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Energy Efficiency in the Residential Sector in the Ukraine

Achieving the Potential

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Abstract

Ensuring energy security, eradicating energy poverty, and reducing GHG emissions from the energy sector are some of the key reasons why energy efficiency will be addressed in the Ukraine. The residential sector, being among the major energy consumers in the national economy, has a large energy saving potential. Multi-storey residential buildings currently require general refurbishment, and this fact opens a window of opportunity for the implementation of energy saving measures in a cost-efficient way.

This research estimates the potential energy savings from the introduction of first-priority technical measures in the Ukrainian multi-storey residential stock, and discusses the policy instruments that have to be used in order for such measures to be realized. The key finding of the study is that a major share of the existing energy saving potential of the Ukrainian residential sector can be realised via simple and first-priority technical energy saving measures, i.e. wall insulation and additional insulation of the thermal envelope, window exchange, heating metering, hot water metering, and installation of temperature regulators.

The major barriers to the implementation of energy saving measures in the Ukrainian residential stock are subsidized energy prices, citizens' energy intensive lifestyles, lack of financial capital for the introduction of energy saving measures, misplaced incentives, lack of investors' interest in energy saving projects, lack of awareness about energy saving options amongst average dwellers and construction specialists, as well as a high rate of corruption at all levels of governance. Potential policy instruments for the Ukrainian context were identified as follows: increased energy performance standards for buildings, compulsory energy audits and labelling of buildings, compulsory installation of heating and hot water meters, increase of energy tariffs for residential users, creation of revolving funds, educational campaigns, and the promotion of ESCOs.

Keywords: energy efficiency, energy saving potential, technical measures, policy instruments, window of opportunity.

Executive summary

The improvement of energy efficiency is among the major tasks that the Ukrainian economy shall tackle in the near future. The issue of energy efficiency is closely connected to national energy security, energy poverty, and the reduction of GHG emissions by the energy sector. Being among the major energy consumers in the national economy, the residential sector has a large energy saving potential. Multi-storey residential buildings currently require general refurbishment, and this fact opens a window of opportunity for the implementation of energy saving measures in a cost-efficient way.

The research questions addressed by the present paper were to assess whether the estimated energy saving potential of the Ukrainian residential sector can be achieved through the implementation of key technical measures, and to determine which policy instruments could be used in order to increase the energy efficiency of chosen technical measures.

The present research was based on literature review of existing technical energy saving measures, with consequent identification of the most suitable measures for Ukrainian multi-storey residential buildings, using various literature sources addressing this issue. Estimation of the potential energy savings of chosen measures is conducted, whilst considering the applicability of these measures for buildings from different time periods and of different construction types. Later on, the key drivers for and barriers to energy efficiency in the Ukrainian residential sector are identified. An overview of existing policy instruments that are used to promote energy efficiency in EU countries is given; this includes further identification of the most suitable policy measures for the Ukraine, taking into account the driving and impeding forces existing in the Ukrainian energy and residential sectors.

In the course of the present study, it was calculated that the total annual energy savings which are possible to achieve thanks to the five chosen technical measures are 119.84 TWh, which constitutes about 42% of the total energy consumption by the Ukrainian housing sector each year (285.33 TWh), and almost 12% of the total annual energy demand of the country (983.898 TWh). Using previous studies, it was determined that the total energy saving potential of the Ukrainian residential sector lies between 10 and 50%. Hence the main finding of the present research is that a major share (84%) of the energy saving potential of the residential sector in Ukraine can be realized through five simple measures: (1) external wall insulation and additional measures for the insulation of the thermal envelope; (2) window exchange; (3) metering of heating; (4) metering of hot water; (5) heating regulators.

The major barriers to increased energy efficiency in the Ukraine are subsidized energy prices for residential users (which typically results in citizens having an energy intensive lifestyle); lack of financial capital for the introduction of energy saving measures; misplaced incentives, as housing-operating offices (ZhEKs) are not interested in the improvement of the energy performance of buildings; lack of investors' interest in energy saving projects; lack of awareness and knowledge about energy saving options among average dwellers and construction specialists, as well as a high corruption rate at all levels of governance.

In the course of the present study, the most suitable and urgent policy measures that should be employed in the Ukraine in order to increase energy efficiency in residential buildings were identified as follows:

- Increased energy performance standards (for refurbished as well as newly constructed buildings) in State building codes, which will ensure that the opportunity to implement energy saving measures in the most cost-efficient way is not lost.
- Compulsory energy audits and energy labeling of buildings.
- Compulsory installation of heating and hot water metering.
- The establishment of tariffs on energy services (electricity, DH, natural gas) for residential users, at a level that would cover long-run marginal costs.
- The creation of local revolving funds and other means of financially supporting energy saving initiatives.
- Educational campaigns targeting average citizens and construction business professionals.
- The support and promotion of ESCOs.

Further research on several issues is recommended: investigation into consumers' behavior, into actual energy consumption by households via energy audits, as well as into the rate of already implemented energy saving measures in the Ukrainian residential stock. Furthermore, examination of the technical properties of buildings – with regards to the energy performance of the different types of residential houses – is needed, in order to select the most appropriate technical measures, and to implement them in a cost-efficient way. Another field for future research could be deep policy analysis, including investigation of all stakeholders and of direct and indirect barriers, with consequent identification of the most applicable policy instruments in the field of energy efficiency for Ukraine, and of the means for their enforcement.

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1 Introduction

1.1 Background

Energy security is one of those areas which any country considers as a strategic issue. Ukraine has its own economic, geographic, and political circumstances that make energy problem so important. First of all, it is worth mentioning that about 85% of oil and 75% of natural gas as well as nuclear fuel used by Ukraine are imported from Russia or through territory of Russia (International Energy Agency, 2006). Second, Ukraine is key transit country in terms of oil and natural gas to Europe from Russia, as 80% of natural gas and about 14-17% of oil is transported through its territory. The transit being one of the income sources for Ukraine, makes the country also depended on it, and in case of political tension with Russia and construction of new pipelines passing around Ukrainian territory the country will not get expected financial and fuel resources. Moreover, Ukrainian transit infrastructure also requires huge investments due to its poor technical condition, while prices for Russian natural gas are constantly increasing over time for Ukraine. Figure 1-1 below shows rapid change of natural gas price established by Gazprom over last four years.

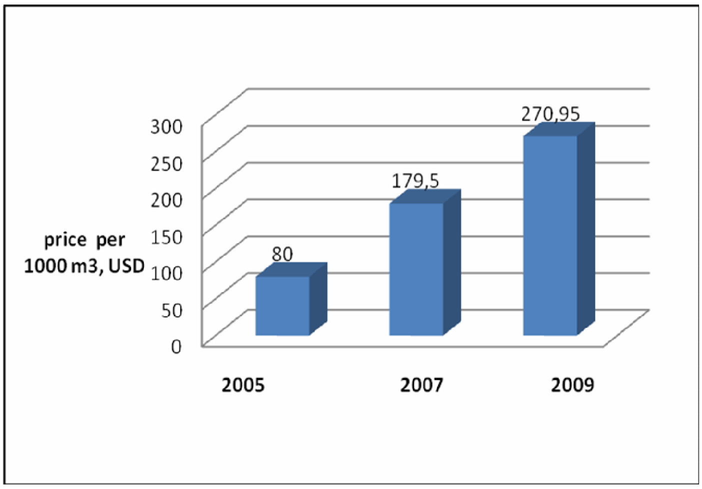


Figure 1-1 Dynamics of natural gas prices for Ukraine imposed by Gazprom

Source: Ukrainska Pravda, 2005; Toping, 2007; Economichna Pravda, 2009.

The key policy document concerning energy issue in Ukraine is the Energy Strategy to 2030. According to the Strategy, in order to ensure energy security Ukraine has to rely mainly on coal and nuclear power generation, i.e. to decrease consumption of oil and natural gas and. Among other objectives of the Strategy are the following:

- To supply the energy demand in the country in a sustainable way;
- To ensure reliable, safe, and stable operation and development of Ukrainian energy system;
- To “reduce the cost per unit production and use”, using such measures as energy efficiency and energy saving technologies introduction, reduction of the share of

energy-intensive technologies in national economy, and rationalization of industry structure in the country;

- To integrate energy system of Ukraine into European energy system via electricity exports and consolidation of Ukraine's position as major oil and gas transit country;
- To reduce negative impact on environment by energy sector (Ministry of Fuel and Energy of Ukraine, 2006).

The key drawback of this document is that it is mainly based on political goals, not on real statistical or modelled data. Although the Strategy pays certain attention to energy saving and decrease of energy intensity of Ukrainian economy, the energy saving potential is only roughly estimated and major attention is focused on industrial sector of economy (but still no flexible market mechanisms, mainly norms of energy use per unit of production). Ukrainian NGOs being not satisfied with the proposed by governmental Strategy energy mix created their own version of Ukrainian Energy Strategy – "Non-nuclear (or Alternative) Energy Strategy of Ukraine" (IEA, 2006).

According to the Alternative Energy Strategy of Ukraine, the highest priority shall be given to the following options in order to increase energy efficiency in the country and decrease dependency on the natural gas imported from Russia (Mama-86 et al., 2006):

- Decrease of heat and electricity losses during generation, transportation, and consumption;
- Use of renewable sources of energy;
- Introduction of co-generation technologies;
- Utilization of heat discharge at boiler houses;
- Use of industrial gases;
- Utilization of coal-mine methane;
- Reconstruction of gas transportation system;
- Utilization of natural gas pressure.

The Alternative Strategy highlights that there exist high energy saving potential for thermal energy and electricity on the end-use stage. In these terms all measures are divided into three categories presented in the Table 1-1 below.

Table 1-1 Energy efficiency measures proposed by the Alternative Energy Strategy

Type of measures	Technical measure
Measures of metering and monitoring of amount and quality of consumed resources	Modern systems of metering of energy resources consumption
Measures of regulation of consumed resources	Introduction of automated systems of energy consumptions management
Measures aimed at decrease of energy losses	Installation of energy saving equipment
	Introduction of modern systems and power electronics
	Construction/refurbishment of residential buildings according to energy efficiency norms (i.e., thermal envelope insulation)

Source: constructed based on the Mama-86 et al., 2006.

The issue of energy efficiency is crucial for Ukraine also due to the fact that it is directly connected to issue of energy poverty. Currently energy tariffs are constantly increasing in

Ukraine as a result of many internal and external factors, which makes the poor not able to buy needed level of energy services. Implementation of energy efficiency measures will allow population to get same quality of services using less energy, and as result to decrease payments on energy bills (Deriy and Allen, n.d.).

According to Csoknyai (2005), the refurbishment of panel buildings (i.e., prefabricated multi-storey buildings constructed from concrete or reinforced concrete panel) in CEE (Central and Eastern Europe) region is an urgent issue nowadays (as cited in Novikova, 2008). Such situation is caused by the fact that although holding structures of panel buildings are expected to endure for 50-100 years, windows and other building service systems are already out of order as their lifetimes is about 30 years. In Ukraine not only panel buildings, but also brick constructions built after World War II are currently in extremely poor state and require refurbishment which opens an opportunity for simultaneous improvement of their energy performance. At the same time, poor living conditions in the panel buildings, such as "high heating energy consumption, uncontrollable heating systems and poor thermal comfort especially in summer, create the problem of 'poverty islands'" (Nagy, 2007 cited in Novikova, 2008). These types of houses are usually occupied by low income people, while due to poor insulation dwellers have to pay high energy bills, which destroys their already small budgets. Hence dwellers of panel buildings are not able to invest in measures to increase energy saving and energy efficiency in their houses.

The third reason to improve energy efficiency is to reduce air pollution and GHG (greenhouse gas) emissions. Ürge-Vortsatz and Novikova (2008) state that, more than 1/3 of global CO_2 emissions origin from energy use in the building sector that is second largest emitter after industry. It is also supposed that abatement measures can be applied in a cost-effective or low-cost way with simultaneous maintenance or even increase of energy services quality. It is argued that about 80% of energy efficiency in building can be introduced at low or no cost (Ürge-Vortsatz and Novikova, 2008). See Fig. 1-2 that shows GHG mitigation potential of different sectors of economy worldwide in relation to their cost.

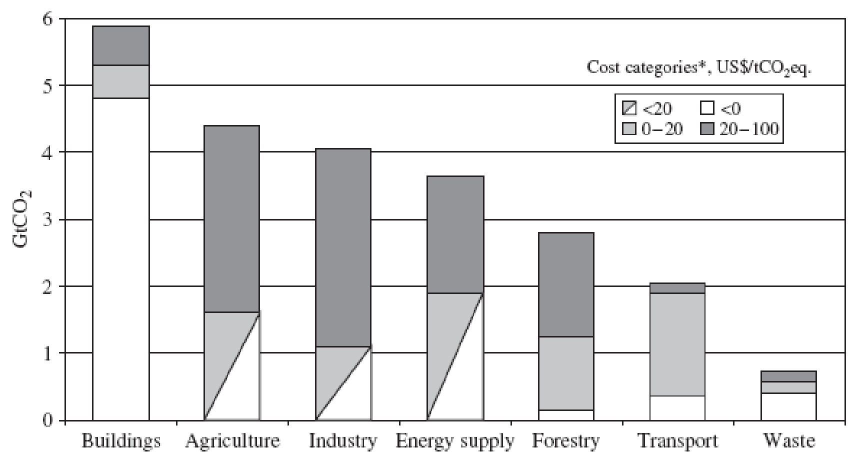


Figure 1-2 Estimated GHG mitigation potential and at sectoral level in 2030 in different cost categories.

Source: Ürge -Vortzatz and Novikova, 2008.

In Ukraine energy sector is the key source of air pollutants emitting 75% of SO_2, 50% of PM and 45% of NO_x (IEA, 2006). Overall GHG emissions from energy sector constitute 69% of total emissions of GHG. Even though, according to majority of forecasts Ukraine, being Annex I country to the Kyoto Protocol, will be able to comply with its obligations under the Protocol in any case of economic development, it is on the 20th place in the rank of countries-emitters of CO_2 from combustion of fuel and on the 8th place – according to CH_4 emissions from energy sector (IEA, 2006). Ukraine has big potential as host country for JI (Joint Implementation) projects and also might be required to introduce GIS (Green Investment Scheme) after sale of its AAUs (Assigned Amount Units). So decrease of GHG emissions from buildings might become an option here. Furthermore I would like to indicate that in 2003 17% of total GHG emissions in Ukraine are related to activities of heat and electricity production. Overall, mentioned activities turned to be the largest individual GHG source in the country in respect to the percentage share of emissions (Ministry of Environmental Protection, 2005). According to the Climate Change Initiative in Ukraine (2008), in 1998 20% of total CO_2 emissions of the country were produced by the housing and municipal sector.

Energy efficiency not only relates to energy security, energy poverty and environmental emissions, but introduction of energy efficiency measures also brings co-benefits to society, which include “creation of jobs and business opportunities, increase economic competitiveness, improved indoor and outdoor air quality, as well as increased comfort, health and quality of life” (see e.g. Levine et al., 2007). This point of view also share Ürge-Vortsatz et al. (2003), as reduction of energy bills payment allows population to spend saved money on consumer goods, thus improve social welfare and increase GDP growth rate, which causes so called multiplier effect (cited in Novikova 2008).

