NORWEGIAN UNIVERSITY OF LIFE SCIENCES

Preface

“A nation that can't control its energy sources can't control its future.” (Obama 2006, p.102)

The Ukrainian heating system is dependent on natural gas, mainly imported from Russia. This particularly applies to the heating market. Therefore energy efficiency and conservation in this market are essential parts of Ukraine’s quest for becoming more energy independent.

This thesis is as a joint venture between the School of Economics and Business at the Norwegian University of Life Sciences (UMB) in Ås and a Norwegian business partner, Differ Group. It is written as a part of our M.Sc. in Energy Economics and Industrial Economics and Technology Management respectively.

Working on this very important and interesting subject has been a great experience for us. We have learned a lot, and the opportunity to travel on a research trip to Ukraine has made the work a lot easier. We have seen some of the challenges with our own eyes, and in addition benefited from talking to experts in the field of energy efficiency.

We would first and foremost like to thank our supervisor, Eirik Romstad, for giving us the opportunity to work with this subject. He has helped us out a lot and has been very accessible and motivating throughout the entire process. Differ Group’s work on the Ukrainian electricity market has given us quick access to relevant articles and reports. Special thanks to Christian Hammer for many helpful comments.

Finally, we are very grateful to our families, loved ones and friends for support and encouragement during the process of writing the thesis.

Ås, May 15th 2012

Simen Gurholt Evensen and Nadya Fedoryshyn

Executive Summary

The level of energy efficiency in Ukraine has been very low compared to the European countries ever since the country gained independence in 1991. Energy efficiency improvement and reduction of gas dependence has been a high priority on the political agenda, at least since 1994 when a law of Ukraine on energy conservation was approved. However, this issue has never been more important than today, almost two decades later, as Ukraine is facing drastic increase in the import price of gas. At the same time, domestic energy tariffs are low as a result of extensive state subsidies to energy consumers, in particular in the residential sector. Artificially low energy prices together with institutional barriers slow down the process of energy efficiency improvement.

The aim of this thesis is to investigate which segments of the Ukrainian heating market are most suitable for installation of different types of heating technologies and energy saving measures that will improve the level of energy efficiency. In these segments, we analyze the factors behind consumers' investment decision and choice of energy efficiency improving measure. By performing a number of cost–benefit analyses, we test which technologies are most preferable at different levels of energy prices and initial investment costs. In our analysis, we are particularly interested in the performance of geothermal heat pumps in the Ukrainian heating market for consumers with different levels of heat demand.

There are several important results of our analysis. First of all, at present Ukrainian energy price levels for residential sector consumers, gas boiler is the most economically favorable technology as the net present value (NPV) of investment into this technology is the most positive in the short- and medium-run. Geothermal heat pump becomes the best alternative technology only in the long-run and under the assumption of high rates of price increase. The similar interrelation between gas boiler and heat pump NPVs occurs for non-residential sector consumers. For heat pumps to become more favorable than gas boilers in the short-run, the prices for gas should be about 8 times as high as present Ukrainian level in the residential sector, but only about twice as high for the non-residential sector consumer.

Another finding in this thesis involves additional insulation and heating meters. Due to relatively small initial investment cost, these energy saving measures seem to be the most attractive for heat consumers. However, the results of cost-benefit analysis show that due to the low level of Ukrainian district heating tariffs, only few energy saving measures are economically favorable in the short-run.

Therefore, our results confirm that energy prices in Ukraine are too low to provide incentives for energy conservation and energy efficiency improvement. This is especially the case for the residential sector, where energy prices are about twice as low as in the commercial and industrial sectors. Relatively high prices in the non-residential sectors in combination with expectations of further price increases and the wish to improve competitiveness in the market stimulate investment into energy efficiency improvement.

Thus, the consumers in the residential sector must also face higher tariff for gas, electricity and district heating in order to become more willing to save energy. The price increase should be combined with state programs aimed at making energy saving and energy efficiency improving technologies more accessible. Such programs need to be supported by reforming the legislation system in order to reduce institutional barriers and stimulate investment in the area of energy efficiency.

Sammendrag

Energieffektivitetsnivået i Ukraina har vært veldig lavt sammenlignet med de europeiske landene helt siden landet ble uavhengig i 1991. Forbedring av energieffektiviteten og reduksjon av gassavhengigheten har vært høyt prioritert på den politiske agendaen, spesielt siden 1994 da den ukrainske loven om energikonservering ble vedtatt. Temaet har imidlertid aldri vært så viktig som i dag, nesten to tiår senere, siden Ukraina nå står overfor en drastisk økning i importprisen på naturgass. Samtidig er energitariffene innenriks lave som et resultat av utstrakte subsidier til energikonsumentene, særlig i boligsektoren. Kunstig lave energipriser sammen med institusjonelle barrierer bremser prosessen med å forbedre energieffektiviteten.

Målet med denne oppgaven er å undersøke hvilke segmenter i det ukrainske varmemarkedet som er mest egnet for installering av ulike typer oppvarmingsteknologi og energisparende tiltak som vil bedre energieffektiviteten. I disse segmentene analyserer vi faktorene bak konsumentenes investeringsbeslutninger og valg av energieffektiviserende tiltak. Ved å utføre en rekke nytte-kostnads-analyser kan vi teste hvilke teknologier som foretrekkes ved forskjellige nivåer på energipriser og investeringskostnader. I analysen vår er vi spesielt interessert i hvordan den geotermiske varmepumpen presterer i det ukrainske varmemarkedet for konsumenter med forskjellig varmebehov.

Analysene våre viser flere viktige resultater. Først og fremst gjør de nåværende ukrainske energiprisene i boligsektoren at gassbrenner er den mest økonomisk lønnsomme teknologien da nåverdien (NPV) av en investering i denne teknologien er mest positiv på kort og mellomlang sikt. Geotermisk varmepumpe blir den mest lønnsomme teknologien kun på lang sikt og med antakelser om høy økning i energipriser. Det samme forholdet mellom nåverdien for gassbrenner og varmepumpe forekommer for konsumenter utenfor boligsektoren. For at varmepumpe skal foretrekkes foran gassbrenner på kort sikt, må prisene på gass bli 8 ganger så høye som de nåværende ukrainske gassprisene i boligsektoren, men bare rundt to ganger så høye utenfor boligsektoren.

Et annet resultat i oppgaven omhandler ytterligere isolasjon og varmemålere. På grunn av relativt lave investeringskostnader, ser det ut til at disse energisparende tiltakene er mest attraktive for varmekonsumenter. Resultatene fra kostnad-nytte analysene viser imidlertid at det lave nivået på ukrainske fjernvarmetariffer medfører at kun et fåtall av energisparingstiltakene er økonomisk lønnsomme på kort sikt.

Resultatene våre bekrefter derfor at energiprisene i Ukraina er for lave til å gi insentiver til å gjennomføre energisparingstiltak og forbedre energieffektiviteten. Dette gjelder særlig i boligsektoren hvor energiprisene er rundt halvparten av de i kommersiell og industriell sektor. Relativt høye priser utenfor boligsektoren kombinert med forventninger om ytterligere prisøkninger og ønske om å forbedre konkurranseevnen i markedet stimulerer til investeringer i energieffektivitetsforbedring.

Det er derfor viktig at tariffene for gass, elektrisitet og fjernvarme øker også for konsumentene i boligsektoren for at disse skal bli mer villig til å spare energi. Prisøkningen bør kombineres med statlige programmer som sikter på å gjøre teknologier for energisparing og energieffektivisering mer tilgjengelig. Slike programmer må underbygges ved å forbedre lovgivningen for å redusere institusjonelle barrierer og stimulere til investering i energieffektivitetsforbedring.

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1. Introduction

Energy saving and energy efficiency are important concepts in a world where cheap and readily accessible energy is scarce. Increasing demand accelerates the need for more efficient energy use, and a finite quantity of fossil energy demands preparation for a day with a sustainable energy system based on renewables. Dividing remaining resources of fossil fuels by yearly production (R/P-ratio), yields an estimate of years left with respective non-renewable resources. Given constant fuel production volumes, no new discoveries in the world and no considerable technical change there are about 46, 59 and 118 years left of oil, gas and coal respectively (British Petroleum 2011).

Measurable effects such as increasing land and sea temperature, increasing snow and ice melting and rising sea levels confirm this. The earth's temperature has been measured with adequate precision since 1850, and eleven of the last twelve years (1995-2006) have been among the twelve warmest (IPCC 2008). Global warming is therefore evident, and is according to the Intergovernmental Panel on Climate Change (IPCC) likely due to human activity.

These challenges need to be met by a variety of solutions. Energy conservation and energy efficiency is a part of the answer to these challenges. The great potential of effective energy use and energy conservation to achieve a sustainable energy future and as a greenhouse gas reduction measure is well documented (IEA 2012). It is often referred to as the cheapest and cleanest sources of energy (Ellis 2011).

Ukraine is only one of many countries where energy saving and efficiency are on the agenda. Large demand for heat, old and inefficient heating technologies, as well as outdated heating networks result in high heat consumption levels relatively to GDP. This situation makes the heating sector an interesting case to study in relation to energy efficiency and energy conservation. Ukraine plans to reduce its consumption of natural gas and increase utilization of environmental heat (Energy Strategy 2006). Important questions include which energy sources will replace gas, and how this will influence energy efficiency. Moreover, we want to find out which energy efficiency technologies and measures will be most favorable and in which sectors.

How a geothermal heat pump[1] can function as an energy efficiency measure in Ukraine's energy system and how it will compete economically with traditional heating will be evaluated. This technology is given special focus in the thesis due to the initiative from Differ Group (hereafter Differ)[2]. Which factors will make the geothermal heat pump a competitive heating technology and what are the present market conditions for heat pumps is of special interest to Differ.

By identifying the sectors of the heat market that are most suitable for energy efficiency measures and pointing out what factors will lead to greater implementation of these measures, we hope to provide better information for policy makers and stakeholders taking decisions on investments in the heating market. Well implemented measures in some sectors may initiate measures in other sectors and ultimately lead to better overall energy efficiency in Ukraine. In addition to the environmental advantages, better energy efficiency will involve significant economic benefits.

1.1 Problem Statement

This Master's thesis focuses on the potential and markets for measures that are aimed at increasing energy efficiency in the heating sector, and will discuss the incentives for and barriers to successful implementation of these measures.

The technical potential for energy efficiency may be high, but the potential that realistically can be met with different measures are probably a lot less. Economic aspects, institutional barriers and even corruption can reduce the technical potential for energy efficiency and saving. By exploring the extension of these factors and defining their significance, the measures that are most feasible can be identified. Different technologies may suit different conditions and segments in the market. Traditional technologies may not involve the best solutions with respect to energy efficiency and conservation. Future changes in energy prices, legislation and other factors may influence what technologies are preferable.

[1] We focus on geothermal heat pumps in our analysis. This type of heat pumps is chosen for the analysis because of
[2] Differ is a company founded in 2010 with a goal to scale up the small scale carbon reduction technologies in the developing countries by investing in start-ups, developing own concepts and companies, advising project developers to do the same and in-depth analysis of market conditions in developing countries.

There are basically three issues we find of particular relevance given our short introduction to heating and potential energy savings in Ukraine:

1. Which sectors in the Ukrainian heat market have the greatest potential for energy efficiency improvement?
2. What is the market for various alternative heating technologies and energy saving measures? How does a geothermal heat pump perform in the market?
3. What are the mechanisms behind investment decisions in energy efficiency measures? What factors stimulate and hinder investment?

1.2 Research Approach

In this master thesis we are interested in the analysis of the sectors in the Ukrainian heating market with the largest potential for energy efficiency improvement. In these sectors, we analyze different alternatives of energy saving technologies based on secondary statistical and price data.

However, the detailed secondary statistics in our area of interest is insufficient. Therefore it is necessary to support our empirical research with primary information collected during our field trip to Kyiv. Experiences from businesses and organizations working in the field of interest will be invaluable for the research team in understanding the mechanisms and examining our hypotheses. This is particularly the case for the institutional aspects – it is not that long since Ukraine gained independence from the Soviet Union, and the legacy from the Soviet command economy still plays an important role in Ukraine: existing technologies and infrastructure, the modus operandi of government and institutions, and people's expectations are still colored by past experiences.

Through our study tour to Ukraine we seek to gain insights into the following issues (which in turn will help us to answer our problem statements):

- General overview of energy saving and energy efficiency situation;

- Segments with highest potential for energy efficiency improvement;
- Use of different heating technologies and energy saving measures, with focus on geothermal heat pumps.

Secondary data and the field trip experiences will then be used in the following:

- Conceptual analysis of the energy sector with emphasis on the heat markets using experiences gained from our Ukraine field trip;
- Net present value estimates of what we perceive to be the most relevant investment alternatives where uncertainty is sought captured by varying key parameters like future energy prices;
- Implications for the development of a modern market for energy savings in the heat market in Ukraine.

1.3 The Structure of the Thesis

The thesis consists of six chapters. In this first chapter, we have introduced importance of studying energy efficiency and energy saving measures in Ukraine, and we have formulated our main problem statements and outlined our research approach. The second chapter describes present situation, current energy prices, as well as relevant legislation and policy objectives in the area of energy use in Ukraine. Our third chapter gives an overview and analysis of different segments of the heating market. In the end of this chapter, sectors with the largest potential for energy efficiency improvement are selected. The fourth chapter studies theoretical background behind investment decision in the energy efficiency improvement measures and energy saving technologies. In the fifth chapter, specific cases of energy saving technologies implementation are studied. The comparison of installation and operational costs of several alternatives (geothermal heat pump, gas boiler, district heating, biomass boiler and insulation) is made, taking into account different scenarios of energy price dynamics. Finally, we draw conclusions and suggest some policy measures that would improve energy efficiency.

2. The Energy Situation in Ukraine

This chapter serves as a background and gives a brief overview of the energy situation in Ukraine. Some figures on the current energy efficiency level in Ukraine are compared to those of other countries. The role of legislation and institutions in Ukraine is highlighted, and in the end of the chapter energy price levels in Ukraine and other European countries are compared and discussed.

2.1 Energy Efficiency Dynamics

After the fall of the Soviet Union, Ukraine has inherited an industrialized economy with many old and inefficient facilities, which use much energy in production. Today, the country is a net importer of energy supply, producing only 20 % and 25 % of its demand for oil and gas respectively, and relying heavily on imports to cover its energy needs, mostly from Russian Federation (IEA 2006). At the same time, the Ukrainian economy is extremely energy intensive, meaning that it has very high ratio of energy use per GDP. Indeed, the country is consuming 2-3 times more energy per unit of GDP than some other European countries (Figure 2.1), which is also 2,6 times higher than the world average.

It is important to note that the energy intensity indicator is imperfect, as it does not take into account some exogenous factors that may explain different levels of energy consumption across countries. For example, energy consumption in Ukraine might be higher than average in Europe because of colder climate. The large share of "black economy" is also likely to lead to overestimates of the energy intensity parameter of Ukrainian economy. Nevertheless, energy intensity can be seen as an indicator of an economy's potential to improve energy efficiency (Fankhauser & Lavric 2003).

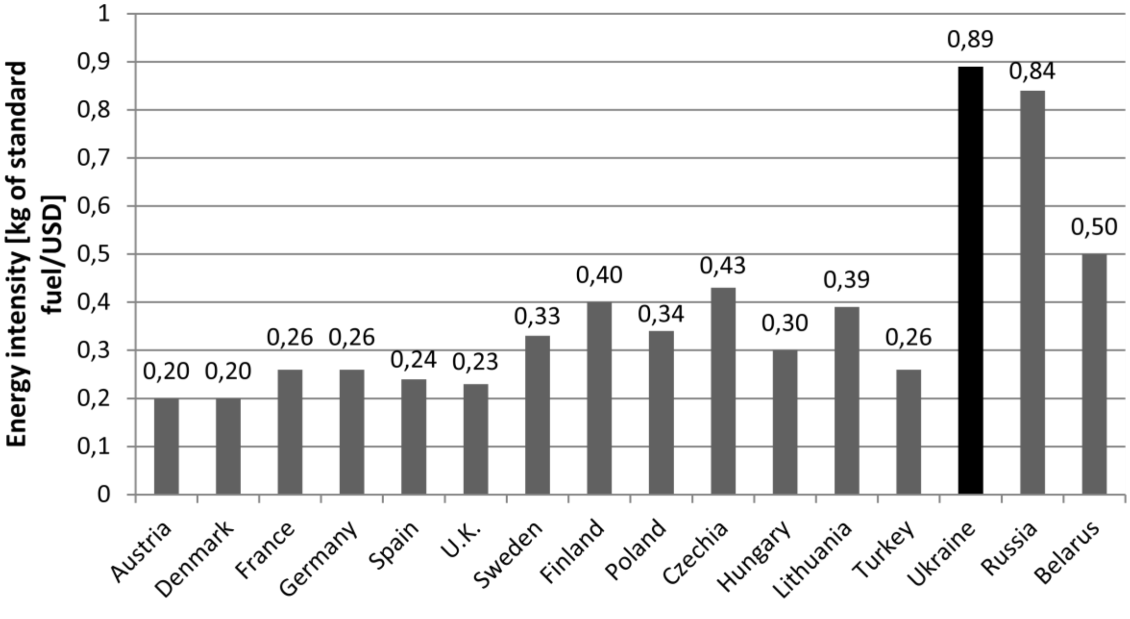

Figure 2.1 GDP Energy intensity, kg of standard fuel per USD (2003, 2004) (Energy Strategy 2006).

Although Ukraine has taken some important steps towards reducing its use of energy – its energy efficiency has improved by 30 % compared to 1995 estimates (IEA 2006) – it is clear that the country lags behind the rest of Europe in terms of efficiency in the energy sector.

According to “Energy Efficiency Rating for Ukrainian Regions”, efficiency indicator of Ukraine amounted to only 52 % of the EU level in 2008. This means that Ukrainian economy was consuming about two times more energy per unit of GDP than the EU average. The efficiency indicator equaled 33 % in the agricultural sector, 44 % in the industrial sector, 72 % in the sector of services, and 62 % in the residential sector. The saving potential compared to EU equals about 27 Mtoe, which accounts for almost 20 % of the Ukrainian energy supply in 2008 (Bigday et al. 2011). The effects of such low energy efficiency levels are lower competitiveness of Ukrainian production and reduced welfare for Ukrainian population.

Although overall energy efficiency is relatively low, the efficiency ratings vary across the country. The best three oblasts (regions) on aggregate efficiency rating are Vinnitsa with 71 % and Chernovtsi and Odessa both with a rating of 70 %. The savings potential are estimated to 127,5 MEUR, 58,7 MEUR and 189,0 MEUR respectively. In the other end, Dnipropetrovsk, Poltava and Luhansk have the lowest aggregate ratings with 43 %, 39 % and 38 % respectively.

The savings potential in these regions are estimated to 2629,9 MEUR, 492,2 MEUR and 1384,5 MEUR (Bigday et al. 2011).

One of the main reasons for high energy intensity is inefficiency in the heating sector (Ivanenko & Petryna 2012). Large shares of the Ukrainian population (roughly 60 %) are provided with heating and hot water via the extensive district heating network (Semikolenova et al. 2012). The state of the system therefore plays an important role in overall Ukrainian energy efficiency, making district heating particularly interesting to investigate. District heating is heat supply to the consumers through a common heat network (Tsarenko 2007).The district heating system in Ukraine involves a significant loss of energy and therefore reduced energy efficiency. Figure 2.2 shows how a common district heating system is set up and the possible losses at each level. In Ukraine, the heat is delivered directly from the producer to the consumer.

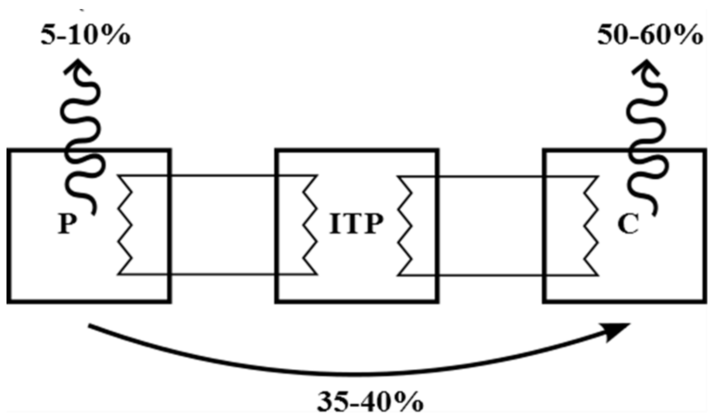

Figure 2.2 District heating system with heat producer (P), individual heat station (ITP) and consumer (C). In Ukraine heat is transferred directly from producer to consumer. Estimated losses are illustrated at each point (Ivanenko & Petryna 2012)

The highest relative losses occur at consumer level, with poor state of the buildings and lack of possibilities for heat regulation the most significant contributors. Large shares of heat are also lost during transportation, about 50 % due to poor insulation and 50 % due to direct water leakage. Overall about 60 % of heat is lost during transportation and end use (Semikolenova et al. 2012). Figure 2.2 gives an idea of where energy efficiency and saving measures will have the best effect on overall energy efficiency. Measures to improve energy efficiency in the district heating system and where these measures are to be implemented are discussed in chapters 3 and 5.

2.2 Legislation and Policies

The issues of improving energy efficiency and reducing energy use have been one of the priorities of Ukrainian government ever since gaining independence. Already in 1994 Ukraine approved an energy conservation law (Law of Ukraine "On Energy Conservation") with the following aims:

- Combination of methods of economic stimulation and financial responsibility for the purpose of rational and efficient use of fuel and energy resources;
- Popularization of economic, ecologic and social advantages of energy conservation;
- Increase of public educational level in this sphere (Arzinger 2011).

