CONVERTING ENERGY SUBSIDIES TO INVESTMENTS: SCALING-UP DEEP ENERGY RETROFIT IN RESIDENTIAL SECTOR OF UKRAINE

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master in Energy and Environmental Policy

Spring 2017

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ACKNOWLEDGMENTS

First of all, I would like to acknowledge and thank to the US Department of State and the Fulbright Graduate Student Program for the financial support of my studies at the University of Delaware at the Energy and Environmental Policy Program.

I am thankful to my academic advisor Dr. Lado Kurdgelashvili for valuable guidance during my thesis research and for highly useful quantitative skills and knowledge that I acquired from his course. Additionally, I am very grateful to all other professors and instructors at the University of Delaware, who supported me during studies.

I am sincerely grateful to the Edmund S. Muskie summer internship program and my supervisors at the Pacific Northwest National Laboratory, who provided me with the opportunity to gain real-world experience in advanced research during highly intensive summer internship at the PNNL.

I deeply thank my colleagues and friends from many countries who helped me during application to the Fulbright program and during my studies in the United States.

Finally, I dedicate this thesis to my parents and younger brother for their full and unconditional support throughout my life.

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ABSTRACT

After collapse of the Soviet Union, Ukraine inherited vast and inefficient infrastructure. Combination of historical lack of transparency, decades without reforms, chronical underinvestment and harmful cross-subsidization resulted in accumulation of energy problems, which possess significant threat to economic prosperity and national security. High energy intensity leads to excessive use of energy and heavy reliance on energy import to meet domestic demand. Energy import, in turn, results in high account balance deficit and heavy burden on the state finances. A residential sector, which accounts for one third of energy consumption and is the highest consumer of natural gas, is particularly challenging to reform.

This thesis explores energy consumption of the residential sector of Ukraine. Using energy decomposition method, recent changes in energy use is analyzed. Energy intensity of space heating in the residential sector of Ukraine is compared with selected EU member states with similar climates. Energy efficiency potential is evaluated for whole residential sector in general and for multistory apartment buildings connected to the district heating in particular. Specifically, investments in thermal modernization of multistory residential buildings will result in almost 45TWh, or 3.81 Mtoe, of annual savings. Required investments for deep energy retrofit of multistory buildings is estimated as much as $19 billion in 2015 prices. Experience of energy subsidy reforms as well as lessons from energy retrofit policy from selected countries is analyzed. Policy recommendations to turn energy subsidies into investments in deep energy retrofit of residential sector of Ukraine are suggested. Regional dimension of existing energy subsidies and capital subsidies required for energy retrofit is presented.

Chapter 1

INTRODUCTION

Today Ukraine is facing unprecedented challenges since its independence. High energy intensity, occupation of Crimea and military conflict with Russia in Eastern Ukraine, lack of transparency and institutional capacity, high interest rates and uncertainties in macroeconomic condition are the main barriers that prevent transition to economic growth and sustainable energy development. At the same time, Ukraine has enormous untapped energy efficiency potential.

Studies show that improving Ukrainian energy intensity to the average EU level will reduce total energy consumption by half. In monetary terms, possible savings are more than $12 billion in 2010 prices. Residential sector and industry have highest potential for energy savings, as they are the largest consumers of energy. The share of industry and housing sector in improving energy efficiency is one third each. International Energy Agency in its report on Ukraine in 2012 estimated energy efficiency potential as 27 million tons of oil equivalent (toe) or about 30% of its current energy use. This amount constitutes 34 billion cubic meter (bcm) of natural gas. To compare: in 2014 total natural gas consumption was almost 43 bcm, while in 2015 – 33.8 bcm.

Ukraine can avoid natural gas imports. Investments in energy efficiency improvements and increase of domestic natural gas production will allow to halt gas import within ten years (Naftogaz 2015a).

At the end of 2014 new Parliament of Ukraine was elected and new Government was appointed. In November and December 2014, Parliament of Ukraine adopted and approved Action Plans of both Parliament (Rada 2014b) and Government (Rada 2014a), respectively. Adopted within one month, these two strategic documents demonstrate long term reform commitments of executive and legislative branches of the government. In general, documents are synchronized in terms of primary objectives. Among main strategic priorities in both documents is reform of energy sector in general and phasing out of energy subsidies in particular. According to each of the documents, energy subsidies should be completely removed during 2015-2017. Accordingly, prices for both electricity and natural gas should be adjusted to real cost levels.

With gas and heating tariffs real import cost parity, millions of households are struggling to pay household utility bills driving social anxiety and tension. To avoid further drop of living standards and in order to protect socially vulnerable population, the Government provides social assistance program or energy subsidies. Increase of energy subsidies from 17-20 billion UAH in 2015 to expected 80 billion UAH in 2017, or 3.7% of GDP, possess significant pressure on state budget. One of the most effective way to decrease pressure on state budget while protecting poor is deep energy retrofit of existing housing stock.

It is expected that gas and heating prices will be finally adjusted to 100% parity between the domestic gas tariffs and the cost of imported gas by the April 2017. This will make investments in Ukrainian energy efficiency market financially attractive. Size of energy efficiency market in residential sector of Ukraine is estimated between $36-57 billion. One of the most important question, the government is facing today is how to convert existing energy subsidies into energy efficiency investments in the residential sector.

1.1 Overview of Ukrainian Energy Sector

1.1.1 Energy Balance

The energy sector of Ukraine is undergoing massive transformational changes. Total primary energy supply (TPES) had decreased from 132 million tons of oil equivalent (Mtoe) in 2010 to 90 Mtoe in 2015. Annexation of Crimea and military conflict with Russia in Eastern Ukraine were the main reasons for structural changes

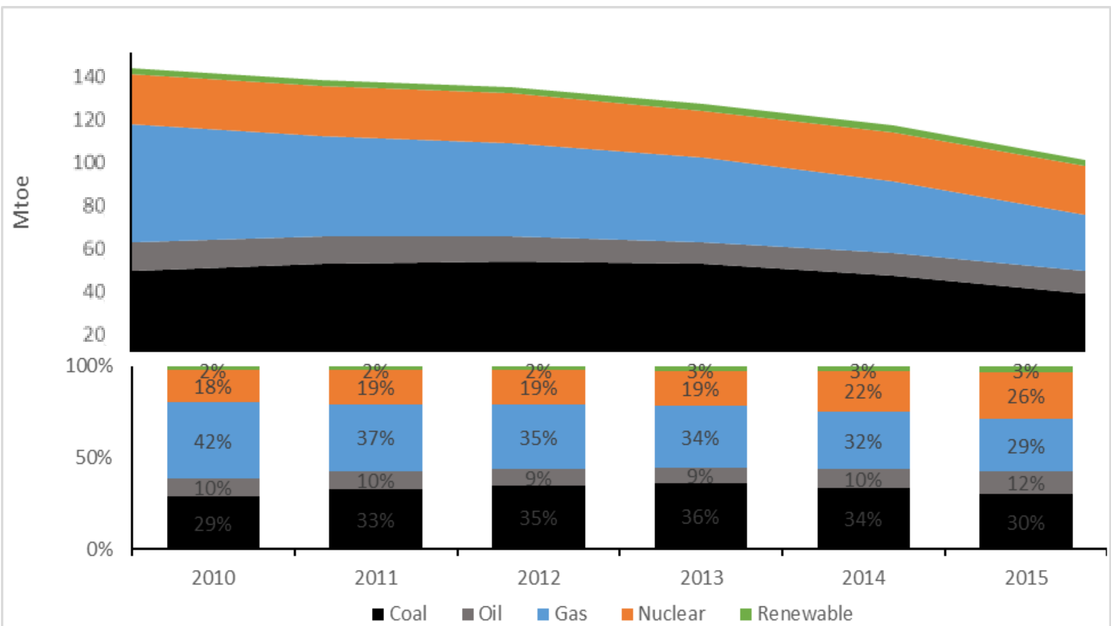

Figure 1. Structure of total primary energy supply in Ukraine, 2010 – 2015
Data source: Ukrstat (2016)

in the economy, significant drop in economic activities and in reduction of both energy supply and consumption during 2013-2015 (Dodonov 2016).

Natural gas for decades has been primary source in national energy supply, has lost it positions and was replaced by other fuels. During five-year period, from 2010 to 2015, share of natural gas in energy balance dropped sharply from 42% in 2010 to 29% in 2015. Over the same period, there has been gradual increase in nuclear energy use. Fifteen units at four nuclear power plants generate about 53% of all country's electricity while share in TPES rose from 18 in 2010 to 26 per cent in 2015.

Share of coal in energy balance increased from 29% in 2010 to 36% in 2013 but due to Russia invasion of the coal rich Eastern Ukraine, its share dropped to 30% in 2015. Oil and oil products with some fluctuations represent 10-12% of total primary energy supply. Renewable energy, dominated by large hydro power plants, accounted for remaining energy sources with 3 per cent of TPES in 2015.

Total final consumption decreased from 74 Mtoe in 2010 to 50.8 Mtoe in 2015. Decrease in energy consumption has been observed among all sectors with highest drop in industry – almost 9 Mtoe or 35%. Residential and industrial sectors are the biggest energy consumers with 33 and 32 per cent shares respectively. Black metallurgy consumes more than half of industrial energy use.

In 2013, for the first time in history, share of residential sector exceeded that of industrial sector, reflecting deindustrialization and structural change in the economy, experienced by other post-communist countries during the transition period.

1.1.2 Energy Intensity

After collapse of the Soviet Union Ukraine inherited vast and inefficient infrastructure. Due to lack of reform and investments, Ukraine is one of the top-ten countries with highest energy intensity in the world (World Bank 2015c). Non-transparent energy pricing dominated for two decades, obsolete industrial technologies and processes, as well as poor insulation of housing stock, are the main reasons for enormously high energy intensity of Ukraine. For example, as for 2011, 41% of all Ukrainian steel has been produced using highly energy-intensive open hearth furnaces, which are largely abandoned in developed countries due to low energy efficiency of the process (Sukhorukov et al 2011).

Although Ukrainian energy intensity is still one of the highest in the world, the rate of decrease of energy intensity during the last two years is also one of the fastest in the world. During the period between 2000 and 2015, energy intensity of Ukraine

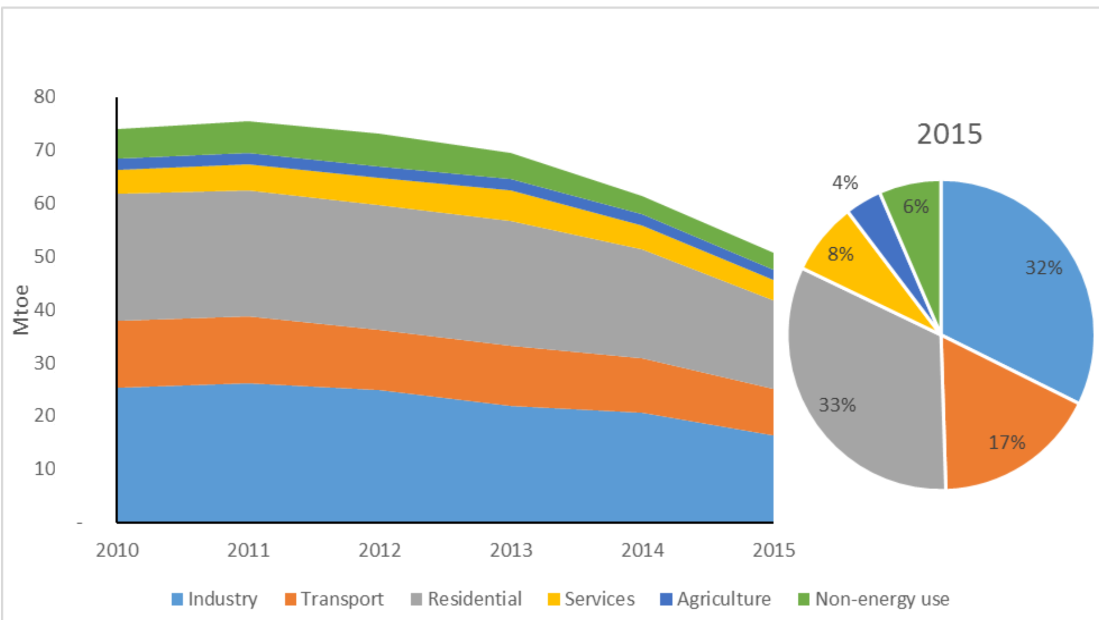

Figure 2. Structure of total final energy consumption in Ukraine, 2010–2015
Data source: Ukrstat (2016)

had been decreasing by 4.3% per year, while between 2014-2015 this indicator was even higher – 4.5% per year.

Table 1. Change in energy intensity over time in selected counties

Change in Energy Intensity, %/year

	1995-2014	2000-2014	2005-2014	2010-2014
Ukraine	-3%	-3%	-3%	-4%
Poland	-3%	-2%	-3%	-3%
Czech Republic	-2%	-2%	-2%	-3%
Estonia	-2%	-1%	0%	-2%
Russian Federation	-2%	-2%	-2%	-2%
Kazakhstan	-3%	-1%	-1%	-2%

Source: Author's own calculations based on IEA (2017b)

Despite significant energy intensity improvements over the last 20 years, with rate of decrease in energy intensity reaching 3% per year, Ukraine still uses three times more energy per unit of GDP (adjusted for purchasing power parity) then OECD countries.

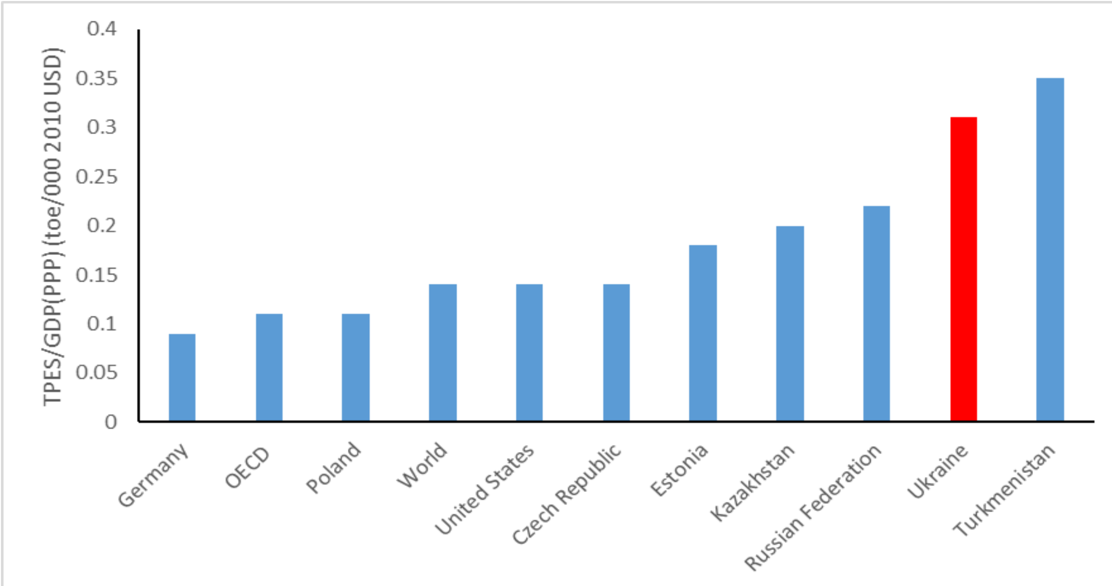

Figure 3. Energy intensity of selected countries in 2014, toe per $1000 GDP (PPP)
Data source: IEA (2016)

High energy intensity leads to the significant dependence on imported energy sources. To satisfy its energy needs Ukraine has been historically importing various energy resources. Share of energy import has been declining over the last decade and

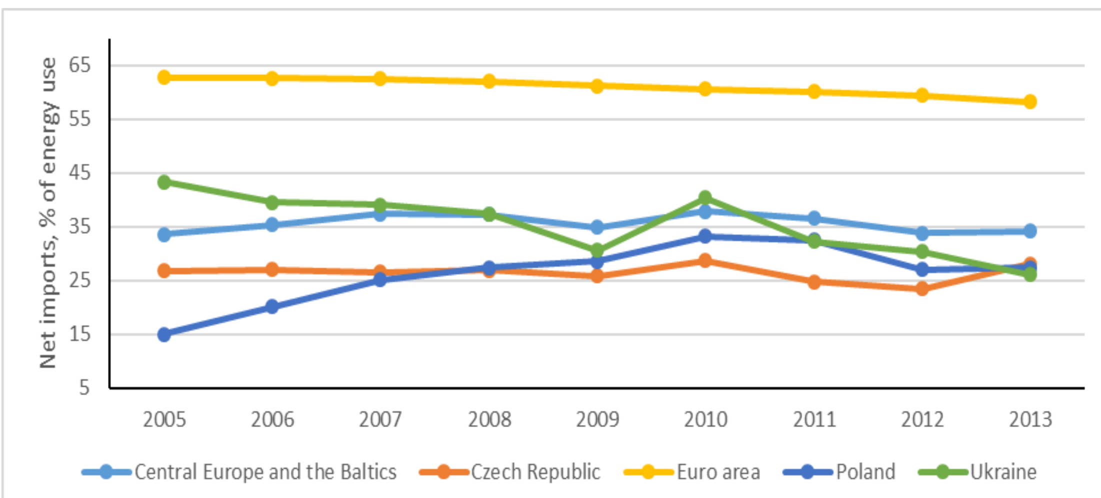

Figure 4. Share of energy import in energy use in selected countries, %
Data source: World Bank (2017a)

in 2013 import accounted for 26% of energy use. Despite this indicator is one of the lowest in region and Ukrainian history, energy dependency still possesses threat to the energy and national security in terms of security of supply.

Energy import also puts significant pressure on public finance and thus whole financial system of Ukraine. Even though cost of energy import dropped from $28 billion in 2011 to $11 billion in 2015, its share in total cost of import is fluctuating in a range of 27-35%. Energy import is the largest single category of imports in structure of foreign trade of Ukraine and therefore has direct impact on trade and currency balance of the country.

For example, in 2013 import exceeded export by more than $13 billion. In the same year Ukraine paid $21 billion to finance energy import. Natural gas represents largest portion of Ukrainian energy import. In 2013 alone, $11.5 billion has been paid for natural gas import. Overall, for the period 2007-2015 total cost of gas import was $83 billion, according to the State Statistics Service of Ukraine. To compare, total estimated cost of modernization of residential sector of Ukraine – biggest gas consumer sector – is $36 billion (Naftogaz 2015a). Pressure put on local currency by the energy import is one of the reason of massive devaluation of hryvna in 2014-2015.

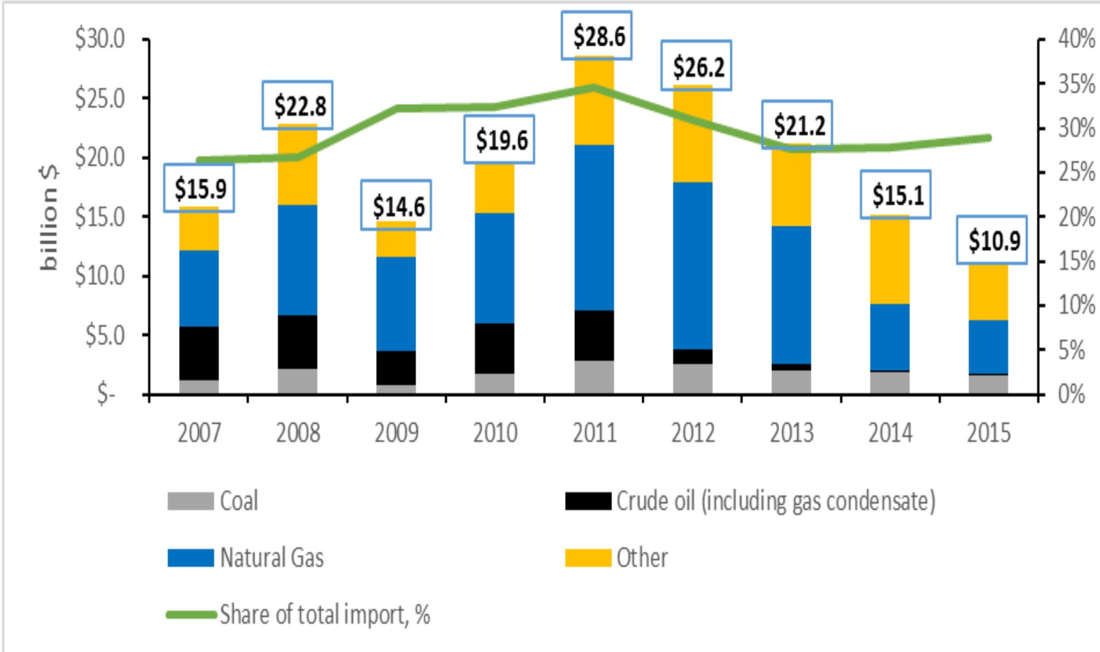

Figure 5. Structure and cost of energy import of Ukraine during 2007-2015
Data source: Energy balances of Ukraine and import statistics from Ukrstat

While in 2013, exchange rate was 1 USD to 8.1 hryvna, two years later 1 USD fluctuated within 23-24 hryvna range.

1.1.3 Natural Gas Supply

Volumes of domestic natural gas production have been changing insignificantly over the 2009-2015 period. Domestic production has been fluctuating within 18-20 billion cubic meters (bcm) per year. In 2015 Ukraine produced 19.92 bcm of natural gas, which covered 67% of the country’s demand (NERC 2016a).

Natural gas consumption dropped from 66 bcm in 2008 to 33.3 bcm in 2016. Despite this drastic drop, third of national gas demand was still met by natural gas imports. Until recently, Russia has been major supplier of imported natural gas. Due to active diversification policy and natural gas market reforms implemented by the Government and National Joint Stock Company "Naftogaz of Ukraine" starting from 2016, for the first time in history, Ukraine has been satisfying its gas needs without gas imports from Russia. All imports of natural gas in 2016 – 11.1 bcm - has been satisfied solely from European suppliers. At the same time, weighted-average import price of natural gas fall from $424.5 per thousand cubic meter (tcm) in 2012 (highest price ever paid by Ukraine and fully supplied from Russia) to $210.5/tcm in 2016 (imported from European gas suppliers). Therefore, for the last five years Ukraine achieved unprecedented in its history results in strengthening energy security by decreasing its import dependency, reducing cost of imported natural gas, eliminating Russia as a monopolistic supplier and diversifying natural gas suppliers.

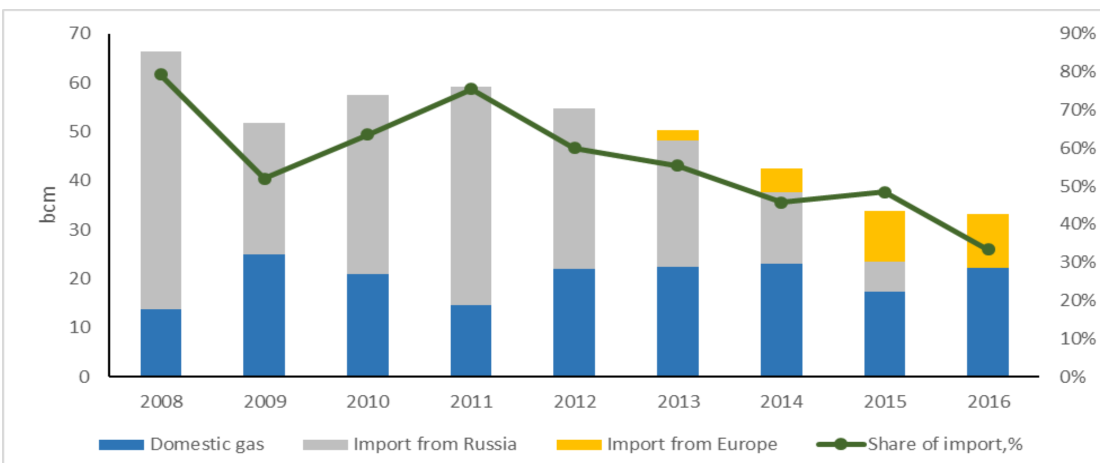

Figure 6. Natural gas consumption and import in Ukraine, 2008-2016
Data source: Naftogaz-Europe (2017) and author's own calculations

As Simon Pirani (2016) asserts:

> "The reduction of gas consumption and Russian imports is one of three deep-going changes in the Ukrainian energy sector. The others are the decline of gas transit, and regulatory reform."

In 2014 Ukrainian government proclaimed an ambition aim to reform energy sector and introduce natural gas market. It is expected that increase of natural gas price to import price parity and imposing clear and transparent regulatory framework will bring competition and investments. Naftogaz of Ukraine estimates that $5.6 billion of investments in natural gas production will increase total national output by more than 10 bcm per year by 2020. This will result in total annual production of 27-29 bcm per annually. In combination with energy efficiency improvements, especially in residential sector, import of natural gas can be fully abandoned (Naftogaz 2015a).

1.1.4 Natural Gas Demand

Ukraine is seventh largest gas consumer in Europe (including Turkey). In 2015 total consumption by all sectors was 33.8 bcm, a 21% decline compared to 2014 (42.8 bcm) (Naftogaz 2015b).

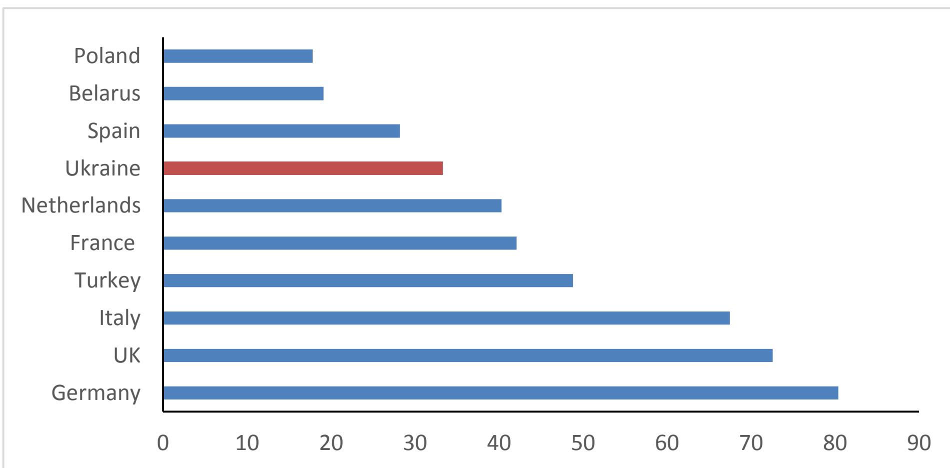

Figure 7. Natural gas consumption in selected European countries in 2015
Data source: Naftogaz (2015b)

More than half of natural gas in Ukraine was consumed in buildings. In 2015 households, district heating companies and government-financed institutions consumed 18.9 bcm or 56% of all natural gas use. Share of industry in gas demand declined from 40% in 2010 to 35% in 2015. The remaining volumes were used for technological purposes during extraction, transportation and distribution of gas. In 2014 and 2015 about 0.4 bcm or about 1% was reported as unauthorized withdrawal in anti-terrorist operation (ATO) zone in Eastern Ukraine (*see Textbox on next page)*

Dnipropetrovsk oblast was the largest user of the natural gas in 2014 (4,329 mln m^3), followed by Kyiv City (3,306 mln m^3) and Kharkivska Oblast (3,005 mln m^3). High share of district heating in Kyiv City (almost 100%) is major reason why single city uses more than any oblast (except Dnipropetrovska oblast).

Residential sector is the largest single consumer of natural gas. Households use natural gas directly for cooking, individual heating purposes, hot water supply as well as indirectly as a heat provided by district heating companies, usually in big cities. In 2015 for this purposes residential sector consumed 17.2 bcm or half of all natural gas

Context and Economic Impact of annexation of Crimea and armed conflict in Eastern Ukraine.

The “Revolution of Dignity”, also known as “Euromaidan” during winter of 2013-2014 resulted in overthrowing of the pro-Russian president Yanukovich. New Presidential and Parliamentary elections were set to May and October of 2014, respectively. During election period, with the absence of legitimate Ukrainian President and Parliament, local authorities of Crimea supported by Russian Special Forces and military personal from Sevastopol Naval Base conducted “referendum” about joining the Russia Federation. Referendum, which took place on March 16, 2014 was proclaimed by international community as “having no validity” (UN General Assembly 68/262 on Territorial integrity of Ukraine). After referendum and annexation of Crimea, several pro-Russia separatists groups seized administrative buildings in Lugansk and Donetsk regions and proclaimed Donetsk and Lugansk People's Republics or DPR and LPR, respectively. In response, Ukrainian government engaged Armed Forces to restore control over cities and areas captured by separatist. Anti-terrorist Operation (ATO) has started. Russian military buildup near Ukrainian border as well as supply of weapon and personal to support separatist resulted in military escalation, loss control over territories, tens of thousands victims and destruction of infrastructure.

During the conflict, Ukraine has lost 20% of its industrial and economic potential (Sobkevich et al. 2015). As for 2013, Crimea accounted for three per cent of GDP and four per cent of total Ukrainian population. Rich in energy resources, mainly coal, Lugansk and Donetsk region historically have been main centers for heavy industry, energy production and extraction industries. Together they hold 15 per cent of GDP and ¼ of all industrial output. Share of areas controlled by separatist in Donetsk and Lugansk regions approximately accounts for 6-7 percent of total area. From 2013 to 2014 Ukrainian GDP decreased by about 10 per cent. By contrast, during this period, industrial production in Lugansk and Donetsk regions dropped by about more than 40 percent and 31 percent respectively. Due to conflict Ukrainian Government lost control over 78 and 84 per cent of industrial capacity in Donetsk and Lugansk regions respectively (World Bank 2015b).

Coal extraction in 2014 dropped by 35%. 115 out of the existing 150 coal mines were located in the occupied territories; 7 of them are completely destroyed, another 63 were pumping out water and only 24 mines are in operation (MFA 2015). With 90 mines under the Ministry of Energy and Coal Industry of Ukraine only 35 located on the territory controlled by Ukraine, while the other 55 (including mines that produce coal anthracite group) are in Donetsk and Lugansk regions currently occupied.

Reduced production of coal in the Donbas, which holds about 80% of coal deposits in Ukraine, damage and destruction of the mining infrastructure, which produced important for energy sector anthracite coal, led to its deficit at thermal power plants, threatening the stability of the energy system of Ukraine, provoking the emergence of a significant shortage of generating capacity. Ukraine forced to increase coal imports: in 2013 the share of coal imports accounted for 9.2%, in 2014 - 11.7% and in January-February 2015 - 14.3% (Sobkevich et al. 2015).

A deficit of coal from mines at Donbass resulted in a shortage of power supply. During winter 2014-2015 shortage reached up to 3,000 MW. As for December 16, 2015 more than 3,700 MW of TPP were offline because of coal shortage (Ukrenergo 2015) by district heating companies, usually in big cities. In 2015 for this purposes residential sector consumed 17.2 bcm or half of all natural gas consumption in Ukraine. Outdated infrastructure, lack of investment and poor quality buildings of Soviet-era provide enormous opportunities for energy savings in residential sector. Natural gas consumption by residential sector will be described in details in the next chapter.