Energy efficiency is not happening by itself, and there are several barriers on the way to achieving it. For instance, in Ukraine the main barriers for such measures are both on the demand and supply sides and consist of (1) low energy costs for end users and consequent energy intensive lifestyle; (2) normative energy bills payments; (3) disinterest form the side of ZhEKs (housing-operating offices) to save energy; (4) lack of motivation for business to make investments into ESCOs (energy saving companies) and market of energy efficiency; (5) lack of enforcement of already existing state programmes in this field and administrative corruption (IEA, 2006). Although buildings sector has such huge energy saving potential, it shall be admitted that “widespread and fragmented nature of the efficiency potential among buildings and among end-users” makes it extremely hard to implement policies aimed at energy efficiency improvement and energy saving measures, especially in the residential sector (Novikova, 2008). To overcome and eliminate barriers main policy instruments that are used in the OECD (Organization of Economic Cooperation and Development) countries in terms of energy efficiency are as follows: energy related taxation and setting of prices, informative instruments, programmes of financial support to purchases and introduction of energy efficient equipment, direct state regulations (OECD, 2007).

All mentioned facts make research in energy efficiency in the Ukrainian buildings’ sector needed to support further energy security, decreased energy poverty as well as simultaneous decrease of air pollution and GHG emissions by the country.

1.2 Objective and research question

Only few studies address the end-use energy saving potential in the Central and Eastern Europe (CEE) and Former Soviet Union (FSU) (Ürge-Vortsatz, 2003). Novikova (2008) states that four large scale studies have been carried out in order to assess the potential of energy saving and GHG mitigation in the CEE and FSU regions. Two of these studies investigate GHG mitigation for Hungary and Estonia carried out by UNEP (United Nations Environmental Programme) in "Economics of GHG Limitations" series (Kallaste et al., 1999; Szlavik et al., 1999); a third study covers GHG mitigation and potential energy savings in the building stock of new EU Member States of 2004 and was conducted by Ecofys upon request from the European Association of Insulation Manufactures (Petersdorff et al., 2005); fourth study covers the impact of mitigation policies in 2020 for the EU-15 and the new EU Member States of 2004 (Lechtenböhmer et al., 2005). Hence, there exist large research gap in the field of the energy efficiency in buildings sector, especially in the CEE region, to which Ukraine also belongs.

For Ukraine, studies on energy efficiency in residential buildings and energy audits in such buildings are almost absent. IEA (2006) has reported a rough estimate of the energy saving potential for Ukrainian housing sector of 10 to 50%. But in order for the whole potential to be achieved, not only all needed technological changes shall occur (i.e., installation of energy efficient equipment), but also goal-oriented programmes on all levels of state governance, as well as behavioural changes in the society shall take place. One key question is how to achieve this potential as soon as possible and in the most cost-efficient way.

The objective of this thesis is to analyze further the potential for energy efficiency in the residential sector in Ukraine. This will be done via identification of some key energy saving technological measures that can be employed in building sector and assessment of potential energy saving of only these key measures. Special restrictions will be acknowledged regarding their applicability to different types of buildings. Moreover, major drivers and barriers to energy efficiency in the buildings' sector in Ukraine will be identified, existing policy instruments employed will be examined, and alternative policies that could be used to overcome and eliminate existing barriers will be discussed.

The research questions addressed are:

- Can the estimated energy saving potential be captured by focusing on few key measures in the residential sector in Ukraine?
- What are key policy instruments to be used in order to increase energy efficiency of these key measures in the building sector?

1.3 Scope and Limitations

Energy saving potential can be classified as a theoretical potential, technical potential, a techno-economic potential, and a market potential. A theoretical potential is limited only by the physical laws of thermodynamics, and expresses "minimum energy demand for given service" (Levine et al., 2007). In other words, theoretical potential is maximum possible potential for improvement. Technical potential depicts the energy savings that can be achieved employing the best available technologies at the time, and it can also include advanced efficiency technologies that still are not commercially available. Techno-economic potential incorporates the principle of cost effective investments, and compares whole life cycle costs of different alternatives. Market potential expressed those potential savings that have high probability to be realized under current market circumstances (Levine et al., 2007). Thus present research examines technical energy saving potential in Ukrainian residential sector, not considering in details costs of proposed measures for energy saving and willingness to pay of dwellers.

Present research considers residential buildings, and the focus is done on the multi-storey apartment buildings. This type of residential buildings prevails in Ukraine, as majority of Ukrainian population is living in cities (67.2% according to data gained during all-Ukrainian population census in 2001) and in Ukrainian cities ownership of individual houses is not much spread (National Population Census, 2001).

The limitations of present research include:

1. Focus is done only on the residential, multi-storey apartment buildings, i.e. public buildings and industrial buildings are not discussed.
2. Technical measures defined by diverse reviewed literature sources as the first-priority, simple to implement, and low-cost are chosen.
3. Due to lack of data sources on Ukraine, energy saving potential of several measures is assumed to be the same as estimated for the CEE region.
4. Due to lack of data about already implemented by dwellers energy saving measures in apartment buildings, the assumption is made that there were no energy saving measures applied in buildings of industrialized construction type.
5. Contrary to what it was expected, communication with representatives of governmental and private organizations working on energy efficiency in the residential sector was rather limited, as it turned to be impossible to arrange meeting with them and information was provided only in a form of reports, i.e. it was extremely hard to receive answers on particular questions asked.

1.4 Research methodology

Present research is based on overview of existing energy saving technical measures with consequent identification of most suitable measures for Ukrainian residential stock using various literature sources (State Programme on Energy Conservation, report of the pilot project on Energy Efficiency in Residential Buildings etc.) addressing this issue. Estimation of potential energy savings due to chosen measures is conducted further, considering applicability of these measures for buildings of different time periods and of different construction types. Later on the key drivers and barriers on the way to energy efficiency in Ukrainian residential sector are identified. Overview of existing policy instruments that are used to promote energy efficiency in the EU and OECD countries is done with further identification of most suitable policy measures for Ukraine, with regard to driving and impeding forces existing in Ukrainian energy and residential sectors.

The key research methods used in the paper were:

- Literature review aimed at gaining general understanding of the issue of energy demand and supply in the country, structure of institutions responsible for energy policy, legislative framework of energy efficiency, state of energy efficiency in the residential stock and main characteristics of residential stock itself, as well as description of technical measures and their energy saving potential. The key sources of data were reports of international and inter-governmental organizations, policies developed by Ukrainian Government, literature on energy saving measures applicable for residential sector both by foreign and Ukrainian authors.
- Review of case-studies documentation that had taken place in Ukraine with further identification of key energy saving measures chosen by project developers and energy

saving results (gained and expected) due to these projects. Key data that was considered in the project documentation was data on energy savings, energy performance of case study buildings, and financial information on projects. The review was carried out simultaneously with personal and e-mail communication with involved stakeholders, i.e. government and private company's representatives.

- Calculations of potential energy savings in residential buildings, with regard to types of constructions for which such measures can be applied, were carried out via simplification of the following formula (Cristiansson, 1996):

$E^i_f = \sum_s \sum_u a^i_{fsu} \text{ X } e^i_{fsu}$,

Where

E^i_f - energy demand for fuels f and year i;

a^i_{fsu} - activity level (e.g., m^2) for fuel f, end-use technology u in sector s and year i, and

e^i_{fsu} - energy intensity (e.g., kWh/m^2) for fuel f, end-use technology u in sector s and year i.

This formula employs the energy end-use model and is used for calculations of energy demand, i.e. helps to estimate changes of energy demand due to change of end-use technologies in sectors of economy under investigation (Cristiansson, 1996).

- Discussion of policy instruments that shall be used in order to overcome barriers on the way to energy efficiency in the residential sector of Ukraine was conducted with regard to Ukrainian context.

The generalised structure of present research is depicted in Figure 1-3 below.

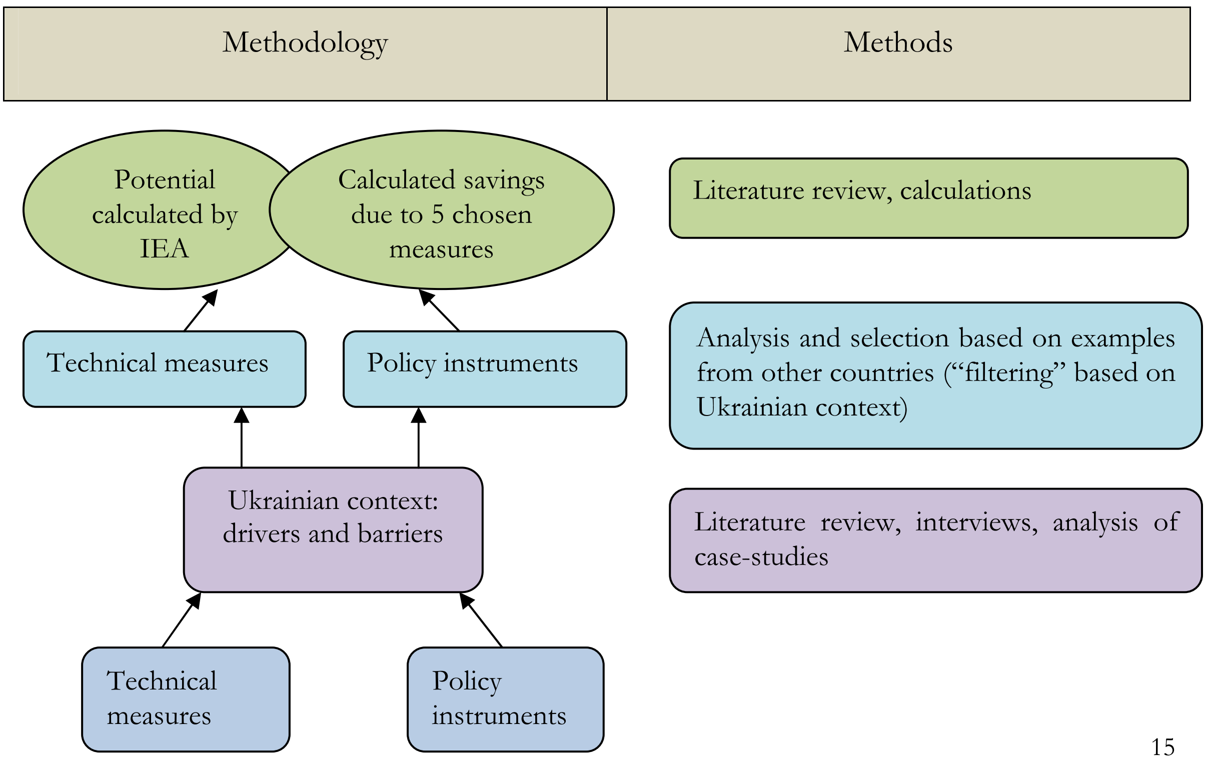


Figure 1-3 Research design

Overall present research is structured in a way that first of all general overview of energy demand and supply in Ukraine are reviewed with description of energy policies, and especially those concerning energy efficiency and savings. Further case studies on energy saving in the residential sector are presented and chosen energy saving measures described in terms of their energy saving potential and applicability to different buildings' types of Ukrainian residential sector. Using data from previous chapters of research, assessment of potential energy savings in case of installation of chosen technical measures in residential buildings they are applicable to is carried out. Finally, policy recommendations are given based on the identified drivers and barriers for energy efficiency in the residential sector in Ukraine and policies for energy efficiency in other countries.

2 Experience in energy efficiency in Ukraine

In present Chapter, in order to address the issue energy efficiency in Ukrainian residential sector, first of all, the general picture of energy demand and supply in the country shall be described, as well as major institutions responsible for energy policy shall be given consideration. Such description is important in terms of choice of policy instruments for improvement of energy efficiency in buildings sector that is discussed in Chapter 5. Further case studies on implementation of technical measures for energy efficiency in residential sector are examined with regard to existing types of multi-storey apartment buildings in Ukrainian residential stock.

Total final energy use in Ukraine in 2004 was on the level of 84.6 mill t.o.e. (983.898 TWh) (IEA, 2006). The main consumers of energy in the country were industry and housing sectors with shares from total energy use 39% (or 32.9 mill t.o.e or 383.720 TWh.) and 29% (or 24.5 mill t.o.e. or 285.330 TWh) respectively. The other sectors and their energy demand are as follows: transportation – 15%, petrochemical industry – 6%, agriculture and forestry – 4%, commercial and public services – 3%, others – 4%, see Fig. 2-1 (IEA, 2006).

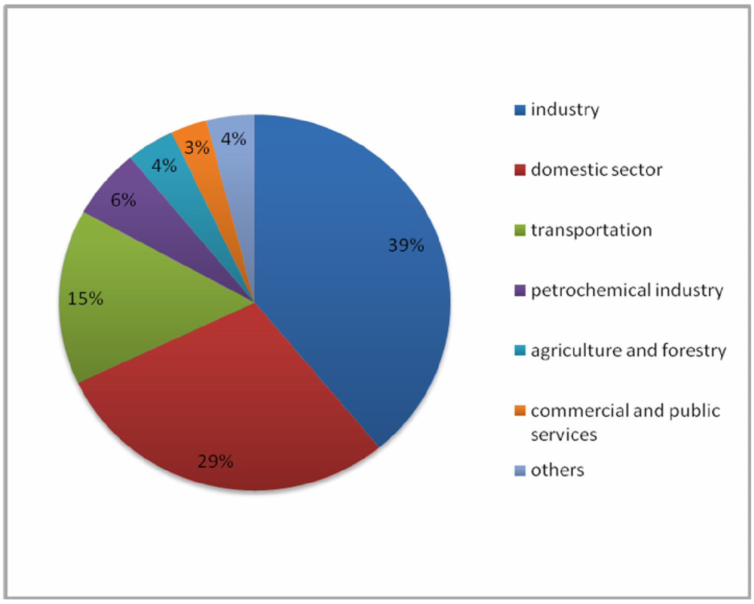


Figure 2-1 Energy consumption by sectors of Ukrainian economy, 2004.

Source: IEA, 2006.

The main energy sources used in the housing sector in Ukraine are natural gas – 55% of total final consumption, thermal energy – 24%, and coal – 11% (IEA, 2006). Those fuels that are mainly used on the thermal power plants and boilers which produce only thermal energy are presented in the table below.

Table 2-1 Consumption of the fuels on the thermal power plants and boilers that produce only thermal energy in Ukraine in 2005, %

	Natural gas, %	**Mazut, %**	**Coal, %**
Thermal powers plants	76-80	15-18	5-6
Boilers that produce only thermal energy	52-58	12-15	27-36

Source: IEA, 2006.

Ukrainian housing sector, being the second largest consumer of natural gas, uses 31% of it. Also according to the Energy Strategy of Ukraine to 2030, during the period of 2005-2030 the electricity consumption in municipal and housing sectors is estimated to increase from 41.7 TWh to 143.6 TWh (Ministry of Fuel and Energy of Ukraine, 2006). Currently share of electricity consumption by housing sector is rather big comparing with other sectors of econmy, for example, during period of 2006-2007 the consumption of electricity by housing and municipal sectors was 11.2% and by households - 19.3%, which constitutes 30.5% from total electricity consumption in the country (NEC UkrEnergo, 2007). Meanwhile the main fuels used for electricity production in Ukraine are as follows: nuclear – 48%, coal – 25%, natural gas – 21%, and hydro – 6% (IEA, 2006). As it was mentioned before, about 75% of natural gas and nuclear fuel used in Ukraine are supplied from Russia or through Russian territory, which poses again an issue of energy security.

According to estimations, total energy saving potential for Ukraine is about 42-48%, considering 1990 as baseline year and implying that only already existing energy saving technologies will be widely used, i.e. not including potential technological advances (Ministry of Fuel and Energy of Ukraine, 2006). The biggest share from the total energy saving potential of the country is expected to be in industry sector – 57%, then in the fuel-energy sector itself – 21%, the housing sector is on the third place – 11% (i.e. approximately 31.386 TWh of energy can be saved), and 7% in transportation from total energy saving potential in the country (Ministry of Fuel and Energy of Ukraine, 2006).