Practical implications of the energy conservation act include tax preferences for producers of energy-efficient equipment and companies using equipment working on alternative energy sources, and priority financing of energy saving measures. For example, import fees and tax preferences for energy saving technologies are regulated by the Resolution of the Cabinet of Ministers of Ukraine no. 444 "Question of import of energy-saving materials, equipment and components on the customs territory of Ukraine" issued 14.05.2008. It states that technologies that are approved for specific energy efficiency improvement projects can be imported without paying import VAT and customs fee (The Cabinet of Ministers of Ukraine 2008).

Some energy efficiency improving projects, can apply for state financial support in the framework of State Target Economic Program on energy efficiency and the development of energy production from renewable energy sources and alternative fuels for 2010-2015. To receive support, these projects must fulfill a number of criteria, which are outlined in the Directive of Ministry of Economic Development and Trade no.105 "On approval of the competitive selection of energy efficient projects for their public support at the expense of the state budget to support the State Target Economic Program on energy efficiency and the development of energy production from renewable energy sources and alternative fuels for 2010-2015" issued 06.10.2011 (Ministry of Economic Development and Trade 2011).

For example, for projects that implement use of heat pumps in municipal enterprises and budget institutions, the following criteria are taken into account:

- Share of substitution of fossil fuels;
- Reduction of budget spending;
- Reduction of emissions to the environment;
- Payback period;
- Period of project implementation (Ministry of Economic Development and Trade 2011).

Some other laws regulating energy efficiency and use in Ukraine include:

- the Law of Ukraine “On Electric Power Industry” (1997);
- the Law of Ukraine “On Alternative Energy Sources” (2003);
- the Law of Ukraine “On Heat Supply” (2005);
- the Law of Ukraine “On Amendments to the Law of Ukraine “On Electrical Power Industry” as to stimulation of alternative energy sources use”(2009). (Arzinger 2011).

Main policy directions and objectives in the energy sector are declared in the “Energy Strategy of Ukraine for the Period until 2030” (hereafter Energy Strategy), which was approved in March 2006. It provides an overview of the present Ukrainian energy sector, and sets such broad goals as:

• Create favorable conditions for meeting energy demand in a sustainable way;
• Increase domestic energy security;
• Assure efficient energy use, introduce energy-saving technologies, and reduce the share of energy-intensive technologies;
• Diversify energy supplies;
• Integrate Ukraine’s energy system into the European energy system (IEA 2006).

Still, despite of a number of laws and regulations, Ukrainian legislation is incomplete and policies are not well-coordinated between state institutions in different spheres of the economy. There are many laws and regulations that contradict each other (IEA 2006). This results in little progress in energy efficiency improvement and lack of investment in this area. For example, illdefined property rights in the apartment blocks lead to little investment in improving heating facilities in the residential sector. Besides, investors receive no guarantees that their investments will be returned as there is no legal procedure that will enforce consumers to pay for heat. “Nonpayment does not lead to any consequences such as disconnection from the energy supply or sequestration of debtors” (Dodonov et al. 2001) Incomplete legislation system, complicated system of permitting and an subjective court system all create complications and lack of transparency for heating market participants, and are therefore some the reasons of high bureaucracy and corruption levels.

Another important barrier to the investment into energy efficiency improvement is the complicated system of cross-subsidies (IEA 2006). In Ukraine, the energy prices of industry sector consumers are substantially higher than the prices for residential consumers. Because of this, it is argued that industrial energy consumers cross-subsidize the energy use of households. Large industrial energy consumers are then compensated for such cross-subsidization with the tax preferences (Burakovsky et al. 2004). The negative implications of such policy are described by Ordover et al. (1994, p.7):

“The direct result of this policy has been and will continue to be shortages and the overuse of inputs that are, in fact, costly to society; a less direct result has been and will continue to be a lack of funds for capital upkeep and modernization; a still less direct (but ultimately very important) result will be that new businesses will hesitate to invest if they require dependable utility service”.

2.3 Energy Prices

Energy prices in Ukraine are generally very low compared to most other European countries. This section presents prices for natural gas, district heating and electricity in Ukraine, and compares these prices with the average price level in the European Union (EU).

2.3.1 Natural Gas Prices

Household consumer prices for natural gas in Ukraine and the average price in EU are shown in Figure 2.3. Households with different consumption levels pay different prices.

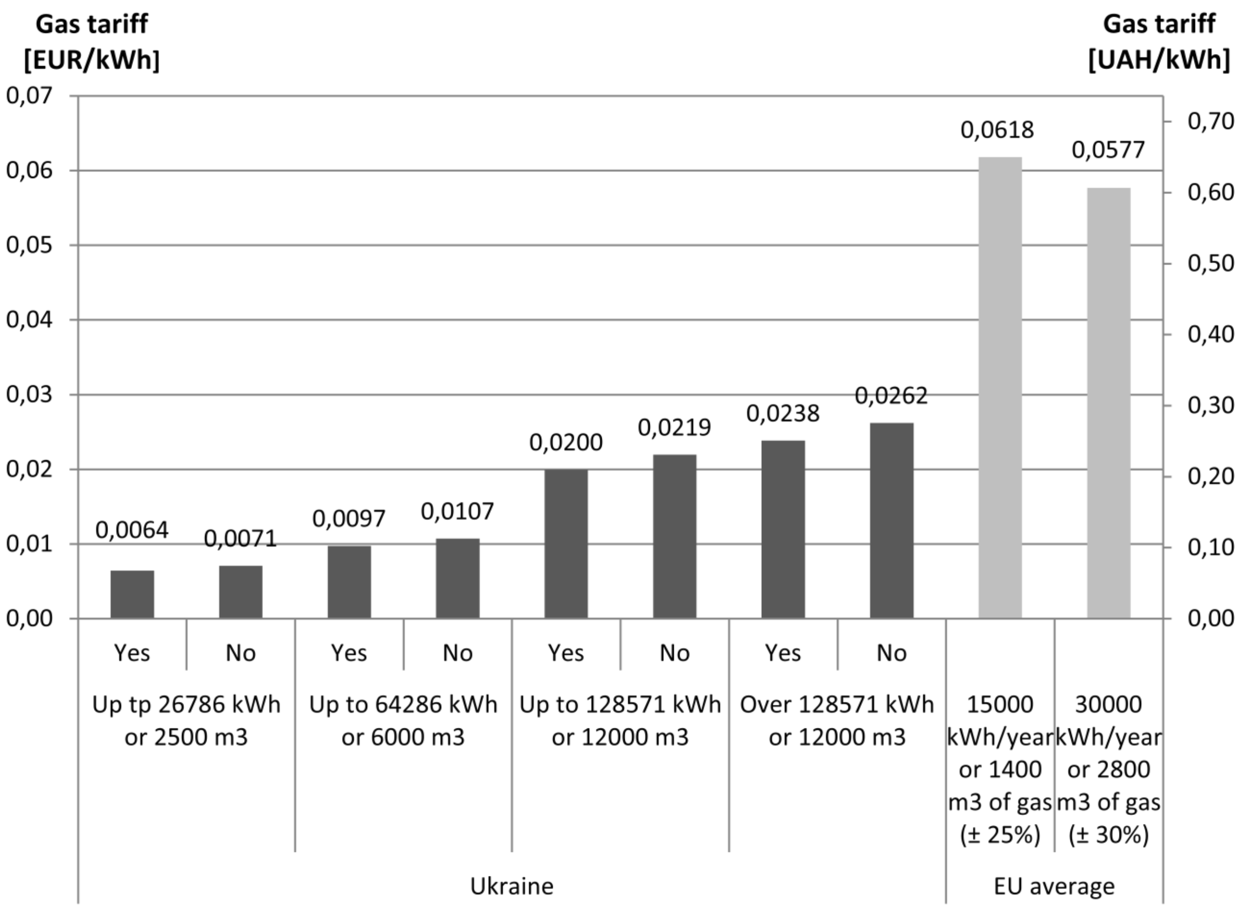

Figure 2.3 Natural gas tariffs for household consumers for different consumption levels in Ukraine and the EU average. Yes – households with gas meter, No - households without gas meter (EEP 2012; NERC 2012a)

There is also a differentiation between residential consumers with and without installed meters that measure gas consumption. Tariffs for consumers with installed meters are slightly lower than for consumers without meters. This difference in gas tariffs is aimed at motivating consumers to install gas meters in order for authorities to be able to control the quantity of gas consumed and calculate the correct gas payment.

An EU average consumer pays up to nine times as much for natural gas as a Ukrainian consumer. Even consumers in Ukraine with a very high consumption level pay a low natural gas price. Ukrainian consumers with a consumption of over 12000 m^3 per year pay only under one third of what an EU average consumer pays for about 3600 m^3.

The difference between natural gas prices for industry consumers in Ukraine and EU average is much smaller than the same difference for the residential sector consumers. This is shown in Figure 2.4

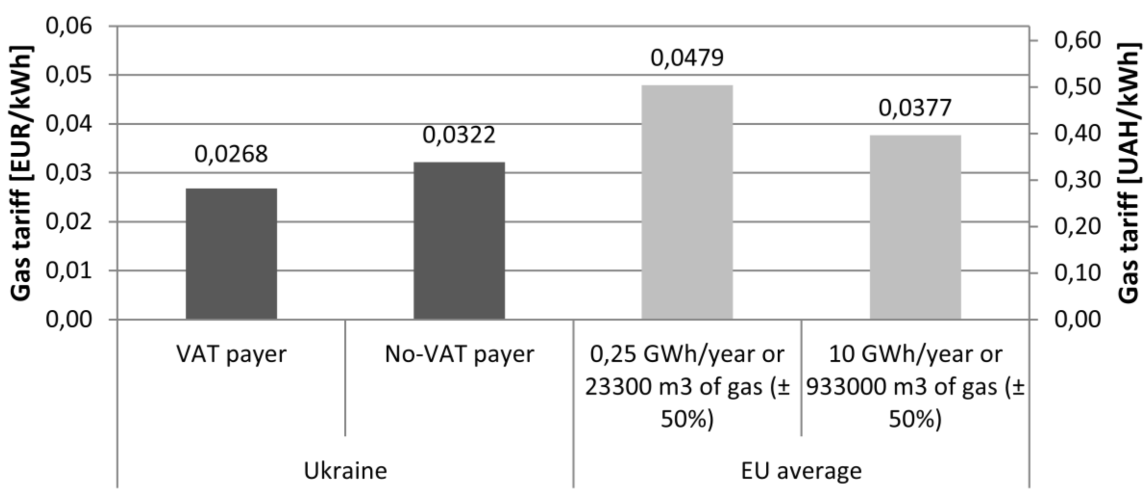

Figure 2.4 Natural gas tariff for industry consumers in Ukraine and EU average without VAT (EEP 2012; Gas Ukraine 2012).

While EU average gas prices are lower for the industry compared to EU households, the Ukrainian industry pays more for gas than household consumers in Ukraine. From Figure 2.4 we can see that heavy EU average industry consumers pay about 1,4 times as much as Ukrainian VAT paying industry consumers, while EU average low consumers pay almost 1,5 times as much as Ukrainian VAT paying consumers.

The large difference in gas prices for residential sector and industrial sector consumers suggests that authorities use price discrimination as an instrument to maintain low tariffs in the residential sector. In other words, as discussed in section 2.2 industrial sector gas consumers cross-subsidize residential sector consumers.

2.3.2 District Heating Prices

Figure 2.5 compares the district heating prices for Ukrainian household and commercial consumers with the average European district heating price[3]. Ukrainian commercial consumer price level is higher than the average European level. Household consumers in Ukraine pay at average under half of the average European price.

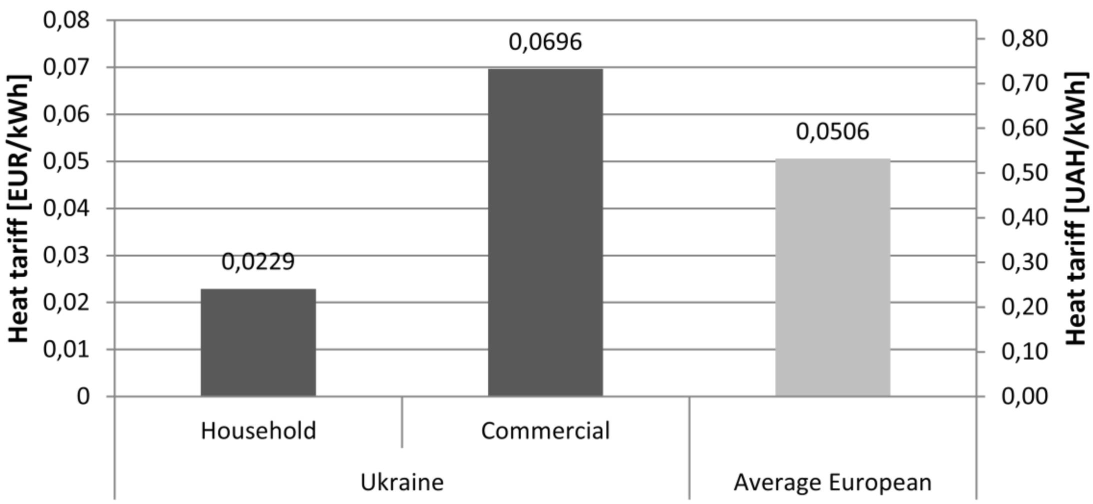

Figure 2.5 Average district heating tariffs for Ukrainian household and commercial consumers, and average district heating tariff for a European Heat and Power member country (EHP 2012; Krogerc 2012a; Krogerc 2012b).

Like in the case of the natural gas prices, it seems that commercial sector consumers pay so high prices to cross-subsidize household consumers. Except for households that consume over 12000 m^3 of natural gas per year, the prices for heat in Ukraine are higher than the natural gas price, both for residential sector consumers and industry.

[3] This price is the average district heating price from 2009 for the 27 member countries of Euroheat and power (EHP), an international association of district heating and cooling.

2.3.3 Electricity Prices

As is the case for the natural gas prices, the electricity price is also low in Ukraine. This price depends on consumer type. Industry and households are the two main groups and experience the biggest difference in prices, but there is also some differentiation within these groups.

Figure 2.6 shows electricity prices for households in Ukraine and average electricity prices for households in EU.

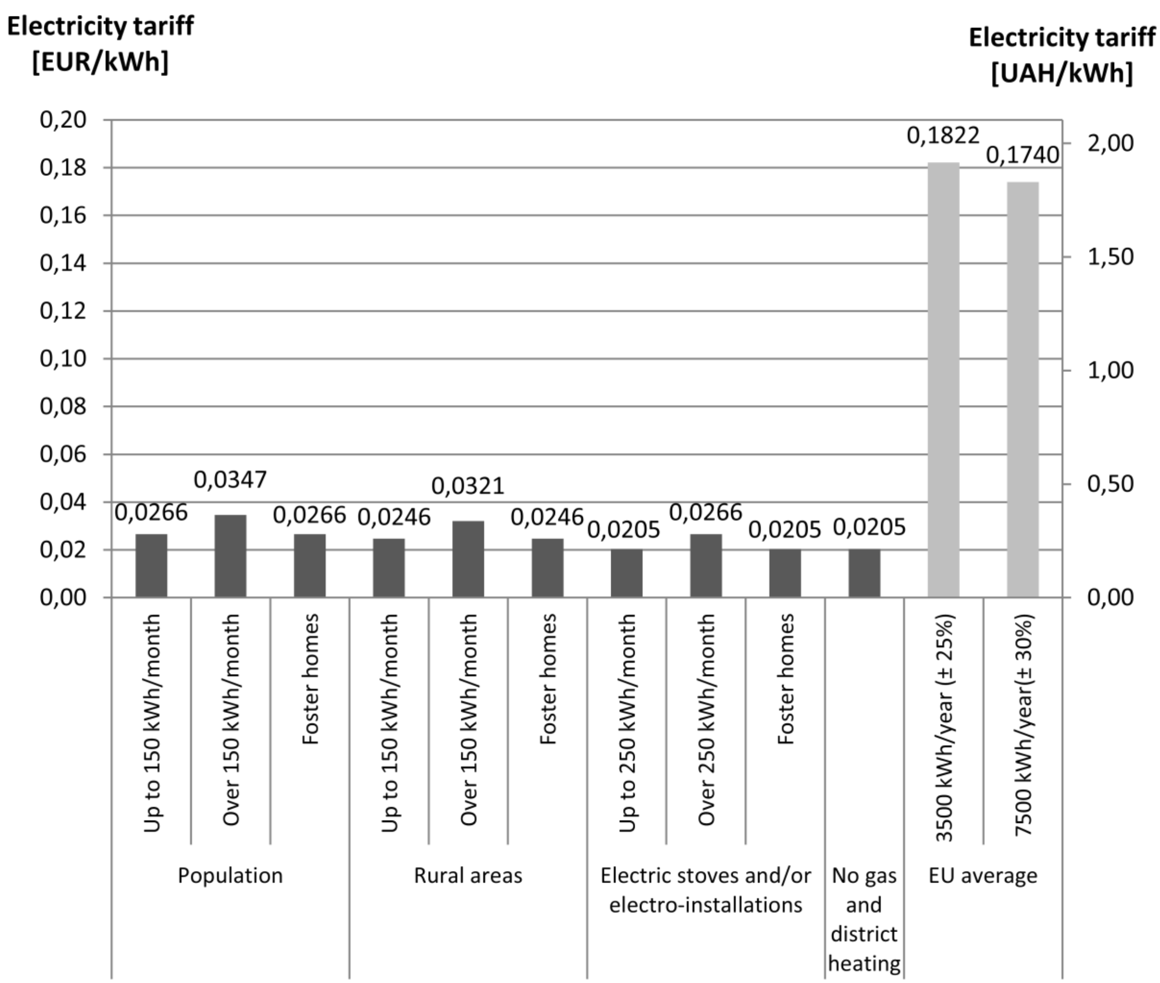

Figure 2.6 Electricity tariffs for households divided in different consumer categories in Ukraine and the average EU household electricity prices for two consumption levels. The tariffs are listed in UAH/kWh and EUR/kWh (EEP 2012; NERC 2012b).

Households pay 0,0266 EUR/kWh for consumption up to 150 kWh/month. When this limit is exceeded the price is 0,0347 EUR/kWh which is also the highest tariff for residential consumers. For households with electric stoves and/or electro-installations, the breakpoint limit is 250 kWh/month. If one assumes constant electricity consumption, these limits would equal 1800 kWh/year and 3000 kWh/year.

Compared to the average electricity price in EU, the Ukrainian electricity prices are very low. The EU average electricity price for a consumption of about 3500 kWh/year are over 5 times higher than the price for consumption in excess of 1800 kWh/year for regular population in Ukraine. The electricity tariffs in Ukraine are different depending on consumer type. For example, household consumers without connection to gas pipe and district heating pay the lowest tariff.

Industrial consumers in Ukraine are divided into two different voltage levels. Figure 2.7 shows the electricity prices for the industry in Ukraine and the EU average price for two consumption levels.

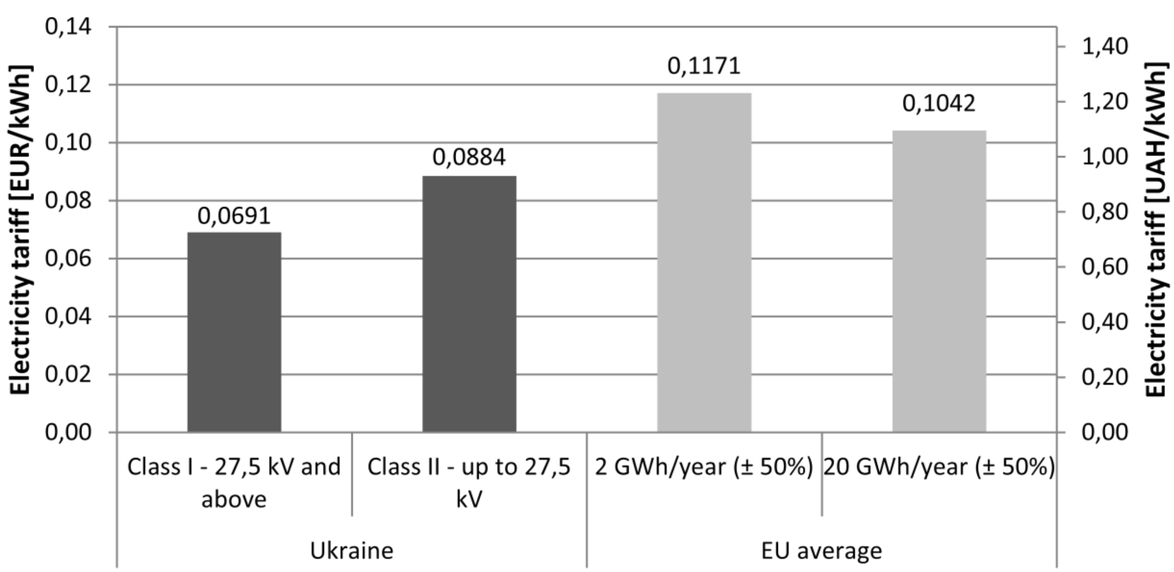

Figure 2.7 Electricity tariffs for industry use in Ukraine and corresponding average EU prices. The tariffs are listed in UAH/kWh and EUR/kWh, VAT is not included (EEP 2012; NERC 2012c).

The highest EU average price is about 1,3 times higher than the highest price in Ukraine, while the lowest prices are separated by a factor of 1,5.

In comparison to the electricity prices for household consumers, the difference between EU average and Ukrainian electricity prices for industry use is smaller, though the prices in Ukraine are still lower. Big differences in the Ukrainian electricity prices for households and industry also in this case indicate a cross-subsidizing from industry to household consumers.

2.4 Discussion

As can be seen from the previous sections, overall energy prices in Ukraine are very low, and prices are kept low as energy is regarded as a basic social service. Such attitude towards energy, as well as some other goods and services (i.e. telecommunications, transport) is typical for the post-socialist countries in the Eastern Europe where state-owned enterprises were heavily subsidized in the past by former socialist governments in order to keep prices artificially low (Ordover et al. 1994). In order to be able to subsidize one type of consumers (residential sector), the higher financial burden is laid on the other types of consumers (industrial sector).

