Results of Collaboration Between NRDC and NIISF/CENEf on Building Energy-Efficiency Standards in Russia

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Over the last seven years the Natural Resources Defense Council (NRDC) has supported Russian specialists, primarily from the Center for Energy Efficiency (CENEf) and the Research Institute for Building Physics (known by its Russian initials NIISF), in improving the energy efficiency of Russian buildings. This paper describes results of this collaboration.

Since 1988 NRDC, CENEf, and NIISF have performed joint research on real energy consumption for both single-family and multi-family buildings and have conducted blower-door tests for airtightness of buildings. New analytic methods have been developed for assessing whole-building thermal performance based on measured data. The most useful measure of energy performance of Russian buildings is climate-adjusted specific energy consumption during the heating season; this figure is calculated from thermal-envelope properties, climate data, and other input parameters. These new methods are now being applied in national, regional, and local building standards in Russia, in both prescriptive and performance-based codes.

Another building-code innovation is the ''Energy Passport,'' which is a certification system that integrates code enforcement, building commissioning, and market-based incentives for further efficiency beyond code requirements. Though more research is needed to gauge its effectiveness in practice, the Passport is already appearing in regional codes around Russia.

INTRODUCTION

Russia is the world's third-leading emitter of carbon dioxide from fossil fuel combustion, after the United States and China (World Resources Institute 1994). About one-fourth of the nation's demand for energy comes from buildings sector--and as Russia moves away from a planned economy based on heavy industry, buildings can be expected to account for an increasing share of national energy consumption. In the late years of the former USSR, about 370 million tonnes of coal equivalent were consumed annually by Soviet buildings, mostly for space heating, domestic hot water, and lighting.

Multifamily buildings in Russia consume an average of twice as much energy as similar buildings in the US, and single-family buildings three times as much as their American counterparts. Heat supply and end-use are particularly inefficient. The average specific-energy consumption for space heating and domestic hot water of Russian buildings (normalized to heated area and degree-days) is about twenty-five percent higher than that of buildings in Germany, and more than sixty percent higher than that of buildings in the United States (IEA 1995). The main reasons for such high levels of heat-energy consumption are insufficient building-shell thermal performance, lack of metering and controls for heat supply, and heavily subsidized energy costs, which lead to an absence of consumer incentives to conserve.

The Natural Resources Defense Council (NRDC), a non-profit American environmental organization, is working with Russian partners--primarily the Research Institute for Building Physics (known by its Russian initials NIISF) and the Center for Energy Efficiency (CENEf)--to promote greater energy efficiency in the buildings sector in Russia. These efforts emerged in 1988, as an outgrowth from NRDC's collaboration with the Soviet Academy of Sciences on issues of nuclear test-ban verification, and with both the Soviet and US Academies of Science on energy efficiency. When the Soviet Academy convened two conferences in 1988 (one on global warming and the other on energy efficiency), it invited NRDC to participate; there NRDC made contact with its Russian counterparts in building research and regulation. NIISF is an agency of the National Academy of Architecture and Building Science, charged with developing national Russian standards for thermal performance of buildings. CENEf is a nongovernmental nonprofit organization dedicated to promoting energy efficiency in Russia.

This working relationship has also involved a number of other agencies in Russia and the United States. Principal collaborators include Battelle Pacific Northwest National Laboratories (which played a critically important role in creating CENEf), the US Environmental Protection Agency, the US Agency for International Development, Princeton University, the City of Seattle, the Massachusetts Institute of Technology, and a newly formed American nonprofit organization called the Institute for Market Transformation.

DIRECTIONS OF JOINT RESEARCH

To date, joint projects have been carried out in four areas: modeling of building thermal performance; blower-door testing of buildings; development and modification of national and regional building standards; and initiation of ‘‘Energy Passports’’, a new system integrating code compliance, commissioning, and market transformation. These efforts have led to a variety of improvements in regional and national standards. (See Table 1, below.)

NRDC has also worked extensively with officials, scientists, and utility managers in the North Caucasus region to promote integrated resource planning in decisionmaking on energy supply. Though this approach has been most commonly applied in the US to electric power supply, NRDC and its regional partners have been working to adapt this mechanism to the heat supply system as well. NRDC’s efforts on building energy efficiency fit into this IRP framework; the work can help assure that lower-cost improvements in building energy efficiency are implemented before higher-cost upgrades to heat supply systems.