Energy saving potential for Ukrainian housing sector itself according to estimations varies from 10 to 50% (i.e., expected energy savings are in the interval from 28.53 TWh to 142.67 TWh) (IEA, 2006). Pilot projects carried out recently showed that at least 20-30% of energy can be saved in case of successful implementation of technical measures (IEA, 2006). The main problem with estimations on energy efficiency potential in the housing sector is absence of data on actual energy consumption, as less than 10% of houses connected to the DH (district heating) network are equipped with heating meters (State Statics Committee, 2008).

2.1 Institutions responsible for energy policy in Ukraine

The system of governmental organs responsible for energy policy in the country has hierarchical structure (see Fig. 2-2). On the highest level there are President of Ukraine, Verkhovna Rada of Ukraine (Parliament), Cabinet of Ministers and Prime-Minister (IEA, 2006).

The institutions accountable to the Verkhovna Rada and responsible for energy issue are Committee for Fuel and Energy, Nuclear and Nuclear safety; Committee for Environmental

Policy, Nature Protection and Chernobyl Consequences; Committee for Construction, Transport, Housing and Communal Services, and Communication.

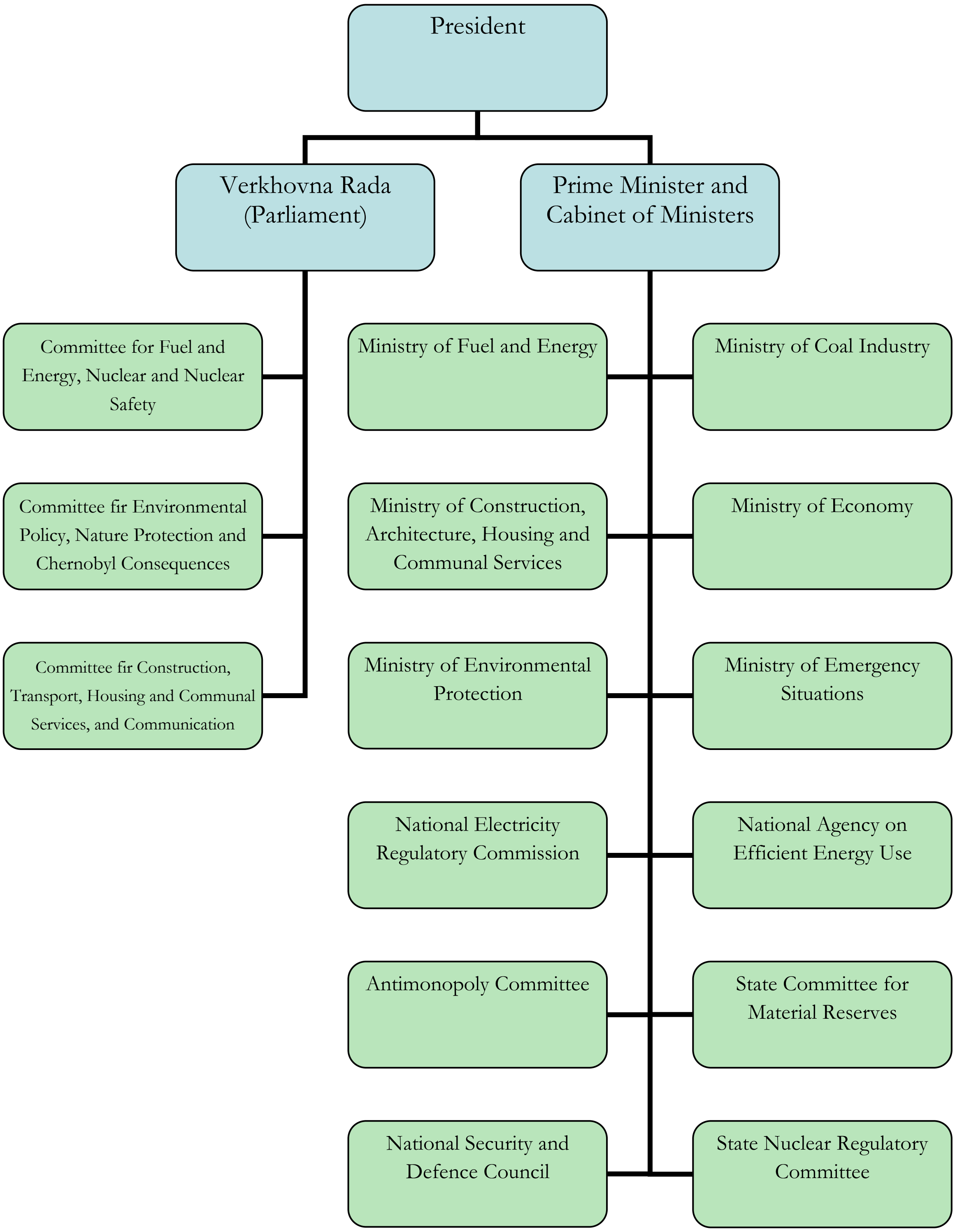


Figure 2-2 Key energy policy institutions of Ukraine

Source: IEA, 2006.

The IEA (International Energy Agency) report states that distinguishing feature of Ukrainian energy policy is "the Soviet style distinction between 'large-scale energy' (large-scale fuel production and generation) and 'small-scale energy' (residential energy services including DH and distributed generation" (IEA, 2006).

In terms of executive power accountable for energy issue in Ukraine I would like to discuss briefly key governmental bodies in this field and their functions below (IEA, 2006):

- Ministry of Fuel and Energy is the key governmental structure in terms of energy issues in the country, as it develops main policies, is responsible for local renewable energy development, as well keeps control over assets in sectors of oil, gas, electricity and DH. The Ministry takes part in the process of preparation of contracts for fuel supply etc.
- Ministry of Construction, Architecture, Housing and Communal Services is mainly responsible for energy policies (including energy efficiency and energy saving) and energy supply in residential sector.
- Ministry of Environmental Protection is responsible for such energy related issue as coordination of Climate Change policy of the country and reduction of GHG emissions.
- National Agency on Efficient Energy Use is responsible for energy use, energy efficiency, renewable and alternative energy, energy metering and monitoring.

The other governmental institutions related to the energy policy in Ukraine (but not mentioned above) are State Statistics Committee, Ministry of Finance, Ministry of Agriculture, Ministry of Industrial Policy, State Committee for Technical and Consumption Policy, and Ministry of Justice.

Key state institutions responsible for energy saving in Ukraine are National Agency of Ukraine on Efficient Energy Use that started to operate since spring 2006, and State Inspection on Energy Saving that was created in 1999. The Ministry of Construction, Architecture, Housing and Communal Services also carries out activities aimed on increase of energy efficiency in the sector of DH and construction.

Major independent organizations promoting principles of energy efficiency in Ukraine are as follows (IEA, 2006):

- *Private*: Agency for Rational Energy Use and Ecology (ARENA-Eco), Alliance to Save Energy, International Center for Policy Studies and the Ukrainian Center for Economic and Legal Analysis, Association of Ukrainian Housing Services Companies, Association of Energy Service Companies (working with local ESCOs), Association of Industrialists and Entrepreneurs.
- *State*: UkrESCO, Institute of Energy, Institute for Energy Saving and Energy Management, Institute for Technical Heat Physics, KyivZNIIEP (in English - Ukrainian State Zonal Scientific and Research Institute of Civil Engineering), Gas Institute.

On the regional level policy measures concerning energy efficiency are implemented in accordance to decisions of the former State Committee for Energy Conservation of Ukraine (which was later incorporated into Ministry of Fuel and Energy), i.e. each oblast (province) administration is supposed to create department of energy saving. Among key tasks of such departments is coordination of energy saving activities on the regional and municipal levels due to creation of corresponding departments in cities' administrations. Such departments usually carry out informative activities and cooperation with NGOs during implementation of technical measures on energy saving (IEA, 2006). At the same time the State Energy Saving Committee introduced competitive ranking for Ukrainian oblasts' administrations in order to stimulate energy efficiency. The competition was based on following key indicators: decrease of energy intensity, investments into energy saving measures, installation of meters, regional programme on energy saving implementation, and reporting on energy efficiency measures. Among policy documents developed in these terms is the "Complex Reconstruction Programme for Residential Buildings of the First Period of Industrial Buildings' Construction" was developed for Kyiv region by the Institute "Kyivproekt" and a scientific-research Institute of Social-Economic Problems of the City. According to the Programme, construction of new buildings and resettlement of dwellers from old houses that are in non-satisfactory conditions (including poor energy performance) is supposed to be carried out with further refurbishment of these old houses (ESCO, 2003).

The ownership status of Ukrainian residential stock is not homogeneous, while about 85% of apartments are privatized, but responsibility of taking care about commonly used area (e.g., elevators, corridors etc.) is not clearly defined. Usually responsible for these areas are ZhEKs (housing-operating offices). The share of private ownership of apartments in multi-store buildings is less than 5%. Due to possibility of loosing state municipal subsidies dwellers are mainly not interested in creation of condominiums. Mentioned difference and unclearness in the ownership status creates problems even when dwellers are willing to repair such commonly used facilities as heating system, because issue of financing stays unclear and also depends on income level of each particular dweller. That is why even low-cost and fast paying back measures are usually not introduced (IEA, 2006). ZhEKs are accountable to municipal administrations and are actually intermediate actors between service providers (heating, electricity, water supply etc.) and consumers. ZhEKs are also responsible for repair works and collection of municipal payments. But the main problem here is that ZhEKs often do not have needed financial and human resources to operate on the proper level (IEA, 2006).

2.2 Policy instruments for energy efficiency in the residential sector in Ukraine

2.2.1 Legislative acts on energy efficiency

In terms of situation with policy on energy efficiency in the residential sector in Ukraine the key role is played by the group of control and regulatory mechanisms. Among most important legislative acts in the field of energy efficiency is the Comprehensive State Programme on Energy Conservation created in 1995 by Cabinet of Ministers of Ukraine. The key goal of the Programme is development of main directions of State policy on energy saving, which implies creation of legislative basis, favourable economic environment, and effective system of State management of energy saving. The strategic objective of the Programme was achievement of same level of energy consumption per unit of production as the developed countries have by Ukraine. The Programme aimed at assessment of total existing and future energy saving potential, as well as for each branch of economy in particular. It also identified sources and mechanisms of energy saving and efficiency financing. This legislative document was created for purpose use on different levels, including state, branch, regional, and local levels, as well as level of particular enterprises. The Programme was supposed to be divided into three consequent stages, i.e. 1st - 1996-2000, 2nd – 2001-2005, 3rd – 2006-2010. And it was expected that on the first and second stages low-cost and short-term measures would take place, followed by more expensive and advanced measures starting from 2006. But such expectation was not fulfilled due to economic and political crisis in the country. According to the Programme estimations, energy saving potential for the housing sector was on the level of 11.5%, which was expected to be achieved mainly due to introduction of modern construction and refurbishment techniques, improvement of thermal insulation and energy saving characteristics of buildings (Cabinet of Ministers of Ukraine, 1999).

Next important document is State Law "About Energy Conservation" that was prepared by the Ukrainian Parliament in 1994 and amended in 1999, 2005, and 2006 (Verkhovna Rada, 2006). This Law identifies legislative, economic, social, and environmental basics of energy savings for all types of institutions located on the territory of Ukraine and all Ukrainian citizens. Among key principles stated in the Law are as follows:

- Creation of state level economic and legislative conditions in order to increase interest in the energy saving from the side of juridical and physical persons;
- Popularization of energy saving, increase of people's awareness towards this issue;
- Joint use of economic stimulation and financial responsibility methods in order to introduce rational use and economical consumption of energy resources;
- Introduction of payments for direct consumption and unreasonable use of fuel and energy resources;
- Step-by-step transition to the mass introduction of metering equipment for fuel and energy resources;
- Introduction of energy labelling system for electric domestic appliances.

The Law states importance of economic market-based instruments on the way to increase of energy savings. Among economic instruments indicated in the Law are fines for unreasonable use of energy resources via introduction of additional payments on energy sources, introduction of subsidies and taxes as well as loan concessions, financial stimulation for staff members and individual workers for energy efficient work, increased depreciation rate for energy efficient equipment. At the same time Law implies creation of state system of energy standards for different branches of economy. In order to carry out all mentioned policy measures the following financial sources are identified: Fund for energy saving, own and loaned financial sources of enterprises and institutions, State Budget of Ukraine, local budgets, as well as other sources.

In addition, the issue of energy efficiency in the housing sector is addressed in several following legislative acts (ESCO, 2003):

- Decree by the Cabinet of Ministers of Ukraine "About Installation of Metering Facilities for Water and Thermal Energy in the Residential Stock";

- Project of Decree by the Cabinet of Ministers of Ukraine "About Approval of List of Measures Aimed at Stimulation of Population to Co-finance Installation of Heating, Hot and Cold Water Meters";

- Project of State Law "About Energy Saving in the Housing and Communal Sphere".

Recently Ministry of Construction, Architecture, Housing and Communal Services proposed project of new State Law "About Energy Efficiency in Buildings". According to this document, heat losses from buildings shall be minimized via insulation of thermal envelope, installation of energy saving windows, retrofitting of roofs, and renovation of heating supply systems, as well as lightning and ventilation. The draft of this Law also implies compulsory energy audits in all buildings and consequent energy labeling (Association of "Producers of Insulation Materials and Development of Energy Saving Technologies, 2009).

2.2.2 Flexible Kyoto Mechanisms and their implications for energy efficiency in residential sector

Improvement of energy efficiency in the housing sector turned to be not among the priority types of projects under JI (Joint Implementation) mechanism due to small size of projects, their dispersion, small potential gains of ERUs (emission reduction units) for each particular project, and short crediting period for JI (Korppoo and Gassan-zade, 2008). At the same time, GIS (Green Investment Scheme) becomes a promising option for energy efficiency in housing sector. In short, an idea of GIS was introduced on the 6th Conference of the Parties for Kyoto Protocol. The key principle of this instrument is that revenues gained from trade of AAUs (Assigned Amount Units) surplus are used for "environmentally related purposes" (Korppoo and Gassan-zade, 2008). The main intention of GIS is to finance actions that are aimed at GHG emission reduction or social benefits. In this terms so called "hard" and "soft greening" are distinguished on the basis, whether received money are used for quantifiable reduction of GHG or for introduction and support of climate change policy respectively (Korppoo and Gassan-zade, 2008).

The sale of AAUs by Ukraine to Japan took place in the end of March 2009, and consequently Ukrainian Government claimed that funds gained from this operation will be purposely used according to the GIS by Ukrainian side, i.e. aimed at improvement of energy efficiency in the country. It was stated that priority direction for GIS are modernization of boiler-houses and heating supply systems due to wide introduction of heat pumps, introduction of modern technologies of waste utilization, construction of modern incinerators with combined heat and hot water supply (Novikova, 2009).

2.2.3 Energy performance standards for appliances

The first system of labelling for electrical appliances in Ukraine was introduced in 2003 and was based on the Directive of EU about standards for appliances. Ukrainian standards are called DSTU (state standard of Ukraine) and take into consideration following categories of equipment: refrigerators and freezers, washing machines and driers, dishwashers, electrical stoves, water heaters, lightning equipment, and air conditioning systems. According to the rules, each piece of equipment shall have a label depending on to which class of energy efficiency it belongs and correspond to the minimal standards of energy productivity. At the same time mentioned standards are not applied on practice, although even in the State Law of Ukraine "About Energy Saving" energy labelling is stated as one of the key principles of national energy saving policy (IEA, 2006).

