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Russia's R&D for Low Energy Buildings: Insights for Cooperation with Russia

R Schaaf
M Evans

May 2010

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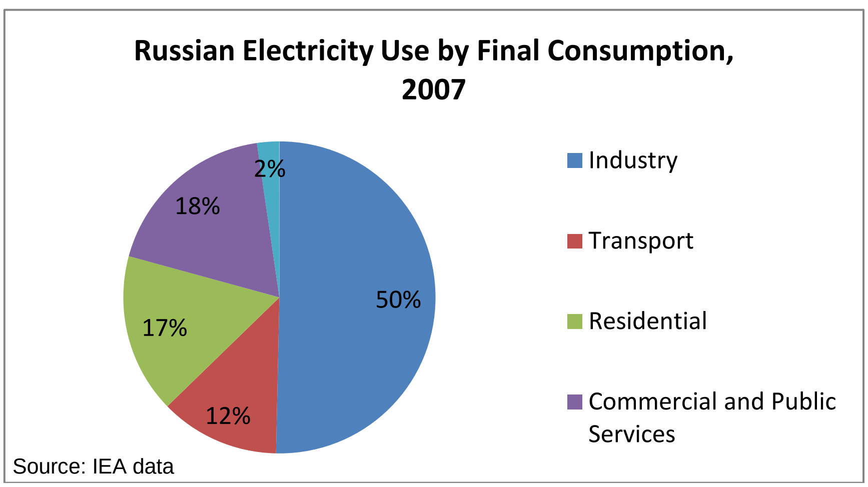
1.0 Summary

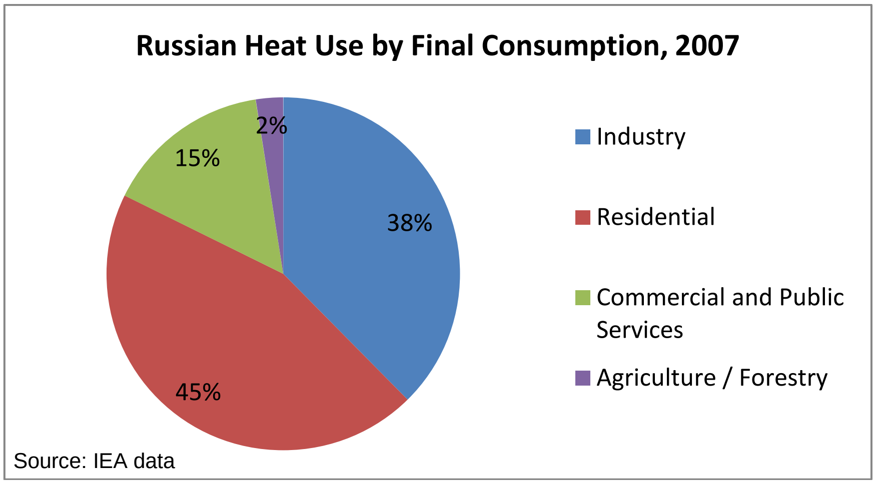
Russian buildings are the largest energy consumers in Russia. The Russian buildings sector also ranks among the largest globally in terms of energy consumption, a reflection of the cold climate, the inefficient legacy of Soviet construction and Russia's size. Historically, Russia has had a well-developed R&D infrastructure, including research institutes that focused on building energy issues. This capacity suffered when funding dropped dramatically following the collapse of the Soviet Union. Since 2002, however, the Russian government has made R&D investment a priority again. The government and private sector both invest in a range of building energy technologies. In particular, heating, ventilation and air conditioning, district heating, building envelope, and lighting have active technology research projects and programs in Russia. There are some success stories regarding commercialization, but the fact that there are not more may in part be attributable to the gap in funding for many years and to the lack of historic emphasis on marketable technology development in research institutes.

2.0 Introduction

Russia's building sector demands a great deal of energy, especially considering the climate in most of the country and related heating needs. According to the International Energy Agency (IEA), the buildings sector was the largest single energy consumer in Russia, accounting for 35% of total final energy consumption. Globally, Russia ranks 4th in terms of energy consumption in buildings (behind the United States, China and India, and ahead of Japan).

