federal and regional levels by means of "concentration of basic work on the use of the potential of energy conservation in regions."

The Russian Academy of Architecture and Construction Science (known by its Russian initials as RAASN) is the country's leading technical agency working on energy efficiency in buildings. RAASN, in conjunction with the successor agency to the State Construction Committee of the Russian Federation (Gosstroi), has been carrying out and will carry out policy on energy and resource conservation in Russia. The Academy has formally resolved that energy and resource conservation is one of its high-priority directions -- "by means of research, development of experimental designs, promotional material, demonstration projects, and implementation of advanced achievements to work toward the increase of the resource and energy efficiency of the architectural-construction and residential communal sector of Russia, and of civil construction, including energy-efficient development of infrastructure of cities and their systems, which will make possible actual reduction of demand for heat and electric energy." (Ilyichev 2003)

Basic tasks and high-priority objectives for the activity of RAASN in the area of resource and energy efficiency for coming years have developed, including the following:

1. National and regional policy strategies for sustainable development;
2. A new integrated systems approach to city planning, construction, and heat supply;
3. New code and recommendatory documents: codes for consumption of heat energy for heating and hot water supply, codes for cold water supply, energy passports of buildings

and heat and water supply systems, with accompanying technical regulations and guidelines;

4. Research, development, and market transformation programs for construction materials and goods;
5. Research, innovation, and upgrades in heat supply.
6. Super-efficient model homes (KERM buildings).

Prospective Activity

The strategic goal of RAASN is energy and resource conservation, with accompanying maintenance of the indoor environment in civilian buildings and the improvement of the quality of life of the population. RAASN's agency-specific objective for achieving this strategic goal is the creation of energy- and resource-minimizing technical approaches and energy-efficient technologies for buildings with a demand for primary energy reduced by 50 percent or more compared with the baseline of 2001. Fulfillment of this objective, in turn, involves several areas of planned work.

The first area involves making energy conservation more consistent with legal and regulatory requirements. The law "On Technical Regulation" places at the forefront safety of operation of civilian buildings, which includes energy and thermal safety. Detailed technical rules on thermal, energy, and environmental safety of civilian buildings should be developed for new highly-efficient buildings (those that fall in categories A and B of the new rating systems). These technical rules must contain basic conditions: comfort within the occupied premises of the buildings, thermal performance of buildings and energy conservation, soundproofing, natural and artificial lighting, and environment and architecture. They will include parameters for indoor environment, to provide for the health of people living within.

In conjunction with the first area, RAASN sees the need for development of unified codes for energy conservation in civilian buildings, taking account of heating, cooling, domestic hot water, and artificial light. The new codes will provide for reduction of expenditures for heating in civilian buildings in terms of primary energy of not less than 33 percent to 50 percent.

RAASN's plan calls for developing programs for the formation of requirements for market transformation for energy-efficient construction materials, with the goal of creating a national manufacturing base for such materials and reducing dependence on foreign producers.

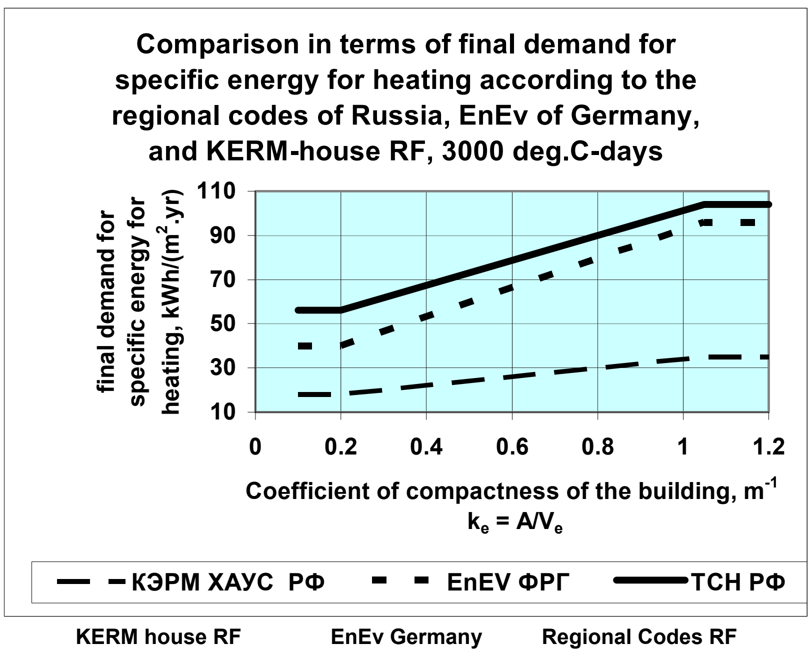
The result of this work will be new, more progressive national codes for design of civilian buildings and wide national availability of new energy-efficient construction materials and technologies as well as construction and architectural solutions for new and renovated buildings.

