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Household demand for natural gas in Ukraine—the effects of the subsidy reform

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Abstract. Implicit natural gas and heat subsidies for households had been the main driver of a host of problems for Ukraine, including wasteful gas consumption, low energy efficiency, large budgetary costs and foregone revenues for domestic production. Between 2014 and 2016, however, implicit natural gas subsidies were entirely removed and implicit heat subsidies lowered. This paper estimates the effect on household gas demand from this subsidy removal by estimating the price elasticities of demand for both household gas and heat consumption, using cross-sectional data from a 2014 household living condition survey. The results reveal that the price elasticity of gas and heat consumption is –0.2 and –0.15, respectively. Additionally, we estimate short and long-run effects from the subsidy removal on energy efficiency improvements. Altogether, the model predicts between 5.7 and 9.3 bcm decline in annual natural gas consumption, constituting a 26–42% decline from the 2014 baseline. The change will result in net yearly savings for the Ukrainian budget of around 1.1%, while simultaneously stimulating domestic production by almost doubling the dollar value of the household market for gas. The Ukrainian experience can serve as an example for policymakers considering energy subsidy reforms.

Keywords: Energy, Natural Gas, Subsidies, Ukraine

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1 Introduction

Subsidies on fossil fuels are causing adverse effects on the economy and environment, stimulating inefficient resource allocation and excessive energy consumption. Subsidies are either explicit, for example through cash or in kind transfers to parts of the population, or implicit, most often through interventions in energy prices. Globally, the size of explicit energy subsidies is large, equaling USD 493 billion in 2014, or 0.6 percent of global GDP (International Energy Agency [IEA], 2015). Ukraine is a case in point, in 2014 paying some 0.4% of GDP in explicit subsidies for utility services, 0.5% in implicit heat subsidies, and another astounding 5.6% in implicit subsidies for natural gas for household use. The very substantial size of the subsidy is the result of a regulated very low price of natural gas both used directly by households as well as transformed by District Heating Companies into heat for the population. A host of problems have emanated from this policy choice. First, Ukraine has the lowest energy efficiency level in all of Europe in terms of energy use by households (Repko et al., 2015). Second, as Ukraine needs to import a sizeable share of its gas consumption from abroad, partly financed by the state budget, the level of budgetary deficit fluctuates together with the import price, becoming a source of large volatility for the state budget. This is further amplified by the depreciation of the Ukrainian currency which negatively affects Ukraine's ability to pay for dollar- and euro-denominated gas imports from Russia and Europe. Last, the subsidized prices of natural gas have been used as a means to extract corrupt rents for the political elite, utilizing preferential access to subsidized gas and then reselling it at higher prices.

Reforming this system has proven very hard. For the last decade almost every Ukrainian government has agreed with the International Monetary Fund (IMF), as a part of a package of reforms, to rapidly decrease the subsidies for natural gas, with no apparent progress. In the aftermath of the financial crisis, in November 2008 the Tymoshenko government agreed to phase out the subsidies over 3 years, then in September 2010 the Azarov government promised to do so over 2.5 years, and finally in March 2015 the Yatseniuk government agreed to phase out the subsidies over 2 years (Naftogaz, 2015c). The system has been so hard to reform in part because of regulatory capture by interest groups earning rents from the previous system, and in part due to public opposition for gas price increases. Yet, between 2014 and 2016, Ukraine has significantly raised the prices of gas, entirely removing implicit subsidies on natural gas in May 2016. This makes Ukraine a dramatic example of a country abolishing an implicit subsidy for natural gas. This paper sets out to estimate the effects from this reform on the total Ukrainian demand for gas. In order to do that, the price elasticities for natural gas and heat consumption are calculated and an estimate of the market size for natural gas in 2020 in Ukraine is made. The lessons learned from Ukraine will be valuable also to evaluate the potential for similar reforms in many other countries with wholly or partly unreformed subsidy systems of natural gas, such as Russia, Uzbekistan, Kyrgyzstan, Kazakhstan, Iran etc. The purpose of this study is to answer the following research question:

> What effect will the removal of implicit subsidies on natural gas and heat have on the household demand for gas?

We look at the removal of two separate but related subsidies: the implicit gas subsidies for households and district heating companies, as well as the implicit heat subsidies for the population. To do this, the elasticities of demand for gas and heat will be estimated using the 2014 household living condition survey dataset compiled by the State Statistics Service of Ukraine (see State Statistics Service of Ukraine, 2016a). Additionally, the long-term effects from energy efficiency improvements resulting from the price increase will be estimated, creating different scenarios for the extent of investment in energy efficiency measures. This analysis is used to create three scenarios for Ukrainian household gas demand. Having done this, we will be able to draw conclusions on:

- The size of Ukrainian household demand for natural gas under three different scenarios.
- The net change in the burden on Ukrainian public finances from decreasing payments for gas price subsidies. This analysis will also take into account the increasing payments for explicit subsidies in the form of assistance to vulnerable households, scheduled to be introduced as compensation for the increased prices.
- The size of the increased value from gas sales available to gas production companies after the subsidy removal.

In order to do this, Section 2 will begin by giving an overview of the gas sector of Ukraine, including the level, the composition, and the changes of household gas consumption over time. The section continues with the structure of the market, including the role of Naftogaz, District Heating Companies and regional gas distribution companies as well as the role of corruption in the gas market. Section 3 goes through the subsidy reform, including the current and future gas and heat tariff systems. The tariffs paid are contrasted with the import and domestic production prices and thus the estimate of the total value of the implicit subsidies is obtained. Section 4 gives an overview of the current levels of Ukrainian energy efficiency and the potential for Ukrainian energy efficiency improvements and their effect on gas consumption in the short and the long run are reviewed. Subsequently, Sections 5 through 7 discuss the methods, data limitations, and the result of the model. Having done this, Sections 8 and 9 use the results from the previous sections to calculate different scenarios for the size of the market after the reforms. These scenarios are then used to evaluate the effect from the subsidy reform on key areas of importance, as outlined above.