The cross-subsidization leads to poor incentives for the energy consumers to cut their consumption and invest in energy efficiency, as well as economic losses for the energy providers. As a result, the energy providers lack funds to invest in newer and more energy efficient equipment.

None of the energy prices discussed in the previous sections are determined in markets. The National Electricity Regulation Commission of Ukraine (NERC) regulates the electricity and gas tariffs, while the district heating tariffs are approved by the local authorities according to the Law on Heat Supply. The Ukrainian government is well aware of the implications resulting from low energy prices and the Energy Strategy outlines plans for prices to gradually move towards the prices of EU markets (Park 2011). This is easier said than done. Increasing prices (often by a large amount at once) has led to more people not being able to pay their energy bills. Energy pricing is a hot political issue, and signals of price increases are therefore not well received by the voters. The Ukrainian government is constantly under pressure from the International Monetary Fund (IMF) to increase natural gas prices (Argus Media 2012). This is one of the main criteria to get loans from the IMF. It is believed that energy prices will go up after the parliamentary election in October of 2012. Some experts in the area of energy efficiency expect that gas prices will increase by as much as 50 % in the district heating sector and up to 100 % for the residential consumers after the election (Geletukha 2012; Ivanenko & Petryna 2012). Despite such a large increase, gas prices for the majority of residential consumers will still be low in comparison to the prices for EU consumers.

Drastic price increases in Ukraine have happened before. For example, prices for state and industrial sector more than doubled in a period of less than one year, having increased from 1122 UAH/ 1000m^3 in 2008 to 2424 UAH/ 1000m^3 in 2009. In 2010, the sector of communal services faced an increase of about 50 % in gas prices (Figure 2.8).

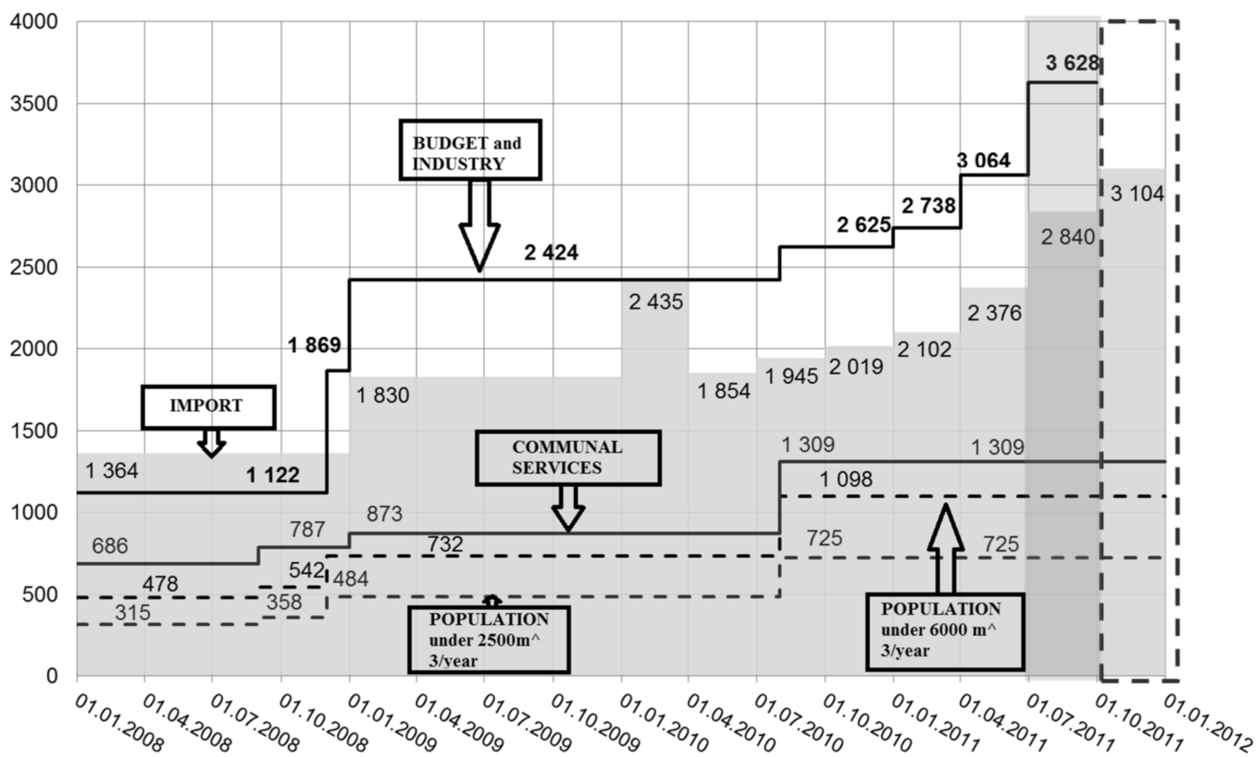

Figure 2.8 Gas prices in the Ukrainian market for different consumers, UAH/ 1000m^3 (Geletukha 2012)

Figure 2.8 confirms the situation described previously in this chapter that there is significant difference in gas prices for different types of consumers, specifically between population (residential sector) and budget (state) and industrial sectors. Moreover, this gap has been increasing during the last few years – in 2008 the difference between the lowest and the highest price was about 1000 UAH/1000m^3, and by 2011 this difference was round 3000 UAH/1000m^3. Enterprises and organizations in budget and industrial sectors have mostly been paying even higher price for gas than import price level. This supports the suggestion that they in such a way cross-subsidize much lower prices for population.

The gas price level for population is so low that it is below the profitable price for heat producers. However, according to Law of Ukraine "On Heat Supply", if the tariffs for heat from thermal power station and boilers that are approved by local government on the base of heat producer calculation, are lower than economically sound cost including marginal profitability level, the local governments must compensate the losses from the local budgets (Tsarenko 2007). This means that the state has to allocate a large share of its budget to keep gas prices low. Indeed, Ukrainian government spent 3,4 billion EUR (about 11 % of budget expenses) in 2010 and 2,2 billion EUR (about 7 % of budget expenses) in 2011 to support low prices for gas in the residential sector (Geletukha 2012).

This problem can be solved by increasing prices gradually, and allocating saved money from price increase into reducing heat consumption among population. In other words, the government needs to reallocate means from subsidy in low gas prices to investment in new energy saving equipment. The energy bill will be higher for the consumers, but can then be reduced over time because of decreased use (Geletukha 2012).

3. Overview of the Heat Market

This chapter gives an overview of the Ukrainian heat market. Characteristics of each sector in the market are discussed based on the segmentation by important features of buildings and factors explaining energy use. One of the main purposes of this chapter is to provide information about segments in the Ukrainian heating market where there is relatively large scope for energy efficiency improvement measures. We will in turn use this information to analyze the specific factors influencing investment decisions and choice of heating technology in these segments.

3.1 Overview and Forecasted Development

As of 2010 the Ukrainian energy supplies are mostly based on fossil fuels. Total primary energy supply (TPES) in 2010 was over 130 million tons of oil equivalent (Mtoe), which equals approximately 1515 TWh. Natural gas (43 %), coal and peat (28 %) nuclear (18 %) and crude oil (9 %) make up the largest part of energy supply.

Most of the energy supply is consumed in order to generate electricity and produce heat. Heat is produced by heat plants and combined heat and power plants (CHP plants), as well as directly on site. Including losses and the energy industry’s own use, the total heat produced by heat plants and CHP plants in 2010 was just over 15,7 Mtoe or 182,6 TWh. Natural gas is the primary energy source in both heat and CHP plants with 9,4 and 5,4 Mtoe being consumed respectively. Some coal and peat are used, while the shares of oil products, biofuels, waste, and nuclear are almost negligible. The total final consumption of produced heat (i.e., consumption after losses and the energy industry’s own consumption) amounts to about 12,3 Mtoe or 143 TWh.

To improve social welfare the Energy Strategy aims to increase the security of energy supply and promote sustainable economic development. Some changes to the energy balance are planned to achieve the goals of the strategy. When the strategy was issued, total energy supply in 2010 in the basic case was predicted to be about 168,5 Mtoe, which is over 38 Mtoe more than supply turned out to be.

Table 3.1 shows how the consumption of the largest shares of the energy balance, fossil fuels and nuclear, is supposed to develop from 2005 till 2030 according to the Energy Strategy and compares it to the actual development of the energy balance so far. From the table, it is clear that the aim of Ukrainian authorities has been to reduce gas consumption by replacing it with higher consumption of other fossil fuels, especially coal. However, the total energy consumption has gone down instead of increasing as expected. The planned decrease in gas consumption could therefore be reached by a relatively lower increase in the shares of other energy sources in total consumption.

Table 3.1 Energy consumed from fossil fuels and nuclear power generated in 2005 and 2010 in addition to the predictions made for the future in the Energy Strategy (Energy Strategy 2006; UkrStat 2012)

Energy form	**2005**	**2010***	**Forecast [Year]**			
			2010	2015	2020	2030
Coal consumption [Mtoe]	31,0	36,5	41,6	52,1	57,6	72,1
Oil consumption [Mtoe]	18,4	11,5	19,7	21,4	21,4	24,3
Natural gas consumption [Mtoe]	62,8	55,5	55,5	51,3	44,1	40,6
Nuclear power generated [Mtoe]	7,6	7,7**	8,7	9,5	13,7	18,8
Total [Mtoe]	119,8	111,2	125,5	134,3	136,8	155,8

Note: *actual data from UkrStat **calculated by using efficiency of 33 % for the nuclear power plants.

It is worth noting that the Ukrainian government plans to compensate for the reduction in gas consumption by doubling coal and nuclear, and by increasing oil consumption by almost a third.

How Ukraine sees the future with respect to the energy balance influences the way the country will produce its heat. In Table 3.2, the production of heat in 2005 and forecast of heat production for the future are listed by heat sources. In the energy strategy, no significant increase in heat produced from nuclear power plants is foreseen. However, from 2005 till 2030, it is predicted that heat from electrical heat generators, mainly heat pumps will increase from 0,2 to 18,0 Mtoe in the base case.

Table 3.2 Structure of heat generation now and forecasts till 2030. All numbers are in Mtoe (Energy Strategy 2006)

Heat sources		**2005**	**Forecast [Year]**			
			2010	2015	2020	2030
Total generation of thermal energy [Mtoe]		24,1	28,0	31,7	36,4	43,1
Power plants, including cogeneration [Mtoe]	Gas and liquid fuel	4,6	4,6	4,0	3,6	2,9
	Solid fuel	0,6	0,6	1,4	2,2	4,4
	Nuclear energy	0,2	0,2	0,2	0,3	0,3
Boiler houses [Mtoe]		14,9	18,6	20,5	21,9	10,4
Power heat-generators and heat transformers*[Mtoe]		0,2	0,3	1,4	3,3	18,0
Individual heat generators [Mtoe]		2,4	2,5	2,7	2,9	3,3
Thermal secondary energy resources [Mtoe]		1,2	1,0	1,1	1,3	1,9
Other sources		0,2	0,2	0,4	1,0	1,9

Note: *Heat pumps, accumulating electrical and electro hydrodynamic heaters

From the table we can see that to be able to reduce the use of natural gas and boiler houses, extensive use of power heat generators and heat transformers, which includes heat pumps, accumulating electrical and electro hydrodynamic heaters, are to be implemented in the future.

Gas consumption is also forecasted to be reduced in the heating production from power plants, by almost 37 %. Heat production from boiler houses, which mostly consume natural gas, is to be reduced by 30 %. Consumption of solid fuel is supposed to increase, thus there may be potential for biomass to be used to a larger degree. In 2010 0,6 Mtoe of biofuel and waste were expected to be consumed in Ukrainian CHP plants. In addition, the energy strategy assumes an increase of over 37 % in heat produced from individual heat generators. Alternative technology (e.g., biomass boilers or heat pumps) may be introduced as such generators.

In the next section, different segments of the heating market are studied in more detail to determine where alternative heating technologies and energy saving measures are most suitable to introduce.

3.2 Heating Market Segmentation

In order to gain a better insight into the demand for different heating technologies and energy saving measures, it is useful to study the characteristics of consumers in the heating market. Individuals' and firms' preferences for heat consumption are likely to depend on the type of buildings they reside in, the possibilities for individual pricing of energy use, etc. For this purpose, we separate the market into segments based on some important features of buildings. Some of these features include:

1. Economic sector, e.g. residential, industrial, agricultural, commercial etc.
2. Location, e.g. city, rural settlement of urban type or village
3. Property rights, e.g. state owned building, partly privatized building or private owned building
4. Type of building, e.g. apartment block or independent house
5. Access to gas pipe
6. Age

For buildings in each segment, collect information on the important factors that explain energy consumption patterns and the scope for energy savings measures. These factors include, for example:

- Demand for heat;
- Demand for electricity;
- Fuel/energy source used for heating;
- Technology used for heating;
- Cost of shifting to an alternative heating technology;
- Institutional and legal issues;

By studying the peculiar characteristics of the segments, we would be able to learn more about heat consumption patterns and the possibilities for energy efficiency improvement in each segment. In the segments with relatively high potential, we are interested in studying which technologies and mechanisms are most suitable for reducing energy use at a lower cost, and possible policies that can be used to increase energy savings.

3.2.1 Energy Use by Sectors

Figure 3.1 presents the heat, natural gas and electricity consumption in different economic sectors for 2010. According to this figure the industry and residential sectors stand out as those with the highest consumption levels. The total consumption of gas is larger than the heat and electricity consumption combined.

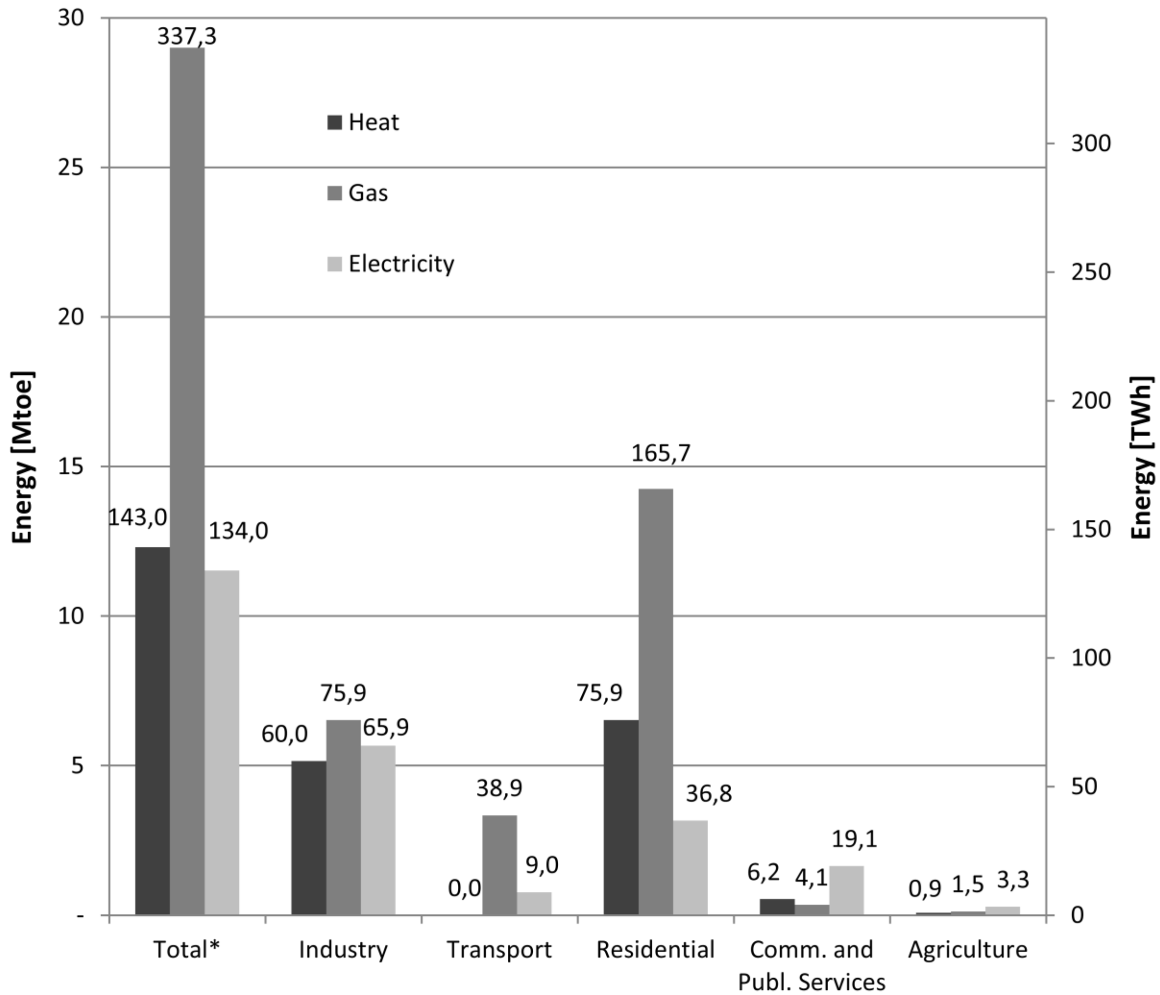

Figure 3.1 Heat, gas and electricity consumption by economic sectors for 2010 (UkrStat 2012).

Note: Consumption is measured in thousand toe on the left axis and in TWh on the right. The labels over the bars are in TWh. The total heat and electricity consumption do not include the respective energy industries' own use and losses.

The final consumption (i.e., after electricity and heat generation by dedicated heat plants and CHP plants) of natural gas in 2010 accounted for almost 29 Mtoe or 337 TWh. Out of these, 14,2 Mtoe (166 TWh) were consumed in the residential sector. This is clearly the largest share of all sectors accounting for 49 % of total gas consumption. The industrial sector's share is about 22 %, while the share of transport equals about 11 %. Communal and public sector and agriculture consume relatively small shares of gas.

Total heat consumption amounts to about 143 TWh. The residential sector is the sector with the highest heat consumption level, with almost 76 TWh being consumed in 2010. This accounts for about 53 % of total heat production. Industry is the second largest heat consumer with a share of 42 %.

The sectors of communal and public services and transport are consuming much less heat. The communal and public services consumed just over 6 TWh of heat, while the agricultural sector consumed only about 1 TWh.

The industrial sector is the largest electricity consumer, consuming about 66 TWh which is almost twice as much as the residential sector and about three times as much as the sector of communal and public services.

The residential sector is clearly the one with largest potential for energy efficiency improvements. Most of the heating in this sector is based on district heating systems. High consumption levels and inefficiency are not only because of low gas prices, but also due to outdated heating equipment in the majority of buildings, lack of insulation and large share of losses and leakages in transportation network as a result of no real measures of its reforming for 20 years. At the same time, those households that have installed insulation of building facades and windows still face high energy bills and have to regulate temperature in the apartment during the winter season by opening windows. The reason for this is that heating bill is calculated only based on the apartment area, not on the actual heat consumption and need. Installation of heat metering and regulators of heat in each apartment can be a solution to this problem. Installing equipment which allows heat supply to be matched with demand reduces final heat consumption. Consumption-based billing allows households to benefit from this decrease, as average household expenditure on heating goes down, making district heating more affordable (Semikolenova et al. 2012).

The residential sector is also characterized by institutional barriers, unclear property rights, lack of legislation that require long-term process of changes and reforms, thus preventing investment and short-term efficiency improvement.

The industrial sector also has high potential for energy efficiency improvement due to high levels of energy consumption. However, a large share of heat in this sector is used in the production process. Therefore, the main potential rather lies in the modernization of the production lines and technologies than in the improvement of heating system (Ivanenko & Petryna 2012).

The analysis of energy consumption in different economic sectors shows that there is large potential in some sectors, but also significant barriers that slow down energy efficiency improvement. It is necessary to look at the heating market in more detail to be able to say whether possibilities outweigh barriers, and whether there are segments with high energy efficiency improvement potential.

3.2.2 Differences Between Rural and Urban Areas

The location of a building plays an important role in terms of the type of building and technology used for heating.

Among buildings in villages, a large share are cottages and the so called "cottage towns" which are located in the suburbs of big cities and represent the upper segment of real estate market. In the cities, apartment blocks prevail.

In the majority of cities and in some rural settlements of urban type, centralized district heating prevails. In large cities, heat is produced by large heating plants (CHPs or large boiler plants) and transmitted to consumers by long heating networks. The total length of these networks in Ukraine amounted to about 33 800 km in 2010 and they are in the communal property (UkrStat 2012). In smaller cities, heat is supplied by district heating companies owned by either the Ministry of Fuel and Energy or municipalities.

Rural areas in Ukraine usually use decentralized heating systems. Decentralized heating is organized as individual heating (for a building) and private (autonomous) heating (for an apartment or a house) (Tsarenko 2007). The heat is usually produced by small heating boilers and generators, which mainly use natural gas, but also liquid and solid fuels are used.

Autonomous heating has minimum transportation losses and provides more flexibility in heat consumption of households. On the other hand, there is an additional cost of installation of autonomous equipment. Centralized heating is characterized by large transportation losses (5 – 32 %) (Energy Strategy 2006). Therefore, it is most suitable to produce and distribute heat to large high-density residential areas (for example, big cities). For the same reason, decentralized heating appears most efficient in rural and private cottage areas. There are even cases when the district heating companies suggest heat consumers to install individual boilers in order to improve energy security and reduce the company's financial risk (Venediktov 2012).

3.2.3 Property Rights

As of 2010 the building sector accounted for more than 57 % of final heat consumption. The building sector is defined as a combination of residential sector, and the sector of communal and public services. More than 85 % of residential buildings were privatized in 2006. However, the responsibility for common areas such as roofs, doors, lifts, electricity, heat and water and sewage infrastructure are usually not on the apartment owners'. The municipalities often use their own housing maintenance companies to take care of the common areas. Therefore, the building as a whole usually lacks a clear owner. Some building owner associations for multi-storey buildings exist (less than 5 %) but the process of forming such condominiums is moving slowly. The possibility of losing municipal subsidies by starting condominiums hinders the development. Commercial and public buildings ownership is clearer, but can complicate if the building is in connection with a residential building (IEA 2006).