DEVELOPING A METHODOLOGY FOR ASSESSING WHOLE-BUILDING ENERGY CONSUMPTION

In 1988 NIISF and the Center for Energy and Environmental Studies at Princeton conducted experiments to assess energy consumption and thermal performance of a single-family house near Moscow (Matrosov, Artemov, Norford & Socolow 1989). Tests of a new highly-insulating window technology, an example of which was constructed for NRDC and NIISF with the assistance of Lawrence Berkeley National Laboratory, were conducted both in the NIISF laboratory and in a real apartment building (Matrosov, Butovsky, and Watson 1994). Later, NRDC joined NIISF in seeking to develop and test a methodology for assessing the effects of insulation levels and other energy-relevant properties on energy consumption in existing and newly built Russian single-family houses and multi-story buildings.

NRDC and NIISF tested two buildings during 1992 and 1993 (Matrosov, Butovsky & Watson 1994). The first build-

Table 1. *Areas of Collaboration and Results in Russia*

Areas of collaboration	Results in Russia
Developing a new methodology for building thermal performance analysis using data of real energy consumption of buildings	Drafts of two new Russian standards: ‘‘Residential buildings: methods for determining specific energy consumption’’ and ‘‘Thermally heterogeneous enveloping structures: a method of calorimetric determination of heat transfer coefficient’’
Blower-door airtightness testing, and methodological instruction	Testing of Russian single- and multi-family buildings A draft of the national Russian standard ‘‘Building and Construction: Methods for determining air permeability’’
Development and enhancement of regional and national building standards	New, more stringent energy-efficiency requirements in the main national Russian Building Code ‘‘Thermal Engineering’’ A new draft regional building code ‘‘Energy Efficiency in Buildings’’ Introduction of performance-based compliance paths to regional and national building codes
Developing the concept of building Energy Passports (certification for code compliance & commissioning)	Implementation of Energy Passports into the new Moscow building code ‘‘Energy Conservation in Buildings’’ Developing a draft version of an Energy Passport to be included in the national and regional standards

ing was a standard two-story, unoccupied single-family wooden panelized house, with three rooms on the first floor and two rooms on the second floor. A prefabricated test house was assembled on-site in Kirov, where the average winter temperature is -5.8 ºC [21.6°F] and the duration of the heating season is 231 days. NRDC and NIISF calculated the normalized annual heating energy consumption at the building site as 443 kWh/(m^2.yr) [140,000 Btu/(ft^2.yr)] for an electric space-heating system, 748 kWh/(m^2.yr) [237,000 Btu/(ft^2.yr)] for a boiler using natural gas, 806 kWh/(m^2.yr) [256,000 Btu/(ft^2.yr)] using an oil- or coal-fired boiler, and 996 kWh/(m^2.yr) [315,000 Btu/(ft^2.yr)] using a coal stove. (Note: These figures show energy use at the building site; total fuel use for electric heating, taking conversion and transmission losses into account, would typically be 3-4 times higher.) Parametric studies on energy consumption were developed for variants of the house with different levels of insulation and airtightness. We found that a practical combination of insulation and infiltration measures should reduce specific heating energy consumption by 37% for all fuels.

The second monitoring project studied the energy consumption of a high-rise building as a whole. The field experiment was designed to measure the heat for space heating delivered to an occupied 17-story apartment building (''P44'') by district heat. The building has four sections, 15,005 m^2 [161,430 ft^2] of floor area and 256 flats. In the experiment measurements were taken of P44's indoor air temperature, outdoor air temperature, temperature of the supply and return water from the district heat system, and the flow rate of the district heat system. From the experimental data and the design outdoor air temperature in Moscow (-29°C [-20.2°F]), the maximum rate of heat energy consumption for this building was calculated at 725 kW (2.47 MBtu/hr), which was at least 1.6 times less than the design level.