2 The Ukrainian natural gas sector

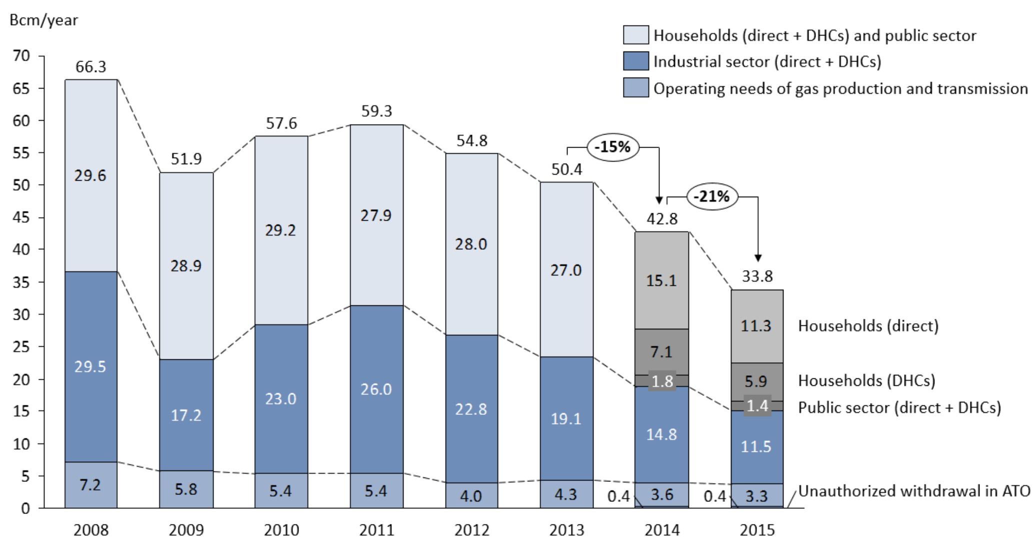
2.1 Development of gas consumption in Ukraine

In this paper, we are primarily concerned how the removal of natural gas and heat implicit subsidies affects household consumption in Ukraine. The first step in order to understand this relationship is to look at what is driving the gas demand. When discussing the pricing of natural gas in Ukraine, a distinction has to be made between the consumption by, on the one hand, households and district heating companies, and on the other hand industrial consumers. The focus of this paper is on the former, where the tariffs have been state-regulated and subsidized, while the tariffs for the Ukrainian industry were adjusted to import-parity prices almost a decade ago (Henderson & Pirani, 2014).

Ukraine emerged as an independent state in 1991 with gas heavily subsidized and used in an extremely wasteful way. The domestic natural gas consumption of 118 bcm placed Ukraine as number 3 in the world at that time, after the U.S. and Russia (Sarna, 2013). Since then the Ukrainian natural gas consumption has been decreasing, especially since 2007 and again from 2012. We note that the heavily gas reliant Ukrainian industry suffered tremendously from the 2008 financial crisis, with consumption almost halving only between 2008–2009 but then quickly rebounding in the coming years as growth took on again. Household consumption, on the other hand, shows a much more stable pattern, explained by the price of gas for households in real terms being almost constant until 2014.

Between 2013 and 2015, the total consumption decreased by 33%, to 33.8 bcm (Naftogaz, 2016b; see Figure 1 below). One of the key drivers of this decrease is the loss of control over Crimea and areas in Donbas, all heavy gas consuming regions. Donbas, out of which around 30% is now under separatist control, in the time prior to the conflict was directly responsible for around 20% of total Ukrainian gas consumption. We estimate that the loss of areas in Donbass and the loss of Crimea is responsible for around 1/3 of the total decline in the period.[1] The other two thirds of the decline was caused by industry and household demand rapidly declining. Between 2013 and 2015, industry output was in free fall, driving down industrial gas consumption by almost 40%. At the same time, households experienced a 119% weighted average USD increase of the tariffs for natural gas (see Figure 2) while simultaneously experiencing a decline of average per capita income by almost 50% (World Bank, 2016). As a result, the previously relatively constant Ukrainian household consumption of natural gas has declined by some 31% from the 2013 level (Figure 1). For our study, the most relevant period of analysis is the years from 2014–2016, since that is the time when gas and heat prices have increased and we can expect households to start adjusting their consumption (see Figure 2).

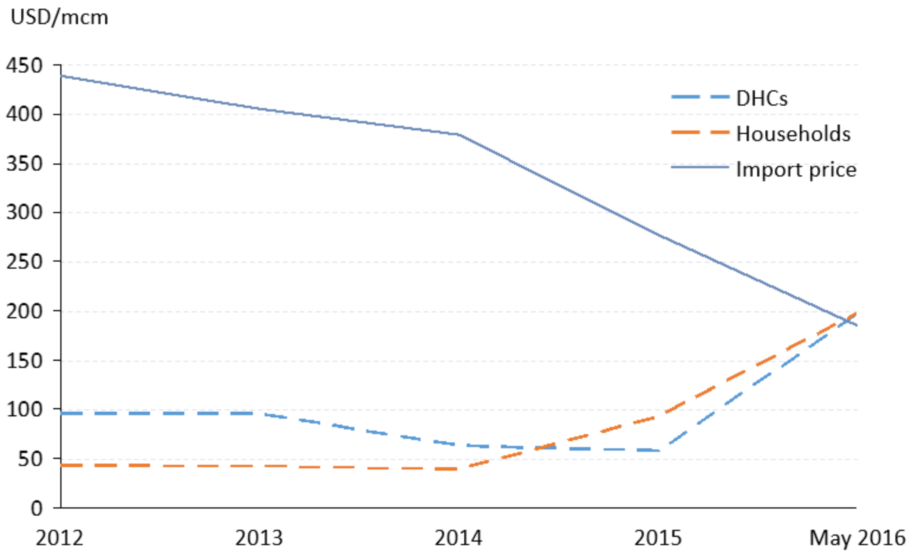
Figure 1: Natural gas consumption in Ukraine, 2008–2015



Source: Own calculations based on Naftogaz (2016c & 2016g).
Note: The figures for 2014 and 2015 exclude Crimean gas consumption.

[1] 2013 rates of total consumption: Donetsk (14%), Luhansk (7%), Crimea (4%). 30% of Donbas and Crimea is around 11% of Ukrainian gas consumption in 2013, which is equivalent to 1/3 of the decrease between 2013 and 2015 (MinReg, 2016).

Figure 2: Prices of gas for households, DHCs, and import prices, 2012–2016



Source: own estimates based on MERT [Ministry of Economic Development and Trade of Ukraine] (2016), Naftogaz (2015a), and press releases.