The ownership structure of residential buildings leads to problems for energy efficiency investments. Since apartment owners do not own the whole building, they often find it difficult to be able to maintain common parts of it. Even if they agree to maintenance or investments, financing can be a problem because of the unclear ownership (IEA 2006).

3.2.4 Type of Building

Whether a building is an independent house, or a multi-storey block, is likely to influence the choice of technology and source of energy used to heat it. This is because different types of buildings usually have different areas, locations and purposes, and thus different needs for energy consumption, different consumption profiles, as well as different energy supply conditions.

Multi-storey blocks in Ukraine are typically much larger in area than independent buildings, and they are mostly located in big cities. They represent not only residential sector, but also public and commercial sectors – schools, health care institutions, hotels etc. These buildings are often connected to the centralized heating network and have access to gas pipe.

Independent houses are located mostly in rural areas and city suburbs, and they are mainly used for residential purposes. Such houses are frequently not connected to gas or heating networks. Hence, autonomous heating systems are more common. These autonomous systems are commonly based on gas, wood, or liquid fuels.

In recent years, however, there has been growing demand for switching from centralized to decentralized heating also in the cities, mainly in apartment blocks in the residential sector. This is because of the poor and outdated state of centralized heating systems, for example no possibility to regulate temperature level or heating season. In most cases autonomous gas boilers are installed in the apartments, and households pay for gas and cold water instead of heat and hot water (Tsarenko 2007).

3.2.5 Access to Gas Pipe

Buildings with access to a gas pipe have the opportunity to produce their own heat with help of an autonomous boiler. A considerable amount of total heat is produced in this manner, by individual heat generators that combust natural gas (Energy Strategy 2006). Over 90 % of Ukrainian cities had access to gas pipes and liquefied gas in 2010, and there were just about 6 % with liquefied gas access only. In the towns, the shares were almost 70 % and 23 % respectively. In the villages, there were 49 % with access to both forms of gas and about 45 % with only liquefied gas access. These statistics are shown in Figure 3.2 below.

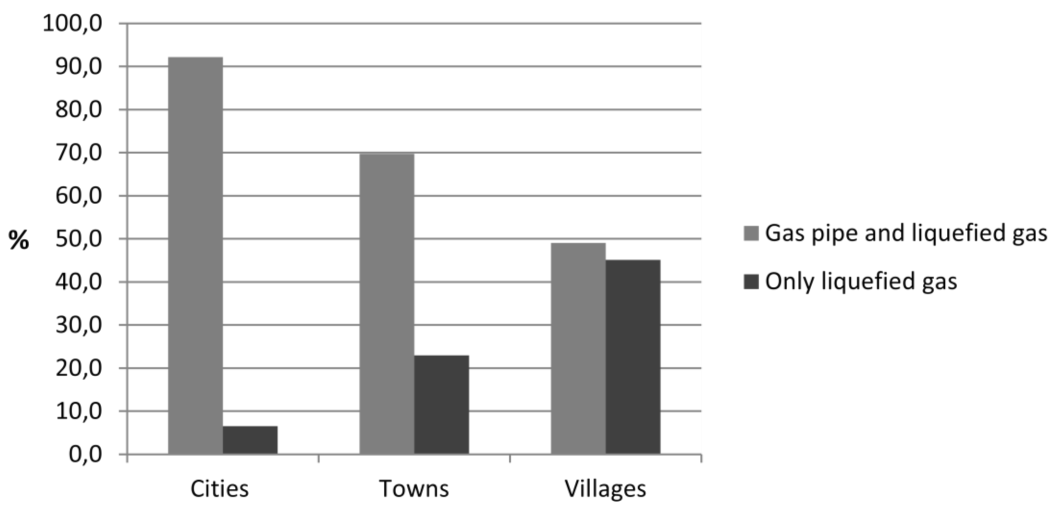

Figure 3.2 Cities, towns and villages access to gas and liquefied gas in per cent as of 2010 (UkrStat 2012).

In 2010 there were over 19,3 million apartments and accommodations in Ukraine. Of these, about 62 % had central heating and over 83 % had access to natural gas. It is difficult to estimate the numbers of buildings with access to central heating only, natural gas only or both from these data. Some buildings may have access to gas, but not central heating. In some cases consumers even disconnect from district heating and use gas for heating instead (see Chapter 3.2.4). The high gas consumption in the residential sector is therefore likely to be a result of gas being used to produce heat and warm water in addition to cooking etc.

3.2.6 Age of Buildings

During the last decade the number of new buildings has been increasing, especially in the residential sector - except the period of financial crisis in 2007-2009. Since 2009, there has been a positive trend for new buildings in the rural areas, while the number of buildings constructed in the cities has remained unchanged. Figure 3.3 shows this development.

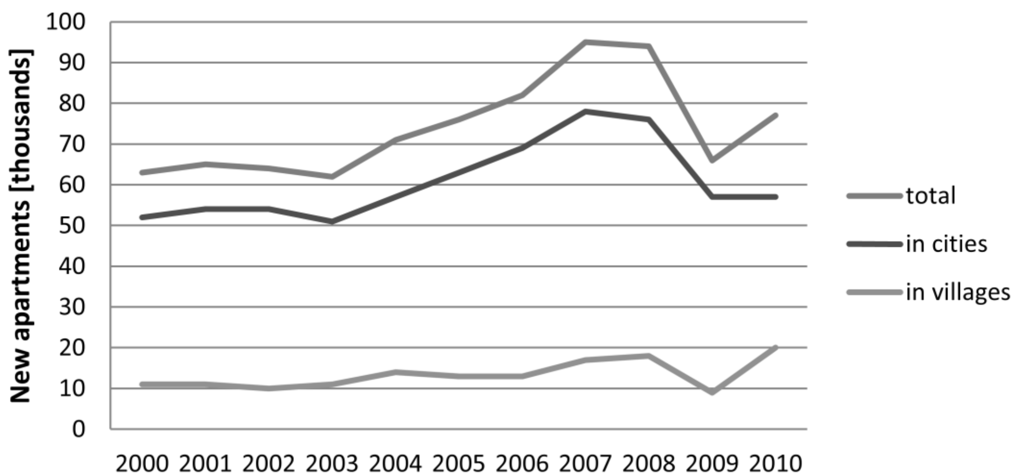

Figure 3.3 Number of new apartments built in thousands from 2000 till 2010 (UkrStat 2012).

More energy efficient and more energy saving technologies are installed in the buildings constructed during the recent years. It is likely that in older buildings more energy is consumed per square meter of living area. This is because of bad insulation and outdated heating systems.

On the other hand, since gas prices remain low, there are insufficient incentives for construction enterprises to use other technologies than gas boilers for heating in the new-built apartment blocks as energy saving measures are not well reflected in housing prices. There are however at the same time examples of solar panels and heat pumps being installed in some new multi-storey buildings of “premium segment”. In the recent years, geothermal heat pumps have become popular for heating new large-area cottages with swimming pools (Geletukha 2012).

Installation of alternative heating technologies in the old buildings connected to district heating is problematic. This is not only because of little financial means to implement energy saving projects, but also because the district heating system and the heating system at user-end (e.g. radiators) is designed for high temperatures (about 95Cº). Technologies as for example heat pumps, cannot warm water to such high temperature, so it can only be installed in the new houses and cannot replace the original heating facilities (Geletukha 2012).

It is probably more convenient to implement energy efficiency measures and install energy efficient heating technologies in new buildings, as it can be done as part of the building process. The number of new buildings is however small compared to the existing building stock. Dividing new built apartments in 2010 by the existing apartments and accommodations currently in stock yields about 4 % new apartments per existing apartments.

3.3 Conclusions

Based on data and other information presented in this chapter, some segments and sectors stand out as favorable for implementation of various energy efficiency and saving measures. We are particularly interested in which sectors it is most suitable to install heat pumps.

The district heating network in Ukraine is large, while the market for other heating technologies to replace district heating is probably more limited because of the inconvenience and need of extra investment. On the other hand, low security of supply and lack of possibilities for heat regulation may lead to some consumers shifting from district heating to autonomous heating. In this case, the characteristics of the existing heat system favor high temperature heating technologies as e.g. gas boilers. At the same time, heat production from individual and autonomous boilers consuming alternative sources of energy is also significant, particularly in the suburbs and in the countryside where remote heating infrastructure or gas pipes are missing.

Residential buildings connected to district heating have an unclear ownership structure. Commercial buildings in towns and cities have clearer ownership structure implying that the investment process here is less complicated. Buildings both in the residential and commercial sector with no district heating access are most interesting with respect to introducing new and more efficient heating systems, such as heat pumps. Residential buildings with these qualities are likely to be found in suburbs or rural areas. Buildings with electricity grid connection, but neither district heating nor gas access, may also be of interest with respect to heat pump installation.

The potential for energy efficiency measures and efficient heating systems to be installed in new buildings is large in one way, but low in another. The possibility of installing new technology without spending extra cost on replacement of the old system makes the market attractive, but the limited amount of new buildings compared to the volume of old housing stock pulls in the opposite direction. New buildings segment is the one with best possibilities for heat pump installation, as heating systems in old buildings are often incompatible with this technology, requiring higher temperature in the pipes and heat distribution system.

Figure 3.5 gives an overview of in which measures and technologies are most applicable in various segments of the heating market, or in other words the arrows point at those segments where each particular measure is most suitable.

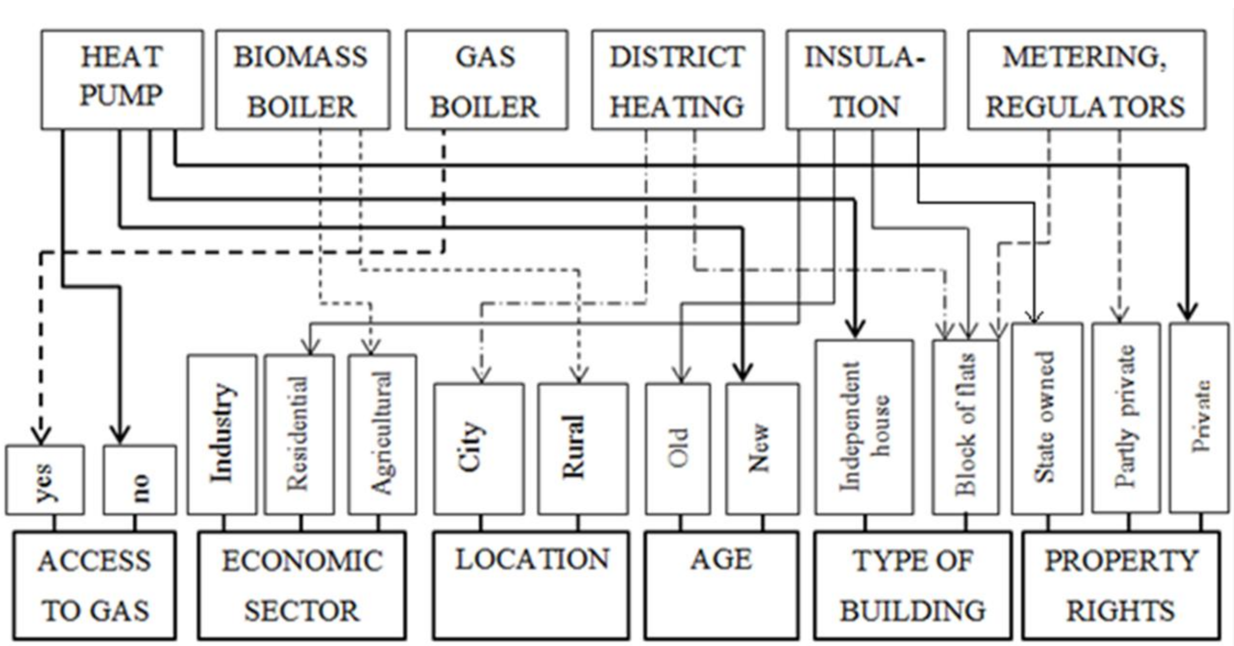

Figure 3.4 Most suitable sectors for implementation of different heating technologies.

It is necessary to note that in the figure, no arrows point at industrial sector. This is due to several reasons. First of all, as discussed in Chapter 3.2.1, the highest potential in this sector lies in the modernization of production technologies, while improvement of technologies and measures connected to heating plays a secondary role. Besides, different segments of the industrial sector are likely to have different preferences when considering the installation of energy efficiency improving heating technologies.

The demand for heat pumps, as was mentioned before, is likely to be limited to the segment of new individual houses in the private sector which do not have access to natural gas. Biomass boilers are most suitable for rural areas and buildings in the agricultural sector because of easy access to solid biofuel. District heating, on the other hand, remains the most suitable heating technology for regions with high population densities, like cities and districts with high concentration of multi-storey buildings. A block of flats is the type of buildings where insulation and installing heat metering and regulation systems is most suitable. The installation of temperature regulators is even more important than additional insulation. It allows consumers to adapt the temperature inside according to their needs and (often) reduce their energy payments. Installing additional insulation without the possibility to regulate temperature in the apartments will most likely lead to excessive heating.

Gas boilers seem to be the technology that is relatively easily installed and quite popular in all types of buildings as long as they have access to gas pipe. What are the reasons for high demand for autonomous gas boilers in all segments of the heating market? After studying the energy situation and the heating market in Ukraine, we see that besides low gas prices there are some other additional factors that are important. First of all, a high share of buildings has access to natural gas. Therefore, it is relatively easier and cheaper to install gas boilers in these buildings compared to other heating technologies. Besides, a gas boiler itself requires much lower initial investment than for example a heat pump. This makes gas boiler preferable for energy consumers with a constrained financial situation.

On the other hand, uncertainty among consumers about future gas prices may weigh in favor of other heating alternatives, such as heat pumps. In chapter 5, we will use NPV analysis to find out what levels of energy prices will make a consumer choose a heat pump for heating instead of a gas boiler. We will also analyze what types of energy consumers are likely to have the highest demand for different heating technologies, with focus on geothermal heat pumps.

4. Theoretical Framework

This chapter serves as a theoretical framework and the basis for the analysis in chapter 5. Energy efficiency improving and energy saving mechanisms are shown with help of production functions and price-demand curves for two cases of change in energy consumption after adoption of new technology. The last section outlines the relevant net present value theory.

4.1 Investment Decisions - Heating

From an economic point of view, there are a couple of basic mechanisms underlying an investment decision. A choice of more energy efficient technology is usually a trade-off between higher initial capital costs and uncertain lower future energy operating costs. Lower future operating costs are related to expected future energy savings, which in turn depend on future energy prices, changes in other operating costs related to the energy use (e.g., pollution charges), intensity of use of the product, and equipment lifetime (Gillingham et al. 2009).

From a production function perspective described by Figure 4.1, a household can achieve lower levels of energy consumption in two ways: by introducing technologies with higher energy efficiency (A), or by inroducing energy saving technologies (B).

The efficient allocation for households is represented by the tangency point where marginal increase in capital cost with respect to energy reduction is equal to their relative price (Gillingham et al. 2009). In the first case, as relative prices change, a household moves from one efficient allocation to another by substituting energy for capital and making higher initial investment in favour of lower future expenditures on energy consumption (Figure 4.1 (A)). In the second case, investment in energy saving technology causes the isoquant to shift in a way favouring more energy efficient use, while relative price remain unchanged (Figure 4.1 (B)).

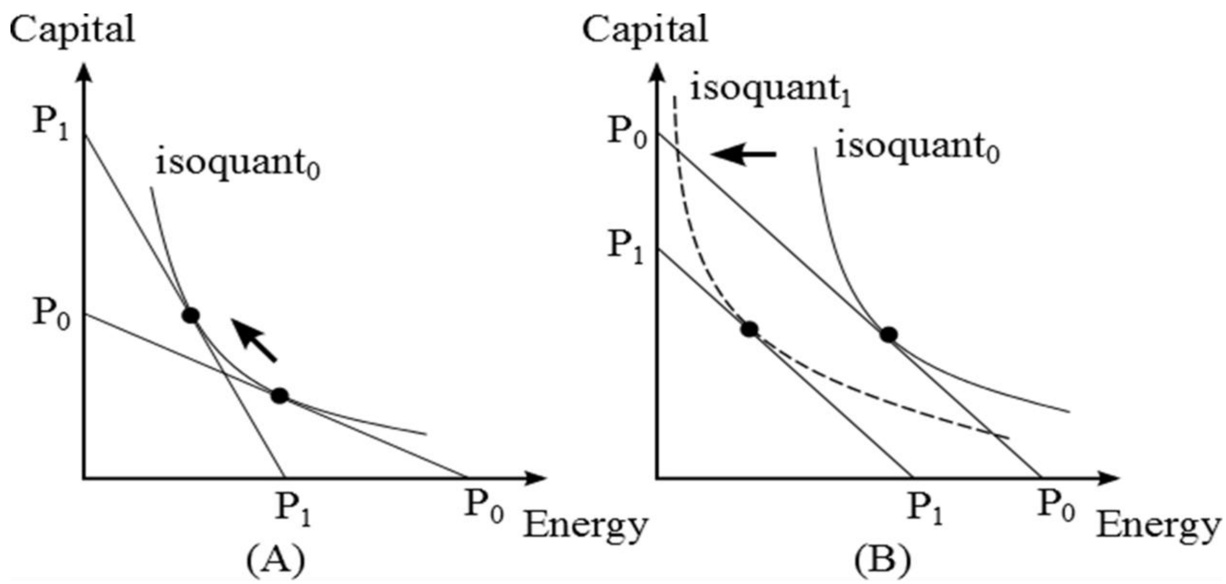

Figure 4.1 Energy Efficiency Improving Substitution versus (B) Energy Saving Technological Change (Gillingham et al. 2009).

Let us consider two specific cases of the reduction in heating consumption. We assume a consumer of energy to be a household connected to a district heating network. This consumer assesses the opportunity to reduce his energy consumption for heating, and can either install some kind of energy consumption reducing technology (e.g. more insulation or new windows), or install a new, and more efficient, heating system (e.g. heat pump). The demand curve for a single consumer of some form of energy, for example natural gas, district heating or electricity, is denoted by *D*. Price of energy, *p*, and quantity of energy, *q*, are measured along the y-axis and x-axis respectively. The consumer is a price taker, which makes p^* given. Initial level of consumption is denoted by q^*.

Installing a consumption reducing technology will reduce the consumer's demand for heating. This is shown in Figure 4.2, where demand shifts from D_1 to D_2. The new quantity, *q'*, and the given price p^* decide the new equilibrium.

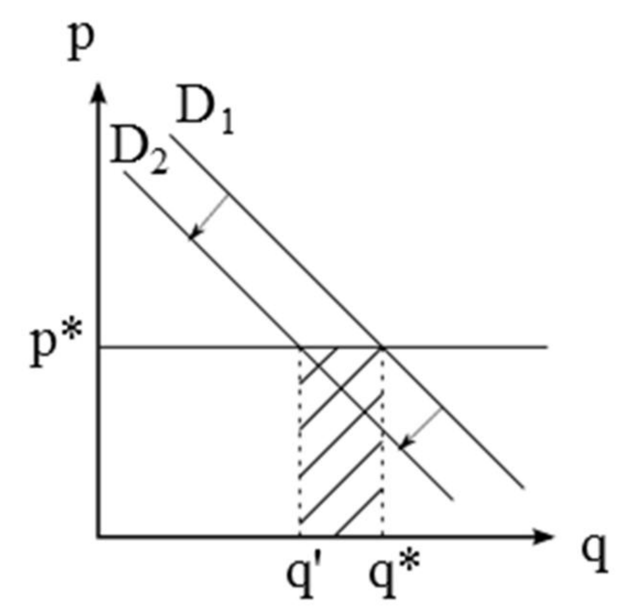

Figure 4.2 Change in energy consumption as a result of installing energy saving technology when prices are exogenously set.

The shaded area represents the saved costs and can be calculated using equation (4.1)

$$CS = p^{*}q^{*} - p^{*}q' \tag{4.1}$$

A consumer choosing to install a heat pump will shift to another source of heating – from district heating to electricity. This means that the consumer's new optimal point on the heat demand curve will be decided based on the electricity price instead of district heating price. The scenario of substituting district heating with a geothermal heat pump is shown in Figure 4.3.

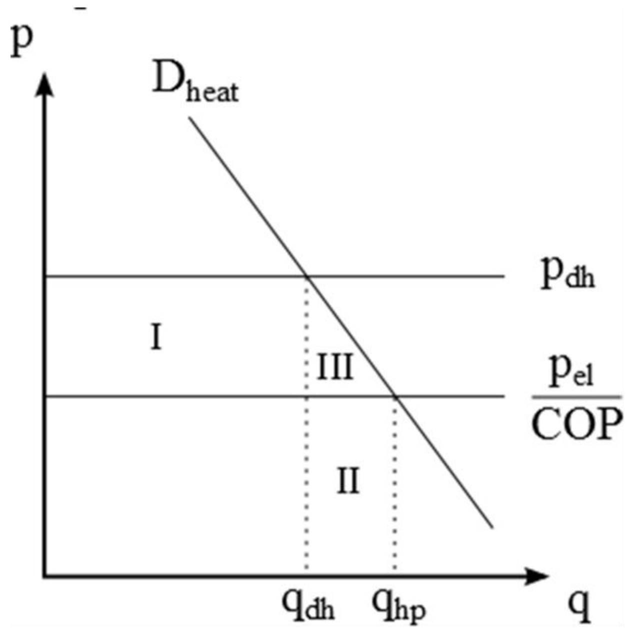

Figure 4.3 Consumer's saved cost as a result of installing more energy efficient technology – geothermal heat pump.