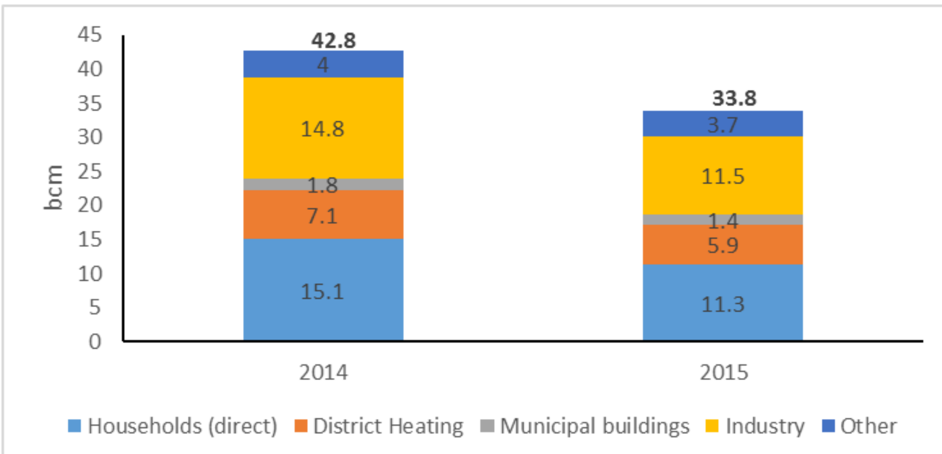

Figure 8. Gas consumption by sectors in Ukraine, bcm
Data source: Naftogaz (2016b)

Improvements in demand-side energy efficiency can provide further progress in reduction of natural gas consumption by reducing demand for import, decreasing cost of energy import, decreasing pressure on trade balance and strengthening national energy security.

For decades, lack of reforms and investments, outdated infrastructure lead to high energy intensity, excessive energy consumption in Ukraine which in turn triggers energy import and other negative drawbacks for the society. Government of Ukraine considers energy efficiency improvements as one of the strategies to addresses challenges Ukraine is facing today.

1.2 Literature Review

Until recently, major body of academic literature about Ukrainian energy sector was mainly concerned about gas relationship with Russia and was connected with corruption and security of energy supply issues. This issue mainly represented by Chow and Elkind (2009), Pascual and Elkind (2010), Balmaceda (2008), Balmaceda (2015), Simon Pirani (2016).

Significant contribution to the field has been made by international organizations. International Energy Agency issued two country reports about energy market development in Ukraine (IEA 2012, IEA 2006). Most recent report (IEA 2015) covers several ex-Soviet countries including Ukraine and describes market and policy development in those countries. Reports from the World Bank (World Bank 2009, Semikolenova et al. 2012) point out on need of cost-reflective tariffs and end-user metering as the key elements of modernization of centralized heat supply.

Concept of turning subsidies to investment is developed by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety as part of technical assistance to the Ukrainian government in scaling-up energy efficiency improvements in residential sector of Ukraine (Berlin Economics 2016, Minregion 2016d). Mechanism, also known as S2I, should establish sustainable financial model based on revolving fund to finance energy efficiency measures in residential sector on a national level.

Subsidies in energy sector have been evaluated in Ogarenko and Hubacek (2013), reports from the International Institute for Sustainable Development (IISD 2016) and the International Monetary Fund (IMF 2015, IMF 2016)

Overview of recent development of Ukrainian energy sector and energy efficiency policy with particular focus on residential sector has been made by Energy Charter Secretariat (Secretariat 2013), Kholod et al. (2015). Several studies estimated energy saving potential in residential sector of Ukraine.

Comprehensive overview of the energy efficiency potential across all sectors have been made by number of studies (IEA 2012, Dodonov 2013, Dodonov 2016). ENSI (2012), Kovalko (2015), Naftogaz (2015b), Minregion (2016a), Dodonov (2016) estimated energy savings potential in residential sector. Development of ESCO market in Ukraine has also been gaining attention (Evans 2000, Yang and Yu 2015, Kovalko 2015, OECD 2015).

This thesis seeks to make a contribution to theoretical and conceptual discussions about ways to scale-up energy efficiency improvements in the residential sector of Ukraine.

1.3 Research Questions

Ukraine has one of the highest in the world energy intensity of economy. Inefficient energy use lead to excessive energy consumption and reliance of energy import, which in turn creates significant threats to energy security and imposes heavy burden on the country's trade balance. In order to meet domestic demand, Ukraine historically has been importing large volumes of natural gas, which is the second largest energy source (after coal) in Ukrainian energy balance. Residential sector is largest consumer of natural gas. Improvements in residential energy use therefore provide enormous opportunities to strengthen energy security and financial stability. Bearing in mind significant importance of natural gas in Ukrainian energy balance and large untapped energy efficiency potential in residential sector this research will focus on two specific questions.

Q1: What energy efficiency potential does Ukrainian residential sector in general and district heating in particular has?

Q2: How to scale-up deep energy retrofit in residential sector from policy design perspective?

1.4 Methodology

Analysis of changes in energy use and measuring driving factors of these changes can be done using decomposition method. In Section 3.1 decomposition analysis of changes in energy use of residential sector has been conducted using Laspeyres method. This method is recommended by the International Energy Agency (Heinen and Week 2013) and also referred as one of the most used decomposition method in academic literature (Ang and Zhang 2000).

Energy efficiency potential of space heating in residential sector is calculated using energy intensity of space heating in selected EU-member states as a benchmark. First, energy intensity of space heating in Ukrainian residential sector is estimated using indicators recommended by the IEA. Obtained result is then compared with relevant indicators from European countries with similar climate conditions. Final energy efficiency potential is calculated as a difference between actual space heating energy consumption of residential sector in Ukraine and potential energy use if energy intensity of the sector was the same as in selected EU countries. Countries, used as a reference, have been selected based on criteria of similar climate conditions measured in heating degree days (HDD) and high share of multistory apartment buildings heated via district heating.

Energy efficiency potential for district heating alone was also calculated. This was done to estimate potential specifically in multistory buildings (with five and more floors) located in urban settlements. This building category represented small share of whole housing stock in terms of number of buildings, but largest share of all households live in multistory apartment buildings. Sample of 42 energy audit reports of multistory buildings from Ukrainian cities was used to evaluate baseline heat consumption and potential savings after implementation of deep energy retrofit measures. Deep energy retrofit assumes comprehensive modernization of building' heating infrastructure and improvements of thermal characteristics by replacing doors, windows and insulation of walls, roof and basement. Using data from official housing stock statistics and information from 42 energy audit reports, whole housing stock in urban area connected to the district heating was then categorized by the 7 periods of construction. Energy efficiency potential is calculated for each of the building category and for the whole housing stock in cities connected to the centralized heat supply. Similarly, required investments were calculated for each of the building category and for all buildings stock with district heating. In order to make correct comparison with other recent studies, investment requirement is adjusted for inflation using consumer price index to reflect investment needs in 2015 prices.

Chapter 2

OVERVIEW OF RESIDENTIAL SECTOR

As of January 1, 2016, total housing stock of Ukraine consisted of almost 974 million square meters, according to the State Statistics Service of Ukraine. Floor area increased by 10 million m^2 in comparison with 2015, but 100 million m^2 less than in 2013. Twelve per cent reduction of floor area is attributed to the temporarily occupied territory of Crimea and part of ATO zone in Donetsk and Lugansk regions in Eastern Ukraine.

Average floor area per capita have not changes much over the last years and

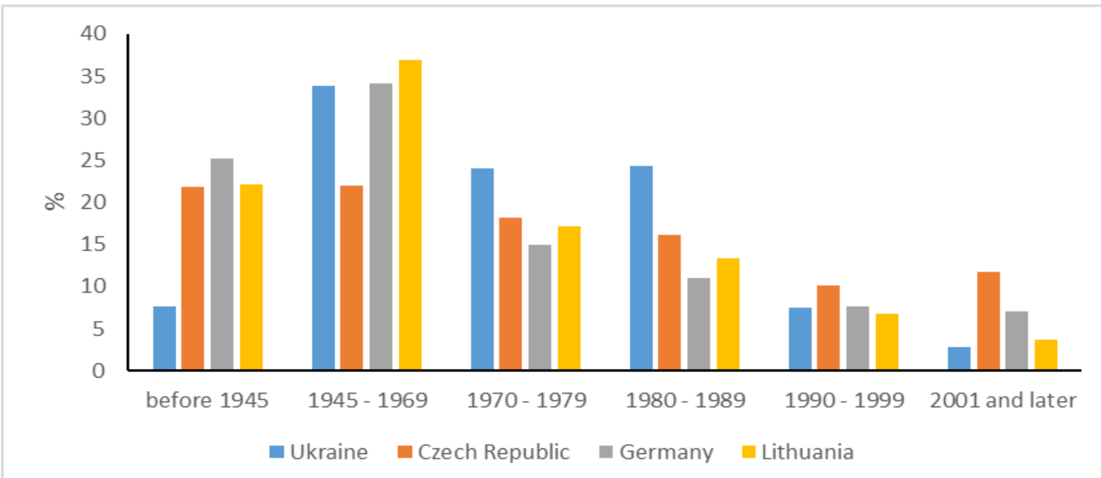

Figure 9. Distribution of housing stock by construction date in selected counties
Data source: Ukrstat (2016) and EC (2017)

was 23.8 m^2 in 2013. For comparison, in 2008 average per capita floor area in Romania was 24 m^2, 35 m^2 in Poland and 53 m^2 in Germany (Enerdata 2017).

In 2015, there were 16.8 million dwellings in Ukraine (number does not include occupied Crimea and ATO zone at Eastern Ukraine) or 57.9 square meter of floor area per dwelling (Ukrstat 2016b). To compare, average floor area of dwellings in the EU was 89 m^2/dwelling, Poland -73.4, Germany – 91.4 (Enerdata 2017).

Table 2. Selected indicators of residential and housing sector of Ukraine, 2011-2016

	Units	2011	2012	2013	2014	2015	2016
Floor area of residential stock	Mln m^2	1,031	1,038	1,045	1,047	966	973
Urban	%	64%	64%	64%	64%	61%	61%
Rural	%	36%	36%	36%	36%	39%	39%
Dwellings	thousand	19,327	19,370	19,368	16,785	16,886	16,867
Households	thousand	17,022	16,984	16,958	16,076	15,073	15,033

Data source: Ukrstat

Sixty per cent of total floor area (and 64% of all dwellings) located in urban area, while remaining share in rural. There are 9,1 million residential buildings, 36% of them in urban areas, while 64% in rural. Equal shares – 47% - out of 15 million households live in individual houses and apartments. Distribution of dwellings by number of rooms is following:

- single room – 13.3%
- two rooms – 34.3%
- three rooms – 35.4%
- four and more rooms – 17%.

Almost 90% of Ukrainian housing stock had been constructed more than 25 years ago using poor building codes and low thermal insulation requirements. Only 2.8% of buildings in Ukraine have been constructed in 2000s under new building codes. To compare, 11.7% of buildings in Czech Republic were constructed in 2000s, 7.1% in Germany, 3.6% in Lithuania.

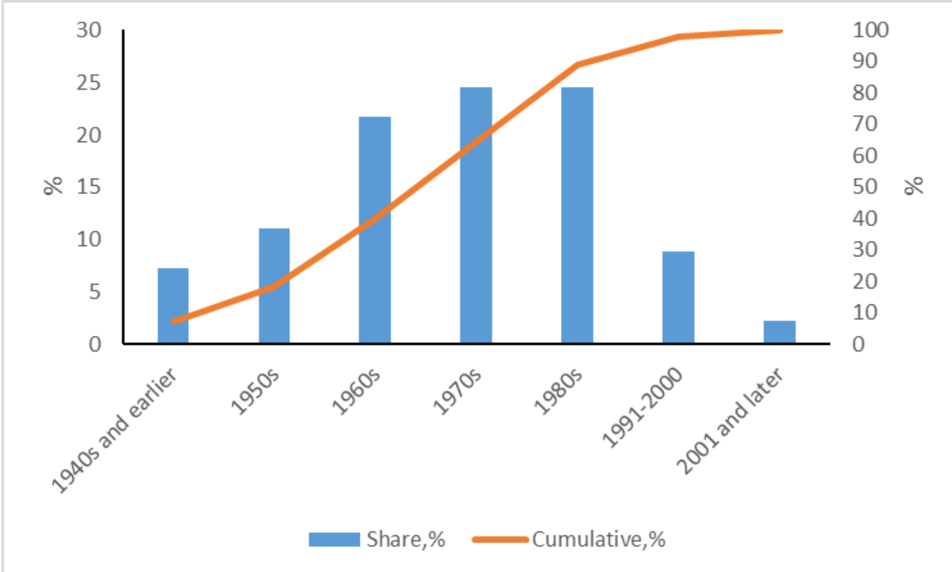

Figure 10. Distribution of households by time of housing construction
Data source: Ukrstat (2016b)

According to the Ministry of Housing and Regional Development of Ukraine multistory housing stock consists from 120,000 buildings (Minregion 2016b). 90% of that stock requires thermal retrofit. Majority of these buildings were constructed as mass series types of buildings during 1970-1980s. Eighteen thousand buildings constructed in 1970s should be retrofitted first, followed by 22.3 thousand buildings erected in 1980s (Segodnya 2016). Moreover, according to the State Statistic Service of Ukraine, as for beginning of the 2016, almost half of all households lived in dwellings and houses that have never went through major repair and renovation. Another 35% of all households live in dwellings with major repairs conducted more than 16 years ago. The most critical situation with obsolete housing infrastructure in big cities where 67% households live in housing without comprehensive renovation.

2.1 Energy Consumption of Residential Sector

High share of buildings constructed with poor thermal insulation requirements leads to inefficient and excessive energy consumption by residential sector. Even though energy intensity of residential sector improved by almost 3 per cent in 2014 in comparison with 2013, it still represents 56% that of the EU level. Increase in residential energy efficiency to EU level will decrease energy consumption of sector by almost 9 Mtoe or 33% of total energy consumption in 2014 (Dodonov 2016).

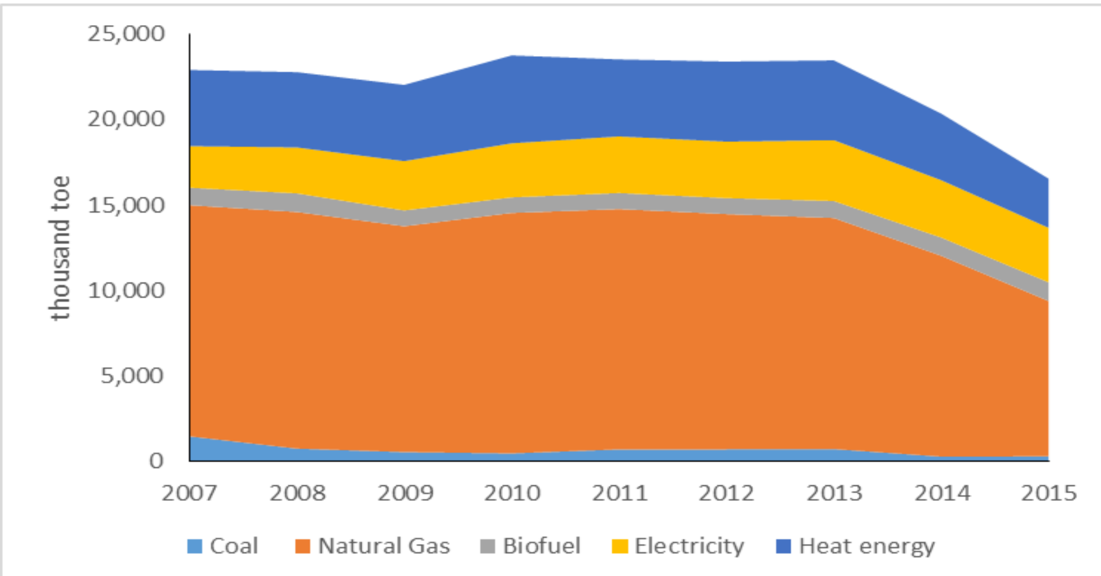

Figure 11. Energy consumption of residential sector in 2007-2015
Data source: Ukrstat, Energy balances 2007-2015

According to the State Statistic Service of Ukraine, final energy consumption by sector fluctuated around 23Mtoe over the period of 2007-2013 with slight decline to 22 Mtoe during world financial crisis in 2008-2009. However, there has been sharp drop in energy use starting from 2013. From 2013 to 2015 (latest available Energy balance) overall energy consumption by households dropped by 30%. Heat energy and natural gas consumption declined by 38 and 33% respectively. Dodonov (2016) claims that occupation Crimea by Russia and lost control over some territories in Eastern Ukraine are the main reasons for such dramatic decrease.

Table 3. Energy consumption by residential sector in ktoe, 2007-2015

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Coal	1,473	757	551	476	708	715	730	290	303
Natural Gas	13,522	13,840	13,213	14,063	14,060	13,760	13,513	11,743	9,083
Biofuel	1,024	1,089	921	914	937	936	996	1070	1,097
Electricity	2,430	2,688	2,886	3160	3,308	3,303	3,559	3,352	3,184
Heat	4,455	4,403	4,459	5,140	4,507	4,682	4,667	3,897	2,874
Total	23,001	22,845	22,084	23,813	23,604	23,466	23,495	20,384	16,554

Data source: Ukrstat, Energy balances 2007-2015

Residential sector represents 33% of total final energy consumption in Ukraine. It's biggest consumer of natural gas and biofuel, 57% and 86% respectively. Industry and residential sectors use equal share of heat energy – 38% each.

There have been only slight changes in structure of residential energy consumption during 2011-2015 period. Share of natural gas declined from 60% in

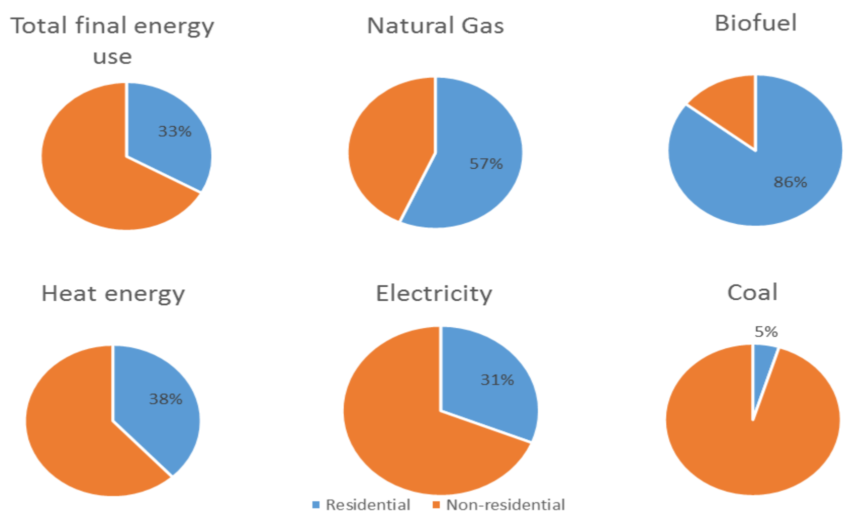

Figure 12. Share of residential energy use in final energy consumption in
Data source: Ukrstat. Energy balance 2015

2011 to 55% in 2015, driven by soaring natural gas prices. Similarly, for the same reason, heat energy use decreased from 19% to 17%. At the same time, share of electricity and biofuel rose by 5% and 3% respectively.

Households use natural gas directly and indirectly. Direct use comprises from customers who consume natural gas for individual heating, heating water and cooking. Households also consume natural gas indirectly as a centralized heat and hot water supply from municipal district heating companies, which mostly run on natural gas.

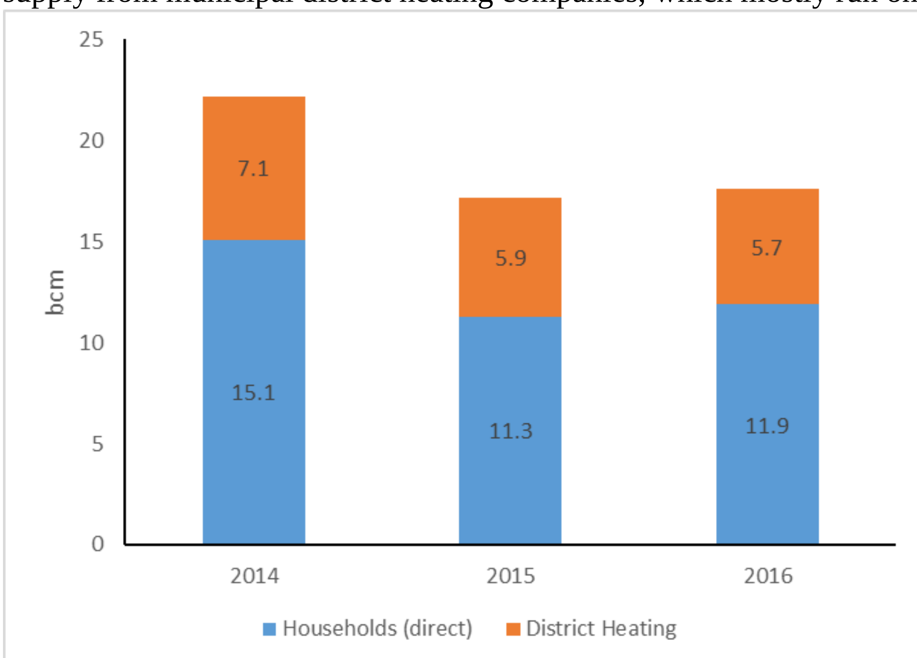

Figure 13. Natural gas use by residential sector in Ukraine, 2014-2016

Data source: Naftogaz (2017)

Direct natural gas consumption by residential sector has been stable during the period of 2006 – 2013. However, starting from 2013 gas use dropped by 6 billion cubic meters (bcm) or 35% compared to 2015 driven by increasing prices for natural gas supply. Direct natural gas use comprised from three categories of users. The first category consists from customers who use gas for individual heating, hot water and cooking purposes. It is the largest group in terms of both number of households and absolute consumption volumes. The second category uses gas for heating water and cooking. Finally, the third category represents households who uses natural gas for cooking purposes only (Naftogaz 2016c).

Table 4. Direct natural gas use by households

User category	Households	% gas use	bcm
Heating + hot water + cooking	7,469	91	10.829
Hot water + cooking	1,111	3	0.357
Cooking	4,468	6	0.714
Total direct use by households			11.9

Data source: Naftogaz (2016c)

2.2 District/individual Heating

Space heating – single most crucial energy service in household sector. More than half (52%) of residential energy consumption in IEA member-states accounts for space heating (IEA 2017a). District heating is considered as the most efficient, economically feasible and least polluting source of heating in urban areas with high population density (Lampietti, Meyer 2002).

As for January 2016, out of 15.03 million households, 37.5% were connected to the district heating systems, while 45.1% had individual heating. Another 16 % had stove heating (Ukrstat 2016b). Detailed data about arrangement of households' housing can be found in the Appendix A. 15.2% of floor area did not have any heating. Total floor area in 2016 was estimated as 973.8 million m^2 (592.5 urban, 381.3 rural). Therefore, out of 973.8 of total floor area, 827 million m^2 used some kind of heating.

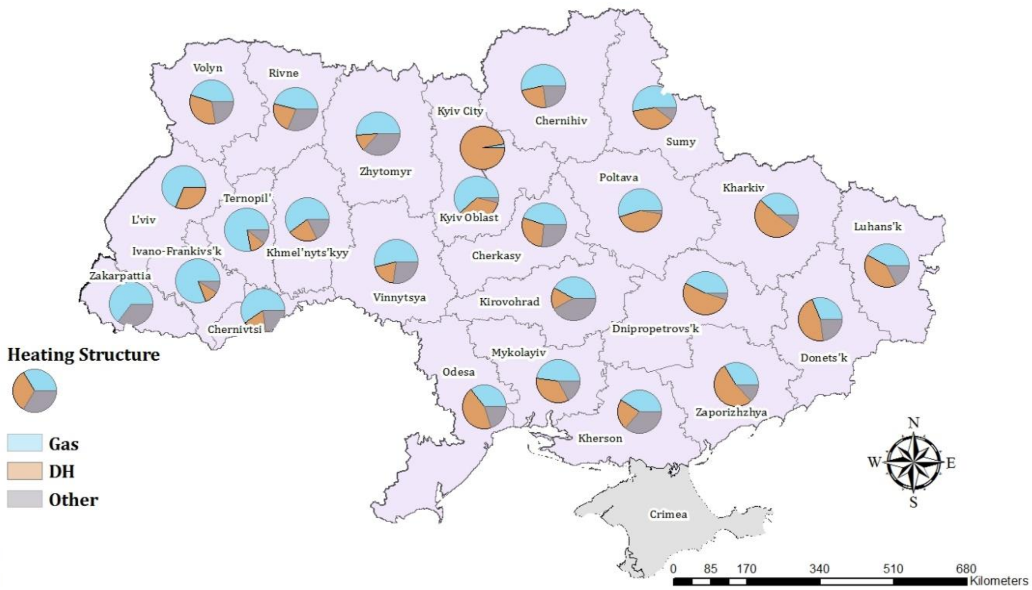

Figure 14. Structure of household heating resources

Data source: Minregion (2016)

Big cities and industrial centers such as Kyiv, Dnipro and Kharkiv have largest share of district heating in their heating structure. Accordingly, they are largest natural gas consumers for district heating and hot water supply. Dnipro and Kharkiv regions, together with Kyiv city account for about half of all natural gas consumed in Ukraine for district heating and hot water supply purposes.

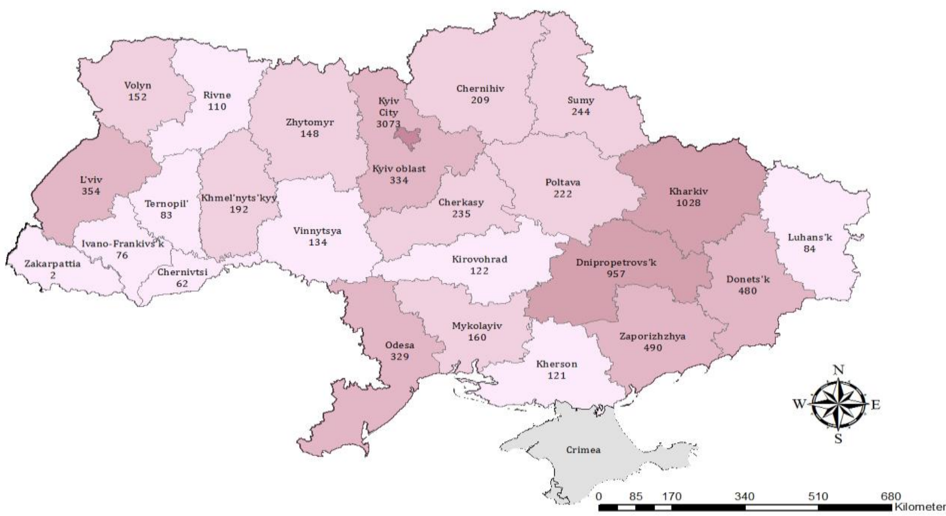

Figure 15. Estimated natural gas consumption for district heating and hot water supply
Dara source: Minregion (2016)

2.3 Tariffs

People respond to incentives (Mankiw 2014). And energy pricing is one of the key instrument that have profound impact not only on whole energy sector, but for other sectors of economy.

Development of Ukrainian energy market, especially, natural gas market has long and complicated history. Although this topic is not major focus of this paper, quick overview of relationship in this sphere can be valuable to understand overall context.

After collapse of the Soviet Union, non-transparent relationship between international and domestic actors in energy sector and manipulation with price formation for different categories of users created vast opportunities for corruption and rent-seekers in the post-Soviet countries in Central and Eastern Europe (Balmaceda 2008). This is especially the case for Ukraine where two decades of lack of transparency in gas import, export and domestic distribution led to multiple negative consequences that cover all aspects of social and economic development of the country. Constant disputes between Ukraine and Russia over natural gas supply issues have been highlighted and brought to international attention during 2006 and 2009 gas crises which resulted in disruption of natural gas supply to other European countries (Balmaceda 2015).

Rise of intermediary companies laid foundation for deep energy dependency from natural gas supply, encouraged wide corruption in state-owned energy companies and political establishment. The role of companies such as Itera, EuralTransGaz and RosUkrEnergo was to import natural gas from Russia at lower price and then resell it at higher price in Ukraine and other Eastern Europe countries and Baltic States. Not surprisingly, these companies and their owners, connected to top officials in Russia, Ukraine and other countries made fortunes on gas trade. Moreover, local natural gas production was primarily used for households. It had been supplied with artificially low, subsidized price while imported gas was delivered to industrial consumers at substantially higher price (Chow and Elkind 2009).

Distorted pricing mechanism on domestic market and absence of transparency and clear regulation between major actors caused profound negative effects on several areas. First, absence of investments in domestic natural gas production. It resulted not only in decline in investments at perspective gas-extraction sites, but also in maintaining output rate at existing wells. Second, reliance on a single natural gas supplier created significant threats for national and energy security. In its turn, natural gas supply dependency from Russia created opportunities for economic and political pressure on the Ukrainian government, high level corruption in two countries. Third, supply of large volumes of imported at high price natural gas to households with low, subsidized tariff created enormous payment deficit for Naftogaz, which in turn created pressure on state budget and fiscal balance. Finally, artificially low tariffs for households drove overconsumption and create disincentive for energy efficiency investments.

As was mentioned before, existence of different prices levels for different categories of consumers created enormous potential for corruption and rent extraction. Subsidized domestic gas intended for households at low-price was resold to industrial customers at much higher price creating vast fortunes for top-executives and officials in political establishment (Rozwałka and Tordengren 2016). During 2012-2013, price of natural gas supplied to industry and other customers were ten times higher than price for households.

Difference in prices resulted in underinvestment in domestic natural gas production. Low gas prices made domestic natural gas production uncompetitive. Stagnation of domestic extraction, in turn, led to increased reliance on imported gas.