APPLICATIONS IN FEDERAL, REGIONAL, AND MUNICIPAL ENERGY STANDARDS

Analyses of building energy performance have led to a variety of positive changes and innovations in national, regional, and municipal building energy standards in Russia. At the regional and local level, the performance approach to compliance is being introduced, allowing for tradeoffs not only within the building envelope, but over the entire system of heat supply and delivery as well. Building energy performance standards have not yet been implemented at the national level, but the Russian Federation Ministry of Construction has shown interest in adopting federal performance standards in conjunction with regional efforts (Russian Federation Ministry of Construction 1994). Meanwhile, federal Russian prescriptive requirements for building envelopes have been strengthened, based on calculated reductions in specific energy consumption.

Setting Standards Based on Specific Energy Consumption per Degree-Day

The most widely applied building standards in the United States use annual energy costs as the figure of merit for determining the energy performance of a building. But because of the erratic shifts in energy prices in Russia, and because of the relative lack of familiarity with state-of-the-art building-energy simulation software, the energy-cost method has been replaced there by a simpler measure of whole-building energy performance.

The key measure of building energy-efficiency performance in Russia is a climate-adjusted value for specific energy consumption for heating the building during one heating season. This parameter, new in its application to Russian codes, is defined as the quantity of heat consumed in the heating period per unit of total heated floor area of a building, per degree-day [Wh/(m^2.ºC.day), or Btu/(ft^2.ºF.day)]. The specific energy consumption parameter is calculated from data on climate, building materials, design, and expected occupancy and use patterns, using methodologies similar to those developed in the NRDC/NIISF experiments described above.

For application as a standard value in national codes, this parameter works best to the extent that it is climate-independent. Separate calculations for numerous regional cases show that the parameter does indeed stay relatively stable across climate zones. Table 2 shows values of the specific heat consumption parameter for cities representing various climate regions; though yearly energy consumption per square meter varies widely, the specific energy consumption is about the same for all regions when the number of degree-days in the heating season is taken into account.

Climate-adjusted specific energy consumption in buildings has been tested in simulations across the most diverse climatic conditions of the territory of Russia. (The methodology of these tests is described in an appendix to the Moscow municipal building energy code [City of Moscow 1994].) Energy-use estimates have been made for the three apartment designs most typical of Russia (5-, 9-, and 17-story) located in 302 climatic regions (3020 test calculations in all). Figure 1 presents the results of these calculations and shows the distribution of buildings by annual specific energy consumption, grouped every 5 Wh/(m^2.ºC.day).

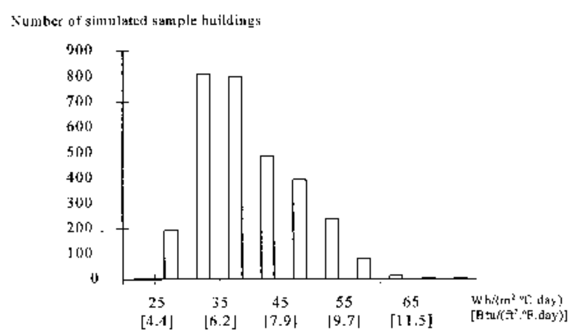
National Standards

Based on statistical analyses of building energy performance, Russia has recently made significant changes to national

__Table 2.__ Specific Energy Consumption of Buildings During the Heating Season (Typical 9-story multifamily building that meets existing comfort requirements)

City	Specific heat consumption kWh/cm²·year)	[Btu/ft²·year]	Per degree-day of the heating season Wh/(m²·°C·day)	[Btu/ft²·°F·day]
Verhoynsk	467	[148,000]	38	[6.7]
Yakutsk	393	[125,000]	37	[6.5]
Omsk	256	[81,200]	39	[6.9]
Samara	195	[61,800]	39	[6.9]
Astrakhan	139	[44,100]	41	[7.2]
Krasnodar	100	[31,700]	40	[7.0]

__Figure 1.__ Distribution of Simulated Sample Buildings by Specific Energy Consumption



building standards (Matrosov, Butovsky & Tishenko 1996; Russian Federation Ministry of Construction 1995). These amendments took effect September 1, 1995, and provide for a considerably higher thermal performance level in new and renovated buildings. From that date on, the designs of all newly constructed or renovated buildings should comply with those amendments, and after July 1, 1996, designs of buildings which do not meet the new provisions will not be approved.