IEA data from 2007 indicates that Russia's total electricity use was over 700,000 gigawatt hours and heat use was almost five million terajoules. Industry is the main electricity consumer, accounting for 50% of the total use, and residential use provides the primary demand for heat, accounting for 45% of the total heating energy (IEA 2009).





A study by the Center for Energy Efficiency and the World Bank looked at building energy use in particular and found that energy efficiency measures could reduce the Russian building sector's energy use by over 47 percent (IFC 2008).

Residential buildings are the main energy consumers within the Russia's building sector. This segment of the building sector alone is a top energy consumer in Russia, second only to manufacturing (IEA 2009, IFC 2008). Russia's building stock includes over 30 billion square feet of residential buildings (Iliychev et al 2005).

The Russian government has placed increasing priority on energy efficiency in buildings under President Medvedev. This has included programs to promote energy efficiency in existing buildings and to conduct research on new technologies. In 2009, the Russian parliament adopted a new Law on Energy Efficiency that is providing a legal framework for even broader changes, such as the phasing out of incandescent bulbs (Ministry of Energy 2010).

This paper provides an overview of recent Russian research and development (R&D) on energy efficient building technologies. A variety of government and private sector agencies play a role in building technologies R&D, but most R&D is carried out under the aegis of the Federal Agency for Science and Innovation (FASI). The state is the major investor in R&D in Russia, and in 2005 state R&D expenditure outweighed private investment by a factor of two (Yegorov 2009).

State research institutes that address aspects of building technology R&D include the Research Institute for Building Physics, and the Central Research and Design Institute for Federal and Public Buildings. Private sector organizations are pursuing advances in heating, ventilation, and air conditioning (HVAC), lighting, and insulation. The Russian government's main funding mechanism for civilian science and technology R&D is the Federal Target Program "Research and Development in Priority Areas of Science and Technology." FASI administers the program through competitive grants to a wide range of state institutes and private sector companies.

Russia has a long history of investing in R&D. During the Soviet era, research institutes were relatively well-funded and prestigious institutions that produced some very innovative concepts and technologies. Energy efficiency, however, was not a major research priority compared to traditional energy or defense. In addition, given the economic structure, there was little to no emphasis on developing marketable, commercially viable technologies. After the collapse of the Soviet Union, research budgets plummeted. As Russia has stabilized economically, the Russian government has increased its research investments. Oil and gas revenue, along with economic growth, have brought in additional tax revenue that has allowed the government to expand funding. At the same time, there is a growing emphasis on energy efficiency. However, the record on commercialization has not kept pace with the funding. This is probably a natural outgrowth of the need for time to develop technology (Russia began to substantially increase R&D investments in 2002).[1] It is also likely that the existing scientific institutions are still learning what commercialization means and to increase the likelihood of a technology's success.

The paper provides an overview of some major research institutions working on building energy technologies. It then describes the major federal R&D funding program and the building energy projects underway. The FASI projects are described in terms similar to those used by the U.S. Department of Energy (DOE) in prioritizing research to allow for easier comparison. The final section maps the FASI projects to focus areas within the DOE Building Technologies Program (BTP) Multi-Year Project Plans (MYPPs).

3.0 Research Institutes and Private Sector Initiatives

A number of state and private agencies play a role in Russian research and development for energy efficient building technologies. On the public side, the Research Institute for Building Physics conducts research on insulation and lighting, and the Central Research and Design Institute for Residential and Public Buildings conducts research on insulation and windows. The Central Research and Design Institute for Residential and Public Buildings (TsNIIEP Zhilishchi) and the Research Institute for Building Physics (NIISF) are examples of state institutions, which conduct research on insulation, lighting, and windows. Within the private sector, firms such as an association of HVAC Engineers (AVOK), Svetlana Optoelectronics, and TechnoNICOL are engaged in R&D in the areas of HVAC, lighting, and insulation.