Finally, regulated natural gas prices for different categories of customers

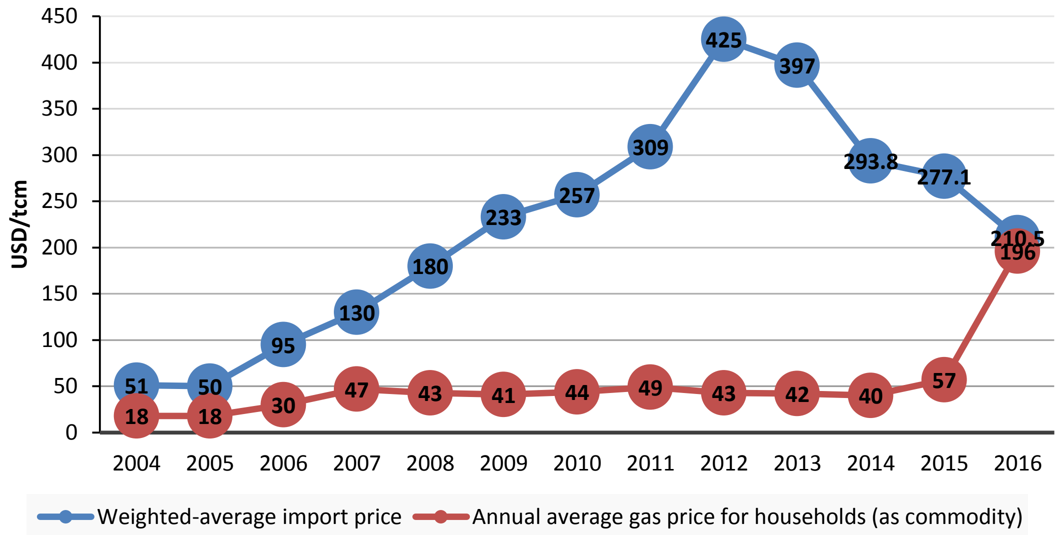

Figure 16. Comparison of annual average gas price for households and weighted-average import price, 2004-2016
Data source: Naftogaz (2015b), Naftogaz (2015a)

created enormous Naftogaz deficit, eventually covered by the state budget and increased public debt. In 2013, deficit of Naftogaz reached 2% of GDP triggered by decreasing sales to industrial customers and increased losses from gas supply to district heating companies. In 2014 alone, Naftogaz's deficit surpassed the rest of state budget deficit and reached 6% of GDP (Naftogaz 2015b).

To address increasing challenges in state finances and deteriorating fiscal misbalances the Government of Ukraine requested financial assistance from the International Monetary Fund (IMF). On April 2014, the IMF Executive Board approved 2-year $17 billion Stand-By Arrangement (SBA) program for Ukraine (IMF 2014). Later, in March 2015, the SBA program was canceled and replaced by the Extended Fund Facility (EFF). The EFF is four-year $17.5 billion program that is based on the SBA and envisions deeper reform commitments of the Government of Ukraine (IMF 2015). The Government of Ukraine committed to eliminate Naftogaz deficit by increasing natural gas and heating tariffs, improve revenue collection, decrease operational costs and restructure the management of the Naftogaz. Both programs, the SBA and EEF, envisioned gradual increase of gas and heating tariffs until full elimination of Naftogaz losses by 2018.

On May 1 and July 1, 2016, the Government of Ukraine published decisions to increase tariffs for gas and heating tariffs to cost-reflective levels. Ukrainian regulation prohibits to set tariffs for household utility services below cost-recovery level. However, before natural gas market reform, cost of gas as a commodity was artificially low because households and district heating companies were supplied with domestic natural gas at significantly low prices than imported gas (NERC 2016b). On April 27, 2016, the Government of Ukraine decided to change natural gas prices supplied to district heating companies (CMU 2016). According to the changes, import parity price of gas as a commodity increases to 4,849 UAH/tcm. Accordingly, with all other elements of cost of natural gas supply, final tariff for natural gas supply to household and district heating companies' increases to 6,879 UAH/tcm. Final tariff for district heating varies from region to region.

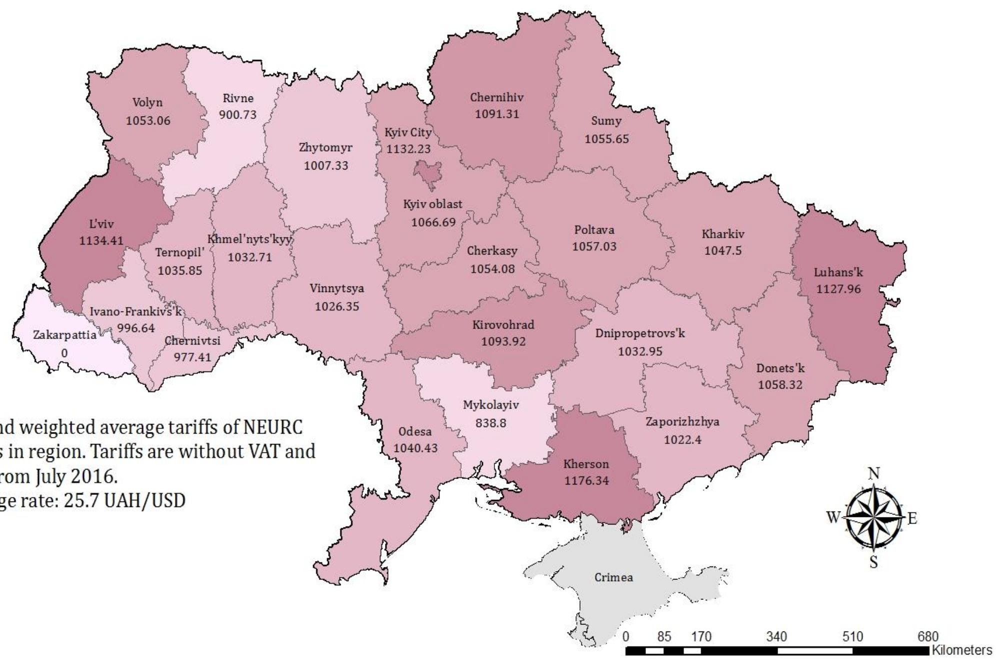

Figure 17. Tariffs for district heating across regions of Ukraine as of December, 2016
Data source: NERC (2016)

Structure of tariff for natural gas supply and heat supply from district heating companies presented below.

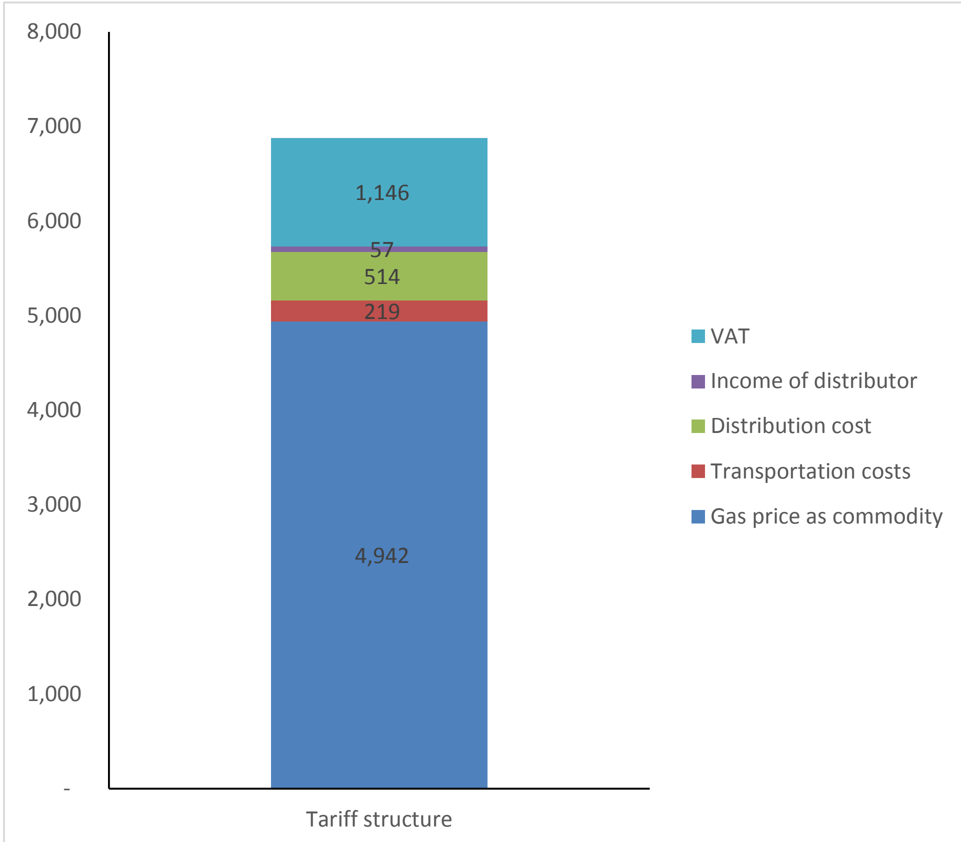

Figure 18. Structure of tariff for households and district heating active from May 1,2016 to March 31,2017
Data source: Naftogaz (2015)

To ensure that tariffs will remain at cost recovery level which is based on gas prices on international markets, periodical adjustments are needed until full liberalization of tariffs that should be implemented no later than April 1, 2017. At the same time, in order to protect vulnerable population from sharply raising tariffs while promoting incentives for energy efficiency investments, the Government of Ukraine committed to monetize subsidies to low-income groups by the end of the Q1 2017 (IMF 2016).

However, despite drastic tariff increase it is still one of the lowest between neighboring EU member states.

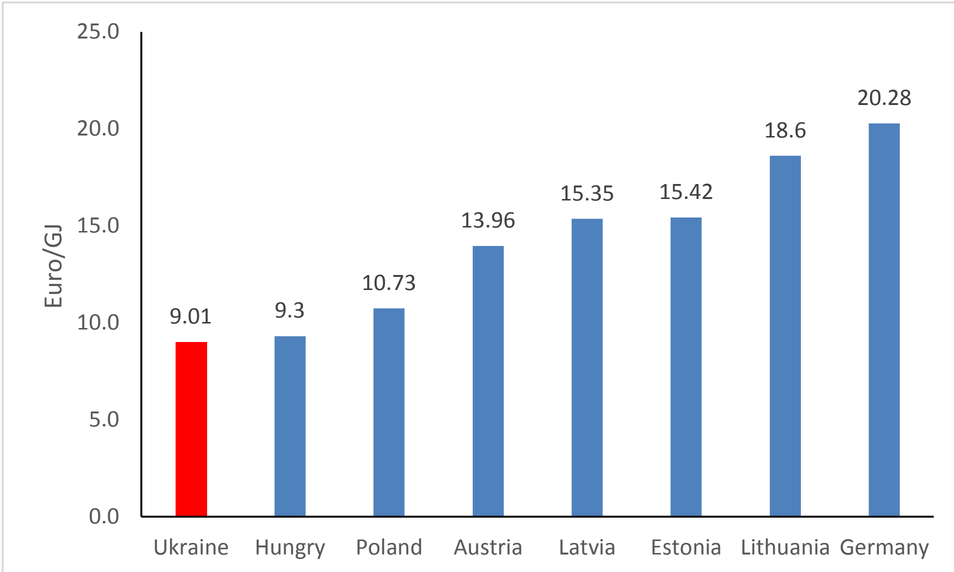

Figure 19. Tariffs for heat supply in Ukraine and selected countries

Data source: NERC (2017)

This and other activities in energy market reforms led to improvements in financial situation of Naftogaz and for state finances in general. Despite unresolved military conflict in Donbass and negative external environment GDP slowly but steadily increases, for the first time from 2012 (IMF 2016). Domestic production of natural gas increased by 200 million m^3 from 19.9 bcm in 2015 to 20.1 bcm in 2016. At the same time, consumption contracted by 600 m^3 from 33.8 to 33.2 billion m^3 (Naftogaz 2017a). Financial results of Naftogaz also demonstrates positive dynamics. During first 9 months of 2016 company declared income of UAH 25.5 billion (mostly driven by income from transit of natural gas) and no financial support from state. To compare, during the same period in 2015 Naftogaz reported UAH 25 billion loses and UAH 17 billion cash transfers from state budget (Naftogaz 2016a).

Energy price reform in gas and district heating supply implemented during 2014-2016 resulted in increasing of energy prices to almost 100% cost reflective and import parity. This had also significant effect on state finances. Despite removal of consumption subsidies, social protection of low-income groups still require large amounts of support from state budget. Context of energy subsidies development in Ukraine will be briefly described in following section.

2.4 Subsidies

Lack of reforms in energy sector combined with non-transparent energy price system led to persistent cross-subsidization in energy sector. Apart from other negative consequences described in previous section, energy subsidies have created enormous pressure on the state budget.

Until recently, chronical cross-subsidization covered main sub-sectors in Ukrainian energy industry. In order to avoid losses of political capital Ukrainian governments and political parties were reluctant to increase energy prices for households to a fully cost reflective level. As a result, energy industry have been suffering from persistent underinvestment. Most of the implicit and explicit subsidies have been used for natural gas/heat supply, coal extractive industry, electricity sector and indirect subsidies for households (IISD 2016).

	2012	2013	2014	2015	2016
Support measures in the gas sector	54%	47%	72%	58%	0%
Cross-subsidization in the electricity sector	28%	33%	20%	29%	0%
Support measures in the coal sector	10%	13%	5%	1%	4%
Targeted subsidies to low-income households	6%	6%	3%	12%	96%
Revenue foregone measures	2%	1%			
TOTAL, UAH million	124,871	114,933	202,829	153,240	37,651
TOTAL, USD million	15,609	14,367	16,902	6,965	1,448
Average Exchange rate, UAH/USD	8	8	12	22	26

Table 5. Government support measures to production and consumption of fossil fuels
Data source: IISD (2016); NBU (2017)

International Monetary Fund estimated that in 2012 alone, on- and off-budget post-tax energy subsidies[1], mainly dominated by gas subsidies, accounted for 7.6% of GDP. From this amount only 1.3% of GDP were budget-financed energy subsidies. The remaining 6.3% were off-budget subsidies aimed to cover financial loses of energy state-owned enterprises that supplied energy to households with price below cost reflective level financed by increasing governmental debt via state bonds or other fiscal instruments not reflected in the state budget. At the same time, most of these subsidies have been captured by middle- and high-income groups (IMF 2014).

[1] Post-tax energy subsidies is a sum of pre-tax subsidies, defined as a difference between benchmark price and price paid by end-user plus cost of correction for externalities, such as pollution, not reflected in cost of energy. More details about different types of energy subsidies will be provided in Chapter 4.

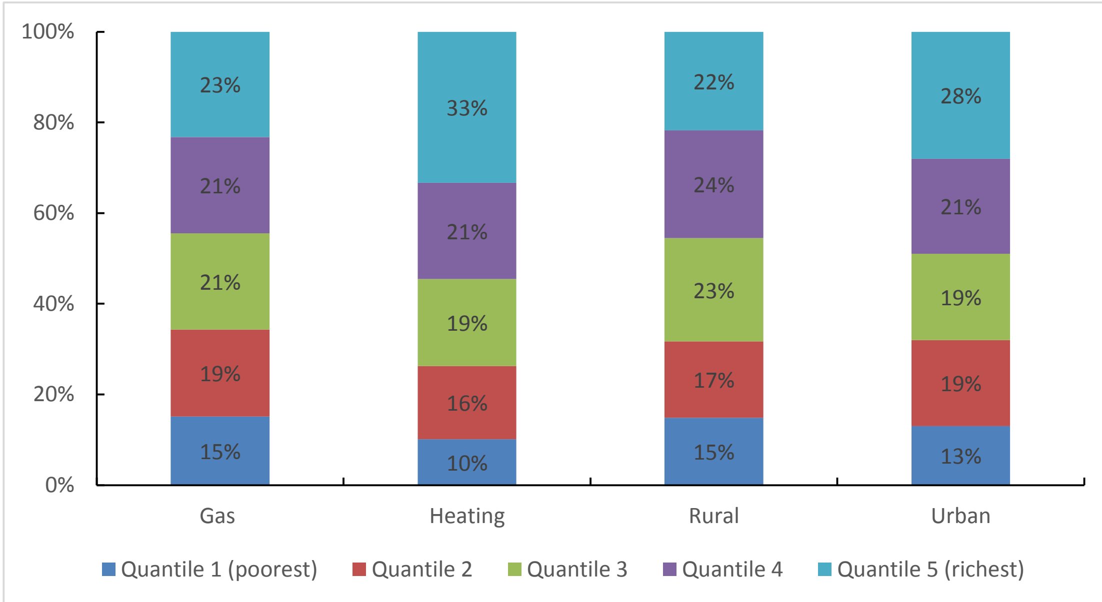

Figure 20. Distribution of energy subsidies by income groups (as of 2012)
Data source: IMF (2014)

Energy subsidies peaked during 2012-2014 driven by huge difference between costs of imported natural gas and cost of natural gas supplied to households. In 2014, explicit subsidies, reflected in the state budget accounted for almost 1% of GDP, while another whopping 5.6% of GDP were accounted for implicit subsidies in natural gas supply for households (Rozwałka and Tordengren 2016).

As part of agreement with the IMF and in order to reduce large budget deficit, the Government of Ukraine in 2015 started adjustment of natural gas prices to import parity level. As a result of price increase and other restrictions of state spending, government deficit (including Naftogaz) in 2015 accounted just 2% of GDP compared with 10% in 2014 (World Bank 2016). Deficit of Naftogaz alone decreased from 5.6% in 2014 to just 0.9% of GDP in 2015 (World Bank 2015c). However, increased prices for natural gas eliminated implicit subsidies but required substantial budget support for low-income groups.

With elimination of off-budget support to natural gas supply to households and sharp increase of prices for all customer categories to import parity level, the Government introduced financial support to protect poor from energy price shocks. The eligibility and conditions for energy subsidies from state changed several times over 2014-2016 period. To apply for subsidy household should submit application and income declaration which reflects total income of all members of household. Amount of subsidies are based on total income of household and total cost of household utility services consumed. Since some utility services such as district heating supply and natural gas supply are not yet 100% metered, total cost of energy use of the households is calculated by using characteristics of dwellings (such as area of dwelling) and social norms of household utility services use. Social norms of consumption of energy have been generally decreasing over 2014-2016, but still considered by some researchers as too high relative to actual consumption (VoxUkraine 2016).

Starting from 2015 both application for state subsidies and total volumes of subsidies have been constantly increasing. Following several price adjustments during 2015-2016 number of application for energy subsidies has been growing every year in comparison with same month of previous year.

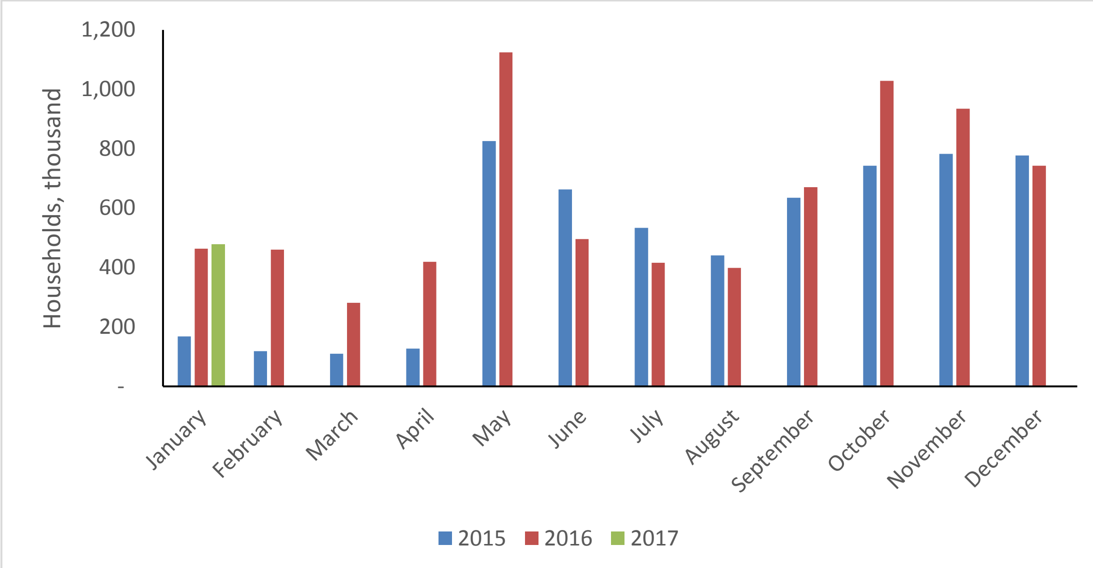

Figure 21. Monthly distribution of applications of households for subsidies

Data source: Ukrstat (2017)

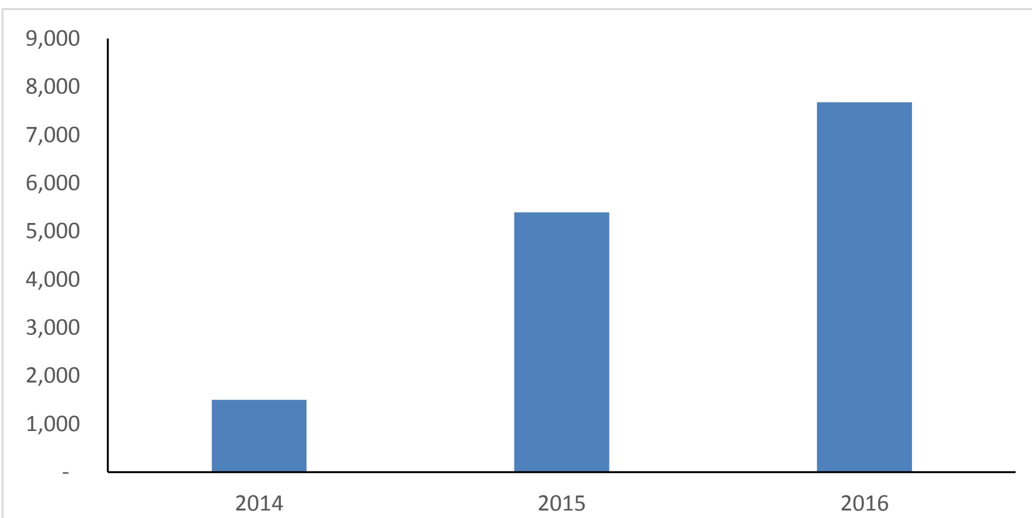

Figure 22. Number of households receiving energy subsidies

Data source: Ukrstat (2017)

According to the State Statistics Service of Ukraine, more than 7.6 million households were receiving subsidies, a 42% increase than in previous year.

Amount of subsidies in monetary terms has also been raising rapidly.

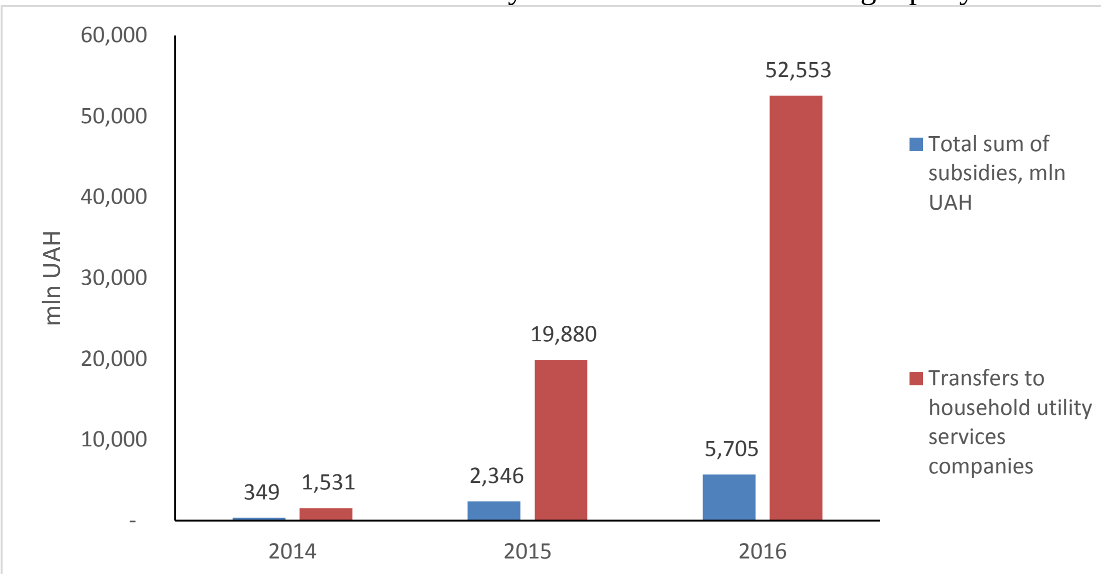

Figure 23. Amount of subsidies to households and companies that provide household utility services
Data source: Ukrstat (2017)

Total sum of subsidies provided to households increased from 349 million UAH in 2014 to more than 5.7 billion at the end of 2016. At the same time, amount of cash transfers to the companies that provide household utility services (mainly gas, heat and hot water supply) sky-rocketed from UAH 1.5 billion in 2014 to 52.5 billion in 2016. Households who live in urban areas account for more than 60% of all subsidies for household utility services. Regional distribution of state subsidies in 2016 can be found in Appendix D.

Amount of subsidies for 2017 is assumed to be similar to 2016. However, Government of Ukraine is planning to monetize subsidies, i.e. fully transform them into direct cash transfers to the households (Ukrinform 2016).

2.5 Energy Efficiency in Residential Sector

Ukraine has vast untapped energy efficiency potential. International Energy Agency (2012) points out at large energy savings potential in Ukraine. Citing Maissner et al. (2012), IEA's country report claims that if Ukraine's energy efficiency level was the same as of the European Union, 27 Mtoe of energy consumption could be saved annually. Imposing enabling legal framework for energy efficiency investments in buildings and industrial sector is one of the main challenges for policy makers, according to the report.

Using methodology of the International Energy Agency, Dodonov (2016) compares energy efficiency of the European Union and Ukraine. He concludes that increase of Ukrainian energy efficiency level to that of EU average level, Ukraine can reduce energy consumption by 27.1 Mtoe. This represents of 53 per cent of total final energy consumption of Ukraine in 2015. In other words, energy efficiency improvements alone can decrease energy consumption of Ukraine by half. In terms of natural gas this potential constitutes 27.1 billion cubic meter of gas which is 1.5 times more than Ukraine imported in 2014. Largest potential for reduction in energy consumption have industry and residential sector – 33% each. The remaining efficiency potential is in energy transformation and service sectors.

Table 6. Estimation of energy efficiency potential in Ukraine, 2012-2014

	Energy efficiency, % to EU			**Energy savings potential, 000 toe**		
	2012	**2013**	**2014**	**2012**	**2013**	**2014**
Ukraine	**57.1**	**58.2**	**60**	**33,996**	**32,165**	**27,127**
Agriculture	**77.2**	**74.5**	**119.4**	**499**	**572**	**(392)**
Industry	**57.1**	**62.1**	**59**	**11,673**	**9,421**	**9,233**
Mining	**41.3**	**41.2**	**37.1**	**952**	**978**	**983**
Manufacturing	58.1	63.6	60.6	10,721	8,443	8,250
Food & Tobacco	59.8	47.5	62.5	771	871	630
Textile & Leather	58.5	74	74.5	31	16	14
Wood	45.8	39.9	45.3	90	117	101
Paper & Printing	112.9	127.8	125.5	(37)	(78)	(61)
Chemical	18	38	51.5	1,985	1,108	562
Non-metallic minerals	47.2	51.5	59	830	745	512
Steel industry	66	70.2	61.7	6,091	4,975	6,007
Machinery	17.1	23.5	22.5	676	509	393
Transport equipment	37.6	44.5	52.5	283	18	91
Construction	17.7	17.4	20.9	338	311	217
Services	**32.8**	**31.4**	**35.2**	**3,387**	**3,940**	**3,020**
Residential	**53.1**	**53.1**	**56**	**11,005**	**11,008**	**8,968**
Fossil Fuel Power Plants	**66**	**65.9**	**66.2**	**7,093**	**6,913**	**6,081**

Data source: Dodonov (2016)

One of the first attempt to estimate energy saving potential in the residential sector had been made by Worley Parsons's report commissioned by the European Bank for Reconstruction and Development (EBRD 2011). The study estimates technical energy saving potential of residential sector as 136 million MWh/year (11.7 Mtoe/year[2]) or roughly half of actual consumption by this sector in 2011. If delivered,

[2] Conversion rate 1 MWh = 0.085 toe

energy savings measures will result in €2.6 billion ($2.78 billion) of monetary savings annually. According to the report, wall insulation provides highest savings – 35%. But this measures is also the most expensive among others. Total required investments are estimated as €41.9 billion ($44.8 billion).

Table 7. Estimation of energy efficiency potential and required investment

Measures	**Savings, MWh**	**Savings, Mtoe**	**Savings, %**	**Investments required, mln €**
Additional insulation of walls	47,410,354	4.07	35%	€ 14,700
New windows	25,914,884	2.22	19%	€ 10,300
Additional insulation of roof	26,309,974	2.26	19%	€ 8,600
New automated substation and TRV[3]	14,800,732	1.27	11%	€ 1,700
Indoor lighting replacement	5,226,509	0.44	4%	€ 200
Replacement heat generator with high efficient boiler	16,433,639	1.41	12%	€ 6,400
Total savings, Ukraine	**136,096,092**	**11.67**		**€ 41,900**

A study conducted by Energy Savings International AS and financed by the Energy Community analyses energy efficiency potential in buildings among member states of the Energy Community (ENSI 2012). Study convers potential of family houses, apartment buildings, healthcare facilities, education, other service and commercial types of buildings. Using thermal, geometrical and technical properties of

[3] TRV - thermostatic radiator valves

each of building categories and comparing them with reference building report estimated cost effective energy savings potential of buildings stock. According to the report, all considered building categories in Ukraine have energy saving potential of 28.1 TWh annually or 2.41 Mtoe. Required investments estimated as 7.89 billion Euros ($8.34 billion). Aggregate investments requirement as well as estimated savings potential across buildings categories presented in table 7.

Table 8. Estimated investments needed and energy saving potential in Ukrainian buildings

Building category	**Savings**		**Investments required**
	MWh/a	€/annually	€
Individual houses	15,938,900	261,293,300	3,575,592,800
Apartment buildings	9,744,500	320,808,300	3,037,653,700
Healthcare	475,300	26,543,750	286,281,250
Education	1,717,100	85,714,300	874,857,100
Other (services, trade)	226,000	11,760,000	117,585,000
Total	28,101,800	706,119,650	7,891,969,850

Data source: ENSI (2012)

In special report dedicated to energy efficiency of heat supply in Ukraine commissioned by the United Nations Development Program, Dodonov (2015) compares efficiency of heat supply in Ukrainian residential sector with the energy efficiency indicators in the EU countries. In this report, he also ranks most efficient and inefficient Ukrainian regions in terms of heating in residential sector. He concludes that if energy efficiency of residential in Ukraine will be the same as of the EU, potential energy savings can reach 8.4 Mtoe annually. These savings are also equivalent to 10.3 bcm of natural gas use, which represents half of Ukrainian natural gas import in 2013 with total cost of $4.3 billion.

In its annual report for 2015 the NJSC "Naftogaz of Ukraine" (Naftogaz 2015b) asserts that over the last ten years Ukraine has spent more than $50 billion on subsidizing natural gas supply for residential sector. At the same time, full-scale modernization and retrofit of residential sector of Ukraine was estimated as $36 billion, implying that instead of subsidizing natural gas supply to households, the government could invest in residential stock retrofit.

Table 9. Estimate of investments requirement for household sector modernization

Measure	**Investments required, billion $**
Insulation of apartment buildings	$15.9 billion
Insulation of private houses	$14 billion
Upgrading networks of heat producers	$3.7 billion
Metering and thermoregulation in apartment buildings	$2.4 billion
Total	**$36 billion**

Source: Naftogaz (2015b)

Kovalko (2015) estimated market for ESCO in energy retrofit of Ukrainian housing stock. He calculates potential energy savings in Ukrainian residential stock by assuming that in 2020 residential energy use by Ukrainian buildings will have the same heat use indicators that Germany had in 1984/1995. Potential energy savings in residential sector estimated as 12.3 and 10.5 bcm annually for final and heating energy use, respectively (about 20-30% of total final energy consumption). In terms of MWh potential savings estimated as 114.9 TWh (or roughly 9.76 Mtoe[4]). To achieve this

[4] Conversion rate 1 MWh = 0.085 toe

savings, as much as $46 billion should be invested in deep energy retrofit for residential buildings.

The Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine in cooperation with international organizations prepared a comprehensive report about residential sector of Ukraine (Minregion 2016a). According to the report, $6.5 billion lost annually as economic losses caused by excessive consumption, expenditures on gas import and energy subsidies. Improvements in buildings (both residential and public) thermal insulation has highest potential in increase of energy efficiency in Ukraine and in reduction of natural gas consumption. Total potential natural gas savings are estimated as 11.4 bcm annually, which represents more than half of natural gas import. While insulation of building provides highest gas reduction potential, the most efficient measure in terms of investments is modernization of both individual and district heating boilers as well as modernization of district heating pipeline networks. Report does not mention which methodology has been used in calculating energy reduction potential.

Table 10. Estimation of energy efficiency potential and required investment

Measures	**Gas consumption reduction potential**	**Investments required**	**Gas consumption reduction per $1 billion of investments**
Insulation of multistory buildings	2.3 billion m^3	$17 billion	135 million m^3
Insulation of individual houses	4.7 billion m^3	$28 billion	168 million m^3
Modernization of individual boilers	1.7 billion m^3	$4 billion	425 million m^3

Insulation of public buildings	0.3 billion m^3	$2 billion	150 million m^3
Modernization of heat production system and networks	2.4 billion m^3	$6 billion	400 million m^3
Total	**11.4 billion m^3**	**$57 billion**	

Data source: Minregion (2016a)

Energy subsidies, which will be further discussed in the next chapter, for decades have been major barrier for investments in energy infrastructure and energy efficiency improvements, especially in residential sector. As Pascual and Elkind (2010) claim:

> “Instead of proceeding with energy reform designed to promote transparency and economically rationally outcomes, Ukraine has used the energy sector as a massive domestic subsidy vehicle…Inevitably, that means that Ukrainian taxpayers subsidize energy consumption, which, rather than promoting energy efficiency, only adds to the demand”.

Transforming energy subsidies into investments in energy efficiency is set as one of the goal of Government of Ukraine (Government of Ukraine 2016).

Table 11. Summary of studies in energy efficiency potential and required investments

Source	Sector, year	Potential savings	Investments required
EBRD (2011)	Residential, 2010	11 Mtoe	€ 41.9 billion
IEA (2012)	All sectors, 2010	27 Mtoe	N/A
ENSI (2012)	Buildings, 2012	2.41 Mtoe	€ 7.81 billion
Kovalko (2015)	Buildings, 2010	9.76 Mtoe (114.9 TWh)	$46 billion
Naftogaz (2015)	Residential, 2015	N/A	$36 billion
Dodonov (2015)	Residential, 2013	8.4 Mtoe	N/A
Dodonov (2016)	All sectors, 2014	27 Mtoe	N/A
Dodonov (2016)	Residential, 2014	8.9 Mtoe	
Minregion (2016a)	Residential, 2015	11.4 bcm natural gas	$57 billion

Studies show that Ukraine has enormous untapped potential for energy efficiency improvements. By increasing energy efficiency of Ukraine to that of EU level, the country can reduce its energy consumption by half. Industry and residential sectors share largest portion of this potential – 33% each. Comprehensive modernization of housing and district heating sectors can decrease natural gas consumption by more than 11 billion m^3, or more than half of current natural gas import. This will have profound positive implication on trade balance, national and energy security and will reduce pressure on national currency. Until recently, cross-subsidizing of natural gas supply has been major factor of lack of transparency and investments in energy infrastructure. Turning energy subsidies into investment can provide financing, necessary for full-scale modernization of housing sector of Ukraine. Residential energy efficiency market of Ukraine is estimated as $36-57 billion.

2.5.1 Analysis of Barriers and Reasons of Current Energy Crisis

If country has so large untapped energy efficiency potential, why large-scale implementation of energy efficiency measures are not occurring? Like in other developing countries, Ukrainian energy efficiency sector is suffering from numerous barriers. Biggest international development organizations that are operating in Ukraine, such as the USAID, the EBRD and IFC identified following major barriers (Rada, 2015):

- Weak legislative and regulatory environment that prevent energy efficiency investments, which include not clear definitions and responsibilities of ownership authorities and management in multifamily residential houses;

- Financial resources are generally available, but cannot be effectively utilized because of poor governance, high transaction costs and associated risks;

- Still persistent subsidies system (although there is a significant progress that has been achieved recently);

- Poor governance and significant institutional capacity gaps which manifested in lack of coordination between different state agencies and ministries responsible for energy efficiency;

- Unstable macroeconomic environment results in high interest rates and therefore high payments and lack of financial motivation in energy efficiency investments;

- Lack of information and low public awareness about existing policies, technologies, incentives, benefits and successful stories.

Countrywide sociological survey about attitudes of Ukrainians toward energy efficiency and conservation confirms that lack of awareness among population is one of the biggest challenge to be addressed (NECU 2015). The results of survey demonstrated significant challenges for policy makers to plan, design and implement successful energy efficiency policy. Absolute majority of respondents (86%) think that

> "central and local authorities have to take responsibility for development and implementation of energy saving programs in households".
>
> Moreover, report concludes,
>
> "collective energy saving measures in multistory buildings can be characterized with a relatively low popularity".

In other words, most of the surveyed individuals are reluctant for self-organization into collective entity that will run and share responsibility on the multi-stored residential buildings – step necessary for increasing energy efficiency in highly ineffective residential sector in Ukraine. Furthermore, due to lack of information (one of the most common in all developing countries market barrier), almost 80% of Ukrainians believe that in general population consumes insignificant amount of energy and therefore, there is no urgent importance of aggressive and active energy efficiency improvements in residential sector. In fact, in 2013, for the first time, the residential sector became the biggest consumer of energy (33.8% of TFC) followed by industry (31.5%) and transport (16.2%). What are the reasons for such attitude of population?

It is widely accepted that each developing country has market failures and barriers that are generally common almost for other countries (such as subsidies, lack of regulatory and policy capacity, underdeveloped financial system etc.). At the same time, each country has its own unique and contextual factors that possess significant barriers. Ukraine, therefore, also has its unique features of energy efficiency market development. Those features are deeply rooted in history, culture and shapes social-behavioral aspects of market energy development.

Paternalism and ex-Soviet mindset

As a result of long period of colonial and soviet oppression, Ukrainian society has strong public request on paternalism (Naftogaz 2015a). During these periods, citizens had not had an effective means of influence on governance. That resulted in formation of behavioral pattern in which citizens avoid responsibility for their actions or tend to shift this responsibility to others. State-subsidized prices of basic goods, selective justice, non-accountability of government that adopts political decisions rather than legal - a component of culture that has evolved over the centuries. Finally, relying on Government, Ukrainians do not trust it. While it’s known that public participation in decision making process brings legitimacy to decisions and increase efficiency of local and governmental policy (Sanders et al. 2014), centrally planned, hierarchical society, inherent to the ex-Soviet countries including Ukraine, suffered from very law legitimacy, community involvement and public acceptance of energy policy. Consequently, energy transformation towards sustainable energy policy in ex-communist society is impossible without interactive policy-making, increasing role of communities, public involvement and rule of low based on democratic institutions.

Networks, prime movers and institution gap

As Jacobsson and Johnson (2000) pointed out, not only market and institutional failures are influence transformation processes. It is also network failure that prevents emerge of new technologies and leads to the weak connectivity between actors favoring new technologies and new energy systems. Therefore, for more rapid policy and institutional changes that will boost energy system transformation "prime movers" are required. Those are the most active actors on the market that will raise public awareness, shape and influence local and national political agenda, and create networks of producers, suppliers and consumers, develop market knowledge, competence and will overcome resistance of an "incumbent" energy system. Lack of networks, strong prime movers with significant organizational and financial capabilities can be attributed to the reasons that prevent strong energy efficiency market development and diffusing in Ukraine.

It also can be argued that post-communist countries have unique combination of market failures that make sustainable energy transition in general and energy efficiency policy development in particular are extremely complicated. Abrams and Fish (2015) provide analysis of public institutions development in post-communist countries. They argue that in contrast to currently widespread beliefs in academic environment, policies are the first prerequisite to successful economic development and only then followed by institutions. They conclude that among all new independent states that emerged in Eurasia after collapse of the Soviet Union and former Yugoslavia, the Estonian case showed most prominent results in conducting successful economic reforms. And the main reasons for that success were ideologically driven leaders, which imposed “hard budget constraints” (HBC). HBC immediately removed state subsidies, soft loans and other privileges that were mostly utilized by individuals, who build fortune on unfair political and economic competition. Therefore, it can be concluded that most of the reforms and technical assistance in energy sector provided by international financial institutions (such as IMF, the World Bank Group, the EBRD, the USAID, SIDA, GIZ etc) to developing countries, including to Ukraine, failed mostly because main barriers such as subsides, soft loans, lack of transparency in public institutions and funds are still in place.

ESCO market

Direct role of some of these barriers in market failures has been demonstrated for energy service companies (ESCO) market in Ukraine (Yang, Yu 2015). In particular, analysis of ESCO project financed by Global Environmental Fund (GEF) during 1998-2013 identified following barriers that prevent development of ESCO market in Ukraine:

1. While ESCO business model is commonly deals with energy efficiency projects, Ukrainian ESCO project in Rivne focused mostly on construction and modernization of boilers in district heating system in Rivne;
2. Unlike to international standards and practice, ESCO projects in Rivne were financed through grants without involvement of business capital or funds from homeowner associations which implies that funds received from grants are not included in balance sheet of ESCO as well as in tariff and, therefore, subsidized energy prices while encouraging more energy demand;

3. Subsidized natural gas prices and tariffs for district heating provided disincentives for any projects in energy efficiency improvements making them financially unsustainable;

4. With one of the highest cost of capital among European countries, Ukrainian ESCO projects were struggling to attract financing from commercial banks;

5. Savings share between ESCO and municipal customers (schools, hospitals etc) were not clearly defined in legislation which put additional risk for ESCO projects.

Combination of traditional and country specific barriers had made ESCO model financially not sustainable, too risky and costly. In the result ESCO model – one of the most common mechanism for energy efficiency improvements and proved to be effective in the US and China didn’t takeoff in Ukraine.

Even though in 2015 and 2016 legislative regulation for ESCO contracts in municipal area had been significantly improved, municipal entities were still reluctant to sign ESCO contracts. As for first half of 2016, none of the municipal entities signed ESCO contracts (Minregion 2016c).

Chapter 3

SCALING-UP DEEP ENERGY RETROFIT IN UKRAINIAN RESIDENTIAL SECTOR

3.1 Energy Efficiency of Space Heating in Residential Sector

As was discussed in Chapter 1 Ukraine has large untapped energy efficiency potential across all sectors. Several studies estimate that by increasing level of energy efficiency to that of EU average, Ukraine can decrease energy consumption by 27 Mtoe or 44% of baseline total final energy use in 2014 (61.4 Mtoe). Industry and residential sectors have largest potential for energy consumption reduction due to efficiency improvements. While detailed description of energy efficiency potential in all sectors with particular focus on households have been made in Chapter 1, this chapter will evaluate energy efficiency potential for space heating in residential sector.

3.1.1 Methodology

Analysis of driving forces of change in energy consumption can provide valuable insights for policy analysts. Measuring and quantifying consumption patterns over some period of time provides foundation for cross-country analysis, impact evaluation of enacted policies and technologies. For this purpose decomposition analysis for space heating energy use was conducted.

Several methods have been developed to analyze underlying factors of change in energy demand. Collectively they can be divided as aggregated and disaggregated. Latter case provides most accurate and meaningful results about energy demand characteristics of a country in general or sector in particular (for instance, natural gas consumption per detached dwelling). Aggregate method, on a contrary, is focusing on top-down approach where country's demand is analyzed with aggregate sectoral level (for example per capita energy consumption) (Bhattacharyya 2011).

Most common methods used for decomposition analysis of energy demand are Laspeyres method, Paasche index, Simple average divisia method, Fischer Ideal, Parametric Divisia Method I (PMD I) and II (PMD II), Log Mean Divisia I (LMD I) and II (LMD II) (Heinen, Week 2013). In comprehensive study Ang and Zhang (2000) reviewed 124 papers on energy decomposition methods and concluded that Laspeyres index method was the most commonly used among researchers. The International Energy Agency (Heinen, Week 2013) also asserts that Laspeyres, as well as LMD I were preferred methods for decomposition analysis.

For simplicity and due to lack of data, to analyze driving factors for change in energy consumption in Ukraine during 2010-2015 Laspeyres method was used. The IEA defines three major factors that affect energy demand: activity level, structure and energy intensity (OECD 2004). Laspeyres method allows to evaluate impact of all of these three factors on residential energy use. According to the methodology, energy consumption of residential sector is a sum of energy use in five sub-sectors: space heating, water heating, cooking, lighting and appliances.

This paper analyzed changes in residential space heating only. Each factor is calculated while others are kept constant. Activity factor represents changes in population of the country during considered period. Energy intensity of residential sector is calculated as energy use of residential sector divided by floor area heated. Finally, structure is measured as floor area heated per capita (Bhattacharyya 2011).

Specifically, changes in activity effect is calculated as:

$$Q_{effect} = (Q^t - Q^0)\sum EI^0 S^0$$

where,

Q – change in population, S – change in structure, EI is energy intensity, 0 – represents a base year, t – represents end year.

Similarly, change in intensity is calculated as follows:

$I_{effect=} (Q^0)\sum(EI^t - EI^0)S^0$

Finally, structure effect is calculated as follows:

$S_{effect=} (Q^0)\sum(S^t - S^0)EI^0$

Overall change in energy use (by each sector) can be calculated using the following formula:

$\Delta E = Q_{effect} + I_{effect} + S_{effect}$

Energy efficiency potential for space heating was estimated using following steps. At first, energy intensity of space heating in residential sector was calculated. Achieved results then compared with selected EU member states. Using energy intensity of space heating in EU countries as a benchmark, potential reduction in energy consumption for space heating in Ukraine was estimated. Using structure of final energy use in residential sector in terms of both Mtoe and bcm, potential reduction of gas consumption for space heating needs was then calculated.

Energy intensity of space heating in residential sector can be estimated in terms of energy used per capita, per dwelling and per square meter of floor area. These are indicators of second level as opposed to more aggregated indicators of first level such as total space heating consumption and contribution of each energy source to final energy use for space heating. International Energy Agency (2014, p.46) recommends to use as an indicator space heating energy consumption per floor area heated. To calculate the heated area, a total floor area in a given year was adjusted so that only permanently occupied dwellings were included. To do that, total area was multiplied by factor that represents share of total area with any kind of heating. Heating can be provided by means of district heating networks, individual heating mostly using gas fired boilers and stoves that burn biofuel (i.e. wood) and coal.

To estimate total energy used for space heating final energy consumption by residential sector was adjusted to exclude energy that was not used for heating purposes. For the purpose of this modeling, total electricity energy use was excluded from heating, while natural gas consumption was adjusted to exclude share of natural gas used for cooking and hot water heating.

Final energy intensity for heating was then calculated by dividing energy used for heating in Mtoe by total floor area heated. Final energy intensity of space heating in residential sector of Ukraine is then compared with intensity indicators of some EU member states that have similar climate conditions, measured as Heating Degree Days (HDD). Based on 5-year average HDD criteria with base temperature of 15.5 C Poland and Latvia had been selected as benchmark countries with similar climate conditions. Germany was also included as benchmark country and as an example of country with one of the most aggressive building retrofit program.

Table 12. Average 5-year HDD in selected countries, 2012-2016

Country	Weather Station ID	HDD
EU27	Average*	2098
Germany	EDDB	2433
Czech Republic	LKPR	2678
Poland	EPWA	2720
Ukraine	UKKK	2970
Latvia	EVRA	3265
Lithuania	EYVI	3331

Estonia	EETN	3468

Source: DegreeDays.net (2017), EEA (2016)
* - for the EU value is average across all member-states during 2010-2014

Methodology for estimating energy efficiency potential is based on Dodonov (2016). Energy efficiency potential is calculated as difference between actual energy consumption for space heating and hypothetical energy consumption if Ukrainian energy intensity was the same as in benchmark country:

$$HES = E - HEE,$$

where HEE is hypothetical energy savings in space heating in Ukrainian residential sector, E – actual energy use for space heating by households in Ukraine and HEE – hypothetical energy use for space heating in Ukraine if energy intensity will reach that of a benchmark country.

Hypothetical reduction in natural gas consumption for heating needs in billion cubic meters (bcm) is calculated based on proportion between actual natural gas use in Mtoe, corresponding to that real volumes in bcm and hypothetical reduction in of energy use for space heating in Mtoe:

$$HES_{ng} = HES/NG_{actual}*FHE_{actual};$$

Where, HES_{ng} is hypothetical reduction of natural gas consumption measured in bcm, HES – hypothetical energy savings described above measured in Mtoe and FHE_{actual} is actual final energy use for space heating in Mtoe.

3.1.2 Data sources

Energy consumption in Ukrainian residential sector as well as data on availability of heating for households have been obtained at the State Statistical Services of Ukraine (Ukrstat, 2016c). It should be noted that at different places the Statistics Service reports different shares of housing that have any kind of heating sources. Moreover, data on heating service is presented as share of total floor area that have heating as well as share of dwellings with heating. For example, in description of the Ukrainian housing stock at the web-site it is said that in 2015 68.7% of total floor area is equipped with heating (without specifying source of heating) (Ukrstat, 2017b). At the same time, in specialized periodic publications issued by the State Statistics Service of Ukraine (2016a, 2016b) reported share of heating in terms of both floor area and dwellings is about 84%. The difference in reporting is because in specialized publications reports the share of floor area equipped with district heating, individual heating and stove heating, while data on web-site represents only district hearing and individual (without stove heating). In this paper, it is assumed that permanently occupied dwellings use only district heating and individual heating (mostly with a natural gas as a source), while share of dwellings with stoves is considered as "summer houses". Therefore, in this modeling, permanently occupied dwellings are assumed as dwelling that have centralized or individual heating.

To calculate final energy use for space heating data from energy balances of Ukraine was used. Data for calculation of energy used for space heating was obtained from Energy Balances of Ukraine (see Appendix B). Final energy consumption for space heating is assumed as final consumption by households of coal, biofuel, heat energy and 73% of natural gas use. Households use directly natural gas for cooking, individual heating and heating water. Assumption about share of total natural gas use for individual heating was derived from Minregion (2016a), where it was stated that in 2014 households used 15 bcm of which approximately 11.3 (or 73.3%) was released for individual heating.

Data on energy intensity statistics for space heating for the selected EU member states has been obtained in Mure-Odyssee database (Enerdata 2017). This database collects and analyses key energy statistics from 28 EU member states plus Norway. Calculated energy intensity indicators for space heating in Ukrainian residential sector expressed in kilogram of oil equivalent per square meter (koe/m^2) for a given year was then compared with similar indicators from Poland, Germany and Latvia. In both cases (for Ukraine and for EU member states) indicators calculated for a normal climate without climate adjustments. For that reason, as was mentioned before, countries with similar climate conditions were selected as a benchmark countries. Climate data expressed as 5-year average heating-degree days was gathered from DegreeDays.net (2017) and EEA (2016).

3.1.3 Results

During the period of 2010 – 2014 space heating energy consumption by residential sector droped from 16.8 to 13.8 Mtoe, or by 18%. To analyze reasons for sharp drop Laspeyres decomposition method was utilized. Results of the decomposition analysis demostrated which factors had largest effect on the variation in energy consumption during this period.

Decomposition analysis shows that during the period, activity (change in population) and structural changes (variations in dwellings size) had almost equal effect on energy use, reduction by 0.2 and 0.1 Mtoe respectively. At the same time,

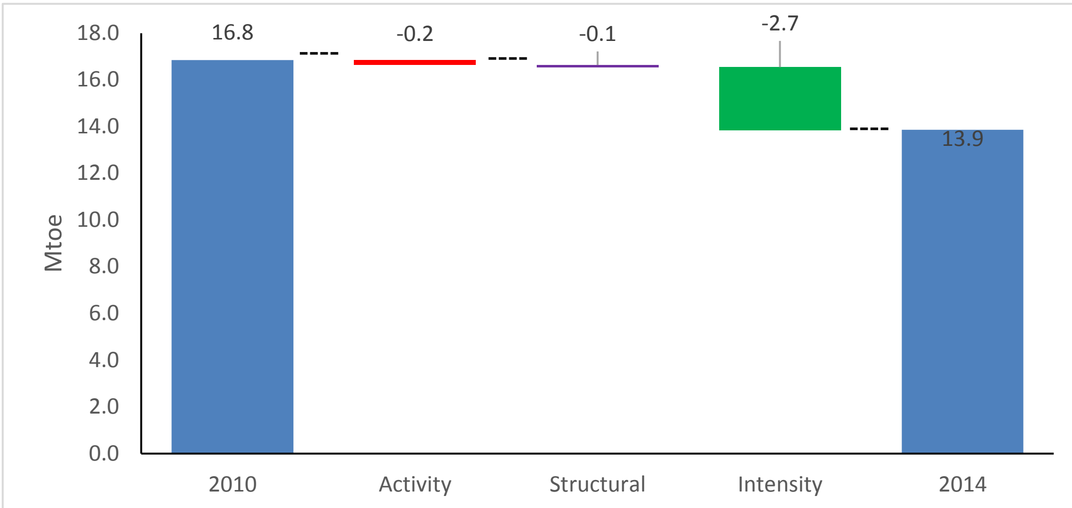

Figure 24. Results of the decomposition analysis of changes in space heating energy use, 2010-2014
Data source: Author's own estimate

largest impact in drop in space heating energy use was in improved intensity (ratio of space heating energy on m^2 of floor area). This factor contributed to reduction of space heating by almost 3 Mtoe over the 5 year period. It should be noted, that reduction in energy consumption was even more profound if energy statictics from 2015 were included, however, in this analysis period of 2010-2014 is analysed in order to be consistent and comparable with data from selected EU member states, where statistics for 2015 were not yet available.

As for 2014 space heating energy intensity in residential sector of Ukraine was 21 kg of oil equivalent per square meter (koe/m^2), a 16% reduction from 2010. However, despite 3.2% annual rate of imprvements this indicator was still almost by

20% higher than in Latvia (3,265 HDD), which also inhereted inefficient residential stock from post communist era and has even colder climate compared to Ukraine (2,970 HDD).

The difference between energy intensity of space heating compared with Poland and Germany was even wider – 30 and 45 per cent, respectively. Further efficiency improvements in space heating energy use in Ukrainian residential sector can provide significant potential in reduction of energy use, avoided natural gas import and accordingly reduced pressure on trade balance from energy import costs.

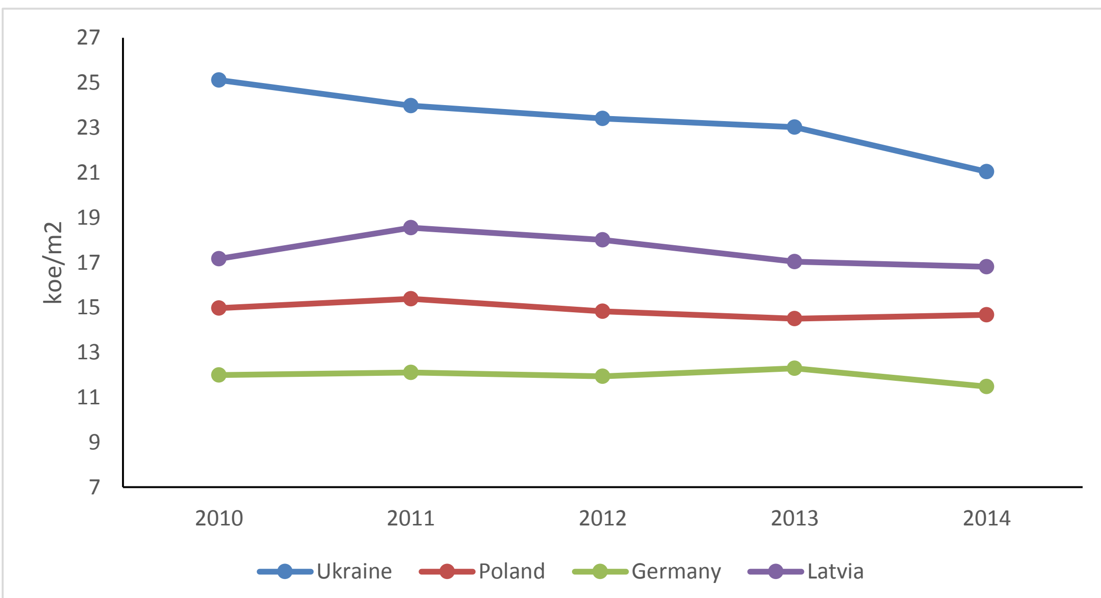

Figure 25. Change in energy intensity for space heating in selected countries, 2010-2014.
Data source: Enerdata (2017) and author's own calculations.

Table 13. Energy efficiency potential of space heating energy use in residential sector of Ukraine in comparison with selected countries

	Potential reduction				
Benchamark country	Mtoe	%	bcm of natural gas	Share of gas import, %	Avoided cost from import/year
Latvia	2.785	20%	4.03	36%	$782,019,923
Poland	4.201	30%	6.08	55%	$1,179,810,744
Germany	6.301	45%	9.12	82%	$1,769,281,235
EU	7.164	52%	10.37	93%	$2,011,841,127

Data source: Author's own calculations

Assuming that weighted cost of imported natural gas in Q3 of 2016 was $194 per thousand cubic meters (Naftogaz 2016d) total cost of avoided natural gas import can be calculated. Analysis shows that if Ukrainian space heating energy intensity in 2014 would be the same as in Latvia and Poland, this would lead to reduction of 4 and 6 bcm natural gas use, respectively. In monetary terms, annual cost of avoided import will be $782 mln and $1.2 billion, respectively. If compared with Germany energy intensity of space heating, savings will be even higher – 9.12 bcm and $1.7 billion. According to the latest data from Naftogaz (2017b), Ukraine imported 11.1 bcm in 2016. Therefore, potential reduction of natural gas use can equal to 55% of total import, if Ukraine's energy intensity of space heating was the same as in Poland in 2014.

3.1.4 Discussion

Decomposition analysis of space heating energy use revealed significant influence of intensity in total change. This suggests that during considered period there has been large investments in energy efficiency in residential sector, and specifically in space heating. However, literature review does not support this assumption. During 2010-2014 there were no significant investments in improvements in heating sector, except infrastructure projects in supply-side district heating modernization projects in several cities financed via international financial institutions. Another possible reason for such big impact of decreased energy intensity is fluctuations in statistics. This is especially the case, for year 2014. In March-April 2014 Crimea was occupied by Russia and some territories were lost in Eastern Ukraine. This dramatic changes possibly were not fully synchronized with changes in some statistical data. For example, while total population reported by the statistics did not change much during 2013-2014, share of total floor area equipped with all kind of heating increased from 64% to 68%. Compared with statistics for previous years, when percentage of heated area has been increasing by maximum of 1% annually, sharp increase of 4% during 2013-2014 seems as an anomaly.

Results of the analysis of energy efficiency potential in space heating energy use in residential sector of Ukraine is comparable and consistent with results reported in other studies. Dodonov (2016) estimated potential energy savings in space heating for 2014 as 8.9 Mtoe. Minregion (2016a) analyzing potential in energy savings in residential sector in 2015 reported total 11.4 bcm of reduction of natural gas use. However, both studies estimated potential with EU average space heating energy intensity as a benchmark. This study, however, was mostly focusing on Latvia, Poland and Germany as benchmark and not on EU because climate conditions in EU on average is not comparable with Ukraine in terms of heating degree days. Since energy intensity of space heating in all studies is not climate adjusted, therefore, comparison with EU is not relevant, as EU as a block has significantly less HDD (2098) in comparison with Ukraine (2970). However, in order to verify applied methodology and achieved results, energy efficiency potential with EU as a benchmark was also analyzed and presented in Table 13. Achieved results is almost equal to estimation made by Minregion (2016a) in terms of potential reduction of natural gas use. Difference between this analyzes with estimate made by Dodonov (2016) is 1.7 Mtoe (25%) and can be cause by difference methodology with manipulation with data.

Availability and quality of data limits accuracy and precision of analysis. This is especially the case with estimation of natural gas use in Ukraine for individual heating. For example, as for February, 2016 more than 7.4 million households use directly natural gas for space and water heating, cooking. This category of customers consumed 91% of all natural gas. Other 1.1 million households (3% of gas use) consumed gas for water heating and cooking. Only for cooking purposes natural gas was used another 4.4 million households, which account for 6% of gas use (Naftogaz 2016c).

Table 14. Structure of natural gas use by residential sector in 2015

User category	*Households, mln*	*% of gas use*	*bcm*
Heating+hot water+cooking	7,469	91	10.283
Hot water+cooking	1,111	3	0.339
Cooking	4,468	6	0.678
		100%	11.3

Data source: Naftogaz (2016c)

Using this data it is possible to estimate, albeit roughly, average and, accordingly, total gas use for each of gas using purposes. Results are presented in Figure 20. It is estimated that in 2015, 8 bcm or 71% of total direct natural gas use (11.3 bcm) was used for individual heating. This is consistent with estimate from Minregion (2016a), where it was estimated that in 2014 11.3 out of 15 bcm, or 73.3%

was used for individual heating. Discrepancies in estimation can be attributed to changes in natural gas use from 2014 to 2015.

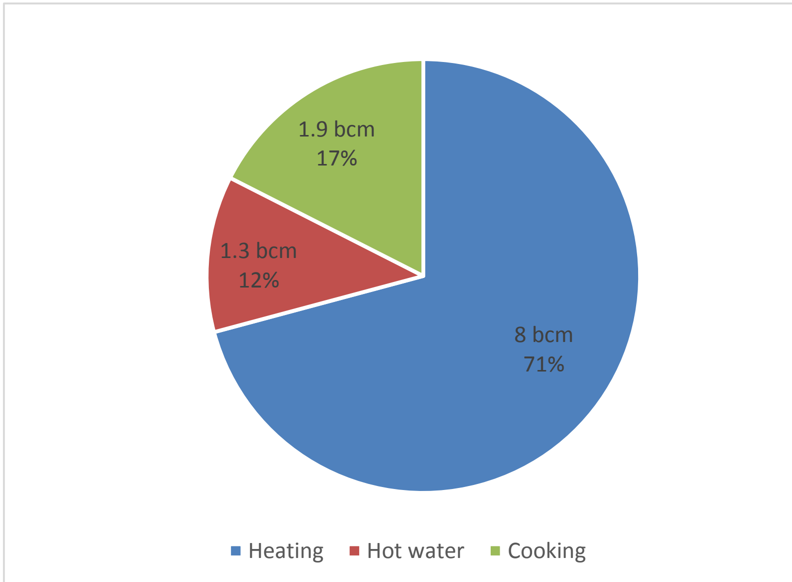

Figure 26. Structure of direct natural gas use by households (estimate)
Data source: Naftogaz (2016b) and author's own estimate

3.1.5 Limitations

Several limitations may cause distortion of analysis results and should be addressed in further studies.