The initial adjustment is where the price of district heating, p_{dh}, crosses the demand for heat, D_{heat}. Thus, the initial consumption of district heating is in the point q_{dh}. The electricity price, p_{el}, is adjusted for the heat pump's coefficient of performance (COP). This factor decides how many units of heating energy the heat pump will deliver for every unit of electricity it consumes. As COP of modern geothermal heat pumps is usually high (varying between 4 and 5), the new heat price, $p_{hp} = \frac{p_{el}}{COP}$, will most likely be lower than the district heating price p_{dh}. When a consumer decides to install a heat pump, his/her new optimal level of consumption will be in the point q_{hp}, which is larger than initial consumption q_{dh}. This means that after the heat pump installation, a household enjoys higher comfort level, being able to consume more heat at a lower price. However, the area (II) also represents the increase in costs due to the increased heat consumption. The saved cost after a heat pump installation equals the area (I) due to the lower level of pricep_{hp}. Thus, the net saved cost will equal (I –II), or:

$$SC = p_{dh}q_{dh} - p_{hp}q_{hp} = (p_{dh} - p_{hp})q_{dh} - (q_{dh} - q_{hp})p_{hp} \qquad \textbf{(4.2)}$$

The area (II) as well as expression $(q_{dh} - q_{hp})p_{hp}$ is negative as long as household's consumption of heat increases after heat pump installation, $q_{hp} > q_{dh}$. Therefore, the saved cost will be positive when area (I) is larger than area (II) and negative when area (II) is larger than area (I). In other words, the higher the initial price and consumption of district heating and the lower the price and consumption for heating after a heat pump installation, the larger is the saved cost. The area (III) in the Figure 4.3 is then the net welfare gain of the household.

Figure 4.3 describes the situation when a consumer has enough financial means to make an investment in a heat pump that covers his/her heat demand and will replace district heating totally. However, it may also be possible that a heat pump installed has insufficient capacity to satisfy consumer's demand, so a spare technology is installed in addition to the heat pump. In Ukraine, this technology most likely would be a gas boiler. Consumer's saved cost and welfare gains will then also depend on the price of gas and the quantity of heat produced from the gas boiler. Appendix F: outlines two possible situations when a gas boiler is used as a spare technology.

From all cases of change in energy consumption discussed in this chapter, it is obvious that the prices for different types of energy decide how profitable it is to reduce energy consumption. In Figure 4.2, the benefit from reducing demand equals the price, p^*, times the reduction in energy consumption from q^* to q'. In the case of heat pump installation, in Figure 4.3, the larger the difference between prices for district heating and electricity/COP, the greater is the benefit from shifting to heat pump.

4.2 Net Present Value (NPV)

To describe a decision on investment in more energy efficient technology and energy saving technology further, it is useful to introduce net present value (*NPV*).

Net present value is a crucial indicator of the project efficiency and feasibility evaluation. It is the way of examining costs (cash outflows) and revenues (cash inflows) together (Palm & Qayum 1985). Net present value is a sum of the present values of negative and positive annual cash flows:

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \quad \textbf{(4.3)}$$

where:

CF_t – cash flow in year t;
T – duration of the project;
r – annual discount rate.

It is important to note that when evaluating private investments of households, there are not always obvious positive cash flows involved, but rather cost savings compared to the initial technology or another alternative technology. Therefore, when evaluating an investment decision of a consumption unit, like energy saving or efficiency equipment, the cash flow must be substituted with a flow of net operating cost saving for each time period (CS_t). The initial investment (*I*) in the project - occurs in present time ($t = 0$) and is not discounted. Therefore, the expression for *NPV* can also be formulated as in equation (4.4).

$$NPV = -I + \sum_{t=1}^{T} \frac{CS_t}{(1+r)^t} \tag{4.4}$$

For the case where a consumer decides on the investment in the energy saving or the more energy efficient technology – heat pump (as in the cases from Figure 4.2 and Figure 4.3.), equation (4.5) shows the setup for calculating the *NPV*:

$$NPV = -I + \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[p_{dh}\Delta q_{dh,t} - p_{hp}\Delta q_{hp,t}\right] \tag{4.5}$$

The negative initial investment, I, yields cost savings $p_{dh}\Delta q_{dh,t}$ from the first period, $t = 1$, till the life of the investment ends at *T*. In the case from Figure 4.2, $\Delta q_{dh,t}$ is the distance from q^* to q' as a result of decreased demand for heat. For the case where a heat pump is to be installed (Figure 4.3), $\Delta q_{dh,t}$ will correspond to the decrease in consumption of district heating after shifting to heat pump. The second part equals all costs of operating the heat pump. For the case with an energy reducing technology only, the last part in the summation is zero.

A positive net present value means that the investment is profitable. If the net present value is zero, the investor will be indifferent as to whether to make the investment, and a negative net present value indicates that the returns are worth less than the initial cash outflow and the investment is not a good one.

From equation (4.5) we can see that the discount rate, *r*, has an important role in making the investment decision. By discounting all project cash flows, we take into account the cost of capital. Cost of capital represents the expected return on the project which should be at least equal to the rate of return of an alternative investment at no risk (for example, putting money in a bank). High discount rate decreases the *NPV* of the project. If the investment in the project is funded by a bank loan, a high interest rate will make the loan more expensive. This is because a high interest rate will make the value of future incomes smaller, as it requires higher annual payments to repay debt.

Another important factor influencing *NPV* of the project in this case is energy price, *p*. High energy prices give incentives for energy saving among consumers and shifting to more energy efficient technologies, even those with high initial investment cost (e.g. heat pump). Low prices for energy on the other hand, discourage consumers from investing into alternative technologies, as *NPV* is likely to be zero or negative in this case.

In the next chapter, we will compare different heating technologies using the net present value (NPV) analysis. As we include cost savings in our NPV analysis, the net present value for one technology must therefore be calculated by using some alternative technology as a reference. Thus, the saved cost will be represented by the expenses that would have occurred if the reference technology was not replaced.

5. Comparative Analysis and Results

This chapter is an in depth analysis of the technologies and measures that are most suitable to apply in the sectors with highest potential for energy efficiency improvement. First, we discuss advantages and disadvantages of some heating technologies and energy saving measures considering the situation in the Ukrainian heating market, with focus on geothermal heat pumps. Relevant cases are then studied where different heating technologies are compared. Different scenarios with respect to energy price dynamics are evaluated.

5.1 Heat Pumps

This section includes the outline of how a heat pump performs as an energy efficiency improving measure in the Ukrainian energy system, as well as the analysis of the heat pump market in Ukraine.

5.1.1 The Heat Pump as an Energy Efficiency Measure

How a heat pump will perform with respect to overall energy efficiency depends on how the electricity it consumes is generated. In the Ukrainian energy system, electricity is mostly generated using coal and nuclear energy. Figure 5.1 shows a common example where electricity is generated by a thermal power plant with a typical efficiency (η) of 35 %. The energy efficiency of the power plant is the energy output of the system divided by the energy input. The electricity is then consumed by a heat pump with an average coefficient of performance (COP) at 4,5. This means that the heat pump will deliver 4,5 times as much heating energy as electrical energy consumed. The circles in Figure 5.1 represent the amount of the given form of energy, and the heat circle is the largest. This means that the amount of heat extracted from the environment by the heat pump more than covers the amount of energy lost when converting fossil fuel to electricity. Thus the heat pump performs well as an energy efficiency technology with these assumptions, although there may be other technologies that are more profitable.

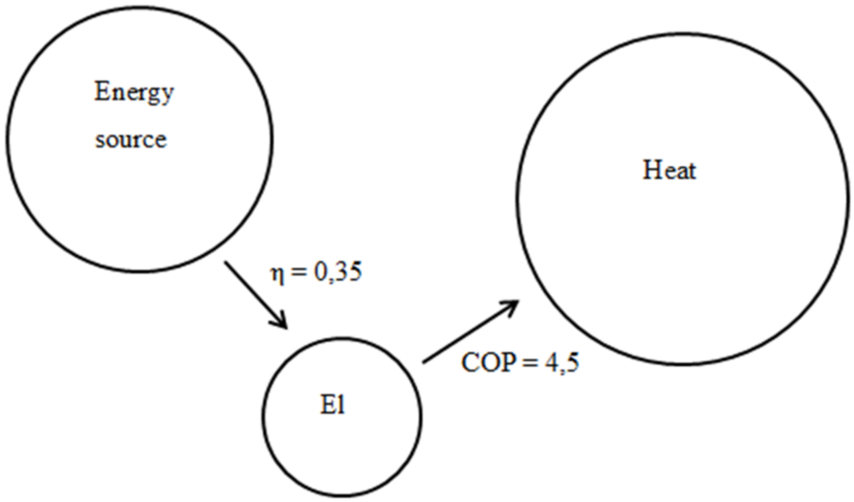

Figure 5.1 Lost and gained useful energy when converting fossil fuel to heat via electricity and heat pump.

When the conversion efficiency from fossil fuel to electricity is 35 % as in Figure 5.1, the lowest COP that will regain initial amount of energy is almost 2,9. If this conversion efficiency is reduced to 30 %, the COP has to be over 3,3. The idea is that if the energy in the generated heat by using a heat pump is not at least as high as the initial amount of fossil energy, for example coal, it would be more energy efficient and possibly more profitable to produce this heat directly rather than going through heat pumps. This is a simplified example, not accounting for transportation losses in the grid and the fact that the Ukrainian electricity system is a complex system based on different energy forms. However, it gives an idea on which properties of a heat pump are important in order for it to work as an energy efficient measure.

5.1.2 The Heat Pump Market in Ukraine

Heat pumps are a relatively new technology in the heating market of Ukraine. Most firms selling this technology have been functioning in the market for about 8-10 years. At the same time this market is growing at a high rate. For example, according to Malynovsky (2009), about 100 heat pumps were installed in Ukraine in the beginning of 2008, while by 2009 additional 200 -350 were sold, and sales were expected to double the year after. According to the Energy Strategy, Ukraine expects to increase energy production using heat pumps by more than 10 times until 2030 compared to 2010 levels.

Today, there are numerous companies represented in the heat pump market, providing a wide range of services – sales, engineering services, installation, and maintenance of various types of heat pumps. The majority of these companies also sell other types of heating systems – gas boilers, solar panels etc. About 85 % of heat pumps sold in the Ukrainian heating market are imported. Hence 15 % of the installed heat pumps are produced in Ukraine. Most of these are assembled using imported parts.

Though the demand for heat pumps is growing, sales numbers still remain quite low compared to traditional heating technologies. The sales of less than a thousand heat pumps per year[4] in an economy the size of Ukraine suggest that heat pumps are not regarded as promising or profitable by most users. There are several reasons for this.

First of all, because of subsidized gas prices, in particular for residential consumers, measures such as insulation have long payback period at recent subsidized gas prices, according to experts (Geletukha 2012). Consumers therefore face insufficient incentives for introducing energy saving technologies.

Moreover, heat pumps have relatively high prices compared to other technologies in the market, and considerable installation costs that amount to about 50 % of overall capital cost. Climate conditions (cold winters) are unfavorable for installation of the cheap air-air heat pumps. Air-water pumps are only feasible in the Southern Ukraine (because of the low temperatures in the winter season in other parts of the country), but can also be used for water heating during the warm season (spring – autumn). The type being sold most often is also the most expensive one – geothermal heat pumps. This is also the type we want to include in our net present value (NPV) analysis further in this chapter.

[4] This estimation is based on information acquired in Kyiv from the interviews with heat pump producers.

At the same time, a geothermal heat pump is an expensive investment (about 20 000$), and the payback period of this technology is about 20 years, so few consumers can afford to install it (Oksenych 2012).

Lack of state support was often pointed out under interviews in Kyiv (Vasylenko 2012) as another major barrier for development of the heat pump market. Many actors in the Ukrainian heating market believe that state support programs, such as possibility to take cheap credits to install energy saving technologies, will make alternative technologies (like heat pumps) more affordable. However, subsidies for heat pumps do not appear to be a sensible policy as removing other distorting energy subsidies in Ukraine both would be a more direct and less costly approach for increasing energy saving measures in Ukraine. It would also reduce the strain in Ukraine's already pressed state budget. Increases in gas tariffs for residential consumers, though politically unpopular, will stimulate energy saving among population and can also be combined with state support to those who are not financially capable of paying their energy bills.

The additional reason why the heat pump market is narrow is that they produce heating temperature up to 40-60 Cº. The Ukrainian district heating system is designed in such a way that the temperature in the pipes must be around 95-100 Cº for sufficient heating. This means that heat pumps are not compatible with the existing heating systems leading to additional costs if they are to be installed in old buildings instead of traditional boilers (Geletukha 2012).

The only market segment for heat pumps is thus new buildings, where one can install 40 Cº tubes in floors or walls. One would therefore expect that the demand for heat pumps is highest for new private houses, commercial buildings and charity projects. Heat pumps are also a feasible technology for heating swimming pools.

Thus, though heat pumps have some clear advantages in terms of energy efficiency improvement, there are also some major barriers that prevent the development of the heat pump market. In order to see whether this technology has the potential to become more popular in the future, we need to study some alternative heating technologies in more detail and compare their characteristics to those of geothermal heat pumps.

5.2 Other Measures and Technologies in the Analysis

This section outlines the characteristics of technologies we will include in our model to analyze the mechanisms behind the investment decision. It describes insulation, new windows and heat regulation as energy saving measures and district heating, gas and biomass boiler as alternatives to heat pumps. The current status of these technologies in Ukraine is described.

5.2.1 Insulation and Heat Regulation

Modern district heating substations with automatic regulation of heat supply, temperature regulating valves (TRV) at building level, additional insulation of walls and roof, as well as new and more energy efficient windows are mentioned as some of the most feasible energy efficiency measures. Table 5.1 presents savings that can be obtained by implementing such measures in different buildings in central northern and east northern Ukraine (Worley Parsons 2011).

Table 5.1 Estimates of energy savings for different measures in central northern and east northern Ukraine (Worley Parsons 2011).

Measure	**Savings per heated area [kWh/m^2]**		
	Apartment block before 1980	Apartment block after 1980	Single family house
Additional insulation of walls	32,8	42,5	59,6
New windows	27,0	41,7	26,1
Additional insulation in roof	12,8	3,6	40,4
New automated substation	9,8	9,5	-
TRV installation	9,8	9,5	11,0

Additional insulation of walls is the measure associated with the largest amount of savings per m^2. Among the three types of buildings, single family houses can save most by installing wall insulation. For example, for a single family house with a floor area of 200 m^2 and annual heat demand of about 60 000 kWh (calculations based on the Table G-1in Appendix G:), the estimate of annual energy savings after wall insulation will equal about 12 000 kWh, or as much as 20 % of annual demand for heat.

Utilization of energy saving measures varies to a large extent in investment and installation cost. For example, insulation of the walls can be done by installing a new facade on the outside of the old one or by inserting more insulation from the inside. In the first case, material costs are relatively high while installation is straightforward. For the second case there are relatively low material costs, but this method requires more effort in the installation process.

The type of building where insulation is installed plays an important role with respect to the level of installation costs. If energy saving measures are installed in the building process in new buildings, the level of installation costs will be lower than for old buildings where the installation of these measures is impossible without costly renovation.

5.2.2 District Heating

As mentioned earlier, a large share of buildings in Ukraine is connected to the district heating network. At the same time this network is now facing some important challenges. The persistence of artificially low tariffs set by local governments has led to low levels of financial sustainability and service quality of district heating companies. "Low tariffs meant district heating companies could not cover their costs, resulting in large debts owed to the natural gas sector, and an inability to make needed investments. Protracted underinvestment has taken its toll on efficiency and quality of service. Most of the assets are close to or beyond the end of their design life resulting in low quality of service and higher operating costs. Poor service has caused dissatisfaction and distrust among customers" (Semikolenova et al. 2012).

Clearly, heating tariffs have to increase in order to match the cost of heat generation. At the same time, some households will find it difficult to pay higher tariffs due to difficult economic times. A solution to this problem would be to reduce heat consumption to compensate for increasing prices for heating. According to Semikolenova et al. (2012) this can be achieved by:

- Assigning high priority to providing targeted subsidies to poor consumers to advance tariff increases;
- Installing individual heat substations with temperature controls (15-25 percent savings);

- Implementing energy efficiency measures to improve building envelops (20-25 percent savings);
- Installing heat-cost allocators (15-20 percent savings);
- Decreasing supply costs by reducing network losses and increased use of combined heat and power plants (10-20 percent savings).

In addition to large investment, the sector is also in need for reformation. According to the Ministry of Regional Development, Building and Housing of Ukraine, there are plans to deregulate the heating system and divide it into generation, distribution and consumption. According to the Ministry, generation of heat will be privatized, distribution will be regulated by local authorities, and consumption will be under the responsibility of building owners. Private ownership in the sector of heat generation will probably lead to an increase in tariffs, but will also stimulate the implementation of energy saving measures. Besides, this mechanism will provide more clarity in property rights for households (or associations of building owners), but will also include some additional responsibilities, like maintenance and repair of buildings.

However, the heating market deregulation should be preceded by creation of a sufficient regulatory framework that will clearly define the rights and responsibilities of all participants in the market. Today, Ukraine still lacks clear and transparent legislation addressing these issues.

Clearly, district heating in Ukraine is characterized by low level of energy efficiency and requires long-term and costly reformation. However, this heating technology remains the only likely alternative for the majority of households due to relatively low heat tariffs and no incentives and financial means to invest in energy conservation.

5.2.3 Gas Boilers

Autonomous gas boilers are currently the most popular heating technology alternative to district heating in Ukraine. This is mainly due to low gas prices. Besides, it provides consumers with a possibility to regulate the temperature in their apartments and the length of the heating season.

Hence, it increases comfort levels for consumers. Besides, gas boilers are cheaper than the alternative technologies, such as heat pumps, and have much lower installation cost.

Installation of gas boilers is more energy efficient than connecting to district heating, as new gas boilers use less gas than outdated district heating facilities to produce the same amount of heat. Besides, in case of installation of gas boilers in separate buildings or apartments, transportation losses are minimized.

On the other hand, the preference for gas boilers in the Ukrainian market is based on the low gas prices, and the situation may change completely after the increase in gas prices, which is expected to happen quite soon. Further in this chapter we investigate the performance of gas boilers compared to other technologies at different levels of gas prices.

5.2.4 Biomass Boilers

Biomass boilers are also an alternative heating technology that we include in the NPV analysis. First of all, these boilers are based on renewable energy sources (wood, straw, manure, municipal solid waste and other organic waste) and are therefore relatively environmentally friendly. Today, about 0,7 % of energy in Ukraine is produced from biomass, thus making biomass the second largest renewable energy source after large hydropower (0,9 %) (Geletukha 2012). Still, this share is low compared to other European countries. Increasing the share of biomass boilers in the heat production will make the Ukrainian heating system less dependent on gas and lead to higher level of energy security.

However, heat production based on biomass has the largest potential for implementation in the commercial sector. There are more than 2000 boilers installed in Ukraine, but there are practically no examples of biomass boilers in the residential and communal sectors. The main reason for this is that biomass cannot compete with gas in these sectors due to the low gas prices to residential consumers. For example, there are no registered cases where a biomass boiler has replaced a gas boiler. The main segment where biomass boiler appears to be a realistic alternative to gas boilers, and where the majority of boilers are installed, is the agricultural sector. In this sector, biomass is readily available, and in some cases enterprises have no fuel expenses at all.

Today, the biomass boiler market seems to be quite narrow and unable to compete with gas-based technologies. Still, we are interested in studying further in this chapter the possible development in this market as a result of an expected future gas price increase.

5.3 Analysis

In this chapter, a few cases of NPV analysis with varying input characteristics will be presented and evaluated. It is interesting to find out under which conditions different technologies become preferable. In the first case, we study the case of energy saving measures, such as buildings insulation and installation of new windows. Then, in case two and three, we turn to the comparative analysis of the heating technologies discussed in chapter 5.2. Finally, in the fourth case, we analyze which factors will make geothermal heat pump the most favorable investment alternative.

5.3.1 Case 1: Energy Saving Measures – Insulation and Heat Regulation

This section evaluates energy efficiency measures for three types of buildings. An apartment in a building block up to 7 floors, which were mostly built before 1980, an apartment in a block with more than 7 floors, mostly built after 1980 and a single family house. We perform NPV analysis to find initial investments that make the NPV zero at different time frames.

Energy savings are based on saved costs due to reduced district heating consumption at two different price levels: district heating tariff for Ukrainian residential consumers (Ukr res) of 0,0229 EUR/kWh and the average European district heating price of 0,0506 EUR/kWh. The discount rate is set at 10 % and the district heating prices are assumed to increase with 5 % each year.

The results are shown in Table 5.2. It lists the maximum amounts of the initial investments for the various energy efficiency measures that will make each measure profitable for different time periods. In other words, it is interesting at which maximum level of initial investment the net present value for a given measure and time period will be equal to zero. The three different types of buildings and their floor area are listed in the left column.

Table 5.2 Investment amounts for different energy saving measures that make the NPV zero after 5, 10 or 20 years for three different building types. The amounts are calculated for Ukrainian residential and European district heating prices (Worley Parsons 2011).

Building type and size	**Measure**	**Investment making NPV zero after [EUR]**					
		5 years		10 years		20 years	
		Ukr res	European	Ukr res	European	Ukr res	European
Apartment in block before 1980 100 m^2	Additional wall insulation	328	726	589	1 300	958	2 117
	New windows	269	595	483	1 067	786	1 737
	Additional roof insulation	128	282	229	506	372	824
	New automated substation	98	216	175	387	285	631
	TRV installation	98	216	175	387	285	631
Apartment in block after 1980 100 m^2	Additional wall insulation	424	937	760	1 680	1 238	2 735
	New windows	416	920	746	1 648	1 214	2 683
	Additional roof insulation	36	79	64	142	105	232
	New automated substation	95	209	170	376	277	611
	TRV installation	95	209	170	376	277	611
Single family house 200 m^2	Additional wall insulation	1 190	2 629	2 132	4 712	3 472	7 671
	New windows	521	1 151	934	2 063	1 520	3 359
	Additional roof insulation	806	1 782	1 445	3 194	2 353	5 200
	TRV installation	220	485	394	870	640	1 416

For the case of Ukrainian district heating price levels we see from Table 5.2 that maximum initial investment in insulation, new windows and heat regulation must be relatively low to be profitable

- even for a time frame of 20 years. This is clearly due to the low (under half of the European level) district heating price for residential sector consumers in Ukraine.