Looking at the regional distribution of the decline of consumption, in 2015 aggregate natural gas consumption in Ukraine decreased in all regions except in Odessa, where a small increase was observed.[2] The most dramatic decline is found in the Luhansk and Donetsk regions, portions of which remain controlled by separatists, experiencing gas consumption declines of –67% and –46%, respectively. It is worth noting that both these regions were heavy gas consumers prior to the war with large industrial gas consumption. When adding up the decrease from only these two regions together, they account for a third of the decrease in total gas consumption between 2014 and 2015 (3.1 bcm; Naftogaz, 2016h). It is important to note that some of this decline in consumption stems from the fact that Ukraine has partly stopped supplying the separatist controlled areas with gas, although the majority of the decline is still attributable to real decreases in the demand for gas.

Household direct natural gas consumption is divided into different categories depending on their usage. The first category of households use gas only for cooking through a gas stove and a gas oven. These households typically also rely on district heating companies for hot water and heating, which they purchase separately from their gas bill (although as mentioned above heating is mostly derived from gas as an input). The second category uses gas for cooking and also for warming up the water, but gets heating from district heating companies (DHCs). The third category uses gas for cooking, hot water and heating, and in total consumes 83% of total household consumption of gas in Ukraine (Naftogaz, 2015c).

[2] The 4% (0.09 bcm) consumption increase in the Odessa region is explained by the intensification of the Odessa Port Plant activities (+0.26 bcm). At the same time, households in the region reduced gas consumption from 0.66 bcm to 0.54 bcm (–19%), a decline comparable to that of residential customers in other regions of Ukraine (Naftogaz, 2015c).

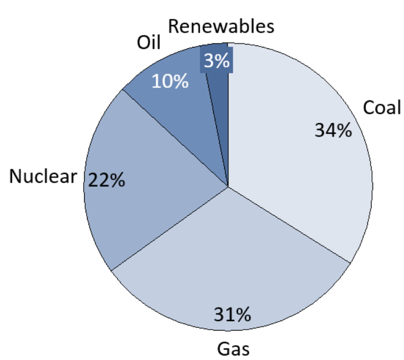
A second major consumer of gas in the household market is DHCs, providing the population with heat in the form of hot water. Forty percent of households rely on district heating companies for their heating needs (The Ministry of Regional Development, Construction, and Communal Living of Ukraine [MinReg], 2016). In 2015, those DHCs constituted 17.5% of all the Ukrainian gas consumption (5.9 Bcm; see Figure 1 above). It is worth noting that the percentage decrease in gas consumption for district heating from 2014 to 2015 is smaller than for other household gas usage. This is explained by the dual effect from lower real price increases for heating compared to other gas usage (see Section 3) and very low rates of metering and regulation devices for heating, which makes it very hard for households to respond to price changes (see more in Section 4 on energy efficiency).

Last, households which do not have a central gas connection often use refillable liquefied petroleum gas (LPG) cylinders to fuel their cooking stoves. According to our estimates based on the household survey, in 2014 nearly 13% of Ukrainian households owned gas cylinders. LPG is also increasingly popular as a car fuel. In 2015, LPG accounted for almost a quarter of all Ukrainian car fuel consumption and the total LPG consumption reached 1.1 million tons (Kuyun, 2016). LPG, however, consists of propane and butane which are different hydrocarbons than methane—the dominant gas distributed through the central gas network to households and the DHCs. LPG is a calorifically richer and heavier gas that is imported and distributed by rail and road rather than pipeline. Demand for LPG is therefore outside of the scope for this paper, although this growing market could also be an interesting focus of a demand study.

2.2 Overview gas sector of Ukraine

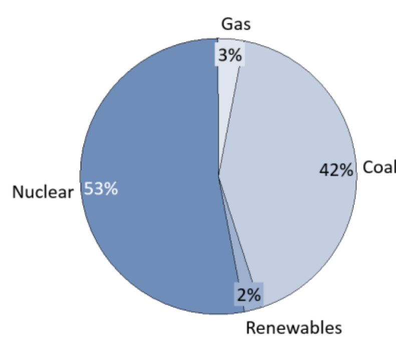
In total, as much as 31% of Ukraine's primary energy is supplied by gas (Figure 3), despite the fact that only 3% of electricity is produced with gas (Figure 4). This is the result of gas having a very prominent position in heat generation. Gas accounts for almost three-quarters of fuel consumed by both district heating companies (DHCs) and households with private heating systems (MinReg, 2016). In addition, gas is widely used for heating water, representing around 25% of the total gas consumption of DHCs (1.5 bcm) and is also often used for cooking by households.

Figure 3: Natural gas consumption in Ukraine, 2014



Source: MinReg (2016)

Figure 4: Ukrainian electricity generation by energy source, 2014



Source: MinReg (2016)

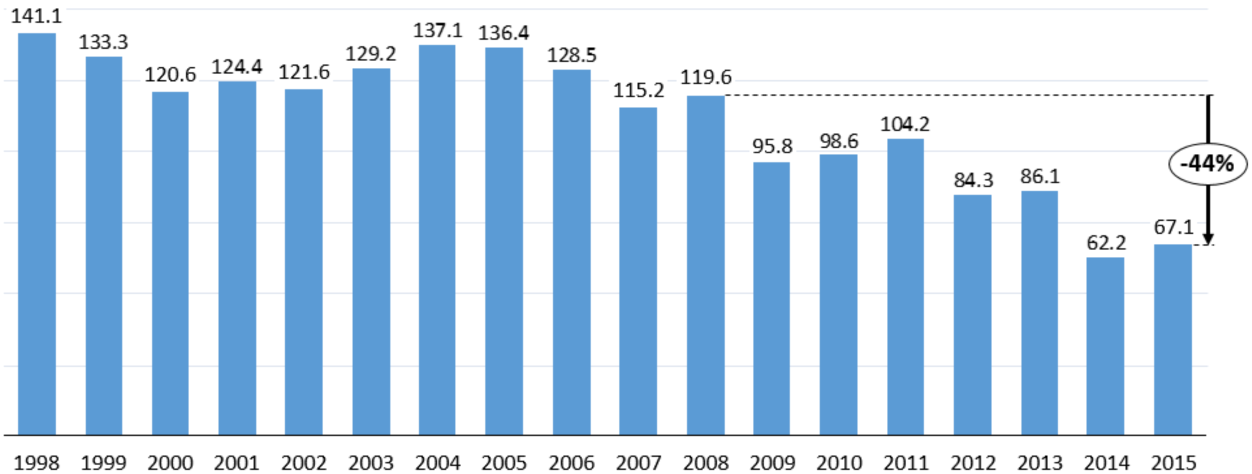
Naftogaz, the state-owned gas and oil giant, has a central role in the gas system of Ukraine, controlling both upstream operations (production of gas and oil), domestic transmission and distribution pipeline networks (through Ukrtransgaz), transit of Russian gas to Europe, Ukrainian gas imports, as well as gas storage. To this day, all gas sold to households is sourced from Naftogaz, which acquires it either through domestic production or imports.