3.1 Central Research and Design Institute for Residential and Public Buildings

The Central Research and Design Institute for Residential and Public Buildings (TsNIIEP Zhilishchi) was founded as a research institute for clean and healthy homes in 1949. It began writing residential building construction standards during the Soviet era and continues to do so today on a national, regional, and sectoral basis. Its current mandate includes researching potential resource and energy savings in residential and industrial construction as well as piloting new technologies in these areas. TsNIIEP Zhilishchi runs a laboratory on heating and air conditioning in which they develop energy efficient windows and research building cladding, lightweight structures, and insulation.[2]

3.2 Research Institute for Building Physics

The Research Institute for Building Physics (NIISF) is a state institution, which develops national standards for insulation, lighting, acoustics, and ecology in construction, and conducts research and development at thirteen test laboratories. The test laboratory on building envelope includes centers that focus on building insulation and the thermal characteristics of building materials. Their primary activities

[1] Per Yegorov (2009), R&D funding levels as a percent of GDP dropped precipitously in the early 1990s. The decline in funding for materials and equipment was even greater, as many institutes prioritized maintaining their payrolls. Funding levels began increasing after the turn of the twenty-first century, and investment in capital assets picked up in 2002.

[2] See www.ingil.ru for additional information.

consist of materials testing and standards development. Another test laboratory, the lighting systems test laboratory, addresses building technologies and develops energy efficient lighting products.[3]

3.3 AVOK

HVAC Engineers throughout the former Soviet Union are organized through an association called AVOK, which is something like a Russian version of ASHRAE. Part of AVOK's mission is to facilitate joint research and development between its members. Although the website does not provide any information on R&D activities among AVOK members, it is nevertheless a promising forum for mobilizing and coordinating HVAC R&D efforts. AVOK's organized constituency of HVAC engineers could be used for targeted grant solicitations or to identify partnership opportunities.[4]

3.4 Svetlana Optoelectronics

Svetlana Optoelectronics has developed a variety of LED lighting products. It was founded in 1996 and is based in St. Petersburg. Its initial activities were focused on fire detection equipment, but most of its current business is for LED lighting. Svetlana Optoelectronics LED products include strips and modules for indoor lighting as well as exit signs, lit paving stones, and underwater lights. Box 1 provides further details on Svetlana Optoelectronics' history and success.

3.5 TechnoNICOL

Founded in 1993, TechnoNICOL is a private company that develops construction materials including insulation and roofing. The company opened a Science Center in 2004 to conduct research on roofing and insulation materials. The Science Center researches properties of roofing, waterproofing, and insulation materials with a focus on how products age. It also develops new products and improved production processes. One of the Center's priority tasks is to develop energy efficient building technologies. It carries European manufactured insulation, but has five product lines of its own. Its Science Center typically is able to introduce one to two new products per year (TechnoNICOL 2004; Yarrieltor 2007).[5]

4.0 Federal Target Program R&D

The Federal Agency for Science and Innovation (FASI), under the Ministry of Education and Science, implements the Federal Target Program "Research and Development in Priority Areas of Science and Technology." It is the main source of government funding for building energy efficiency R&D. The program runs in five-year cycles, and the current program ends in 2012. The program's objectives are to develop and commercialize technologies deemed critical to Russia's development through the so-called Critical Technologies list, to develop Russia's human resources, and to build the capacity of educational institutions and small enterprises (Federal Target Program 2010). Building technologies such as heating systems, insulation, and lighting are included in the Critical Technologies list under the item, "Technology for energy efficient transportation, distribution and consumption of heat and electricity".

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[3] See www.niisf.ru/ for additional information.
[4] See www.abok.ru/ for additional information.
[5] See also www.tn.ru.

Box 1: Svetlana Optoelectronics Success Story

Svetlana Optoelectronics is a private Russian company based in St. Petersburg, which has developed a range of LED lighting products including indoor lighting, exit signs, lit paving stones, and underwater lights. The company's success can be attributed to a confluence of factors including a parent company with military R&D background, a supportive economic cluster environment in a St. Petersburg Innovation Technology Center, partnerships with various research institutions, and a FASI grant.

Svetlana Optoelectronics is one of nine subsidiaries of Svetlana, a state owned company formerly a part of the Soviet defense industry but with an increasingly diverse portfolio. Each of the subsidiaries does its own R&D in a wide range of electronic technologies such as transistors, microwave devices, power transmission tubes, microcontrollers, and microprocessors. Because defense research organizations were some of the best funded and best equipped organizations during the Soviet period, the fact that Svetlana Optoelectronics' parent company came out of that sector indicates that the parent company has good equipment and human resources to support the subsidiary.