KERM Buildings

Looking toward the longer term, NIISF of RAASN has developed basic stipulations for a new strategy for construction of Russia for the period after 2015. The essence of this strategy lies in the creation of civilian building complexes from *KERM buildings* -- known by their Russian initials, these buildings provide for comfort while minimizing the use of energy and resources.

KERM buildings, as currently envisioned, will consume about one-third to one-half the energy of buildings built in minimal compliance with current codes (22-42 $kJ/m^2 \cdot {}^oC \cdot day$). This level of performance will require the development of a system of overall energy indices, new approaches for building materials, floor plans and building geometry, and methods for their assessment for the building on the whole and for the types of energy being consumed. Design of such buildings must be carried out with the use of highly efficient, environmentally clean and durable materials and technologies. In addition, possibilities for use of both new and traditional construction materials must be researched, including especially light concrete, porous concrete, and wood, and moreover -- various technologies of use of heat in the process of heat transfer throughout the building envelope, in the distribution of ventilation air, in the incidence of solar radiation in the building, and also systems of low-temperature heat energy of the ground, water, drain waters, and air must be used. Automated systems for regulation of microclimate are needed. For KERM buildings, the aggregated life-cycle expenditures of energy for production of construction materials will be taken into account, not just performance after installation, facilitating a more thoroughly rational choice of the most truly energy-efficient and resource-conserving materials to choose for construction.

Figure 3. Comparative Analysis of Final Specific Consumption of Heat Energy As a Function of the Coefficient of Compactness[6] of a Building: 1) Sample KERM Building, 2) German Codes and 3) Russian Regional Codes



In many villages spread throughout Russia, decentralized sources of heat supply are much more efficient than centralized heat supply. Residential districts constructed from KERM buildings may be organized independently from centralized heat supply systems. These districts may therefore have a completely different architectural and engineering profile from traditional housing developments. The result may be new technical approaches for external envelopes, HVAC equipment, and building floor plans and geometry for multistory residential buildings and systems for their heat supply.

[6] The coefficient of compactness is a building's surface area divided by its volume.

Since 2005, the RAASN has been working with relevant agencies to secure land and financing to build the first KERM buildings, focusing on possibilities in Moscow.

Conclusion

The Russian Federation has continued its twelve-year trend of steep progress on building energy codes. Recent progress has included continued development and implementation of new performance-based codes, with accompanying advances in rating systems, incentive programs, field verification of calculation methodology, application of new design approaches for compliance, and market transformation. Ukraine and Kazakhstan have proceeded rapidly as well with their own new codes, integrating successful elements of the model code that underlies Russian regional and federal codes.

Looking ahead to the medium term and longer term, the Russian Academy of Architecture and Construction Sciences has set an ambitious new agenda for sustainability, emphasizing comfort, the indoor environment, minimization of consumption of material resources, in addition to energy efficiency. This agenda, to be realized in the form of KERM buildings, will expand traditional concepts of the building sector, to encompass life-cycle costs and energy consumption, as well as upstream heat-supply efficiency.

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