2.3 Programs and case studies on energy efficiency

In 1999 the Programme of Residential Buildings of First Mass Construction Series Reconstruction was approved by Cabinet of Ministers of Ukraine. According to this

Programme, buildings that were constructed during 60-70ss from panel and brick materials constitute together 72 million m^2 in total living area, i.e. 23% of total Ukrainian residential stock. The Programme implied insulation of external walls, installation of energy saving windows and balcony doors, insulation of water pipes, as well as installation of meters for water, natural gas, and thermal energy. Such measures were expected to result in 1/3 reduction of energy consumption by residential stock. If one would compare mentioned intentions to current state of affairs, it might be shown that according to statistical data till 1st January 2008 22.6% of residential stock was equipped with of cold water meters, 6.78% - with hot water meters, 17.8% - with thermal energy (heating) meters, 1.01% - with temperature regulators (Cabinet of Ministers of Ukraine, 1999).

2.3.1 Energy saving in Odessa

The other worth mentioning programme on energy saving was developed by Odessa city administration, called "Energy Saving in Odessa City during 2007-2010" (Lubov, 2009). This programme consists of five sub-programmes, i.e. "Energy Saving in the Fuel and Energy Sector in Odessa", "Energy saving in the Housing, Municipal and Social Sphere", "Energy Saving in the Industrial and Construction Sectors", "Organizational and Technical Measures of the Goal-Oriented Programme on Energy Saving in Odessa during 2007-2010", "Alternative Energy". The total cost of the Programme's implementation is 482,134 thousand UAH (i.e., about 48 thousand EUR). The expected results of the Programme implementation are as follows:

- Savings of the fuel and energy resources – 1307.23 GWh;
- Electricity savings – 367.59 GWh;
- Thermal energy savings – 162.71 GWh;
- Natural gas savings – 44.09 mill m^3;
- Monetary evaluation of savings – 147,987640 UAH, i.e. about 14.8 mill EUR, which makes up to 5% of the expenditures on the fuel and energy resources purchased by city.

According to creators of the Programme total energy saving potential of Odessa city is about 40% of the current energy demand, which is described by different categories in the Table 2-2 below.

Table 2-2 Dynamics of energy consumption per person in Odessa city

Indicators of energy consumption, units	**Years**				
	2003	**2004**	**2005**	**2006**	**2007 (forecast considering the Programme)**
Consumption of natural gas, m^3/person	343	325	334	320	300
Consumption of electricity, kWh/day/person	1.50	1.80	1.90	1.90	1.75

Indicators of energy consumption, units	**Years**				
	2003	**2004**	**2005**	**2006**	**2007 (forecast considering the Programme)**
Consumption of thermal energy, Gcal/person	2.30	2.40	2.20	2.40	2.20

Source: Lubov, 2009.

For housing sector of Odessa city energy savings are expected to be as follows during 2007-2010:

- Thermal energy – 84.29 GWh;
- Electricity – 70.43 GWh;
- Natural gas – 148.27 GWh.

Key technical measures that are the most applicable for Odessa were identified by local researchers and specialists (see Table 2-3). All of these measures are expected to take place during 2007-2010, but they will result in energy savings even after end of this period.

Table 2-3 Technical measures chosen for the residential sector in Odessa and their energy saving potential

№	**Measure**	**Savings of the fuel and energy resources per year**
1.	Energy examination of small and autonomous boiler-houses	No data available
2.	Installation of meters of hot and cold water in residential stock	10-25%
3.	Reconstruction of heating systems in residential stock	10-20%
4.	Substitution of current lightning equipment by energy efficient one	5-20%
5.	Installation of modern energy efficient heat exchangers during construction of new central heating stations and refurbishment of already existing ones	10-20%
6.	Installation of automated systems of electricity control and accounting	5-30%
7.	Development of documentation, procurement, installation, and adjustment of automated release of heat and hot water in the central heating stations	10-20%

№	Measure	Savings of the fuel and energy resources per year
8.	Installation of gas accounting equipment with electronic correction in small boiler-houses	15-30% of financial savings
9.	Installation of heat accounting equipment in small boiler-houses	10-20%
10.	Installation of heat meters on consumer level	5-20%
11.	Installation of modular boiler-houses	10-20%
12.	Installation of individual heating stations in residential buildings	10-30%
13.	Installation of frequency transformers at the central heating stations and pumping stations	20-40%
14.	Laying of pipes' networks in the foam polyurethane insulation	15-30%
15.	Installation of informative and diagnostic systems in the networks	5-20%
16.	Step by step substitution of electricity accounting equipment 2.5 by 2.0	Increase of billing payments for consumed electricity by 10-15%
17.	Conversion of cable lines form 6 kW to 10 kW	Decrease of losses
18.	Installation of automated control of street lightning networks	Decrease of losses

Source: Lubov, 2009.

2.3.2 Pilot project on energy efficiency in residential buildings in Kyiv

As it was already mentioned above, the only pilot project on energy efficiency improvement in Ukraine that has already assessed results was carried out jointly by Swiss Agency for Development and Cooperation and Ukrainian institutions. The project focused on two multi-storey residential buildings in Kyiv. Among key achievement of the project were increase of indoor temperatures from 12-16°C to 18°C and improvement of payment discipline for utilities by 30-50% (ARENA-Eco, 2000; ARENA-Eco, 2008).

The preparation phase of the project lasted from 1996 to 1997 and was aimed at understanding of state of affairs in the building sector, ownership status situation and demand side management activities in the country. To identify cost-efficient energy saving measures and structure of energy consumption in the residential buildings energy audits were conducted for four typical buildings. Overall it was decided to introduce low-cost and self-financing energy saving measures in two cooperatively owned residential buildings in Kyiv. The pilot implementation phase of the project started in 1998. The objects for pilot project were two multi-storey residential buildings in the capital of Ukraine, Kyiv city, that were located in one of the residential districts, Moskovskiy, and their addresses were Cruiser

Aurora Street, 5, and Gorky Street, 100. Later on the project results were monitored and its results assessed during next stage, 2000-2003 (Deriy and Allen, n.d.).

According to Deriy and Allen (n.d.) project had following key goals:

1) "To establish a revolving fund for financing of energy efficiency project;
2) To allow consumers to enforce their legal right to know the actual consumption volume of thermal energy and hot water, and to pay according to meter readings instead of estimated consumption norm based on square meters of heated space or per capita water consumption;
3) To introduce incentives for customers to save energy and reduce utility bills;
4) To develop and implement organizational and technical energy saving measures with short payback periods".

Pilot buildings located in the one of residential districts of Kyiv were owned by housing cooperatives "Teremky-1" (Cruiser Aurora St. building) and "Akademichny-14" (Gorky St building). Both of these multi-storey buildings were built from light concrete (see Fig. 2-3 and 2-4) and "connected to the secondary loop of DH system, with the heating system heat exchangers located in the substation servicing six buildings each" (ARENA-Eco, 2000). In each of the buildings there were four pipers connected to the DH system, i.e. supply and return pipes for heating, and supply and circulation pipes for hot water (ARENA-Eco, 2000).

Figure 2-3 Cruiser Aurora St. building.

Figure 2-4 Gorky St. building.

Source: ARENA-Eco, 2000.

During identification of the most suitable measures to be implemented in the pilot buildings such financial criterion as their pay-back period was considered, thus only measures with pay-back period of less than three years were chosen, considering heat tariff of 18 USD/Gcal, which was assumed to be sound for the whole project period (ARENA-Eco 2000).

Three following types of technical were installed measures in both buildings under the study (ARENA-Eco, 2000):

- Building level heat meters in order to assess actual thermal energy consumption of heating and hot water, as a result, to switch to consumption-based billing and motivate dwellers to reduce their thermal energy consumption;
- Heating system regulators in order to avoid over-heating during warm periods in heating season;
- Radiator reflectors in apartments in order to reduce heat losses through walls and decrease heat demand during heating season.

The additional measures that took place in the Aurora St. building were as follows:

- Building-level cold water meters;
- Apartment-level hot water meters, that had much bigger stimulation effect on the dwellers to reduce their consumption comparing to building-level metering;
- Insulation of heating and hot water pipes in the basement that allows to decrease rapidly heat losses;
- Replacement of worn-out heating and hot water pipes;
- Balancing of heating system in the building, i.e. reduction of flow rate in heating pipes, which was found to be excessive before the project implementation, with further balancing of the whole system;
- Sealing of joints in the wall panels;
- Installation of the double-glazed windows in the commonly used areas (ARENA-Eco, 2000).

An interesting feature of the project was that in the both buildings owners of one of the apartments were chosen as energy motivators. Consequently, energy motivators were in charge of printing out meters' data; monitoring of energy situation and suggestion of possible ways for further improvement of energy efficiency; informative and motivating function for other building dwellers; heating adjustment according to weather conditions; control of equipment's operation; interaction with ARENA-Eco representatives (ARENA-Eco, 2000).

According to monitoring over four following years (2000-2003), average annual savings for Cruiser Aurora St. building were: hot water – 3739 m^3, cold water – 1499 m^3, thermal energy – 163,400 kWh. It is important to mention that over four years of project savings of hot water increased from 5 to 40%. Overall, an average savings over four years of project execution were as follows: 21% for thermal energy, 17% - cold water, and 29% - hot water (Deriy and Allen, n.d.). Simultaneously paying discipline of utility bills increased up to almost 100% in the project buildings, as well as energy efficiency measures decreased the amount of household receiving residential utility subsidies from 8 to 1 in the Cruiser Aurora street building.

The key conclusions drawn after project execution were as follows (ARENA-Eco, 2000):

1. Energy saving in Ukrainian residential sector can be done in the technically feasible and cost-effective way.
2. There is huge need in the cooperation with heating supplier in order to receive required permissions, to commission equipment and switch to meter-based contracts for heating payments.

3. The heating saving potential of low-cots measures with payback period of 3-4 years is about 25-30%.
4. The ultimate requirements for hot water savings are apartment-level metering and consumption-based payments for this utility with simultaneous increase of hot water supply quality and prevention from uncontrolled mixing of hot and cold water inside building.
5. It is advisable to choose person who will regulate heating supply of the building and supervise all heating related issues in the building, i.e. energy manager/motivator.
6. On the stage of initial introduction it is better to envision such financial mechanism that implies no or low costs for owners of apartments in the building and further pay back of invested funds.
7. It is crucial to maintain cooperation with local authorities in order to introduce energy saving measures.
8. Creation and promotion of ESCOs will bring improvements of energy efficiency in buildings.
9. There exists a need for further study of Ukrainian legal framework in order to ensure sustainability of energy efficiency measures in buildings.
10. Joint Implementation mechanism may provide additional financing opportunities for energy efficiency projects in Ukrainian buildings.

2.4 Types of Ukrainian residential buildings

Applicability of different energy saving measures in the residential buildings depends on the construction type of particular building. In these terms the following key types of multi-storey buildings in Ukrainian residential stock are distinguished (Dom-2000, 2009):

1. Panel buildings (1950s – 90s).

This group represents old panel buildings, typical panel buildings, refurbished typical panel buildings of Soviet period, and panel buildings constructed since 1991 from reinforced concrete and ceramsite (expanded-clay) concrete. All these buildings are constructed from rather cheap materials, have simple outer décor, have from 3 to 22 floors, ceiling height is 2.5-2.75 m, there are four or more apartments per floor, internal area of apartment is rather small. Such type of apartment buildings is prevailing in modern Ukrainian cities. For example, there are 3882 (33% of total number of buildings) of such buildings in Kyiv nowadays.

2. Old brick buildings (middle of 1950s – 80s).

Majority of these buildings was constructed during governance of Khrushchev and that's why they are usually called "Khruschevki". Officially period of their construction began in 1955 after Decree of Soviet government "About Fight against Architectural Redundancies". Typical features of these buildings are thin walls, low ceilings (2.5 m), short durability period and extremely small internal area of apartments. There are 2908 of these buildings in Kyiv.

3. Modern brick buildings (after 1991).

This type unites all brick buildings constructed after gaining independence of Ukraine 1991. That's the reason why height of ceiling increased to 3 m, number of floors is usually up to 30, and internal area of apartments became bigger. Dwellers of these buildings usually have more financial sources and willingness to have independent utilities systems and improve efficiency of these systems. Number of such buildings in Kyiv is 758.

4. So called “Stalinki”, i.e. buildings constructed mainly during governance of Stalin (1920s – middle of 1950s).

Majority of these buildings was constructed after end the World War II. Key features of such constructions are high ceilings – 3-4m, thick brick walls, number of floors – from 2 to 13, there are usually 2-4 apartments per the floor. Number of such buildings in Kyiv is 1921.

5. Departmental (agency-level) brick buildings (constructed before 1991).

Such apartments were supposed to be the best among buildings constructed during Soviet period. They are built from brick, have 4-20 floors, extremely good internal planning, and high ceilings – 3m. Typical area of single-room apartment is 34-42 m^2, two-room – 48-69 m^2, three-room – 62-92 m^2. There are 845 of such buildings in Kyiv.

6. Buildings constructed before the Social Revolution in 1917.

Typical features of these buildings are thick (up to 1m) walls, high ceilings – 3.2-4.5m, high windows, there are usually up to 8 floors, 2-3 apartments on a floor. Majority of these buildings require refurbishment due to long existence time, but at the same time they are usually occupied by well-off dwellers, which have more financial sources to improve state of utility services systems and building in general. There are 1574 of such buildings in Kyiv.

First two types of buildings (panel and old brick buildings) have same distinguished features and can be generally called industrialized buildings. Such buildings typically have very simple outer façade (there will be no aesthetic problems in case of attaching external wall insulation) and are now in poor condition, i.e. require urgent refurbishment which can be coupled with introduction of higher energy performance standards. At the same time majority of buildings in total Ukrainian residential multi-storey building stock are not equipped with energy saving measures, such as energy efficient windows, due to lack of incentives to save thermal energy, which is caused by the absence of metering equipment for hot water and heating in majority in the multi-storey residential buildings.

3 Technical measures employed for energy efficiency in residential buildings

As it was mentioned in previous chapters, estimated energy saving potential of residential sector in Ukraine lies between 28.53 TWh and 142.67 TWh. In order to realize energy saving potential particular practical measures shall be identified, starting with most promising and urgent ones. Reviewing data on case study on energy efficiency in Kyiv and energy saving programme for Odessa, it can be noticed that such measures as installation of metering devices for hot water and heating are mentioned in both of the reports (Lubov, 2009; ARENA-Eco, 2000). In addition, by policy documents of Ukrainian government it was identified that improvement of thermal insulation of industrialized buildings is vital measure to take place (e.g., Programme of Reconstruction of Residential Buildings of First Mass Construction Series), such measure as well was identified by developers of the project on energy efficiency in residential buildings in Kyiv (ARENA-Eco, 2000; Cabinet of Ministers of Ukraine, 1999).

International literature sources also admit that building sector has a great potential for energy efficiency via different technical measures, which include "passive solar design, high efficiency lightning and appliances, highly efficient ventilation and cooling systems, solar water heaters, insulation materials and techniques, high-reflectivity building materials and multiple glazing" (see e.g. Levine et al. (2007). Although undoubtedly higher energy saving potential lies in the newly constructed buildings, retrofitting of already existing ones is also important, as the turnover of housing stock is relatively slow. The study by Ecofys states that it is advisable to introduce energy efficiency in buildings using principle of "Trias Energetica", i.e. first of all energy demand and energy losses shall be maximally reduced or avoided. Further the remained energy demand shall be supplied with energy from renewable sources with simultaneous use of fossil fuels with maximal efficiency (Petersdorff et al., 2005).

In general, space heating is accountable for the largest energy use in buildings in cold regions. For example, in the EU and EIT (Economies in Transition) countries it counts for 2/3 of total energy use, followed by lightning and air conditioning depending on climatic zone. Hence one of the simplest measures to reduce energy consumption in cold climate is thermal insulation of building, made via use of "high levels insulation materials, optimizing the glazing area, and minimizing the infiltration air" (Levine et al., 2007).