Understanding the importance of the subsidies' role in Ukrainian gas consumption also requires looking at how Ukraine's gas is sourced: either from Ukrainian domestic production or from imports from Russia or the EU. In 2015, Ukrainian state and private producers supplied 19.9 bcm of natural gas. This marks a 3% decline from 2014, caused by the loss of production assets in Crimea and a lack of investments in new extraction capacity (Naftogaz, 2016d). Given the 2015 total gas consumption of 33.8 bcm, the local production provided for more than a half of the total demand (Naftogaz, 2016g).[3] Additionally, 16.4 bcm of gas was imported from Europe and Russia, with as much as 63% of that gas coming from the European direction—up from just 26% in 2014 (Naftogaz, 2016e). This remarkable shift of supply was made possible by the increasing integration between Ukrainian and European gas markets, exemplified by the introduction and expansion of the reverse flows through Budince, Slovakia, which accounted for 94% of European imports in 2015 (Natural Gas Europe, 2016). Ukraine's rapid expansion of the European imports is to a large extent a consequence of a Ukrainian political decision to diversify their gas supply in the wake of escalating political tensions with Russia. This is part of a larger strategy to increase Ukraine's energy security, by increasing diversity of supply, increasing domestic production and decreasing domestic consumption. The subsidy reform will help accomplish the latter, driving a decrease in consumption, which will decrease the need for Ukraine to import gas.

Both Russia and the EU see Ukraine as a strategic partner due to its large gas transportation system and its underground storage facilities. Ukraine has an entry capacity of 288 bcm/year and an exit capacity of 151 bcm/year in the direction of the EU. The annual utilized capacity, however, has been falling for the last 10 years and in 2015 stood at only 67.1 bcm (see Figure 5). From a Russian perspective, it would be advantageous to limit the need for Ukrainian transit, through an expansion of the Nord Stream pipeline, exporting directly to the European markets. Due to these problems, transit through Ukraine has been in a long-term decline, while still remaining an important node for the security of supply of large parts of Europe.

[3] Not all gas produced in Ukraine is consumed in the country: some is added into storage and some is exported. Between 2013 and 2015, Ukraine noted around 2 bcm of increased storage of gas (Naftogaz, 2016c).

Figure 5: Natural gas transit through Ukraine, bcm



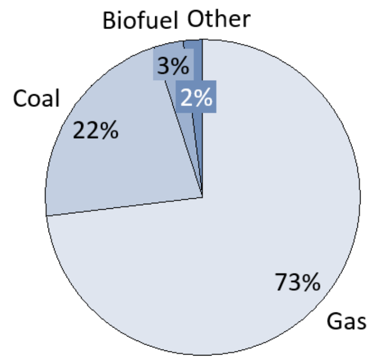
Source: Own graph based on Naftogaz (2015e) and Interfax Ukraine (2016).

Additionally, Ukraine possesses the largest system of underground gas storage facilities in Europe. It consists of 12 separate facilities with a total capacity of around 31 bcm. This constitutes over a quarter of the total EU-28 capacity (Naftogaz, 2015c). The majority of the storage capacity is conveniently located in western Ukraine, close to the European markets. Getting access to these storage facilities is an important part of the negotiations between Ukraine and the EU.

2.3 District heating companies

Around 40% of Ukrainian households rely on district heating companies (DHCs) for the provision of hot water and heating (MinReg, 2016). To produce this thermal energy, the state-owned, municipally administered DHCs rely on around 30,000 boiler houses as well as 250 combined-heat and power plants fueled with gas (MinReg, 2016). The boiler houses differ significantly in output, with as few as 161 of them representing more than 50% of production, then followed by a majority of boiler houses with very small capacity. Primarily, these boiler houses are fueled with gas, making up 73% of total fuel usage for centralized heating (Figure 6). This share might decrease somewhat over time as gas prices increase, as exemplified by the 800 boiler houses directed mainly towards wood during 2015. DHCs are major consumers of gas, in 2015 consuming 5.9 bcm, 17.5% of the total Ukrainian gas consumption. When producing heating, around ¾ of DHCs costs are directly derived from purchasing fuel in the form of gas (MinReg, 2016). This makes the functioning of DHCs important to understanding the future of gas consumption in Ukraine.

Figure 6: 2014 fuel consumption for district heating generation



Source: MinReg (2016).

District heating systems are widely used in central and eastern European countries as well as in the Nordic countries. District heating can be an efficient way of providing especially urban areas with heat generation, if the energy losses in production and transmission are minimized. In Ukraine, the district heating system has remained mostly unreformed since the collapse of the Soviet Union. The municipality-run DHCs suffer from severe under-financing caused by the tariffs being set at 77% of their cost of delivering the service (2015), up from 64% in 2014,[4] but still below a sustainable level allowing long-term investments in new infrastructure (MinReg, 2016). The main problems with the current way DHCs services are provided are that the billing is seen as unfair and non-transparent by the users, and that the quality of the service is considered to be very low (Semikolenova, Pierce & Hankinson, 2012). The first problem stems from the fact that consumption is often not metered and thus does not represent actual usage of natural gas, ignoring the effect from things like the number of radiators in each apartment, construction materials of the building and so on. The second problem stems from perceived quality issues, such as late starts of the heating season or the need to pay additional money for heat engineers and plumbers, although it technically is part of the fee for residential rental payment.

As a further result of the low tariffs, DHCs' payment rates for their gas consumption are low. Generally, the severe underfunding of DHCs and the fact that there has been no legal way for Naftogaz to cut off supply to individual DHCs, who are behind on payment for their gas consumption (Naftogaz, 2015c). The importance of this phenomenon can be illustrated by the overall level of payment by DHCs. In 2012, 68.9% of outstanding bills were paid, then dropping to the abysmal 29.9% in 2013, followed by 61.3% in 2014 (National Commission for State Energy and Public Utilities

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[4] This is only part of the subsidy in the delivery of heat, though, since the DHCs buy heavily subsidized gas from Naftogaz, at UAH 1,271/mcm, 79% lower than the import-parity price of UAH 6,086/mcm in 2015.

