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Low-Energy Future of Russian Building Sector

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ABSTRACT OF THESIS submitted by:

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According the path-dependency theory implemented to the pattern of energy use, the energy saving potential can be "locked-in" by inefficient use of energy due to the high costs of switching to a more efficient technology.

In this paper the potential of energy savings and the "lock-in effect" for the Russian building sector are estimated by means of modeling final energy use for space heating. The "lock-in effect" is the potential energy savings untapped due to the lack of policy development. The most considerable final energy use savings and lock-in effect (more than 50% by 2050) are estimated for the scenario of a significant increase in the market penetration of advanced buildings. In case no policies are introduced, this potential is less than 2%.

To realize the energy savings potential active policy development has to take place in Russia to address existing barriers and drive market transformation towards higher energy efficiency. The analysis of energy efficiency policy instruments has shown that certain steps have been made in this direction. The most significant step is the adoption of the Federal Law "On Energy Savings…" in 2009. However, further development of policies with the focus advanced construction and renovation is required.

The present analysis of recent projects in Russia shows that there is a positive tendency towards energy efficiency improvement in Russia. Taking into account the government's activities and plans, it is very likely that the building sector will follow the path of actively reducing its energy consumption.

Keywords: energy efficiency, Russia, lock-in effect, market transformation, policy instruments

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Chapter 1. Introduction

This chapter presents the main problem of the research as well as the aim, objectives and the structure of the thesis.

1.1. The problem of energy efficiency in buildings

One of the greatest global challenges in the world today is the unsustainable use of energy resources (Metz *et al.* 2007). The impacts of this phenomenon are extremely diverse and affect different sides of life on our planet (Lapoche *et al*. 1997). Perhaps the most devastating and currently acute effect of the impacts caused by irrational energy use is contribution to anthropogenic climate change. At the same time, the use of energy is essential for economic growth, which is vital especially for developing countries and economies in transition. Thus, it is very important for these countries to use energy resources in a more efficient way.

One of the sources which contribute to growing energy consumption and the emissions of greenhouse gases (GHG) is the building sector. This sector also provides lower-cost solutions to the problem of energy savings and GHG emissions' reduction (Ürge-Vorsatz and Novikova 2008). Thus, in relation to meeting the climate change challenge, energy efficiency in the building sector has been rapidly coming into focus (Ürge-Vorsatz and Koeppel 2007).

However, especially in developing countries and economies in transition, there is no clear understanding of the opportunities to improve energy efficiency in the building sector. Consequently, these opportunities are not covered by existing policies and a lot of energy savings are "locked in" inefficient use of energy (Lechtenbohmer and Tomas 2003). This fact is mainly caused by the lack of scientific information relevant to implement policy instruments in the building sector, use of fossil fuels and old technologies. This situation can be worsened by the high energy intensity of the economy, which in combination with the lack of efficient policy instruments causes inefficient use of energy and substantial energy losses.

1.2. The scope of the study - Russian Federation

One of the examples of an economy in transition can be Russia. This country has been chosen for the analysis because it remains one of the most energy intensive economies in the world and, thus, contributes greatly to the problem of climate change (Bashmakov *et.al.* 2008). At the same time, it has a great potential for energy efficiency improvement which is not realized at the moment due to different barriers (Bashmakov *et.al.* 2008). The building sector has been chosen because it is one of the main energy consumers in the Russian economy (see Figure 1).

The government is presently working on the modernization of a federal program targeted to promote energy efficiency. The G8 summit in St. Petersburg in 2006 also raised the problem of energy efficiency issues in the country (Bashmakov *et.al.* 2008). In November 2009 the Federal Law on Energy Efficiency was adopted in Russia, which is a great step towards institutionalization of energy efficiency (EE) in Russia. However, these separate steps are not sufficient for moving the Russian economy towards higher EE and locking out the huge potential for energy savings. For this purpose, a complex EE policy supported by effective work of EE institutions should take place. It leads to transformation of the whole market and considerable unlocking of energy savings. In this paper EE market transformation is defined as a considerable increase in demand and supply of EE products and technologies.

In this situation a strong scientific substantiation for further EE policy development is required.

1.3. The aim, main question, objectives and structure of the research

Thus, the main aim of the thesis is to estimate the potential for energy savings in the Russian building stock and analyze how the development of energy efficiency policies can drive market transformation towards higher energy efficiency in Russia. It is made by means of final energy use modeling and potential energy savings analysis and the analysis of policies. In this regard, the main research question can be formulated as follows:

What potential for energy savings is "locked-in" in the Russian building sector and what can be done to "unlock" it, taking into account the development of energy efficiency concept and the current policies in the Russian Federation?

To achieve this goal several objectives have to be attained:

1. To develop a model for Russian building stock and final energy use in buildings
2. To elaborate several scenarios of the trends in energy consumption of Russian building stock by 2050
3. To calculate the potential energy savings for each scenario, the "lock-in effect" and interpret the results
4. To analyze the existing energy efficiency policies in Russia, their role for reduction of the barriers to energy efficiency and limitations.
5. To give recommendations on energy efficiency policies development to achieve energy savings.

The paper consists of eight parts. In the first chapter the introduction to the research is presented. As was shown above, it includes the description of the research problem, the scope of the study, research aim, objectives, main question and the structure of the study.

The second part presents the general information about energy use in Russia, including the overview of statistical data for the building sector specifically. It also illustrates the evolution of the energy efficiency concept in Russian energy policy.

In the third part the theoretical framework is elaborated for the research. The research is based on the main concepts of the traditional theory of path dependency, for the first time proposed by David (1985) and Arthur (1989). The key aspect of this theory related to the topic of the study is technological "lock-in". The main idea of the technological understanding of the lock-in is that technologies and technological systems follow specific paths that are difficult and costly to escape. Thus, the technologies existing in the economy at the moment tend to persist for extended periods even when there are already more advanced competitors (Perkins 2003). In order to overcome the lock-in, first of all institutional change is required to provide the market transformation towards higher energy efficiency.

The fourth chapter presents the methodological design of the study. It is based on the model of final energy use for space heating which gives the opportunity to estimate energy savings potential and "lock-in effect" in the Russian building sector by 2050. The chapter describes the main methodological steps, assumptions and scenarios. It also proposes the approach for the analysis of existing energy efficiency policy instruments in Russia. The policy analysis includes the role of policy instruments for overcoming the barriers to EE improvement, their limitations and recommendations for further development.

The fifth chapter presents the main results of the study. It is divided into two main parts. The first part contains the results of model stimulation for four scenarios. And the second part – the implication of policies' analysis and recommendations for further EE policy development. It contains actions necessary for unlocking energy savings of Russian building sector.

The discussion section presents analysis of the most probable developmental path for the Russian building sector, taking into account the results of scenarios' stimulation, policy analysis and perspectives of energy efficiency improvement in Russia. Finally, conclusion part gives a summary of the results and the directions for the further research in the field.

Thus, the main contribution of this paper is the analysis of the potential and possibilities to bypass the inefficient energy use and "unlock" potential energy savings by means of energy efficiency policy development. This paper might be interesting for policy-makers, specialists and students, dealing with energy efficiency issues and other people interested in the subject.

Chapter 2. Energy efficiency background of Russia

The history of the development of the energy efficient concept in Russia is not long – about 15 years and should be analyzed in the context of energy use in Russia. Thus, this chapter starts with the overview of the main energy statistics of Russia, followed by the analysis of the development of energy efficiency issues in Russian energy policy.

2.1. Energy use in Russia

With 2.5% of the global population, the Russian Federation has almost 45% of natural gas, 13% of oil, 23% of coal, and 14% of uranium potential of world resources; it produces more than 10% of the world's primary energy (PEEREA 2007).

The abundance of energy resources, cold climate, and a huge territory with uneven distribution of population, domination of heavy industries, oil and natural gas production in Russian economy are factors which contribute to the very high level of Russian energy intensity (World Bank 2008).

Figure 1 shows the energy intensity in Russia from 1991 to 2007. The original data for the Figure 1 can be found in the Annex (Table 12). Energy intensity is one of the main quantitative indicators of the connection between the economic development and energy sources utilization. As economic development is usually accompanied by an increase in energy consumption and energy intensity shows the relation between these two variables, thus, the high rate of energy intensity indicates an ineffective use of energy by the economy (Belyi 2009).

Energy intensity indicator is calculated as the relation between energy consumption of a county and economic output, usually, GDP (Belyi 2009). In this paper data for energy intensity are calculated, according to Formula (1):

$$Energy\,Intensity_n = \frac{Primary\,Energy\,Consumption_n}{GDP\,per\,capita_n}, \quad (1)$$

where n – the number of a year

In our case primary energy consumption is measured in Btu[1] and GDP per capita – in US dollars of 2005. Thus, energy intensity is measured in Btu per US dollar.

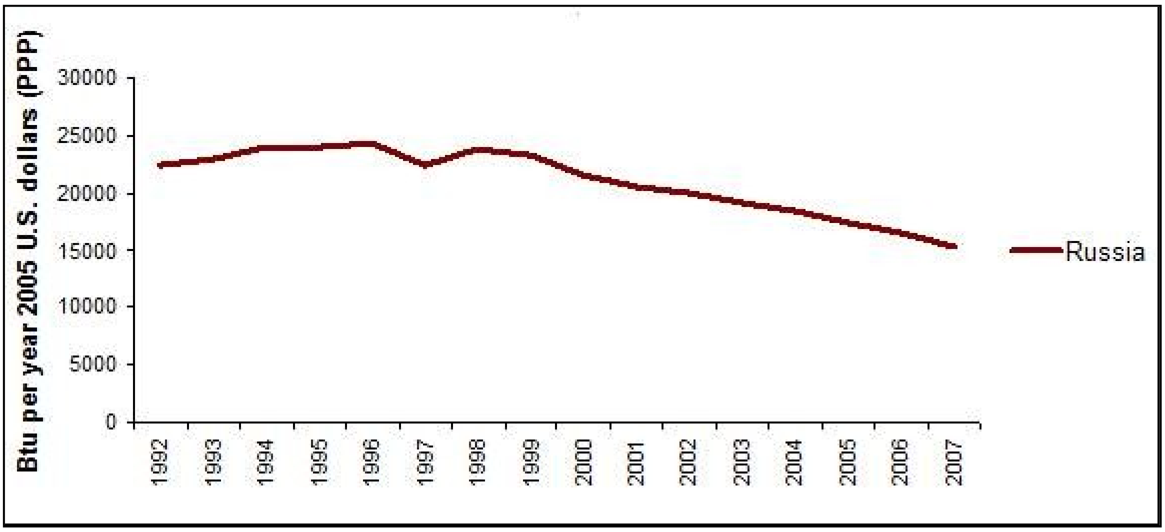


Figure 1. Energy Intensity in Russia, 1992-2007

Data Source: US EIA (2007)

In comparison with developed countries energy intensity of Russia has the most energy intensive economy (Mitthone 2010). Figure 2 presents a comparative dynamics of energy intensity in Russia, France, Germany and the United Kingdom in 1992-2007.

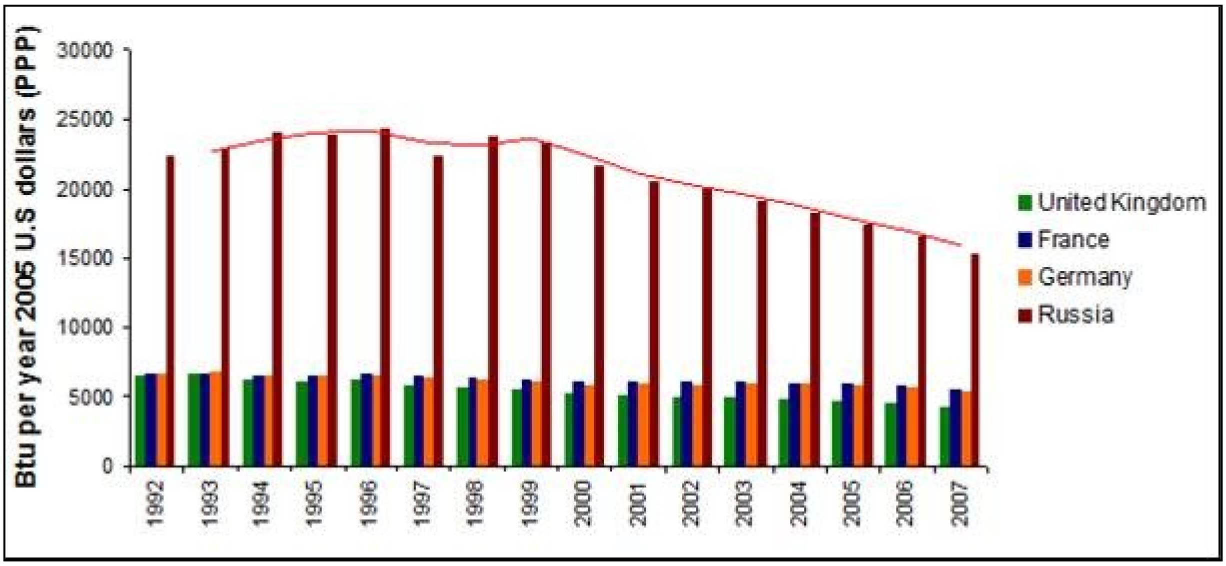


Figure 2. Energy intensity in Russia, France, Germany and the UK

Data Source: US EIA (2007). The original data see in Table 12, Annex.

[1] A British Thermal Unit (BTU) is the amount of heat energy needed to raise the temperature of one pound of water by one degree F. This is the standard measurement used to state the amount of energy that a fuel has as well as the amount of output of any heat generating device (Riches n.d.)

It is often assumed that if there is a significant decrease in energy intensity at the end of the period in relation to the beginning of the period, then there is some energy efficiency improvement in a country (Belyi 2009). The decrease in energy intensity can be calculated, according to Formula 2:

$$EI\ Decrease = \frac{EI_{end} - EI_{begin}}{EI_{begin}} \times 100\% \ ; \qquad (2)$$

where *EI* – energy intensity, *end* – the end of the analyzed period, *begin* – the beginning of the period. If the decrease has taken place by the end of the analyzed period the result should be negative.

Thus, if a country has a significant decrease in energy intensity during a continued period of time (at least 10 years), that means that energy efficiency improvement has been taking place. However, energy intensity is a much more complicated index, influenced by different macro- and micro factors. Therefore, it cannot show directly whether there is an energy efficiency improvement in an economy or not. The case of Russia is a very good example to illustrate this point.

The decrease in energy intensity calculated according to Formula (2) by 2007 is more than 30%:

$$EI\ Decrease_{RUSSIA} = \frac{15312 - 22336}{22336} \times 100\% = -31{,}4\%$$ [2]

During the 1990s the country's energy intensity increased in spite of the general economic depression and the fall in per capita energy use. During the initial stage of transition process (1990-1995) the poor energy productivity of Russian economy deteriorated greatly. In the early 2000s the economic recovery caused the demand increase. Consequently, the energy intensity of Russian GDP declined significantly in 2000-2006. However, the economic recovery has been marked by an absence of effective national energy efficiency policies, unbalanced energy pricing policies, the lack of proper legislation and regulations in the energy

[2] Numbers in the calculation are the values of energy intensity of Russian in 2007 and 1992 presented in Table 12, Annex.

field, institutions and general public awareness of energy saving opportunities (PEEREA 2007). Thus, the considerable decrease in energy intensity cannot be related to energy efficiency improvement. It has resulted "from structural changes and economy of scale effects, while loading up old, built back in the Soviet era, production facilities" (Bashmakov *et al.* 2008). In other words, during the analyzed period there was no market transformation towards higher energy efficiency in Russia.

Russia has a huge opportunity to reduce its energy costs and lower its energy consumption. It could lower its consumption of natural gas and, in turn, increase its exports of natural gas and the flow of rubles back to Russia (Mitthone 2010).

One of the largest end-use sectors in Russia is the building sector. It consumes about 35% of total final energy consumption of the country (see Figure 3). The building sector includes residential (27%), commercial and public buildings (8%). About 75% of the sector's energy is consumed in the residential buildings (Mitthone 2010).

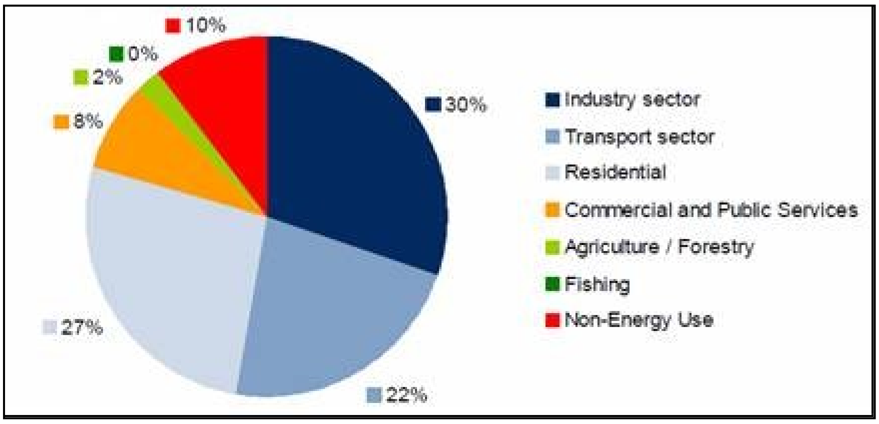


Figure 3. Final energy consumption by sector, 2006

Source: Sustainable Energy Development (2007)

Approximately 70 percent of the energy used in the building sector comes from natural gas, either directly or for generating electricity and producing heat used in buildings (Mitthone 2010).

Space heating is the leading energy end-user (58%) in the building sector, followed by hot water (25%), cooking (10%), lighting (2.6%), and appliances (4.5%). The share of appliances in electricity consumption stands at 52% and corresponds very well to similar shares in many other countries (Bashmakov *et al.* 2008).

Table 1 shows absolute values (in mtoe) for energy use of different activities in the residential sector with a breakdown by energy source. It can be seen that the most of energy is consumed during heat generation and gas utilization.

Table 1. Residential sector energy end-use structure, 2005 (mtoe)

	Coal	Petroleum products	Gas	Other solid fuels	Electricity	Heat	Total
Heating	2.47		12.05	0.76	0.79	46.68	62.94
Hot water	0.36	0.18	5.71	0.18	0.36	20.34	26.94
Cooking		0.73	9.42		0.57		10.72
Lighting					2.81		2.81
Appliances					4.84		4.84
Total	**2.83**	**0.91**	**27.18**	**0.94**	**9.37**	**67.02**	**108.25**

Source: Bashmakov *et al.* (2008)

The Russian building sector has a great potential for energy conservation. Technical potential for energy savings in the sector is estimated as more than 55% (World Bank 2008), about 85% of technical potential is economically viable, 72% is market attractive with the 2010 energy prices (Bashmakov *et al.* 2008). In the period from 2002 to 2005 the calculated energy savings in the building sector in terms of primary energy were around 240 PJ, or 8.6 million tons of coal equivalent, and has also led to an overall reduction in emissions of greenhouse gases of 16.4 million tons (Matrosov *et.al* 2007?). By the end of 2008 the cumulative energy savings since 2002 were already 771 PJ or 27.8 million tons of coal equivalent. The decrease in energy use had also caused the reduction of GHG emissions by 1.7 million tons annually and the cumulative reduction of 59 million tons CO_2 (Matrosov 2009).

Such energy savings are especially urgent in the light of RF Presidential Edict No.889 of 4 June 2008 which set the goal of 40% reduction of energy use for heating in the building sector by 2020 with the level of energy use in 2007 as a baseline. The achievement of this goal presumes that from 1 January 2010 multi-family houses of four storeys or less and premium and high-rise houses must be designed as B-class buildings with 20% reduction of energy use for heating in relation to a normative value. And from 1 January 2016 these types of buildings will have to be constructed with a 40% reduction of energy use for heating and other multi-family houses – with a 20% reduction (Matrosov 2009). Such considerable savings can be achieved by improving energy efficiency in buildings.

2.2. The energy efficiency concept

Energy efficiency (EE) in general is the level of service provided by a unit of energy, but it can also be the level of service provided by a unit of expenditure (Boardman 2004). In respect of buildings

> **Energy efficiency is the ability of a building or its engineering systems to provide a specified level of energy consumption for maintaining optimal microclimate conditions in compliance with the current level of modern building technologies development and norms of environmental protection**
> (Egerat. and House 2007).

The criterion of the energy efficiency of a building is a value of limited final energy consumption which is used during designing, constructing, commissioning as well as further maintaining, according to its class of energy efficiency (Egerat and House 2007). The improvement of energy efficiency in buildings means the reduction of energy consumption per square meter of floor area. The most important consequence of EE improvement in the building sector is the reduction of greenhouse gases (GHG) emissions and, consequently, the mitigation of its contribution to climate change. There are a lot of other co-benefits of energy efficiency improvement in the building sector.

First of all, energy efficiency of the building sector enhances local air quality, contributing thereby to the improvement of public health and avoidance of structural damage to buildings and public works. The diffusion of more energy efficient technologies in buildings makes the quality of life higher and increases the value of buildings. These benefits may include: improved thermal comfort, reduced level of outdoor noise infiltration due to triple-glazed windows or high-performance wall and roof insulation (Jakob 2006), reduced heath risks associated with increased moisture inside the buildings through thermal bridges and damp basements (Metz *et al.* 2007).

Secondly, more energy efficient buildings often have the co-benefits of improving occupants' health and work productivity (Leaman and Bordass, 1999). Moreover, the implementation of energy efficient technologies achieves substantial "learning" and economies of scale, resulting in costs reductions (Metz *et al.* 2007).

Thirdly, the investments in energy efficiency often have a positive impact on employment rates by creating additional jobs and business opportunities (Jochem and Madlener 2003). The

European Commission estimated that a 20% reduction in EU energy consumption through energy efficiency improvement by 2020 can create about one million new jobs in Europe (European Commission 2003).

Another benefit of energy efficiency improvement in the building sector is the reduced energy bills of households. This benefit is especially important for low-income households, which in case of reduced energy costs can afford more adequate energy services and equipment. In this regards, energy efficiency can be a way to address the energy poverty problem, which is acute not only for developing countries, but also for developed ones (Metz *et al.* 2007).

Finally, co-benefits of energy efficiency of buildings include improved energy security and system reliability (IEA 2004b). This benefit is quite important for the European Union it has a high dependency on energy imports. Energy efficiency can reduce the level of energy dependency and, consequently, increase energy security, as well as generate additional macro-economic benefits because reduced energy imports will improve the trade balances of importing countries (European Commission 2003).

Thus, the improvement of energy efficiency has a lot of benefits, which are acute for Russia at the moment. There are two aspects of energy efficiency improvement: technological and political. The technological aspect means that the energy efficiency of a building can be increased through different technological decisions. However, the existing technological solutions dominating the market aggravate introducing and spreading more progressive (in other words, energy efficient) technologies due to certain barriers, e.g. accompanying costs and behavioral patterns (Altman 2000). It creates the "lock-in effect", when inefficient technologies remain dominant in the market even when efficient ones have already been invented. This can be supported by the ideas of the traditional path-dependency theory (David 1985 and Arthur 1989), which is presented in the section devoted to the theoretical framework.

2.3. The evolution of the energy efficiency concept in Russia

In Russia energy efficiency has become a priority of the energy policy only recently. The evolution of the energy efficiency concept in Russia can be observed through its energy strategies, adopted first in 1995, then in 2003 and finally in 2009 and the introduction of the norms and regulations.

For the first time energy efficiency was mentioned as a goal of Russian state policy was in the Energy Strategy of Russia 1995 (IEA 1995). One crucial goal of this Strategy was "a radical reduction in the use of material, labor and natural resources to satisfy the needs of society with regard to energy" (IEA 1995). This goal does not mention energy efficiency directly but the reduction in the natural resources use presumes that they should be used in a more efficient way. The Strategy 1995 admits the rise in energy efficiency together with energy conservation as a priority of the national energy policy, pointing out the transition from "large-scale production" to more efficient energy consumption (Belyi and Petrichenko 2010).