To investigate whether the measures could be profitable or not, we need to compare the optimal initial investment levels from Table 5.2 with the investment in different measures that occurs in reality. Table 5.3 contains some values of estimated investment costs of the relevant measures. The investment costs are assumed to be the same for new and old apartment blocks. The costs are listed per heated area and in total when multiplied by living area.

Table 5.3 Calculated investment costs for the various energy efficiency measures for each building type. Investment amounts per heated area are assumed to be the same for new and old apartment blocks (Worley Parsons 2011).

Building type and size	**Measure**	**Investment**	
		Per heated area [EUR/m^2]	Total [EUR]
Apartment in block before and after 1980 100 m^2	Additional wall insulation	12,3	1 230
	New windows	7,9	790
	Additional roof insulation	6,9	690
	New automated substation	2,0	200
	TRV installation	1,2	120
Single family house 200 m^2	Additional wall insulation	16	3 200
	New windows	12	2 400
	Additional roof insulation	9,7	1 940
	TRV installation	1,5	300

Among the different buildings, measures are most profitable in the single family house. Figure 5.2 compares the actual investment costs to all investment costs that make the NPV zero after 5, 10 and 20 years for the single family house. Both Ukrainian and average European district heating prices are shown. Except for new windows, every measure is profitable for the single family house paying Ukrainian district heating tariff, but only in the long term (20 years). Assuming European price levels, all measures except new windows receive positive NPV within 10 years. Investment in new windows becomes economically favorable only after 20 years also when we assume and when European price levels are assumed.

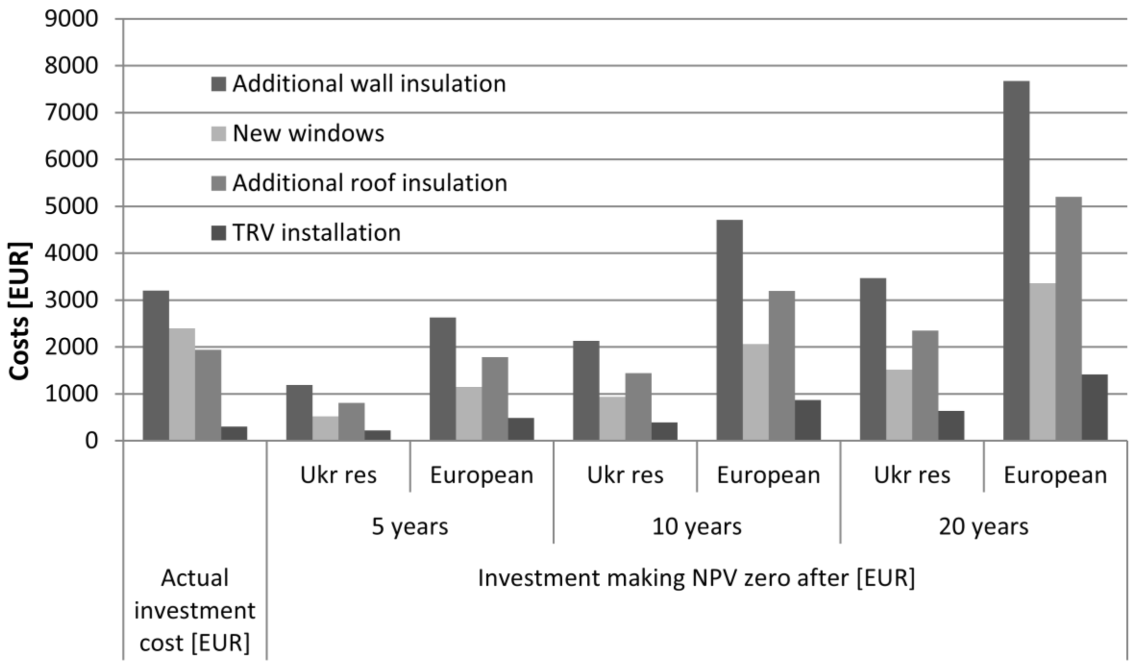

Figure 5.2 Actual investments in various energy efficiency measures and the investment levels that make the NPV zero after 5, 10 and 20 years for a single family house of 200 m^2.

The energy efficiency measures are generally less profitable in the apartments than for the single family house. In the old apartments, all investments in energy saving measures become profitable only after 20 years or more if the consumers pay Ukrainian district heating price levels. For the European price level, the payback period for different measures varies. For example, investment projects in new windows will receive positive NPV already after 5 years, while extra insulation of walls and roof will have a payback period of 20 years.

Generally, for all building types TRV installations will be paid back after 5 years at European price levels and 10 years at Ukrainian price levels. New automated substations have a payback period of 5 years when we assume European price levels, but will be profitable after 20 years when prices are set at present Ukrainian levels. In most cases implementation of these measures is even more important than additional insulation and installation of new windows as excessive heat is already a problem and the inability to regulate the indoor temperature will lead to unchanged energy use.

5.3.2 Case 2: Energy Efficient Heating Systems – Residential Sector

There are a number of factors involved when deciding the net present value of different heating technologies. The price level and forecasted price development of the different forms of energy, the value of initial investment, discount rate, lifetime and technical characteristics of the technologies as well as heat demand for the respective building will influence the calculation.

We choose one specific category of consumers for the NPV analysis. We assume our consumer to be a household with the demand for heat equaling 30 000 kWh/year. This household is connected to district heating network, and has to make a choice between the base-alternative of remaining connected to district heating or shifting to another energy efficient technology. As alternatives to district heating, the household evaluates the following technologies:

1. Geothermal heat pump Viessmann Vitocal 200 – G requiring initial investment (including installation cost) of about 10 000 Euro;
2. Gas boiler Viessmann Vitopend 100 – W requiring initial investment of about 1 000 Euro;
3. Biomass boiler Kalvis K-2-12 requiring initial investment of about 1 500 Euro.

To make the comparison of these heating technologies as precise as possible, it is important to consider their basic technical characteristics.

First of all, we choose technologies with about equal capacity level – from 9,7 kW to 12 kW. This is to make sure that the costs of investing in these systems will be comparable. We also assume that all technologies are able to cover the total heat demand.

As mentioned in section 5.1.1, the heat pump will use a certain amount of electricity to produce a larger amount of heat by extracting heat from the environment. This ratio is determined by the coefficient of performance (COP). The case for a gas boiler or a biomass boiler is different. These boilers are characterized by an efficiency factor, in the same way as the power plant from section 5.1.1. This means that neither the gas nor biomass boiler can convert all the energy stored in the gas or biomass into heat energy, the efficiency is however considerably higher than for a thermal power plant. Therefore, every technology will consume a different amount of energy to produce same amount of heat.

For each technology, we assume the maintenance cost to be at an annual level of 5 % of initial investment.

Another important factor in the NPV analysis, as was mentioned before, is the discount rate. When choosing a discount rate, it should be at least as high as the rate of some alternative project. For example, the household could decide put money on the deposit account in the bank instead of investing in a new heating technology. In this case, investing into a new heating technology should have at least as high discount rate as the bank's interest rate. Therefore, we choose for our analysis a discount rate equal to the interest rate on deposits in euros (as all our input data is in euros) in a Ukrainian bank. This rate is equal to 7,5 % (PrivatBank 2012).

We set Ukrainian prices at their present values. Besides, we want to access the realistic trend of price increase during three different time periods of NPV analysis – 5, 10 and 20 years.

To forecast the possible price increase we analyze the past data on price levels of gas, electricity, district heating.

Based on Figure 2.8, we can evaluate the average annual gas price increase during the last five years. The results are represented in Table 5.4. The gas price has increased from about 44 to 116 euro per 1000 m^3, or on average by 29 % per year.

Table 5.4 Calculation of average yearly gas price increase.

Year	**2008**	**2009**	**2010**	**2011**	**2012**
Price in UAH/1000 m^3	478	542	732	1098	1098
Exchange rate [UAH/EUR]	10,98	11,44	10,57	10,29	9,5
Price in [EUR/1000 m^3]	43,53	47,38	69,25	106,71	115,58
Price increase per year [%]		8,83	46,17	54,08	8,32
Average price increase [%]	29,35				

As far as electricity tariffs for households are concerned, the increase has not been as drastic as for gas prices. In fact, these tariffs have not been revised between 2006 and 2011. Because of this, the average yearly price increase (in EUR) equaled only 3,3 % in the abovementioned period. In 2011, however, tariffs increased by about 30 % relative to 2010 levels and further increases by about 25 % were observed in 2012. This is shown in Table 5.5.

Table 5.5 Calculation of average yearly electricity price increase (TRIOS 2012).

Year	2006	2007	2008	2009	2010	2011	2012
Price of electricity [UAH/kWh]	0,244	0,244	0,244	0,244	0,244	0,3167	0,3648
Exchange rate [UAH/EUR]	6,65	7,33	10,98	11,44	10,57	10,29	9,5
Price of electricity [EUR/kWh]	0,037	0,033	0,022	0,021	0,023	0,031	0,038
Price increase [%]		-9,28	-33,24	-4,02	8,23	33,33	24,77
Average price increase [%]	3,30						

Table 5.6 represents the increase in prices for district heating for consumers in the residential sector in the period from 2005 to 2011. Calculations show that during this period, the price has on average increased by about 20 % every year.

Table 5.6 Calculation of average yearly district heating price increase (Krogerc 2012a).

Year	2005	2006	2007	2008	2009	2010	2011
Price for heat [UAH/Gcal]	58,23	80,77	115,2	144,56	179,45	246,38	280,3
Exchange rate [UAH/EUR]	6,017	6,65	7,33	10,98	11,44	10,57	10,29
Price for heat [EUR/Gcal]	9,68	12,15	15,72	13,17	15,69	23,31	27,24
Price increase per year [%]		25,51	29,40	-16,23	19,14	48,60	16,86
Average price increase [%]	20,55						

Based on the results presented in tables 5.1 – 5.3 and interviews with experts in Kyiv (Geletukha 2012), we can forecast an average annual price increase of gas, electricity and district heating in the nearest future. It is most likely that prices for import of gas from Russia will increase. We therefore assume that prices for gas and district heating (as heat is to a large extend produced from gas) will grow by about 20 % annually. Prices for electricity are likely to increase at a lower rate, as most of electricity is produced using coal and nuclear power. Thus, we assume the rate of electricity price increase to be equal to 15 %.

It is quite complicated to find information on price for solid biofuel and its dynamics and estimate the average annual price increase. Different sources provide different estimates of prices for biomass (Geletukha 2012; Geoteplo 2012). This is because there are many different types of biomass used for heating, as well as a large number of relatively small producers in the Ukrainian market. Based on the sources and our own calculations we assume the price to equal 0,02 EUR/kWh. Since the statistical information on past biomass price dynamics is unavailable, we assume that prices for solid biofuel increase at about the same rate as the prices for electricity – 15 % annually.

In general, it is necessary to point out that the analysis includes a number of assumptions a variation of which will change the NPV outcomes in the model. These assumptions apply to such factors in the analysis as maintenance cost, discount rate, rate of price increase, and the value of initial investment. The model also disregards the influence of political insecurity and institutional barriers on the NPV, though they play an important role behind the investment decision.

Based on the characteristics of technologies, price statistics and expected price increase, we calculate the net present value for investments in alternative technologies for the periods of 5, 10, and 20 years. The model and results are summarized in Table 5.7.

Table 5.7 NPV calculation for residential sector consumers (present level of Ukrainian energy prices).

Technology	**District heating**	**Gas boiler**	**Heat pump**	**Biomass boiler**
Heat demand [kWh]	30 000	30 000	30 000	30 000
Capacity [kW]		10,7	9,7	12
Efficiency/COP	1	0,9	4,4	0,8
Energy consumption [kWh]	30 000	33 333	6 818	37 500
Initial investment [EUR]	0	1 000	10 000	1 500
Maintenance cost [% of initial investment]	5	5	5	5
Discount rate [%]	7,5	7,5	7,5	7,5
Energy source	**District heating**	**Gas**	**Electricity**	**Wood**
Price per unit energy [EUR/kWh]	0,0229	0,0097	0,0347	0,02
Annual price increase [%]	20	20	15	15
Technology		**Gas boiler**	**Heat pump**	**Biomass boiler**
NPV 5 years	-	1 133	-7 235	-1 480
NPV 10 years	-	4 831	-2 022	-114
NPV 20 years	-	22 348	25 107	14 077

It is clear from the table that in the short run a gas boiler is the most attractive investment, as its NPV is highest for the payback period of 5 years. Both the NPV of investment in biomass boiler and heat pump have negative values after 5 years, heat pump being the least economically desirable alternative with the most negative NPV. The situation is the same after 10 years. In the long run (20 years) the heat pump has a higher NPV than the gas boiler. The NPV of investment in the biomass boiler is the lowest after 20 years.

A more detailed comparison of change in NPV during the whole period of analysis is presented in Figure 5.3.

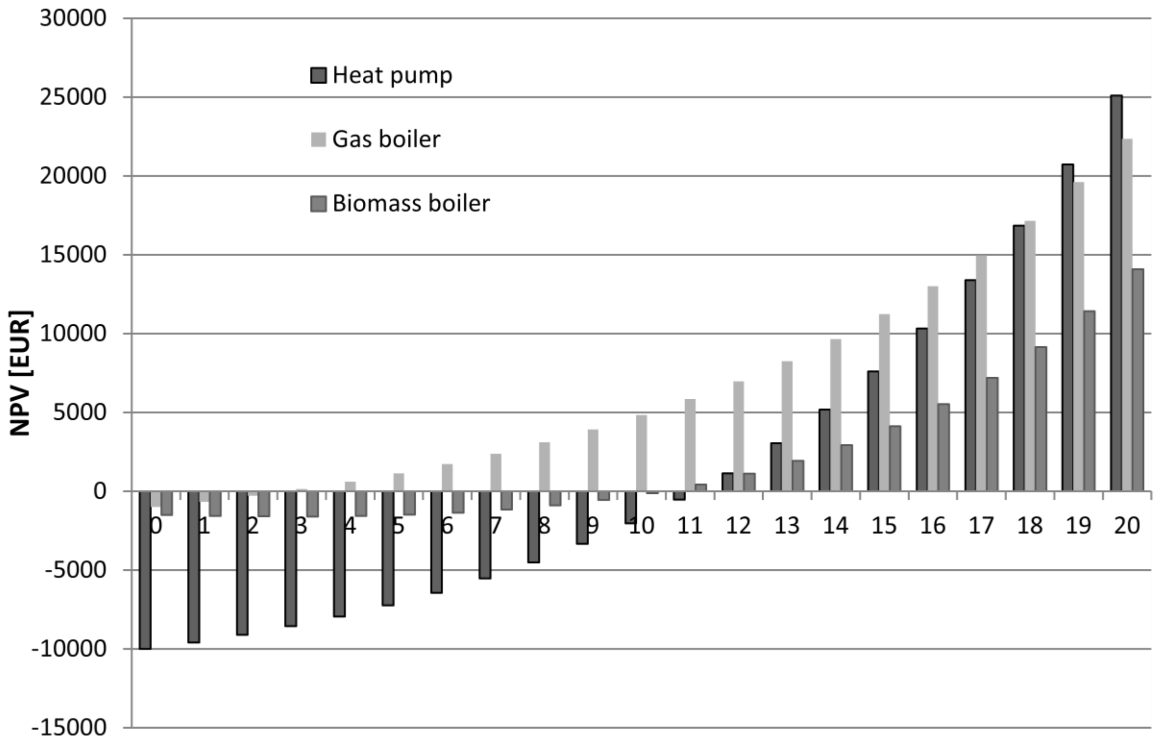

Figure 5.3 Comparative analysis of NPVs for a residential sector consumer.

We can see that an investment in gas boiler results into higher level of cost savings compared to district heating already in the third year after its installation. For a heat pump, the breakpoint threshold compared to district heating occurs in the 12^{th} year after installation, while for biomass boiler this period equals 11 years. Only after as long as 18-19 years, the heat pump becomes more economical than the gas boiler.

Thus, as we expected, the gas boiler is the most economically attractive technology compared to district heating, heat pump and biomass boiler. The heat pump and the biomass boiler have much longer payback period and cannot compete with gas boiler in the short and medium run. This is due to high value of initial investment in case of investment in heat pump and relatively high prices for fuel in case of investment in biomass boiler. The efficiency of the biomass boiler is also lower than the efficiency of the gas boiler. The gas boiler, on the other hand, has a relatively short payback time due to low gas prices.

It is important to note that 15 % and 20 % annual rate of increase in prices of energy sources is quite large and the assumption of such growth can only be realistic in the short run, or until prices reach a specific threshold, like European price level (in this case, 16 years for electricity and 18 years for gas). In the next case we will study the NPV of the three investment alternatives for a consumer in the Ukrainian non-residential sector that faces price levels closer to the European and a small rate of price increase.

5.3.3 Case 3: Energy Efficient Heating Systems – Non-residential Sector.

The investment decision made by heat consumers in the non-residential sector (by non-residential we mean any other sector in the economy, for example industrial, commercial, state etc.) is interesting to study as these consumers pay much higher prices for all sources of energy than consumers in the residential sector. In this case, we will also analyze a NPV for investments in gas boiler, heat pump and biomass boiler. Clearly, non-residential sector consumers will have higher demand for heat and will require installation of technologies with larger capacity – for this case we set the capacity needed to be about 80kW. This means that the value of initial investment will also be higher.

We choose the following alternatives for evaluation:

1. Heat pump Viessmann Vitocal 300-G requiring initial investment of about 40 000 Euro;
2. Gas boiler Viessmann Vitodens 200-W requiring initial investment of about 6 000 Euro;
3. Biomass boiler Vitoligno 100-S requiring initial investment of about 6 500 Euro.

Prices for electricity and gas for this type of consumers are close to European price levels, while district heating prices are in fact higher than average district heating tariff in European countries (Figure 2.5.). Since the price levels are relatively high, it is unlikely that they will increase at a high rate in the future. Therefore, we assume that prices will increase at the current inflation rate, which in the end of 2011 was around 5 % (Minfin 2012b). The results for 5, 10 and 20-year periods are summarized in Table 5.8.

Table 5.8 NPV calculation for non-residential sector consumers (present level of Ukrainian energy prices).

Technology	**District heating**	**Gas boiler**	**Heat pump**	**Biomass boiler**
Heat demand [kWh]	300 000	300 000	300 000	300 000
Capacity [kW]		80	85,6	80
Efficiency/COP	1	0,98	4,8	0,88
Energy consumption [kWh]	300 000	306 122	62 500	340 909
Initial investment [EUR]	0	6 000	40 000	6 500
Maintenance cost [% of initial investment]	5	5	5	5
Discount rate [%]	7,5	7,5	7,5	7,5
Energy source	**District heating**	**Gas**	**Electricity**	**Wood**
Price per unit energy [EUR/kWh]	0,0696	0,0268	0,0884	0,0200
Annual price increase [%]	5	5	5	5
Technology		**Gas boiler**	**Heat pump**	**Biomass boiler**
NPV 5 years	-	50 279	28 173	55 932
NPV 10 years	-	100 311	88 779	111 434
NPV 20 years	-	184 331	190 558	204 640

The net present values of the investments in the three technologies become positive in the 3rd year. This is linked to the fact that the district heating prices are very high. From Figure 5.4 we can see that gas boiler and biomass boiler become more economical than district heating already in the next year after investment. The biomass boiler has the most positive net present value for the whole analysis period. This is due to the low price assumed for biomass in comparison to gas and electricity prices. However, it is important to note that the type of biomass boiler in this analysis is one of the cheapest models and combusts wood, which is the cheapest form of solid biofuel. The results would most likely be different with a more expensive and automatic pellets boiler.

Figure 5.4 shows that even the large initial investment in the heat pump is paid back fast, but compared to the gas boiler the heat pump installation acquires the same level of NPV only after 16 years. In the 17th year, the heat pump NPV exceeds the gas boiler NPV.

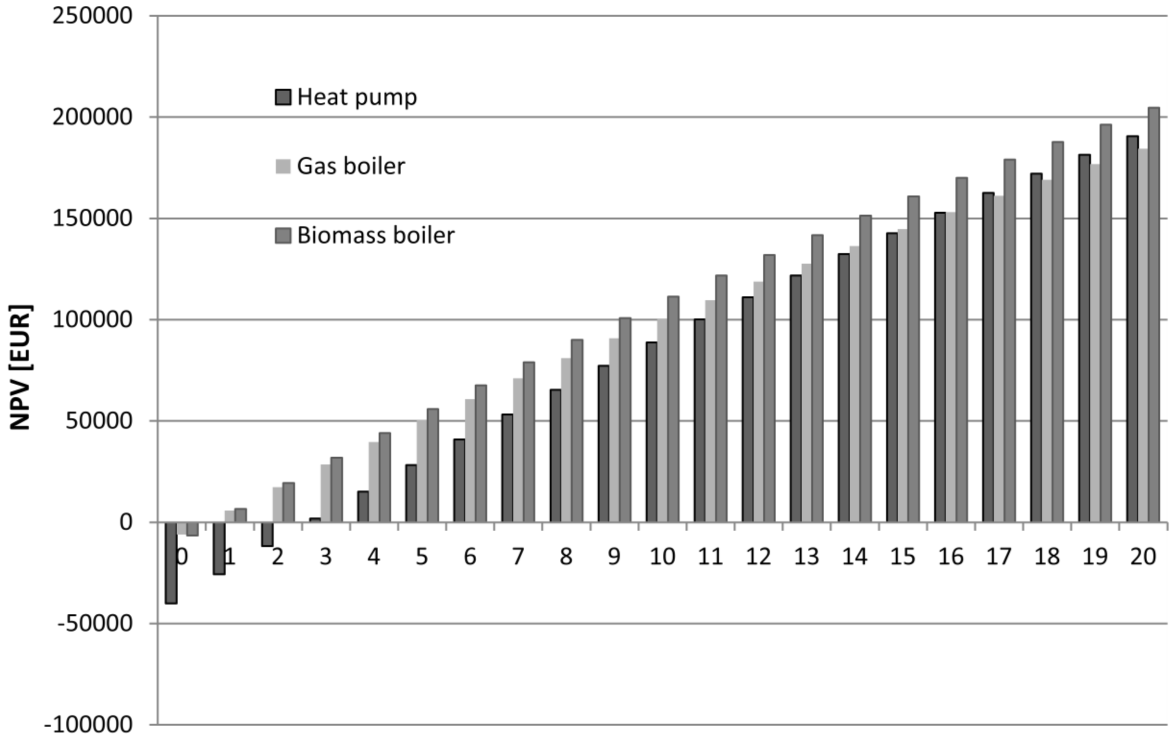

Figure 5.4 Comparative analysis of NPVs for a non-residential sector consumer

From Figure 5.4 it is clear that shifting from district heating to an alternative technology is in general much more attractive for the non-residential consumer than for consumers in the residential sector. All three technologies become economically favorable compared to district heating already in the third year. The main reason for this is the high level of prices for all sources of energy, combined with higher heat demand than for consumers in the residential sector. Due to these factors, heat consumers in the non-residential sector have strong incentives to invest into energy conservation and install more energy efficient technologies.