First, to improve accuracy and relevance of comparison between countries energy intensity should be adjusted for climate variations between countries. In this study, HDD has been one of the selection criteria for benchmark countries. Moreover, HDD data has been collected for country's capitals which may not reflect climate conditions for the whole country.

Second, discrepancies in methodology used in this study with methodology used by Enerdata to calculate energy intensity for benchmark countries can also skew results of the comparison and estimation of energy efficiency potential in space heating energy use in residential sector of Ukraine. However, similarity in share of space heating in total households energy in the EU and Ukraine may indicate that methodology used is comparable and thus results are relevant. Specifically, share of space heating in household energy consumption in the EU dropped from 71% in 2000 to 67% in 2012 (Lapillonne, Pollier et al. 2014). Similar trend has been observed in Ukrainian residential energy use: share of space heating in total households energy use decreased from 73% in 2007 to 66% in 2015.

Third, there is no Ukrainian statistics about electricity use for heating purposes in residential sector, widely used in underheated multistory buildings connected to district heating. Lack of this data tends to underestimate final energy use for space heating in residential sector.

Finally, real savings achieved after implementation of energy efficiency measures can be lower (and sometimes significantly) than anticipated savings due to so called “rebound effect” (Sorrell, 2007). Moreover, it is even possible that energy efficiency improvements can resulted not in significant energy savings, but even in increase of total energy consumption – phenomena known as “backfire” (Sorrell, 2009). For example, because of significant reduction of heating costs after implementation of energy efficiency measures, household can afford to buy more home appliances, which will offset some energy savings, achieved after thermal renovation of their house or apartment thus reducing overall savings.

3.2 Assessment of Energy Efficiency Potential in District Heating and Required Investments

3.2.1 Methodology

Energy efficiency potential for space heating and amount of investments for deep energy retrofit is calculated using data from 42 energy audit reports of multistory residential buildings. Both potential of energy savings and investment requirement is estimated for multistory buildings which have 5 or more floors located in urban area and connected to the district heating. Additionally, all residential multistory buildings are categorized by age of their construction. Both potential and investments are then calculated for each of the category separately and as a whole. Whole residential stock of multistory buildings is represented by 7 categories, broken by construction periods: 1) before 1919; 2) 1919-1945; 3) 1946-1960; 4) 1961–1970; 5) 1971-1980; 6) 1981-1990; 7) 1991 – after.

The International Energy Agency (IEA) recommends to use space heating energy consumption per floor area heated as an indicator of energy intensity (IEA 2014, p.46). For that reason, in order to correctly estimate energy intensity for each category of building, percent distribution of each category of building should be converted in percent distribution by floor area. Percent distribution by each category of buildings is calculated using number of buildings of each category from official statistical data (Ukrstat 2011, Ukrstat 2016a). It is therefore assumed that the same percent distribution has total floor area of residential buildings. Since not all floor area in urban area is connected to district heating, total area is adjusted to the area equipped with district heating. Then total floor area in urban areas connected to the district heating is disaggregated to the floor area for each of the categories of buildings by age of construction using the same percent distribution of number of buildings.

Using data from energy audit reports conducted by the Ukrainian ESCO "EcoSys" average investments per square meter for deep energy retrofit was calculated for each of the categories of buildings by age of construction. By deep energy retrofit following energy efficiency measures are assumed in energy audit reports:

1. Comprehensive upgrade of heating system of the building, including installation of individual heat substation, heat cost allocators, thermostatic radiator valves, thermal reflectors behind the radiators etc.
2. Insulation of façade of building;
3. Roof insulation;
4. Replacement of all windows and doors;
5. Modernization of ventilation by installing heat recuperator in each apartment;
6. Insulation of entrances to the building and upgrade of lightning in areas for common use (i.e. stairways, entrance areas etc).

Total investment requirement for each building category and for whole multistory housing stock with district heating was calculated by multiplying total floor area of each of building categories by average investment estimate for deep energy retrofit derived from energy audit reports. Total investment requirement in general and for each of the building category in particular was then adjusted to inflation to estimate investments in 2015 value of local currency. Adjustment for inflation was made by using consumer price index (CPI) in a year when energy audit reports made and CPI in 2015. To compare obtained results with existing estimates of investment requirements in literature amount of investments in local currency was converted to US dollars using average weighted exchange rate in 2015 (21.9 UAH/USD).

Similarly, energy efficiency potential in residential stock connected to the district heating was calculated from the energy audit reports. Each report contained baseline heat of each of the building audited and potential savings after implementation of energy efficiency measures. Annual energy savings was calculated by multiplying difference between baseline heat consumption per square meter and heat consumption after deep energy retrofit measures have been implemented by existing total floor area of each of the building category. Total annual energy savings of each of the building category was then summed and presented in GWh and Mtoe.

Levelized cost of energy (LCOE) of deep energy retrofit was calculated and compared with current tariffs under different scenarios using methodology derived from the World Bank (2015a). Specifically, levelized cost of energy of energy retrofit for each building category was estimated by dividing total investment cost for retrofit for this category by present value of annual savings. Present value was calculated for two scenarios: cost of capital which represents current interest rate on commercial market in Ukraine – 25% and cost of capital provided by the International Financial Institutions (IFI), such as World Bank, with interest rate – 2.07% (rate was derived from the World Bank report). For both scenarios useful lifetime of energy efficiency measures was assumed as 20 years.

Then LCOE of deep energy retrofit was calculated by assuming three scenarios of capital subsidies – 30, 50 and 70%. Calculated scenarios assume two values of cost of capital – provided by the IFIs (2.07%) and market rate (25%).

Selected scenarios were then compared using supply curve method, derived from World Bank (2015). Supply curve graphs provide visually appealing correlation between investment requirement and potential savings. In supply curve, the LCOE of each building category was plotted against total cumulative energy use reduction (Peltier, 2009).

3.2.2 Data Source

Energy audit reports were provided by the US Agency for International Development (USAID) and the International Financial Corporation (IFC) using official request for information.

Percentage distribution of buildings by age of their construction was calculated based on data derived from the report published by State Statistic Service of Ukraine "Housing Stock of Ukraine in 2010" (Ukrstat 2011). This was the latest report that provided data on age and regional distribution of residential stock in Ukraine. Newer reports do not provide this data.

Total floor area connected to the district heating was derived from latest available report "Housing Stock of Ukraine in 2015" (Ukrstat 2016a). Using latest available data on floor area was a choice better than using data from report for year 2010, because it provided more accurate and relevant data on residential stock bearing in mind loss of territories in Crimea and Donbass region. Specifically, data was derived from the section on arrangement of total residential areas with district heating in urban settlements. Using total floor area equipped with district heating in urban settlements (434 million m^2) and yearly distribution of construction of residential buildings (data from 2010 report) floor area for each category of building by year of construction was calculated.

To calculate investment requirements for 2015 consumer price index was used. CPI data were derived from the World Bank (2017c) open data web-source.

3.2.3 Results

Summary of input data from the official statistics and main findings are presented below:

Buildings type by age	Total number of buildings	Percentage distribution	Floor area with DH,m^2	Av. investment in EE per m2, UAH
< 1919	469,326	5%	20,069,298	687
1919-1945	1,197,867	12%	51,223,137	687
1946-1960	2,552,198	25%	109,136,982	687
1961-1970	2,445,067	24%	104,555,850	570
1971-1980	1,645,922	16%	70,382,846	456
1981-1990	1,092,574	11%	46,720,603	460
1991 >	756,682	7%	32,357,203	397
Total	10,159,636		434,445,920	
Source:	Ukrstat (2011)	Calculated	Ukrstat (2016a) and calculated	Energy audit reports and calculations

According to the calculations, total cost of deep energy retrofit of all multistory buildings in urban settlements connected to district heating is estimated was 19.035 billion USD in 2015 prices. Potential energy savings due to implemented energy efficiency measures are expected to be 44.8 TWh, or 3.81 Mtoe. Results and distribution by buildings by age of their construction are presented below:

Table 15. Potential energy savings and investment requirements for deep energy retrofit of multistory buildings connected to district heating

Buildings type	Annual energy savings, GWh	CAPEX, million USD (2015)
Before 1919	2,228	1,050

1919-1945	5,686	2,679
1946-1960	12,114	5,709
1961-1970	10,246	4,537
1971-1980	7,153	2,443
1981-1990	4,664	1,637
1991 -	2,718	979
Total	**44,808**	**19,035**

Comparison of LCOE using market interest rate with current tariffs (as of January 13, 2017; NERC 2017b) shows that implementation of comprehensive energy efficiency improvements is not financially attractive:

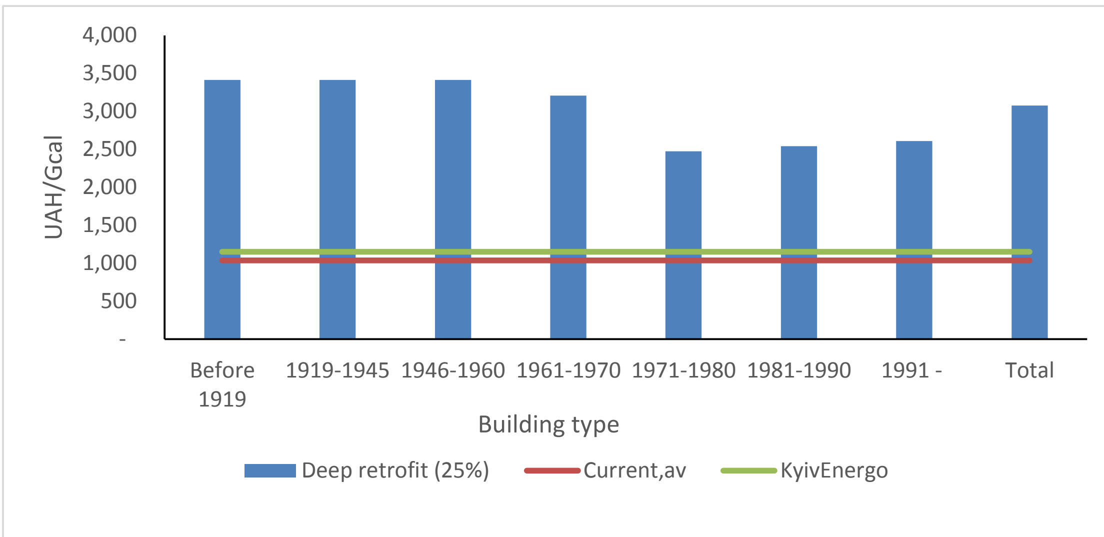

Figure 27. Comparison of LCOE with current tariffs using market interest rate (25%)
Data source: NERC (2016) and own calculations

However, LCOE of retrofit using cost of capital provided by the World Bank (2.07%) is financially attractive for building types as well as for comprehensive retrofit of the whole residential stock:

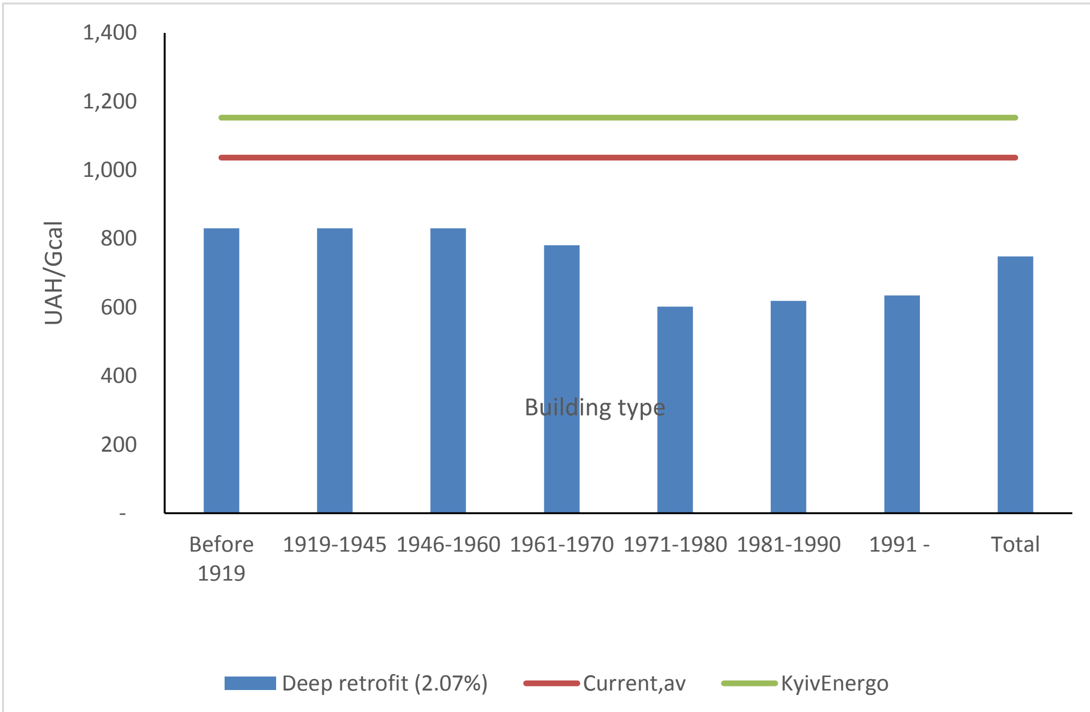

Figure 28. Comparison of LCOE using 2.07% rate with current tariffs
Data source: NERC (2016) and author's own calculations

In order to make investments in deep energy retrofit of residential stock more financially attractive support measures are required. Figure 30 presents analysis of simple payback periods under several financial conditions. Without any government support, total payback period for deep energy retrofit of whole residential stock is almost 12 years. The shortest payback period among all building types by age of construction have buildings constructed during 1970s followed by buildings constructed in 1980s – 9.4 and 9.7 years respectively. At the same time, payback period for all types of buildings will be less than 4 years if 70% capital subsidies are applied. It should be noted though, that this is simple payback period which does not take into account cost of capital, which in this case can be large bearing in mind interest rate on commercial market at 25%.

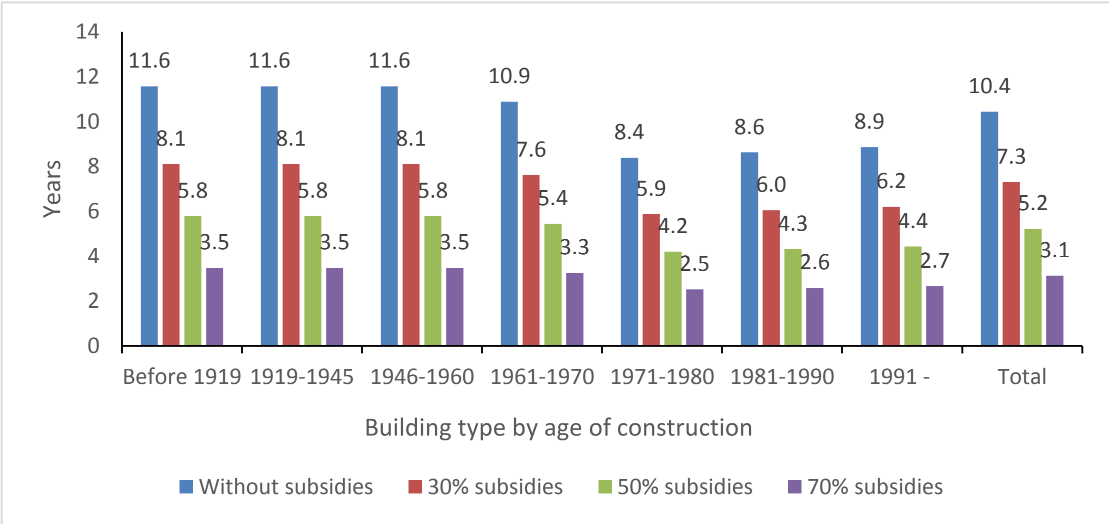

Figure 29. Simple payback period with and without capital subsidies

Data source: Author’s own calculations

Table 16. Financial indicators of investments in deep energy retrofit

Building Type	CAPEX (mln $)	Capital Subs.	CAPEX with Subs. (mln $)	Annual Savings (GWh)	LCOE (2.07%) $/kWh	LCOE (25%) $/kWh	SPB, years
Before 1919	1,050	30%	735	2,228	0.020	0.083	8.1
		50%	525		0.015	0.060	5.8
		70%	315		0.009	0.036	3.5
1919-1945	2,679	30%	1,875	5,686	0.020	0.083	8.1
		50%	1,340		0.015	0.060	5.8
		70%	804		0.009	0.036	3.5
1946-1960	5,709	30%	3,996	12,114	0.020	0.083	8.1
		50%	2,854		0.015	0.060	5.8
		70%	1,713		0.009	0.036	3.5
1961-1970	4,537	30%	3,176	10,246	0.019	0.078	7.6
		50%	2,269		0.014	0.056	5.4
		70%	1,361		0.008	0.034	3.3
1971-1980	2,443	30%	1,710	7,153	0.015	0.060	5.9
		50%	1,222		0.011	0.043	4.2
		70%	733		0.006	0.026	2.5
1981-1990	1,637	30%	1,146	4,664	0.015	0.062	6.0
		50%	819		0.011	0.044	4.3
		70%	491		0.006	0.027	2.6
1991 -	979	30%	686	2,718	0.016	0.064	6.2
		50%	490		0.011	0.046	4.4
		70%	294		0.007	0.027	2.7
Total	19,035	30%	13,324	44,808	0.018	0.075	7.3
		50%	9,517		0.013	0.054	5.2
		70%	5,710		0.008	0.032	3.1

Levelized cost of energy of energy retrofit of each type of buildings plotted against cumulative annual energy savings can be visually presented using supply curves. This method also helps to compare LCOE of retrofit of each building type with existing tariffs. Several supply curves are presented below.

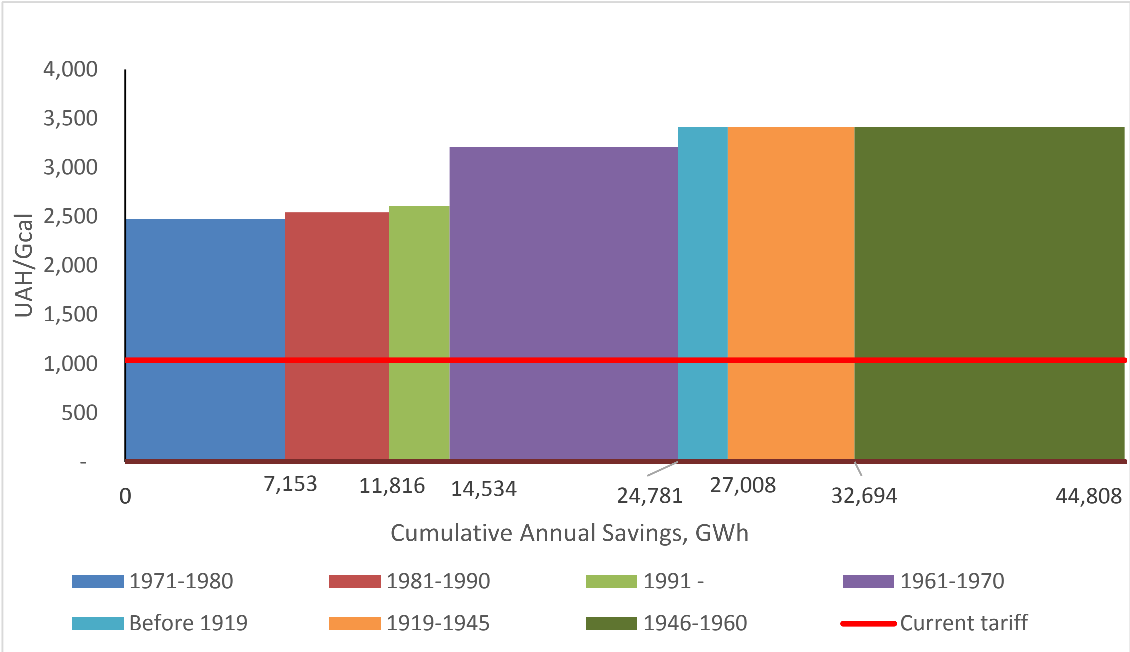

Figure 30. LCOE of Deep Thermal Retrofit at 25% discount rate

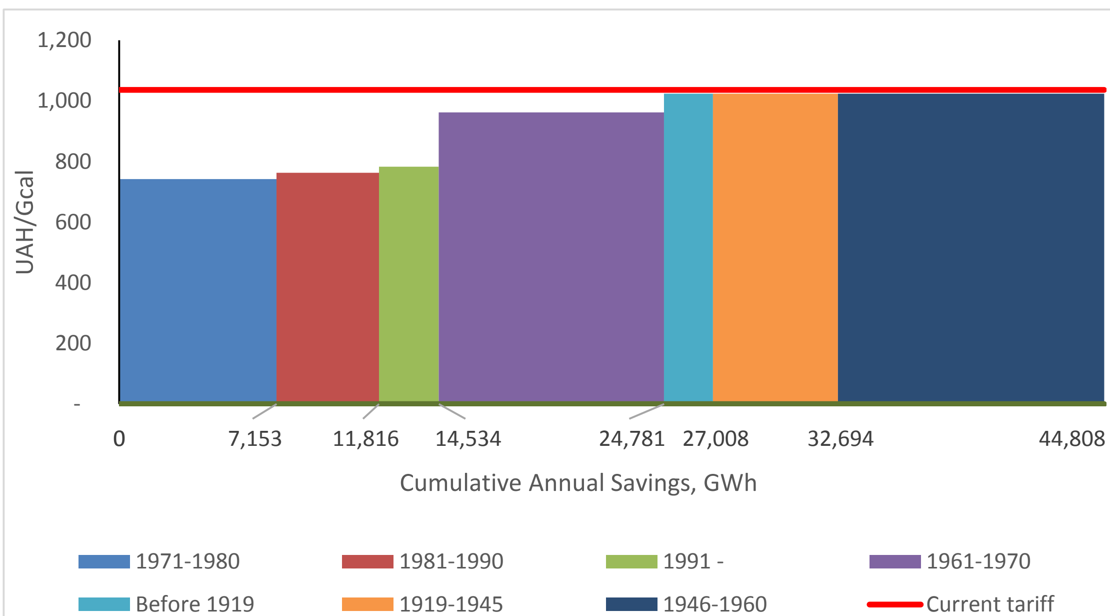

Figure 31. LCOE of Deep Thermal Retrofit at 25% discount rate and 70% capital subsidies

It can be seen from analysis that simple payback period for each type of building will be less than ten years if at least 30% capital subsidies are provided. Moreover, LCOE of energy savings will be less than current average cost of heat supply only if 70% of capital subsidies are ensured.

3.3 Regional Dimension of Investments Need in Energy Efficiency

It was estimated that country-wide investment requirements for deep energy retrofit in residential multistory buildings is approximately $19 billion in 2015 prices. In order to make these investments financially attractive government support in a form of capital subsidies is required. However, amount of required investments as well as capital subsidies varies significantly from region to region. For example, as for 2014 (latest available data) Kyiv as a municipality alone provided 23% of all country's heat energy supplied to households (Ukrstat 2015). Moreover, amount of heat energy for households in Kyiv in 2014 was almost the same as for two others biggest country's heat generators and suppliers – Kharkiv and Dnipropetrovsk oblasts (regions) combined. Therefore, investment distribution across Ukrainian regions are not uniform. This section will provide regional analysis of investment requirement.

State Statistical Service of Ukraine provides data on regional distribution of floor area in square meters connected to the district heating. Using average investment requirement per square meter for deep energy efficiency improvements total cost for each region can be calculated. One of the approach to calculate average investment per square meter is to derive average value from energy audit data and then adjust this value to inflation in 2015. Using this approach will result in total investment requirement of $15 billion in 2015 prices. However, this result is $4 billion less then investment estimate based on types of buildings by age of construction. Such large discrepancy in investment estimate can be explained by small size of sample of energy audit reports, which does not cover all possible building types constructed in different periods of types. For example, energy audit reports do not contain any cases from building constructed in 1940s and 1950s. Another possible reason for difference in estimate is quality of data provided by official statistics. For example, first estimate was based on assumption that floor area distribution by age has the same distribution as distribution by number of building with five and more floors. Regional distribution of investment, at the same time, does not have distribution by age, but by total floor area in each region (oblast). To overcome this discrepancy in total estimate, average investment per square meter was calculated by dividing initial investment requirement estimate ($19 billion) by total floor area connected to the district heating. Achieved value then is multiplied by floor area connected to the district heating in each region to achieve total invest cost for each of the region. Regional distribution of investment requirement is presented in following table.

Table 17. Regional floor area and required investments

Region	Floor area with DH, m^2	Investments, million USD (2015)
Vinnytsia	10,852,312	476
Volyn	6,837,631	300
Dnipropetrovsk	48,886,867	2,142
Donetsk	32,046,884	1,404
Zhytomyr	9,615,523	421
Zakarpattia	6,937,312	304
Zaporizhia	22,887,020	1,003
Ivano-Frankivsk	8,340,570	365
Kyiv Oblast	22,188,469	972
Kirovohrad	9,089,372	398

Luhansk	7,671,015	336
Lviv	17,738,991	777
Mykolaiv	12,674,897	555
Odesa	22,613,947	991
Poltava	13,506,226	592
Rivne	7,626,565	334
Sumy	13,114,654	575
Ternopil	8,000,153	351
Kharkiv	45,619,874	1,999
Kherson	9,956,171	436
Khmelnytskyi	10,225,046	448
Cherkasy	10,307,564	452
Chernivtsi	4,509,918	198
Chernihiv	9,827,931	431
Kyiv city	63,371,008	2,777
Total	**434,445,920**	**19,035**

Data source: Ukrstat (2016a); own calculations.

434 million square meters of floor area connected to the district heating represents 45% of total floor area in Ukraine as for 2015 (973 million m^2). Total investment requirements for deep energy retrofit only in residential buildings connected to the district heating require more than $19 billion in 2015 prices. As was estimated in previous section, levelized cost of energy of investment in deep energy retrofit can be lower than existing tariffs only when 70% of capital subsidies are provided. Total cost of needed capital subsidies is therefore – $13.3 billion. To compare, GDP of Ukraine in 2015 was $90.6 billion in 2015 US dollars (World Bank 2017b). In other words, capital subsidies in deep energy retrofit of just 45% of total floor area requires almost 15% of whole Ukrainian GDP in 2015. Considering current macroeconomic hardships, it will be difficult for the Government to allocate significant amounts of state funding for state support of energy retrofit.

However, as was mentioned in Chapter 2, due to rapid increase of gas and heat tariffs more and more households applied and got subsidies, provided by the state to protect low-income households from price shocks. Specifically, as for December 2016, 43.6% of households were receiving subsidies. Moreover, 68% of all households receiving subsidies are living in urban settlements. Furthermore, 68% of total amount of state subsidies transferred to municipal utility services companies to cover cost of services provided for low-income groups is also in urban settlements (detailed information about regional distribution of state subsidies is provided in Appendix D).

Following economic model of investments in energy efficiency retrofit of residential stock will be based on an assumption, that whole stock will be retrofitted in 20 years. Bearing in mind that total floor area connected to the district heating is estimated as 434 million m^2 more than 21 million m^2 should be retrofitted every year. This constitutes annual retrofit rate of 2%, which can be considered as quite aggressive and ambitious target. Knowing total floor area and investment requirement for every region, annual retrofit rate and investment needs for every region can be calculated and compared with existing subsidies for household utility services in urban settlements. Results of calculation and comparison can be found in the Table 18.

Table 18. Comparison of existing regional HUS subsidies with capital subsidies needed

	1	2	3	4	5
Region	70% capital subsidies, million $	Regional distribution, %	Capital subsidies per year, million $	Existing HUS subsidies, million $	Balance (4 - 3), million $

Vinnytsia	$333	2%	$17	$54	$37
Volyn	$210	2%	$10	$34	$23
Dnipropetrovsk	$1,499	11%	$75	$121	$46
Donetsk	$983	7%	$49	$93	$44
Zhytomyr	$295	2%	$15	$51	$37
Zakarpattia	$213	2%	$11	$16	$5
Zaporizhia	$702	5%	$35	$64	$29
Ivano-Frankivsk	$256	2%	$13	$37	$24
Kyiv Oblast	$681	5%	$34	$59	$25
Kirovohrad	$279	2%	$14	$43	$29
Luhansk	$235	2%	$12	$34	$23
Lviv	$544	4%	$27	$95	$68
Mykolaiv	$389	3%	$19	$30	$10
Odesa	$694	5%	$35	$29	$(5)
Poltava	$414	3%	$21	$70	$50
Rivne	$234	2%	$12	$37	$25
Sumy	$402	3%	$20	$69	$49
Ternopil	$245	2%	$12	$40	$28
Kharkiv	$1,399	11%	$70	$113	$43
Kherson	$305	2%	$15	$31	$16
Khmelnytskyi	$314	2%	$16	$46	$31
Cherkasy	$316	2%	$16	$56	$40
Chernivtsi	$138	1%	$7	$19	$12
Chernihiv	$301	2%	$15	$54	$39
Kyiv city	$1,944	15%	$97	$72	$(25)
Total	**$13,324**	**100%**	**$666**	**$1,369**	**$702**

As it can be seen from the Table 18, current level of existing subsidies for households' utility services that cover 68% of households in urban settlements exceeds annual investment requirement for the whole country by $700 million. The only two exceptions are Kyiv and Odesa, where amount of capital subsidies needed for retrofit exceeds existing subsidies for households' utility services. This can be explained by economic factors. Both Kyiv city and Odesa region are considered as regions with higher than on average in Ukraine income per capita and therefore lower demand for

HUS subsidies. State Statistic Service points out that both Kyiv and Odesa region has lowest share of households receiving subsides compared with other regions, 23% and 18%, respectively (Ukrstat 2017). At the same time Kyiv is a capital and largest city in the country, while Odesa is among the biggest both in term of population and housing stock.

3.3.1 Discussions

Estimated energy savings potential for multistory buildings in urban area is 44.8 TWh annually. At the same time, largest study on overview and assessment of energy efficiency in residential sector of Ukraine conducted in 2011 (EBRD 2011) estimated technical energy saving potential of apartment buildings as 45.1 TWh. Therefore difference in estimate of energy saving potential of this study and EBRD report is less than 1%. EBRD's report also estimate total area of multistory buildings as 478 million m^2, while in this study floor area in urban area of multistory is considered as 434 million m^2. The difference can be attributed to the loss of territories controlled by Ukrainian government during military conflict with Russia-backed separatists and occupation of Crimea in 2014. The EBRD report does not specify investment requirement for multistory buildings.