Regulation [NCEPUR], 2015). As of February 1, 2016, the debt of DHCs to Naftogaz amounted to UAH 24.8bn, or around USD 1bn (MinReg, 2016). This represents an additional direct cost to the state, through transfers to Naftogaz, to finance the deficit of DHCs, caused by too low tariffs in combination with incentive-incompatible legislation. The legislation required to allow Naftogaz to cut off supply to non-paying customers is yet to pass in Parliament, and if it does, it needs to survive legal challenges and there needs to be political willingness to implement it, before it would actually affect the non-payment rates.

The continued reforms of the heating tariffs, coupled with the introduction of consumption-based billing through investments in meters, would help with many of the issues outlined above. This, in turn, should allow for greater energy-efficiency in the delivery of heating services, decreasing the consumption of natural gas. It would also give consumers the incentives to change their consumption, decreasing wasteful heat usage. For a more detailed overview of the potential for these type of measures, see Section 4 on energy efficiency.

2.4 Corruption and subsidies for gas

Heavily subsidizing gas for households, while at the same time applying a much higher, market-based price to industry consumers, allows for arbitrage and rent-seeking. Getting hold of the cheap gas and selling it expensively is very lucrative if the price differentials are as large as they were in Ukraine (up to 10 times). Having a system with very low levels of metering of gas consumption, until recently the case in Ukraine, makes it easier to get away with these practices. Large business conglomerates, with a vertically integrated business group controlling both gas supply companies with access to subsidized gas and also simultaneously having a stake in industries reliant on gas as an input, are best placed to profit from this price differential. One example of this is Dmytro Firtash's business group that simultaneously controls *oblgaz*es and chemical plants. Another example is the use of the partly state-owned UkrNafta, which through a 42% minority share held by Privat Group, controlled the board and directed the output of the company to the business interests of the Privat Group, even though Naftogaz owned 50% plus one share. A political struggle over the control of UkrNafta erupted in 2015 between Naftogaz and Privat Group, seemingly resolved in favor of Naftogaz through a change of the legislation on how many votes are required to win votes in the board of the company (Chazan, 2015).

Estimating the amount of gas involved in this type of illicit reselling of household gas to industries is difficult, but gas industry experts put the total size at around 1.5 bcm/year before the April 2015 price increase and possibly at 0.5 bcm/year or lower after the price increase (Maslichenko, 2016). The price reforms of gas are diminishing the scope and incentives for all types of gas-related rent-seeking, which, together with an increased level of metering and transparency throughout the whole system, should already in 2016 bring to an end *oblgaz*es' ability to resell gas to industry consumers at higher prices as well as other arbitrage opportunities. This large decrease of the scope for corruption in the gas sector of Ukraine as a result of the subsidy reform should be considered a major success of the Ukrainian government.

3 Subsidy reforms

The Ukrainian natural gas pricing structure, with large differences between consumer prices, industry prices, and import prices, had long been a major source of economic rents for the political and business elites of the country. Upon gaining independence, Ukraine was endowed with a Soviet system for managing natural gas, where gas prices for households and industry were set centrally and no market for gas existed. The implicit subsidies in the form of underpriced gas for households had served as a social policy which became increasingly expensive in the recent years.

In the Ukrainian public debate, household prices well below the import price have often been justified by populists who have been arguing that cheap domestic gas production, which since the 90s stood at around 20 bcm/y (Pirani, 2007, p. 46; Naftogaz, 2015g), should be used for the population's needs. In accordance with the Ukrainian legislation, any domestic gas extraction firm which is at least 50% directly or indirectly state-owned must sell all of its marketable gas to Naftogaz at subsidized state-determined tariffs so that cheap gas is available to the public (Naftogaz, 2015c). Needless to say, this has been one of the core reasons for the continued stagnation of Ukraine's main gas producer, Naftogaz's subsidiary Ukrgazvydobuvannya (UGV), despite its low extraction costs compared to the import prices.[5]

Since the state-controlled local production does not provide enough gas to cover the household gas demand—in 2014 it accounted for 63% of the consumption,[6] Naftogaz has historically incurred large losses from reselling imported gas at a subsidized price. Together with the rising gas import price and massive hryvnia depreciation of 2008–2009 and 2014–2016, this resulted in large transfers from the Ukrainian state budget to cover deficits of Naftogaz. In 2014, they reached the magnitude of 27% of the Ukrainian national budget, or 6% of GDP (Naftogaz, 2015a). The drain from the state budget, together with the IMF's pressure to reform the pricing of natural gas in order to get an extension on a USD 17bn loan, made the Ukrainian government drastically decrease the household implicit gas subsidies, beginning in 2014 and finishing on May 1, 2016 when implicit gas subsidies were fully removed.

In accordance with economic theory, implicit subsidy should be understood as a governmental transfer to households in which the Ukrainian government has an opportunity cost of providing the subsidized prices, which has to be compensated through fewer public services or higher taxes (cf. Mitra & Atoyan, 2012). This is in line with the methodology of the IEA (2014, p. 315) and pre-tax subsidy definition of the IMF (Clements *et al.,* 2013, p. 7).[7] Thus, we define implicit subsidies as not only including a direct loss from a below-the-cost sale of the imported gas but also an implicit loss in

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[5] In 2014, the average cost of production of conventional gas in existing wells was USD 25-30/mcm while gas from new wells cost USD 50-80/mcm (Naftogaz, 2015c). In 2015, UGV was selling its gas to Naftogaz for USD 20/mcm net of 70% royalties and other taxes (Naftogaz, 2015c).

[6] In 2014, 13.9 out of 22.1 bcm, or 63%, of gas consumed by households and DHCs producing heat for households was domestically produced (Naftogaz, 2015c).

[7] For a more comprehensive discussion of different methods for estimating subsidies used by international organizations, please refer to Box 1 in Bárány & Grigonytė (2015).