Since the time this Strategy was developed different building norms and standards have been steadily adopted in Russia. In 1992-1993 a new ideology for the buildings' codification from the energy point of view was developed. Then, the first building standards were adopted for the city of Moscow in 1994 (Osipov and Matrosov 2006). In 1995 serious amendments were made in Federal norms on building heat technology. Since 2001 these norms have provided a 40% reduction in heat consumption. In 1996 the State Standard (GOST 30494-96) on internal microclimate characteristics of dwelling houses and public buildings was approved by the State Construction Company (Gosstroj). This standard was aimed to provide people inside a building with comfortable microclimate conditions. Between 1998 and 2005 regional building codes on energy savings were developed in more than 53 regions of Russia, including a new version of the one in Moscow (MGSN 2.01-99).

In 2001 Construction standards and regulations for Single-family houses (SNiP 31-02-2001) were adopted. In this period Gosstroj approved three State Standards on energy audit of existing buildings (GOST 31166-03, GOST 31167-03 and GOST 31168-03). In 2003, on the basis of experience in the regions new Construction standards and regulations on Thermal Performance of Buildings (SNiP 23-03-04), related Code of Practice (SP 23-101-04) "Designing the Thermal Performance of Buildings" and new Construction standards and regulations for Multi-family houses (SNiP 31-01-03) were adopted. As a result a new system of normative documents on designing and operation of buildings with lower energy consumption was created (Osipov and Matrosov 2006).

In this system Construction standards and regulations on Thermal Performance of Buildings can be considered as a core. Per se it represents Russian Building Codes, containing norms for both new and existing buildings.

In 2003 a new Energy Strategy of Russian Federation by 2020 (hereafter ES 2003) was adopted. The Strategy set two main goals regarding energy efficiency: (1) the structural transition of Russian economy towards the industries with low energy intensity; (2) the realization of the potential of technological energy savings10. ES 2003 stated the necessity of development of a stable and sustainable investment climate for energy saving projects, support specialized business in the field of energy savings, fulfillment of activities under flexibility mechanisms of the Kyoto Protocol, incorporation of energy efficiency and energy saving measures into regional and municipal development programmes. ES 2003 as well as the previous one does not set clear targets in respect of energy efficiency improvement and energy intensity reduction (ESR 2003).

Despite the declared strengthening of energy efficiency strategy in the second Strategy, the monitoring of the implementation of ES 2003, conducted in 2005 (Byshyev and Troitskij 2005) showed that its important goals had not been achieved. ES 2003 presumed that the realization of technological potential of energy savings should reduce about 30-35% of GDP energy intensity (Byshyev and Troitskij 2005). The target has never been reached, which basically demonstrates the weakness of the regulatory framework of the energy efficiency support. Consequently, Russia failed to decrease the energy intensity of its economy, and, consequently, energy savings at the national level; it did not create an investment climate, and did not develop the integral system of energy legislation. The legislation in force remained fragmentary and insufficient for the effective state regulation of the energy sector in the situation market economy. Thus, the Strategy did not manage to create the proper institutional structure, necessary for the effectiveness of policy implementation. The main reason for the failure of the Strategy is that it did not become the reference which all government actions were checked with (Byshyev and Troitskij 2005). Thus, the suspense of the main problems indicated by the Energy Strategy by 2010 and new socio-economic conditions in Russia caused the necessity of developing a new Strategy (Belyi and Petrichenko 2010).

The next Energy Strategy by 2030 was adopted in 2009 and now is in force (hereafter ES 2009). The ES 2009 has a target to improve energy efficiency and reduce the energy intensity of economy to the level of the countries with similar natural and climatic conditions, such as

Canada and Scandinavian countries (ES 2009). It means that the Strategy sets a more or less concrete quantitative goal and shows that Russia in its policy orients to developed countries. However, these goals still include neither concrete figures for energy savings and energy efficiency improvement nor deadlines by which these targets should be achieved (Belyi and Petrichenko 2010). ES 2009 will be discussed in more detail below. The greatest advantage of the current Strategy is that most of its provisions have got the reflection in the Federal Law No. 261-FZ "On Energy Savings and Energy Efficiency Increase and Amending Certain Legislative Acts of the Russian Federation" (hereinafter - "the Law" or "the Law On energy savings") was adopted in November 2009. It was signed by the President on 23 November 2009 and published officially on 27 November.

The aim of the Law is to create a legislative, economic and organizational basis for the stimulation of energy savings and improvement of energy efficiency (Federal Law of RF #261-FZ). That means that energy efficiency is admitted as one of the priorities of Russian energy policy. The Law aims at improving the demand-side management in the energy consuming sectors. The Law determines five main principles of legal regulation in the field of energy savings and energy efficiency improvement:

1) Effective and rational use of energy resources;
2) Support and stimulation of energy savings and energy efficiency improvement;
3) Consistency and complexity of the activities in the field of energy savings and energy efficiency improvement;
4) Planning of energy savings and energy efficiency improvement;
5) The use of energy resources with due consideration of resort, production and technical, ecological and social conditions (Federal Law of RF #261-FZ).

Thus, the Federal Law on energy savings is an important step towards increasing energy efficiency and achieving energy savings. However, it has certain limitations, such as a lack of mandatory targets which must be achieved, concrete measures, incentives for energy efficiency improvement and institutional framework for further energy efficiency policy (Belyi and Petrichenko 2010). Moreover, for instance, energy audits or energy metering, have been proposed by the previous Law on energy conservation of 1996 and have never been implemented. Therefore, it is hard to judge on the future effectiveness of the Law on energy savings as it totally depends on how its provisions will be implemented by the government.

Chapter 3. Theoretical framework. Path-dependency theory and market transformation in respect of energy efficiency

The main concept analyzed in this study is "lock-in effect" in respect of energy savings. Basically, it means the lost opportunity to save energy. In the existing scientific and analytic literature this meaning can be found very rarely. Usually, the lock-in effect is considered in relation to technology and, thus, is mainly analyzed as a phenomenon in the literature devoted to technological change and path-dependency.

In this chapter the overview of the path dependency theory is given in relation to technological development and then the concept of market transformation is analyzed as a way to overcome the "lock-in effect" of inefficient utilization of energy technologies.

3.1. Traditional path-dependency theory

According to traditional path-dependency theory (David 1985 and Arthur 1989), a technological system chosen first in an economy has an advantage of increasing returns which increases over time. Productivity and related costs are time-dependent so that newcomers to a market would face a competitive barrier in comparison with the technologies which are dominant at the market. This situation can cause the problem of path-dependency when the economy keeps utilizing a dominant and usually less efficient technology even if a new and more efficient one has been introduced (Altman 2000).

Even if the economic agents know about the higher efficiency of a new technology, it is difficult for them to choose it, because the costs of switching to a new technology are higher than those of utilizing the inefficient one (usually in the short-run) (see Figure 4). The higher efficiency of a new technological solution does not generate the economic forces itself to displace the inefficient technological regime. Thus, once "locked-in", the inefficient technological solutions cannot be displaced by the market forces alone. Figure 4 presents a schematic process of path-dependency; the average cost is assumed to be a negative function of time.

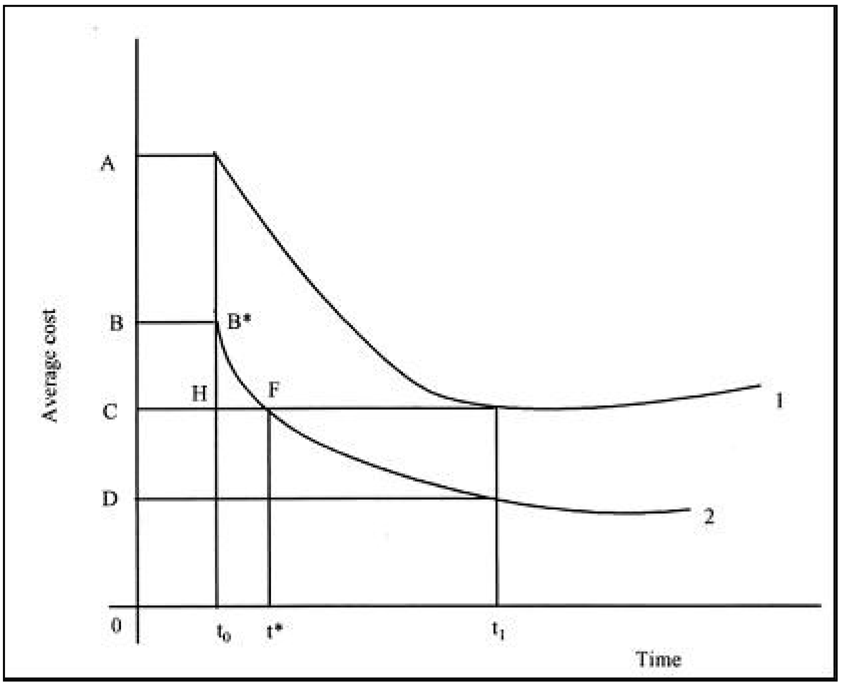


Figure 4. Path-dependency

Source: Altman (2000)

Curve 1 represents the inefficient technological regime, which was introduced first. Curve 2 represents the regime with higher efficiency. If the technological regime 2 takes place at the same time with the technological regime 1, then its average costs would be lower (0D vs. 0C) and it is very likely that the choice of the market will be made for regime 2. However, in case when the regime 2 takes place later, e.g. at the moment when regime 2 has been at the market for the period of time t_0t_1, regime 2 will face "an initial competitive disadvantage of BC", which will be eliminated only at the period of time t* (Altman 2000).

After the moment t* the difference in costs between regimes is eliminated and regime 2 becomes more profitable. After an uncertain and unpredictable period of time a new equilibrium price is established consistent with the costs of the efficient regime (Schumpeter 1974).

The main idea of the path-dependency theory in terms of technological development is that once the technological path has been chosen it is very difficult to change it, even for a more efficient one, because of accompanying costs and behavioral patterns
(David 1985; Arthur 1989; Altman 2000).

3.2. The technological understanding of the “lock-in effect”

When the chosen path or solution “becomes a permanent or a stable equilibrium” (Altman 2000) the concept of “lock-in” arises. It means that inefficient technologies are dominant and the market cannot shift to more efficient ones. Thus, the technologies dominating in the economy tend to persist for a certain period of time even if more advanced competitors’ are present (Perkins 2003).

In the literature different reasons for the occurrence of lock-in effect are discussed. Perkins (2003) sees one of the reasons in the idea that the nature and direction of technological advance are strongly shaped by the cognitive framework of actors (Perkins 2003). Nelson and Winter (1977) used the term technological regimes to describe these frames while Dosi (1982) refers to them as technological paradigms. All of them point to the existence of certain “principles” that define the boundaries of technological community members’ thoughts and actions. These boundaries presume that efforts to improve a technology are based on past knowledge. The result of it is that technological possibilities and solutions that lie beyond these boundaries are rarely explored (Dosi 1982). Thus, the technologies are more likely to develop incrementally following certain trajectories, structured according to the existing mental framework of the technological community, rather than change radically (Perkins 2003).

Another reason for occurrence of lock-in has roots in the idea of increasing returns to adoption of a technology. Increasing returns mean that the more a technology is adopted the higher its attractiveness on the market (David 1985 and Arthur 1989). In a situation where two or more technologies are competing for a market share the increasing returns can create the situation when a technology which has been adopted earlier among the competitors can generate a snowballing effect and benefit from greater improvement. In fact, under conditions of increasing returns, technologies that fail to win early adoption success might eventually find themselves locked-out from the market, unable to compete with the earlier adopted one (Perkins 2003).

This process can have negative effects for the whole society by locking it in the situation of the dominance of inefficient technologies. The earlier adoption of such a technology can take place because technological choice during the early stages of competition is characterised by ignorance and uncertainty about qualities and properties of different options. Consequently, a technology that would have required higher initial investments and/ or additional learning might find itself being locked-out by a more affordable one (Perkins 2003).

Jaffe and Staving (1994) have shown that the tendency for postponing the adoption of new technologies by agents caused by their expectations. For example, if purchase and/or installation costs are declining, it can cause the intention of the agents to wait, despite the fact that current net benefits of adoption are positive. The same tendency occurs if adoption is taking place very fast and information about the technology is increasing rapidly. The willingness to wait with adoption could also take place if government subsidies or tax credits are increasing sufficiently rapidly over time. It can be explained by the agents' expectation of higher benefits in the future, which causes their decision to postpone their investment even in case of the currently positive benefit-cost picture.

Another reason for procrastination of new technologies' adoption is network externalities. Network externalities are the external advantages given to the users of a technology by another's use of the same technology. These advantages result from the fact that each technology is a part of broader networks consisting of many, interdependent technologies and infrastructures, which enable existing technologies to work together (Perkins 2003).

Network externalities strengthen the lock-in effect by raising the barriers for new technologies to spread on the market. That means that switching to a novel technology would require corresponding changes in the related infrastructure and the rest of the technological system (Metcalfe 1997). Thus, such a change could cause a considerable inertia among involved actors. The costs of change include the expenditures for the replacement of physical elements of the technological system and change of associated work practices, skills and patterns of behaviour. The most significant consequence from this situation is that where switching to a new technology would be profitable, users may resist to switching to a new technology and continue choosing the existing options (Perkins 2003).

Safarzyńska and van den Bergh (2010) also support the view that network externalities lead to lock-in of consumers' choices. However, they have also revealed that the consumers' choice is influenced by "the snob effect" - the desire for distinction from others. The stronger its influence is, the lower the likelihood of market lock-in is (Safarzyńska and van den Bergh 2010). Thus, if a company or an individual is eager to distinguish itself from other consumers it is very likely that they will choose a product (technology), which is not widely spread on the market. In this regard “the snob effect” can reduce “lock-in effect”.

Lock-in effect can also be reduced by the fact that performance of new technologies improves and their costs reduce during the process of learning, when individuals and organisations get more experience in using them. These learning effects are commonly presented as learning curves, showing a reduction in unit costs with rising cumulative output. They are rather broadly analyzed in the literature (Grübler and Messner 1998; Goulder and Mathai 2000; Schneider and Goulder 1997; Wigley et al. 1996; Anderson 1999; Grubb et al. 1995; Löschel 2004; Mulder 2005, etc.).

Mudler (2005) concludes that a slow switch to a new technology temporally reduces the productivity level of the capital stock. It prevents agents from immediate and “total” switching and instead induces a gradual adoption of new technologies resulting in coexistence of old and new technologies.

Therefore, according to the existing literature, the lock-in effect, on the one hand, is caused by the technological paradigm dominating on the market, including certain skills, habits and outlooks, and on the other hand, increasing returns to adoption, which creates specific incentives structures to maintain existing technologies (Metcalfe 1997).

3.3. The “lock-in effect” and energy savings

During the last two decades technological “lock-in” has caught the attention of scholars interested in the links between technological and environmental change (Kemp 1994; Rip and Kemp 1998; Unruh 2000).

According to Metz *et.al.* (2007), the ‘lock-in’ effects of infrastructure, technology and product design choices made by industrialized countries in the post-World War II period of low energy prices are responsible for the major recent increase in world GHG emissions.

Technologies differ with respect to their energy use and waste generation (Booth 1998; Grübler *et al*. 1999). The key conclusion made in the literature is that developed economies are locked into a complex of hydrocarbon-intensive technologies and infrastructures (Rip and Kemp 1998; Arentsen *et al*. 2002). It explains the current situation when the growing concern about the negative impacts of fossil fuel use is accompanied by impossibility to switch quickly to zero-emitting substitutes. It can be explained by the fact that hydrocarbon technologies have been benefiting from learning effects and technological network development for several decades, which all together hinder the innovation and diffusion of technologies that lie outside this fossil fuel technological paradigm.

Another reason is the resistance of private and public institutions to radical change. Many of them are interested in maintaining the current technological paradigm and, thus, they are contributing to reinforcing lock-in effect (Kemp 1994; Unruh 2000)

There are very few sources of literature, which apply the term of lock-in directly to energy savings. For example, in Groot *et al.* (2001) the impact of adoption subsidies on the amount of energy savings is analyzed, taking into account an uncertain nature of technological progress. It is stated in this work that increasing investment subsidies for energy-saving technologies can favor a lock-in into relatively inferior technologies. Firms that have adopted the technology generate knowledge on how to use and improve the technology, creating a learning effect for the firms that have not yet adopted the technology. As a result, the technology improves over time and ultimately matures. Thus, at the time of maturation of the technology not all firms have adopted it. A high subsidy scheme stimulates adoption in both the short and long run resulting in a relatively high number of firms that has adopted the technology, also when it has matured (Groot *et al.* 2001). Thus, such subsidies can create the incentives to wait until the technologies will mature and adopt it with lower risk and costs. It causes the lock-in of energy savings, which could have been achieved in the situation when the majority of firms adopt the technology at the early stage of its introduction. Thus, lock-in of energy savings always goes in hand with the adoption of energy efficient technologies.

Norberg-Bohm (1990) and Mulder (2005) state that the widespread adoption of existing energy-saving technologies could significantly reduce energy use, especially in the short and medium run. Mulder (2005) uses the term "energy efficiency paradox" to describe the lock-in effect, in the same way as in Jaffe and Stavins (1994) do. Mulder defined it as "a considerable gap between the most energy-efficient and cost-effective technologies available at some point in time and those that are actually in use" (Mulder 2005).

Jaffe and Stavins (1994) propose two groups of factors for explaining a gradual diffusion of energy efficient technologies: market failures, including information problems, principal/agent slippage, and unobserved costs; and the explanations that do not represent market failures: private information costs, high discount rates, and heterogeneity among potential adopters. They demonstrate how the diffusion of energy efficiency technologies can be directly hindered by principal/agent problems in new residential buildings. Jaffe and Stavins also have revealed that "artificially low" energy prices can provide another market-failure explanation of the paradox. At the same time their analysis showed that decreases in the costs of adoption accelerate technology. Among other factors they noted that departures from temperate climatic conditions, and increases in income and education can accelerate diffusion. Jaffe and Stavins have also come to the conclusion that high discount rates can hamper the adoption of energy-saving technologies for renovation. Lower adoption costs and government programs in the form of subsidies or tax credits will stimulate the adoption.

In general, the problem of lock-in is rather common for the building sector. Rohracher (2001) found that this sector traditionally has low levels of innovation, mass production from large suppliers, and separation of design from construction. Dewick and Miozzo (2004) in their study of Scottish building sector pointed out that "[t]he different aims of the parties involved in the construction chain may not be easily reconciled and traditional approaches to construction may reinforce these differences, hindering efforts to introduce innovation."

3.4. Market transformation as the way to overcome the "lock-in effect" in the building sector

In terms of energy efficient technologies in the building sector, path-dependency means that the market cannot transform quickly from old inefficient technologies to new more energy efficient ones, due to certain barriers (see Table 2). Consumers are not providing a pull towards energy efficiency, usually because they are ignorant of (or indifferent to) the range on the market, or the energy implications of their purchases. Producers are usually aimed at maximizing their profits, so without additional incentives they are unlikely to switch to the production of energy efficient products. Without a positive design focus from manufacturers or a clear demand from consumers the market will not deliver energy efficiency naturally (Boardman 2004).

A significant increase in demand and supply for energy efficient products and technologies on the market can be defined as market transformation (Schlegal *et al.* 1997). It can be stimulated by certain actions (co-called interventions) from outside the market. A market intervention is "a strategic effort by an utility and other organizations to intervene in the market, causing beneficial, lasting changes in the structure or function of the market, leading to increases in the adoption of energy efficient products, services and/or practices" (Schlegal *et al.* 1997). Such interventions are usually caused by the implementation of different policy instruments, aimed at increasing energy efficiency.

To drive market transformation the policies ("interventions") have to address existing barriers to energy efficiency. The barriers, which hinder energy efficiency market transformation in the buildings sector and the possible market interventions (policies) aimed at reducing these barriers are considered in Table 2.

The process of reducing these barriers resulting from a market intervention and evidenced by market effects, which are likely to last after the intervention is withdrawn, creates market transformation. In this regard, a market effect is a change in the structure of a market or the behavior of participants in a market that is reflective of an increase in the adoption of energy-efficient products, services, or practices and is causally related to market intervention(s) (Rosenberg *et al.* 2009). In other words, a market transformation means that the volumes of purchases of a specific product are transformed into purchases of a higher quality (in our case – efficiency) product (Schlegal *et al.* 1997).

Table 2. Major barriers to EE in the building sector and possible policy instruments

Barrier Categories	Definitions and Examples	Possible policies
Financial barriers	Lack of appropriate financing for the long-term benefits, higher up-front costs for EE improvements, lack of internalization of environmental, health, and other external costs, energy price subsidies	Budgetary instruments: tax rebates, subsidized loans, subsidies to EE improvements, regulations, removal of energy price subsidies, market-based mechanisms
Cost competitiveness	Lack of the ability of EE technological decisions to compete with traditional ones	Appliances standards, building codes, subsidies, tax rebates to EE decisions
Technological barriers	Technological obstacles related to reseach, development and demostration EE measures	Subsidies, loans for research and development, information instruments, market-based mechanisms
Behavioral barriers	Tendency to ignore small energy saving opportunities, organizational failures, non-payment and electricity theft, tradition, behaviour and lifestyle, corruption	Support, information and voluntary action, voluntary agreements, information and training programs, market-based mechanisms
Administrative barriers	Lack of support at the regional and local levels to stimulate the energy efficiency improvement	Creation of local agencies to promote energy efficiency projects, financial incentives, command and control insruments
Political and structural barriers	Lack of political motivation to support the market initiatives needed for the improvement of EE, slow process of drafting local legislation, gaps between regions at different economic level, insufficient enforcement of standards, lack of detailed guidelines, tools and experts, lack of incentives for EE investments, lack of equipment testing/ certification, inadequate energy service levels	Enhanced implementation of command and control mechanisms, policy incentives to encourage EE building design, ehhanced international cooperation and technology transfer, public leadersip programs
Information barriers	Lacking awareness of consumers, building managers, construction companies, politicians of the opportunities and benefits of EE improvement	Awareness raising compaigns, training of building professionals, command and control instruments

Data Source: Ürge-Vorsatz and Koeppel (2007); Belyi (2009)

Therefore, market transformation goes towards reduced energy consumption and higher energy efficiency of economy. On this way several stages of market transformation can be considered (Energy Charter Secretariat 2009):

1. Low-efficiency market. The strategy aims to reduce or eliminate sales of high energy-consuming products. Energy efficient technologies are limited due to high costs and most of them are imported. Most common policy instruments are minimum energy performance standards and negotiated agreements with market parties;
2. Medium-efficiency market: the strategy aims to shift the energy efficiency of the products to a marginally higher energy efficiency class. Energy efficient technologies become more competitive and wide-spread due to subsidies. Most common instruments are categorical energy labels, in combination with fiscal incentives

3. High-efficiency market: the strategy aims to increase the sales of energy efficiency products and use of energy efficiency technologies. Energy efficient technologies are wide-spread and take a significant share of the market, steadily replacing old inefficient technology. The strategy typically builds on fiscal incentives and market-based mechanisms;
4. The state of the art: the strategy aims to bring new products and technology with higher energy efficiency to the market. Possible instruments are R&D support and a government or utility procurement programme for such high energy efficiency products (Energy Charter Secretariat 2009).

Thus, from the considerations given above, it can be concluded that the market would autonomously deliver energy efficiency improvements only if producers could benefit from it or if the customer is particularly strong. In all other circumstances, energy-efficient technologies are brought to market as a result of policy (Boardman 2004). Therefore, market transformation is mainly caused by policy change. It is also shown that different institutions work at each stage of the market transformation process and drive the moving from one stage to another.

Summing up, the technological development, including the evolution of energy efficient technologies, follows certain paths which cause the lock-in effect of inefficient technologies in an economy. To unlock the more efficient technologies a market transformation has to take place. The natural process of the market transformation towards higher energy efficiency takes a long time, but it can be stimulated through introduction of policy instruments aimed at improving energy efficiency.

3.5. Quantification of the “lock-in effect” in literature

The issue of quantifying the lock-in energy savings is hardly covered in the existing literature. The attempts for calculating potential energy savings in the building sector in the literature are not directly related to the concept of the lock-in effect. For example, it is presented by Johansson *et.al*. (2007) that by applying commercially available heating technologies in the Swedish building sector it is possible to achieve a 47% reduction in primary energy use for heating with a 34% decrease in heat demand together with 77% reduction in CO_2 emissions and in electricity used for heating. However, the authors do not introduce the concept of the lock-in effect in their work; thus, it is hard to consider their results as an attempt to quantify this phenomenon.