Svetlana Optoelectronics was founded in 1996 and was based in a newly opened Innovation Technology Center (ITC) in St. Petersburg. The cluster included thirty innovation enterprises (over sixty firms have cycled through) pursuing areas such as opto- and microelectronics, microwave engineering, chemistry, metalworking, and software. The ITC model was developed to connect small firms to research institutes and to develop commercial products for local industries.

The St. Petersburg location also provides a conducive environment for technology research. Around the time that Svetlana Optoelectronics was founded, St. Petersburg had the highest education level in all of Russia. The number of scientific firms rapidly expanded in St. Petersburg in the mid-1990s while it shrank in Russia overall. The City of St. Petersburg made science and technology development a priority in its development policies. In addition to founding the ITC, the City set up an Innovation Council in 1996 for representatives of technology parks, innovation centers, and other research organizations to advise on the local legal environment and financial incentives for science and technology.

As a result of these factors, Svetlana Optoelectronics is one of the ITC's main success stories. It started with 15 employees and funding from the Foundation for the Assistance of Small Innovative Enterprises (FASIE) and grew to over 600 employees. Additional funding from the Russian Foundation for Technical Development, credit banks, and a FASI award in 2005 helped it expand its operations, and its annual turnover increased 550% between 2000 and 2007.

The company originally developed fire detection devices, and the optical elements of those devices facilitated the transition to developing LED lights. A 2004 award from FASI for "Development and introduction of competitive electric energy saving technologies" enabled the company to invest USD 20 million in LEDs. They anticipated that this funding would expand their production capacity to half a million lamps per year. Svetlana Optoelectronics further expanded their capacity through a variety of partnerships with Russian scientific and academic institutions.

Sources: Kihlgren 2003; www.soptel.ru; www.rfntr.neva.ru/eng/default.php?mid=2&smid=7; www.rmg.ru/en/get-analytics-file/item/583?time=1268487357

The total funding for the current FASI R&D program is approximately USD 6.5 billion, of which 4.5 billion is provided through the federal budget (Burger 2008). FASI grants require that implementing agencies provide matching contributions at an average rate of 30 percent. The Federal Target Program includes five program blocks and five priority areas. The funding levels and distributions for these sectors for the period 2007-2012 are outlined in Tables 1 and 2.

Table 1: Funding by Program Block

Program Blocks:	**Funding** (billion USD)	**Percent of funding**
General Knowledge	1.4	18%
Technology Development	4.1	53%
Commercialization	1.4	18%
Research Infrastructure	0.2	3%
Innovation Infrastructure	0.7	9%

Source: Burger 2008.

Table 2: Funding by Priority Area

Priority areas:	**Funding** (billion USD)	**Percent of funding**
Life Sciences	1.1	25%
Nanoscience and Nanotechnologies	1.7	40%
Information and Telecommunication	0.4	8%
Environmental Management	0.4	9%
Energy and Energy Efficiency	0.8	18%

Source: Burgher 2008.

The program blocks on general knowledge and technology development are organized by priority area, whereas the commercialization program block is organized based on whether the project was initiated by the government or the private sector.

A review of FASI's 2009 competitive grants through the general knowledge and technology development blocks reveals a number of projects addressing energy efficient building technologies. These include projects in the DOE priority areas of system integration, lighting, windows and envelope, and HVAC. HVAC is a primary focus area for Russian building technologies R&D, and projects within this area address heat pumps, heat exchangers, thermal energy storage, ventilation, and air conditioning. The 2009 projects are to be implemented over five to 29 months and with funding levels from USD 60,000 to USD 3.6 million (FASI 2010 a-e).[6]

[6] FASI competition information accessed from www.fasi.gov.ru/fcp/compl/konkurs2009 and www.fasi.gov.ru/fcp/compl/konkurs2008.

4.1 System Integration

The project related to system integration is a demonstration project of energy efficient office buildings. The implementing agency is developing schematics for two administrative buildings: a 430,000 square foot judicial building and a 1,485,000 square foot city tower. The buildings will have integrated HVAC, refrigeration, water, lighting, automation, and control systems. The goal is to increase energy savings not less than 35 percent over typical buildings of those sizes.