Numerical values for these new standards were chosen via simulations similar to those whose results are shown in Figure 1. For 486 locations in the Russian Federation, the design values and standards still in force under existing standards were used to calculate the specific energy consumption for heating different types of buildings. For those calculations, eight types of multi-story and the same number of one- and two-story buildings were taken, each with envelope designs. Required target levels for specific energy consumption were set such that 95% of the sample buildings would comply. Then two reduced levels for specific energy consumption were approved and the corresponding prescriptive thermal performance standards for residential buildings were set on this basis. The new prescriptive standards will be introduced in two stages, each corresponding to an approved reduction in specific energy consumption:

--20% for new and 40% for renovated buildings at the **first** stage (1995–1999);
--40% for all kinds of buildings at the **second** stage (starting January 1, 2000).

Table 3 shows the specific aspects of the strengthened requirements for thermal resistance of building envelopes.

Whereas previous standards allowed for higher energy use by certain construction-material types, the new standards apply to envelopes of all types. The new standard encourages the use of efficient thermal insulation of low thermal conductivity in multi-layered envelopes, such as mineral wool, foamed polyurethane and cellular polystyrene, and for practical purposes excludes single-layer envelopes from use. The new requirements will likely force structural reorganization of the Russian building industry toward the production of multi-layered wall panels.

Regional Standards

The improved capacity for normalization of whole-building energy use has led to a major innovation in Russian building

Table 3. *Minimum Required Areal Thermal Resistance for Residential Building Envelopes for Stage I (effective September 1, 1995) and Stage II (effective January 1, 2000)*

Number of degree-days in the heating season, °C.day [°F.day]	*Stage I: Sept. 1995–Dec. 1999* Standard areal thermal resistance of envelopes, $m^2.°C/W$ [$ft^2.°F.hr/Btu$] Walls	Roofing (attics included)	Floors above building arches, cold crawl spaces, or basements ventilated with outdoor air	*Stage II: Jan. 2000 and thereafter* Standard areal thermal resistance of envelopes, $m^2.°C/W$ [$ft^2.°F.hr/Btu$] Walls	Roofing (attics included)	Floors above building arches, cold crawl spaces, or basements ventilated with outdoor air
2,000 [3,600]	1.2 [6.8]	1.8 [10.2]	1.6 [9.1]	2.1 [11.9]	3.2 [18.2]	2.8 [15.9]
4,000 [7,200]	1.6 [9.1]	2.5 [14.2]	2.2 [12.5]	2.8 [15.9]	4.2 [23.8]	3.7 [21.0]
6,000 [10,800]	2.0 [11.4]	3.2 [18.2]	2.8 [15.9]	3.5 [19.9]	5.2 [29.5]	4.6 [26.1]
8,000 [14,400]	2.4 [13.6]	3.9 [22.1]	3.4 [19.3]	4.2 [23.8]	6.2 [35.2]	5.5 [31.2]
10,000 [18,000]	2.8 [15.9]	4.6 [26.1]	4.0 [22.7]	4.9 [27.8]	7.2 [40.9]	6.4 [36.3]
12,000 [21,600]	3.2 [18.2]	5.3 [30.1]	4.6 [26.1]	5.6 [31.8]	8.2 [46.5]	7.3 [41.4]

Note: Degree-days in Russia are calculated based on a base temperature of 18 °C (64.4°F), and are counted only during the heating season, which is independently defined based on outdoor temperature patterns. Russian averaging processes for calculation of degree-days also differ slightly from Western methods.