However, investment estimate for multistory buildings was made in one of the most recent study (Minregion 2016a). According to the report, total investment need for retrofit of multistory buildings is $17 billion. This is $2 billion less than estimate of this study ($19 billion in 2015 prices). The Minregion (2016a) report does not specify methodology used for their estimation, however one of the reasons in difference can be floor area data used in this report. Specifically, total investment for multistory buildings in urban area was calculated for all floor area equipped with district heating in Ukrstat data. However, it can be argued that not all reported in official data floor area in fact is heated from district heating source. For example, official data says that total floor area in Zakarpattia region equipped with the district heating is almost 7 million m^2. In reality all residential stock in this region is actually disconnected from this district heating and heated by individual sources. The same can be partially relevant for other regions. Moreover, only in Kyiv almost all heat to residential sector is delivered via district heating. Furthermore, 434 million m^2 provided by official data as floor area in urban settlements connected to district heating constitutes 45% of all country's floor area. At the same time, another official report from Ukrstat (2016b) describing arrangement of households' housing in 2016 says that only 38% of all households have district heating in their dwellings[5]. Therefore, investment needs estimated in this study should be considered on a higher end and the real investments requirement can be significantly lower than $19 billion in 2015 prices.

In general, it can be concluded that findings of this report are relevant, consistent and comparable with existing literature.

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[5] In should be mentioned that this Ukrstat report confirms that households in Zakarpattia region do not use district heating.

Chapter 4

TURNING SUBSIDIES INTO INVESTMENTS

4.1 Introduction

Energy subsidies can have both negative and positive implications. Subsidies to support renewable energy development and subsidies as a support to low income population aimed to reduce energy poverty are examples of energy subsidies with positive impacts. Fossil fuel and electricity subsidies to address energy poverty issues are mainly common in developing countries, while renewable energy subsidies are prevailed in affluent countries (Strand 2016).

The International Monetary Fund distinguish two types of subsidies: pre-tax and post-tax subsidies. Before-tax is the most common methodology which evaluates direct government spending on fossil fuels and electricity consumption. Contrary, after-tax subsidies is rather recent approach.

The idea behind after-tax subsidies is that by not imposing environmental tax which bring quantity of energy supplied to socially optimum level, governments in fact are subsidizing excessive energy use (Strand 2016).

Before-tax (or pre-tax) subsidies are estimated as difference between energy prices on international markets (with transportation and distribution costs) and domestic retail prices. This approach is also known as “price gas”. One of the advantages of this approach is that it allows to estimate subsidies paid not directly from budget, but rather as losses of state-owned companies. For non-commodity energy products, such as electricity, amount of subsidies calculated as a difference between domestic retail electricity prices and estimated cost reflective prices.

After-tax subsidies (or post-tax) aimed not only cover all supply cost (pre-tax), but also a negative externalities such as GHG emissions, environmental pollution, premature deaths etc. (Strand 2016).

Several policy options are available to address negative externalities in energy use. Fiscal instruments, such as fuel taxes, emission taxes and tradable emission auctions are considered as a most effective way to address externalities. First of all, well-design and targeted fiscal instruments utilize all possibilities of externality mitigation. Studies from the US report that carbon taxes several times more effective in limiting CO_2 emissions than renewable energy promotion policies (Krupnick et al. 2010). Second, fiscal instruments achieve reduction in environmental damages at most cost effective way. Third, environmental taxes achieve balance between economic cost and benefits for environment (Parry 2016).

Energy subsidies cause significant negative drawbacks on all aspects of social life and economic activities. They lead to wasteful and excessive consumption and disincentives implementation of more energy efficient behavior and production. Energy subsidies impose large and not-transparent fiscal burden, encourage corruption and cause environmental damage, pollution and GHG emissions.

Despite the fact that subsidies have multiple negative consequences they still widespread. One of the reasons for that phenomena is imperfect information. While true cost and consequences of energy subsidies are not obvious and clearly understood by general public, their benefits are well understood by various groups who benefit from them most. There are substantial evidences that middle and upper classes use more energy and spent on it smaller part of their income compared to lower classes (Bauer et al. 2013, Clements et al. 2010, IEA 2011).

Another important barrier in removing energy subsidies is that politicians tend to have problems with imposing higher energy prices due to political election cycles. This barrier can be addressed by authorizing independent body to set prices based on clearly defined and communicated price formation method or formula.

Direct compensation via mean-tested cash transfers can be relatively easy and not expensive way to protect vulnerable population from removing energy subsidies. Rather than subsidizing all categories and most of all middle and rich classes, targeted cash transfers will be provided only to those who are in need. These subsidies will not depend on real energy use and therefore will not discourage investments in energy efficiency. Moreover, cash transfers can even provide more incentives to invest in energy saving measures as decreased energy consumption will increase financial benefits since transfers are not connected to actual energy use. So the total outcome of phasing out of retail level energy subsidies and imposing targeted cash transfers will reduced energy use, investments in energy efficiency and more efficient distribution of welfare (Pani, Perroni 2016).

4.2 Lessons Learned From Cutting Energy Subsidies in Other Countries

IMF study on energy subsidies (Clements 2013) estimate global and regional distribution of both pretax and posttax subsidies. Pretax-approach which covers oil products, electricity, coal and natural gas account for $492 billion USD in 2011. This amount equals to 0.7% of world’s GDP. Posttax subsidies, at the same time, are estimated as about 2 trillion USD or 2.9% of world’s GDP. OECD countries responsible for 40% of global post subsidies, while developing countries account for largest share of pretax subsidies. Phasing out of posttax subsidies will result in 15% of

CO_2 reduction and will have other positive spillover driven by reduction of global energy use.

For traded energy goods and products pretax subsidies calculated as follows:

Pretax subsidy = Pw – Pc,

where Pw is price on product on international market plus transportation and distribution cost, Pc is price paid by final consumer. If energy good is not traded on international market, for example, electricity, subsidy is calculated as difference between estimate of cost recovery level price (includes generation, transportation and distribution) and price for end-user.

To calculate posttax an efficient taxation value needed. This tax incorporates cost aimed to address social and environmental externalities associated with consumption of particular energy good or product. When corrective tax is incorporated then posttax calculation formula is:

Posttax subsidy = (Pw + t) – Pc,*

where t* is corrective tax and other variables as described above.

Tracking and calculating energy subsidies may be challenging as the way how they financed and recorded varies from country to country and may transform over time. Subsidies can be financed directly from state budget as transfers to the state-owned enterprises that incur financial loses by selling energy at price below cost-reflective level. This transfer from state budget can be financed via increased taxes, debt or inflation (in case if debt is monetized). One of the most widespread mechanism, however, is recording of subsidies as a financial losses or decreased profits of state-owned enterprises, decreased tax disbursements to the state budget or as a combination of several forms (Coady, Fabrizio et al. 2013).

4.2.1 Negative Consequences of Energy Subsidies

Instead of taxation of fossil fuels, many countries are subsidizing them in the amount of more than $490 billion as of 2011 (Parry et al. 2014). Energy subsidies to fossil fuels lead to multiple negative consequences. Bauer et al. (2013) summarize adverse effects of energy subsidies into three categories: macroeconomic, environmental and social consequences. Specifically, energy subsidies cause following inauspicious implications:

- Deteriorate fiscal balances and divert public funding and private investments from more important areas including energy efficiency improvements. Implementation of energy reform can release funds previously spent on energy subsidies and allocate them to education, health or to boost productivity in other areas;

- Distorts resources allocation by encouraging excessive energy use, which in turn results in deterioration of environment, spurs pollutions and worsen public health;

- Encourage capital and energy intensive productions. Phasing out of energy subsidies in long term perspective will lead to reallocation of resources toward more productive and energy efficient activities that will boost economy and drive employment;

- Deplete natural resources and discourage renewable energy development;

- Excessive energy consumption driven by subsidies creates pressure on account balance in countries dependent on energy import;

- Encourage corruption and smuggling with neighboring countries. Low domestic fuel prices promotes illegal trade with neighboring countries where prices are at cost reflective level. In turn, this leads to losses of revenues from taxable products;

- Distort welfare distribution due to transfers of larger amount of subsidies to higher income population. Energy subsidies especially among low and middle income countries are poorly targeted. For example, on average 20% of low income households receive only 10% of natural gas subsides and about 9% of subsidies on electricity. Similar distribution pattern observed at other fuel products. To avoid raising poverty and to protect low-income groups from removal of energy subsidies, well targeted mitigation measures should be implemented;

- Jeopardize access to energy and other resources for future generations.

Bauer et al. (2013) also analyzed experience of energy subsidy reform in 28 reform episodes in 22 countries. Seven countries in Sub-Saharan Africa, two emerging economies in Asia, three countries in the Middle East and North Africa, four countries in Latin America and the Caribbean, three countries in Central and Eastern Europe. 14 of the 22 case studies cover fuel subsidy reform, seven – electricity sector reform and one case study on coal sector reform. 12 out of 28 reform episodes are considered as successful, 11 as partially successful and five as not successful. Episodes considered as partially successful are episodes where reversal or incomplete realization of reform took place. Summary of energy subsidy reform episodes can be found in Appendix C.

Alleyne et al. (2013) provide analysis of lessons learned from experience in reforming energy subsidies. Key elements of successful reform implementation as well as barriers to successful accomplishment of energy subsidy reform are summarized in next two subsections.

4.2.2 Barriers for Energy Subsidy Reform

Lack of information about energy subsidies. As was mentioned before, energy subsidies are often not reflected in budget, which makes them difficult to recording and tracking. Wide public usually not aware of real cost of fuel products or energy service, it is comparison with international market prices, about adverse impact on state budget, balance-of-payment etc. All these make energy price adjustment particularly challenging from public perspective point of view. In 17 out of 28 episodes lack of information has been an important obstacle in implementation of energy reform. Energy price reforms implemented without proper communication campaign can result in incomplete implementation or even reversal of reform. This is especially the case during times of political crises. On a contrary, when population is informed about negative consequences of energy subsidies and large benefits of price adjustment it can accept even substantial price increase (Alleyne et al. 2013).

Even if general public is aware of magnitude and negative impacts of energy subsidies it still can strongly oppose to energy price adjustment. One of main possible reason for that is absence or lack of confidence in government's ability to use additional funds wisely. Problems with accountability and transparency are particularly challenging in countries with long history of corruption and poor public policy.

Despite that most of subsidies are captured by middle and high-income groups, adjusted energy prices possess significant poverty risk for lower income groups. Removal of energy subsidies causes escalation of household's spending's on cooking and heating and can increase overall poverty level. Therefore energy price adjustments should be accompanied with mitigation measures to address potential adverse impacts on low-income groups.

Phasing out of subsidies accompanied with increasing energy prices can raise concerns over impact on whole economy. This includes inflation, competitiveness on foreign markets, further volatility of domestic energy prices. Thus subsidy reforms should be implemented along with macroeconomic stabilization measures such as economy stimulation packages. State funds saved after energy price adjustments can be invested in big infrastructure projects to boost overall economic activity.

Generally, opposition to energy subsidies reform less intensive during periods of high economic growth and low inflation. Otherwise, compensation measures should be imposed.

Another barrier for successful reform implementation can be resistance from interest groups. Groups and organizations which benefited from energy subsidies can be interested in maintaining status quo and thus present well organized opposition. On the contrary, those who will benefit from removing subsidies are disorganized and dispersed. Therefore, policy designers should address concerns of those who will lose from reform implementation. Usually, labor unions and state-owned enterprises can organize powerful opposition to reforms. Experience of Poland and Mexico demonstrates that if not addressed, concerns of unions can block reform (Alleyne et al. 2013). Particularly strong opposition can be from affected by subsidy reform industry with numerous and narrow-skilled workforce such as coal miners. To increase likelihood of successful reform implementation, governments should actively communicate with union to address their concerns.

4.2.3 Key Elements of Successful Implementation of Energy Subsidies Reform

Alleyne et al. (2013) drawing from international experience outline following factors that will increase likelihood of successful energy subsidy reform implementation:

- Clear long-term reform plan with defined objectives;
- Comprehensive communication campaign;
- Adequate sequencing of energy price increase;
- Reduction of production subsidies at state-owned enterprises;

- Protection of socially vulnerable population;
- Transparent, independent and automatic mechanism for energy price formation.

Clear long-term reform plan with defined objectives, comprehensive analysis of potential impact of reform and wide consultations with stakeholders.

During fuel subsidy reform in 2010, the Government of Iran identified clear objectives, compensating measures, timing of reform. Wide information campaign launched prior to reform pointed that primary goal of reform is to replace price subsidies with direct cash transfers deposited to bank accounts opened specifically for that. Aim of cash transfers were to discourage overconsumption of energy and decrease smuggling.

Well-designed plan of reform prepared before the start of reform is one of key elements of successful implementation. Experience of countries with successful energy subsidy reform shows that plan should incorporate a) clear long-term objectives, b) assessment the potential impact of reforms, and c) consultation with stakeholders.

Comprehensive communication campaign and raising public awareness about magnitude of subsidies and real impact on budget.

Wide communication campaign is crucial for successful reform implementation. It can mobilize broad political consensus and public support. In turn, this will triple likelihood of successful reform implementation. Communication strategy should have clear key messages about aims of reforms, cost of energy subsidies and their impact of budget. Particular attention should be paid to potential benefits of phasing out of subsidies. Specifically, information campaign should articulate additional budget revenues saved from subsidy removal that will be spent on high-priority areas such as education, health etc.

Adequate sequencing of energy price increase which can be different for various energy fuels and products.

Gradual phase by phase reform approach gives households and business necessary time to adjust to new environment and build credibility by demonstrating that funds saved from subsidy removal are spent well. Additionally, such approach can reduce negative impact of raising energy prices on inflation and provides time to phase in compensation measures to protect poor. In 17 out of 23 reform episodes with successful or partially successful reform results phased reform approach was implemented. On a contrary, too fast and sharp increase in energy prices can result in very strong opposition to reform. Simultaneous increase of energy price with other socially important products can generate fierce opposition. Overall, experience shows that on average five years are required for successful or partially successful reform implementation.

Price adjustment for different energy products and services can be adjusted with different sequencing. Price increase can be more rapid for energy products consumed mostly by higher income groups and business. Such products can be for example gasoline or jet fuel. As soon as safety nets are imposed, further phases of price increase can be implemented for energy products more important for household budgets of lower income groups, such as electricity. At the same time some portion of savings from previous increase can be used to finance cash transfers to socially vulnerable population.

However, gradual and sequenced approach in reform implementation also has challenges. First of all, longer period of energy prices adjustment can decrease budget savings in short term. Therefore there is trade-off between goals of increasing budget savings from price increase and mitigating negative impact of such increase in low-income groups. Second, longer period of reform phasing out of energy subsidies can give time for political opposition to mobilize resistance to reform. These and other barriers can be addressed by long-term commitment of government to follow established reform plan. Long term commitment to follow reform plan also can include ensuring commitment of successive governments. Building broad political consensus and mobilizing wide public support can help to overcome strong political opposition over time.

Reduction of production subsidies at state-owned enterprises by improvements in efficiency.

State-owned energy producers and suppliers often get significant budget support to cover financial and production losses. Better governance, revenue collection and demand management can boost efficiency of SOEs and decrease need of subsidies.

Governance of energy SOEs can be improved by increasing in quality of financial and operational reports. Better reporting can be valuable in identifying operational inefficiencies (such as excessive staff) and vulnerabilities (for example, places where large losses occur). Next stage to improve governance is to establish target indicators based on this reporting information. Promotion of competition in energy sector also can increase efficiency and governance performance of energy SOEs.

Demand side management is effective tool to shift demand to periods where cost of supply is lower by charging higher prices during peak periods. Gradual increase in metering coverage of customers can improve revenue collection.

Reforming and restructuring of energy SOEs can involve laying off significant part of workers in company or whole industry in general which can generate social anxiety and fierce opposition to reform. To mitigate that risks, special social assistance program can be imposed. In case of coal industry reform in Poland, unemployed miners received access to social assistance program and job trainings.

Protection of socially vulnerable population.

Imposing targeted measures to protect poor is crucial during energy subsidy reform. Well-designed mitigation policy helps build and maintain public acceptance and support. Phasing in targeted measures before start of reform will demonstrate commitment of government to support low-income groups. If case transfers are untargeted, then they can be limited to amount consumed by poor. This approach will generate fiscal saving because often low-income groups consume significantly less amount of energy then higher income groups.

To increase fiscal savings cash transfers should aim only low-income population. In 18 out of 28 reform episodes, targeted mitigation measures were imposed. Targeted cash transfers is a preferred method to mitigate negative impact of energy subsidy reform on low-income population. They give flexibility to recipients in purchasing optimal type and level of energy needs. They also substitute supply of subsidized energy to all households which usually tend to be expensive and prone to abuse.

Cash transfer program can be unconditional (for example in Indonesia) and conditional (Armenia). The program can be designed also to improve collection rate and energy efficiency. For example, households which receive cash transfers and do not pay energy bills or over consume energy can be deprived from further participation. Conditional transfers can also be linked with requirement for households to make certain type of investments which directly address root cause of poverty, such as investment in education or health. This programs proved to be effective in low-income emerging economies.

Institutional reforms which establish transparent, independent and automatic mechanism for energy price formation.

Even when initial energy price adjustment was successful, energy subsidies can appear again driven by increased prices on international energy markets. This has been the case in 11 out of 28 reform episodes, considered as partially successful because of reappearance of energy subsidies. To avoid this, mechanism for energy price formation should be automatic and depoliticized (Alleyne et al. 2013).

Imposing automatic pricing formula can help avoid reversal of energy subsidy reform. This mechanism formula will follow dynamic of energy price on international markets automatically adjusting prices on domestic market. Automatic pricing mechanism also can support acceptance of reform as public will be aware that energy suppliers will not get enormous profits due to price increase on domestic market.

To avoid sharp increase in domestic price triggered by raising on international markets, smoothing mechanisms can be imposed. Such mechanisms can include only gradual transmitting increased international prices to domestic prices. For instance, domestic prices should not rise more than five per cent per month from current level (Alleyne et al. 2013).

Another important step to increase public acceptance and maintain automatic pricing mechanism is to delegate responsibility for pricing to independent institution.

Every country has its own unique circumstances, political and socio-economic environment during energy subsidies reform implementation. For that purpose it's difficult to distinguish policy recommendations that will be effective in other country. However, IMF study provides several barriers that should be addressed in order to increase probability of successful energy subsidy reform implementation.

Additionally, World Bank's report (Laderchi et al. 2013) point out that targeted cash transfers to protect vulnerable population from price shocks is not sustainable solution because it still represents significant amount of resources and recurrent expenditures. Investing of energy efficiency, at the same time, can be a viable option to protect socially vulnerable population and will help to lower demand. Therefore, integration of social protection measures with policy focused on demand side energy efficiency improvements is a sustainable solution that should be addressed in policy design.

4.3 Case Studies From Successful Energy Efficiency Programs in Residential Sector

4.3.1 Germany

4.3.1.1 Introduction

Germany is considered as world leader in energy efficiency (IEA 2013, ACEEE 2016). The Government of the Germany has placed energy efficiency improvements as one of the top priority of its national energy policy to secure energy supply, decrease GHG emissions, and while boosting economy and creating new jobs.

Residential buildings accounts for more than one third of total German's final energy use. Most of this energy us used to supply homes with heat and hot water (BMWi 2016). To increase efficiency in energy use by residential buildings, the Government established policy framework focused on new buildings and existing housing stock. Constant improvements in energy efficiency in new buildings mainly ensured by constant revisions of buildings minimum energy performance requirements.

The cornerstone of policy in energy efficiency in existing buildings are preferential loans, provided by the Operation of Kreditanstalt fur Wiederaufbau ("KfW"). KfW is public bank established after Second World War as a part of the Marshall Plan. Activities of the KfW in providing low-interest loans for buildings retrofit is considered as a "big success": from 1996 to December 2004, they provided over 330,000 loans spread over 850,000 buildings. Some 95% of those loans were for refurbishment, not construction. For the year 2004 alone, these loans amounted to a total of €4.42 billion (De T'Serclaes 2007).

The KfW program provides financial incentives for deep energy retrofit measures. One of the main feature of KfW loan program for retrofit of existing buildings is that it closely connected with standards for new buildings. Financing is granted only to energy efficiency measures that go beyond existing thermal requirements for new buildings (Hilke and Ryan 2012a).

Context

After the Second World War Germany was severely suffering from the high unemployment, massive destruction of industrial potential and residential stock. As part of the reconstruction efforts the Marshall Plan was developed and implemented. One of the key element of Marshall Plan was establishment of the Kreditanstalt für Wiederaufbau or KfW. Initially the KfW was designed to provide and recover loans for industry and private sector to restart German's economy. In 1970s, after the oil crisis with rising concerns over energy security issues, KfW started to provide low-interest, subsidized loans for thermal refurbishments of buildings. In 1990s, following reunification with German Democratic Republic (GDR) KfW shifted its focus on thermal retrofit in GDR and achieved unprecedented results. Half of GDR houses – about 3.6 million dwellings – were retrofitted just during that decade (Schröder et al. 2011).

First policy regulations on buildings thermal standards have been introduced in 1977 driven by raising concerns over energy security during oil crisis. New requirements covered both new buildings and existing buildings during reconstruction. From this time, standards have been constantly tightened during several revision phases. To understand magnitude of changes in buildings thermal standards it is worth noting that buildings constructed in 2013 require only quarter of energy used by buildings build in 1997. Moreover, deep energy retrofit of old building would decrease its energy demand to 40% of a completely new building erected in 1987 (Galvin and Sunikka-Blank 2013).

Overview of residential stock

Residential space and water heating in Germany consume around 15% of all energy use. As for 2014, German housing stock comprised roughly 19 million buildings and around 40 million flats. Out of that figures, 14 million buildings were single and two-family houses (~19 million flats) and 5 million multi-family buildings (21 million flats). Around 64% of residential housing stock had been built before 1977 when first energy efficient building codes were imposed.

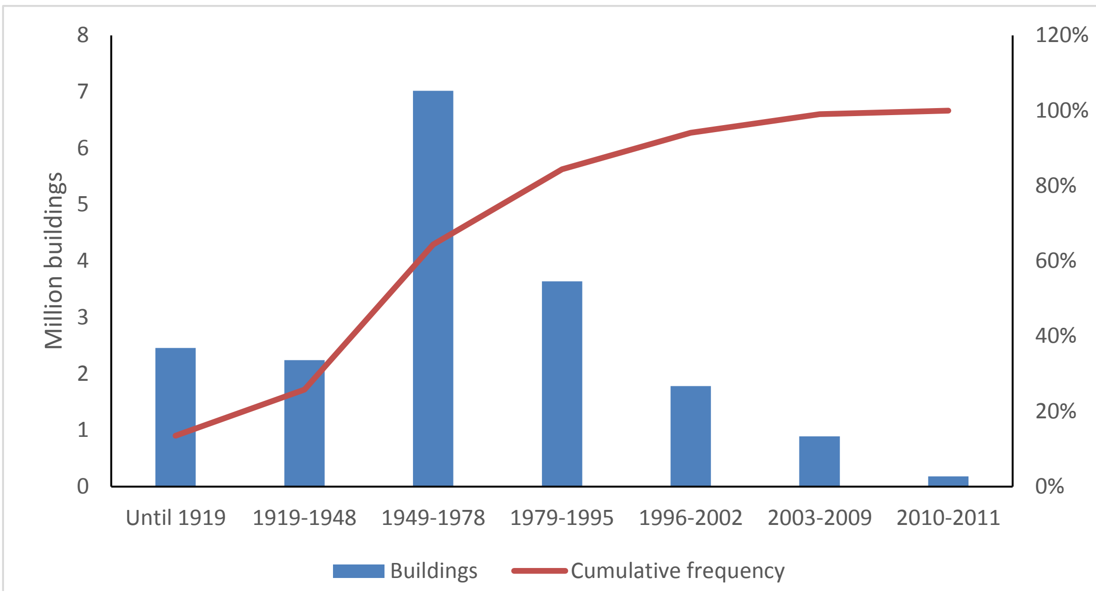

Figure 32. Distribution of residential building stock by age of construction
Data source: BMWi (2015)

Several revisions of building codes resulted in introduction of more stringent building thermal requirements. Average annual energy consumption per square meter began to fall.

Table 19. Distribution of buildings by annual energy consumption

Period	Ordinance	Number of buildings	Average annual consumption
1979 – 1995	First and Second Thermal Insulation Ordinance (WSVo)	3.64 mln	146 kWh/m^2a

1996 – 2002	Third Thermal Insulation Ordinance (WSVo)	1.78 mln	102 kWh/m^{2}a
2003 – 2009	First Energy Saving Ordinance (EnEV 2002)	0.89 mln	71 kWh/m^{2}a
2010 – 2011	EnEV 2009	0.18 mln	50 kWh/m^{2}a

Data source: BMWi (2015)

However, largest share (about 7 million) of buildings were constructed after 1949 and before the introduction of First Thermal Insulation Ordinance (WSVo). This category of buildings has highest annual average annual consumption per square meter (BMWi 2015).

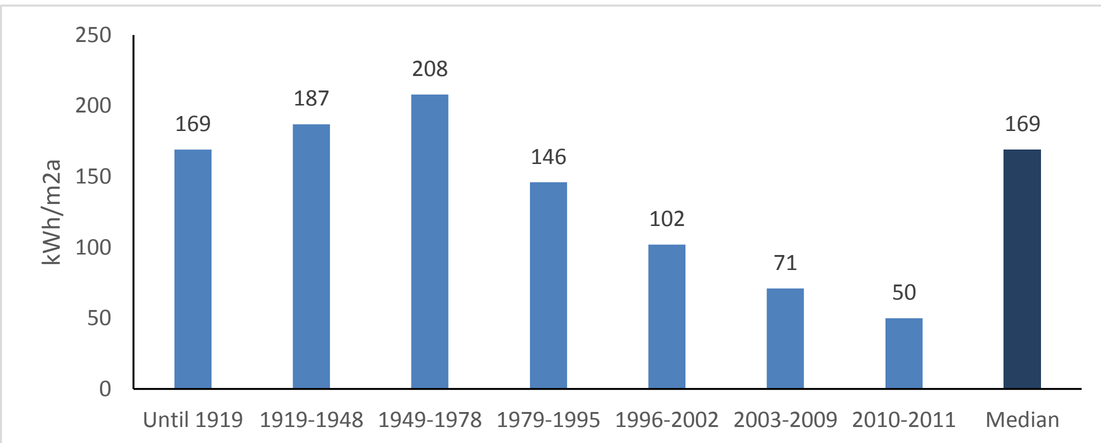

Figure 33. Distribution of average annual consumption per m2 of housing stock by age of construction.
Data source: BMWi (2015)

One of the unique feature of Germany's residential sector is high share of rental dwellings. Unlike to the EU, about 55% of all dwellings in Germany are rented and remaining 45% are owner occupied. This makes tenant-landlord dilemma especially vocal for energy retrofit policy (Schlomann and Clemens 2016).

4.3.1.2 Regulation Imposed

Federal Ministry of Economics and Technology (BMWi) is a main federal body responsible for implementation of energy policy in general and energy efficiency policy in particular. This includes implementation of EU energy efficiency Directives.

The Federal Agency for Energy Efficiency (BfEE) oversees overall control over the achieving energy efficiency targets set up by the Government. Administratively, the BfEE is within the Federal Office of Economics and Export Control, which in turn is under the BMWi.

The Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is in charge of renewable energy development and climate policy.

Finally, German Energy Agency (DENA) also plays one of the most important role in implementation of national energy efficiency policy. Dena serves as an interaction actor between industries, private sector and the government. It is a for-profit organization and its governance comprised from representatives of the Government, KfW, Allianz SE, Deutsche Bank AG and DZ BANK AG (Schlomann et al. 2010).

There are two general approach to energy efficiency in buildings: deep energy retrofit and smaller, incremental improvements. Deep thermal retrofit is more technically challenging and financially expansive in terms of both absolute costs and costs per unit of energy saved. Meanwhile, incremental improvements are cheaper and technically easier to implement on a larger scale with larger savings per euro invested. Germany's approach to thermal retrofit is considered as deep energy retrofit. However, constant revisions of thermal standards for both new buildings and retrofit, which make them further stringent and tight can violate economic and technical feasibility of thermal improvements. Furthermore, revision of standards increases cost of new houses and retrofit which brings equity and affordability issues as well as disincentives homeowners to invest in thermal upgrades.

German Federal Government has set for itself ambitious national climate target. According to the climate policy, Germany commits to reduce 80% of GHG emissions from 1990 level by 2050. To achieve this target, the Government integrated its energy and climate policy in one regulation framework with aggressive, well developed and targeted instruments. All of them are focusing on three pillars: demand, incentives, and information.

Germany has several unique features in promoting energy efficiency improvements in buildings. While other countries are focusing in market instruments and voluntary commitments, Germany puts more emphasize on mandatory requirements. With the introduction of First Energy Saving Ordinance ("EnEV") in 2002, all residential and non-residential houses have to be upgraded to new minimum energy performance requirements during major refurbishments of the buildings. For example, even during partial repairmen of building, such as modernization of roof, replacement of windows or additional wall insulation, elements being repaired should meet new, modern thermal requirements.

Another pillar of German climate and energy policy is heavy reliance on subsidies to stimulate deep energy retrofit with thermal requirements even stricter than existing standards. In Government's perspective, thermal energy upgrades will significantly reduce fuel demand in a long run and therefore will always payback during lifetime of the implemented measure (with some exceptions) (Galvin and Sunikka-Blank 2013).

Evolution of building codes

After five revisions of building codes during last 40 years, average maximum permitted primary energy consumption for space and water heating in new buildings decreased from 265 kWh/m^2a in 1977 to just 70 kWh/m^2a in 2009, almost 75% reduction.

Table 20. Maximum primary energy consumption and loses for space and water heating in new buildings and during retrofits

Ordinance	Active from	kWh/m^2a for new buildings	W/m^2K for new buildings	Wall thickness for new buildings	Wall thickness for partial retrofit	Wall thickness for full retrofit
WSVO	1977	265	0.96	3 cm	-	-
WSVO	1982	220	0.78	5 cm	-	-
WSVO	1995	150	0.68	8 cm	-	-
EnEV	2002	100	0.60	12 cm	12	8
EnEV	2009	70	0.48	16 cm	16	12

Data source: Galvin and Sunikka-Blank (2013)

After revision in 1995 U-values has been set for parts of the building, not for a whole envelop as was before. During the revision in 2002, every building intended for reconstruction of at least 20% of some of its elements (i.e. roof, walls) should increase thermal performance of this element to the level of *at least* as good as for a new building. If whole building was planned for complete renovation thermal standard was allowed to be 40% less stringent than standard for a new building.

Second revision of the “EnEV” in 2009 decreased minimum portion of element being renovated from 20% to 10% (for example, if only 10% of roof was planned for renovation, then this portion should meet thermal requirements of roofs set for new buildings). Another important feature of this revision, is that every new building now should have any kind of renewable energy installed.

Such aggressive increase in thermal standards met strong opposition from construction industry. It was argued that EnEV 2009 standard caused significant increase in retrofit costs to the level exceeding economic viability. Serious discussions between the Government, industry and expert community resulted in postpone of standards further revision scheduled for 2012 (Galvin and Sunikka-Blank 2013).