5.3.4 Case 4: Favorable Conditions for Investment in Geothermal Heat Pump

From the previous two cases it is clear that heat pump is not the most attractive technology in the short run. Gas boiler has the shortest payback period both for residential and non-residential sector consumers. For both categories of consumers, NPV of investment in heat pump became more positive than that of gas boiler only in the long run – after 19 and 16 years respectively. In the third case we would like to study under which conditions investment in geothermal heat pump is more economical than in gas boiler in the short run, meaning that it receives greater NPV already after 5 years. In other words, we would like to see what levels of gas and electricity prices will result in zero NPV of heat pump installation when compared with gas boiler 5 years after investment for different values of initial investment.

The consumer has to make an investment choice between heat pump and gas boiler. This means that if the consumer chooses to invest in heat pump, the total value of initial investment will equal the value of heat pump installation minus the value of gas boiler.

For the analysis, we choose three types of consumers:

- A consumer living in an apartment or small individual house. We assume that this consumer needs to make an initial investment of around 10 000 EUR to satisfy the heat demand of around 30 000 kWh/year;
- A consumer living in a large individual house. This consumer has heat demand of about 100 000 kWh/year and his initial investment in heat pump installation will equal about 16 000 EUR;
- A consumer in the non-residential sector, with heat demand of about 400 000 kWh/year, who has to invest 40 000 EUR in heat pump installation.

For these three levels of initial investment, we calculate the level of gas and electricity prices that correspond to zero value of NPV in the 5^{th} year after investment. We assume that price of electricity varies between the Ukrainian and the EU level, and is at least twice as high as the gas price (this is because electricity is a high-grade form of energy compared to gas). The results are presented in Table 5.9.

Table 5.9 Energy prices needed to achieve a zero 5-year NPV for different levels of initial investment.

Initial investment [EUR]	Heat demand [kWh/year]	Gas price [EUR/kWh]	Electricity price [EUR/kWh]
10 000	42 078	0,0815	0,1629
16 000	106 332	0,0516	0,1031
40 000	385 956	0,0355	0,0710

For the household with heat demand of about 40 000 kWh/year, investment in a geothermal heat pump will become the most economically desirable alternative in 5th year at a relatively high level of gas and electricity prices. Gas price in this case even exceeds the present EU gas price level, while electricity price is slightly lower than the EU level. Prices for residential consumers in Ukraine are not likely to reach such high levels in the nearest future. Even if annual price increase equaled 20 % for gas and 15 % for electricity, the prices would reach the values represented in Table 5.6 only after 12 -13 years. This means that today, for a household with relatively small demand, gas boiler is the most preferable investment alternative.

For the household with larger demand for heat, the level of gas and electricity prices at which the NPV for heat pump for the period of five years equals zero is much lower. These prices are now lower than EU levels of gas and electricity prices, but still higher than the present Ukrainian prices. This means that heat pump is not economically favorable for this type of consumers at present gas price level in Ukraine. However, if consumers anticipate considerable gas price increase in the nearest future, they might evaluate heat pump to be a better investment alternative than a gas boiler.

In the case with the non-residential sector consumer, the prices at which heat pump investment receives higher short-run NPV than for a gas boiler are quite close to the levels which this category of consumers is paying today. Electricity price from our results is lower than the electricity tariff set for the industrial sector consumers – 0,0884 EUR/kWh. Gas price in this case is still higher than its present level in Ukraine paid in non-residential sector – 0,0268 EUR/kWh. However, if a 20 % price increase occurred in the next few years, the price level from Table 5.6 would be reached after only one or two years. This means that heat pump is likely to be a realistic and profitable alternative to a gas boiler – even in the short run – in the non-residential sector with the high levels of both demand for heat and energy prices.

6. Summary and Policy Recommendations

This chapter outlines the results of the research and discusses the main conclusions of the master thesis with focus on the research questions. Finally, the most important policy measures to improve energy efficiency in the Ukrainian heating sector are suggested.

6.1 Conclusions and Answers to Research Questions

Ukraine has a major potential for energy efficiency improvement, but at the same time the country faces numerous barriers that slow down the implementation of energy efficiency improvement measures. Low energy tariffs create no incentives for energy conservation among population. At the same time, the transition from the system where heating, gas and electricity are almost "human rights" as the public perceive they must be available to anyone, to the system where prices are set by the market is complicated, long lasting and politically unpopular.

In this master thesis, we investigate what factors can speed up this transition process and under which conditions more energy efficient technologies can be preferable already now or in the nearest future. Segmentation of Ukrainian heating market allows us to allocate the most suitable market segments for various energy efficiency improving measures. We use the cost-benefit analysis to understand what determines heating consumers' investment decision and choice of heating technology in the segments of interest. To summarize our results we answer the research questions of the thesis.

- *Which sectors in the Ukrainian heat market have the greatest potential for energy efficiency improvement?*

The main sectors in the Ukrainian economy that require energy efficiency improvement are residential and industrial sectors. While in the industrial sector competition stimulates implementation of energy efficient technologies and high energy prices secure short payback period, in the residential sector the situation seems to be quite different. Here, the possibility of implementation of quick and cheap energy saving measures is mostly limited. Low heating tariffs make most of the alternative technologies to district heating uncompetitive. However, when we analyze the heating market in more detail, we can point out different segments where there is potential demand for various technologies alternative to district heating. This brings us to the second research question:

- *What is the market for various alternative heating technologies and energy saving measures? How does a geothermal heat pump perform in the market?*

Some technologies and energy saving measures, like biomass boilers, geothermal heat pumps and some types of insulation are only suitable in the narrow segments of the heating market. Other technologies, like gas boilers, seem to be installed in all types of buildings which have access to gas pipe.

The market for heat pumps in Ukraine is relatively new, but growing at a high rate. However, the demand for geothermal heat pumps remains limited because of high price and technological peculiarities. Geothermal heat pump is therefore the most suitable technology for installation within the small segment of new large individual houses in rural areas without access to natural gas and with large demand for heat.

- *What are the mechanisms behind investment decisions in energy efficiency measures? What factors stimulate and hinder investment?*

To have a better understanding about what makes consumers in different economic sectors shift to an alternative (and more efficient) heating technology and what factors stand behind consumers' choices of a heating technology, we use NPV analysis. We study consumers' savings and costs in connection with installation of a new technology for heating and calculate net present values of the investments for different time periods. From the analysis we can easily see that at the present Ukrainian energy price levels, gas boiler is the only economically favorable alternative to district heating. For a residential consumer a gas boiler has a payback period of only three years compared to district heating, while for example for a geothermal heat pump this period equals to 12 years.

The most important factor that would stimulate installation of more energy efficient technologies is an increase in energy prices. As we assume in our model that gas and electricity prices approach European levels, a geothermal heat pump becomes a more favorable technology than a gas boiler also in the short run. However, this happens only for consumers in non-residential sector and consumers in the residential sector with high levels of heat demand. Generally, the larger the demand for heat, the more favorable the geothermal heat pump technology becomes compared to other heating technologies. This supports our finding that heat pumps are most suitable for installation in large individual houses.

Another important factor in the choice of energy efficient technology is the value of initial investment. The high price of a geothermal heat pump limits the number of potential buyers and makes it uncompetitive with a gas boiler, which has much lower price and installation cost. For the average households, geothermal heat pump is a too expensive investment even at European energy price levels.

Some of the less capital intensive energy efficiency improving measures such as heat regulators, insulation and new windows are favorable in the long run when assuming Ukrainian district heating prices. Heat regulators will be paid back most rapidly. This is convenient, as regulators in our opinion are the most essential energy saving measure. Without a heat regulator, other energy saving measures will have no effect. The low investment costs make additional insulation and new windows more attractive than alternative heating technologies, but at the current Ukrainian price level, the long payback period results in low incentives for investments.

Besides low prices, additional factors such as imperfect legislation system, lack of law enforcement and complicated system of permits create high levels of insecurity and risk for potential investors and therefore hinder investment in the area of energy efficiency improvement.

6.2 Policy Recommendations

Annual expenses on gas price subsidies for residential consumers have constituted a large share of Ukrainian budget during the last few years. Moreover, gas price subsidization has had an undesirable effect of excessive gas consumption among population. On the other hand, a tariff increase would not only cost politicians the sympathy of their voters, but would also affect negatively the economic situation of the most vulnerable heat consumers.

In our opinion, it is possible to improve energy efficiency and at the same time minimize the negative consequences of energy price increase by adopting the following policy measures:

- Gradually remove subsidies for gas prices in the residential sector, as they produce undesirable distortions. This can be implemented in combination with targeted support of the poorest energy consumers in the residential sector;
- Develop programs of state support for projects of installation energy efficient technologies and energy saving measures;
- Improve legislation system and reduce institutional barriers connected to import, purchase and installation of energy efficient technologies, in such a way reducing the insecurity and improving the investment environment;
- Reform and deregulate the heating system, open for privatization of heat production sector. This will make the sector more competitive, and therefore more energy efficient;
- Increase awareness among population about the importance of energy conservation, inform about the possibilities of energy efficient technologies installation and the savings potential.

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Appendix A: Terminology

CHP	combined heat and power
COP	coefficient of performance
CS	cost savings
D	demand
EHP	Euro Heat and Power
EU	European Union
EUR	Euro
Gcal	giga calorie
GDP	gross domestic product
I	initial investment
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ITP	individual heat station
km	kilometers
kWh	kilowatt hour
MEUR	million euros
Mtoe	million tons of oil equivalent
NERC	National Electricity Regulation Commission of Ukraine
NPV	net present value
p	price
q	quantity
r	discount rate
T	project duration
t	time period
toe	tons of oil equivalent
TPES	total primary energy supply
TRV	temperature regulating valve
TWh	terrawatt hour
UAH	Hryvnia
V	voltage
VAT	value added tax

Appendix B: Exchange Rates, Unit Conversions and Energy Density

Exchange rates UAH/EUR

Table_Apx B-1 Exchange rate UAH/EUR (Minfin 2012a).

Year	2005	2006	2007	2008	2009	2010	2011	2012
UAH/EUR	6,017	6,65	7,33	10,98	11,44	10,57	10,29	9,5

Unit conversions

1 toe = 10 Gcal = 11 630 kWh

Energy density

Natural gas: 10,741 kWh/m^3

Appendix C: Discussion topics for interviews with non-profit organizations and authorities

1. General questions

    1.1. Reasons for high energy intensity;
    1.2. Best measures to improve energy intensity/efficiency;
    1.3. The Government's attitude/participation to improve energy efficiency;
    1.4. Public knowledge/attitude towards energy efficiency;
    1.5. Heating market segments with potential for energy efficiency improvement;
    1.6. Energy price dynamics and expectations;
    1.7. Barriers to investment in energy efficiency improvement measures;

2. Energy saving measures and technologies used

    2.1. What factors do you consider as most important in firms' choice of energy saving technology?
    2.2. What energy saving technologies are the most popular among your clients?
    2.3. What technologies are most efficient in terms of energy saving and cost?
    2.4. Do projects usually include combination of different energy saving measures, and which?
    2.5. Advantages of new technologies vs. modernization. Prices, energy saving, maintenance need.

3. Investment decision

    3.1. What factors do firms have to take into account when making investment decision (financing, institutional barriers - differences for technologies/measures/new vs. modernization etc.)?
    3.2. How long does it take, on average, for a project to pay back?

Appendix D: Discussion topics for interviews with heat pump producers

1. General questions

    1.1. Reasons for high energy intensity;
    1.2. Best measures to improve energy intensity/efficiency;
    1.3. The Government's attitude/participation to improve energy efficiency;
    1.4. Public knowledge/attitude towards energy efficiency;
    1.5. Heating market segments with potential for energy efficiency improvement;
    1.6. Energy price dynamics and expectations;
    1.7. Barriers to investment in energy efficiency improvement measures;

2. The commercial market for heat pumps

    2.1. What are the main client categories? (Public vs. private; blocks of flats vs. individual houses; heating market segments)
    2.2. How big is the market? (Annual sales; Number of heat pump producers;)
    2.3. Is it a market in growth? (Historical annual growth; Predicted growth;)
    2.4. How many suppliers of heat pumps are there in the market today?
    2.5. Which regions have the largest potential for heat pumps sales?
    2.6. Which heating technologies are the strongest competitors to heat pumps?

3. Product information

    3.1. Which products/technologies are the most popular?
    (Air-air; Air-water; Earth-water; Sizes and specifications)
    3.2. What are energy efficiency characteristics of heat pumps compared to other technologies?

4. Main barriers preventing people from buying heat pumps

   4.1. Power prices;
   4.2. Financing:
   4.3. Do there exist any financing facilities/leasing companies for heat pumps in Ukraine today? (Governmental/regional/local/private?)
   4.4. How easy/difficult is it to get financing?

5. Foreign ownership

   5.1. Regulations regarding private ownership;
   5.2. Local content regulations for imports/business;

6. Regulatory drift

   6.1. Is the regulatory framework promoting heat pumps? (Will it to a larger degree promote heat pumps in the future?)

Appendix E: Interviews

AlTherm

«AlTherm» is the producer of the range of geothermal heat pumps under the trademark «AIK», assembled in Ukraine from the components of foreign producers. The production of AIK heat pumps equals to about 300 pieces of equipment per year and is represented by a wide model range of domestic and industrial heat pumps with a capacity from 6 kW to 1 MW, with the ability to work in the heating and cooling regimes, and possibility of interaction with the solar collectors and other sources of heat.

Interview with: Oksenych Sergiy Mykolayovich

Date: 28. 03.2012

- Altherm has been functioning in the Ukrainian market for 8 years, producing heat pumps "A&K" in Ukraine from foreign parts.
- In the beginning it was difficult to sell heat pumps in the Ukrainian market, because of little knowledge among consumers and state authorities about the technology. Besides, legislation regulating import of heat pumps was missing, and it was difficult to get approvals in customs control as heat pumps were even considered ecologically dangerous equipment.
- Heat pump is an expensive investment (about 20 000$) and payback period is about 20 years. Still, there are segments in the heating market with demand for heat pumps – private houses, commercial buildings, charity projects.
- During 8 years, Altherm has sold 200 heat pumps, of which 70 were sold in 2011. The company is cooperating with distributors, service companies – do not sell directly to customers.
- According to the Altherm vision, heat pumps will be as popular in the future as gas boilers are now. This is because gas prices are going to grow considerably. At the same time, Altherm's vision is that electricity prices will not increase as much as gas prices, because more electricity will be produced by nuclear power plants.

- About 85 % of heat pump sales in the Ukrainian heating market are imported heat pumps of foreign producers. 15 % are heat pumps produced in Ukraine, mostly from foreign parts. This share includes Altherm and 3-4 other firms.
- Though heat pumps “A&K” are set together in Ukraine, Altherm is following European standards of production. Quality is the most important factor for the firm when producing heat pumps, so they import parts of the highest quality and follow the development of technologies.
- Not all firms in the market sell heat pumps of high quality, this is a problem, because there are no common standards to evaluate quality of heat pumps.
- Because of cheap labor, Altherm managed to reduce the price for their heat pumps by 30-40 % comparing to foreign imported equipment, and the payback time is shorter.
- Besides of higher price, imported heat pumps have other drawbacks. First of all, there is lack of parts available in Ukraine, so when heat pump needs repair, it can take a few months to import parts from abroad. Lack of control menu in Russian is apparently another important issue.
- Barriers in the market – lack of financing. There is demand for heat pumps in many segments of the market, but there is need for credit, state programs of support etc.
- Altherm is now discussing possibilities for cheap credit for commercial and state actors willing to buy “A&K” heat pumps. They see that in some cases it is even cheaper to install heat pumps and pay rents, than to pay for gas.
- The firm sells mostly geothermal heat pumps, but has plans of selling air-water heat pumps.

Scientific Engineering Centre “Biomass”

Scientific Engineering Centre "Biomass" Ltd. (SECB) was established in 1998. From the moment of its establishment this organization has provided consulting and engineering services in the field of energy production from biomass (wood, straw, manure, municipal solid waste and other organic waste), development of JI projects under Kyoto Protocol, energy efficiency, energy audits, design of energy facilities.

Interview with: Geletukha Georgiy Georgiyovich

Date: 27.03.2012

- Ukraine is dependent from natural gas, which accounts to 42 % of energy sources consumption. Prices for gas are increasing – from 50$/ thous. m3 in 2004 to 416$/ thous. m3 in 2012. High prices for gas should result into energy efficiency stimulation.
- However, prices for gas are low for district heating companies and population, because of state subsidies. Prices for commercial sector equal 4500 UAH/thous. m3, while for district heating companies the price is 1300 UAH/thous. m3, and it is even lower for population – 700 UAH/thous. m3. Because of such subsidizing, there is no possibility for competition for gas in the heating sector. Investors see no economic sense in replacing gas-based technologies by other technologies.
- Ukraine spent 3,4 bill. EUR of budget expenses in 2010 and 2,2 bill. EUR in 2011 to support low prices for gas.
- Population is demotivated to replace gas. Even such measures as insulation have payback period of more than 25 years at recent subsidized gas prices. Need to increase gas prices for population and communal sector.
- Ukrainian government is constantly under pressure of IMF to increase price of gas for residential sector. This is one of the main criteria to get loan from IMF. However, the government refuses to increase prices till October 2012, when the Parliamentary election is going to take place. After election, Georgiy forecasts a 50 % gas price increase in the district heating sector, and a 100 % increase in price for the population.
- Biomass boilers are an alternative to gas boilers, but only in the commercial sector. There are more than 2000 boilers installed in Ukraine, but practically no examples of biomass boilers in the residential and communal sectors. Biomass cannot compete with gas in these sectors. No example where a biomass boiler have replaced a gas boiler. Projects are done where biomass are readily available, almost free, like on a farm.
- CHP (biomass) is a more economically profitable alternative, because of the “green tariff” for electricity production from biomass of 12,3 c/kWh. Such facilities have 5-8 years payback time.

- Increase in gas prices can lead to increasing share of people not paying gas and heating bills. This problem can be solved by first increasing prices slowly, and then allocating saved money into reducing gas consumption among population. In other words, reallocate means from subsidy to investment in new equipment. Gas payment will be higher for population, but can then be reduced over time because of decreased use.
- Heat pumps are expensive, having more than 25 years payback time. They are usually installed in individual buildings by rich people. This is more a “fashion trend”, as there is no economic reason to install heat pumps.
- The additional reason why heat pumps cannot be installed more often, especially in old buildings, is that they produce the heating temperature up to 40 Cº. Ukrainian heating system is designed in such a way that the temperature in pipes must be around 95-100 Cº for sufficient heating. This means that heat pumps are not compatible with the existing heating systems. The only market segment for heat pumps is thus new buildings, where one can install 40 Cº tubes in floors or walls. Heat pumps are also a feasible technology for swimming pools. Some cases of heat pumps using canalization water for heating have also been implemented.
- Air-air heat pumps are not technically suitable for Ukrainian climate conditions, especially cold winter months.
- Among renewable energy sources the largest shares are represented by biomass – 0,7 % of total energy production, and large hydro – 0,9 % of total energy production.
- There are a number of programs of support in the area of renewable energy production. However, these often remain on paper. In reality, there is support of “the chosen ones” – influential businessmen lobby their areas of interest, and the plans and state programs are written to support them. Example: in January 2012, SAEE published their plan for changes in the Energy Strategy until 2030. This plan includes increase in the production of solar, wind and small hydro energy. Biomass is not included. Reason: lobbying of interests of businessmen in solar and wind sectors, making situation more difficult for their competitors.
- Another example: veto by president of Ukraine for “green tariff” for the production of energy from biogas. There is no logical reason for this, but it is not in the interest of some business who will receive additional competition.

State Agency of Energy Efficiency (NAER)

According to the resolution of the Cabinet of Ministers of Ukraine N 412, 2006, National Agency of Ukraine on Ensuring of Efficient Use of Energy Resources (NAER) is a central authority of executive power with special status which activity is directed and coordinated by Cabinet of Ministers of Ukraine. NAER is a specially authorized central authority of executive power on ensuring of state policy realization in the sphere of efficient use of energy resources and energy-saving. Main tasks of NAER are:

- carrying out of unified state policy in the sphere of efficient utilization of energy recourses and energy-saving;
- providing share increase of alternative types of fuel in the demand and supply balance of energy carriers;
- creation of state system monitoring production, consumption, export and import of energy carriers, improvement of system of calculation and control of energy carriers consumption;
- providing of functioning of unified system for regulation of considerable expenditures of energy recourses in social production.