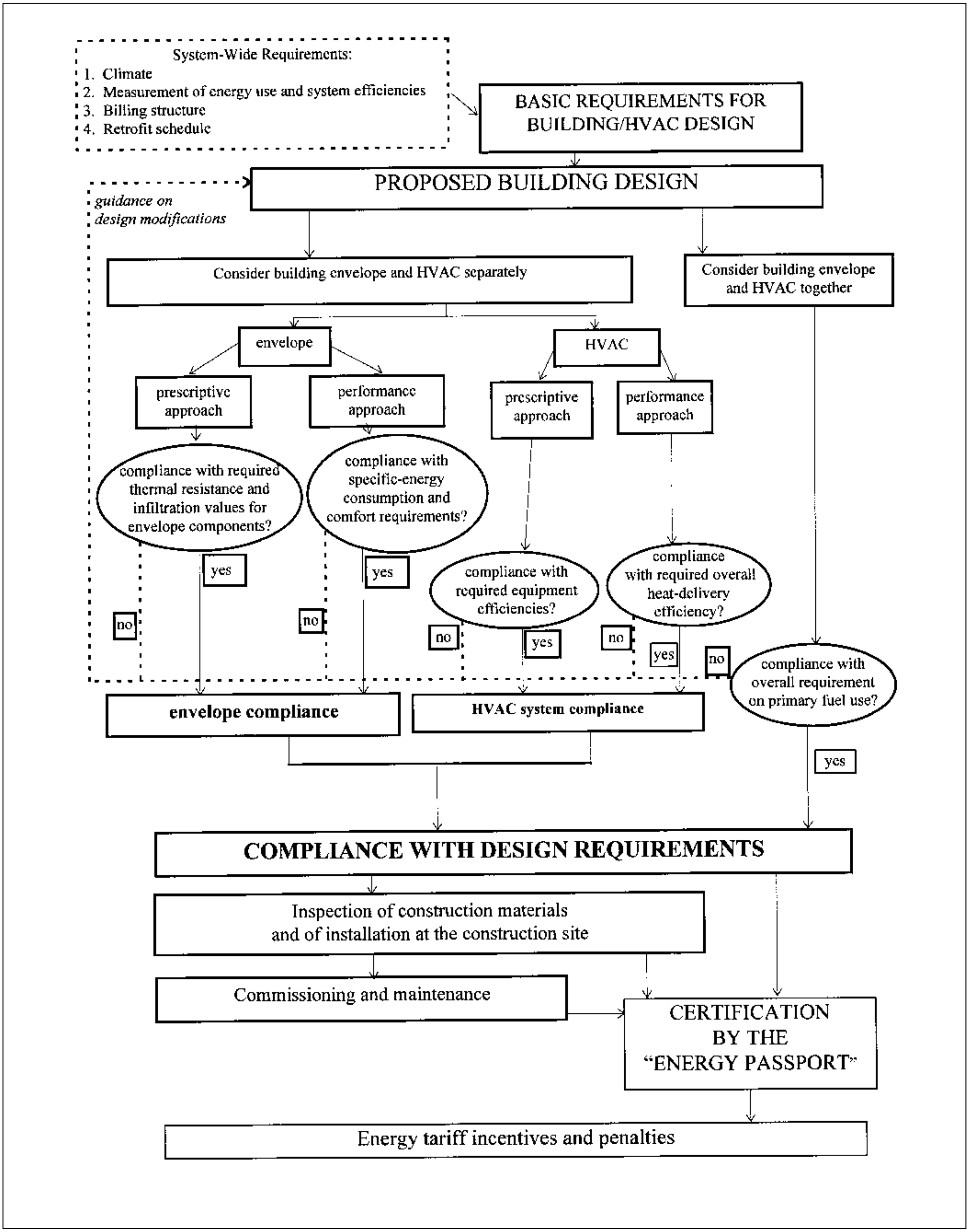
codes: the introduction of performance-based as well as prescriptive paths to building code compliance. During NRDC-sponsored visits to the United States, Russian scientists learned about the performance approach--which allows tradeoffs at the designer's discretion among the performance characteristics of different building components, as long as some overall energy parameter is met. Based on this exposure, they sought to develop a performance approach that would work under the unique economic conditions of Russia (Matrosov, Butovsky & Goldstein 1994).

Recently NRDC, CENEf, and IMT, in collaboration with representatives of the Massachusetts Institute of Technology and the City of Seattle Department of Construction and Land Use, have developed draft regional standards for building thermal performance and heat supply for Chelyabinsk in the southern Urals, and Rostov in the northern Caucasus. This document sets forth requirements for building energy, thermal performance, and mechanical systems, and allows for numerous performance tradeoffs within the building envelope, within the HVAC system, and between the envelope and the heating system. The standard uses the specific energy consumption (per degree day) parameter described above, and enhances the requirements of the federal standards. This model regional standard is intended to be adopted and enforced by regional administrations. Figure 2 shows the structure of the proposed standards.