Updated EnEV codes have been enacted from May 1, 2014. New standards which became effective from 2016 require 25% reduction in energy use for new buildings in comparison with EnEV 2009. Thermal performance of existing buildings during refurbishment were not changed during this revision (Marianne et al. 2014).

Subsidies

Federal subsidies in a form of loans and grants are major instrument to incentives households for implementation of energy efficiency measures in both existing buildings and new houses. Wide range spectrum of incentives for different categories of customers sometimes collectively called CO_2-building refurbishment program and implemented via the KfW.

KfW raises funds for refurbishment program on financial markets and distribute them via local commercial banks in a form of low-interest loans. KfW is able to provide highly attractive low-interest funding because of two reasons. First, since KfW is public bank and therefore its obligations are guaranteed KfW has AAA credit rating which allows to raise money at very low interest rate on financial market. Second, federal government ever year provides funding from the national budget which decreases interest rate provided by bank even further. This allows bank to provide preferential loans with interest rate lower than commercial banks market. Subsidized interest rate results in 7-12% savings in NPV of loan amount. Repayments of loans provided by KfW are secured via secondary land charge on debtor property. First charge is often assigned to the first mortgage. While first charge is the most secure right and no other charge can take priority, secondary land charge is considered as sufficient guarantee for KfW loans. However, applications for KfW loans are still subject to credit check and approval at the on-lending, local bank. Usually, loan-to-value ratio of lender does not exceed 1 (Schröder et al. 2011).

CO_2 refurbishment of buildings program started in 2001 and was focusing on providing low-interest, subsidized loans during whole building renovation only. Previous program, "CO_2 Reduction Program", funded single measures and was replaced because of low utilization rate of CO_2 reduction potential of buildings. However later, "CO_2 refurbishment of buildings" also started to cover partial refurbishment and customers received option to choose low-interest loan or grant.

Amount of subsidies depends on the level of energy efficiency improvements due to refurbishment in comparison with existing standards for new buildings. In general, the more improvements exceed standards for new buildings, the more subsidies will be available for particular project. Every project is evaluated in terms of both overall energy consumption (Q_p) and transmission loss standard (H_t).

Table 21. Description of level of subsidies and required energy performance standards

Standard name	Q_p as % of new building standard	H_t as % of new build standard	Average Q_p (kWh/m^2a)	Improvement on average EnEV retrofit standard	Subsidy as % of thermal costs	Max. subsidy
KfW-Effizienzhaus 55	55%	70%	40	60%	20%	€15,000

KfW-Effizienzhaus 70	70%	85%	50	50%	17.5%	€13,125
KfW-Effizienzhaus 85	85%	100%	60	40%	15%	€11,250
KfW-Effizienzhaus 100	100%	115%	70	30%	12.5%	€9,375
KfW-Effizienzhaus 115	115%	130%	80	20%	10%	€7,500

Data source: Galvin and Sunikka-Blank (2013)

Level of subsidies in each case is aimed to compensate additional costs for improvements that go beyond existing standards. Projects that will improve energy performance to the level of existing standards will pay for themselves during the lifetime of the measures (usually 25 years) and thus do not require financial support. Therefore subsidies are intended to compensate refurbishment that otherwise will be considered as not economically viable. One of the outcome of this incentive is that this type of subsidies finance only highly economically attractive projects.

Another important feature of the Federal regulation on thermal retrofit is that projects are economically viable only when linked and synchronized with buildings maintenance and repairs cycles when part of retrofit costs are in maintenance “anyway costs” budget. Therefore, if projects are conducted out of regular major maintenance cycle, economic viability criteria may not be met driving cost of already expensive retrofit project even higher. Furthermore, some projects can be economically viable if thermal upgrade will be made to lower that required by regulation thermal standard, but this is prohibited by regulation.

Applications for grant are submitted directly to the KfW, while applicants for loans should apply to any local bank. Both applications, for grant or loans, should be submitted with signature of energy expert (Hilke and Ryan 2012b).

The program is financed through federal budget allocation process and revenues from Energy and Climate Fund. Thus, amount of available funding depends on priorities and decision making process of current government and contribution from the Energy and Climate Fund, which is financed through CO_2 cap and trade system and auctioning of CO_2 certificates. Similarly, interest rate of KfW loans depends of availability of available resources, when rate is raising when amount of available resources is decreasing (Hilke and Ryan 2012b).

Finally, German government surprisingly do not require inspection of the buildings being retrofitted and instead relying more on occasional surveys, so there is no systematic evaluation of effectiveness of energy retrofits Galvin and Sunikka-Blank (2013).

“Economic viability”

As was mentioned before, German government promote and advertise deep thermal retrofit measures as investments that will pay for themselves during useful lifetime of the measure or as “economically viable”. Households are required by law to include thermal retrofit measures during planned major refurbishment of the house. By including in the regulation concept of “economic viability” the government aims to protect households by requiring only measures with payback period equal to useful life of measure. However, this approach has several disadvantages that questions economic and technical feasibility of measures, predicted savings and overall possibility to reach climate targets.

German regulation clearly distinguishes “anyway costs” and “additional thermal costs”. For example, during retrofit of roof and walls, expenses on removing old renders, tiles, removing old layers and putting new layer of paint account to “anyway costs” – or expenses that will occur anyway during scheduled renovation of building and therefore do not included in total cost of thermal renovation project. “Additional thermal costs” are applied only insolation materials and labor costs related to them. Therefore, if total costs of deep thermal retrofit to EnEV requirements vary from €500 to €1,200 per m^2 of floor area, the ‘additional thermal costs’ may range only from €100 to €300.

Obviously, this leaves households which do not want to wait until planned major reconstruction of their building out of this scheme. In this case, for households who are willing to have warmer dwellings, decrease their footprint, all costs associated with thermal retrofit will be “additional thermal costs”. This aspect can be one of the explanation why thermal retrofit rate in Germany is lower than expected. In combination with lack of inspection, this also creates an incentive to ignore EnEV requirements and conduct thermal upgrade to the level, which households see appropriate and economically reasonable.

Furthermore, economic viability is calculated on theoretical and calculated assumptions about baseline energy consumption of building and thus similarly estimates potential energy saving potential. However, actual, metered energy consumption is often well lower than calculated baseline which leads to decrease of potential savings, increases payback period. According to the studies, largest economically feasible potential for energy savings in multistory buildings build in 1958-1968 is 41%. Large share of buildings has potential gains of about 20%. The average energy reduction potential of buildings constructed after Second World War is 25%.

It is therefore suggested to adjust thermal retrofit policy so that it will be based not on "economic viability" and mandatory obligation to meet thermal requirements set up by EnEV, but on "economic optimum" that will focus on achieving of maximum gains at lower cost (Galvin and Sunikka-Blank 2013).

4.3.1.3 Results

Schröder et al. (2011) argue that during 1990s, KfW funded refurbishment of about 50% of all dwellings of former GDR. Roughly 3.6 million dwellings were retrofitted during just ten years.

In 2006, each building retrofitted using KfW funding under the "CO_2 Building Rehabilitation Program" decreased CO_2 emissions by almost 60%. At the same time, measured energy consumption of treated floor area decreased ten times, from 275 kWh/m^2 to 25 kWh/m^2 per year (Schröder et al. 2011).

About quarter of CO_2 emission reduction from existing building stock during 1990-2006 is attributed to the KfW preferential loans. "CO_2 Building Rehabilitation Program" is the second most successful energy policy implemented until 2007, while first place is given to EnEV building codes program (Schröder et al. 2011).

In 2008 about 36,000 loans were issued under CO2 Building Rehabilitation Program with total subsidies €2.9 billion. This investment activities secured and created 225,000 jobs. Total 134,000 dwellings were retrofitted which resulted in decrease of energy consumption of 1,530 GWh. At the same time CO_2 emissions dropped by 58% while €3.1 billion were saved from heating bills (Schröder et al. 2011).

Total outcomes of KfW programs during four year periods are estimated as:

- Retrofit of 1 million existing homes;
- Construction of 400,000 new highly energy efficient homes;
- 894,000 jobs created directly in building and other related industries;
- €27 billion disbursed in loans and grants;
- More than €54 billion of investments.

Due to implemented policies targeted on new residential buildings, share of natural gas and fossil fuels in structure of heating systems dropped significantly and was mainly replaced by renewable energy sources and increased share of district heating. From 2000 to 2014 share of natural gas in structure of heating system in new flats dropped from 76% to almost 50%, while share of electric heating pumps skyrocketed from less than one percent to 20 per cent in 2014 (BMWi, 2015).

Schröder et al. (2011) report that by 2010, about 9 million dwellings constructed before 1979 have been renovated to new building standards via KfW-funded low-interest loans. At the same time, during 2002-2009 energy use by new buildings decreased by half from 120 to 60 kWh/m^2 per year. Energy use of retrofitted buildings decreased to approximately 80 kWh/m^2 per year. Overall, for every €1 spent on KfW subsidies, additional €9 were spent in loans and private investments which indicates a leverage ratio 1:10. Furthermore, KfW activities resulted in cutting cost on heating by €1 billion per year during 2006 and 2009, while reducing CO_2 emissions by almost 4 $MtCO_2$ annually.

As of 2012, annual energy retrofit rate in Germany was 0.8-1%. Average calculated reduction in energy use in projects that received KfW funding is reported as

33%. At the same time, measured energy consumption reduction is estimated as 25%. The Government was aware and concerned by such slow rate of improvements because with such rate 80% reduction goal by 2050 certainly will not be met (Galvin and Sunikka-Blank 2013).

By the end of 2016 situation with rate improved, however not significantly. While EU average retrofit rate of housing stock is 1 per cent, Germany has highest rate of buildings energy retrofit rate among all EU member states – 1.75% (EC 2017). To achieve 2050 emissions targets retrofit rate should be 2.1% (Galvin and Sunikka-Blank 2013).

Despite lower than expected retrofit rate, rate of decrease in residential space heating energy use in Germany is about 3%, which can be attributed to energy efficiency improvements and one of the highest among other EU member states (MURE-ODYSSEE 2015).

The KfW program also has made significant impact on market. More than €23 billion have been disbursed as loans during 2001-2010. Average size of the loan for four-dwelling house was about €80,000 during 2005-2010. Single family houses account for 75% of all disbursed loans. Further analyses of loan characteristics demonstrates that households tend to implement less efficient option of retrofit despite the fact the level of financial support if proportional to the depth of thermal retrofit. In 2010 8,000 projects aimed to reach KfW-EH 100 level have been financed with KfW support, compared to only 112 KfW-EH 55 projects (Hilke and Ryan, 2012).

Table 22. Estimate of ratio of public costs to energy and emission savings

	2008	2009	2010
Total cost of the programs (million €)	973	1608	1155

Total final energy savings achieved (GWh/year)	1605	2789	2592
Public costs per KWh saved (in €) with 30 year life time	0.020	0.019	0.015
CO_2e emission savings (tons/year)	572,000	995,000	946,000
Public cost per ton CO_2e saved (€)	57	54	41

Data source: Hilke and Ryan (2012)

During economic crisis of 2008-2010 and raising concerns over employment, one of the goal of KfW program became job creation. KfW funded activities in thermal refurbishment created or preserved about 210,000 jobs in 20008 alone (Schröder et al. 2011). Financing of the programs increased dramatically in 2009 as part of government's economic stimulation package. It is reported that every million Euro invested, two KfW programs have generated or saved on average 16.4 persons per year, which can be considered as a quite successful result for maintaining and creating workforce during economic crisis (Hilke and Ryan, 2012)

4.3.1.4 Lessons Learned

Development of Germany's energy retrofit policy has unique history and context, which makes it harder to replicate in other countries. The driving force of German's deep energy retrofit policy – the KfW bank – has been created as part of the Marshall Plan for reconstruction of Germany after the Second World War.

Germany's energy retrofit policy relies on three pillars:

1. Clear and aggressive regulation;
2. Financial incentives and stimulus to conduct energy efficiency measures;
3. Providing information and expert support (via energy advisors).

Set up of special investment vehicle – public KfW bank – which channels retrofit subsidies via local banks. This mechanism increases efficiency and leverage.

KfW subsidies are performance-based and targeted for the deep energy retrofit of whole house, rather than small incremental savings.

Qualified energy advisors support proved to be effective tool to properly evaluate needs of every households needs in energy retrofit. This tool also helped to accumulate significant experience in deep energy retrofit for the whole Germany's construction industry.

Aggressive energy savings targets for existing and new buildings supported by constantly revised buildings codes and attractive preferential loans and grants for retrofits that goes beyond existing building codes.

Active involvement of local energy agencies and activities of DENA as a platform of communication of engineers, planners, researchers etc.

These and other factors are considered as a drivers of Germany's success in energy retrofit of existing buildings (Schröder et al. 2011).

One of the unique feature of German deep energy retrofit policy is its connection with building codes for new buildings. Once the thermal requirements for new buildings revised and became stricter, requirements for thermal requirements during refurbishment adjusted automatically. This mechanism ensures that only most aggressive measures that require additional support will be financed with KfW funds (Hilke and Ryan, 2012). In turn, this approach decreases impact of so called "free rider" effect, when public funds used for energy efficiency measures that would have been implemented anyway without subsidies.

Raising public awareness and information campaign in combination with energy advisors also considered as one the factors that lead to success of KfW program (Hilke and Ryan, 2012).

However, analysis of several decades of German's energy policy aimed for buildings energy retrofit identified following technical-related flaws:

- Constantly increasing thermal standards for buildings retrofit lead to diminishing returns of every incremental U-values required by regulation. Specifically, the thicker the insulator required to reach lower U-value, the less economically viable project will be. With U-values lower than 0.4, which corresponds to 8-10 cm of insulator, economical advantage of measure falls dramatically;
- Geometry and physical properties of large portion of existing stocks puts further technical and economics constrains of deep-energy retrofit projects required by the regulation. Such common building elements as basement ceilings, walls alongside balconies, around windows, additional corners, orientation to non-Sun side are typical barriers which lowers profitability of measures;
- Insulated houses require proper ventilation capacity and regime in order to avoid mould issues which can increase installation cost and daily energy usage since most of German dwellings rely on natural ventilation;
- Behavior energy savings potential needs to be reassessed and properly addressed in promoting campaigns;
- Retrofitting to very high level should not be compulsory, especially for households that cannot afford it (Galvin and Sunikka-Blank, 2013)

Experience of Germany in designing and conducting policy focused on energy retrofit of existing buildings provides valuable lessons for policy makers and researchers. Despite significant progress and highest retrofit rates among EU member states, Germany is still lagging behind in achieving its highly ambitious climate targets for 2050.

4.3.2 Lithuania

4.3.2.1 Introduction

Lithuania is Baltic state and the former Soviet republic with population about 3 million people and area of 65,300 km^2. In 2003 Lithuania held referendum about EU accession and one year later, in 2004, got EU membership. In the following years country, had been experiencing rapid economic growth. During 2004-2008 period GDP of Lithuania was growing on average 7.8% per year. GDP growth at this time was one of the fastest growing across all EU member states. However, in a wake of global financial and then economic crisis, GDP growth slowed down to 2.9% in 2009 and decreased by almost 15% in 2009. From 2009 economy returned to growth and fully recovered from financial crisis in 2012 (Gaigalis and Skema 2014).

As for 2015, Lithuanian GDP per capita was $14,147 in current prices, compared with $32,000 in EU average (World Bank 2017d). Climate in Lithuania considered as cold with average winter temperature –5°C, while almost every winter temperature drop to –20°C and sometimes can be even –34°C (Sirvydis 2014).

After collapse of Soviet Union, Lithuania inherited enormous for its size power generation capacity. To illustrate, total installed capacity of power plants was three times more than demand and export demand combined (Vilemas 2010).

Power sector comprises from more than 4,000 MW of installed capacity, 68% of which is thermal power plants, 25% - hydro and remaining – renewables, mainly biofuel. Natural gas and various form of biofuels are major fuel sources. Despite that energy intensity of Lithuania decreased by more than 50% during 1995-2004, it still 2.5 more than EU average (Sirvydis 2014).

Lithuania is energy dependent country. One of the conditions for EU accession EU was to shut down Ignalina Nuclear Power Plant. INPP with 3,000 MW of installed capacity, played major role in electricity generation as it produced about 70-80% of country's electricity. However, INPP had the same design as Chernobyl NPP and according to the EU nuclear safety standards it was technically impossible to increase safety of INPP with RBMK-type of reactor to acceptable level. So Lithuania agreed to shut down first unit be the end of 2004 and second – by 2009 (Gaigalis and Skema 2014).

After shutdown of the Ignalina Nuclear Power Plant, share of energy import in primary energy supply increased from 50% in 2009 to 76% in 2013 (World Bank data). Reduction of energy intensity therefore will decrease country's vulnerability to price shocks on international markets and reduce greenhouse gas emissions. Despite high reliance on energy import, several infrastructure projects contributed to the energy supply diversification. Specifically, LNG terminal had been completed in 2014 while Lithuania-Sweden ("NordBalt"), and Lithuania-Poland ("LitPol") electricity interconnections became online in late 2015 (OECD 2016).

According to the Lithuanian energy balance for 2015, transport sector is the largest energy consumer, followed by the residential sector (Statistics Lithuania 2016).

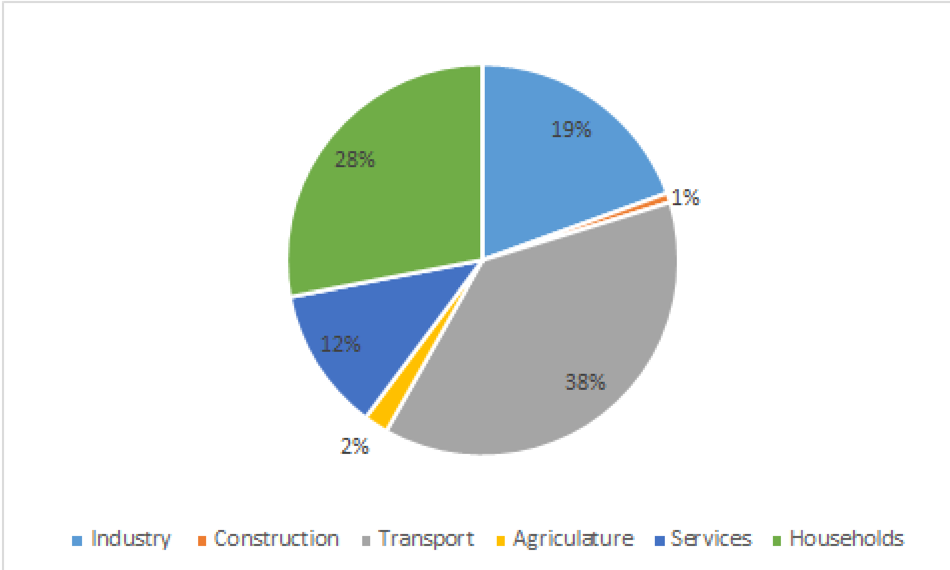

Figure 34. Final energy consumption of Lithuania in 2015
Data source: Statistics Lithuania (2016)

Residential sector is largest consumer of heat. In 2015 sector accounted for 54% of heat consumption. About 63% of heated area in urban areas heated with district heating. Municipalities run more than half of all district companies, while remaining operated by various form of public-private partnership. As for 2014, district heating tariffs were reviewed and regulated by the National Commission of Control of Prices. Tariffs can be adjusted annually or per months and local councils should pass resolution of each revision. Because of local political involvement, local councils tried to keep tariffs low and that’s why tariffs did not reflect all production cost, which undermines financial viability of the district heating companies. More than 26,600 buildings are heated by district heating companies. 73% of these buildings are multistory buildings. As for 2012, about 17% of customers had outstanding debts to district heating companies. Heating energy intensity per heated area in Lithuania is among highest among European countries with similar climate conditions (Sirvydis 2014). Overall, total energy saving potential of final energy consumption by 2020 is 17% compared with energy use in 2009.

According the Lithuanian statistics, in 2012 housing stock comprised from 37,379 apartment blocks, 439,767 single and two-family houses and 1,752 houses for various social groups; total – 478,898 residential buildings.

As of 31 December2012, the stock of dwellings amounted to 85.8 million m^2 of useful floor area. 54.5 million m^2 of such amount were in urban and 31.3 million m^2 – in rural areas.

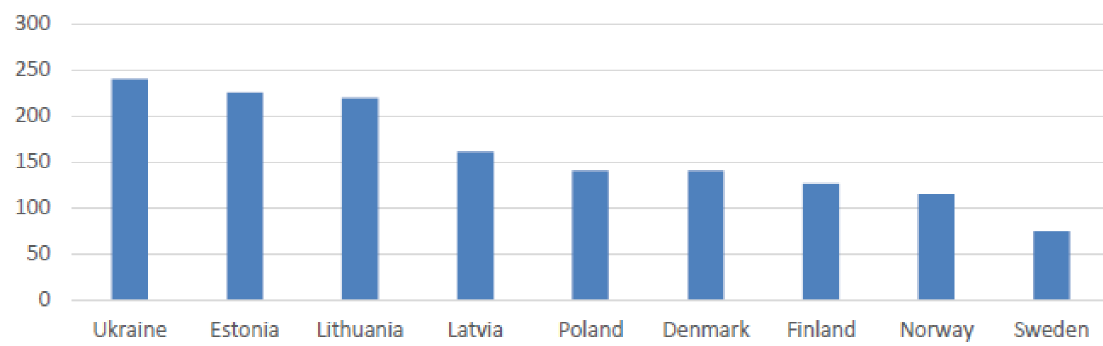

Figure 35. Heat consumption per heated area in kWh/m^2
Data source: Sirvydis (2014)

According to the housing regulation, maintenance of the multistory buildings is compulsory and can be done via three forms (Sirvydis 2014):

- Establishment of Homeowner Association (HOA); 17% of all building operated by the HOAs;
- A Joint Activity Agreement (JAA) - similar to HOA but with one distinguish feature - decision making process in JAA is based on share of the property of JAA owners instead of just one voice per apartment in HOA; 3% of buildings operated by the JAA;

- "Administrator" is appointed by the municipality in buildings which did not decided to establish HOA or JAA; 80% of all buildings operated by the "Administrators", usually in a form of municipal housing maintenance companies.

4.3.2.2 Regulation Imposed

As has been mentioned, energy intensity of Lithuania decreased by more than 2.2 times during 1990-2004 with rate higher than among EU15 member states. Structural changes in economy have been major driving factor behind energy intensity improvements. Another driving factor is energy prices. In 1997 all energy prices in Lithuania have been adjusted to cost reflective level. The Control Commission for Energy Prices and Energy Activities had been established also in 1997. It is an independent body with authority to regulate energy prices in gas, heat and electricity sectors based technological and economic factors without any political influence (Streimikiene et al. 2008).

In 1996 the Ministry of Environment established the Lithuanian Environmental Investment Fund (LEIF). The objective of the Fund is to address environmental externalities caused by enterprises and increase their environmental standards in compliance with the Environmental Strategy of the Republic of Lithuania. The European Commission and the USAID took commitments to allocate financial support and technical assistance for the Fund. The main source of revenue for the Fund, however, is 20% and from 2003 30% of pollution tax imposed according to the Law on Environmental Pollution Tax. The Fund provides grants and low interest loans. LEIF loans can be extended by the commercial banks in a form of co-financing. Loans are issued in local currency, for maximum 5 years, provided by the Credit Institutions which shares risk of non-repayment from their own fund, interest of loan is calculated only on margin set by the financial institution, meaning that the Fund does not have interest for its own part (Valuntiené 2009).

In 2002, the Parliament of Lithuania adopted Energy Law. It prescribes that all imported or domestically produced gas-fired heaters and hot boilers with nominal power 4-400 kW should meet certain energy efficiency requirements. Additionally, home appliances both imported and domestically produced should have energy-efficiency labeling.

On a supply-side, the government imposed regulation that promotes transition from imported fossil fuel to less expensive domestic fuel, such as biofuel, in a district heating systems. For that purpose, the Methodology for Pricing of Centrally Supplied Heat and Hot Water was adopted in 2003. According to the Methodology, tariffs of district heating companies is fixed for 3-5 years and during this period companies can replace equipment that run on cheaper fuel. The difference between tariffs fixed for determined period allows to yield profit and facilitates return on investments. Additionally, feed-in tariff equal for 1.2-1.4 of average electricity rate was introduce in 2005 to encourage development of cogeneration (Streimikiene et al. 2008).

Lithuanian policy on promotion of energy efficiency in residential sector can be divided on three periods:

First period (1996-2004) - implementation of Energy Efficiency Housing Pilot Project by the World Bank with technical assistance from several European Governments;

Second period (2005 – 2010) - started after approval of The Lithuanian Housing Strategy;

Third Period (2010 – ongoing) - start and implementation of the Joint European Support for Sustainable Investment in City Areas (JESSICA) project.

Short description of each of the period will be provided below.

First period: Lithuania Energy Efficiency Housing Pilot Project (1996–2004)

A project financed by the World Bank, aimed to increase energy efficiency improvements in residential sector by providing credit line to the HOAs. Project was also supported by the technical assistance provided by Danish and Dutch governments. Technical assistance assumed set up of advisory centers, free advices to the HOAs and households in technical, financial and other matters of the energy efficiency projects. Additionally, private companies were trained to conduct energy audits, project supervision etc. Public communication campaign has been effective tool to attract 193 HOAs, 25 owners of individual houses to take on loans for energy efficiency improvements.

Overall, technical assistance of the project included consultants in following areas: banking; energy, technical monitoring, social monitoring, public information, public institutions, training, HOA organization (Sirvydis 2014).

Features of the loans and subsidies:

- Only one bank participated in project without committing own funds for credit line and acting more like an agent;
- Loans borrowed in local currency at 11% interest rate (below market rate) with minimum 10% contribution from HOA or household, 10 years of maturity period and without mortgage requirement;
- After 1999, Government provided 30% of grant for loan principal, but not more than \$12.5/m2 of living area; partial VAT exemption was introduced an addition to the grant;

- Only registered HOAs without outstanding arrears for household utility services were eligible for loans, which could be spent only for energy efficiency improvements;

- HOA should reach common agreement to apply for a loan and amount of loan repayments from HOA was dependent from apartment size of each household.

Generally, two types of subsidies have been provided: 1) capital subsidy which varies from 10 to 30% depending from level of energy efficiency measures implemented, subsidy should not exceed $16/m^2$ of useful area; 2) subsidies for low-income groups which cover down payment cost (not more than 10%); credit insurance premium and part of debt service.

When World Bank project ended in 2001, the Lithuanian Government extended energy efficiency program based on a project until 2003 and provided state financing for it (Taylor et al. 2008)

The Lithuanian Housing Strategy was approved by the Government in 2004. The Strategy points out on need to establish a sustainable funding mechanism for energy efficiency improvements in buildings. The need of adequate funding and crediting mechanism and financial assistance to low-income households to implement energy efficiency improvements has been established during the implementation of Energy Efficiency Housing pilot project. The Strategy also encourages creation of homeowner associations (HOAs) in order to increase energy efficiency investments in housing. Specifically, state financial assistance is available for HOAs for energy use improvements (Streimikiene et al. 2008).

Second Period: "Multi-Apartment Buildings Modernization" Program.

Later same year, 2004, the Government launched the "Multi-Apartment Buildings Modernization" Program. The program highlighted two major challenges:

increase of energy prices and its adverse impact on households and energy dependency concerns. The objective of the program was to encourage energy efficiency improvements in multistory residential buildings by providing subsidies for housing modernization. The mechanism assumes 5% of project cost as contribution from building owners, up to 95% as loan from the financial organization and up to 50% as a subsidy from the Ministry of Environment. Amount of subsidy depended on a depths of energy efficiency improvements (i.e. 50% subsidy available when walls and roof insulation is assumed in a project) (Valuntiené 2009).

Throughout period conditions and amount of state subsidies varied:

- 2005- 2007: between 15-30% depending on the depths of energy efficiency measures implemented;
- 2007-2009: 15,30,50% if C class of energy efficiency performance achieved;
- 2009-2010: 15% of state subsidies.

Amount of subsidies depended on general economic activity. During high period of economic growth state subsidies increased from 15-30% to 50%. However, in 2009, driven by global economic and financial crisis state subsidies decreased to 15%. Financial support for technical assistance, preparation of documentation etc could be up to 50%. Full 100% subsidies were provided to low-income households to cover loan repayment through heat subsidies. Average loan amount – 5,800 Euro per apartment. Achieved reduction in annual heat consumption per building during this period was 30-46% (Sirvydis 2014).

During this period, also several fiscal measures were imposed to promote energy efficiency improvements in residential and construction sectors. Value Added Tax (VAT) for heat supply to households has rate of just 5%, compared to standard

VAT rate of 18%. The difference between standard and special VAT rate is covered by the state budget. Similarly, VAT rate for housing construction, renovation and retrofit is set to 9%. In this case, difference between VAT rates was financed by state budget, municipal sources and soft credits issues by state funds (Valuntiené 2009).

In third period new lending mechanism, launched in 2009 was developed by the European Investment Bank and financed via European Regional Development Fund (ERDF)[6]. Access to EU funds allowed Lithuanian government to provide low-interest loans without increasing financial burden on a state budget. Initial allocated funding was 227 million EURO (127 million Euro from ERDF, while remaining raised from national funding). The Housing and Urban Development Agency (HUDA) under the Ministry of Environment served as an administrator of the rules and conditions for participation in (Joint European Support for Sustainable Investment in City Areas) JESSICA instrument.

The interest rate for JESSICA was set at 3% fixed with loan maturity period of 10-20 years. The energy efficiency modernization package includes following measures:

- Replacement of windows with double-glazed, sealed-unit plastic windows;
- Building's walls Insulation with 15cm of expanded polystyrene and rendered finish;
- Roof insulation with 20 cm of expanded polystyrene and watertight finish;
- Doors replacement;

[6] Currently, one of five EU Structural Funds

- Glazing of balconies;
- Installation of balancing valves within the heating distribution system inside multistory building.

However, despite attractive financial terms and conditions of the scheme, take-up rate of the JESSICA program was rather low. Following reasons have been identified as barriers: 1) Existing regulation required consensus by majority members of HOA in the building. However, because of difference in social status, experience and knowledge between members this consensus was often difficult to reach; 2) Project implementation required pro-active approach of HOA members in various project stages and activities such as conducting tenders, contracts, project supervision etc. In turn, this required significant amount of time and specific expertise, that households often did not have; 3) Reluctance of apartment owners to take on debt and long-term repayment liability in a shade of difficult economic situation.

In order to address these and other obstacles, the government amended program to give permission to building administrators to take on loans for thermal retrofit. This change facilitated financial arrangement with lending organizations (which were selected by the EIB) and improved technical commissioning of the renovation projects. Under new scheme, loans will be repaid through administrators via savings that apartment owners make on heating payments.

State subsidies cover up to 15% of cost of renovation projects. Subsidies are paid after implementation of energy efficiency measures and achieving of at least C class Energy Performance Certificate. Another 15% of subsidies are available (until end of 2014) from Climate Change Program if project achieves 40% or more energy savings. Climate Change Program is financed through revenues from carbon credits, GHG emissions allowance etc. Technical assistance can provide up to 100% of project management and technical documentation costs. Additional funds are available for communities around Ignalina Nuclear Power Plant.