4.2 Lighting

The lighting project is focused on LED lighting for public spaces as well as residential and ancillary buildings. The implementing agency is developing prototypes based on light panels and organic LEDs (OLEDs) with a power range between 16 and 80 watts and luminosity of 75 watts. The project also calls for external controls to manage luminous flux. The goal is to reduce energy consumption six times compared to incandescent bulbs and to reduce operating cost four times compared to incandescent bulbs and 1.2 times compared to existing LEDs.

4.3 Windows and Envelope

The project related to windows and envelope is for the development of a window with high-R glazing and framing. The project should result in a domestic pilot of wood and PVC double-glazed windows filled with inert gas and placed in framing with low thermal conductivity. The window and frame design should address air permeability, temperature and humidity control, and wind loads, and the heat transfer goal is 0.8 square meters times degrees per watt.

4.4 HVAC

FASI funded multiple projects related to HVAC, and those projects address heat pumps, heat exchangers, thermal energy storage, ventilation, and air conditioning. The heat pump program is for the creation of a hybrid heat pump, using both thermal energy storage and ground source heat pumps (GSHPs) to provide heating and cooling in dense urban areas. The GSHP should produce temperature variations of plus or minus 18°F and should be designed to utilize low-grade heat at depths not greater than 77 yards. Heat and cold water storage capacities should regulate the space temperatures to not be above 77°F and not be below 14°F. Coolants under consideration include water, propylene, or ethylene glycol based solutions.

The project for heat exchangers is for the design of high-efficiency heat exchangers for office buildings, which increase heat exchange by 50 percent. The model should reduce the material consumption, mass, and size of the heat exchanger by 30 percent. The implementing agency should create a range of experimental designs and a prototype that reduces energy consumption by 30 percent.

Another HVAC project is for the design of technical schemes and a prototype for thermal energy storage in mass-produced, multi-story apartment buildings. The heat storage unit should be able to heat space up to one gigajoule per cubic meter and reduce costs 30 percent compared to coal or oil heat.

FASI is funding two projects that address ventilation. One is a heat recovery unit in a ventilation system, and the other addresses natural ventilation in mass-construction buildings. For the heat recovery unit, the implementing agency is to produce schematics, a laboratory sample, and test results for a system that is able to work in a variety of climates. The natural ventilation system project addresses the design of inlet and exhaust vents with efficiencies 10-15 percent greater than a typical product. The vents should be able to function in areas where a weeklong ambient air temperature would be as low as -30°C.

Russia's recent research on air conditioners focuses on cooling through cold water storage for large complexes. The implementing agency is to produce a laboratory sample that reduces purchase and installation costs by at least 25 percent and operations costs by at least 10 percent. The target payback period is five years. When fully charged, the storage unit should have the capacity to store 60 kilowatt hours per cubic meter. The unit should be able to recharge fully within twelve hours.

4.5 Commercialization

Commercialization receives less focus than technology development in the Federal Target Program, with 18 percent of funding going to commercialization and 53 percent toward technology development. The commercialization program block funded fewer projects than the general knowledge or technology development program blocks, and none of the 2009 projects addressed building technologies. However, commercialization is sometimes addressed as a component of projects in other program blocks, for example through market assessments. Commercialization also is incorporated into monitoring and evaluation, as the number of technologies commercialized is one of the program's targets and performance indicators (FTP 2010b).

A review of projects in 2007 and 2008 revealed one project addressing ground source heat pumps. The project was to develop and commercialize sensors able to remotely monitor characteristics of ground source heat resources (FASI 2010e). Such information would be relevant for siting buildings or sizing heat systems. The project is to be implemented over two years by an organization, which primarily develops technology for the navy, and the project budget is approximately USD 3.4 million.