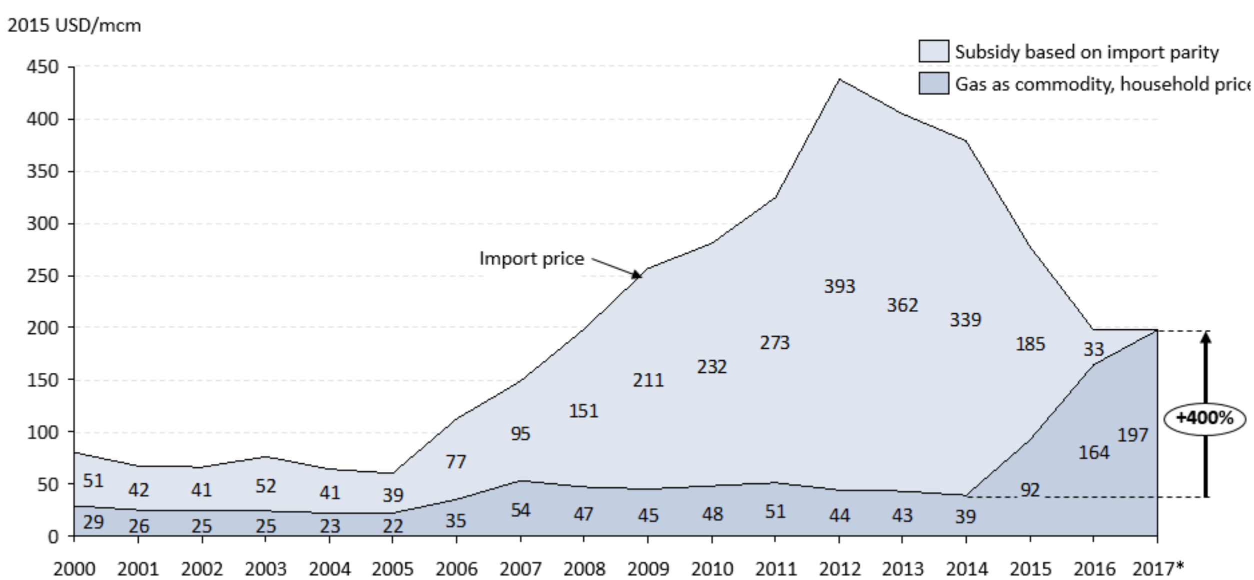
the form of a foregone revenue from a cheap sale of the domestic gas below the market rate. Since there is no competitive gas market in Ukraine which would provide us with a market rate, in order to establish an implicit subsidy level, we need to compare the gas price which Naftogaz charges with a reference/benchmark price that approximates the market price. Since Ukraine is a net importer of gas, we look at the import parity price.

3.1 Gas prices

The household gas tariff in Ukraine is comprised of various components. The largest component is the price of gas as a commodity, that is, the money which Naftogaz receives for the gas it provides. In addition, the price includes a tariff for transportation via the transmission pipelines, a tariff for transportation via the distribution pipelines, a supply tariff, and taxes. Due to the fact that those additional tariffs and taxes do not compensate Naftogaz for the gas purchase, in order to determine the subsidy level what we need to compare with the import price is Naftogaz's price of gas as a commodity.

Between 2000 and 2005, the final consumer price of gas for households was kept at a constant level in the local currency and equaled UAH 185/mcm (Mikhaylovskaya, 2009), or USD 44–47 in 2015 dollars. However, only around half of that price was constituted by the price of gas as a commodity. Given that the import price of Russian gas oscillated between USD 60–80/mcm and the price of gas as a commodity in dollars fluctuated between USD 20–30/mcm (Naftogaz, 2015a), the implicit subsidy during the period was around 2/3 of the import price (Figure 7).[8]

Figure 7: Gas as a commodity—weighted-average household prices and the implicit subsidies



Source: Authors' estimates based on data from Naftogaz (2015a; 2015b & 2016a) and news reports.

[8] Dollar prices in constant 2015 dollars.

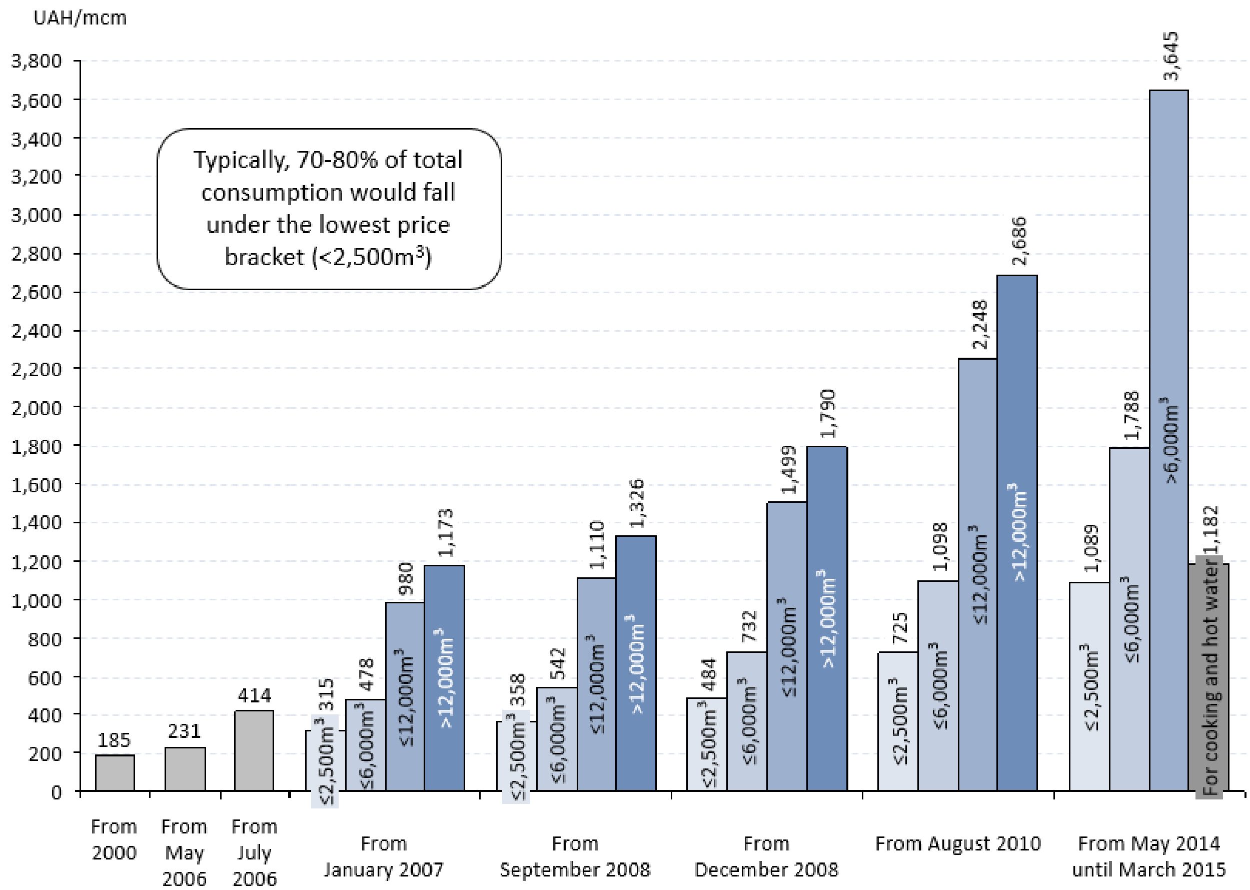
As a result of the 2004–2005 Orange Revolution, the relationship between Ukraine and Russia deteriorated and Moscow decided that it would no longer provide Ukraine with cheap gas, especially given that the European market prices were rising and, thus, so was the opportunity cost (Pirani, 2007). The political dimension of this decision becomes clear when we look at the Russian gas prices for Belarus in the same period, which remained at low levels despite similar economic pressures (Yafimava & Stern, 2007). As a consequence, the Ukrainian import prices started increasing heavily but the household prices failed to rise correspondingly (see Figure 7). After strong hryvnia depreciation in the second half of 2008 and the first quarter of 2009, the gap between the price for household gas as a commodity and the import price grew even larger, despite a 50% increase in household prices during the course of 2008. In total, between 2000 and 2012 the price of gas as a commodity increased by 52% from USD 29/mcm to USD 44/mcm. In the meantime, however, the import price rose from USD 80/mcm to USD 438/mcm, a drastic increase of 448%.[9] Consequently, the weighted-average import price of 2012 grew to a staggering 10 times of the price the households paid, translating itself to a subsidy of USD 393 for every thousand cubic meter consumed by a Ukrainian household.