Another study conducted by Bergman *et.al.* (2008) admits the presence of lock-in in the UK housing sector: "The mainstream residential building sector in the UK is not only unsustainable, it is locked-in to unsustainable practices, and favours optimisation and incremental change over radical change". By means of modeling they have calculate that "the landscape changes of climate change (perception) and rising fuel prices can in themselves lead to a one third reduction in direct CO2 emissions from the residential sector by 2050 relative to 2000, despite countervailing demographic changes". Policies supporting renovation and demolition of inefficient housing and high quality new-build, combined with regulations and subsidies supporting actors who encourage low CO2 emission practices, produce even more considerable emission reductions - nearly a half.

Different modeling tools are utilizes in the field of technological change. However, Löschel (2004) states that there are a lot of weaknesses in quantifying the impacts of technological change, learning-by-doing and learning-by-using and related phenomena. In his view, future extensions of the presented approaches should be targeted towards an improved realism in the modeling of technological change. Löschel summarizes the treatment of technical change in well-known climate change models, analyzed in the following works: Jorgenson and Wilcoxen (1990), Nordhaus (1994), Barker and Köhler (1998), Buonanno *et al.* (2000), Tol (1999), Capros *et al*. (1997), Goulder and Mathai (2000), Goulder and Schneider (1999), Burniaux *et al.* (1992), Dowlabadi (1998), Alcamo *et al.* (1998), Barreto and Kypreos (1999), Grübler and Messner (1998), Babiker *et al*. (2001), Böhringer (1999), Kouvaritakis *et al.* (2000), Nordhaus (1999) and Carraro and Galeotti (1997). These models, however, mainly deal with investment, R&D, learning-by-doing, spillover, backstops, diffusion curves, technology snapshots, autonomous energy efficiency improvements, price induced energy efficiency improvements and other issues, but not with quantifying the lock-in effect itself.

Thus, the analysis of the existing literature has shown that there are some works analyzing the issues of technological change by means of modeling. However, the field of quantifying the lock-in effect the lock-in effect presents itself a gap of knowledge. The attempt to reduce this gap is made in this thesis. The model for calculating the lock-in effect of energy savings in the building sector of Russia is presented in the following chapter.

Chapter 4. Research design and methodology

Chapter 3 has described the theoretical framework of this study and is devoted to explaining the concept of the "lock-in" effect. It gives the essential base and understanding of the main concepts for the development of the approach for quantifying potential energy savings and the lock-in effect of the Russian building sector, which presents itself a part of the research design of this study.

The last section of the previous chapter has shown that overcoming the lock-in of energy savings in buildings can be stimulated by the introduction and development of energy efficiency policies. Thus, the methodology of this study also includes the analysis of the policy instruments in Russia in terms of reducing the barriers to energy efficiency improvement in buildings and the elaboration of recommendations for their further improvement.

The present chapter describes the research design, its limitations, equations used and assumptions applied.

4.1. Research design scheme and data used

As has been noted above, the methodology of the study includes four main parts:

1. Model for estimating energy savings potential and lock-in effect in the building sector;
2. Analysis of the current market penetration of passive-houses
3. Analysis of the existing energy efficiency policy instruments in the building sector;
4. Recommendations for further development of energy efficiency policies

The first part includes the elaboration of the model for final energy use in the Russian building stock, the development of different scenarios of its evolution by 2050, calculation of energy savings potential for each scenario and "lock-in effects".

The second part includes the analysis of the passive-house market penetration in Russia to determine the stage of the market transformation of the building sector towards higher energy efficiency.

The third part shows whether existing policy instruments help to overcome the "lock-in effect" of energy savings and drive the market transformation towards higher energy efficiency. For this purpose, the policy instruments are divided into three groups: command-and-control, budgetary, market-based, information mechanisms, and the role of each group for reducing barriers to energy efficiency improvement (see Table 2) is analyzed.

The fourth part covers the possible improvements of policy instruments in order to realize the energy saving potential calculated in the first part and unlock the diffusion of energy efficient technologies.

Different data have been used for the different methodological parts. Figure 5 presents the overall scheme of the research design, including the structure of the methodological parts, interconnection between them and the input data. The input data for each part will be discussed in more detail below.

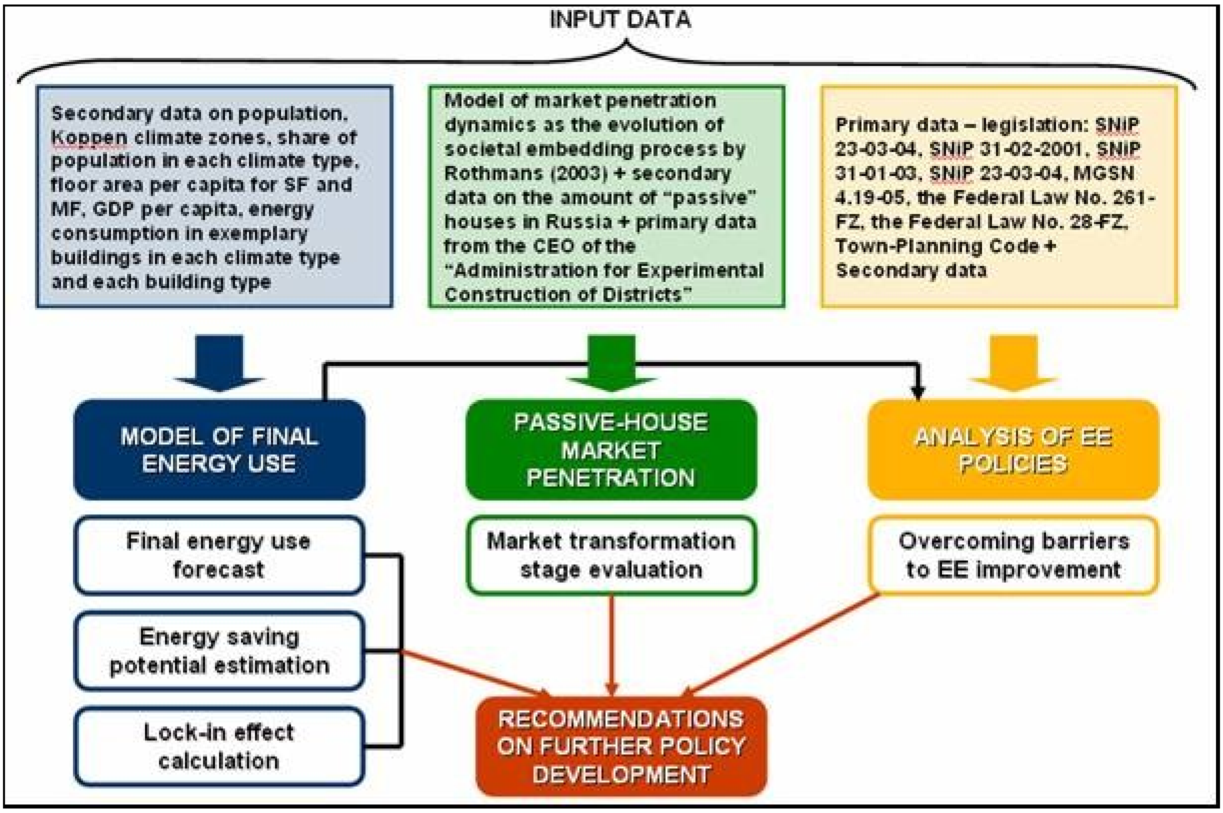


Figure 5. The scheme of the research design

4.2. The model for estimating final energy use and lock-in effect in the Russian building sector

As it has been outlined above, there is a gap in knowledge of quantifying the lock-in effect of energy savings. In this section the model for estimating energy savings and calculating the lock-in effect in the building sector of Russia is presented. The energy savings take place due to the process of the market transformation towards higher energy efficiency. The model includes four scenarios with different speed of the market transformation and different incentives for it. The period of time considered by the model is 2005-2050.

The model is based on the novel holistic approach which considers buildings as a complex system, instead of the component-based approaches which analyze buildings as the sum of their components. This new approach is based on energy performance of different types of buildings, i.e. energy use[3] per square meter of useful space.

The methodological approach used in the model was elaborated by the research team, including the author of this paper, of Centre for Climate Change and Sustainable Energy Policy[4] of Central European University (Budapest, Hungary). The model produced by the team includes 11 regions, covering the whole world. Thus, the conclusions drawn from this model could be made either at the regional or world-wide scale.

The main contribution of this thesis is twofold. First of all, the model's methodology was developed for the concrete country which allows for getting results and further recommendations at the national level. The country-wide scale of modeling seems to be reasonable for policy-makers as they are interested in the situation within their country. Secondly, the data specifically for Russia have been collected, which increases the robustness of the results. The modeling for the regional level (each region includes a number of countries) usually presumes the aggregation and extrapolation of the data obtained for one country to the whole region. The gaps in data have been addressed either by the application of assumptions or the additional and more complex analysis (see Section 4.2.6.). Thirdly, the original model for 11 regions was elaborated in the MS Excel package by means of rather complicated Macro due to enormous amount of input data. Any changes and improvement of the model require specific programming skills. The model for Russia includes smaller amount

[3] Energy use includes final energy use in buildings for space heating and cooling, measured in kwh/m^2/year
[4] http://3csep.ceu.hu/

of data and calculations, which has given the opportunity to build the whole model in Excel without utilization of the Macro. It makes the model more user-friendly and allows for using it for any county (region) by changing certain data points.

The model includes data for different types of buildings (single-family, multi-family and commercial and public), different climate types (warm moderate and cold moderate), energy consumption in different building stock types (standard, retrofitted, new, advanced new and advanced retrofitted). The main methodological aspects of the model and data used are presented below.

4.2.1. Building types

The model distinguishes three different categories of buildings: single-family (detached or attached), multi-family (4 or more levels, terraced, etc), and commercial & public buildings (government offices, hospitals, recreation centers, and standard office buildings). All three categories of buildings are split by three climate types. Final energy use is then calculated from the total floor area, climate zone, and building type, which is typically given as kWh/m^2/year. Since building floor area is the primary variable (since this is what scales the total energy consumption), a model for floor area growth has been constructed.

4.2.2. Building stock types

Five types of building stocks are considered in the model: standard, retrofitted, new, advanced new and advanced retrofitted building stocks. They differ according to the final energy uses. Usually, standard building stock consumes the highest amount of energy, as presented by the existing buildings without recent renovation, thus it includes all old buildings in the analyzed region. Retrofitted building stock includes buildings after recent renovation (no later than one year), thus, such buildings consume less energy than standard buildings (usually 20-30% less). New building stock covers buildings, which have been constructed and put in operation during one year. These buildings are assumed to be constructed according to higher energy performance standards than standard buildings, and, thus consume less energy than the standard ones and even retrofitted ones. Advanced new and advanced retrofitted building stocks include buildings which were either constructed or renovated according to advanced building standards. Thus, these buildings consume much less energy than ones belonged to other types.

4.2.3. Climate types

There are three climate types which are used in the model for Russia: arid, warm moderate and cold moderate climates. These types are built on the basis of the Köppen Climate zones, excluding the polar climates where an insignificant number of buildings is assumed. Figure 6 represents the Köppen-Geiger world map of Climate Zones.

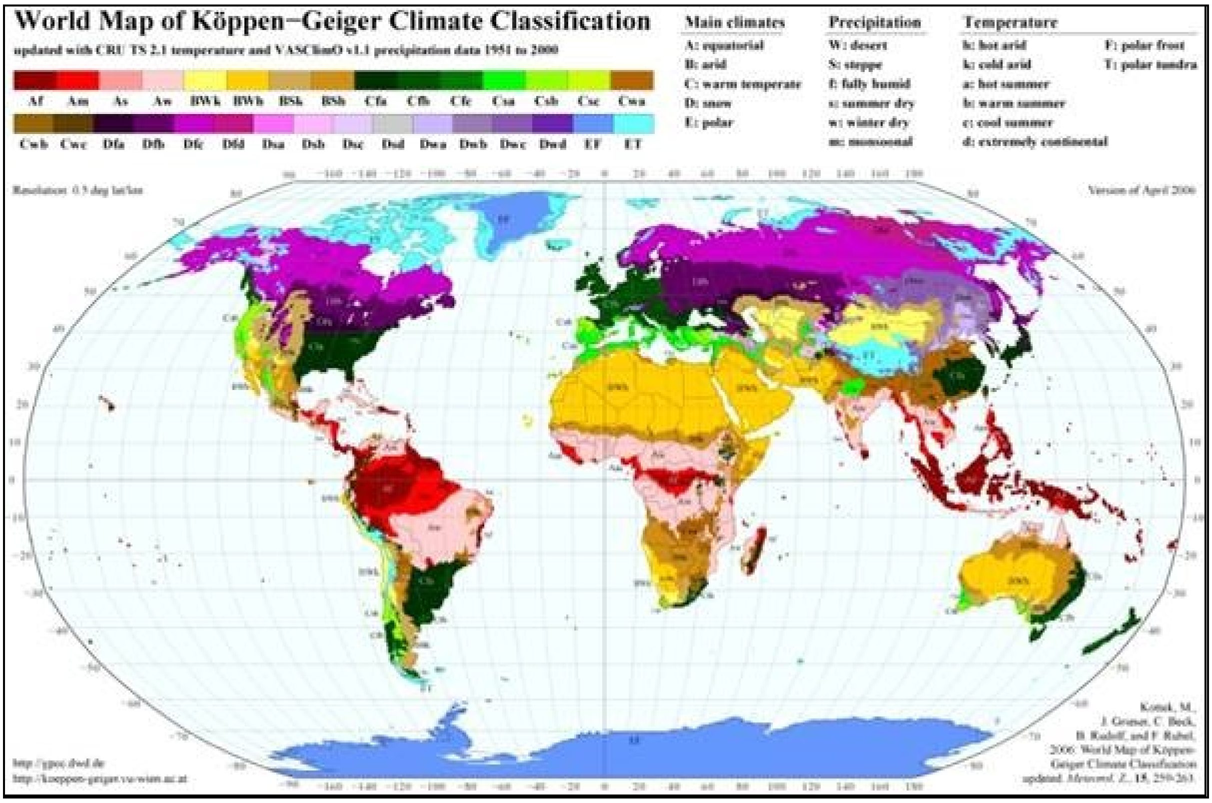


Figure 6. World Map of the Köppen-Geiger Climate Classification

Source: Ruben and Kottek (2010)

4.2.3. The assumptions of the floor area change

It is assumed that the retrofit rate is the same for each year of the whole period of the analysis and, based on the data from Odyssee database, is fixed at the level of 1.4% (Odyssee 2007).

The demolition rate is also constant and obtained using the Odyssee Database, statistical agencies, and personal communication with experts, as 0.5% per year (Odyssee 2007).

Buildings are retrofitted and demolished until 8% of the original 2005 levels of building stock remains. This 8% signifies the building stock that cannot be extensively retrofitted or demolished and is considered as "Heritage" building stock.

4.2.4. The main methodological steps

There are seven methodological steps which should be taken to get the final results which are the energy savings by 2050. Figure 7 presents these main stages.

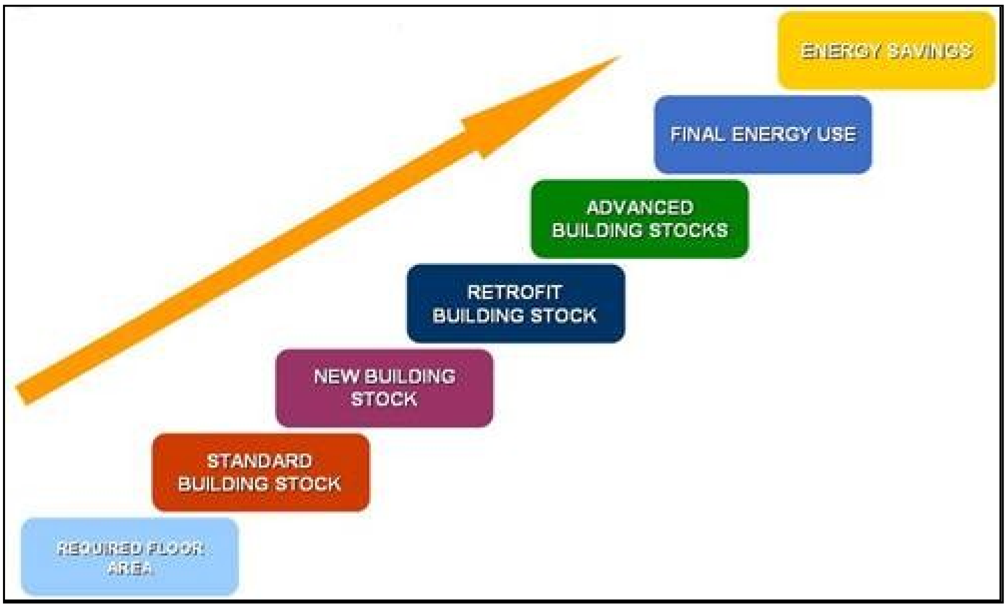


Figure 7. The main methodological steps of the model

Step 1. Required floor area calculation

The basic concept of the model is the required floor area, which means the floor area in millions of square meters required for meeting the demands of society. It is calculated differently for residential (single-family and multi-family buildings) and commercial buildings. Figure 8 shows the scheme for calculating the required floor area.

For calculating the floor area of residential building stock, the data of population, share of population in each building type and floor area per capita, occupied in single-family and multi-family buildings are used. The share of population in each type of buildings is calculated based on the data of urbanization rate in Russia. It is assumed that the urban population lives in multi-family houses and the rural population in single-family houses. For the floor area per capita, occupied in each building type, it is assumed that by the year 2050 this parameter in Russia will achieve the level of OECD countries. The original data given above is contained in the Annex, Table 13 - Table 18

The data and algorithm for the calculation of the required floor area for commercial buildings are different. As Figure 6 shows, it is calculated based on the data of commercial floor area.

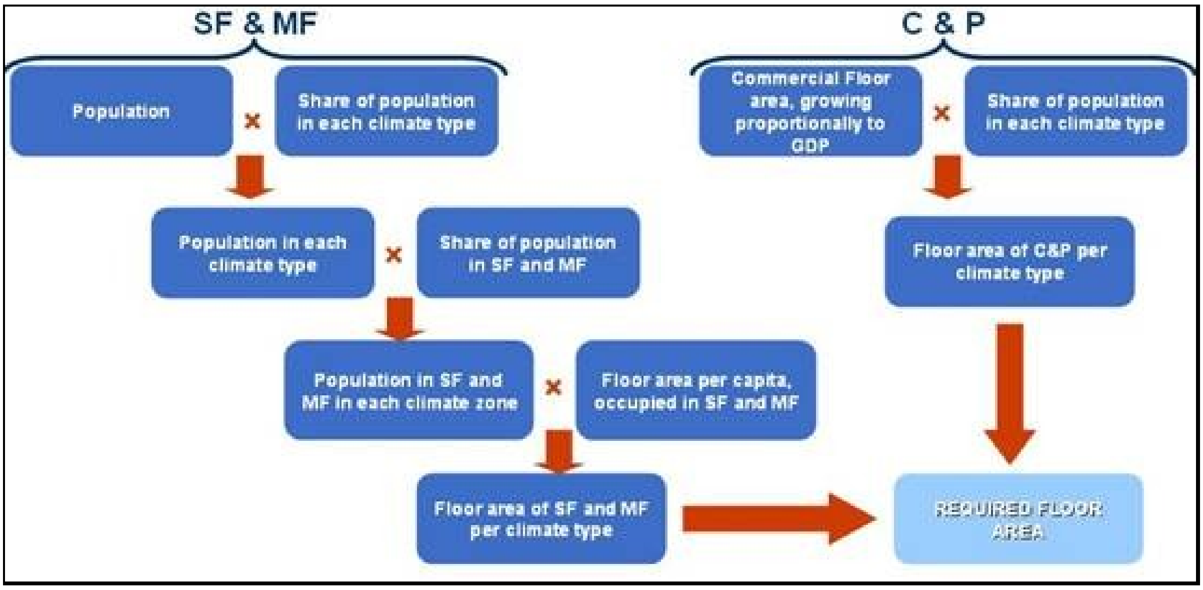


Figure 8. The calculation of required floor area

Step 2. Standard building stock calculation

The procedure of calculating the standard building stock is presented in Figure 9. It uses the data on required floor area, calculated at the previous step, demolition and retrofit rates. For each year the building stock which has been demolished is taken out from the required floor and the retrofitted building stock is subtracted from the result. It is necessary to put the condition that the building stock after demolition and the standard building stock itself should not be more than the heritage building stock, as was assumed above.

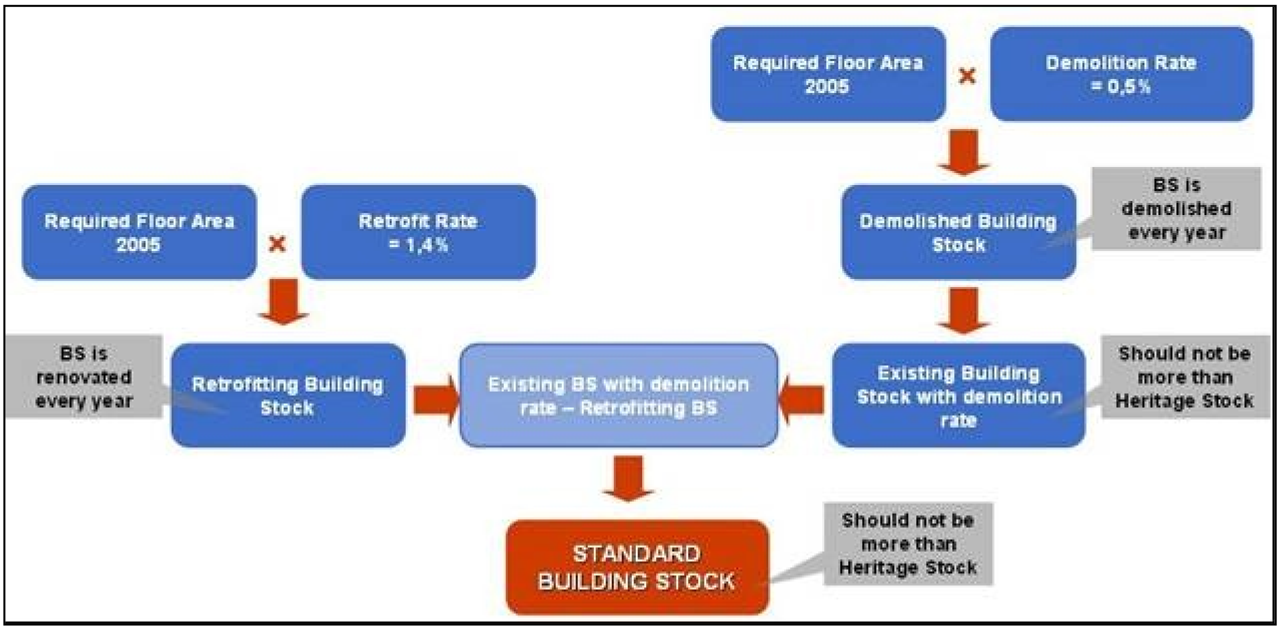


Figure 9. The calculation of standard building stock

Step 3. New building stock calculation

The calculation scheme for the new building stock is shown in Figure 10. It is simply the difference between the required floor area, calculated at the first step, and the existing building stock after demolishing, calculated at the second step. It is also important to put the condition which will prevent the new building stock from becoming negative. It usually takes place in the situation when the population declines as in the case of Russia.

Step. 4. Retrofit building stock calculations

Retrofit building stock is a result of subtracting standard building stock from existing building stock with demolition rate (see Figure 11). As with new building stock, it is necessary to introduce the condition which will prevent the retrofit building stock from negative values.

Step 5. Advanced building stock calculation

Advanced building stock consists of advanced retrofitted and advanced new building stock. These types of building stocks are calculated as multiplying by share of these buildings in new and retrofit building stocks respectively (see Figure 12). The share of advanced buildings could be changed according to the model's assumptions.