Thus, it was decided by author of present research to focus on several measures that are expected to have high energy saving potential with simultaneous simple installation and low costs, i.e. (1) metering of heating, (2) hot water metering, (3) external wall insulation and additional measures on improvement of thermal envelope insulation, (4) exchange of windows, and (5) temperature regulators.

3.1 Energy efficiency in the thermal envelope

Thermal envelope prevents building from undesired heat and mass transfer between interior and outer conditions (Levine, 2007 in Novikova, 2008). According to estimations, improvement of thermal envelope insulation is one of the most promising measures from the energy saving point of view, as it "can reduce heating requirements by a factor of two to four" (Levine, 2007).

Levine et al. (2007) estimated that usual heating requirements of buildings in the CEE region vary in the interval 250-400 kWh/yr. There are several key elements that define effectiveness of thermal envelope, they are as follows:

1) levels of insulation in the walls, ceiling and basement floor (including moisture condensation and thermal bridges);

2) insulation properties of windows and doors;

3) inside-outside air exchange rate, which derives from the air-tightness of the envelope, as well as "wind, inside-outside temperature differences and air pressure differences due to mechanical ventilation systems or warm/cool air distribution" (Levine, 2007).

Here it is important to explain key insulation characteristics of any type of material used as a construction component, i.e. R-value and U-value. The R-value reflects thermal resistance of material, hence the higher the number of R-value is the better insulation properties material has. The U-value is reciprocal to R-value, as it represents the heat conductivity of material (Encyclopaedia Britannica, 2009).

3.1.1 External wall insulation

In Central and Eastern Europe (CEE) countries, nowadays external wall insulation is extensively used and is done via "attachment of the insulation material to the outer surface of external walls" with further coating with final layer (Petersdorff et al., 2005).

In Ukraine this type of insulation became popular recently and the material that is most commonly used for such measures is plastic foam. According to information provided by one of the companies specialized on the external wall insulation for multi-storey buildings (Partstroyservice), this type of insulation increases average winter temperature on 7-8°C. Costs of material itself and all required works are 230 UAH per m^2, i.e. about 23 EUR per m^2 (Partstroyservice, 2009). The insulation properties of plastic foam is due to the fact that its thermal transmission or U-value is 0.031-0.042 W/m^2°C, comparing to 1.700 W/m^2°C for reinforced concrete and 0.770 W/m^2°C for normal brick (Stolit, 2004).

At the same time, one shall keep in mind that external wall insulation is suitable not for all types of buildings due to aesthetic reasons. For example, old (built before Socialist Revolution) buildings will loose their outer façade features in case of their external insulation. But in case of industrialized panel buildings, which always have very simple outer design, external wall insulation can be applied. Such measure might even improve exterior of industrialized buildings as prevailing amount of them looks out-dated nowadays.

3.1.2 Improved windows (exchange of windows)

Heat transmission of window refers mainly to the heat conductivity of glass, frame, spaces between panels, and to transmission of solar radiation (Harvey, 2006 in Novikova, 2008). At the same time, air-tightness of the envelope and "driving forces such as wind, inside-outside temperature differences, and air pressure due to mechanical ventilation systems or warm/cool air distribution play key role in the air exchange rates" (Harvey, 2006). According to Levine et al. (2007) modern window technologies are able to prevent from 65-75% of heat losses comparing to standard non-coated double-glazed windows due to such measures as "use of multiple glazing layers, low-conductivity gases between glazing layers, low emissivity coatings on one or more glazing surfaces, and use of framing materials with very low conductivity" (in Novikova, 2008). The low-cost options aimed at increasing energy efficiency of windows include filling up leaks with foams or weather striping of windows and doors.

Referring to CEE data, U-value of windows before and after retrofitting usually significantly varies not depending on climatic zone. Table 3-1 shows that energy performance characteristics of improved windows is up to two times higher comparing windows before retrofitting and installation of more energy efficient windows in new EU Member States (Petersdorff et al., 2005).

Table 3-1 Characteristics of improved windows in three climatic zones in EU-2004 Member States

Region	**Before retrofitting, W/m²K**	**After retrofitting, W/m²K**
Baltic Republics	3.0	1.66
Poland	3.5	2.00
CZ-HU-SL-SK	4.0	1.70

(CZ - the Czech Republic, HU - Hungary, SL – Slovenia, SK - Slovakia)

Source: Petersdorff et al., 2005.

According to representative of Euroviknobud (Ukrainian company specialised on sale and installation of windows), windows claimed as energy efficient have three layers of glass and their inter-glass space is filled with argon. U-value for such type of windows is 1.64-1.42 W/m²°C. The installation costs and price of the window itself come up to 3550 UAH (i.e., about 355 EUR) (Euroviknobud, 2009). In addition, the representative of the company mentioned that according to new State Standards of Ukraine (DSTU) R-value for windows is supposed to be 0.6 m²°C/W and higher (compare to 0.5 m²°C/W in the old version of State Standards). No additional data on the energy saving properties of this type of energy efficient windows was available.

Currently, many Ukrainians living in the multi-storey buildings change old wooden window frames for modern plastic windows, but due to financial constrains these newly installed windows usually are not the energy saving ones. For comparison, price of usual plastic window is 1494 UAH, i.e. about 150 EUR per window with required works, which is more than twice less than price for energy efficient window described above, and its U-value is about 1.92 W/m²°C (Euroviknobud, 2009).

Overall, the exchange of windows is an easily implemented option (as it does not require any particular building properties), and thus can be implemented in any type of multi-storey residential building. There is no specific data available on share of buildings (or apartments) with already exchanged windows, but the assumption might be made that energy efficient (and simultaneously more expensive) windows are installed in properties owned by richer stratum of society. Thus this measure has high potential for panel (industrialized) buildings, which are usually occupied by citizens with lower income.

3.2 Meters of heating

The share of DH (district heating) systems in Ukraine is more than 57% from total heating supply in the country (State Statistics Committee, 2008). Existing system of centralised heating supply in residential stock was mainly constructed in the period of mass construction of residential buildings, i.e. 60s – beginning if 80s, and there has been almost no renovation since that time (ESCO, 2007). As it was estimated by the Ministry of Construction of Ukraine, from generation till end use about 60% of thermal energy is lost (IEA, 2006). The losses in the centralized heating supply happen on the several key stages that are described in the Table 3-2 below.

Table 3-2 Losses of energy in the DH systems that operate using natural gas, %

	Current average losses, %	**Losses rate after energy efficiency improvement due to technical measures, %**
Generation of thermal energy	22.0	14.5
Transportation of energy	25.0	13.0
Heat exchangers	5.0	2.0
End use	30.0	10.0
Total losses	60.0	38.0

Source: IEA, 2006.

From the data in the Table 3-2 it is possible to conclude that addressing end users of energy (introduction of energy saving measures on building level) will bring result of 1/3 of heat losses reduction (IEA, 2006). And here one of the main problems is absence of data on consumption of thermal energy by end users, while current data is mainly estimated by models and is based on the normative consumption. Such situation leads the fact that end-users pay their utility bills based not on their actual consumption, as well as they are the ones to bear all expenditures for heat losses during transmission, as there are no heating as well as hot water metes that actually monitor amount of hot water and heating entering building system. At the same time knowledge about real need of consumers will make it easier to create projects of heating supply processes, develop and improve systems of heating supply, and also will stimulate investments (Shevtsov et al., 2007).

3.3 Control (regulation) of space heating

In general, improved heating control may reduce cost of space heating for over 20% (Harvey, 2006 in Novikova, 2008). As proof of energy saving due to heating control, the data collected from experiment in Serbia, where in panel buildings connected to DH the installation of heat flow meters and heating controls took place might be used. During this pilot project, households were paying their heating bills on the normative basis depending on apartment size, but were able to adjust heating to their requirements. As a result the heating demand of buildings under study decreased by 10.5 -15% (Živkovi et al., 2006). According to Novikova (2008), in case of thermostats installation energy savings can be up to 20% for typical district heated flats in Hungary.

Probably one of the most potential measures that can be used in Ukrainian residential stock in order to reduce heat energy use is installation of thermostatic radiator valves (TRVs). For example, Novikova (2008) mentions that TRVs are "convenient solution for controlling consumed heat supplied by DH system or by building (block) heating system". TRVs allow dwellers to adjust room temperature to needed level and are argued to be able to save 10% of total thermal energy (Novikova 2008).

The biggest problem with TRVs installation in the typical Ukrainian multi-storey buildings is need to install by-pass lines as radiators are usually installed sequentially from highest floor to the lowest one. As a result stop of heating in one apartment stops heating flow in all subsequent apartments and decrease comfort as well as ability of other dwellers to adjust temperature to their requirements (based on Novikova, 2008). This problem can be solved to certain extend in case of installation of temperature regulators on the building level, which helps to avoid additional technical problems and expenditures. Such measure, even leading to less energy saving that individual thermostatic radiator valves installation, still brings energy savings as it was shown by energy efficiency project in Kyiv city described above (ARENA-Eco, 2000).

Thus high level of heat demand by panel houses in cased by several main reasons, such as poor insulation and as a result high heating requirements, inability of dwellers to regulate heating level and absence of heating meters (and consequent normative payment not based on actual consumption).

3.4 Hot and cold water meters

Water heating for housing purposes is among the biggest energy consumers in residential sector and usually has rather high energy saving potential. Such inefficiency of hot water supply is caused by "water heating appliances/system, the distribution system, the type of faucets and other sources" (SAVE, 2001 in Novikova, 2008). Same authors state that technical and techno-economic energy saving potential of housing water heating appliance is about 50% and 20-35% respectively.

It has to be mentioned here that in the present research focus is made not on the improvement of water heating for household purposes, distribution and use appliances, but just on the influence of the hot water meters installation on volume of water use and its efficiency.

Overall, energy saving measures that are identified as the most promising and urgent ones for Ukrainian residential stock are external wall insulation and additional measures for insulation of thermal envelope of buildings, installation of energy efficient windows, heating meters, hot water meters, and temperature regulators.

4 Estimation of energy saving potential for key technical measures in Ukraine

In order to assess total energy saving in case of implementation of mentioned technical measures, first of all, the types of buildings for which these measures are applicable have to be identified (in present calculations only multi-storey buildings are considered).
As there is no statistical data on energy efficiency measures installation even in the multi-storey buildings, except for meters of heating, hot and cold water, and temperature regulators, there several following assumptions used for calculations:

- Exchange of windows, wall insulation and other additional measures for buildings' thermal envelope are required and simultaneously applicable for all buildings of industrialized construction type (i.e., for old brick and panel concrete buildings).
- Meters of heating and hot water and temperature regulators can be installed in all multi-storey buildings (excluding share of buildings where it has been already done) connected to DH and centralized hot water supply.

Data used for calculations of potential energy savings due to chosen measures and considering assumptions made is presented below in Table 4-1.

Table 4-1 Data used for calculations of thermal energy savings due to chosen energy saving measures

Parameter	**Meaning**
Total energy consumption by housing sector, TWh	285.330
Share of industrialized buildings of total residential stock	23%
Share of residential buildings connected to the DH	57.5%
Share of residential buildings connected to the centralized hot water supply	40.2%
Share of residential buildings not equipped with heating meters	82%
Share of residential buildings not equipped with hot water meters	93%
Share of residential buildings not equipped with temperature regulators	99%

Source: IEA, 2006; State Statistical Committee of Ukraine, 2008; Cabinet of Ministers of Ukraine, 1999.

The energy saving potential of the chosen technical measures was discussed in Chapter 3. Such data is summarized in Table 4-2 and will be used for calculations further.

Table 4-2 Energy saving measures and their saving potential

Type of measure	**Energy savings, %**
Wall insulation and additional insulation measures	21
Windows exchange	65-75 (average 70)
Heating meters	5-20 (average 12.5)
Heating regulators	10-20 (average 15)

Type of measure	Energy savings, %
Hot water metering	10-25 (average 17.5)

Source: Deriy and Allen, (n.d.); Lubov, 2009; Novikova, 2008.

Energy savings (ES) in the housing sector due to chosen measures are estimated using the following formula:

ES = ESP (%) * BT (%) * EC (TWh),

where
ESP - energy saving potential of measure X;
BT - share of building type where measure X can be implemented;
EC - total annual energy consumption by housing sector (TWh).

External wall insulation and additional insulation measures are assumed to be applicable only for industrialized buildings (old brick and panel buildings), and their share is 0.23 from total residential stock. The energy saving potential for external wall insulation and additional measures was defined to be 0.21, while total annual energy consumption of residential sector is taken as being 285.33 TWh. Thus the expected annual energy saving due to external wall insulation and additional insulation measures is 13.78 TWh.

Same as previous measures, windows exchange option is applicable to all industrialized types of buildings (i.e., for 0.23 from total residential stock). The expected energy saving potential for energy efficient windows is 0.7 (average between 65% and 75%). Consequently, annual energy saving due to windows exchange ought to be 45.94 TWh (using same data on annual energy consumption by residential sector, 285.33 TWh).

Installation of heating meters is applicable to all multi-storey buildings that are not equipped with this measure and are connected to the DH system. The share of multi-storey buildings not equipped with heating meters is 0.82 and share of buildings connected to DH is 0.575. The energy saving potential of installation of heating meters is 0.125 (average between 5 and 20 %). Hence expected annual energy savings due to discussed measure is 16.82 TWh.

Installation of hot water meters is applicable for all multi-storey buildings that are not equipped with this measure (0.93) and are connected to the centralized hot water supply (0.40). The energy saving potential of hot water meters installation is 0.175 (average between 10 and 25%), thus expected annual energy saving gained by such measure is 18.97 TWh.

The last measure to be discussed is installation of heating regulators. It is applicable to all multi-storey buildings connected to DH (because dwellers of these buildings are not able to adjust indoor temperature by themselves due to structure of the DH system on the building level) and not equipped with temperature regulators (share of such buildings is 0.99 for total residential stock). Energy saving potential due to installation of temperature regulators is 0.15 (10-20%). Consequently, the expected annual energy saving of this measure is 24.36 TWh.

Total annual energy saving possible to achieve due to five discussed measures is 119.84 TWh, which constitute about 42% of total energy consumption by Ukrainian housing sector per year (285.33 TWh), or almost 12% of total annual energy demand of the country (983.898 TWh). Thus it might be concluded that almost whole energy saving potential of housing sector, estimated to be 10-50% of annual consumption by sector, can be realized through five simple measures (external wall insulation and additional measures for insulation of thermal envelope, windows exchange, metering of heating and hot water, and heating regulators). Such result can be caused by the fact that until there will be total equipment of housing sector with heating and hot water metering devices there will be no incentive for end-users to save this commodity, and thus no incentive to invest in the energy saving measures. More explicitly the issue of policy stimulation of energy savings and energy efficiency in the housing sector is addressed in the next chapter.

In addition, the other issues that shall be considered are behavioral aspect and so called rebound effect (Levine et al., 2007; Gottron, 2001). The behavior differences with regard to energy use and attitude toward energy saving are supposed to be greater between different countries, but they can occur even within one country, depending on income and education level of different groups of society (Levine et al., 2007). Thus energy saving observed during pilot project in two residential buildings in Kyiv might not be the same in case of introduction of the same measures in other Ukrainian cities or other residential areas. Energy saving potential of discussed technical measures was assumed by present research to be same for whole Ukrainian residential stock, while interaction with dwellers was not considered, and as a result expected energy savings are only rough calculations that can be used for further research in the investigated field.