Interview with: Venediktov Oleksandr Lvovich

Date: 27.03.2012

- Ukrainian state has a goal of increasing energy efficiency, as energy intensity in Ukraine is more than 2,5 times higher than in other European countries. It amounts to 0,633 kg of fuel/UAH.
- Largest share of resources is consumed for electricity production, 20,5 % consumed by heating plants, 13,2 % by boilers producing heat.
- Gas is the most important heating source, and its large share used in residential and communal sector (30 %, or 28,4 billion m3). According to SAEE, the potential for energy saving in the residential and communal sectors is 4- 9 m3 of natural gas, accounting to about 3,6 billion EUR.

- A number of state programs and laws are developed in order to reduce energy consumption in Ukraine. For example, a program “State support of energy saving measures” was implemented in 2009, as two projects were chosen on a competitive basis. First project – in the city of Poltava – included modernization and repair of centralized heating system by installing modern technologies in the boiler stations, and shifting to alternative energy sources. Another project - in the town of Irpin (Kyiv region) – included reconstruction of existing boilers, installation of autonomous electric blocks and cogeneration facilities. As a result, energy saving amounted to 1,3 mln m3 annually.
- The Directive of the Cabinet of Ministers nr.444 issued 14.05.2008 “Budget preferences for import of energy technology” sets the rules for import of energy saving equipment. According to the Directive, the importer does not need to pay customs payment and import VAT for energy saving technologies and parts which are approved for a specific energy efficiency improvement project.
- State Target Program of Energy Efficiency and Development in the Sector of Production of Energy from Renewable Energy Sources and Alternative Types of Fuel for 2010 – 2015.
- Sector and regional programs of energy efficiency improvement (Directive of the Cabinet of Ministers nr. 243 issued in 2010). Received 830 mln UAH of budget expenditures in 2012. These projects included:
    - Shifting from cogeneration based on gas to cogeneration based on alternative fuel;
    - Modernization of existing boilers and changing from gas boilers to boilers based on alternative fuel;
    - Installation of heat pumps;
    - Maintenance and repair of the objects in state sector;
- When we asked about the projects of heat pumps installation, Oleksandr answered that these are few, mainly because heat pumps are expensive comparing to traditional boilers. There are some exceptional occasions of heat pumps installed in hospitals, schools, communal property, but the majority of heat pumps are installed in the private sector.
- The projects of state support are chosen according to some criteria of the state expertise in energy saving. These criteria are outlined in the Directive of Ministry of Economic Development nr.105 issued 06.10.2011.

- Ukraine is seeking cooperation with international investors, and in 2010-2011 the projects had involved up to 10 UAH of investment per 1 UAH of budget costs. The main big investors are World Bank, European Commission, Eastern Partnership Fund and Nefco.
- To our question about private investment in energy efficiency improvement, Oleksandr told us that today Ukraine is only beginning to develop the programs which give the residents of apartment blocks possibility to organize themselves and participate actively in the renovation of their buildings. A relatively small number of such cooperatives of building owners has been created so far, but this is only the beginning of the way.
- There is a motivation among people to save energy, but the financial means are insufficient. Those who can afford it, install solar panels, wind mills, heat pumps and insulate their houses.
- Alternative heating technologies are mostly represented in new buildings in the cities, also in the suburbs, in the so called cottage towns.
- There are cases when the district heating companies suggest heat consumers to install individual boilers in order to improve energy security and reduce the company's financial risk
- The biggest potential for improvement is in the residential and communal sector, as in the industrial and commercial sectors private ownership prevails. This stimulates modernization, installation of new technologies. Besides, it is easier to involve investors in this sector - therefore not that big financial challenge as in residential sector.

UKEEP - Ukraine Energy Efficiency Program

UKEEP is a credit facility developed by the European Bank for Reconstruction and Development (EBRD), targeting Ukrainian private companies in all sectors looking to invest in energy efficiency or renewable energy projects – investments that will decrease energy consumption, increase own energy production or make energy usage more efficient. UKEEP provides free technical assistance by international energy efficiency experts for companies with project ideas that are eligible for UKEEP financing. If a project idea is found feasible, UKEEP can provide debt financing for the project.

Interview with: Ivanenko Dmytro and Petryna Solomiya

Date: 26.03.2012

- UKEEP is a facility helping Ukrainian private companies to receive credit for investment into energy efficiency and renewable energy projects. UKEEP has now been engaged in 53 projects, financing them through Ukrainian and Russian banks (Ukreximbank, VTB).
- Projects include building refurbishment, biomass, installing new boilers, new compressors, insulation, to a lesser extent heating. Many of the projects are aimed at improving technology and production lines, replacing old technology lines by the new ones. In each project, specific equipment suitable for the company is installed.
- Companies by implementing energy-saving projects not only achieve higher energy efficiency, but also benefit from increasing their productivity levels.
- Companies are selected for participation in the UKEEP program on the basis of some criteria, as project feasibility, working conditions, product quality etc. For example, banks prefer projects with internal rate of return at 10 % and with maximum payback period of 5 years.
- UKEEP is an intermediary between companies and banks, providing companies informational and technical assistance to improve and incorporate their project ideas before applying for loan in the bank. After delivering the project, firms receive the answer about project eligibility in 6-8 weeks. During this time, energy audit is performed.
- Projects with biomass that UKEEP has been engaged in are about a 100. They are all based on the principle of easy or even free access to biofuel (peat, forest, agricultural waste). Biomass boilers are often installed close to the regions where peat resources are abundant, or in the companies in the agricultural sector which have access to free biomass resources in the form of straw or other agricultural waste. Otherwise, this technology is not feasible in the competition with low gas prices.
- Market for biomass is growing; more firms in agricultural sector become aware of the possibilities concerning the use of production waste for heating.
- Low gas prices are the reason of low interest and motivation to improve energy efficiency. However, gas price is expected to increase about twice after the October parliamentary election (Dmytro).

- UKEEPs forecasts of gas price when calculating NPV of the project is a 5 % increase every year, and they also include statistics for 3 past years in the analysis. Today, gas price for commercial sector is 4600 UAH/1000m3 including VAT and transportation.
- Biggest potential for improvement in the cities – on the demand side (improving the system of district heating - modernization of pipelines, communications, energy monitoring). Some cities are good examples of this (Lviv), while others promote installation of autonomous heating in multistory buildings (Uzhgorod).
- District heating system with heat producer (P), individual heat station (ITP) and consumer (C). In Ukraine heat is transferred directly from producer to consumer. Estimated losses are illustrated at each point of the figure.

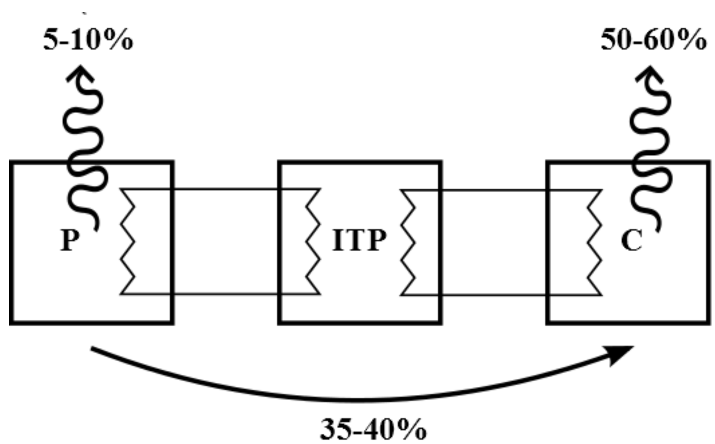

Figure E-1 District heating system with heat producer (P), individual heat station (ITP) and consumer (C). In Ukraine heat is transferred directly from producer to consumer. Estimated losses are illustrated at each point

- UKEEP through their activity has faced a challenge of limited access to information on firms' commercial activity. It is difficult to monitor and collect information, mostly because of the fear of competition, but also because managers are reluctant to changes. "Managers keep distance from making a decision, have no motivation for change" (Dmytro).
- Barriers for the projects of improving energy efficiency:
  1. Negotiation between banks and clients: banks are skeptical to new clients, so the latter often do not receive credit for the reason of "not suitable credit worthiness" (Solomiya).

2. Institutional barriers: At first Dmytro and Solomiya mentioned that getting approvals is not the main problem. However, afterwards Dmytro told us about resistance from state authorities (numerous inspections, corruption). He also mentioned there is no political will for change.

- When firms are making an investment decision, they face the problem of limited money, so the price of technology is important. In this respect, heat pumps are not installed because they are about twice as expensive in use (Gcal/hour) as traditional boilers.
- Choice of technology to a great extent depends on local natural conditions. In the southern Ukraine, for example, it is more feasible to install solar and wind facilities, while biomass is mostly used in the north.
- Usually, a firm is implementing energy efficiency measures step by step: each year, a sum of money is allocated to this purpose, and one year the firm for example replaces windows, , the year after – insulates walls etc.
- Foreign firms and technologies dominate in the market. Ukraine has scientific potential, but little money to realize it. UKEEP has a list of technologies approved for energy efficiency improvement projects (LEME). Among these only 5 % are from Ukrainian suppliers (this share does not include technologies made in Ukraine from foreign parts).
- On the other hand, from 2013, 30 % of Ukrainian participation in every energy efficiency project is required (can also be labor, not necessarily only technologies).
- Residential sector is the most problematic with respect to energy efficiency improvement. There are no state programs of support in this sector, only local initiatives, but they mostly remain on paper as recommendations for the future because of lack of budget money.
- Heat companies have no incentive to install regulators of heat in the apartments, because they will sell less heat. Calculation of how much heat is used is not by measuring equipment, but calculated according to some standard average characteristics of households.
- Heating companies minimize risks by promoting autonomous heating technologies in apartments (in such a way they deliver heat to fewer households).
- Strong lobbying of gas, many parts interested in preserving the status quo.

Viessmann

The Viessmann Group is one of the leading international manufacturers of heating systems. Founded in 1917, the family business maintains a staff of approximately 9,600 employees and generates 1.86 billion Euro in annual group turnover. Viessmann's comprehensive product portfolio includes wall mounted condensing units from 1.9 to 105 kW, freestanding condensing boilers from 3.8 to 6,000 kW and combined heat and power (CHP) stations for oil or bio natural gas, with outputs from 1.0 to 401 kWel and 6.0 to 549 kWth.
Also part of this impressive portfolio are systems for renewables including solar thermal systems with flat-plate and vacuum tube collectors for domestic hot water generation, central heating backup and building cooling, special boilers and combustion units from 4 to 13,000 kW for wood logs, chips and pellets, heat pumps from 1.5 to 2,000 kW for use with geothermal heat, groundwater or ambient air, and photovoltaic systems.

Interview with: Vasylenko Roman

Date: 29.03.2012

- Viessmann has been working in the Ukrainian market for 10 years, but during the first five years the firm sold only about 1 heat pump per year to those clients who asked for this technology. Today, the interest for heat pumps is increasing, and so are sales – Viessmann sells up to 100 heat pumps a year. Even in the years of financial crisis, the sales have been increasing.
- Generally, heat pumps are not popular, mainly because of the price – few can afford it. Viessmann calculates payback time taking into account the expectation of rising gas prices. Still, payback period is quite long - about 8 years because of the low gas prices. To reduce payback period, state support is needed.
- The most expensive types (geothermal) are installed most often. Air-water pumps are only feasible in the Southern Ukraine, but can also be used for water heating during the warm season (spring – autumn).
- All heat pumps are installed as a combination of heat pump with gas boiler. Gas boiler is a spare heating source.

- Heat pumps are installed mostly in the private sector, though there are some few projects being developed in state and industrial sector. Often such projects remain on paper because of lack of financial means.
- Two main barriers for market development – low gas prices and lack of state support programs.
- It is difficult to know the exact number of firms selling heat pumps in the market, many firms selling cheap low quality equipment (for example, imported from China, or produced in Ukraine). Viessmann considers itself as a firm working in “premium segment”, in which there are about 5-6 firms. Other firms are not interesting for Viessmann.
- Ukrainian producers of heat pumps have drawbacks compared to importing firms – it is more expensive, takes loger time to set together heat pumps in Ukraine than to import equipment from abroad. This is because there is no mechanism of construction, no production lines set up.
- Importing firms pay VAT and 5 % customs payment when importing heat pumps. Only those types of technologies that are not being produced in Ukraine at all do not have to pay import VAT.
- Gas boilers are the most popular heating technology. Viessmann sells thousands of such boilers yearly. Another technology is biomass boilers. These types of boilers are installed in residential sector (private houses).
- It is also possible to install heat pumps in apartment blocks, but this possibility is mostly technical. Economically it is not profitable to install heat pumps. Besides, heat pumps can only be installed in the new buildings.
- Heat pumps have relatively high installation costs – about 50 % of all capital cost. At the same time, gas boilers are cheap to install, the main value of investment is the boiler itself.
- Viessmann has calculated costs of use of heat pump and gas boiler on daily basis. For the tariff of 0,78 UAH/m3 (lowest tariff), heat pump has same level of expenses as a gas boiler. For other tariffs (up to 2,7UAH/m3), expenses for gas boilers are increasing, so heat pumps are getting advantage.

Appendix F: Welfare Change - Heat Pump Installation with Gas Boiler as Spare Tech.

Here, we outline two situations of a change in heat consumption and consumer's gains and losses after a heat pump installation with a gas boiler as a spare technology. We use the same denotation as in Chapter 4.1.

In the first case, we outline the situation when consumer has to pay a gas price which is higher than the price for district heating. Consumer's adjustment is represented in Figure D1.

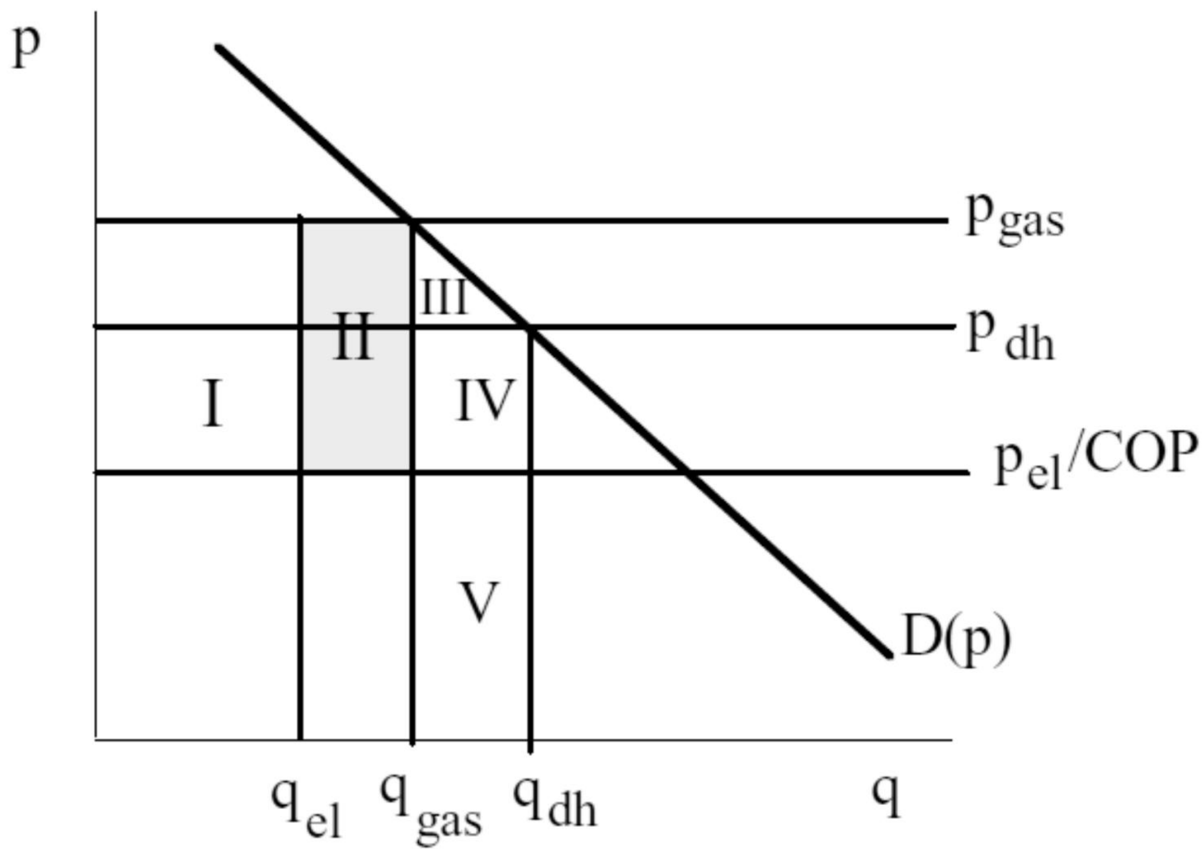

Figure F-1. Change in consumer's welfare after a heat pump installation with a gas boiler as spare technology, $p_{gas}>p_{dh}$

In the figure, the gas price level is over the district heating price, so when consumer chooses a heat pump with a gas boiler as the marginal fuel source, the new level of energy use will be lower than before. This leads to a loss of welfare (III). This situation is probably not very real because the cost savings (I) have to compensate for the welfare loss (III), and the extra cost of heating with gas on the margin (II) in addition to cover the investment cost of a heat pump.

In the second case, we assume the level of gas prices to be lower than prices for district heating. Consumer's new adjustment is represented in the Figure D-2.

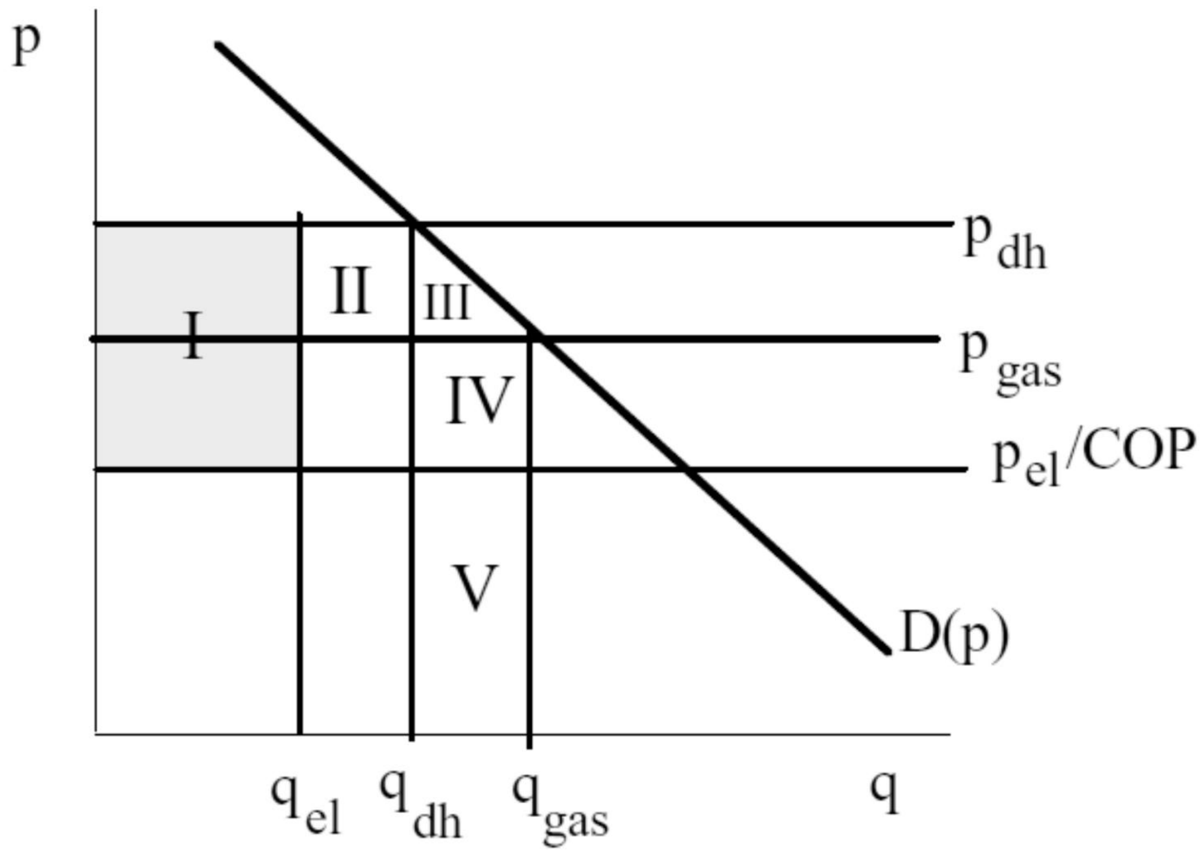

Figure F-2 Change in consumer's welfare after a heat pump installation with a gas boiler as a spare technology - $p_{gas} < p_{dh}$

As the gas price level is relatively low, consumer is able to satisfy his heat demand and even consume more than when using district heating. The reduction in operating costs (I + II) and the net welfare gain (III) are likely to be large enough to make it profitable to switch from district heating to a combination of heat pump and a gas boiler. Again, these benefits must cover the investment costs in the new technology.

Appendix G: Energy Delivered in Central and East Northern Ukraine (kWh/m^2)

Table E-1 shows the estimated delivered energy for space heating (including ventilation), domestic hot water, lighting and various equipment. The delivered energy is listed in kWh/m^2 for different building types in central northern and east northern Ukraine.

Table G-1. Estimated delivered energy in central northern and east northern Ukraine for different purposes in three different building types (Worley Parsons 2011)

Energy delivered in central northern and east northern Ukraine	**Delivered energy [kWh/m^2]**		
	Apartment block before 1980	Apartment block after 1980	Single family house
Space heating (incl. vent.)	165,0	172,0	289,9
Domestic Hot Water	22,0	22,0	14,0
Lighting	10,0	10,0	10,0
Various equipment	12,6	12,6	12,6