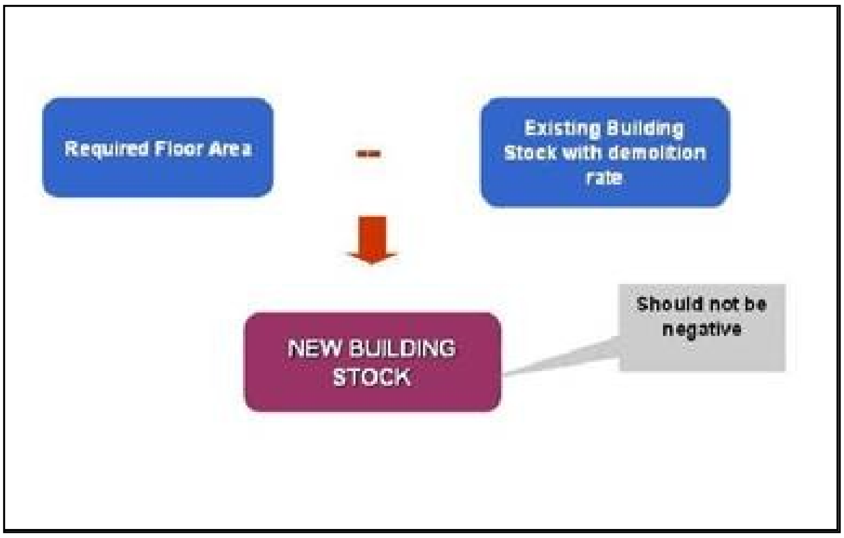


Figure 10. The calculation of the new building stock

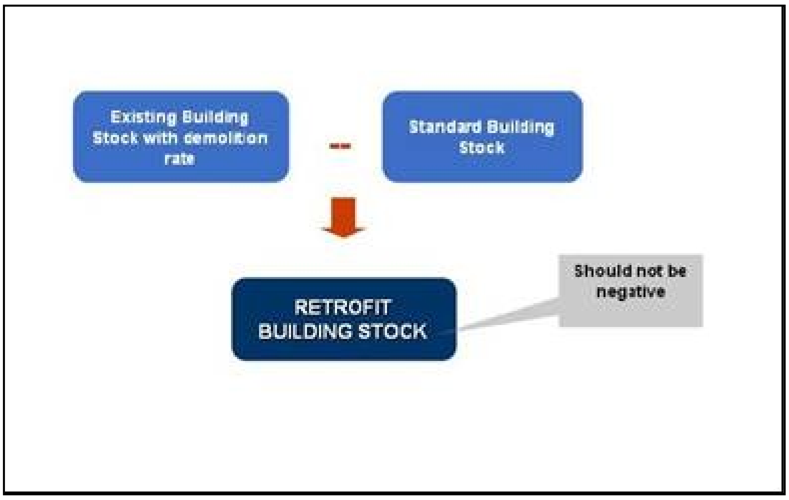


Figure 11. The calculation of the retrofit building stock

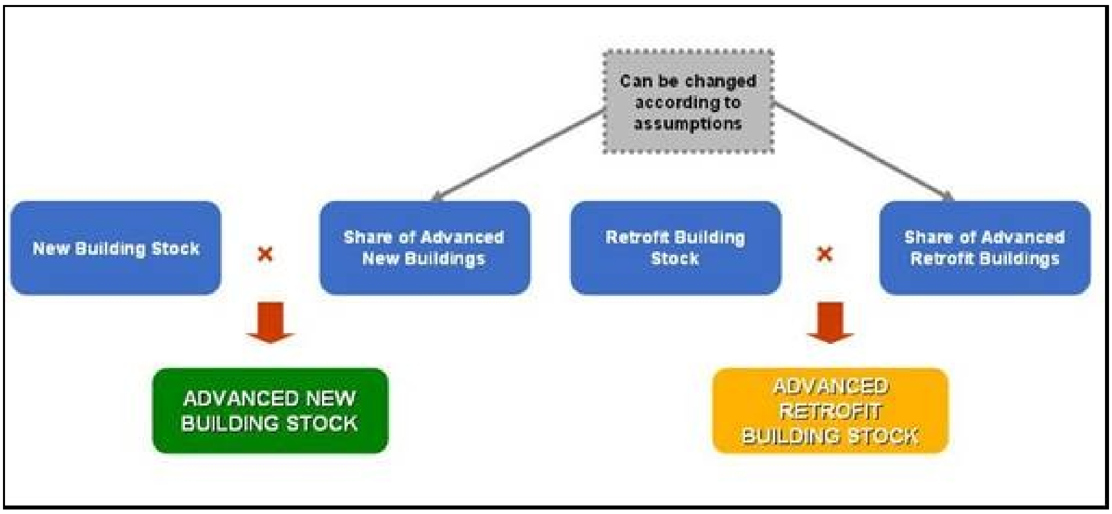


Figure 12. The calculation of the advanced new and retrofit building stock

Step 6. Final Energy Use Calculation

The model uses exemplary approach for collecting the data of energy consumption in buildings. Ideally, it means that for each type of building stock, for each building type and for each climate type the data on energy consumption for space heating of a concrete building was found. And this building is considered to be exemplary for all similar buildings in the country. Such an approach is based on an assumption that buildings of the same building stock type, the same building type and the same climate type consume approximately the same amount of energy for space-heating.

Thus, final energy use in buildings is calculated by multiplying the figures of energy consumption by floor area of corresponding building stock type, building type and climate type:

$$Final\,Energy\,Use_{n} = Floor\,Area_{ijkn} \bullet Energy\,Consumption_{ijkn}, \quad (3)$$

where i – building stock type, j – building type k – climate type, n – a certain year

As a result, final energy use is calculated separately for each type of building stock. Table 3 presents a sample of how this output looks like. Such data output is gained for each building stock type.

Table 3. The sample of output for energy use calculation of a random building stock type

	Year	2005	...	2050
SF	Warm Moderate		...	
	Cold Moderate		...	
	Arid		...	
MF	Warm Moderate		...	
	Cold Moderate		...	
	Arid		...	
C&P	Warm Moderate		...	
	Cold Moderate		...	
	Arid		...	

Step 7. Energy Savings Calculation

In this paper only total energy use is considered for energy savings calculation. Thus, total final energy use (TFEU) is calculated by summarizing final energy use for all building stock type, building type and climate type:

$$Total\,Final\,Energy\,Use_{n} = \sum Final\,Energy\,Use_{ijkn}, \quad (4)$$

where i – building stock type, j – building type k – climate type, n – a certain year

Therefore, energy savings (ES) are calculated by the end of analyzed period (2050) in relation to the beginning of the period (2005):

$$ES = \frac{TFEU_{2050} - TFEU_{2005}}{TFEU_{2005}} \times 100\% \quad (5)$$

The result will be negative in case of reduced TFEU in 2050 in comparison with 2005, which means actual energy savings and positive if TFEU increases by 2050.

4.2.5. Limitations of the model

The first limitation of the model is that the change in floor area is determined by the change in population of a country (region). In other words, if population decreases (like in Russia) it means that fewer buildings are constructed every year and vice versa. This assumption seems to be logical: the fewer people occur in an economy, the less demand for living/working space. However, in reality it is not always true. The construction rate can be rather high even in situation of decreasing population if there is demand for new buildings. It is more relevant for developed countries with significant portion of high-income people, who prefer to live in new dwellings or buy new apartments for rent. In this regard the model also does not take into account migration, which might result in the increase in population and, thus, in demand for a floor area. In developing countries the opposite situation could take place, when the construction rate is lower than population growth due to, for example, limited financing. At the same the increase in construction rate in poor countries is often not feasible because the majority of people living there has low income and cannot afford buying a new dwelling.

The second limitation is that the calculation of final energy use in buildings is based only on the data on space heating and does not include other sources of energy use, which can be significant for the overall energy consumption of a building, for example, domestic hot water, appliances, lighting, cooking, etc. There are two reasons for this limitation. The first one is that the greatest portion of energy in a building is usually consumed during space heating. The second reason is that usually it is more likely to find data on energy use by space heating than by other sources, for example, energy consumption by appliances is very hard to measure at all.

The third limitation is that the model does not distinguish between different energy sources used in buildings for space heating – it takes into account only the final energy consumption of the whole building. Thus, it does not specify what kind of energy resources are used in the building, for example coal or renewable energy. This aspect can be very significant in terms of CO_2 emitted by a building as different energy sources produce different amounts of green-house gases (GHG). The model also can be further improved in this regard if the data on energy use by each energy source in each building type, each type of building stock and each climate type is found.

Another limitation is that the model does not include the estimation of costs of energy use. It leads to the fact that the model can show the potential energy savings, for example, by 2050, but it does not show how much would it cost for an economy. At the same time the information on costs can be the most important factor for policy-makers, who have to evaluate the cost-effectiveness of the measures for promotion of energy efficiency in buildings. The model allows for including the cost data and it can be the direction of the further improvement of the model.

Finally, there is a limitation related to the gaps in data. There is always a lack of reliable statistical information, especially for developing countries and economies in transition, including Russia. The greatest problem is related to the data on energy consumption in buildings, because the majority of buildings either do not have energy meters or these data are simply not available on-line. This limitation requires using assumptions or additional analysis to reduce the gaps in data.

4.2.6. Assumptions for Russia

It has been mentioned above that there are certain gaps in data for Russia exist. As it is stated in SAFE (2002), the model is as good as the input data. Thus, certain attempts have been made to fill these gaps and increase the robustness of results.

The model's methodology (see Figure 5) requires the share of population in each climate type as input data. However, such statistical information for Russia is impossible to find in open sources. Thus, the additional GIS-analysis has been made to get these data.

Another gap is related to the floor area of Russian commercial and public buildings. The estimation of these data has been gained from the available data for Former Soviet Union.

And, finally, certain assumptions for energy consumption for space heating have been made for Russian building on the basis of available estimations and data-points for other regions.

1. Share of population in each climate type

The analysis of share of population in each climate type has been by means of Arcview software. The input data for the GIS analysis includes three main datasets (Annex, Figure 25 - Figure 27): "Administrative borders of the world", "Climate zones of the world according to Koppen's classification" and "The populated places in the world".

Four steps have been made for calculating the share of population in different climate zones. The first step is the selection of Russia for the analysis. For this step the dataset "Administrative borders of the world" has been used. By means of the X-tools extensions and command Intersect Russia was selected for further analysis (see Figure 13). And as a result a new shapefile was created. At the second step the same procedure was done with the dataset "Climate zones of the world according to Koppen's classification" (see Figure 14), and at the third one – for the dataset "The populated places in the world" (see Figure 15). At the fourth step the files gained at the second and the third steps were overlaid. The results are presented in Figure 16.

Figure 13. Selection of Russia from the dataset “Administrative borders of the world”

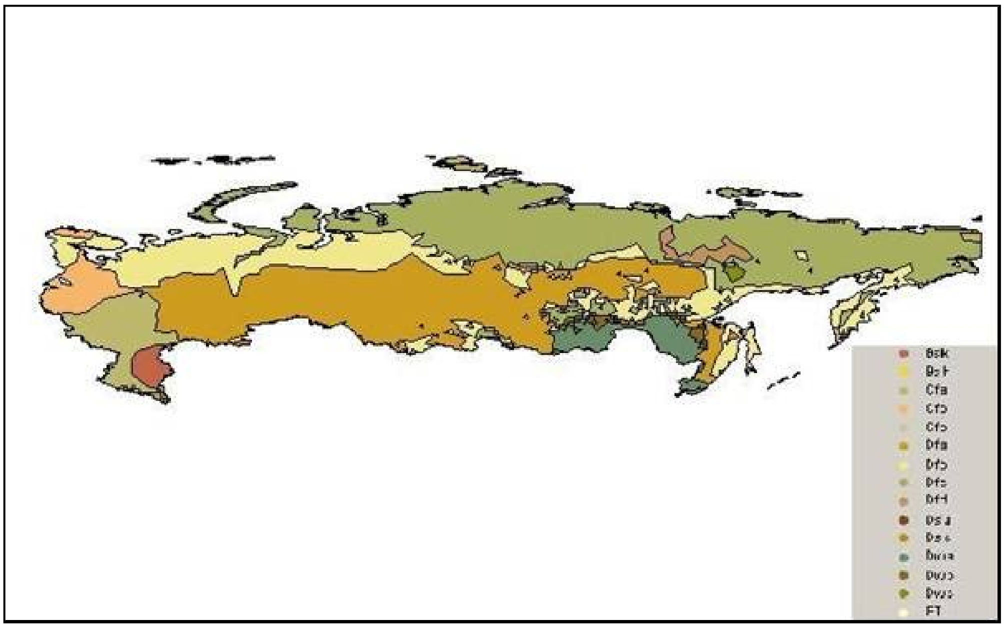


Figure 14. Selection of Russia from the dataset “Climate zones of the world…”

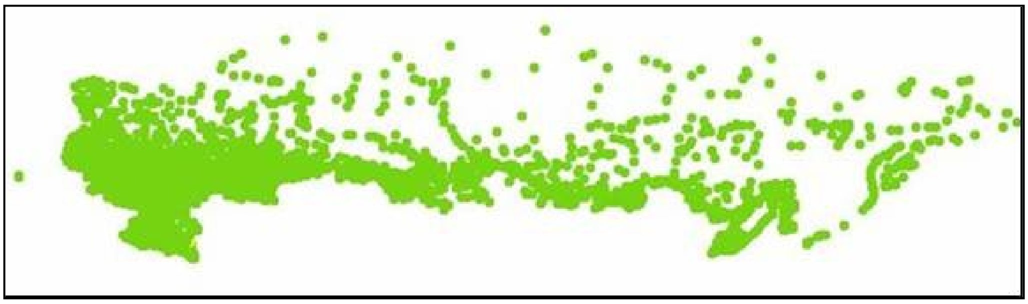


Figure 15. Selection of Russia from the dataset “The populated places in the world”

Figure 16 shows the populated place in the certain climate zone. The dataset “The populated places in the world” contains the data on the population in each place, which gives the opportunity to calculate the number of people in each climate zone by summing up the value of population in places in each climate zone. However, for the model the share of population in each climate type (warm moderate, cold moderate and arid), but not climate zone is needed. For this purpose aggregated climate types have been created.

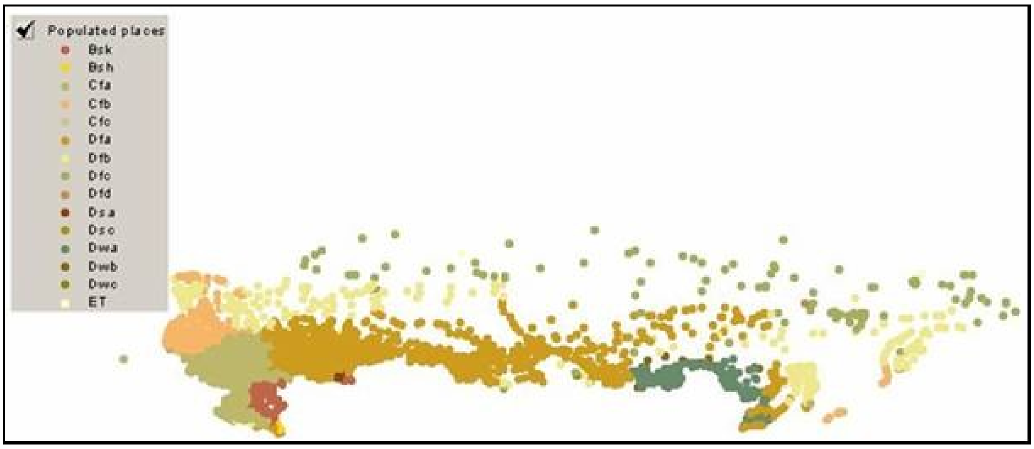


Figure 16. Overlaying of the files with climate zones and the populated places

The analysis has shown, that according to Köppen classification (see Figure 6), there are 13 climate zones in Russia (see Figure 14). Table 4 contains the description of these climate zones. The aggregated climate types were created according to the category "Main climates". Thus, warm moderate climates are classified under the Köppen classification in group C, cold moderate climates fall under the Köppen classification in group D, and arid climates are in group B. The polar climate type is not included in the analysis, according to the assumption that the amount of buildings there is insignificant.

Finally, the population values were summed up for each aggregated climate type and the share of population for each climate type was calculated. Table 4 contains the data of population in each aggregated climate type.

Table 4. Climate zones in Russia

Agregated Climate Type	Main climates	Precipitation	Temperature	Climate Zones
Arid	arid	steppe	cold arid	BSk
	arid	steppe	hot arid	BSh
Warm Moderate	warm temperature	fully humid	hot summer	Cfa
	warm temperature	fully humid	warm summer	Cfb
	warm temperature	fully humid	cool summer	Cfc
Cold Moderate	snow	fully humid	hot summer	Dfa
	snow	fully humid	warm summer	Dfb
	snow	fully humid	cool summer	Dfc
	snow	steppe	hot summer	Dsa
	snow	steppe	cool summer	Dsc
	snow	desert	warm summer	Dwa
	snow	desert	warm summer	Dwb
	polar	-	polar tundra	ET

The data presented in Table 5 is used for the further calculations in the model. It is assumed that the share of population in each climate type remains constant during the whole period of the analysis.

Table 5. Population share in each climate type

	Russia
arid	3%
cold moderate	47%
warm moderate	50%

2. Commercial floor area

The exact number related to commercial floor area in Russia was impossible to find. The commercial area for Russia was calculated through the relation of GDP of Russia and the Former Soviet Union and the commercial floor area of the latter, as:

$$Commercial\,Floor\,Area_{Russia} = \frac{GDP_{Russia} \times Com.Floor\,Area_{FSU}}{GDP_{FSU}} \qquad (6)$$

It is also assumed that the commercial floor area in Russia grows proportionally to GDP and by the year of 2050 it will achieve the level of OECD countries.

3. Energy consumption for space heating

As was explained above, the exemplary approach should be used for collecting the data on energy consumption for space heating in buildings. However, in practice, such data are difficult to find, especially in Russia where energy statistics is either poor or unavailable for public. In the model the data on space heating in Russian buildings presented in (World Bank 2008) have been used. According to World Bank report, the Russian average heating energy consumption for multi-family buildings is 229 kWh/m2/year. The heating energy use for new, multi-family buildings in Russia is 77 kWh/m2/year. Renovated housing stock can consume roughly 151 kWh/m2/year (p.41). The estimation for new buildings is based on a review of the designs of 28 multi-family, which were under construction at the moment of preparing the report (2007-2008) in Moscow. The number for retrofit buildings is based on similar intensities of renovated multi-family buildings in Russia (World Bank 2008). Thus, the data for standard, new and retrofit multi-family buildings in cold moderate climate type[5] have been gained.

The World Bank report also has the estimations for energy consumption in Russian public buildings (p.45). The data in the report are given in Gcal/m^2/year for the buildings built before 1990, between 1990 and 2000, after 2000 and recently renovated. To use these data in the model, it was assumed that buildings constructed before 1990 together with those built between 1990 and 2000 represent the standard (e.g. existing) buildings and buildings constructed after 2000 – new buildings. The average energy consumption has been calculated for these categories and converted from Gcal to kwh. Thus, the data for standard, new and retrofit public building in cold moderate climate type have been gained.

However, these data-points are not sufficient for the model's input data requirements. It is necessary to find data on final energy use for space heating for all types of building stock (standard, new, retrofit, advanced new and advanced retrofit), for all three types of buildings (single-family, multi-family, commercial and public), in all three climate types (warm moderate, cold moderate and arid). Thus, the following assumptions have to be made:

- Standard, new and retrofitted multi-family and commercial and public buildings in warm moderate climate type consume 5% less energy than buildings of the same building stock type in cold moderate climate type.
- Standard, new and retrofitted multi-family and commercial and public buildings in arid climate type consume 7% less energy than buildings of the same building stock type in cold moderate climate type.
- Energy consumption in advanced buildings, both new and retrofitted consume, corresponds to passive-house standard – 15 kwh/m^2 year (Passive House Institute US 2009), except cold moderate climate type, where energy consumption for space heating is assumed to be two times higher.

Table 6 presents figures for energy consumption in Russian buildings, taking into account all the assumptions and data collected. These figures are used in the model.

[5] The data were assigned to cold moderate climate type, because they are related to Moscow, which, according to the Koppen climate classification is located in Dfb climate zone. According to the model assumptions, Dfb climate zone belongs to cold moderate climate type

Table 6. Energy consumption for space heating in Russian buildings

Building Type	Climate Type	Standard	New	Advanced New	Retrofit	Advanced Retrofit
SF	Warm Mod.	240	80	15	160	15
	Cold Mod.	280	93	30	187	30
	Arid	175	58	15	117	15
MF	Warm Mod.	205	68	15	137	15
	Cold Mod.	246	82	32	164	32
	Arid	175	58	15	117	15
C&P	Warm Mod.	180	60	15	120	15
	Cold Mod.	353	118	30	236	30
	Arid	114	38	15	76	15

4.2.7. Scenarios and "lock-in effect" calculation for Russia

Four scenarios have been elaborated for Russia. In the model they are called the following:

1) "Incremental diffusion";
2) "A-class buildings";
3) "Advanced construction";
4) "Advanced renovation".

The descriptions of each scenario are given below.

1. "Incremental diffusion"

This scenario presumes that from 2005 till 2050 the incremental diffusion of energy efficient technology is taking place in Russian buildings. That means that there are neither market interventions, nor significant energy efficient innovations introduced in Russia during this period. However, there is an incremental improvement of energy efficient technology which is presented as a 0.1% decline in energy consumption of new and retrofitted buildings annually. No advanced buildings are introduced by 2050.

2. "A-class buildings"

This scenario includes one market intervention in the form of the improvement of Russian Building Codes in 2015. This improvement requires all new and retrofitted buildings to correspond to the A-class of Building Codes (SNiP 23-03-04), which means a 51% reduction in energy consumption in new and retrofitted buildings in comparison with standard ones.

From 2005 till 2014 the scenario follows the path of incremental diffusion of energy efficient technology. During the analyzed period no advanced buildings are introduced in Russia.

3. "Advanced construction"

The scenario assumes the market transformation towards higher energy efficiency, which results in the fact that from 2011 advanced new buildings are introduced as 1% of new building stock and by 2020 all new buildings are constructed according to advanced standard. Advanced retrofitted buildings are not introduced in this scenario.

4. "Advanced buildings"

The scenario presumes the market transformation towards higher energy efficiency, which results in the fact that that from 2011 advanced new and advanced retrofitted buildings are introduced as 1% of new and retrofitted building stock, correspondently, and by 2020 all new and retrofitted buildings are constructed according to advanced standard.

5. "Lock-in effect" calculation

As has been outlined above, the "lock-in" effect in respect of energy savings is the lost opportunity to conserve energy. Thus, it does make sense to calculate the lock-in effect as the difference between the scenario in which there are no market interventions to achieve energy savings are made and the scenario which presume such actions.

In this research the "lock-in" effect is calculated as the difference between the total final energy use in 2050 for the scenario "Incremental diffusion" and all other scenarios which presume market interventions in relation to 2005 according to the Formula (7):

$$Lock\!-\!in\ effect = \frac{TFEU\,(2050)_{inc.diffusion} - TFEU\,(2050)_{another scenario}}{TFEU\,(2005)} \quad (7)$$

[6],

The result of calculations shows the portion of energy savings locked-in an economy in the absence of market interventions and market transformation towards higher energy efficiency. Thus, to give recommendations on how to unlock these energy savings in the future, the current stage of market transformation for a country should be determined. In this research it is done by means of the analysis of the passive-houses market penetration.

[6] TFEU - – total final energy use for a country. TFEU in 2005 is the same for all scenarios

4.3. The analysis of the passive-houses market penetration

From the chapter devoted to the path-dependency theory and the lock-in effect follows that the extent of the energy efficient technology diffusion reflects the stage of the market transformation towards higher energy efficiency. In other words, the more the best energy efficient technology is spread on the market the higher the stage of the market transformation.

In this regard, in the building sector nowadays the best energy efficient technologies are implemented in "low-energy buildings". However, there is no single definition for low-energy buildings. Generally, this term means that a building has "a better energy performance than the standard alternative/energy efficiency requirements in building codes" (European Commission 2009). Such buildings typically use high levels of insulation, energy efficient windows, low levels of air infiltration and heat recovery ventilation to lower heating and cooling energy, sometimes they also use passive solar building design techniques, active solar technologies or hot water heat recycling technologies to recover heat from showers and dishwashers (European Commission 2009).