Rebound effect has the same root as co-benefits connected to energy efficiency, as it implies that as energy services become provided by more efficient technologies and require less energy per unit of services, it gives for consumer incentive to use to services, so overall energy use might stay the same (the only shift is from fewer to more types of services or amount of service used, e.g. heating to higher indoor temperatures). There are estimated values of size of rebound effects for different types of energy related human activities, and for space heating it is 10-30%, for water heating – 10-40%, and for lightning – 5-20% (Gottron, 2001). Hence even in case of highest rebound effect, there still will be energy savings due to increase of energy efficiency, even though these savings might be lower than expected by mathematical calculations.

5 Policy discussion

Present chapter is aimed at identifying key drivers and barriers on the way to introduction of energy efficiency measures in residential sector that are observed worldwide, and in Ukraine in particular. Further, using international literature sources and with regard to identified driving and impeding forces in the sector, most applicable for Ukraine policy instrument are discussed.

5.1 Drivers and barriers for energy efficiency

Even though, improvement of energy efficiency in residential sector, as well as in any other sector of economy, brings direct and indirect benefits to country, in general there exist significant obstacles for introduction of these measures. According to IPCC (Intergovernmental Panel on Climate Change) Report, significant barriers on the way to energy efficiency in the building sector, which are especially hard to overcome in residential sector, include following (Levine et al., 2007):

- "High cost of gathering reliable information on energy efficiency measures;
- Lack of proper incentives (e.g., in case when landlords are those who would pay for energy saving measures and tenants those who realize benefits);
- Limitations in access to financing;
- Subsidies on energy prices;
- Fragmentation of the building industry and the design process into many professions, traders, work stages and industries".

All mentioned barriers are described more in details in the Table 5-1 and further in present chapter.

Table 5-1 Barriers on the way to energy efficient technologies implementation in the buildings sector

Barrier categories	Definition	Examples
Financial costs/ benefits	Ratio of investment cost to value of energy savings	Higher up-front costs for more efficient equipment Lack of access to financing Energy subsidies Lack of internalization of environmental, health and other external costs
Hidden costs/benefits	Cost or risks (real or perceived) that are not captured directly in financial flows	Costs and risks due to potential incompatibilities, performance risks, transaction costs etc. Poor power quality, particularly in some developing countries
Market failures	Market structures and constraints that prevent the consistent trade-off between specific energy-efficient investment and the energy saving benefits	Limitations of the typical building design process Fragmented market structure Landlord/tenant split and misplaced incentives Administrative and regulatory barriers (e.g., in the incorporation of distributed generation technologies) Imperfect information
Behavioural and organizational non-optimalities	Behavioural characteristics of individuals and organizational characteristics of companies that hinder energy efficiency technologies and practices	Tendency to ignore small opportunities for energy conservation Organizational failures (e.g., internal split incentives) Non-payment and electricity theft Tradition, behaviour, lack of awareness and lifestyle Corruption

Source: Carbon Trust, 2005 in Levine et al., 2007.

As it was mentioned, among key barriers on the way to energy efficiency in buildings sector is the one caused by misplaced incentives. Such situation occurs when stakeholders responsible for investments into energy efficiency are not the ones who actually benefit from future energy savings (Levine et al., 2007). In Ukrainian case, regarding multi-storey residential buildings, the ones responsible for improvement of energy performance on the building level and especially for the commonly used areas of multi-apartment houses are ZhEKs, while dwellers are actually payers of utility bills. Such fact causes the situation when ZhEKs are not actually interested in the improvement of energy performance of buildings, while individual dwellers of apartments are usually not able to initiate energy saving measures on the building level.

Same as in other Former Soviet Union and Eastern European countries, in Ukraine energy prices have been historically subsidized, which creates a situation when energy users, and residential users in particular, have no incentive to save energy. Thus "energy pricing does not reflect long-term marginal costs of energy" and required depreciation of energy sector infrastructure (Levine et al., 2007). Paradoxically, before 2006 electricity, gas, and DH tariffs for individual users in residential sector in Ukraine were even lower than in neighbouring Russia (IEA, 2006). Pricing of electricity and gas for residential consumers stays still below long-run marginal cost after increase of energy tariffs in 2006. In terms of DH and nuclear power the situation is even worse. Only 80% of operational costs of DH are covered by tariff on this utility for residential users (IEA, 2006). At the same time, tariff on electricity generated on nuclear power plants does not provide sufficient funds for future decommissioning of such power plants. Overall, tariffs on DH in Ukraine for residential users do not cover even operational costs, while electricity and natural gas prices cover operational costs, hardly cover maintenance and repair cost. Hence neither tariffs on DH, nor on electricity and natural gas do not cover capital investment costs (IEA, 2006). Such situation with subsidizing energy prices for residential users is done at the expense of industrial sector that pays energy costs on higher tariffs level. Thus that causes cross-subsidizing and distortion of prices on energy product in the country (IEA, 2006).

Low energy prices caused creation of energy intensive lifestyle among average Ukrainian citizens, what especially took place during Soviet Union period (Smith, 2008). Nowadays, almost twenty years after, majority of Ukrainian population is not used to save energy, as people usually try to avoid installation of meters for heating and hot water in their apartments, because it allows using energy services without worrying about increase of utility payments later.

Small sizes of energy efficiency projects and consequently high transaction costs effect in low interest from investors' side in such type of projects. Same situation is observed in case of different groups of society, as the richer usually neglect energy saving measures on apartment or house level due to the fact that energy expenditures constitute a negligible share in their disposable incomes, while the poor often do not have financial sources to introduce energy saving measures (Levine et al., 2007).

The other major barrier on the way to the energy efficiency in buildings sector is imperfect information. Usually it is hard for small enterprises in construction industry to access information about "new technologies, new standards and best practices" (Levine et al., 2007). Simultaneously, for end-users benefits of energy saving measures are often delayed and not directly observable, while prices of energy efficient products are usually higher. And talking about Ukrainian case it is obvious that absence of system when consumers pay their utility bills based on actual energy services (heating and hot water) consumption makes it hard to stimulate dwellers to invest into energy saving and identify most suitable energy saving options.

Among other important barriers in terms of energy efficiency in Ukrainian residential sector is lack of financial capital that can be used for these measures, and especially by low-income households. Limited access to the energy efficient equipment, energy saving construction materials and components also prevent from utilization of energy saving potential of this sector (Levine et al., 2007; Bogomolov, 2008).

Corruption and bureaucracy on all levels of governance in the country creates impediments to all innovations, in particular for energy saving policies and measures introduction (Spector et al., 2006). That causes a situation when it is hard to start business activities in the field, implement voluntary energy saving measures etc. For instance, developers of the pilot project on energy efficiency in residential buildings in Kyiv met such obstacle trying to conduct a switch from normative to actual consumption billing for hot water and heating in project buildings that was intentionally delayed by energy services supplier (ARENA-Eco, 2000).

Overall, the major barriers for introduction of energy efficiency measures in Ukrainian residential stock are (1) subsidized energy prices and as a result typical energy intensive lifestyle of citizens, (2) lack of financial capital for introduction of energy saving measures and (3) lack of investors' interest in energy saving projects, (4) misplaced incentives as ZhEKs are not interested in improvement of energy performance of buildings, (5) lack of awareness and knowledge about energy saving options among average dwellers and construction specialists, as well as (6) high rate of corruption on all levels of governance. All these factors create a situation when market in the sphere of energy efficiency is not well developed and state regulations play key role in the sector.

The present research proved that housing sector of Ukraine has large embodied but not yet executed energy saving potential. Such situation is caused by several factors, i.e. worn-out material and technical basis, lack of incentives both for end-users and energy services suppliers, as well as lack of enforcement of already existing policy instruments. Nowadays, economic and political crisis in the country only decrease interest of government to the issue of energy efficiency in the residential sector, especially in terms of coming Presidential elections in autumn. At the same time, drivers to the improvement of energy efficiency remain, as dependency on imported energy carriers stays the same for Ukraine with simultaneous constant increase of prices for these resources. In addition, already mentioned purpose use of funds gained due to transfer of Ukrainian AAUs to Japan according to GIS (Green Investment Scheme), and clear position of Government that these funds are to be spent only purposely are important for further development of energy efficiency in the residential and housing sectors.

5.2 Policy instruments aimed at improvement of energy efficiency

According to the IPCC Report, among the most successful policies aimed at reduction of energy use in buildings are the following measures (Levine et al., 2007):

- Continuous update of standards for appliances, building codes and labelling.
- Introduction of energy leadership programmes among public sector, e.g. procurement policies, educational works, and promotion of ESCOs.
- Use of financial incentives and energy pricing.

- Utility demand-side management.

In UNEP Report on the assessment of policy instruments for reduction of GHG emission from buildings rather similar to described above division of policy instruments for energy efficiency and their categories is made (see Table 5-2 below).

Table 5-2 Classification of key policy instruments aimed at increase of energy efficiency and reduction of GHG emissions from buildings by different categories

Control and regulatory instruments		**Economic and market-based instruments**	**Fiscal instru-ments and incentives**	**Support, information and voluntary action**
Normative: −Appliance standards −Building codes −Procure-ment regu-lations −Energy efficiency obligations and quotas	**Informative:** − Mandatory audits − Utility demand-side management programs − Mandatory labelling and certification programs	− Energy performance contracting − Cooperative procurement − Energy efficiency certificate schemes − Kyoto flexibility mechanisms	−Taxation −Tax exemptions / reductions −Public benefit charges −Capital subsidies, grants, sub-sidized loans	− Voluntary certification and labelling − Voluntary and negotiated agreements − Public leadership programs − Awareness raising, education, information campaigns − Detailed billing and disclosure programs

Source: Ürge-Vorsatz and Koeppel, 2007.

Petersdorff et al. (2005) concluded that measures on energy efficiency that have to be introduced in the new EU Member States (including Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, and Slovakia) are cost-efficient no matter either they are realized as separate measures or as a package, and the same assumption can be made for Ukrainian residential stock, as it is also representative of post-communist buildings' type. The most cost efficient way to introduce energy efficiency measures in already existing building stock is the one coupled with retrofitting, that is usually required every 30-50 years. Thus, in order to use such opportunity to the full extent, appropriate energy performance standards shall be imposed for refurbished buildings, as lost opportunity will probably postpone such measures for almost half a century (Petersdorff et al., 2005). Overall, expenditures during refurbishment of building will usually be as follows: "energy related investments; costs for maintenance of building envelope and heating systems, which can be combined with energy efficiency measures; and cost for further refurbishment, modernization or alternation without influence on the energy consumption (e.g. change of floor layout etc.)" (Petersdorff et al., 2005).

Further, the detailed description of mentioned above measures is provided with their possible implications for Ukraine. In course of literature review policy instruments for energy efficiency in Ukraine that are already on the stage of development were identified, as well as those instruments that are most applicable for Ukrainian circumstances and would allow overcoming of major barriers for energy efficiency. Such policy instruments are divided into three categories (economic, informative and educational, and state regulations) in order to simplify their discussion.

5.2.1 State regulations

State standards and technical norms for houses still play key role in Ukraine, as the market in this field is not yet well developed. The proper use, enforcement, and continuous update of building codes in the country are extremely important in terms of improvement of energy performance in buildings. Performance-based building codes, which address building as entire system, allow more creativity and freedom for designers and constructors, while ensuring compliance with annual energy consumption requirements. To the contrary, prescriptive codes "set separate performance levels for major envelope and equipment components" (Levine et al., 2007). In Ukraine, for example, currently the transition from already existing prescriptive to performance-based building codes is observed, as in 2006 the draft of new performance-based Building Codes was approved by Ukrainian Government (IEA, 2006). Talking about the energy standards for buildings it is important to mention energy performance of houses in the EU countries. For example, in Germany an annual useful energy input needed for houses of old stock is about 220 kWh/m^2, for newly erected buildings – around 70 kWh/m^2, and for Passive Houses - 15 kWh/m^2 (Schnieders and Hermelink, 2006). Such case might serve as an example for Ukrainian policy-makers during development of new State regulations with further increase of energy performance standards of newly built and refurbished houses, as even buildings constructed recently in Ukraine consume energy on the level of about 300-400 kWh/m^2 annually (Bogomolov, 2008).

The assistance from government in terms of carrying out energy audits in residential buildings or even compulsory audits help an end-user to identify the most promising energy saving options, as well as give recommendations on best investments choices and cost-saving actions (Levine et al., 2007). According to the project of State Law "About Energy Efficiency in Buildings" proposed by Ministry of Construction, Architecture, Housing and Communal Services, energy audits shall become compulsory for all Ukrainian buildings. Such audits shall be carried out by owners of buildings or unions of dwellers and result in energy labelling of buildings and identification of most suitable energy saving options (Association of "Producers of Insulation Materials and Development of Energy Saving Technologies", 2009). Energy audits and labelling would facilitate creation and implementation of governmental policies, as they will provide needed data on the issue of building types, their energy requirements, behaviour and habits of dwellers, as well as on actual results of implementation of different types of energy saving measures.

5.2.2 Economic measures

In order to overcome such barriers on the way to energy efficiency in the residential sector, as misplaced incentives and redundant energy subsidies, the energy price for individual user shall be on appropriate level and cover costs of energy carriers used, costs of energy production and transmission, as well as depreciation of energy systems. Increase of price for energy services is very sensitive issue, thus, it is important to know income per capita in Ukraine. This index being quite low in Ukraine as for European country even before (748.67 USD per capita, 2008) dropped recently due to current economic and political crisis (Nation Master, 2009). So considering such policy measure as increase of tariffs on energy prices, one should not forget that it might decrease level of billing payments as many citizens will not be able to do that due to the lack of financial sources. Such situation was observed in Albania, Armenia, and Georgia in 1990s, where payments' collection levels were about 60% after increase of energy tariffs (Levine et al., 2007). So the right trade-off and right time for increase of energy prices for residential users have to be identified.

Due to installation of hot water and heating meters and simultaneous increase of energy prices for individual users dwellers would observe direct connection between amount of energy services used and increase of billing payment's share in their disposable income. Thus, change of lifestyle and habits of energy use, as well as more investments into energy saving options are expected to take place.

The contentious issue in these terms is availability of financial capital of average citizens in order to use energy saving (usually more expensive) technologies and materials. In course of research on climate protection and energy efficiency in buildings for new EU Member States Petersdorff et al. (2005) concluded that one of the key problem is lack of investments and financial resources that can be used for refurbishment of old buildings. Same situation is observed in Ukraine where even in case of existence of state and local programmes on energy efficiency, all measures stay stated only on paper as shortage of capital makes these measures unrealistic. In their report Petersdorff et al. (2005) offered several key policy instruments that can help to ensure introduction of energy efficient measures simultaneously with refurbishment of buildings:

1. Economic incentives through reduced interest rates on loans for improvements of energy efficiency that go above energy performance standards for refurbished buildings. At the moment, interest rate for loans in foreign currency established by National Bank of Ukraine is 11%, and average interest rate for loans in Euro-zone is 4.32% (European Commission, 2009; Goltsblat, 2008).
   The main issue that has to be ensured in these terms is consistency of subsidy and improved insulation technology. Among drawbacks of such policy instrument is that there shall be "clear indication which measures are subsidized" while there shall be no dependency what equipment supplier is.

2. Regional level revolving funds for refurbishment purposes. Such funds are expected to be managed by public institutions and become financing mechanism for energy efficiency measures. The operation of revolving fund is run due to the fact that money gained from energy savings projects carried out by debtors are returned to the fund, simultaneously other members of fund might take loans for same measures, which creates the ongoing cycle of capital.

3. Lowering level of Value Added Tax (VAT) for products that are able to lead to decrease of energy consumption in buildings, i.e. insulation materials, energy efficient windows, or modern heating technologies etc.
   Currently, VAT in Ukraine is 20% and in the EU rate of VAT is country specific, but not lower than 15% for any country (Europa, 2008; Worldwide-tax, 2009). At the same time, recently heads of EU countries proposed to include energy saving equipment and materials into list of economic activities that are able to receive reduced rate of VAT, i.e. 5% (Europa, 2008).