4.6 Implementing Agencies

FASI's competitive grants are awarded to a wide variety of state and private research organizations as well as consortia of multiple organizations. The variety of organizations receiving funding indicates FASI's commitment to promoting a diverse and competitive market in scientific R&D. The following organizations implemented the energy efficient building technology projects described above:

- APROK TEST
- EnerGeo
- Energy Resource STE
- Energy Saving Technologies and Air Conditioning
- Engineering Center of ventilation and air conditioning INVENT
- Engineering Technology
- Innovation Exhibition Complex "ECOPARK-FILI"
- INSOLAR EERGO
- INSOLAR INVEST
- Moscow Building Research Institute
- Moscow Power Engineering Institute
- North Telecom
- Scientific-Production Association Termek
- TechnoIngPromStroi
- Ural Center for Innovative Technology
- Volgograd State University
- Zavod Pribor

4.7 International Work

In addition to its domestic work, FASI is engaged in a variety of international partnerships, mainly focused on general energy technologies rather than building technologies in particular. Examples include the Carbon Sequestration Leadership Forum, the International Partnership for a Hydrogen Economy, and the Global BioEnergy Partnership (Reutov and Orletskaya 2009). FASI also has co-hosted a number of IEA workshops, including workshops on building technologies. Examples include “Energy Technology Roadmaps as an Instrument for Developing Long-Term Foresights and S&T Policy in the Field of Energy Technologies (June 2009) and “Energy Efficient Engineering Systems in Buildings and Construction” (November 2009).

5.0 Intersections with DOE’s Building Energy Research Priorities

Russia’s R&D in buildings focuses on many topics that are priorities for Russia, either based on the building energy use, or based on the existing research base. For example, there are many projects related to district heating. At the same time, there are several potential intersections with research priorities of the DOE’s BTP. This section provides a mapping of where the FASI-funded projects overlap with BTP’s MYPPs. The Building Technology Program in DOE has developed MYPPs for six areas: System Integration, Analysis Tools, Solar Heating and Cooling, HVAC and Water Heating, Solid State Lighting, and Envelope and Windows.

The above review of Russian investments in building energy research reveals some intersections with BTP priorities in the areas of system integration, lighting, envelope and windows, and HVAC.

Russia	**U.S.**
System Integration	
Office buildings with 35 percent energy savings	New commercial construction with whole building energy performance improved 50 percent
Lighting	
LEDs for public spaces, residential and ancillary buildings based on light panel and OLED models	Novel device architectures to encourage the development of white-light OLED architectures with increased EQE, improved lifetime, and reduced voltage. Panel manufacturing technology to help to address the capital and operational costs in manufacturing, which pose a large barrier to cost reduction of OLED devices. Large-area OLED to support efforts to tackle the significant challenges inherent in the creation of a large-area OLED.
Windows	
Low emissions windows and framing	Highly insulating windows: • High-R glazings • High-R framing • System integration

HVAC	
Hybrid heat pump using thermal energy storage and ground source to provide heating and cooling	Integrated heat pumps for heating and cooling, water heating, ventilation, and humidity control
High-efficiency, compact heat exchangers	Large surface heat exchangers for radiant floors, walls, or ceilings[7]
Cooling systems through cold water storage for large complexes	Radiant cooling
Heat recovery ventilation	Heat recovery Stand-alone, direct expansion dehumidification systems with energy recovery ventilation and possibly hot water pre-heating
Natural ventilation for mass construction buildings	Ensuring comfort and indoor environmental quality

The mapping above indicates areas where Russian and U.S. energy efficient building technology research are addressing similar subjects. In some cases, the methods for addressing these topics are largely disparate. For example, for commercial building system integration, the Russian research will result in the construction of two buildings, while the U.S. research is focused on design, processes, and collaboration. Cases where methodologies are significantly different may be less conducive opportunities to collaborate on joint research; however, these cases point to opportunities for research exchange to complement the different methodological approaches or suggest new ways to address common interests.

6.0 Conclusions

Russia has been expanding its capacity and engagement in building energy technology research. Russian research tends to focus on areas seen as priorities for energy efficiency given Russian conditions. There is less evidence of commercial application of the new technologies, which may reflect the fact that R&D initiated since funding became available again in 2002 has not yet had time to mature. The Russian government and researchers are actively seeking opportunities for international collaboration. FASI in particular has formed several international partnerships and has reached out to the IEA on building energy research.

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[7] The relevant MYPP lists large surface heat exchangers as an unaddressed area, meaning that this is not an active area of research today.

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