Low energy buildings are known by different names and there is a great difference among countries in approaches to define a low-energy house. The variety of concepts hinders the comparison of different countries. To facilitate the evaluation, it is necessary to use one concept for all countries under analysis. As such a framework the concept of "passive house" has been chosen.

According to the definition of the Passive House Institute, a passive house is "a building in which a comfortable interior climate can be maintained without active heating and cooling systems" (Feist 2007). The main requirements to passive construction in Europe are:

- the annual energy consumption for heating should be less than 15 kWh/(m^{2}a) (4755 Btu/ft^2/yr) and not be attained by means of an increase in use of energy for other purposes;
- the combined primary energy consumption of living area should not exceed 120 kWh/(m^{2}a) (38039 Btu/ft^2/yr) for heat, hot water and household electricity;
- additionally renewable energy sources may be used (Feist 2007).

To evaluate the level of implementation of the passive house concept in the building sector of a country it is necessary to analyze the market penetration of passive-houses in this country.

As a model of market penetration dynamics the theory of societal embedding process has been chosen (Rothmans 2003). According to this theory, the technological innovations, including passive house concept, have to go through a societal embedding process before they become common phenomenon in a society. This process has an S-curve shape (see Figure 17) and four phases: preparation, introduction, acceleration and stabilization (Rothmans 2003).

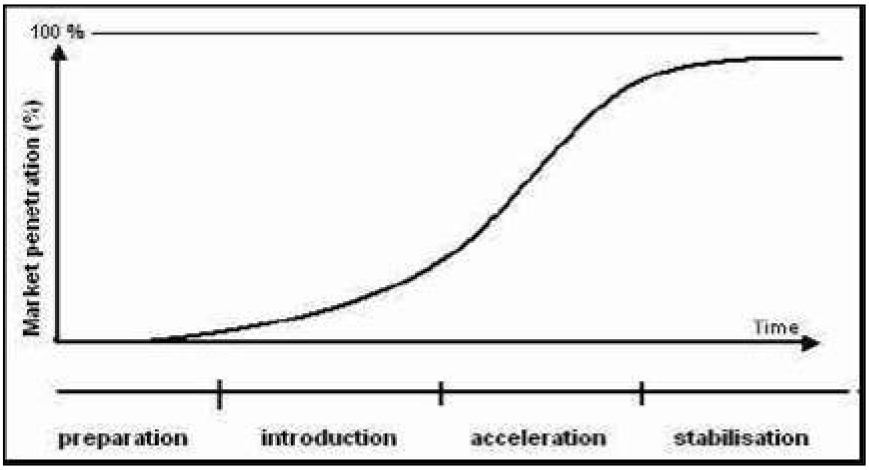


Figure 17. Curve for embedding process of innovations

Source: Rothmans (2003)

During the preparation phase, changes in the societal system are hardly recognizable. Only small-scale experiments in a limited environment and the development of a long-term plans and strategies are taking place. In the introduction phase an innovation concept is introduced in several places, experience is accumulated and actors are mobilized towards a further development goal. After this the acceleration phase starts, which means that an innovative concept has the potential to initiate structural changes in the society. Innovations are spreading much wider, penetrating other markets and starting a new embedding process.

The last stage is stabilization, when the society is completely accepts the innovative concepts and incorporates it in routine. From that time the concept stops to be innovative and becomes business-as-usual (Elswijk and Kaan 2008). These four stages of embedding process applied to the passive houses concept correspond to the stages of market transformation (see Table 7).

Table 7 shows that, for example, if the development of the passive house concept is at a preparation stage of embedding process then it means that there is an low energy-efficient market in this country, etc.

Table 7. Relation between passive houses' embedding process and EE market transformation

Stages of passive houses embedding process	Stages of EE market transformation
Preparation	Low energy-efficient market
Introduction	Medium energy-efficient market
Acceleration	High energy-efficient market
Stabilisation	State of art

4.4. The analysis of the energy efficiency policy instruments in the building sector

It was shown above that the market transformation towards higher energy efficiency is influenced by the existing policy instruments in a country, which play the role of market interventions. To give recommendations on how the energy savings potential can be unlocked through development of energy efficiency policies, the policies existing in a country should be analyzed in respect of reducing the barriers to energy efficiency improvement.

In this thesis, the policy instruments in Russia are divided into three groups: command-and-control, budgetary, and information mechanisms. The chosen methodology presumes the overview of the instruments belonged to each group (if they are present in a country) on the basis of current legislation and secondary information resources, the analysis of the role of each group in overcoming the barriers to energy efficiency, according to the Table 2, their limitations and the recommendations for further development.

The short description of each group of policy instruments is given below to clarify how each of them works in general and what kind of mechanisms they can include.

4.4.1. Command-and-control mechanisms

Command-and-control (CAC) mechanisms can reduce the barriers of cost competitiveness by providing regulations which allow trading only energy efficient products at the domestic market, thereby, excluding inefficient, and usually cheaper, products from the market and increasing competitiveness of efficient ones. Administrative barriers can be reduced by creation of new actors at the nation and/or local levels responsible for the promotion of energy efficiency. If such actors already exist by means of CAC instruments, their competence can be broadened or specified more precisely for more effective work. CAC mechanisms can also reduce political and structural barriers by strengthening the enforcement of energy efficiency standards and certification; and information barriers by informing the public about the changes in the regulation and the reasons for it.

CAC mechanisms make actors change their behavior. However, they can cause public resistance to strengthening the regulation. Corporate and household consumers usually do not count the benefits for society and environment from a more stringent regulation, and mainly take into account the limitations and costs which it brings to them.

CAC mechanisms also increase costs to consumers due to the promotion of energy efficiency improvement. It has a strong influence on low-income households, which often can not afford more expensive energy services and products. Therefore, CAC mechanisms are more effective in combination with information and budgetary instruments. The former reduce information and behavioral barriers to energy efficiency and increase the acceptability of regulatory (CAC) instruments. The latter mitigate financial barriers by creating better conditions for investment in energy efficiency activities and also support low-income householders.

4.4.2. Budgetary mechanisms

Budgetary mechanisms could reduce financial barriers to energy efficiency by creating incentives for energy efficiency projects. They provide the reduction of costs, related to energy efficiency improvement; they also mitigate the barriers of cost competitiveness, making energy efficiency more attractive for energy consumers. In combination with information instruments this attractiveness could be increased even further if consumers are informed about long-term benefits of energy efficiency (e.g. reduced energy bills, positive effect for health, etc.).

However, the implementation of budgetary instruments can be limited by unclear jurisdiction and lack of political will. Thus, to increase their effectiveness, structural, political and also some behavioral barriers (e.g. corruption) should be overcome. In this regard, the effective work of government is vital as it is necessary to provide strong regulation to eliminate these barriers.

As well as some of command and control instruments, taxes can increase the costs of energy services. They reduce purchasing power of low-income people and cause public resistance. Thus, these taxes should be accompanied by tax rebates for energy efficiency and subsidies targeted to low-income households. Such combination helps both partially cover the costs of low-income individuals and make energy efficiency improvement more attractive to them, reducing the barrier of cost competitiveness.

4.4.3. Market-based mechanisms

In terms of energy efficiency, market-based mechanisms (MBMs) are mainly presented in the form of White Certificates (WhC). The basic idea of WhC is that "specific energy saving targets are set for energy suppliers or distributors who must fulfill these requirements by implementing energy efficiency measures among their clients within a specific time frame" (Energy Charter Secretariat 2010). These targets are justified by special certificates. Energy suppliers or distributors, who have achieved larger energy savings that it was prescribed by the target, can sell their unused energy efficiency equivalents in the form of white certificates to suppliers or distributors who have got less energy savings than their targets set.

Market-based mechanisms (MBMs) utilize market forces to alter institutional and individual incentives toward energy efficiency improvement (Karp and Gaulding 1995). MBMs offer positive incentives to improve energy efficiency for a company (Karp and Gaulding 1995). These incentives are aimed at increasing profits and reducing costs due to energy efficiency actions, which make them interesting for large and medium companies. MBMs help to reduce behavioral barriers, as well as budgetary ones, by using "soft" methods (incentives) rather than forcing to change it as in case of CAC. MBMs also reduce technological barriers to energy efficiency as they encourage companies to implement new technological decisions and invest in research and development (R&D) activities.

However, they can affect low-income households as companies, participating, for example, in White certificate schemes, are allowed increasing charges from consumers to cover the costs for energy efficiency improvements. To eliminate this effect, WhCs could be accompanied by subsidy programmes for vulnerable categories of consumers.

4.4.4. Information instruments

These instruments help to take individual actions in households and companies and build public support for local and national EE policies. They also help to create demand for EE products and technologies by informing people about benefits of energy efficiency. In this relation the most powerful tool is product labeling. Either mandatory or voluntary, it is used to inform consumers about energy use of appliances, cars and buildings. Another widely used instrument is information campaign. They give consumers information about the opportunities to reduce energy use and save money. In this regards, they might shift consumers' behavior towards more energy efficient choice of products and services.

Thus, information instruments are aimed at addressing information and behavioral barriers. However, they do not provide direct economic incentives for more energy efficient behavior as subsidies and MBMs. Information instruments can hardly support market transformation by their own and are likely to be additional mechanisms to promote energy efficiency in collaboration with other policies, such as CAC or MBMs or budgetary instruments.

Thus, information instruments are aimed at addressing information and behavioral barriers. However, they do not provide direct economic incentives for more energy efficient behavior as, for example, subsidies. Information instruments can hardly support market transformation by their own and are likely to be additional mechanisms to promote energy efficiency in collaboration with other policies, such as CAC or budgetary instruments.

4.4.5. Evaluation of energy efficiency policy instruments

In the previous section the overview of different policy instruments has been given. However, the introduction of a policy does not mean that it will address barriers to energy efficiency. Each policy instrument should have the ability to do it. In this regard, it is very important to analyze the limitations of each policy instrument and the ways of its improvement.

The evaluation of energy efficiency policy instruments in this thesis includes four main parts. The first one presumes the determination of the presence of a policy group in the country (present or absent). It can be done by reviewing current legislation, state programmes, secondary sources of information, etc. The second part includes the consideration of the barriers to energy efficiency, which can be potentially reduced by the group. The third one presumes the analysis of the policy instruments' limitations, which could aggravate reducing the barriers to energy efficiency. And the fourth part is devoted to providing recommendations for further improvement of policy instruments. Table 8 provides a general scheme for the evaluation of policy instruments.

Table 8. A country's evaluation check-list for EE policy instruments

Policy instruments' group	Presence in a country	Barriers to energy efficiency which can be reduced	Concrete policy instruments in place	Limitations	Recommendations
Command and Control	Yes/No				
Budgetary	Yes/No				
Market-based	Yes/No				
Information	Yes/No				

Chapter 5. Results

In Chapter 4 the methodology for the research analysis has been presented. As shown in Figure 5 there are three main parts of the analysis: model of final energy use, analysis of passive-house market penetration and analysis of energy efficiency policies. These blocks of analysis constitute the basis for the recommendation on further policy development. This chapter presents the results of analysis, according to this structure.

5.1. Results for the model of final energy use

This section shows the results for the model stimulation, described in section 4.2. The results are gained for each scenario and include the dynamics of final energy use in Russian buildings, estimation of energy savings potential by 2050 and calculation of the "lock-in effect" in relation to the "Incremental diffusion" scenario.

5.1.1. "Incremental diffusion" scenario

Figure 18 presents the dynamics of final energy use in Russian buildings from 2005 to 2050.

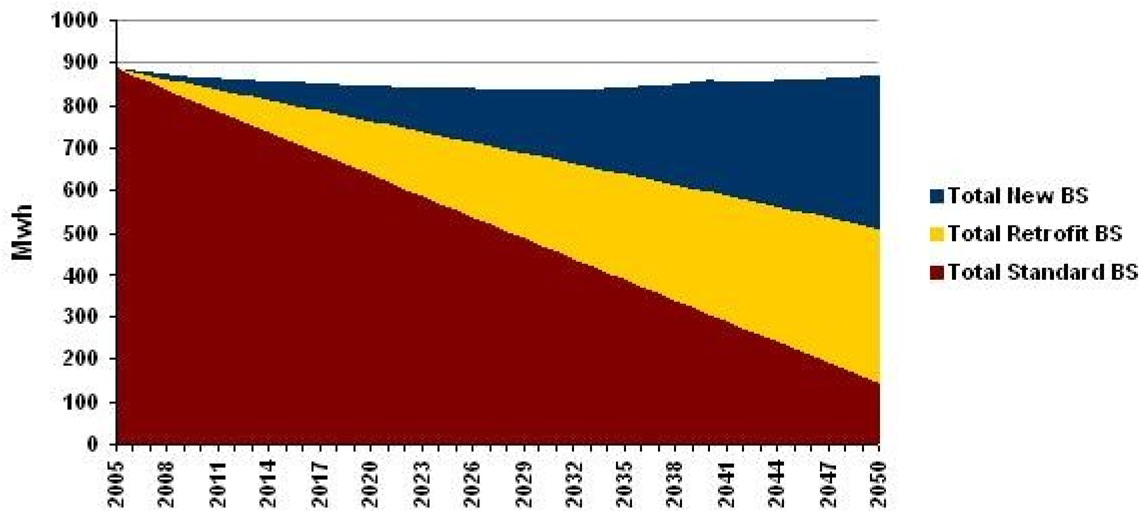


Figure 18. Final energy use for heating. "Incremental diffusion" scenario

Figure 18 illustrates that by the year 2050 total energy use will decrease slightly. Energy use of standard building stock declines, because of its demolition and renovation. It is also assumed that once a standard building has been retrofitted it, will not become a standard one anymore. Thus, standard building stock cannot increase. The decrease in energy use occurs because the amount of retrofitted and new buildings, which consume less energy, grows in the total building stock.

Total final energy use in 2005 is estimated as 885 Mwh, while in 2050 it is 870 Mwh. Thus, according to Formula (5), energy savings by 2050 are insignificant – even less than 2%:

$$Energy\,Savings_{inc.diffusion} = \frac{870 - 885}{885} \times 100\% = -1.76\%$$

Thus, incremental diffusion of energy efficiency technologies in Russia, according to the model's results, will produce hardly any energy savings in the building sector by 2050. Thus, if the market is developing by itself during the analyzed period of time, it will not unlock the energy savings which the Russian building sector has. This result proves the fact that for the improvement of energy efficiency in buildings, which leads to the realization of the energy savings potential, market intervention such as energy efficiency policies, are required.

5.1.2. "A-class buildings" scenario

As has been described above, this scenario takes into account a market intervention in the form of the improvement of Russian Building Codes in 2015. After this year new and retrofitted buildings are supposed to consume 51% less energy for heating. Fig.19 presents the forecast of energy use in this situation.

Figure 19 shows a sharp decrease in energy use in new and retrofitted buildings after 2015, caused by the improvement of Russian Building Codes. Energy use of standard building stock declines without drops, following the same path as in the previous scenario, because it is impossible to change the energy use of an existing building without renovation. Thus, the energy use of standard building stock does not react to the improvement of Building Codes. As in the "Incremental diffusion" scenario, energy use of standard buildings decreases by the end of the period due to reduction of standard building stock, caused by renovation and demolition.

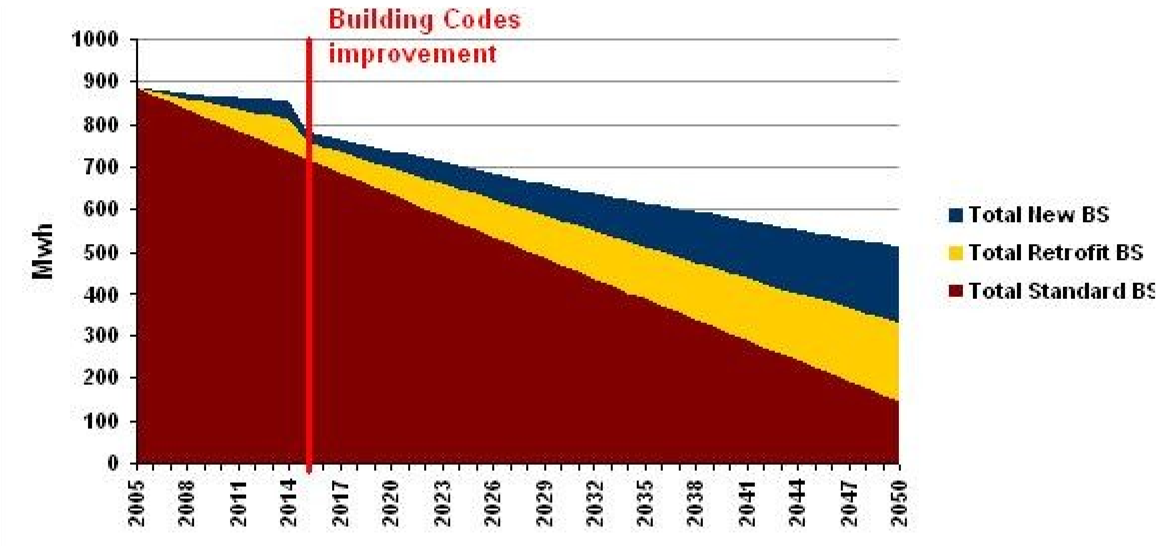


Figure 19. Final energy use for heating. "A-class buildings" scenario

Total final energy use in 2005 remains the same as in the "Incremental diffusion" scenario, because in this year no changes occur, and equals 885 Mwh. In 2050 energy use is much lower than in the previous scenario, - 513 Mwh. Thus, according to Formula (5), energy savings by 2050 exceed 40%:

$$Energy\,Savings_{A-class} = \frac{513 - 885}{885} \times 100\% = -42.10\%$$

This result shows how the introduction of policy instruments can provide considerable energy savings in the long-run. It also leads to the conclusion that in case such improvement of the Building Codes is not introduced, more than 40% of energy savings will be locked-in. The lock-in effect for this scenario can be calculated according to Formula (7) or as the difference between the energy savings potential of "Incremental diffusion" and "A-class buildings" scenarios:

$$Lock\!-\!in\;effect_{A-classbuild} = \frac{870_{inc.diffusion} - 513_{A-class}}{885_{2005}} \times 100\% =$$
$$= 42{,}10\% - 1{,}76\% = 40.34\%$$

5.1.3. "Advanced construction" scenario

According to this scenario, new type of buildings, which consume much less energy for heating, is introduced in 2011 and due to market transformation by 2020 all new buildings correspond to this type. Figure 20 shows the model's results for this scenario.

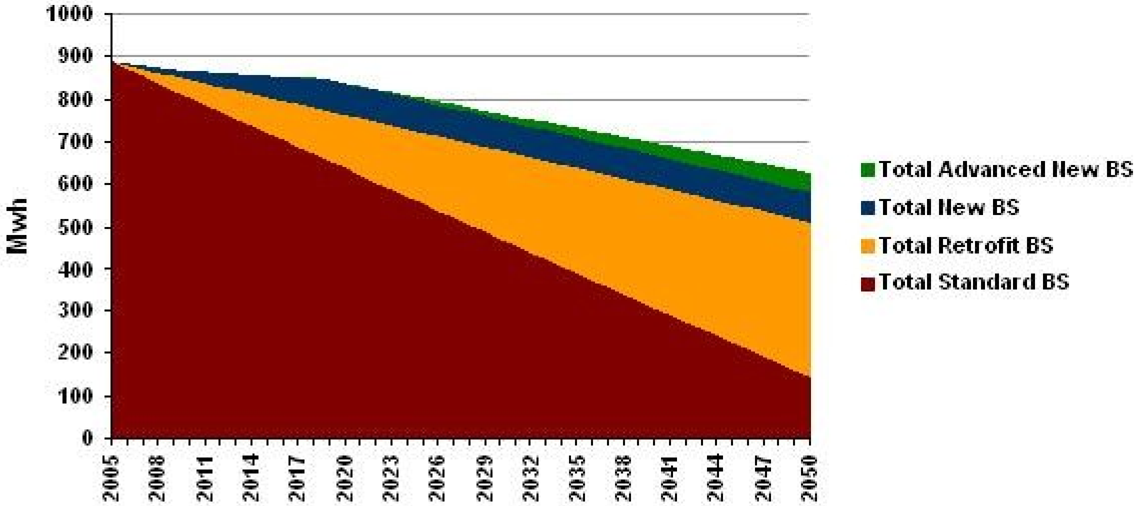


Figure 20. Final energy use for heating. "Advanced construction" scenario

Figure 20 demonstrates the overall decrease in final energy use and appearance of advanced building stock, which occurs as a certain share of advanced buildings' energy consumption in new building stock.

Energy use of advanced new building stocks presents a very small portion of total energy use due to two reasons. The first reason is that advanced new buildings consume on average six times less energy than conventional new buildings. The second reason is that the amount of new building stock constructed each year is rather small according to the model, due to the decreasing population in Russia. Energy savings due to this market transformation are around 30%:

$$Energy\ Savings_{Adv.construction} = \frac{625 - 885}{885} \times 100\% = -29.36\%$$

$$Lock-in\ effect_{Adv.construction} = \frac{870_{inc.diffusion} - 625_{Adv.construction}}{885_{2005}} \times 100\% = 27.60\%$$

Energy savings in this scenario are lower than those caused by the improvement of Building Codes. On the one hand, it follows from the fact that the construction rate of new buildings is not very high, thus, few buildings are being added to new building stock every year. On the other hand, in the "A-class building" scenario the reduction in energy consumption has taken place in the retrofitted building stock as well, which can be evidence of significance of retrofitted buildings for realizing energy savings potential. The next "Advanced buildings" scenario takes this aspect into account.

5.1.4. "Advanced buildings" scenario

In this scenario, market transformation towards higher energy efficiency involves both new and retrofitted buildings. It presumes that by 2020 all new and retrofitted buildings are constructed, according to advanced standards. Final energy use for this scenario in 2005-2050 is presented in Figure 21.

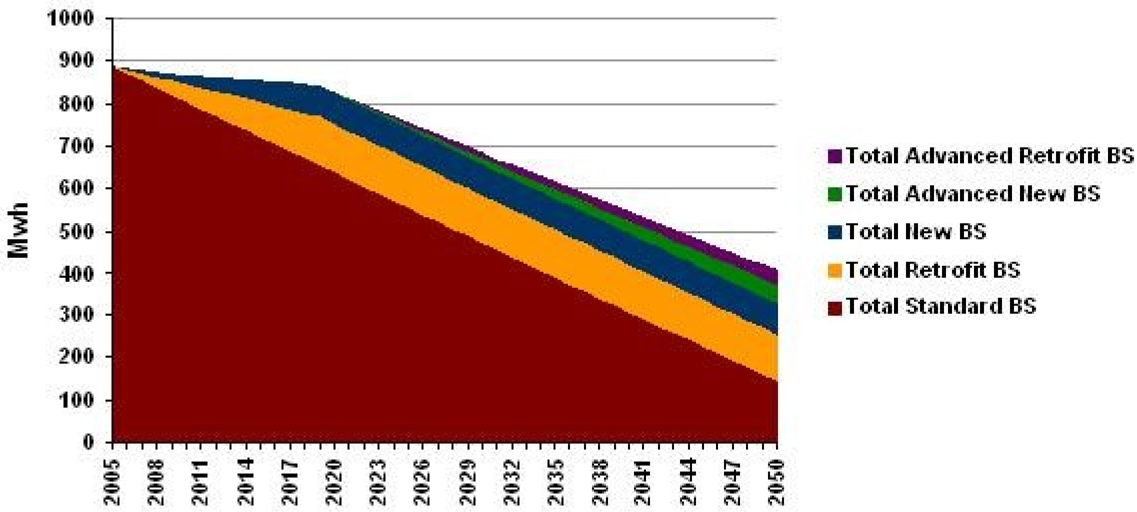


Figure 21. Final energy use for heating in Russian building sector. "Advanced buildings" scenario

Figure 21 shows the contribution of advanced retrofitted building stock to total energy use. Its share is rather low due to low energy consumption in the buildings renovated according to advanced standards.