4. Additional financial incentives aimed at increase interest from investors' side in the energy saving measures during retrofitting of building stock. For example, investors might get a right to increase rental fees after refurbishment up to two times of the costs of energy saved due to measures installed in the building.

   As a successful example of fiscal policy, the UK case might be presented, where to stimulate landlords to improve energy efficiency in their properties Landlords' Energy Saving Allowance (LESA) was introduced by government in 2004. According to LESA, the tax relief up to 1500 GBP per property per annum is given to landlords who invest into "installation of loft insulation, cavity wall insulation, and soil wall insulation in residential property they let" (OECD, 2007).

In terms of current situation in Ukrainian residential sector, implementation of energy saving options, and financial support of such actions, the policy instrument that would address individual dwellers in the optimal way is creation of local revolving funds. This measure is much easier to introduce, as it does not require changes in the national legislation, as reduction of VAT or loan interest rate do. Local revolving funds could make it easier for dwellers of multi-storey Ukrainian residential buildings to invest into energy saving measures. In this case a union of dwellers will act as one entity and there will be no need to fully rely on ZhEK in terms of investments into refurbishment, especially concerning commonly used areas in multi-apartment buildings.

Overall, stimulation for energy saving shall be directed at the following key actors:

- suppliers of energy, for example, by the introduction of stimulating structure of tariffs;

- end-users, i.e. shall include at least audit and regulation of energy consumption and shall create motivation for those who receive subsidies in the residential sector;

- buildings' owners with possibility to use at least a part of budget money saved due to energy saving measures for local needs.

Furthermore, creation and support of ESCOs (energy service companies) are supposed to be among the best practices in terms of increase of energy efficiency in the buildings sector in a cost-efficient way. According to Levine et al. (2007), "ESCO is company that offers energy services, such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property/facility management, energy and/or equipment supply and provision of energy services". The energy performance contract (EPC) signed between ESCO and customer ensures future energy saving or same as current level of energy services with lower costs. Consequently, ESCO's profit from the improvements of energy performance is connected to the size of actual savings. Therewith ESCOs often supervise projects during whole period of its execution with simultaneous trainings and operational assistance (Levine et al., 2007). Rather often ESCOs need initial support from the side of government, but overall they facilitate introduction energy efficiency options, assisting building and apartment owners to access information about technical measures available and their potential results. Thus, ESCOs are able to improve energy efficiency "without burdening public budgets and regulatory interventions to the market" (Levine et al., 2007). In terms of present research information about only one ESCO in Ukraine, UkrESCO, was found. UkrESCO being the fist energy servicing company in Ukraine carries out projects on energy efficiency in industry and municipal sector with use of international grant funds (IEA, 2006). Hence, there exist good example of ESCO operation in the country and more development of such type of business shall take place and be supported by government.

5.2.3 Informative and educational instruments

Educational measures aimed at improvement of energy efficiency are needed both for professionals in the field of construction and end-users. Simple, comprehensive, and user-friendly informative materials on energy efficiency options and proper use of energy saving equipment are able to stimulate interest from dwellers' side in such options, as well as ensure optimal operation and maintenance of energy saving equipment (Levine et al., 2007). Educational campaigns among Ukrainian citizens are extremely important in terms of lifestyles and habits' change that is essential for successful introduction of any other policy aimed at improvement of energy efficiency.

In case of compulsory energy meters installation, consumers will see direct connection between appliances they use and energy consumption, so the educational part of meters' installation is also important. Simultaneously construction specialists and average dwellers shall be informed and trained about available on the market energy saving materials and construction components, as well as potential financial savings due to increased energy performance of buildings due to such measures.

Such measure as building labelling and certification is used to overcome barriers caused by imperfect information on the real estate market, "high transaction costs, long lifetime of building… and displaced incentives between the owner and tenant" (Levine et al., 2007). Building labelling in Ukraine is only on the stage of development. According Ministry of Construction, Architecture, Housing and Communal Services of Ukraine, the compulsory energy audits and following labelling of buildings shall start soon. As a result, an energy passport will be given to the owner of building or to the union of dwellers for term of ten years, and in case of absence of such passport no market operations will be allowed in terms of the building (Association of "Producers of Insulation Materials and Development of Energy Saving Technologies, 2009). Discussed measure is employed in the UK, where since 2007 a Home Information Pack is required to be provided to potential property buyers. Such Pack shall include "key information as regards the quality of the house" (OECD, 2007). This measure is aimed to increase transparency of the whole selling process and to provide property buyers with "better picture of the future heating expenditures they can expect" (OECD, 2007).

But even in case of perfectly developed state regulations they bring results only being enforced. In Ukraine one can observe lack of this part of the chain of policies' operation. For example, goals stated in the Comprehensive State Programme on Energy Conservation of Ukraine, 1995, still remain only on the level of goals with very little progress taken place. Same is applicable to other legislative documents in this field, and especially concerning energy efficiency in the residential sector (as usually industry is seen as having larger energy saving potential and easier to manage).

Overall, it might be concluded that the most suitable and urgent policy measures that shall be employed in Ukraine in order to increase energy efficiency in the residential buildings are as follows:

- Increased energy performance standards for refurbished as well as newly constructed buildings in State building codes that will ensure that opportunity to implement energy saving measures in the most cost effective way is not lost.

- Compulsory energy audits and energy labeling of buildings

These measures have high potential with regard to current Ukrainian circumstances, as state regulations still play key role in the promotion of energy efficiency measures in the residential sector.

- Compulsory installation of heating and hot water metering.
- Establishment of tariff on energy services (heating and hot water) for individual users on the proper level.

Two instruments mentioned above are both aimed at forcing average citizens to save energy in their households and to realize direct connection between consumption of energy services and utility billing payments.

- Creation of local revolving funds and other ways of financial support of energy saving initiatives would allow unions of dwellers of multi-apartment houses to introduce energy saving measures without dependency on ZhEKs.
- Educational campaigns with average citizens and construction business professionals, being supportive measure is still extremely important, especially in terms of lifestyle change.
- Support and promotion of ESCOs would facilitate interest for business side in the energy efficiency in residential sector and help to transfer from totally governmental supported introduction of energy efficiency to more market based activities in the sector.

6 Conclusions

It was identified in the present research that there are several key reasons for Ukraine to pay attention to the energy efficiency in national economy, and in the residential sector in particular. Such factors include dependence on imported from Russia energy resources with consequent political tension, as well as constant increase of price of natural gas and other fossil fuels. The urgent need for refurbishment of buildings, and especially those of industrialized construction type, due to worn-out building service systems, high levels of energy losses, and further creation of unfavourable living condition all cause origination of poverty islands in such types of buildings. The issue of energy poverty is also crucial nowadays for Ukraine, although energy efficiency is poorly addressed in the key energy policy state document – Energy Strategy to 2030. Tackling energy efficiency in addition is able to bring co-benefits to society and decrease GHG emissions by country, what can be used to take advantage of flexible Kyoto mechanisms. Currently there exist large research gap in the field of the energy efficiency in buildings sector in the CEE region, and Ukraine in particular, as only several large studies have been accomplished on this topic.

According to estimations of International Energy Agency (2006), potential annual energy savings in residential sector are in the interval from 28.53 TWh to 142.67 TWh. In order to realize this potential different types of technical measures have to be implemented. Low-cost and first-priority energy saving measures were chosen with the support of two case studies, i.e. (1) external wall insulation and additional measures for insulation of thermal envelope; (2) windows exchange; (3) metering of heating; (4) metering of hot water; (5) heating regulators were assessed in terms of their applicability to different types of buildings. It turned that due to these measures about 42% of annual energy consumption of the residential sector and about 12% of annual energy demand by the country can be saved.

Major barriers existing on the way to energy efficiency in Ukraine are subsidized energy prices, and as a result typical energy intensive lifestyle of citizens; lack of financial capital for introduction of energy saving measures; misplaced incentives as ZhEKs are not interested in improvement of energy performance of buildings; lack of investors' interest in energy saving projects; lack of awareness and knowledge about energy saving options among average dwellers and construction specialists, as well as high rate of corruption on all levels of governance.

Currently there exists a window of opportunity for introduction of energy saving measures in the residential stock, as need for refurbishment makes it easier to introduce changes and make that in the cost-efficient way. Present study identified policy instruments used worldwide in order to overcome mentioned barriers on the way to introduction of measures on energy efficiency.

First of all, in case of application of high energy performance standards for refurbished buildings as well as for the newly constructed ones, the improvement of energy efficiency in already existing stock can be achieved, which is extremely important in terms of slow turnover of building stock.

Second, establishment of energy tariffs for residential users on the level that covers long-run marginal costs with simultaneous compulsory installation of heating meters and hot water meters would be rather simple, but effective measure. Direct connection between amount of energy services used and increase of billing payment's share in disposable income of average citizens would result in voluntary investments into energy saving options on the apartment-level.

In order to provide financial support for dwellers and especially to simplify the process of energy saving technologies installation on building-level in multi-apartment houses, creation of local revolving funds shall take place. The other ways of financial support of introduction of energy saving measures by individual dwellers or unions of dwellers would be an additional stimulating factor in the field.

Introduction of compulsory energy audits and energy labelling would increase dwellers' awareness and knowledge about most applicable for their properties energy saving options. Such measures would also facilitate governmental policies creation and implementation, as they will provide needed data on the issue of building types, their energy requirements, behavioural aspects and habits of dwellers, as well as on actual results of implementation of different types of energy saving measures.

Facilitation of informative campaigns on energy saving for average citizens is supportive policy instrument, but at the same time, this instrument is among most important ones for change of peoples' lifestyle.

Creation and promotion of ESCOs being not policy instrument itself is extremely important in terms of development of market in the field. In case of proper and active operation of market in energy efficiency, government would be able to loosen its control in this field, which is favourable both for business development and government itself, as less effort and money would be required.

Recommendations for future research include investigation of consumers' behavior, actual energy consumption by households via energy audits, as well as the rate of already implemented energy saving measures in Ukrainian residential sector. It is also advisable to examine technical properties with regard to energy performance of different types of residential houses in order to select most appropriate technical measures and implement them in the cost-efficient way. Another field for future research might be deep policy analysis, including all stake-holders, direct and indirect barriers with consequent identification of most applicable policy instruments in the field of energy efficiency for Ukraine and ways of their enforcement.

Bibliography

ARENA-Eco (Agency for Rational Energy Use and Ecology). (2000). *Energy Efficiency in Residential Buildings in Ukraine (RESBUILD).* E-mail communication with Fedorova, G..

ARENA-Eco. (2008). *Energy Efficiency in Residential Buildings in Ukraine.* Retrieved on 10 January, 2009 from http://www.ARENA-Eco.org/en/project/building2.php

Association of "Producers of Insulation Materials and Development of Energy Saving Technologies. (2009). *Obiazatelnye energeticheskie pasporta dlia sdaniy* [Compulsory energy labeling of buildings]. Retrieved on 5 May, 2009 from http://energoeffect.com.ua/newsread.php?id=44

Bogomolov, M.V. (2008) Energozberezhennia v Komunalnomu Gospodarstvi [Energy Saving in the Housing-Municipal Sector]. *Zhytlovo-Komunalne Gospodarstvo Ukrainy.* Retrieved on 6 December, 2008 from http://jkg.com.ua/ukr/article.php?art_id=255.

Carbon Trust. (2005). *The UK Climate Change Programme: potential evolution for business and the public sector.* Technical Report. In Levine et al. 2007.

Cabinet of Ministers of Ukraine. (1999). *Programme of reconstruction of residential buildings of first mass construction series.* Retrieved on 12 March, 2009 from http://www.uapravo.net/data2008/base58/ukr58336.htm

Climate Change Initiative. (2008). *Systemy Centralizovanogo Teplopostachannia* [Systems of Centralized Heating Supply]. Retrieved on 4 January, 2009 from http://www.climate.org.ua/sectors/distrheatua.html

Cristiansson, L. (1996). *Electricity Demand Options in a Time-Dynamic Framework.* Lund University: Lund Institute of Technology, Department of Environmental and Energy System Studies.

Csoknyai, T. 2005. *Fokozott höszigetelésü épület fütési kérdései* [Heating questions of highly insulated buildings]. In Proceedings of the 4th International Conference Climate Change – Energy Awareness - Energy Efficiency. 8-10 June, Visegrad. In Novikova 2008.

Deriy, V., Allen, A. M. (n.d.). *Case Study. Energy Efficiency in Residential Building, Kyiv, Ukraine.* MUNEE (Municipal Network for Energy Efficiency), Alliance to Save Energy.

Dom-2000. (2008). *Typy zhytlovyh budivel* [Types of residential buildings]. Retrieved on 15 March, 2009 from http://www.dom2000.com.ua/articles.php?aid=1285.

Economichna Pravda. (2009). *Tsina na rosiyskiy gas dlia Ukrainy vpysalasia v prognoz.* [Price on Russian natural gas for Ukraine fits the forecast]. Retrieved on 1 May, 2009 from http://www.epravda.com.ua/news/49f6cd5cdf67e/.

Encyclopedia Britannica. (2009). *U-value. Heat Transfer Unit of Measure.* Retrieved on 10 January 2009 from http://www.britannica.com/EBchecked/topic/612195/U-value

ESCO. (2003). *Zagalni Zasady Polityky Energozberezhennia v m.Kyevi* [General Principles of Energy Saving in Kyiv City]. Retrieved on 10 January, 2009 from URL:http://www.esco-ecosys.narod.ru/2003_9/art55.htm.

ESCO. (2007). *Kontseptsia Derzhavnoi Programmy Reformuvannia Organizacijno-pravovyh Vidnosyn v Galuzi Teploenergetyky ta Tehnologichnoji Modernizatsii ta Rozvytku System Teplozabezpechennia Objektiv Zhytlovo-Kommunalnogo Gospodarstva* [Concept of State Programme of Restructuring of Organizational and Legal Relationship in the Sector of Thermal Energy and Technological Modernization and Development of Heating Supply Systems of Objects of Housing and Municipal Sphere] Retrieved on 10 January, 2009 from http://www.esco-ecosys.narod.ru/2007_5/art31.htm.

Europa. (2009). *VAT: Commission Proposes Categories of Services to Which Member Sates May Apply a Reduced Rate.* Retrieved on 15 May 2009 from http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1109&format=HTML&aged=0&language=EN&guiLanguage=en.

European Commission. (2009). *Enterprise Finance Index: Loans.* Retrieved on 15 May 2009 from http://ec.europa.eu/enterprise/entrepreneurship/financing/enterprise_finance_index/loans.htm

Euroviknobud. (2009, 7 April). *Catalog of the energy efficient windows.* Phone communication.

Goltsblat, I. (2008). *National Bank of Ukraine Abolishes Limitations on Interest Rates for Foreign Loans.* HG.org Worldwide Legal Directories. Retrieved on 15 May 2009 from http://www.hg.org/article.asp?id=5457

Gottron, F. (2001). *Energy efficiency and the rebound effect: does increasing efficiency decrease demand?* CRS Report for Congress. Retrieved on 5 May, 2009 from https://www.policyarchive.org/bitstream/handle/10207/3492/RS20981_20010703.pdf.

Harvey, L.D.D. (2006). *A Handbook on Low-Energy Buildings and District Energy Systems: Fundamentals, Techniques, and Examples.* London: James and James. In Novikova 2008.

International Energy Agency (2006). *Ukraina. Ogliad Energetychnoyi Polityky 2006* [Ukraine. Overview of the Energy Policy 2006].