In the period of 2000–2016, the nominal final household gas prices were increased on 9 occasions (Figure 7 and Figure 8). After two increases the gas price reached UAH 414/mcm in July 2006 (Mikhaylovskaya, 2009). Then, on January 1, 2007, a significant change was made when prices were made volume-dependent. Four volume brackets were established: for yearly consumption equal or below 2,500 m^3, equal or below 6,000 m^3, equal or below 12,000 m^3, and above 12,000 m^3. Additionally, each volume category had two slightly different prices, one for metered consumption and another, 10% higher, for non-metered use.[10] The prices were increased further in September and December 2008, August 2010, May 2014, April 2015, and May 2016. As of May 1, 2014, the last volume bracket was abandoned, making "above 6000 m^3" the new highest threshold. At the same time, a new category of prices was introduced for gas consumed exclusively for cooking and heating purposes, which essentially applied to the block of flats with a district heating connection, and again had two price points depending on whether the consumption was metered or not.

[9] Prices in constant 2015 dollars.

[10] The volume of the non-metered consumption in Ukraine has been determined based on a consumption norm, which depended, in turn, on the type of gas use (cooking, heating water, and heating the living area), the apartment/house size, and the number of people registered in it. The price differential aimed at incentivizing households to install meters.

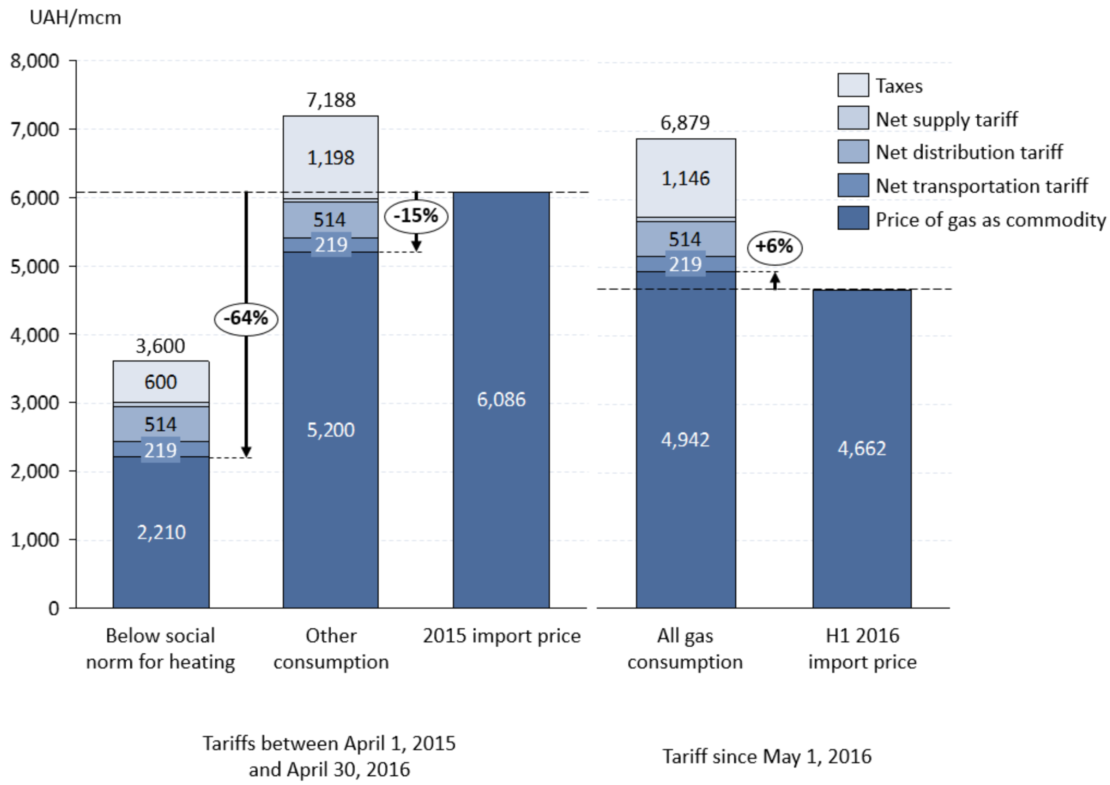
Figure 8: Final household gas prices between 2000 and March 31, 2015



Sources: Mikhaylovskaya (2009); Decree № 812 by НКРЭ Украины from July 13, 2010; and Decree № 420 by НКРЭ Украины from April 3, 2014. The prices shown for 2007 and onwards are metered-consumption prices—the prices for non-metered consumption can, however, be easily obtained by adding 10% to the metered prices.