The chart also shows a considerable reduction in total energy use in 2050. The most significant decline in energy use takes place after 2020, when 100% of newly constructed and renovated buildings correspond to advanced standard. Energy savings for this scenario are more than 54%, which presents the greatest potential among all considered scenarios.

$$Energy\,Savings_{Adv.buildings} = \frac{407 - 885}{885} \times 100\% = -54.06\%$$

$$Lock-in\,effect_{Adv.construction} = \frac{870_{inc.diffusion} - 407_{Adv.construction}}{885_{2005}} \times 100\% = 52.30\%$$

The lock-in effect is also the highest for this scenario, showing that more than 50% of energy savings could be locked-in if advanced buildings do not achieve a dominant position at the Russian market by 2020. However, to realize this scenario a very powerful policy mix is to be implemented in the short-run.

5.1.5. Model results' summary

This section gives the overview of the results. Table 9. Main results for four scenarios gives the information on total energy use in 2005 and 2050, energy savings and lock-in effect for four analyzed scenarios.

Table 9. Main results for four scenarios

Scenario	Energy use in 2005	Energy use in 2050	Energy savings by 2050	Lock-in effect
Incremental diffusion	885 Mwh	870 Mwh	-1,76%	-
A-class buildings	885 Mwh	513 Mwh	-42,10%	40,34%
Advanced construction	885 Mwh	625 Mwh	-29,36%	27,60%
Advanced buildings	885 Mwh	407 Mwh	-54,06%	52,30%

Figure 22 provides the illustration of total final energy use dynamics for four scenarios and the illustration of lock-in effects. The results show that considerable energy savings can be achieved due to market transformation towards higher energy efficiency. This transformation can be driven by market intervention. In the proposed scenarios such market interventions have taken the form of Building Codes improvement and stimulation of constructing and renovating buildings according to advanced standards. The results show that both market interventions produce considerable energy savings by 2050. However, the comparison of results of the scenarios "Advanced construction" and "Advanced buildings" has demonstrated the important role of the retrofitted building stock's improvement for the achievement of high energy savings. This conclusion is proved by the fact that the "Advanced buildings" scenario, which includes the improvement of both new and retrofitted buildings, presents the greatest potential for energy savings.

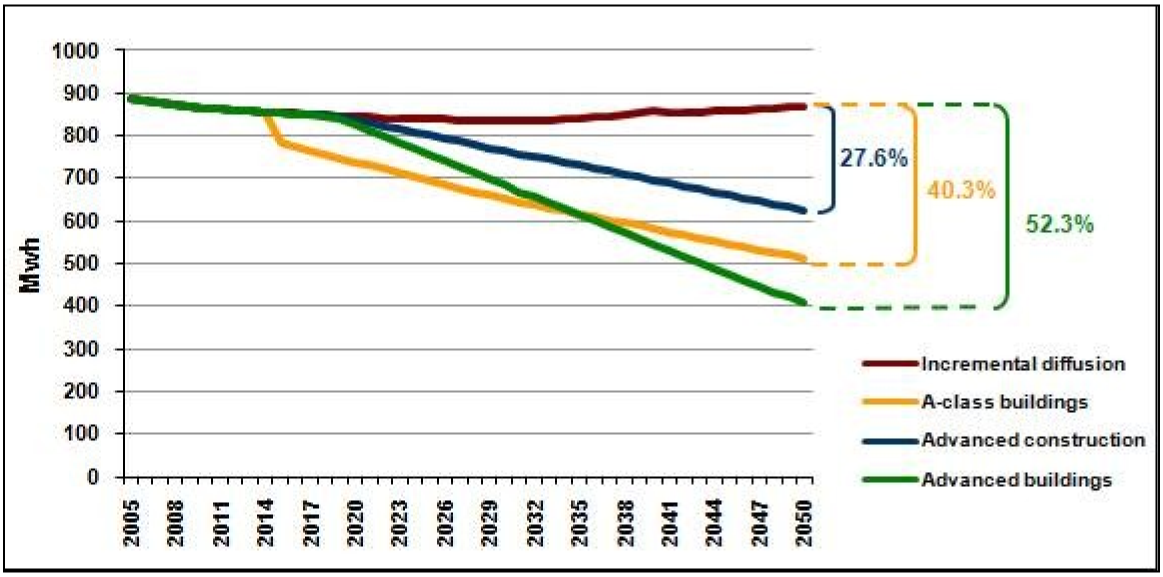


Figure 22. Final energy use dynamics and lock-in effect for four scenarios

Figure 22 also shows a significant lock-in effect for all three scenarios with market interventions. It means that in the situation when the market of energy technologies develops by itself, without any substantial market interventions, which is more or less presented by the "Incremental diffusion" scenario, great energy savings would be locked in inefficient use of energy in the building sector.

5.2. Results for the analysis of passive-houses market penetration

The previous section has demonstrated that there is a considerable lock-in effect of energy savings in the Russian building sector in the absence of market interventions in the form of energy efficiency policies. Before analyzing how policy instruments can help to achieve the energy savings potential, it is useful to determine the stage of market transformation the Russian building sector is located at. In Section 4.3. it has been proposed to use for this purpose the estimation of passive-house market penetration in combination with the model for embedding process of innovations (see Figure 17 and Table 7). Thus, to determine the stage of market transformation it is necessary to have the information about the share of passive-houses in the total building stock.

In Russia this share is tiny. There are hardly any passive-houses registered in Russia at the moment. During data collection the information only for one such project has been found. It is the energy efficient district "Kurkino" in the Moscow region. Its description is given below.

Taking into account the energy consumption achieved and technologies implemented in the buildings in the Kurkino district, it can be concluded that these houses are very close to a passive-house standard. However, such buildings are more the exception than the rule in Russia. Energy efficient technologies are still very rarely implemented in buildings and take a niche position on the market. Due to the increase in the costs of dwellings caused by energy efficiency improvement, such houses usually belong to a premium segment of the market and can be afforded by a limited number of people with high incomes.

Thus, buildings constructed close to passive-houses standards, have only started to be introduced in Russia, as reflected on the curve of the embedding process of innovations (see Figure 23).

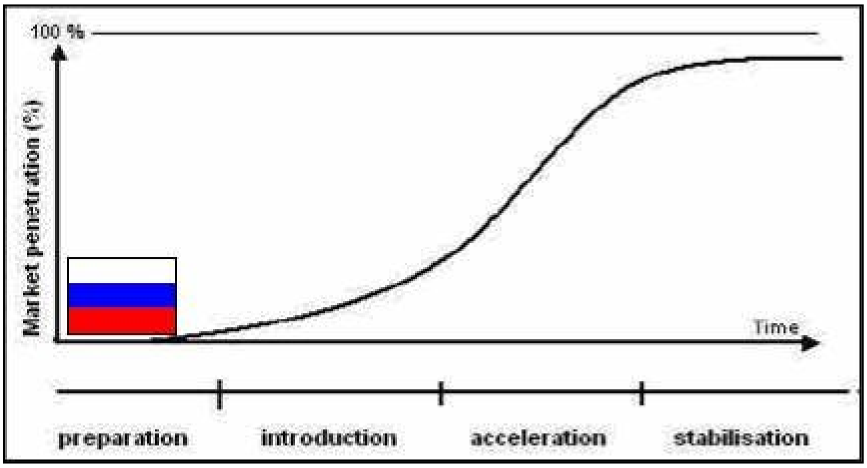


Figure 23. Passive houses market penetration in Russia

Source: constructed based on Elswijk and Kaan (2008)

As shown in Figure 23 and follows from Table 7, the Russian building sector occupies a preparatory stage of the market transformation process towards higher energy efficiency. This conclusion proves the necessity of market interventions in the Russian building sector in the form of energy efficiency policy development. The steps to drive market transformation, which have already been taken in Russia, are discussed in the following section.

ENERGY EFFICIENT DISTRICT "KURKINO"

Location: Russia, Moscow region, Kurkino district

Climate type: Cold moderate

Building type: Multi-family

Year of construction: 2006

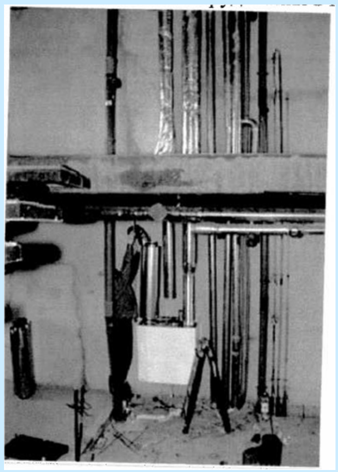
Floor area: 28 3-storey town-houses, floor area per household – 190-210 m^2 plus a garage

Technologies used: freeze proof shallow foundation with insulation, wall insulation with 300-350 mm of cover, triple-glazed windows, heat recovery ventilation with recuperation efficiency up to 90%, gas supply, independent heating supply, solar collectors

Energy consumption: around 30 kwh/m^2/year (heating), 4.5-5.5 lower than in buildings of that type, which consume 160 kwh/m^2/year at average

Costs: project cost – 945 $US/$m^2$
net cost of a square meter of floor area increased on 80-130 $US

A fragment of the main façade



Installation of ventilation system

Kurkino, microdistrict 6

Kurkino, microdistrict 9

Source: Silin (2010) - personal communication

5.3. Results for energy efficiency policies analysis

According to the design, presented in the fourth chapter, the policy instruments are divided into four groups: command and control, budgetary, market-based and information. Below policy mechanisms presented in Russia are considered, according to this classification. The main aim of an energy efficiency policy instrument is to overcome one or another barrier to energy efficiency and, consequently, stimulate market transformation. Therefore, the ability of each group to reduce certain barriers to energy efficiency and their role for market transformation are analyzed.

5.3.1. Command and control mechanisms

This type of policies has proved to be most effective for building sectors worldwide (Metz 2009). The results in considerable energy savings potential for the "A-class buildings" scenario presented earlier also support this view. In Russia policies that belong to this group include: Federal Law No. 261-FZ "On energy savings and energy efficiency increase and amending certain legislative acts of the Russian Federation", the Town-Planning Code and the System of Normative Documents in Building. The last one includes: federal normative documents, construction standards and regulations (SNiPs), state standards (GOSTs), regional normative documents and regional building codes (CENEF n.d.). These policies are mainly aimed at the reduction of energy consumption in building. Nowadays they are presented by the Building Codes and the requirements for energy efficiency of the Federal Law on energy savings and energy efficiency improvement.

1. Building Codes

As Russia is a federate state and consists of 88 territories, buildings codes are presented both at the federal and at the regional levels.

1) Federal Level

There is no single document representing building codes in Russia. The main norms on specific heat consumption can be found in Construction standards and regulations on Thermal Performance of Buildings (SNiP 23-03-04). However, there are other SNiPs which contain norms on energy performance in different building types: single-family (SNiP 31-02-2001) and multi-family (SNiP 31-01-03) houses.

At the same time Building Codes was a great step for Russia on the way to energy consumption and GHG emissions reduction. Besides, the codes are harmonized with international levels and their parameters for energy efficiency have been made consistent with the requirements of the European Union directives (2002/91/EC 2003; SAVE 1993) (Matrosov *et.al*. 2007?).

Russian Building Codes are more performance-based rather than technology-based[7]. The Code sets the requirements on the specific energy consumption of a whole building over the heating season. There are five classes of energy performance of a building from A to E, where A means a very high level of energy efficiency, B – high level, C – normal, D - low and E – very low. This classification is used for new and retrofitted buildings. According to SNiP 23-03-04, D and E classes cannot be assigned to the buildings at the stage of designing. They can be given only to buildings constructed before the year 2000 (Belyi and Petrichenko 2010). The D-class reflects the building norms of 1995. D and E-classes give information to local authorities or buildings' owners about the necessity of the measures at energy efficiency improvement. Conducting an urgent renovation for E-class buildings is prescribed (Osipov and Matrosov 2006).

Required performance levels are set for various building categories based on the number of storeys, building type, floor area, and heating degree-days (Matrosov *et.al*. 2007(?)). The code is assigned to a building according to the deviation of the actual value of specific energy consumption for space heating from the normative value, calculated for this type of building.

According to SNiP 23-02-04, only classes A and B require energy savings: class A - more than 51% and class B –10 to 50% of energy savings in comparison with a normative value. Class C, which is called "Normal Buildings" and includes buildings which are permitted to be built actually allows a 5% increase of energy use in comparison with conventional buildings (SNiP 23-03-04). Table 10 represents the classification of building according to the deviation of their specific energy consumption from a normative value.

[7] Technology standards prescribe the means to be used to reduce energy consumption, while performance standards set the requirements of energy consumption for the whole building (Metz 2009).

Table 10. Building Codes classification in Russia

Class	Name of a class, according to energy efficiency of a building	Value of deviation of actual specific energy consumption from a normative value	Measures recommended by local authorities
For new and retrofitted buildings			
A	Very high	Less than -51%	Economic stimulation
B	High	From -10 to -50%	Economic stimulation
C	Normal	From +5 to +9%	-
For existing buildings			
D	Low	From +6 to +75%	Recommended renovation
E	Very low	More than +76%	Urgent necessary renovation

Source: SNiP 23-02-04

The data on energy performance have to be evaluated regularly, according to the Law "On energy savings…". The responsibility for conducting such evaluation is put on construction companies. In this regard, a project of Decree on the rules of energy performance evaluation and a project of the Federal Law on regulation of multi-family houses have been elaborated. According to the project of the Law, construction companies are obliged to participate in self-regulated organizations and insure the professional responsibility of regulation of multi-family houses. Energy efficient measures in multi-family houses have to be provided by an entity with regulating functions over a multi-family house. Administrative Code and the Law "On energy savings…" presume special fines (from 10 up to 30 thousand rubles – appr. 255-766 euros) for in-compliance with the legislation on energy efficiency (Koval' 2010).

There are also some norms related to energy efficiency of single-family houses in Construction standards and regulations for single-family houses (SNiP 31-02-2001). This document sets certain requirements on energy efficiency of a building, according to the aggregated factor of specific power consumption for space heating. It establishes normative values of specific power consumption and states that the building meets energy efficiency requirements if the calculated value of specific power consumption does not exceed the normative value. The normative values are set depending on the heated floor area and the number of floors. According to these Codes, the extent of a building's energy efficiency is determined by the relation between the normative and calculated values of specific power consumption in a building. The Code sets the following classes of energy efficiency for buildings:

- a house of high energy efficiency if the relation is more than 1.25
- a house of higher energy efficiency if the relation is between 1.1 and 1.25
- a house of normal energy efficiency if the relation is between 1.0 and 1.1 (SNiP 31-02-2001).

However, these requirements for energy efficiency are not very high. For example, the relation equal to 1.25 corresponds to 20% of energy savings, the value of 1.1 means about 9% and the value of 1.0 does not presume any energy savings in comparison with a normative building. Thus, the energy consumption of Russian energy efficient houses is much higher than in European ones. This conclusion is also confirmed by requirements contained in the Russian building norms and rules for thermal performance of buildings (SNiP 31-02-2001).

2) Regional Level

As was outlined before, Regional Building Codes are adopted in the majority of Russian regions. Regions established their own requirements for calculating a building's energy consumption and compliance with local code (IEA 2004a). Figure 24 shows these regions.

Figure 24. Regions of Russia which have Building Codes

Source: Matrosov *et al.* (2006)

Regional Building Codes have to be in compliance with Federal Building Codes, but at the same time there are opportunities to improve energy efficiency of buildings at the local level. For example, in the Khanty-Mansiisk autonomous district the local government made a decision to design only B-class residential houses with the deviation from a normative value between -10 and -50% since 2002 (Osipov and Matrosov 2006). Moscow construction norms (MGSN 4.19-05 "Temporary norms and standards of designing multi-functional high-rise buildings and building-complexes") presume the construction of high-rise buildings, according to A and B classes, with the value of the specific energy consumption for heating 10-60% lower than a normative value (Osipov and Matrosov 2006).

2. Energy Efficiency Requirements for buildings, according to the Federal Law No. 261-FZ

The majority of the provisions of the Law enter into force from the day of its official publication, though modifications to the Tax Code (Part I No. 146-FZ dated 31 July 1998 and Part II No. 117-FZ dated 5 August 2000) will enter into force on 27 December 2009, and modifications to the Code of Administrative Offences No. 195-FZ dated 31 December 2001 – on 22 June 2010. The Law replaces the previous Federal Law "On energy efficiency" No. 28-FZ dated 3 April 1996 which is distinguished by its declarative nature and absence of real measures allowing real development of energy saving technologies in Russia (Tissot 2009). The Law contains several groups of requirements to energy efficiency in buildings, which are discussed in more detail below.

1) Requirements to buildings, constructions and installations

According to the Law, buildings, structures and installations must comply with obligatory requirements on energy efficiency, fixed by the Ministry of Regional Development in concurrence with the Ministry of Energy (ME) and the Ministry of Economic Development (MED). The energy efficiency requirements must be revised every 5 years. They include:

- development of the indicators, representing specific amount of energy use in the buildings or/and constructions;
- designing special requirements relating to the architectural, functional, technological, constructive, engineering and technical solutions influencing the energy efficiency of buildings or/and constructions;
- adopting requirements relating to separate elements of buildings or/and constructions;
- adopting requirements relating to equipment and technologies used in buildings or/and constructions;
- adopting requirements relating to technologies and materials applied in construction, renovation and repairs. (Federal Law No. 261-FZ)

The energy efficiency requirements will be applied to all types of buildings except some categories: religious buildings and structures, objects of cultural heritage, temporary buildings with a planned time of use of less than two years, single-family houses with numbers of floors less than three, country houses, stand-alone buildings with a total useful floor area of less than 50 m^2 (Federal Law No. 261-FZ).

The energy efficiency requirements will indicate the persons responsible for their implementation. The responsibilities for meeting energy efficiency requirement are spread between builder and owner. A builder is obliged to provide the correspondence of buildings to energy efficiency requirements and an owner is obliged to maintain this correspondence. The control of buildings` correspondence to the energy efficiency requirements is performed by the authorities of State construction supervision. The authorities evaluate buildings according to the Town-Planning Code of Russian Federation (Town-Planning Code of Russian Federation 2004). The Law on energy savings and energy efficiency increase has made the amendment to this Code, adding to the mandatory project documentation of buildings the list of measures on providing the correspondence of buildings to the energy efficiency requirements and requirements of equipment with the meters for measuring use of energy resources. The Code also presumes the evaluation of the project documentation according to current technical regulations and requirements. The result of this evaluation is a positive or negative decision related to the correspondence of the documentation to existing requirements. According to the Town-Planning Code, a builder can get the permission for building work only in case of positive decision of project documentation evaluation (Town-Planning Code of Russian Federation 2004). In other words, if a building does not correspond to energy efficiency requirements, such a building is not allowed (Belyi and Petrichenko 2010).

2) Metering of the energy resource use

Another requirement for buildings in relation to energy efficiency, besides reduced value of specific energy consumption, is the obligation of the installation of energy accounting meters ("energy gauges") (Federal Law No. 261-FZ). The requirement for meters installation are spread to all built objects connected to the grid, district heating system, except ramshackle and dangerous objects. The main aim of devices is to provide consumers with data for calculating their energy use (Belyi and Petrichenko 2010).

The Law fixes deadlines for the installation of such equipment. Thus, commercial and industrial buildings and constructions will be equipped with water, natural gas, thermal energy and electrical energy meters by 1 January 2011 (Federal Law No. 261-FZ). In apartments and dwelling houses, the energy gauges both collective (for the whole building) and individual (for separate apartments)) will be in place by 1 January 2012 (Federal Law No. 261-FZ). All buildings which will be put in service after these deadlines must be equipped with analogous devices.

Failure to comply with requirements of the Law in designing, construction, renovation and capital repairs, as well as failure to comply with meters installation requirements entails administrative responsibility. The amount of penalty varies among different categories of consumers: for executives at the rate of RUB 20,000 – 30,000 (approx. EUR 455-682), for individual entrepreneurs at the rate of RUB 40,000 – 50,000 (approx. EUR 909-1,136), for legal entities at the rate of RUB 500,000 – 600,000 (approx. EUR 11,364-13,636) (Tissot 2009). Some other types of administrative infractions will also be introduced in the Code of Administrative Offences.

3) Energy efficient lighting

Regulation on energy efficient lighting is provided by the Federal Law on Energy Savings and Energy Efficiency. The Law bans the production and trade of incandescent electric bulbs with power exceeding 100W for the purposes of alternating current and lightning from 1 January 2011 (Federal Law No. 261-FZ). Optional rules stipulating the prohibition of incandescent bulbs with power exceeding 75W from 1 January 2013 and with power exceeding 25W from 1 January 2014 are also fixed by Law but they are supposed to be revised in future, depending on the first results of the EE program in Russia. The Law provides for the adoption of energy efficiency requirements for lighting equipment and electric bulbs by 1 March 2010 (Tissot 2009).

5.3.2. Budgetary Instruments

Theoretically, this group of policy instruments includes subsidies, price support, tax deductions or exemptions. However, in Russian reality budgetary instruments and energy efficiency improvements are extremely undeveloped. There are no taxes for the use of traditional energy sources in Russia on the contrary, their prices are highly subsidized. The development of subsidy programs comes down to government's plans or limited support to some categories of people.

1. Financial incentives based on Building Codes

The classification systems, discussed above, according to energy efficiency of a building, can become a substantial framework for financial incentives for energy efficient buildings. But Russian codes do not require such incentives and no jurisdiction has yet actually created such incentives for privately funded buildings (Matrosov *et.al*. 2006). However, some steps towards development of such financial incentives were made at the regional level.

In 2005 in Moscow the local government adopted a policy directive which called for financial incentives for the creation of energy-efficient buildings in the city (Matrosov *et.al*. 2006). Only contractors designing city-financed buildings could participate in this Programme. The incentives consisted in the proportional payments 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. In the case of designing a building which consumes 30% less than required by code, with simple payback times of less than three years, a building-design agency gets a 50-percent bonus in addition to their usual design fees (Department of Civil Construction Policy *et al.* 2005).

2. Targeted subsidies

Targeted subsidies are aimed at the support to a certain group of people. Well-designed subsidy program supports only concrete people which meet certain criteria with the simultaneous inducement of efficient use of energy. Thus, it is necessary to determine criteria and control the realization of the program. Possible criteria may include the level of income, district of residence or lack of the access to a service (World Bank 2008).

However, in Russia such programs are not widely spread and implemented mostly at the regional level as a part of complex social and housing programs. The first targeted subsidy program on public utilities payments was introduced in 1994 by the Russian Law № 4218-1 of 24 December 1992 "Concerning the Fundamental Principles of Federal Housing Policy". The Government Decree № 761 of 14 December 2005 established new rules of such subsidies allocation (Misikhina *et.al.* 2007). According to these rules, regional authorities have to develop the standards, in respect of which the local government would allocate subsidies. The criteria which were used in most regions include the normative floorspace and maximum allowed share of a household's expenditures on utilities in the total income. Most of the regions, that took part in the program, set this share at the level of 22% and the norm of the floorspace at the level of 18 square meters per person in a household consisted of three and more people and 21 square meters per person in a two-person household (Misikhina *et.al.* 2007).

5.3.3. Market-based mechanisms

This group of energy efficiency policies proposed by the elaborated model is market-based mechanisms. In Europe this group of instruments is mainly presented by the White Certificate scheme (WhC). However, in Russia there are no market-based mechanisms in place. It can be explained by highly monopolized energy market, while WhC requires a liberalized one. Other barriers include obstructive conditions for functioning EE institutions presented in Table 2, especially the high level of corruption, lack of investments and undeveloped culture of energy savings and energy efficiency concepts among consumers, producers and policy-makers. To implement this group of instruments, great reforms in energy policy have to be made to create the essential institutional capacity and infrastructure and prepare the energy producer to the participation in the WhC scheme.

5.3.4. Information mechanisms

Awareness of the impacts of inefficient energy use and opportunities to control it is vital for effective action (Metz 2009). In Russia one of the barriers to improving energy efficiency in the building sector and not only, is the lack of such awareness (World Bank 2008). Common lifestyles of Russian people do not include the culture of careful use of natural resources, as everybody used to think that they were abundant or endless. Thus, information instruments should be strongly developed as they could create the basis for implementation of other instruments and increase the effectiveness of policies.