Kallaste, T., Pallo, T., Esop, M.-P., Liik, O., Valdma, M., Landsberg, M., Ots, A., Selg, A. Purin,

A., Martins, A., Roos, I., Kull, A. and Rost, R. (1999). *Economics of greenhouse gas 206 limitations. Country case study. Estonia.* Riso, Denmark: UNEP Collaborating Centre for Energy and Environment, Riso National Laboratory. In Novikova 2008.

Korppoo, A., Gassan-zade, O. (2008). Joint Implementation: Looking back and Forward. *In Climate Strategies.* Retrieved on 9 February, 2009 from http://www.climatestrategies.org/reportfiles/ji_synthesis_report_final_201008.pdf.

Lechtenböhmer, S. and Thomas, S. 2003. *Efficient appliances as keystone strategy in long-term energy policies – a policy oriented scenario approach system.* In Proceedings of the 3rd International Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL), 1-3 October, Turin, Italy. In Novikova 2008.

Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., Levermore, G., Mongameli Mehlwana, A., Mirasgedis, S., Novikova, A., Rilling, J. and Yoshino, H. (2007). Residential and commercial buildings. *In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Ed. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Retrieved on 25 March, 2009 from http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter6.pdf

Lubov, A. (2009, April). *City purpose-oriented programme "Energy Saving in Odessa City during 2007-2010".* Association of "Producers of Insulation Materials and Development of Energy Saving Technologies". E-mail communication.

Mama-86 (All-Ukrainian Environmental public organization), National Environmental Center of Ukraine, Youth Environmental Organization "Eco-club" Rivne, Public environmental organization of Dniprodzherzhinsk "Golos Pryrody", Environmental-cultural center "Bakhmat", Artemivsk. (2006). *Conceptsia "neatomnogo" shliahu rozvytku energetyky Ukrainy* [Concept of non-nuclear development of energy sector of Ukraine]. Kyiv.

Ministry of Environmnetal Protection of Ukraine. (2005). *Natsionalnyi Otchet o Kadastre Parnikovyh Gazov v Ukraine za 2003 God* [National Report about the Inventory of GHG in Ukraine during 2003]. Tom 1.

Ministry of Fuel and Energy of Ukraine (2006). *Energetychna strategiya Ukrainy* [Energy Strategy of Ukraine].

NEC UkrEnergo (2007). *Structura Spozhyvannia Electrychnoi Energii po Ukraini za 9 Misiatsiv 2006 ta 2007rr.* [The Structure of Electricity Consumption in Ukraine during 9 Months of 2006-2007]. Retrieved on 25 December, 2008 from http://www.ukrenergo.energy.gov.ua/ukrenergo/control/uk/publish/article?showHidden=1&art_id=57147&cat_id=35381&ctime=1196326168765

Nagy, P. (2007). *Building thermal modernization*. Nyiregyhaza. In: Novikova 2008.

National Population Census. (2001). *Distribution of individual households by the type of occupied living space, number of rooms, average household size, and average size of living and total space*. Retrieved on 30 March, 2009 from http://www.ukrcensus.gov.ua/results/housing_conditions/housing_3/select_83/?botton=cens_db2&box=8.3W&k_t=00&p=0&rz=1_2&n_page=1

Nation Master. (2009). *Economy Statistics: Gross national income per capita*. Retrieved on 9 January, 2009 from http://www.nationmaster.com/graph/eco_gro_nat_inc_percap-gross-national-income-per-capita.

Novikova, A. (2008). *Carbon Dioxide Mitigation Potential in the Hungarian Residential Sector*. Doctoral dissertation. Budapest: CEU.

Novikova, L. (2009, 25 March). Personal communication.

OECD (Organization of Economic Development and Cooperation). (2007). *Instrument Mixes for Environmental Policy*. Instrument Mixes Addressing Residential Energy Efficiency.

Partstroyservice (2009, 7 April). *Pricelist for insulation works*. Telephone communication.

Partstroyservice. (2009). *Heat insulation of facades*. Retrieved on 30 March, 2009 from http://www.partstroyservis.com.ua/sections/utiplenie.

Petersdorff, C., T. Boermans, Joosen, S., Kolacz, I., Jakubowska, B., Scharte, M., Stobbe, O. and Harnisch, J. (2005). *Cost effective Climate Protection in the Building Stock of the New EU Member States*. Beyond the EU Energy performance of Buildings Directive. Germany: ECOFYS. In Novikova 2008.

SAVE. (2001). *Study on water heating - labeling / standards*. The foundation for the policy to be followed in creating an energy use information system for housing hot water appliances. The Netherlands: NOVEM. In Novikova 2008.

Schnieders, J. Hermelink, A. (2006). CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building. *Energy Policy* (34) 151–171.

Shevtsov, A.I., Zemlianyi, M.G., Verbynskiy, V.V. (2007) *Munitsypalna Energetyka: Shliahy Pidvyschennia Effektyvnosti* [Municipal Energy: Ways to Increase Efficiency]. DBNISS. Retrieved on 10 January, 2009 from http://www.db.niss.gov.ua/monitor/comments.php?shownews=342&catid=6.

Smith, K. (2008). *Ukraine's Energy Challenges- Net Assessment*. Otherside. Retrieved on 6 May 2009 from http://www.otherside.com.ua/news/detail.php?lang=3&id=38322.

Spector, B.I., Winbourne, S., O'Brien, J., Rudenshiold, E. (2006). *Corruption Assessment: Ukraine*. USAID. Management Systems International Corporate Offices: Washington. Retrieved on 15 May, 2009 from http://pdf.usaid.gov/pdf_docs/PNADK247.pdf

State Statistics Committee of Ukraine (Derzhavnyi komitet statystyky Ukrainy). (2008). *Zhytlovyi Fond* [Housing Stock]. Retrieved on 22 February, 2009 from http://www.ukrstat.gov.ua.

Stolit-Izoterm (2004). *Stolit – teplozberigauchi tekhnologii* [Stolit – heat saving technologies]. Retrieved on 30 March, 2009 from http://stolit.com.ua/savewarm.php.

Szlavik, M., Palvolgyi, T., Ürge-Vorsatz, D. and Fule, M. (1999). *Economics of GHG Limitations. Country Case Study. Hungary*. Denmark, Riso: UNEP Collaborating Centre for Energy and Environment, Riso National Laboratory. In Novikova 2008.

Toping. (2007). *179.5 za 1000 kubometriv - tsina na gas dlia Ukrainyv nastupnomy rotsi* [179.5 per 1000 m^3 - price for natural gas for Ukraine next year]. Retrieved on 5 May, 2009 from http://mynews-in.net/news/politics/2007/12/05/1258168.html

Ukrainska Pravda. (2005). *Rosiya potroyit tsiny na gas dlia Ukrainy* [Russia is going triple gas price for Ukraine]. Retrieved on 5 May, 2009 from www.pravda.com.ua/news/2005/8/1/13065.htm - 33k

Ürge-Vorsatz, D. And Koeppel, S. (2007). *Assessment of policy instruments for reducing greenhouse gas emissions from buildings*. Report for the UNEP - Sustainable buildings and construction initiative. Budapest, Central-European University.

Ürge-Vorsatz, D., Mez, L., Miladinova, G., Antypas, A., Bursik, M., Baniak, A., Janossy, J., Beranek, J., Nezamoutinova, D. and Drucker, G. (2003). *The impact of structural changes in the energy sector of CEE countries on the creation of a sustainable energy path. Special focus on investment in environmentally friendly energy and the impact of such a sustainable energy path on employment and access conditions for low income consumers*. Report commissioned by of the European Parliament. In Novikova 2008.

Ürge-Vorsatz, D. and Novikova, A. (2008). Potentials and costs of carbon dioxide mitigation in the world's buildings. *Energy Policy* 36, pp. 642 – 661.

Verkhovna Rada Ukrainy. (2006). *Zakon Ukrainy pro Energozberezhennia* [Law of Ukraine "About Energy Conservation"]. Retrieved on 3 April, 2009 from URL: http://zakon.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=3260-15

Worldwide-tax. (2009). *Ukraine: VAT and Other Taxes*. Retrieved on 15 May 2009 from http://www.worldwide-tax.com/ukraine/ukraine-vat-taxes.asp.

Živkovi, B., Todorovi, M. and Vasiljevi, P. (2006). Energy savings for residential heating in two pairs of buildings achieved by implementation of actually consumed energy measuring. *Thermal Science* 10 (4): 79-88. In Novikova 2008.

Abbreviations

AAU	Assigned amount unit
CEE	Central and Eastern Europe
CH_4	Methane
CO_2	Carbon dioxide
DH	District heating
EEC	Energy efficiency commitment
EIT	Economies in Transition
EPC	Energy performance contract
ERU	Emission reduction unit
ESCO	Energy Service Company
EU	European Union
EUR	Euro
FSU	Former Soviet Union
Gcal	Gigacallorie
GDP	Gross domestic product
GIS	Green Investment Scheme
GHG	Greenhouse gases
GWh	Gigawatt hour
IEA	International Energy Agency
IPCC	International Panel on Climate Change
JI	Joint Implementation
kWh	Kilowatt hour
LESA	Landlord energy saving allowance
NGO	Non-governmental organization
NO_x	Nitrogen oxides
OECD	Organization for Economic Development and Cooperation
PM	Particulate matter
SO_2	Sulphur dioxide
t.o.e.	Tonne of oil equivalent
TRV	Thermostatic radiator valve
TWh	Terawatt hour
UAH	Ukrainian Hryvna
UK	The United Kingdom of Great Britain and Northern Ireland
UNEP	United Nations Environmental Programme
USD	United States Dollar
VAT	Value added tax

ZhEK	Zhytlovo-ekspluatacijna kontora (in English, housing-operating office)

Appendixes

Appendix-1: Key data on buildings' characteristics under study in pilot project by ARENA-Eco

Housing cooperative (building owner)	Akademichny-14	Teremky-1
Building address	Gorky St. 1	Cruiser Aurora St. 5 corp. 2
Year of construction	1992	1980
Walls material	light concrete	light concrete
Number of floors	12	9
Number of apartments, including:	46	108
1-room	10	-
2-room	-	54
3-room	26	54
4-room	10	-
Floor area, m^2	2821.5	6092
Number of occupants	113	335

Source: ARENA-Eco, 2000.

Appendix-2: Financial data on project carried out by ARENA-Eco

a) Actual cost data for implemented measures

Measure / Costs in US$	Gorky St. building		Cruiser Aurora St. building	
	Actual	Estimated	**Actual**	Estimated
Building-level heat meter and regulator	**7 035.93**	7 718.00	**5 213.05**	11 820.00
Building-level cold water meter			**497.96**	-
Radiator reflectors	**96.22**	200.00	**718.87**	840.00
Heat insulation of pipes			**2 570.31**	2 900.00
Apartment-level hot water meters			**6 733.95**	7 020.00
Balancing of the heating system			**1 960.93**	-
Energy manager (motivator)	**200.00**	-	**400.00**	-
TOTAL	**7 332.15**	7 918.00	**18 095.07**	22 580.00

b) Original payback estimates for the two buildings

	Gorky St. building	Cruiser Aurora St. building
Planned project cost, USD	7 918.00	22 580.00
Planned energy savings, Gcal/year	162.2	463.0
Planned cost savings, USD/year (at $18/Gcal average expected tariff)	2 919.60	8 334.00
Planned payback, years	2.71	2.71
Planned payback (75% return), years	**3.62**	**3.61**

Source: ARENA-Eco, 2000.

Appendix-3: Measured and estimated heat consumption data for Cruiser Aurora St. building

	Heating degree-days	Heating, Gcal	DHW, Gcal	Total, Gcal
January 2000	685.7	133.2	72.6	205.8
February	518.8	116.5	68.6	185.1
March	506.4	96.5	64.9	161.4
April	134.6	54.6	63.0	117.6
May	0	0	41.0	41.0
Total for 5 months	1845.5	400.8	310.1	710.9
Estimate for normal year	3572.0	775.8	687.6	1525.4
Accepted baseline		1047.0	674.0	1721.0
Estimated savings for normal year		271.2	-13.6	257.6

Source: ARENA-Eco, 2000.

Appendix-4: Measured and estimated heat consumption data for Gorky St. building

	Heating degree-days	Heating, Gcal	DHW, Gcal	Total, Gcal
October 1999	221.0	18.4	23.3	41.7
November	541.3	81.2	27.4	108.6
December	562.4	83.6	23.8	107.4
January 2000	685.7	95.9	24.5	120.4
February	518.8	85.7	34.9	120.6
March	506.4	73.5	36.0	109.5
April	134.6	42.3	32.0	74.3
May	0	0	19.3	19.3
Total for 8 months	3170.2	480.6	221.2	701.8
Estimate for normal year	3572.0	541.5	304.6	846.1
Total building's baseline consumption, including:		534.2	248.1	782.3
Accepted baseline for the cooperative		485.0	228.0	713.0
Paid consumption by the artist's studio		49.2	20.1	69.3
Actual heating savings for 1999/2000 heating season		53.6		
Estimated savings for the normal year		-7.3	-56.5	-63.8

Source: ARENA-Eco, 2000.

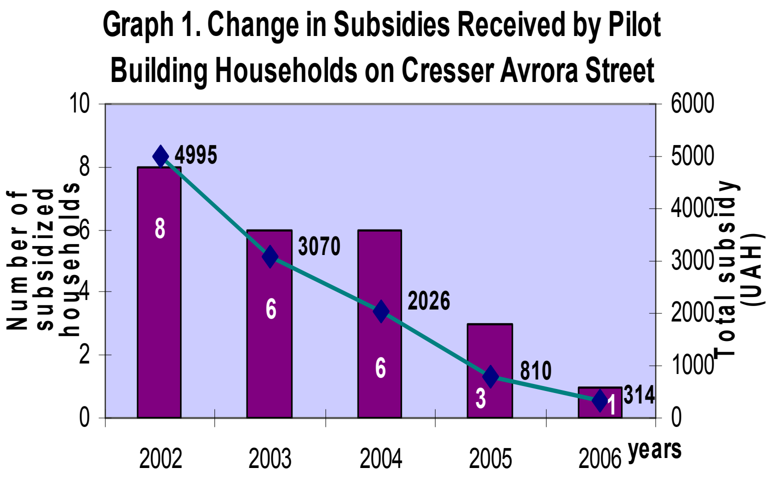
Appendix-5: Average Annual Savings for Cruiser Aurora St. building

	Quantity	UAH	USD
Cold water (m3)	1,499	1,259	252
Hot water (m3)	3,739	12,969	2,594
Thermal energy (Gcal)	149	10,322	2,064
Total			**4,910**
Total savings over 4 years			
	Quantity	**UAH**	**USD**
Cold water (m3)	5,996	4,916	983
Hot water (m3)	14,956	51,878	10,376
Thermal energy (Gcal)	595	41,285	8,257
Total			**19,616**

*Currency exchange rate used: 5 UAH/$.

Source: ARENA-Eco, 2000.

Appendix-6: Change in subsidies structure in course of energy efficiency project by ARENA-Eco.



Source: Deriy and Allen (n.d.).

Appendix-7: Energy savings due to measures discussed in the present research

Type of measure	Calculations	Expected energy savings, TWh
Wall insulation and additional measures (for all industrialized buildings)	0.21*0.23*285.33	13.78
Windows exchange (for all industrialized buildings)	0.7*0.23*285.33	45.94
Heating meters (for all buildings connected to DH and not equipped with meters)	0.125*0.575*0.82*285.33	16.82
Heating regulators (for all buildings connected to DH and not equipped with heating regulators)	0.15*0.575*0.99*285.33	24.36
Hot water meters	0.175*0.402*0.93*285.33	18.67
Total		**119.84**