This regional concept of thermal performance standardization of buildings is based on meeting, independently, two sets of requirements: thermal-comfort requirements for indoor conditions, and overall climate-adjusted specific-energy consumption limits for the whole building.

Like the use of the climate-adjusted specific-energy parameter, thermal performance standardization by comfort conditions is new for Russia. (These new thermal comfort requirements take the same format as earlier condensation protection requirements, but add new engineering content.) The basic measure of indoor thermal comfort is the average indoor temperature in the center of working space, calculated as the mean of average indoor air and radiant temperatures. The latter results from surface temperatures of all envelope components of the premises. Another parameter describing indoor microclimate is local radiant temperature asymmetry, defined as the difference in radiant temperatures between

Figure 2. *Proposed Structure of Model Regional Standards for Chelyabinsk and Rostov*



two opposite-looking surfaces of an object located at any point of the indoor space. An asymmetry requirement imposes a limitation on radiant heat exchange intensity near warm or cold envelope surfaces.

Municipal Codes: Moscow

NIISF, NRDC, CENEf, and their other Russian and American collaborators have also contributed significantly to the first new code for buildings in Moscow. On March 22, 1994, the Moscow Administration adopted a municipal code of energy efficiency standards, which became effective on August 1, 1994. This Code is a joint effort of the Moscow Research Institute for Type and Experimental Design (MNIITEP) and NIISF, with assistance from the Moscow Committee for Architecture. CENEf and NRDC provided the responsible organizations with information on the available tools used around the world in standards for building energy efficiency. The code is to be applied to residential houses and municipal public buildings (nurseries, schools, hospitals, and clinics), and for new construction as well as renovation. This code being implemented in Moscow is expected to result in at least 50% less energy consumption for heating new and renovated buildings (Matrosov and Butovsky 1994).

The new Moscow code requires structural transition of the building-materials industry in Moscow toward production of efficient thermal insulators. This requirement is doubly beneficial, providing for improvement not only in terms of energy efficiency but also in terms of cost. The 1994 cost of materials (47,120 rubles/m^2 [\$9.40/m^2]) consumed in manufacturing reinforced concrete wall panels with an expanded polystyrene warmth-retaining jacket is less that half that of single-layer expanded-clay concrete panels (106,500 rubles/m^2 [\$21.60/m^2])) whereas the thermal performance level of the former panels ($R = 12$, in $ft^2 \cdot {}^\circ F.hr/Btu$) is twice the level of the latter ($R = 5.7$). Similar results have been obtained from the comparison of two clay brick walls, one also having a layer of expanded polystyrene on the outside (214,000 rub./m^2 [\$42.80/m^2], $R = 12$) and the other having no warmth-retaining jacket (308,000 rub./m^2 [\$61.60/m^2], $R = 5.3$).

The design institutes of Moscow already use the municipal code for designing new residential buildings, schools, and nurseries and for adjusting earlier-initiated designs to the new requirements. MNIITEP is modifying the design of houses in its P-55 series to meet new code requirements; the Prefabricated Construction Plant DSK-1 has started to produce this series. One building has been erected so far. Another new design has been developed for houses in the PD-4 series. The plant DSK-4 has also begun to produce this series, and in this case too, one building has been erected. According to the estimation of the Moscow Building Department, implementation of the Code in 1995 will save 238 MBtu of heat per year.

THE ‘‘ENERGY PASSPORT’’: A RATING SYSTEM FOR CODE ENFORCEMENT, BUILDING COMMISSIONING, AND MARKET TRANSFORMATION

Of course, even the most advanced standards cannot promise actual energy savings without effective enforcement. In Russia, enforcement of building energy standards is generally poorly funded and organized (IEA 1995). Actual levels of code compliance are not well understood, and deserve significant further attention.

NRDC, IMT, and CENEf have begun to turn their attention to the pressing need for effective implementation and enforcement of Russian building standards. One of the most exciting innovations taken up to meet this need is the Energy Passport. Energy Passports integrate three key aspects of successful energy-efficiency implementation: code enforcement, commissioning and maintenance, and market incentives for consumers. The system is deceptively simple. The Passport is, in effect, a certification and rating system for the energy efficiency of buildings--not only during the initial design stage, but also after occupancy. (In Russia the term ‘‘passport’’ implies a document that stays with a person, or in this case a building, permanently and at all times.)