1. Buildings' Labeling

The Federal Law "On Energy savings and energy efficiency increase and amending certain legislative acts of the Russian Federation", mentioned above, also sets a very important requirement to indicate the class of energy efficiency of buildings on their facades. The details of the of EE classes corresponding to the relevant list accepted in the EU countries will be defined by the federal ministries (Tissot 2009). This measure will give important information about the energy efficiency of each building and can influence consumers' decisions. If consumers are aware of the benefits of energy efficient buildings, for example, reduced energy bills, decreased use of energy resources, lower level of GHG emissions and, as a result, reduced negative impact on environment, then some would choose to purchase more energy efficient apartments. Naturally, among others reduced energy costs would be the main incentive.

2. Energy audits

There are energy audits of buildings now conducted on a systematic basis. The Law on Energy Savings and Energy Efficiency Increase defines energy audits as an important measure (Federal Law No. 261-FZ). However, it is mandatory only for certain categories of organizations.

Energy audit is devoted to providing information about real energy consumption of inspected actors. It can be made in relation to products, technological processes, juridical persons or individual entrepreneurs. Thus, energy use in buildings plays an important role for such audits. The energy inspection is aimed at gaining the data about energy efficiency improvements, such as the amount of energy resources used, the factors of energy efficiency, the potential of energy savings and energy efficiency improvement, energy efficiency measures and their cost evaluation. The results of energy control must be reflected in energy passports comprising information on availability of energy accounting meters, volume of energy resources used and the modifications of this volume etc. All information contained in the energy passports will be included in the State Energy Register kept by Ministry of Energy (Tissot 2009). This measure can help to collect the information about energy use in buildings, monitor their energy performance and make conclusions about compliance of buildings to their energy efficiency class and necessity of energy efficiency improvements.

3. Information about energy efficient buildings

The Law also presumes the creation of an information system to provide people with information on energy efficiency measures (Federal Law No. 261-FZ). This information provision includes among others informing consumers of the energy efficiency of buildings and distributing the information about the potential of energy savings in communal infrastructure.

One of the major steps in this field is the creation of the state information system in the field of energy savings and energy efficiency improvement. In the building sector it is aimed to provide people, organisations and authorities with objective information about the legislation's requirements and incentives in the field of energy efficiency and the ways these requirements could be met and the incentives used (Belyi and Petrichenko 2010).

5.3.5. Influence of energy efficiency policies on market transformation

The previous sections have given the overview of energy efficiency policies instruments. As has been pointed out above, energy efficiency policies can play an important role in driving market transformation towards higher energy efficiency through reducing certain barriers. In this section the possible influence of each policy group on market transformation is discussed.

1. Command-and-control mechanisms

Mandatory regulations play a very important role in stimulating market transformation in the building sector as they change the behavior of manufacturers and both building and real estate professionals. Regulations' prescriptions make them choose more energy efficient technologies and materials for constructing buildings, increasing, thereby, the demand for energy efficient products and technologies. Thus, command-and-control mechanisms reduce behavioral barriers to energy efficiency. They also address political barriers as they make politicians adopt regulations and producers change their strategy to comply with adopted provisions

CAC increase the demand for energy efficiency goods, which makes them more compatible on the market in comparison with traditional ones. For example, replacement of high-energy consuming bulbs with energy efficient ones will create energy savings, improve energy efficiency of buildings and reduce GHG emissions. Moreover, due to limited demand of incandescent bulbs, the competitiveness of energy efficient bulbs will increase. The life cycle of an energy efficient lamp is 4-5 times longer than this of an incandescent electric lamp, and each energy efficient lamp allows for saving about 50 watt of energy per hour, that also means savings of money for consumers (Nasibov, A. 2009). These facts could address the barriers of cost competitiveness. CAC also could reduce the administrative barriers to EE by creating new actors and widening the scope of competence of existing ones in order to comply with introduced regulations or standards.

Building Codes in relation to new and renovated buildings increase the share of the buildings, which consume less energy, in the total building stock. It also increases the demand to energy efficient building technologies and products, which drives market transformation. On the whole Building Codes potentially have a very large long-term impact on improving energy efficiency in new and existing residential buildings, depending on the way of their implementation.

2. Budgetary mechanisms

Budgetary measures are potentially powerful instruments to drive EE market transformation. They can provide incentives for behavior that saves more energy. For both consumers and producers, budgetary instruments can enable energy savings goals to be achieved at the lowest cost and in the most efficient way (Defra 2003).

Where environmental costs are fully internalised into the price of a product a reallocation of resources in the economy occurs. This is because price signals are changed so that producers and consumers face the environmental costs of goods. Budgetary measures can reduce higher relative prices of energy efficiency products and services and, thus, shift the demand in favor of lower priced alternatives that are more energy efficient. Incentives encouraging consumers to purchase the most energy efficient appliances could help remove inefficient ones from the market. A reduction in the price differential between efficient and inefficient appliances should induce consumers to buy the most efficient products. In the same way producers are encouraged to restructure away from producing more energy-consuming products (Defra 2003). Thus, budgetary instruments have the potential to address financial barriers and the barriers of cost competitiveness. They also can encourage technological developments and new processes offering greater energy efficiency, thereby reduce technological barriers.

Technological improvements will stimulate the further strengthening of regulations, which will encourage wide range of producers to correspond higher energy efficiency standards.

Budgetary measures are more effective when they are combined with other energy efficiency polices. For example, in combination with the information programmes, raising consumers' awareness, they may be potentially effective in influencing consumer choices as consumers will be informed about benefits of energy efficient products, reducing thereby behavioral barriers to energy efficiency.

However, there are concerns that taxation policy would be regressive in nature as it would necessarily increase the prices of the cheapest models because they are the least efficient. It will primarily affect low-income category of consumers, making some goods unaffordable. Thus, it is necessary to implement such policies together with subsidies, which support low-income consumers by offsetting their increased costs (Defra 2003).

However, in Russia the effectiveness of these policies is limited greatly, which is discussed in the section devoted to the effectiveness of EE policy instruments.

3. Information mechanisms

The main aim of information instruments is to reduce the information barriers on the way of market transformation. Information programmes are essential in supporting other policy measures; they can contribute to making them clear to relevant actors and therefore more likely to be implemented. However, it is hard to estimate the impact of information instruments as the usually do not have clear targets and highly interacted with other instruments (OECD/IEA and AFD 2008). Generally, information instruments raise public awareness of energy efficiency opportunities and benefits, which, consequently, creates the demand for energy efficiency products and technologies and, therefore, results in energy savings (OECD/IEA and AFD 2008).

Energy efficiency labels are devoted to help the market recognize energy efficiency and act on it. The information provided by labels helps consumers and other end-users to make an informed decision about the true cost of a product, and manufacturers to improve the energy performance of it as there is no way for the market to recognize and value this aspect (Energy Charter Secretariat 2009). Energy audits provide transparent information and energy efficiency improvement recommendations, thereby raising the awareness of the occupants and owners of buildings, which is one of the key issues in both reducing unnecessary energy use and boosting penetration of energy savings technologies. The main purpose of energy passports is to affect purchase and renting decisions. In order to do so the passports have to present tangible benefits gaining from selecting energy efficient product (technology, equipment, etc.) instead of conventional one. Thus, they are able to reduce not only information barriers to energy efficiency, but also increase cost competitiveness.

However, despite the existing potential of information mechanisms it is not being released to full extent in Russia, thus there are certain limitations to their effectiveness and influence on the market transformation, which will be discussed in the section devoted to the effectiveness of the EE institutions.

5.3.6. Limitations of energy efficiency policies in Russia

Previous section has shown that there are three out four groups of energy efficiency policy mechanisms in Russia. These mechanisms have a potential to reduce barriers to energy efficiency improvement, however, in Russian reality their abilities to do it are limited considerably by drawbacks of the policies' implementation. The main limitation for the effectiveness of all policy instruments is that they have been introduced only recently. The Federal Law discussed above was adopted only in 2009. Before this energy efficiency has hardly been promoted by federal legislation. Thus, most of policies are either coming into force or have not been introduced yet. The limitations for each group of EE policy instruments are considered below.

1. Command and Control mechanisms

1) Building Codes

As has been noted above, there was an attempt to harmonize Russian Building Codes with EU directives. However, a comparative analysis between Russian and German standards on energy consumption for heating shows that in Russia these values are significantly higher. In Germany values of energy consumption for heating are between 40 and 96 kwh/(m^2 year). While in Russia these values, corrected for German climate conditions, are between 55 and 105 kwh/(m^2 year). That means that German norms are 20-27% lower than Russian ones for multi-family buildings and 9-10% lower than single-family buildings (Matrosov n.d.).

Therefore, Russian Building Codes are still less energy effective than ones in Europe. Moreover, their provisions do not make difference between retrofitted and new buildings and there are no requirements for achieving a higher energy performance of the buildings after renovation.

Another limitation is that Building Codes do not have strict requirements for renewing building codes. Thus, current building codes are already seven years old and there are no plans announced to renew them in the near future. This fact hinders the energy efficiency improvement in buildings.

Besides that, there is lack of mandatory monitoring of compliance of buildings with their particular building class. Once the energy performance class was assigned to a building, the actual energy consumption of a building should be measured systematically to check whether a particular building meets the requirement of an energy performance class and establish in time the necessity to move a building to a lower class and make some improvements.

2) Requirements to buildings, constructions and installations

The requirements to energy efficiency introduced by the Federal Law on energy savings also have certain limitations. The main limitations of energy efficiency requirements for building, constructions and installations are that they came into force only recently and the Law presumes the creation of institutional infrastructure to support the implementation of these requirements only in the future. Thus, before the creation of this infrastructure these requirements actually do not work. The time required for creation of such infrastructure as well as the effectiveness of created institutions is uncertain. Therefore, the effectiveness of these measures is strongly dependent on the government enforcement to create necessary institutions and regulate the implementation of certain norms.

Another limitation is that single-family houses with numbers of floors less than three are not included into the category of buildings for which energy efficiency requirements are not mandatory. This category of buildings can include premium single-family houses where energy use could be very high, so the necessity to reduce energy use in such buildings is vital.

Moreover, the Law does not set the requirements for utilizing energy efficient technologies and materials in buildings during construction and renovation. In case of the absence of other incentives, it makes construction companies to use cheaper energy inefficient ones hindering thereby energy efficiency improvement considerably. There are also neither requirements nor incentives for utilizing renewable energy in buildings, which lock in existing opportunities to reduce fossil fuels use in buildings.

3) Metering of the energy resource use

As for energy metering the installation of such devices in buildings is a definitely important step towards improving energy efficiency. It has already confirmed its effectiveness, for example, in Denmark (Energie-Cités 2003). However, in Russian reality the effectiveness of this measure is likely to be limited. The problem is that energy use meters are not enough for reducing energy consumption in buildings. Consumers are interested in reducing their energy bills. However, the measuring devices cannot provide energy or financial savings by themselves; they can simply show how much energy is consumed in each particular building unit. Savings will take place only in case of reduction of energy consumption. However, in most buildings in Russia there is no opportunity to control energy consumption in buildings, because they are not equipped with means of energy use control systems, such as thermostatic regulator. Very few buildings in Russia have such devices (Nasibov 2009). The absence of such regulators means that consumers simply are not able to reduce their consumption of heat energy if they have network heating in their dwellings, because they have to consume as much energy as supplied and cannot regulate it. Energy supply companies are eager to make profits and in the situation of relatively low energy prices they provide high level of energy supply. This fact often causes the problem of overheating, when a lot of energy is lost even through simply opening the windows (World Bank 2008).

The Law also proposes a rather complicated scheme for these measures: the devices must be purchased by consumers, installed by a special authorized organization and used by heat supply network. Such a scheme may significantly hinder the process of the devices installation and the monitoring of their work, as people actually do not have incentives, except penalties, to install these meters (Belyi and Petrichenko 2010).

4) Energy efficient lighting

In relation to the measures for energy efficient lighting, there are two main limitations. First of all, only the prohibition of the most high-capacity incandescent bulbs is mandatory. The Law does not ban the production of bulbs with lower capacity. It only declares the possibility of such prohibition. The lack of mandatory wording reduces the effectiveness of actions.

Secondly, the Law does not propose actions devoted to compensating the shut-out of cheap incandescent electric bulbs from the market. There is no hint on how the demand for bulbs will be satisfied. The cost of such bulbs is about eight times higher than the cost of conventional incandescent electric bulbs (Nasibov 2009). As was mentioned above, such bulbs provide energy savings and, consequently, reduce energy bills which will eliminate the difference in prices. Unfortunately, such savings are not as obvious for customers as the higher price.

Command-and-control mechanisms in Russia play a very important role. The adoption of the Federal Law "On energy savings…" is a great step on the way to improvement of energy efficiency of Russian economy on the whole and of the building sector, particularly. However, this group of instruments has certain limitations and requires further development to achieve a significant reduction of the barriers to energy efficiency.

2. Budgetary mechanisms

The effectiveness of budgetary instruments is limited because of a lack of such instruments at the federal level. Some regions can introduce separate programs, but it is only local initiatives almost without governmental control or support. The introduction of budgetary incentives for energy efficiency is strongly hindered by weak institutional capacity and energy cross-subsidies. These facts aggravate the development and the implementation of the policies. Under-pricing also undermines the profitability of industry and its ability to invest (Moltke *et.al.* 2004).

However, the immediate increase in prices to long-term marginal costs level could over-remunerate the owners of generation assets and leave the generation companies with large retained earnings and cash surpluses. Cross-subsidies in the electricity sector are a great problem. Residential electricity prices in relation to industrial prices increase significantly as cross-subsidies are being reduced. However, in many cases industrial prices are higher even though supply costs are much lower (Moltke *et.al.* 2004).

The problem of energy subsidies is worsened by inefficient use of district heat, which is aggravated by the absence of energy meters and heat-control systems in buildings. Thus, the problems of under-heating or, just the opposite, overheating occur. But even when dwellings are heated properly, consumers do not have incentives to conserve it. In large multifamily houses, it is often not possible to adjust the amount of heat supplied to each apartment.

Consequently, consumers have a zero price elasticity of demand, which means that they can not meter, reduce or refuse heat consumption. As a result, many households refuse to pay for heat supplies that they claim they did not request.

In respect of the subsidies for district heating, there are several major problems related to setting heat tariffs:

- Standard cost-plus tariff methodologies used by most municipalities do not motivate suppliers to reduce their costs.
- The lack of metering makes it difficult to set tariffs based on costs.
- There is a lack of coordination in regulating prices between the Federal Energy Commission, which sets gas prices and wholesale electricity prices, the Regional Energy Commissions, which set co-generated electricity and heat prices, and municipalities, which set prices for heat transmission and heat generation by boilers.
- Tariff-setting procedures are not transparent and are driven by political consideration (Moltke *et.al.* 2004).

Targeted subsidies also have certain limitations. First of all, it is the lack of federal and local governments' funding allocated for such programs. Secondly, such programs are not spread widely in Russia and may be introduced mostly at the regional level. Thirdly, even if such programs do exist in regions, most eligible people are not aware of such opportunities. And finally, the application process to such a program, which presumes the preparation of certain documents and inefficient work of bureaucratic organizations, could hinder the process of getting subsidies. Thus, nowadays the effectiveness of budgetary instruments is considered to be limited in Russia, but it can be changed by the appropriate development of these policies.

3. Information mechanisms

The main limitation of information instruments, mentioned above, is that they are not in force yet, but only proposed by the recently adopted Law. Thus, there is a need for institutional capacity for introduction of these instruments and their efficient functioning. There is also a lack of incentives to introduce these instruments, especially in the case of energy audits, as they are voluntary for most of organizations.

Thus, each group of energy efficiency policy instruments has significant limitations which prevent them from functioning effectively nowadays.

5.3.6 Recommendations for further EE policies development

From the analysis presented above it can be concluded that Russia nowadays has a low stage of energy efficiency development. The market will move towards higher energy efficiency if policy instruments work effectively. Nowadays the effectiveness of policies in Russia is low. This can be explained by the fact that the majority of policy instruments have been introduced recently. Their future effectiveness greatly depends on their implementation. Thus, the necessity of their further development and improvement is obvious.

The recently adopted Federal Law "On energy savings…" has set a certain institutional framework, but it is only the beginning of the process. The introduction of the institutions proposed by the Law requires a lot of time, efforts and spending. Thus, it seems necessary to give recommendations to policy-makers for the development of policy instruments. The recommendations are given in respect of the policy instruments' limitations presented above. Table 11 gives the summary of the analysis of EE policy instruments together with limitations and recommendations.

Table 11. Summary for evaluation of energy efficiency policy instruments

Policy instruments' group	Presence in a country	Barriers to energy efficiency which can be reduced	Concrete policy instruments in place	Limitations	Recommendations
Command-and-Control	Yes	Behavioral, political, cost competitiveness, administrative	Building Codes	a lack of high standards for energy performance of buildings	• to introduce mandatory building codes in all regions of the country • to increase the requirements of energy performance classes of buildings at least to the level of European level
				a lack of strict requirements for renewing building codes	• to set the requirement for a certain period of time after which Building Codes must be reviewed and made more stringent
				a lack of requirements for energy performance specifically for retrofitted buildings	• to include the requirement for energy performance of retrofitted buildings at approximately the same level as of new buildings
				a lack of mandatory monitoring of compliance buildings with particular building class	• to introduce a requirement for a mandatory monitoring of energy consumption in buildings and checking their compliance with assigned energy performance class • to set the requirement for a certain period of time after which energy consumption of a building must be measured
			Requirements to buildings, constructions and installations of the Federal Law No. 261-FZ "On Energy Savings and Energy	insufficiency of institutional infrastructure to support the implementation of the requirements introduced by the Federal Law "On energy savings…"	• to establish a special agency for monitoring of energy consumption in buildings and checking their compliance with assigned energy performance class
				single-family houses with numbers of floors less than three are not included into the category of buildings for which energy efficiency requirements are not mandatory	• to extend the list of buildings which the requirements for high energy performance applied to

			Efficiency Increase and Amending Certain Legislative Acts of the Russian Federation”	a lack of the mandatory requirements for using energy efficient technologies in buildings' construction and renovation	• to introduce requirements for utilizing energy efficiency technologies during both construction and renovation of buildings • to introduce requirements for construction of a certain number of passive-houses annually and renovation of a certain number of existing buildings to passive-house level and provide strong incentives for it (for example, subsidies, grants, competitions among constructors)
				a lack of requirements for using renewable energy sources in buildings	• to introduce requirements for utilisation of renewable energy produced both on-cite and off-cite buildings and provide strong incentives for it (for example, subsidies, feed-in tariffs)
			Metering of the energy resource use in the Federal Law "On Energy Savings…"	mandatory installation of energy meters is not accompanied by the mandatory installation of energy use control systems	• to introduce mandatory requirements for installation energy use control systems together with energy meters and provide strong incentives for it (for example, targeted subsidies, information campaigns)
				a lack of financial incentives for energy consumers to install energy use meters and control systems	• to provide strong incentives to energy consumers for installation of energy use meters and regulators (for example, targeted subsidies, information campaigns)
			Energy efficient lighting in the Federal Law "On Energy Savings…"	the prohibition of incandescent bulbs production is limited to those with the highest capacity	• to ban the production of all types of incandescent bulbs
				a lack of incentives for customers to buy energy efficient bulbs	• to provide a well-organized information campaign which presents the benefits of energy efficient bulbs for customers and shows the amount of energy and money savings. • to provide a governmental support for low-income households, for example, in the form of targeted subsidies
Budgetary	Yes	Financial, cost competitiveness, technological	Financial incentives based on Building Codes and Targeted subsidies	a lack of budgetary instruments at the federal level	• to establish governmental subsidies for the construction of more energy efficient buildings covering the part of the costs of more expensive energy efficient design • to introduce grants for conducting energy efficient building projects based on the competition of project proposals made by different constructing companies

				weak institutional capacity	• to cteate new or/and make competent existing financial institutions (banks, funds, trusts, etc.) to deal specifically with energy efficiency projects
				presence of energy cross-subsidies	• to replace cross-subsidies by targeted subsidies for low-income consumers
				a lack of motivation for energy suppliers to reduce their costs supported by the tarrif system	• to introduce tax reduction for constructing companies which carry out energy efficient building projects to reduce their costs of more expensive energy efficient design
				a lack of energy tariff system based on costs	• to utilize incentive rates, when the minimal amount of energy (usually 50-100 kwh per month) for living is offered by reduced tariffs and the amount of energy above this level is billed according to higher prices. Such tariffs provide each consumer with minimal amount of relatively cheap energy. Thus, the value of minimal energy use has to meet this condition (WB and IFC 2007)
				a lack of transparency of the tariff setting system	
				a lack of federal and local governments' funding for targeted subsidies programs	• to attract private funds and allocate them for energy efficiency projects • to create public-private partnerships
				a lack of awareness of eligible people about the targeted subsidies	• to conduct informational campaigns on the regular basis to inform people about current and future subsidies programmes and their conditions
				too complicated process of the application to subsidy programmes	• to establish special free (or low-cost) consultancy services (e.g. phone, face-to-face etc.) to help people apply for subsidies
				a lack of financial incentives for renovation of the existing building stock	• to introduce grants and special subsidy programmes for "deep" renovation, which presumes a considerable reduction of energy consumption • to establish of the fund to provide low-interest loans and credits for capital repairs and renovation

Market-based	No	------------------	------------------	there are no market-based mechanism in Russia	• to start the liberalization of Russian energy market • to promote the benefits of energy efficiency improvement for energy-supply companies • to fight against corruption • to build an institutional infrastructure necessary for functioning of White certificate system (e.g. ESCOs, funds, governor body, etc.)
Information	Yes	Information, behavioral	Provisions on Buildings' Labeling and Energy Audits of the Federal Law No. 261-FZ "On Energy Savings and Energy Efficiency Increase and Amending	a declarative character of the instruments	• to adopt the Law on buildings' labeling which specifies how labels should look like, what kind of information include, when they should be introduced, reviewed and for what categories of buildings they are mandatory • to establish the agency which will issue labels, control and monitor the compliance of buildings with assigned labels. • to establish the agency which will collect the information about energy consumption and savings, opportunities for energy efficiency improvements, current legislation and policy, especially financial incentives in the building sector and make this information available for the public
				a lack of institutional capacity to introduce information instruments and make them work efficiently.	
				is a lack of incentives to introduce information instruments	• introduction of mandatory energy audits for the majority of organizations with certain penalties for non-compliance (regulatory incentives) • introduction of financial incentives in case of voluntary energy audits for the organizations which undertake them, such as tax deduction or subsidies which partly cover costs of the conduction an energy audit

Discussion

The results of the research presented in this thesis have shown that there is a considerable potential to save energy in the Russian building sector. However, this potential nowadays is locked in inefficient use of energy due to path-dependency. This developmental path can be directed to a more efficient one by means of market transformation towards higher energy efficiency.

The model's stimulations for proposed scenarios have shown that strengthening of the Building Codes with the requirement to have only A-class buildings will result in 42% energy savings of final energy for the space heating by 2050 in relation to 2005. Intensive construction of advanced buildings with energy consumption for heating around 15-30 kwh/m^2/year is estimated to provide around 30% of final heating energy conservation. This figure could grow up to 54% if the construction of new advanced buildings is accompanied by deep[8] intensive renovation of existing buildings. At the same time the situation when no energy efficiency policies are taking place will create less than 2% of final energy savings for space heating locking-in the rest of the potential. The scenarios' results have shown a vital role of energy efficiency policy development for Russia.

However, the policy instruments' analysis has not given a clear picture of what developmental path Russia is going to follow in the future. The main reason is that energy efficiency policies have been introduced only recently (at the end of 2009) together with the adoption of the Federal Law "On energy savings…". There are certain limitations of Russian energy efficiency policy, which can be eliminated during the implementation of the Law. Thus, future market transformation towards higher energy efficiency and overcoming the lock-in effect in Russia is totally dependent and the actions of Russian government in implementating the Law and its further development of policies.