Additional financial support is provided for low-income households. These households usually already receiving state support for heat supply. In this context, additional support is provided for debt repayment. Specifically, eligible for supplementary assistance and registered in municipality households can get full compensation of the loan repayment via municipality (which in turn get compensation from state). After amendments made in May 2013, low-income households who refused to participate in retrofit project can lose 50-100% of subsidies until retrofit project is completed for a period of three years. These changes have been made in order to encourage low-income groups in participation in energy efficiency projects.

Barriers and lessons learned from this experience have been addressed in a new program called "EnerVizija". In comparison with previous design of energy efficiency mechanism, new program has following features.

- Municipality initiates, takes responsibility and appoints administrator for energy retrofit project. Apartment owners in the building have to give an approval for the project by voting;

- Building administration company play central role in attracting loans for renovation and project implementation. Loans repaid via monthly building management fee from each of the apartment. This allows to make centralized financial arrangement in a more professional way, assume credit risk from building management company and remove barrier of personal loans for homeowners;

- Technical assistance (procurement, supervision, contracting, management) is provided to the municipalities to increase institutional capacity to manage projects;

- Buildings retrofit projects consist from standard packages of energy efficiency measures and selected on results of cost-benefit analysis. Retrofit projects can be implemented for both single building and group of buildings which increases economy of scale and decreases costs;

- Municipalities select least efficient buildings based on heating consumption and with the help of technical assistance prepare documentation for project implementation to achieve at least C class which yields calculated savings of about 40-50%;

- Repayment period is calculated individually for each project and normally has 10-20 years;

- Project designed in a way, that apartment owners benefit in 10-15% bills reduction immediately after project completion, while the rest savings is used for repayments;

- Project Administrators opens credit lines with financial intermediaries selected by the EIB. Credit line is used to pay all invoices for project concerned, external consultants from technical assistance reviews incoming documents to make sure they are accurate and correct.

- State subsidies are paid to the financial intermediaries as soon as all contractors' invoices submitted, all project works completed and C class in Energy Performance achieved.

4.3.2.3 Results

During first period, energy efficiency loans were mostly spent on building's district heating system modernization, but after introduction of grant subsidies, windows replacement and façade insulation projects started to gain traction. Specifically, out of 229 total projects, 113 aimed for modernization of heating substation in building; 144 financed windows replacements; 41 roofs insulation; 26 retrofitted buildings walls;

Among 96 monitored projects, investments varied from $250 per apartment to $3,500 with average value roughly $1000. Similarly, achieved energy savings varied from 50% savings to even increased heat consumption with average value of 17%

(without adjustments for improved comfort). Experience shows that many households preferred increased indoor temperature and improved comfort level to monetary savings. Without accounting for increased indoor temperature, achieved annual savings are estimated as 25%; 56% of participants reported decreased energy bills, while 48% claimed improved comfort level.

Average payback was 17 years (without accounting for other benefits such as increased value of property, decreased maintenance costs and improved comfort), when grant and VAT exemption is assumed payback period falls to 12 years.

No loan defaults have been observed. Moreover, in many occasions households repaid loans earlier.

Summarized statistics of first period is presented below in a table.

Table 23. Results of energy efficiency program during 1996-2001

	1996–1997	1998	1999	2000	2001	Total
Total amount of loans to HOA, $	74,300	206,000	1,161,000	3,375,500	2,401,200	7,218,000
Amount of grant provided, $	NA	NA	442,300	905,500	692,200	2,043,000
Number of projects implemented	5	18	49	111	46	229
Number of projects advised	87	113	312	113	101	726
Number of buildings audited	46	54	141	66	24	331

Number of investment proposals prepared	27	45	134	75	23	304
Average loan, $	14,850	11,460	23,700	30,400	52,200	31,500

Data source: Taylor et al. (2008)

If two periods are combined, then during 1996-2005 total 1,200 HOA took part in projects; 799 investments proposals have been prepared; 712 were financed; $22 million has been invested in thermal retrofit of which $5.3 financed via the World Bank project (Taylor et al. 2008).

After introduction of EnerVizija Program in 2013 alone, municipalities submitted project proposals for 1,680 buildings across whole country. Out of this number in 917 cases apartment owners agreed to project implementation, of these number, 490 projects were approved by the financial intermediaries, 322 project started procurement process, 194 projects commenced (Sirvydis 2014).

4.3.2.4 Lessons learned

After completion of Energy Efficiency/Housing Pilot Project report from the World Bank (2002) highlights following lessons from first attempts to scale-up energy efficiency in residential sector of Lithuania:

Financial mechanism for residential energy efficiency improvement is not considered attractive without a grant support. Specifically, it was established that 30% of grant is required to increase demand from homeowners;

Spreading of information about success stories drives public attention and interest toward housing energy efficiency improvements. However, without financial assistance i.e. tax benefits or grants, information about success stories alone will not motivate people to implement energy efficiency measures;

Regardless of time and efforts devoted to change people's behavior, the process of learning new experience will be very slow;

Homeowner Associations will be more willing to take a bank loan for home renovation if they are provided with technical, institutional and financial support;

Lack of alienable collateral is significant barrier for private lending.

Additionally, it has been pointed out in another report (Taylor et al. 2008)**,** that evaluation of project financial performance based only on energy savings led to longer payback period. At the same time, projects had other tangible benefits such as increased comfort and property value, which difficult to translate into traditional cash flow and benefit analysis.

Financial performance of loans for energy efficiency can be improved if measures implemented at the time of other renovation works in building. Also, some HOAs constructed new floor in their buildings so that loan can be at least partly financed through revenues from selling or renting area in additional floor.

Unlike to loans for HOAs, which did not require mortgage, loans for single family houses required mortgages and this is one of the reason of low interest from households who live in individual houses. Only 25 loans have been financed.

Energy efficiency investments into underheated buildings result in improved comfort but increased energy consumption and, accordingly, resulted in longer payback period. This problem can also make ESCO reluctant to participate in such energy efficiency projects. In general, actual savings were more than estimated, but this does not account for increased comfort.

Commercial banks were reluctant to participate in projects, as such activities have not been in their strategic interests. One of the main reason for that is generally underdeveloped bank market in mid 1990s.

Technical support in a form of advisory centers played of the key roles in providing marketing, technical and financial assistance to the projects implementation. Initially, this support was provided due to financing from Dutch and Danish government. But after completion of World Bank's project, this services were provided on a fee basis.

Housing and Urban Development Foundation (HUDF) played major coordination role for marketing, promoting and providing assistance to key players. HUDF provide support in establishing and functioning regional advisory centers with energy efficiency consultants for HOAs.

Drawing lessons from all three periods, Sirvydis (2014) highlights following barriers and ways to improve performance of energy efficiency programs in residential sector.

Initially, commercial banks can be reluctant to participate and take risk in renovation projects. This barrier can be addressed by securing financing from several sources: EU structural funds; state subsidies; specialized national funds (revenues from environmental taxes, emission allowance etc).

Apartment owners do not want to take financial liabilities and long term financial commitments. Moreover, large number of individual application from apartment owners can create administrative burden for financial intermediaries to assess creditworthy and financial indicators for each of application. This can be addressed by involving municipalities as municipal buildings management companies as central body responsible for application for loans, project commissioning and implementation. Apart from other benefits this approach offers large financial savings on economy of scale and better efficiency of project selection and implementation. Loan and risk will be on the Administrator, which collect repayments via monthly fixed fees from apartment owners.

Low income households, who already receive heating subsidies, are often reluctant to agree on loans which complicates the process of reaching consensus in a building despite that initially there were offered 100% compensation for loan repayments. Rate of participation significantly increased after adoption of regulation that deprive low-income households 50-100% of state heating subsidies if they refuse to agree on project renovation.

Mechanism that specifies details on how and when loan repayment can be adjusted or extended can be used to minimize delays in repayments of the loans;

Centralized procurement for the projects facilitates and accelerates procurement phase of the project implementation.

Initially, cost of preparatory works can get subsidies only after completion of whole project, which discouraged apartment owners participation. New rules, adopted in 2013 provides more flexibility by financing preparatory works as soon as invoices for such works are received (Sirvydis 2014).

Due to high amount and significant complexity of required documentation and paperwork for renovation project, standardized forms have been developed to facilitate preparation of project documents (this forms include: grant application and payment request forms; standard technical design for renovation of common types of buildings; decision making template for HOAs for project approval among apartment owners;

investment plans; standard tender documentation; template for the energy efficiency program to be approved by the municipalities etc.) (Sirvydis 2014)

Training programs have been developed to increase capacity of municipal administrations to handle such large municipal projects; special software "Enervizija IS" has been developed to track and manage monthly payments from apartment owners.

Since projects managed by the municipal administrators targeted mainly least efficient buildings, HOAs at other buildings can initiate and apply for project renovation individually.

Efforts should be made to ensure required quality of renovation projects. This can be done by special training programs, deposits paid by the contractors prior to work which will be returned after completion of works and confirmed high quality of works; appointments of experts to monitor quality of project implementation.

Municipalities should develop a plan and coordinated efforts with heat supply companies to prepare to future decrease in heat demand due to energy efficiency projects. Heat supply companies should plan necessary investments for these adjustments. However, part of the heat demand reduction from existing buildings can be compensated by increase from the new customers, including from new buildings.

Almost two decades of experience allowed to design effective tool which combines several funding sources, wide technical assistance to apartment's owners and HOAs, special attention to the low-income groups. Design, implementation and results of the JESSICA program can be considered as a successful mechanism to scale up residential energy retrofit in post-communist countries. In May 2015, European Investment Bank, signed agreement with the Government of Lithuania about establishing of “Jessica II” Fund with amount of EUR 150 million. As for May 2015, about 250 buildings have been retrofitted under JESSICA program and another 1,000 under implementation (EIB 2015).

Chapter 5

CONCLUSIONS AND POLICY RECOMMENDATIONS

After collapse of the Soviet Union, former Soviet republics, especially with cold climate, inherited vast highly inefficient infrastructure. This is especially the case for multistory apartment buildings. Ukrainian residential sector had challenges common for other former Soviet republics, such as Belarus and Baltic States. Households' heat use was mostly not-metered, billing was based on fixed norms and thus couldn't be controlled by occupants. Dominant for long period reliance on central government formed paternalistic mindset among population and later contributed to slow development of self-management practices and formation of house owner associations (HOAs). HOAs at the same time lack creditworthiness and are reluctant to take loans on commercial market with high interest rates and generally unavailable mortgages (Taylor et al. 2008).

Ukraine facing unprecedented challenges nowadays. Due to occupation of Crimea and loss of territories in Eastern Ukraine, country has lost about 20% of its industrial and economic potential. With continuing occupation and military conflict with Russia-backed separatist in Donbass region, Ukraine is struggling to embark on path of economic recovery and financial stability.

One of the main challenges is energy sector. Lack of transparency, accountability, chronical underinvestment's resulted in one of the world's highest energy intensity. In combination with cross-subsidization, this led to excessive energy consumption. To meet domestic energy demand, Ukraine relies on energy import, which deteriorates national balance of payments, increases national debt and undermines energy security. Natural gas is the second largest source of in the total primary energy supply (after coal) and largest source of energy import. Until recently, Russia was the main source of imported natural gas. High level of subsidies to households, intransparent bilateral relationship in natural gas supply, specifically in mechanism of natural gas price formation, resulted in several gas supply crises and large deficit for Naftogaz, which was eventually covered from the state budget and other sources.

Persistent natural gas subsidies for households created enormous fiscal deficit while discouraging investments in domestic natural gas and energy efficiency. Residential sector accounts for one third of total final energy consumption and 57% of country's natural gas use. At the same time, residential sector has vast untapped energy efficiency potential. Therefore, energy efficiency improvements in residential sector provides multiple benefits such as reduced reliance on natural gas import, improved balance of payment, decreased energy intensity, better resource allocation and equity distribution etc.

Struggling with deteriorating state finances, economic recession and decreasing standards of living, Ukrainian government with the support from the International Monetary Fund announced comprehensive reform plan at the end of 2014. The reform of energy sector has become of the major aim of the Government. Removal of implicit and explicit natural gas subsidies while protecting the poor is a key element of the energy reform. Several sharp price adjustments have been implemented. Two years later, economy has started to demonstrate positive dynamics. Despite ongoing military conflict in Eastern Ukraine, GDP slowly but gradually increases, inflation dropped significantly, Naftogaz declared positive income, domestic natural gas production started to increase. During 2016 no natural gas was imported from Russia, for the first time in history. However, significant amount of state funds is allocated to protect low-income groups after sharp increase of energy prices for households to import-parity level. Almost half of all Ukrainian households, receive state support to meet energy needs. Energy efficiency improvements in residential sector can significantly decrease pressure of energy subsidies on the state budget. One of the main challenges, the Government of Ukraine is facing today is how to convert these subsidies into investments in energy efficiency improvements of residential stock.

As for 2015, space heating accounts for 66% of final energy consumption in residential sector. During 2010-2014, space heating energy consumption by households dropped by 3 Mtoe, a 18% reduction. Three factors have been considered as drivers of changes: changes in size of population, changes in size of dwellings and changes in intensity, measured as ratio between energy used for space heating and floor area heated. Decomposition analysis shows that largest impact on change in consumption has been made by change in intensity, i.e. energy efficiency improvements. However, it seems more likely that such changes were also attributed to inconsistency of official data during 2014, when occupation of Crimea occurred.

Overall, energy intensity of residential space heating improved by 16% during 2010-2014. Despite such improvements, the level of space heating intensity is 20% higher than in Latvia, 30% than in Poland and 45% than in Germany. Accordingly, this percentage difference represents potential energy efficiency improvements of Ukrainian residential sector compared with these countries. Increase of space heating energy intensity of Ukraine to that of Latvia will result in reduction of energy consumption by 2.7 Mtoe. Natural gas consumption will decrease by 4 bcm annually, which represents 36% of total natural gas import in 2016. Avoided cost due to decreased gas import are estimate as much as $782 million in Q1 2016 prices. If space heating energy intensity will reach level of Poland, this will result in 4.2 Mtoe reduction in energy use. Reduction of natural gas use estimated as 6 bcm with total avoided cost of import as much as $1.2 billion annually in 2016 prices. Potential benefits will be even higher if Germany's space heating energy intensity used as a benchmark.

Modernization of district heating sector is particularly challenging from one side, and potentially more beneficial from another. 434 million m^2 or 45% of total floor area is connected to the centralized district heating supply located in urban area. At the same time, as much as 68% of total subsidies to low income groups to cover costs of household utility services, are provided to the households in urban areas. According to the studies, largest losses that lead to inefficient energy use occurred in residential buildings. Therefore, modernization of housing stock connected to the district heating provides vast opportunities in reduction of both final energy consumption and energy subsidies to support poor to meet their energy needs.

Total cost of deep energy retrofit of multistory buildings in urban areas is estimated as much as $19 billion in 2015 prices. Such investments in thermal modernization of buildings will result in almost 45TWh, or 3.81 Mtoe, of annual savings. This accounts for 35% reduction compared to space heating energy use in 2015. Levelized cost of energy of deep energy retrofit is estimated as 2,735UAH/Gcal, compared to weighted average price of 1,036 UAH/Gcal of existing tariff in Ukraine. LCOE of thermal modernization is financially unattractive for investment and significantly higher than existing tariff for heat supply because of high market cost of capital of 25%. If cost of capital for investment in deep energy retrofit will be the same as provided by the International Financial Institutions, or 2.07%, then LCOE will be lower for all types of building and for whole residential stock considered (666 UAH/Gcal of retrofit compared with 1,036 UAH/Gcal of existing tariff).

In order to make LCOE of retrofit at least the same as existing tariffs for heat supply, capital subsidies are required. With 25% interest rate on commercial market, 70% of capital subsidies are needed to make investments economically viable. Total cost of such capital subsidies is $13.3 billion.

Energy Efficiency Fund proposed by donor organizations as part of the “S2I” concept can present sustainable financial vehicle to finance energy efficiency improvements on a national level. Simple organizational structure of such financial instrument is presented below.

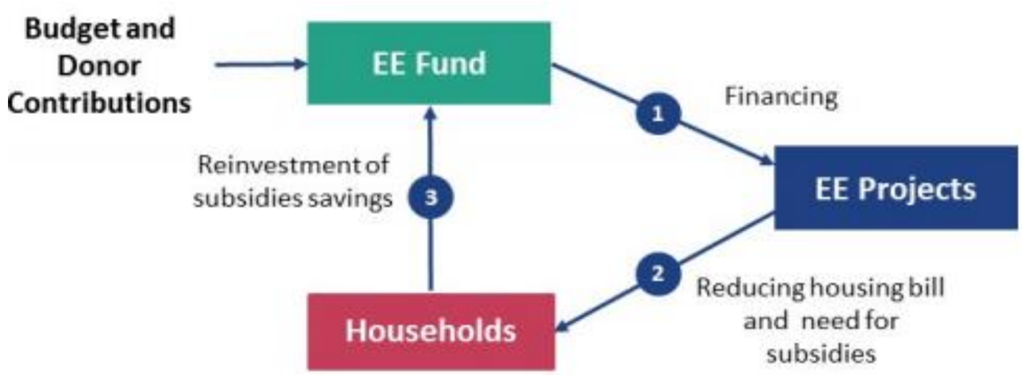

Figure 36. Mechanism of converting households’ subsidies in investments via Energy Efficiency Fund
Data source: Minregion (2016d)

If Government will commit to retrofit whole residential stock connected to the district heating during 20 years, then total annual subsidy requirement is $667 million (not considering inflation and other economic factors). This amount is almost two times more than existing subsidies for household utility services for low-income households in urban areas. Moreover, analysis of regional distribution of existing subsidies and capital subsidies needed for retrofit, shows that in all regions (except capital Kyiv and Odesa oblast) existing subsidies are exceeding amount of capital subsidies needed for deep retrofit. Therefore, existing utility subsidies will be enough to finance retrofit of whole housing stock in urban areas connected to the district heating during 20 years.

Policy recommendations

In 2014-2015, the Government of Ukraine embarked on path of energy sector reform. One of the main part of that reform is phasing out of implicit and explicit energy consumption subsidies. Drawing on experience of other countries (Clements 2013), following steps should be implemented in order to increase likelihood of successful reform implementation:

1) Comprehensive reform plan;
2) Wide communication strategy;
3) Phased energy price increase and sequencing;
4) Improvements in management efficiency of energy state-owned enterprises;
5) Mitigation measures for social groups employed in affected industries (such as coal miners etc);
6) Depoliticization of energy pricing, setting independent professional body for price regulation and setting an automatic mechanism for energy price formation.

Experience of neighboring countries with similar climate and high share of district heating can provide some lessons that can increase rate of energy efficiency improvements in residential sector. Lessons learned from several decades of energy efficiency policy implementation in Germany and Lithuania can be replicated and adopted with minor adjustments in Ukrainian context.

First of all, existing regulation should be amended in a way that will allow municipal building management companies (or Administrators) to initiate and implement energy efficiency project on behalf of apartment owners. Experience of Lithuania demonstrates that this can significantly facilitate rate of energy efficiency improvements. Specifically, it will have following benefits:

- Lower capital cost. Administrators will be able to take on loans and will have lower cost of capital than commercial bank loans for households and HOAs.

- Economy of scale. Administrators will be able to initiate and submit projects of energy retrofit of the whole district that will reduce overall cost of the project.

- Setting right priorities. Municipal organizations have better information about their supply area and therefore can identify and rank buildings which have higher losses, inefficiency and therefore should be retrofitted first.

- Reduced transaction costs. Administrators have all required technical expertise and skilled staff.

- Integrated approach in supply-demand side modernization**.** This will increase effectiveness of resource allocation and smooth adjustment of supply side to decreased heating demand.

- Greater opportunity for donors. Administrators can form project pipeline on a scale attractable for major international financial institutions such as The World Bank Group, EIB, EBRD, USAID, KfW, NEFCO, E5P etc. Smaller donor organizations can provide technical assistance to the administrators and municipal utilities for a project development, implementation, monitoring and verification.

- Greater transparency during implementation. Since projects will be financed through the major IFIs, they will be less vulnerable to general corruption issues. Transparent centralized procurement will be secured by both IFIs and recently introduced e-procurement system “ProZorro”, which already had been proved to be effective and internationally recognized.

- Higher safety and reduced peak loads in winter. Most inefficient buildings are more exposed to fires due to obsolete electricity wires inside the building and higher electricity demand during winter because of increased number of electric heaters. By retrofitting these buildings first, fire safety will be significantly improved while reducing peak demand.

With retrofit projects, initiated and implemented by utilities, financed by IFIs and repaid via bills and S2I mechanism, split incentive barrier will be effectively addressed. Moreover, because of increased cost and social attractiveness of buildings default rate should be significantly lower since most such buildings will always be fully occupied.

Energy retrofit projects initiated by Administrators will meet people’s expectations in a region with dominated paternalistic views (“Government should take care of our buildings, not we”). Otherwise, rate of improvements in these regions will be significantly slower, which will result disproportion in regional development.

Retrofit of the most inefficient buildings in regions with the most passive population will address majority of socially vulnerable parts of society thus addressing energy poverty program and effectively utilizing state subsidies to this group as repayments for retrofit, which in turn will increase effectiveness of subsidies to investment mechanism.

Subsidies for energy retrofit should be assessed individually and provided on a base of cost benefit analysis which will make retrofit projects cost effective but without overspending of public funds;

Secure sustainable funding for subsidies for retrofit via several sources including state budget, special energy efficiency and/or climate funds and credit lines from international financial institutions.

Constantly review building codes for new buildings, so that energy performance requirement will become more stringent over time.

Suggested mechanism combines element of utility demand-side management, on-bill financing (repayments will be made via heating bills) and subsidies to investment mechanism. It can increase rate of building renovation; decrease import of natural gas and pressure on account balance; reduce vulnerability to price shocks on energy markets; increase safety of socially vulnerable people; boost economic growth and labor market; increase effectiveness and transparency of resource allocation; cooperation between donors.

Overall, total required investments for deep energy retrofit of multistory buildings is $19 billion in 2015 prices. This will allow to decrease energy consumption for heating by more than 44 TWh per year or 3.81 Mtoe. About 70% of capital subsidies is required to make levelized cost of energy of retrofit lower than existing heating tariffs. Multistory housing stock in urban settlements can be retrofitted during two decades which yields annual retrofit rate as 2%. Existing subsidies for low income households to cover expenses for housing utility services in urban areas two times higher than annual requirement of capital subsidies for deep energy retrofit. Therefore, existing energy subsidies can be effectively converted to the investments in energy efficiency. Suggested policy recommendations, based on experience of other countries can facilitate energy subsidy reform and increase rate of energy efficiency improvements in residential sector.

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Appendix A

ARRANGEMENT OF HOUSEHOLDS' HOUSING

	All households		including, those who live:					
			in city dwellings				in rural area	
			in big towns	in small towns	total			
	2015	2016	2016		2015	2016	2015	2016
Number of households (thousand)	15,073.7	15,033.4	5,897.9	4,211.5	10,125.0	10,109.4	4,948.7	4,924.0
Households own (%):								
central heating	37.2	37.5	77.5	24.2	55	55.3	1	0.9
individual heating	45	45.1	20.2	60.9	38.1	37.1	59.2	61.5
plumbing	78.5	79	99	85.6	93.4	93.4	48.1	49.5
sewer	77.6	78.4	98.9	84.5	92.3	92.9	47.6	48.5
hot water supply	38.1	39.2	68.6	27.7	50.2	51.5	13.5	13.7
gas boiler	16.3	15.8	14.4	22.5	18.5	17.8	11.6	11.8
central gas supply	79.3	78.1	88.9	79.4	86	85	65.6	63.9
canister gas	11	11.4	0.4	8.5	3.7	3.8	25.9	27
electric stove	5.4	5.8	9.3	5.9	7.5	7.9	1.2	1.6
shower or bath	74	74.8	96.8	80.9	89.3	90.2	42.8	43.3
phone	37.2	29.9	40.8	29.3	45.7	36	19.8	17.4
garbage chute	14.3	13.5	30.6	5.1	21.3	20	0	0.2

Data source: Ukrstat (2016b)

Appendix B

KEY ENERGY STATISTICS OF UKRAINE (MTOE)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Production	84,998	84,260	79,339	78,712	85,485	85,247	85,914	76,928	61,614
Import	64,975	65,263	48,506	51,260	58,055	46,520	39,722	34,437	31,575
TPES	139,330	134,562	114,420	132,308	26,438	122,488	115,940	105,683	90,090
TFC	85,955	83,283	67,555	74,004	75,852	73,107	69,557	61,460	50,831
Industry	*32,852*	*30,942*	*22,629*	*25,327*	*26,253*	*24,845*	*21,864*	*20,570*	*16,409*
Transport	*15,417*	*15,141*	*12,396*	*12,627*	*12,611*	*11,448*	*11,280*	*10,327*	*8,750*
Residential	*23,001*	*22,845*	*22,084*	*23,813*	*23,604*	*23,466*	*23,495*	*20,384*	*16,554*
Services	*4,956*	*4,952*	*4,176*	*4,643*	*4,802*	*5,037*	*5,745*	*4,663*	*3,838*
Agriculture	*2,003*	*2,095*	*1,981*	*2,027*	*2,236*	*2,184*	*2,234*	*2,012*	*1,957*
Non-energy use	*7,712*	*7,295*	*4,269*	*5,547*	*6,008*	*6,116*	*4,932*	*3,500*	*3,318*

Data source: Ukrstat, Energy Balances of Ukraine, 2007-2015

Appendix C

SUMMARY OF COUNTRY ENERGY SUBSIDY REFORM EPISODES

Region/ Country	Energy Product	Reform Episode	Reform Outcome	Reform impact	IMF-support
Central and Eastern Europe					
Turkey	Fuel	1998	Successful	SOEs turned from net loss to net profitability	Yes
Armenia	Electricity	Mid-1990s	Successful	Electricity sector financial deficit declined from 22% of GDP in 1994 to zero after 2004	Yes
Turkey	Electricity	1980s	Successful	Generated additional revenues for maintenance	Yes
Poland	Coal	1990-1998	Unsuccessful	N/A	Yes
	Coal	1998	Successful	The industry became financially viable and achieved substantial reduction in government transfers	No
Emerging and Developing Asia					
Indonesia	Fuel	1997	Unsuccessful	N/A	Yes
Indonesia	Fuel	2003	Unsuccessful	N/A	No
Indonesia	Fuel	2005	Partially successful	Subsidies declines from 3.5% of GDP in 2005 to 1.9 % in 2006	No
Indonesia	Fuel	2008	Partially successful	Subsidies declines from 2.8% of GDP in 2008 to 0.8% in 2009	No

Philippines	Fuel	1996	Successful	More than 0.1% of GDP	Yes
Philippines	Electricity	2001	Successful	Subsidies declined from 1.5% of GDP in 2004 to zero in 2006	No
Latin America and the Caribbean					
Brazil	Fuel	1990s-2001	Successful	From 0.8% of GDP in subsidies in mid-1990s to revenue generating since 2002	Yes
Chile	Fuel	Early 1990s	Successful	N/A	No
Peru	Fuel	2010	Partially successful	0.1% of GDP	No
Brazil	Electricity	1993-2003	Successful	0.7% of GDP	Yes
Mexico	Electricity	1999/ 2001/2002	Unsuccessful	N/A	Yes
Middle East and North Africa					
Iran	Fuel	2010	Partially successful	Growth in the consumption of petroleum products initially stabilized	No
Mauritania	Fuel	2008	Unsuccessful	N/A	Yes
	Fuel	2011	Partially successful	Subsidies declined from 2% of GDP in 2011 to close to zero in 2012	Yes
Yemen	Fuel	2005	Partially successful	Subsides declined from 8.7% of GDP in 2005 to 8.1% in 2006	No
	Fuel	2010	Partially successful	Subsidies declined from 8.2% of GDP in 2010 to close to 7.4% in 2011	Yes
Sab-Saharan Africa					
Ghana	Fuel	2005	Partially successful	50% price increase on average	No

Namibia	Fuel	1997	Partially successful	More than 0.1% of GDP	No
Niger	Fuel	2011	Partially successful	0.9% of GDP	No
Nigeria	Fuel	2011-12	Partially successful	Subsidies declined from 4.7% of GDP in 2011 to 3.6% in 2012	No
South Africa	Fuel	1950s	Successful	Successfully avoided subsidies and secured supply	No
Kenya	Electricity	Mid-1990s	Successful	Subsidies declined from 1.5% of GDP in 2001 to zero in 2008	Yes
Uganda	Electricity	1999	Successful	2.1% of GDP	Yes

Source: Alleyne et al. (2013)

Appendix D

REGIONAL DISTRIBUTION OF SUBSIDIES FOR HOUSEHOLD UTILITY SERVICES IN 2016

Oblast	Total amount of subsidies to households, million USD			Transfers to HUS companies, million USD		
	Total	Urban	Rural	Total	Urban	Rural
Ukraine	**219.41**	**130.89**	**88.52**	**2,021.28**	**1,368.54**	**652.73**
Vinnytsia	12.14	5.56	6.58	95.52	54.12	41.40
Volyn	7.15	3.94	3.21	54.72	33.83	20.89
Dnipropetrovsk	13.20	10.04	3.16	148.53	121.05	27.48
Donetsk	8.50	7.63	0.87	103.15	93.42	9.73
Zhytomyr	8.52	5.49	3.03	74.65	51.46	23.18
Zakarpattia	5.03	1.67	3.36	41.26	15.92	25.34
Zaporizhia	8.32	6.12	2.19	79.11	63.64	15.47
Ivano-Frankivsk	11.29	3.83	7.45	84.29	36.87	47.41
Kyiv Oblast	10.61	5.35	5.27	102.39	58.74	43.65
Kirovohrad	6.19	4.71	1.48	54.99	43.18	11.81
Luhansk	5.20	3.42	1.78	47.79	34.39	13.40
Lviv	17.31	8.85	8.46	151.50	95.34	56.16
Mykolaiv	4.29	2.95	1.34	41.35	29.55	11.80
Odesa	4.64	3.00	1.64	38.97	29.25	9.72
Poltava	11.79	7.53	4.26	114.79	70.38	44.41
Rivne	7.30	3.28	4.02	66.83	37.16	29.66
Sumy	9.17	6.24	2.93	93.72	68.64	25.08
Ternopil	12.62	4.64	7.98	87.03	40.20	46.83
Kharkiv	11.35	8.66	2.69	138.21	113.30	24.90
Kherson	4.71	3.37	1.33	42.17	30.89	11.28
Khmelnytskyi	10.00	4.85	5.15	82.38	46.23	36.15
Cherkasy	10.09	5.33	4.76	92.01	56.21	35.80
Chernivtsi	5.00	2.10	2.90	42.56	19.06	23.50
Chernihiv	9.30	6.61	2.69	71.34	53.66	17.68
Kyiv city	5.72	5.72		72.04	72.04	

Data source: Ukrstat (2017)
Note: exchange rate used 26 UAH/USD