The Passport document begins in the hands of the building designer, who provides required information on location, design, materials, intended use of the building, and other key characteristics. These parameters are used to calculate a normalized figure for the specific energy consumption of the building (heating energy use per square meter-degree-day), which is then compared to a standard value to determine code compliance. The standard value for allowed specific energy consumption is selected so as to maintain the required microclimatic comfort parameters over the heating season. Buildings must not exceed certain additional limits, for the overall areal heat transfer coefficient of the building envelope, and for heat losses due to infiltration. The Passport simplifies compliance by clearly showing all data requirements, and by enhancing the ease and transparency of these calculations. The Passport also gives building-plan examiners a convenient set of data for use in enforcement.

But the usefulness of the Passport does not end with the design and construction process. The Passport also requires measurement of building energy performance at least one full year after occupancy. This requirement links code compliance to actual building energy efficiency in practice, instead of design alone--that is, continued certification depends on ongoing good performance. This arrangement gives building operators a strong push to take up regular commissioning schedules--that is, to monitor and maintain building energy systems, and to fix energy-wasting problems promptly. The Passport also enhances the convenience of commissioning by pulling together design and performance documentation--records which are now often kept separately and haphazardly, if at all.

This required monitoring of building operation makes information available to the building owner about possible discrepancies between expected and actual performance. With this information, the building owner can trace the causes of poor energy performance and hold the responsible parties accountable. This type of ''private-sector code enforcement'' will certainly help to ensure compliance with standards. More broadly, Energy Passports should help create market value and demand for reliable delivery of energy efficiency in building design and construction.

The Passport also brings energy efficiency into the market dynamics of real estate itself. It gives potential buyers and tenants an idea of what they can expect from their building's energy performance. As pricing schemes change and private ownership of real estate becomes more common, Russian consumers would be able to make more rational purchase decisions with information conveniently available on both design levels of consumption, and actual energy use.

Energy Passports are even more powerful market-transforming tools when, as in Moscow, they are supported by incentives for the building owner and/or ratepayer. There, the system of Energy Passports calls for reduced energy tariffs for buildings that exceed the efficiency requirements of codes. Thus a building that is 20% more efficient than code requirements would qualify the owner for a lower tariff for his or her utility costs; a 35% reduction would provide an even greater tariff reduction. Some US utilities have expressed interest in similar schemes, especially for electricity use in commercial buildings.

But Energy Passports for buildings, for all their promise and good sense, are still a relatively untested idea. Russian code officials and scientists are keenly interested in answering some key questions about passport implementation. Where Energy Passports are already required by code, are they being implemented as specified? To what extent? What are the major obstacles to implementation? In conjunction with regional officials, CENEf and NIISF hope to investigate these questions further. Various parties on the American side, led by IMT, will seek to offer technical and material assistance, as part of a general program of support for effective enforcement of standards.

CONCLUSION

The transfer to Russia of energy-efficiency technology and policymaking know-how is hampered by numerous barriers of logistics, communications, politics, institutions, and culture. (See, for example, Martinot 1995). The work of NRDC and IMT with CENEf and NIISF has had its share of these difficulties, especially in reconciling divergent technical approaches, communicating clearly, and defining priorities. Throughout the course of these projects, both sides have become aware that American solutions cannot simply be transplanted in Russia, but must instead be adjusted for compatibility with Russian conditions. The key to this successful working relationship has been patience and persistence over the long term; years of collaboration have generated mutual confidence, good will, and openness to each other's ideas and criticisms. Just as importantly, long-term collaboration has raised the legitimacy of the policy recommendations of NRDC, IMT, CENEf, and NIISF among key agencies in Russia.

Now, the joint Russian-American work is starting to show concrete results, in the form of stricter, more flexible, more cost-effective standards. American experience has helped to steer Russian standards in new directions that should boost building energy efficiency in cost-effective ways. NRDC, IMT, and their American partners will continue to provide support to the Russian side, particularly focusing on questions of effective implementation of the standards. And we hope soon to see a flow of ideas in the reverse direction as well, as the Russian notion of Energy Passports takes root in the United States.

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