The analysis of the first steps in the implementation of the Law taken in the first half of the year 2010 might provide some ground for determining what scenario is more likely to take place in Russia. This period has demonstrated a considerable increase in measures devoted to energy efficiency improvement. First of all, Russian President, Dmitrij Medvedev, has passed a Decree, according to which energy intensity of Russian GDP has to be reduced by 40% by

[8] Deep renovation in this context means the renovation according to an advanced standard, which presumes energy consumption for space heating at the level of 15-30 kwh/m^2/year

2020 in comparison with the level of 2007. This reduction is supposed to be achieved by means of energy efficiency improvement.

In this regard, the conduction of six energy efficient projects in the following years has been approved at the federal level. These projects include measures on energy efficient lighting; installation of energy use meters and control systems; energy efficient renovation of the entire districts in several cities and using their experience for the whole country; installation of energy efficient technologies in public buildings (schools, hospitals, etc.); production and installation of energy efficient equipment especially in heating networks. The President also pointed out that the realization of these projects should be accompanied by information campaign on the promotion of energy efficiency. The main aim of this campaign, according to Medvedev's views, is to change people's consciousness which in turn will stimulate a behavioral change (RIAN 2010).

By July 2010 the realization of the energy efficient projects, mentioned above, has been started in several regions of Russia. For example, in Nizhnevartovsk the "Smart city" progamme has begun, which presumes the implementation of energy saving technologies in the electricity supply (Samotlor-jekspress 2010). In the Permic region the "New light" project has been introduced recently. It will result in installation of energy efficient light sources in 35 pilot buildings this year. During 2012-2013 the number of buildings is going to be extended considerably (Energy efficient Russia 2010b). In Belogorsk a long-term targeted programme on energy efficiency improvement of municipal education has been introduced, providing considerable energy savings. In this city a steady implementation of energy saving measures has been taking place for the last few years, which saves 3% of energy annually (RIA Vostok Media 2010).

From September in Moscow new low-energy consuming multi-family houses are going to be constructed, decided by the Moscow Mayor Give his name here. after his visit to advanced buildings in Paris. Old buildings in Paris consume approximately the same amount of energy for heating as ones in Moscow – 200-240 kwh/m^2/year. At the same time, advanced buildings in Paris use no more than about 15 kwh/m^2/year. At a special committee meeting, the Moscow Mayor gave the instruction to design buildings with similar energy consumption in Moscow (Komsomol'skaya Pravda 2010). The Russian President gave instructions for the conduction of another advanced building project after visiting the Green Light House in Denmark during the Russian-Danish business forum this spring. The Green Light House combines utilization of solar and ground energy for heating, natural ventilation and zero CO_2 emissions. At the forum several agreements on cooperation and experience exchange between Russian and Danish companies were signed. As a result, in Russia two projects similar to the Green Light House and energy efficiency improvement progammes for Saratov and the Tatarstan regions are being developed in collaboration with Danish partners (RBC 2010).

Advanced low-rise multi-family houses are going to be constructed in Chuvashia. The building works are planned to start at the beginning of 2011. They are going to be 3-storey blocks with 24 apartments, which will consume approximately 70% less heating energy than a conventional house of the same type due to utilization of the modern technologies and innovative materials. The technologies will include heat pumps, light-emitting diodes (LEDs) and even solar cell batteries (Energy efficient Russia 2010a).

These projects will increase the market penetration of advanced buildings and energy efficient technologies and materials, which will drive market transformation towards higher energy efficiency. This gives the ground to conclude that the "Incremental diffusion" scenario is unlikely to take place in the future because of active market interventions in the form of constructing new advanced buildings. Thus, a certain part of energy savings locked in this scenario will be "unlocked". It makes the "Advanced construction" and "Advanced buildings" scenarios more likely to happen. However, these scenarios are rather ambitious, assuming that by 2020 all new and/or retrofitted buildings will be constructed according to advanced standard. Thus, it is possible that in reality it will happen later than 2020 but the tendency towards this goal can already be seen.

It should also be noted that "Advanced construction" scenario is more likely to take place than the "Advanced buildings" scenario due to several reasons. First of all, it is easier to achieve low energy consumption in a building by constructing it from scratch using new technologies and designing an independent heating supply system (or even passive heating) than to renovate an existing energy inefficient building with district heating, inefficient technologies, design and materials and achieve the same low level of energy use. Secondly, such a "deep" renovation might require greater investments than construction of a new building. Thirdly, the projects presented above are aimed at new construction. In other words, to the best of the author's knowledge, there are neither projects on "deep" renovation nor programmes stimulating such projects in Russia. It is a sad fact because even if the "Advanced construction" scenario is realized, around 25%[9] of energy savings will be locked in buildings not renovated according to advanced standards.

Thus, special policy instruments offering incentives for "deep" renovation should be introduced to realize the"Advanced buildings" scenario. The "A-class buildings" scenario also seems to be too ambitious. According to the Decree of the Ministry on Regional Development №262 of 28 May 2010, existing building classes are going to be modified, introducing seven classes instead of the five existing ones:

For newly constructed and renovated buildings

- A – very high class of energy efficiency. Level of heating energy consumption is more than 45% lower than that, presumed by an existing C class
- B++ - higher. Level of heating energy consumption is 36-45% lower than in the existing C class
- B+ - higher. Level of heating energy consumption is 26-35% lower than in the existing C class
- B – high. Level of heating energy consumption is 11-25% lower than in the existing C class
- C – normal. Level of heating energy consumption in comparison with the existing C class is from +5 to -10%

For existing buildings

- D – lower. Level of heating energy consumption is 6-50% higher than in the existing C class
- E – low. Level of heating energy consumption is more than 51% higher than in the existing C class

Moreover, a schedule for improving energy efficiency of buildings has been introduced:

- From 2011 it is required to construct buildings with the class of energy performance no lower than C
- From 2016 – no lower than the class B+
- From 2020 – no lower than the class B++ (Koval' 2010)

[9] It is a difference between percentages in absolute magnitude of energy savings in "Advanced buildings" scenario (54.06%) and "Advanced construction" scenario (29.36%). 54.06%-29.36% = 24.70%

Taking into account these modifications, existing A-class includes a new A-class and the most efficient part of the class B++. Thus, it is very unlikely that the proposed schedule, which is already a big step towards energy efficiency improvement in the Russian building sector, will be strengthened even more in the way proposed by the "A-class" scenario (mandatory construction and renovation, according to A-class, from 2015).

However, according to the Decree, government authorities ought to provide programmes varying from energy performance classes B to A, which will create financial incentives for buying and living in such houses. The Ministry of Economic Development has declared that it is possible to apply special reduced tariffs for the buildings with high energy performance and fines for ones with low energy performance (Koval' 2010). Thus, certain steps are taken towards mandatory improvement of energy performance of buildings and it is likely that the level of energy performance proposed in the "A-class buildings" scenario will be achieved in future but not in 2015.

Summing up, the proposed scenarios have been elaborated more for showing a significant energy saving potential hidden in the Russian building sector than precise forecasting its future development. It is very hard to predict how energy efficiency policies will be developing in the future, because most of them have been introduced only recently, but there is an obvious positive tendency towards energy efficiency improvement. Thus, it is very likely that the Russian building sector will follow the path of active reduction its energy consumption. This path might be less ambitious than the "Advanced buildings", "A-class buildings" and "Advanced construction" scenarios, but, probably, it will combine features of all of them, resulting in energy savings much higher than in the "Incremental diffusion" scenario.

Conclusion

In this paper the potential of energy savings “locked-in” Russian building sector has been estimated by means of modeling final energy use for heating purposes. The country has been chosen as a good example of economy in transition with high energy intensity of the economy, which needs a great improvement of the energy efficiency of the building sector and the development of energy efficiency policy. The stage of energy efficiency market transformation has been evaluated by analyzing the market penetration of passive houses in the country. The impact of the energy efficiency policies on the market transformation towards higher energy efficiency has been analyzed in respect of their potential reduction of the barriers to energy efficiency and existing limitations. The analysis is based on the path-dependency theory, which in this context means that once a country has chosen its developmental path, it is very difficult and costly to switch to a more efficient one.

The main contribution of the thesis is the forecast of final energy use for space heating in the Russian building sector, calculation of the potential energy savings by 2050 in relation to 2005 and estimation of the energy savings, which can be lost (“locked-in”) due to the lack of policy development. The model uses the original data specific for the Russian building stock, assumptions based on literature review and experts’ opinions and the results of additional analysis by means of GIS analysis with Arcview software.

The model of final energy use in buildings includes four scenarios: “Incremental diffusion”, “A-class buildings”, “Advanced construction” and “Advanced buildings”. They differ according to the way of the reduction of final energy use for heating by 2050. The “Incremental diffusion” scenario presumes that there is a 0.1% annual decrease in final energy use for space heating in the building sector and neither policy improvement nor advanced buildings are introduced in the economy. This scenario estimates 1.76% reduction of final energy use for space heating in the Russian building sector by 2050 in relation to 2005.

The “A-class buildings” scenario is based on the improvement of Building Codes requiring 51% of final energy use reduction for space heating in new and retrofitted buildings in comparison with standard ones. It results in 42.1% of savings in final energy for space heating purposes in the Russian building sector by 2050 in comparison with 2005. In the “Advanced construction” scenario from 2011 advanced new buildings are introduced and their share in newly constructed buildings achieves 100% by 2020. For this scenario energy saving potential by 2050 is 29.36%. Finally, the "Advanced buildings" scenario besides introduction of new advanced buildings includes the same measures for retrofitted ones. It estimates a 54.06% energy saving potential of final space heating energy use in the Russian building sector.

For each scenario, except "Incremental diffusion", the "lock-in effect" of energy savings has been estimated. "Lock-in effect" is the lost opportunity to save energy because of existing barriers to energy efficiency improvement and a lack of actions to reduce these barriers. For the "A-class buildings" scenario the "lock-in" effect is 40.43%, for "Advanced construction" scenario 27.6% and for the "Advanced buildings" scenario – 52.3% in relation to "Incremental diffusion" scenario. Basically, these numbers mean the percentage of energy savings which could be lost if the measures presumed by scenarios are not introduced.

Thus, scenarios' results can be very useful for policy-makers as they show the necessity to implement certain policies in Russia. The model shows that it is important to stimulate construction and renovation of advanced buildings and strengthen the Building Codes as these measures provide the most considerable energy savings.

The market penetration of passive houses illustrates the level of the energy efficiency market development in a country. This criterion has been chosen, because the concept of passive houses nowadays combines the best technological solutions in the building sector. Thus, the stage of the market embedding of the passive house concept reflects the stage of the market transformation of the building sector. This criterion shows that Russia is now at the beginning of the preparatory stage of the passive houses embedding process, as it has hardly introduced any passive house projects. That corresponds to the low effective stage of the market transformation in Russia.

The analysis of energy efficiency policies in Russia has shown the presence command-and-control, budgetary and information instruments. Market-based instruments are not introduced in Russia mainly due to its highly monopolized energy market, undeveloped institutional capacity and infrastructure. Each of the present group of policy instruments has a potential to reduce certain barriers to energy efficiency improvement. Command-and-control instruments can reduce behavioral, political, administrative barriers and the barriers of cost competitiveness; budgetary mechanisms - financial, technological barriers and the barriers of cost competitiveness; informational instruments – informational and behavioral barriers. All energy efficiency policy instruments in Russia have certain limitations. Most of them are related to a lack of institutional capacity and infrastructure, strict obligations and incentives for energy efficiency improvement. They can be explained by the recent introduction of these measures and can be eliminated or at least reduced by further policy development.

In this regard, certain actions are taking place in respect of the implementation of the Federal Law No. 261-FZ “On Energy Savings and Energy Efficiency Increase and Amending Certain Legislative Acts of the Russian Federation”. These actions include projects on constructing energy efficient buildings in a number of cities (Moscow, Nizhnevartovsk, Belogorsk, etc.) and improvement of Building Codes, including the schedule for the improvement of buildings’ energy performance. These activities give the ground to assume that the Russian building sector will follow the path of active reduction of its energy consumption. This path might be less ambitious than the “Advanced buildings”, “A-class buildings” and “Advanced construction” scenarios, but it will probably combine features of all of them, resulting in energy savings much higher than in “Incremental diffusion” scenario.

The main outcome of the research is that Russia is very far from the “state of art” stage, where the best energy efficient technological solutions have the dominant share of the market. Thus, a lot of actions should be taken in the country to overcome the lock-in effect, caused by path-dependency on inefficient technologies. Russia has started moving towards this stage by the development of energy efficiency policy instruments and the future developmental path greatly depends on the government authorities’ efforts to promote energy efficiency in the country. The results show that main emphasis in further policy development should be put on the construction of new advanced buildings and deep renovation of existing ones.

The areas of further research of this problem could include the implementation of the proposed methodology to other countries in the world. It would be worth applying this model to the countries of the Former Soviet Union or to developing countries. The model for final energy use in the building sector can be used for these countries as well. However, the analogous research for developing countries and the economies of transition is likely to face a problem of the lack or absence of the data. Thus, such research will require more time and the implementation of qualitative methods, such as interviews with local policy-makers and energy experts. The model for the evaluation of the market transformation stage can also be improved by including other factors into the analysis, such as specific energy efficient technologies and use of renewable energy in buildings. This will require more careful analysis of available information for the analyzed country(ies) for durable period of time.

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Annex. Data for the model of final energy in the Russian building sector

Table 12. Energy intensity in the United Kingdom, France, Germany and Russia from 1992 to 2007

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
United Kingdom	6528	6590	6296	6058	6260	5880	5669	5509	5259	5217	5042	4963	4847	4757	4564	4291
France	6594	6658	6501	6532	6705	6521	6432	6307	6139	6162	6049	6049	6012	5923	5794	5586
Germany	6659	6736	6532	6540	6505	6370	6249	6041	5895	5961	5840	5961	5965	5787	5709	5380
Russia	22336	22941	24006	23932	24305	22384	23818	23315	21535	20497	19891	19092	18353	17337	16522	15312

Source: US EIA (2007)

Table 13. Population in Russia 2005 – 2050

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Population	**143,5**	**142,8**	**142,2**	**142,0**	**141,9**	**141,7**	**141,4**	**141,1**	**140,8**	**140,4**	**140,0**	**139,6**	**139,1**	**138,6**	**138,0**	**137,4**	**136,7**	**136,0**	**135,2**	**134,4**	**133,5**	**132,6**	**131,6**

Year	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Population	**130,6**	**129,6**	**128,5**	**127,4**	**126,8**	**126,2**	**125,6**	**125,0**	**124,5**	**123,9**	**123,3**	**122,7**	**122,1**	**121,5**	**120,9**	**120,3**	**119,7**	**119,1**	**118,5**	**117,9**	**117,3**	**116,7**	**116,1**

Source: GKS RF (2009a), GKS RF (2009b)

Table 14. Urbanization rate in Russia 2005 - 2050

Urbanisation rate	0,729	0,729	0,730	0,731	0,731	0,732	0,733	0,734	0,735	0,736	0,737	0,738	0,739	0,739	0,740	0,741	0,742	0,742	0,743	0,744	0,744	0,745	0,745

Urbanisation rate	0,746	0,747	0,747	0,748	0,753	0,758	0,762	0,767	0,772	0,777	0,782	0,787	0,792	0,794	0,796	0,798	0,800	0,802	0,804	0,806	0,808	0,810	0,812

Source: Moj Gorod (2006), GKS RF (2009a)

Table 15. Floor area per capita occupied in each type of buildings

m^2/person	Russia 2005	Russia 2050 = OECD
SF	21,8	45,8
MF	20,5	28,0

Source: GKS RF (2008), Odyssee (2007).

Table 16. GDP (PPP) of Russia 2005 – 2050

Russia	2005	2010	2020	2030	2040	2050
GDP,bln $	**764**	**845**	**1240**	**1942**	**3242**	**4948**

Source: GEA

Table 17. GDP and commercial floor area in Former Soviet Union, 2005

FSU GDP 2005	797
FSU Com Floor Area 2005	669

Source: GEA

Table 18. Commercial floor area in Russia and OECD, 2005

Russia 2005	Russia 2050 = OECD
642	15717

Source: GEA

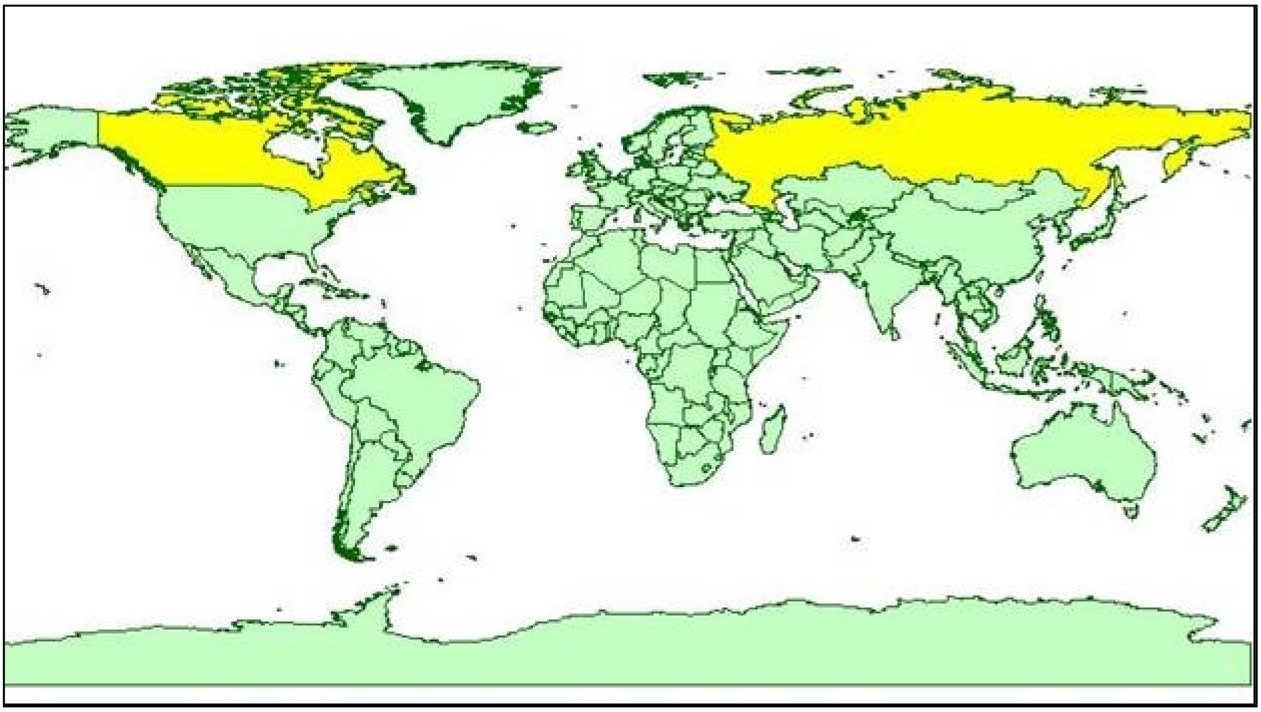

Figure 25. Administrative borders of the world

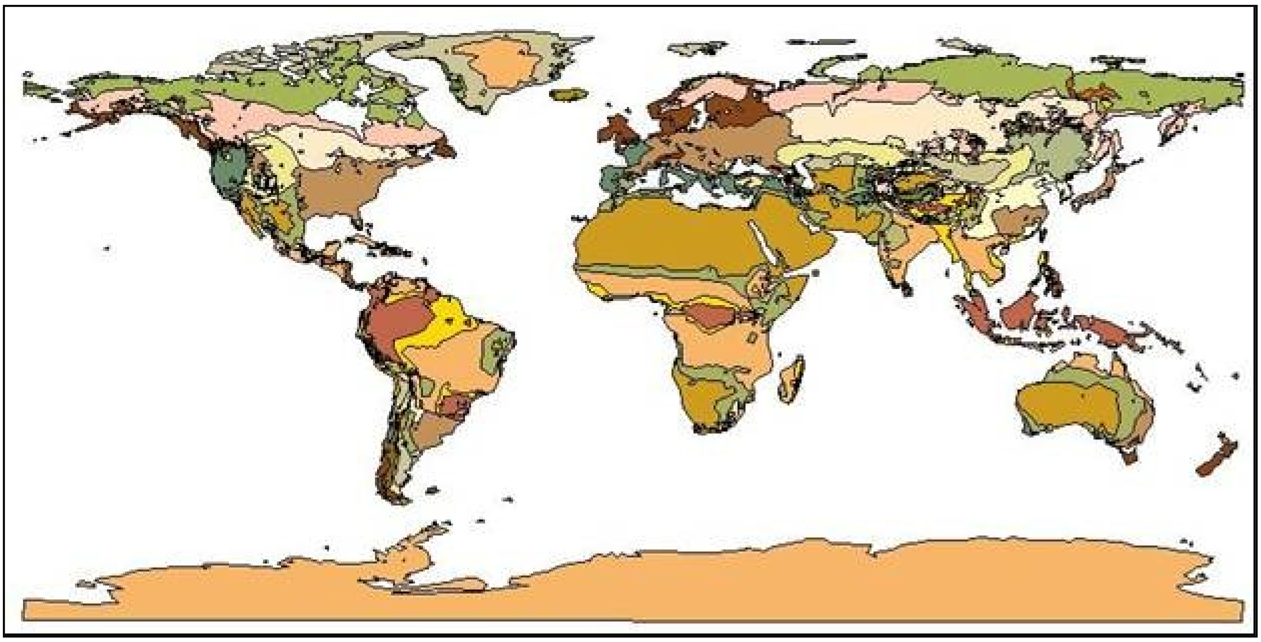

Figure 26. Climate zones of the world

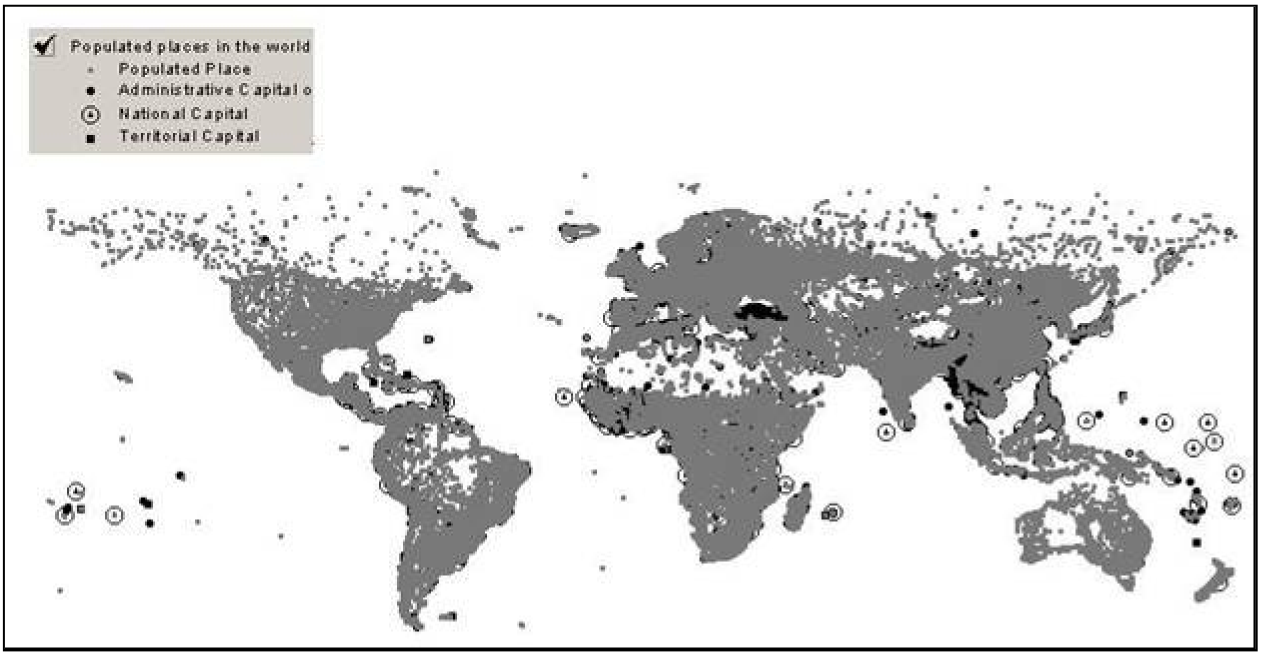

Figure 27. Populated places of the world