Notably, the price system was constructed in such a way that once a household consumed more than a given threshold volume, it would pay a higher price not just for the volume above the threshold but rather for the entire consumption. This could have strong consequences for a household, for example a family which in a given year consumed 2,501 m^3 of gas would have to pay a significantly higher bill than a family which consumed 2,500 m^3. This system, however, was abolished on April 1, 2015, when a substantial price increase was enacted together with a simplification of the pricing system. From this moment onward, only two household gas prices existed (Figure 9). A lower rate of UAH 3,600/mcm was assigned to households which, among others, used gas for producing heat. Moreover, this discounted price was applied only to consumption below the so-called social norm—that is the first 1,200 m^3 consumed, and only during the heating season—from October to April. A higher price, UAH 7,188/mcm, applied to any aforementioned consumption exceeding 1,200 m3 and for all the consumption in the other months. This price was also applicable all year round to households not buying gas to produce heat, independently of the volume consumed (see Decree № 420 by НКРЭ Украины from April 3, 2014). Given the weighted-average 2015 import price of USD 277/mcm, the prices for gas as a commodity after the April 2015 price increase stood at 36% of the import parity for the consumption within the social norm and at 85% for all other consumption (Figure 9).

Figure 9: Final household gas tariffs after April 1, 2015



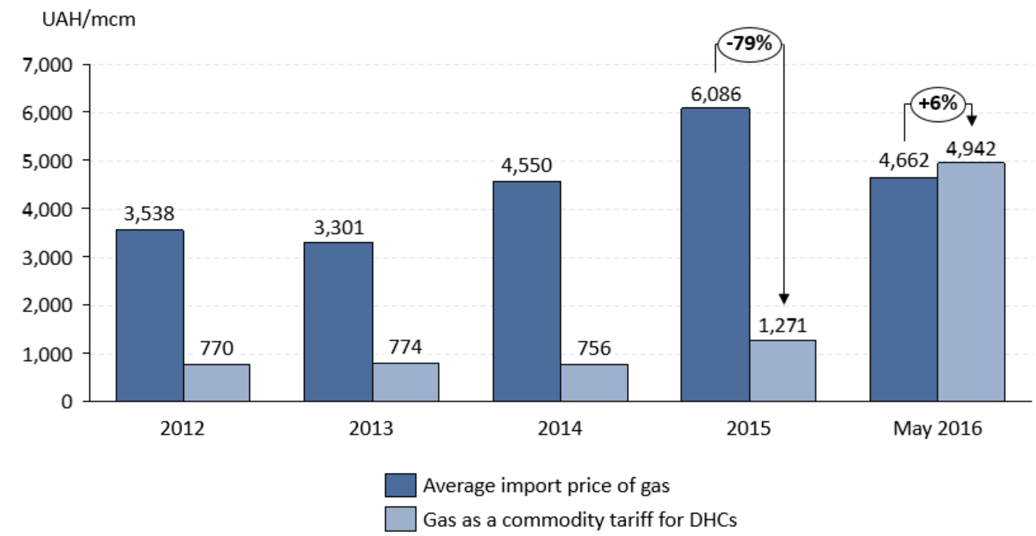
Source: own estimates based on data from MERT (2016), Naftogaz (2015a & 2016f), and USD 185 estimate of the import price in H1 2016.

With a much lower import price in the first half of 2016, it was possible for the government to achieve import-parity a year ahead of schedule. On May 1, 2016, gas tariffs were unified and set at UAH 6,879/mcm—for the first time in history at the import parity (Figure 9).

3.2 District heating tariffs

The district heating prices exhibited a similar trend as the gas tariffs. Despite the increasing gas import prices between 2006 and 2012 (Figure 6), the heat tariffs were not adjusted and the gap between them kept on growing. Since the DHCs produce heat for the populations' needs, the government kept the prices artificially low to reflect the local production cost rather than the real value of heat. Additionally, the heat tariff was mispriced in yet another way. Not only did DHCs receive artificially cheap gas but they also sold the heat at below the already subsidized production cost (Figure 10 and Figure 11).

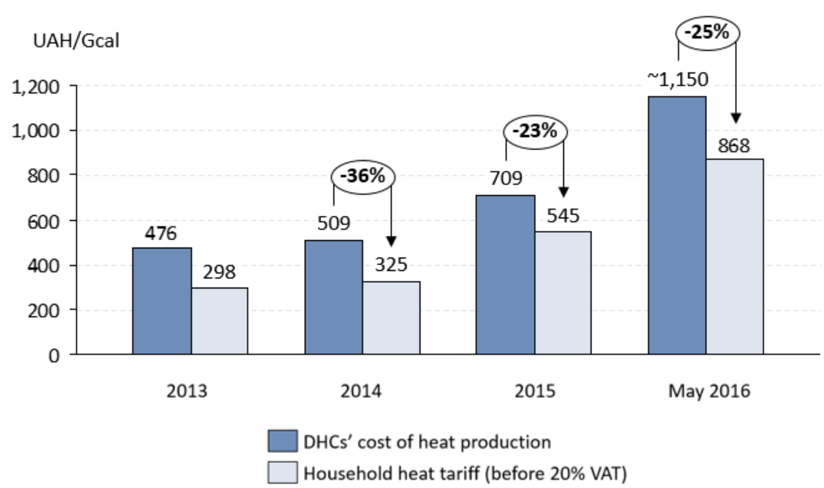
Figure 10: Gas tariffs for DHCs



Source: Own estimates based on MERT (2016), Naftogaz (2015a), and press releases. The import price based on weighted-average import prices and an average UAH/USD exchange rate of a given year. For May 2016, USD 185/mcm import price assumed.

In 2014, the annual average price of gas as a commodity that Naftogaz charged the DHCs was UAH 756/mcm (Naftogaz, 2015a). Given that the weighted average import price of 2014 was USD 379/mcm, or around UAH 4,550, the gas for DHCs was sold at 17% of the import price. The average weighted heat tariff before VAT was, in turn, UAH 325/Gcal, although the average heat production cost equaled UAH 509/Gcal (MinReg, 2016; Figure 11). Thus, in addition to a subsidy for gas sold to DHCs, the heat consumed by households was further subsidized by over a third. This second cost had to be covered by transfers either from the local or state budgets (MinReg, 2016).

Figure 11: Heat production costs and tariffs



Source: authors' estimates based on MERT (2016) and MinReg (2016).

On May 1, 2016, the price of gas as a commodity for DHCs producing heat for households was set at the import-parity level of UAH 4,942/mcm—the same price as the price of gas as a commodity for households (MERT, 2016). Effectively, both households and DHCs prices for gas were thus unified and set at the import price, bringing an end to the implicit gas subsidies.[11] At the same time, however, the heat tariff did not increase enough to fully reflect the cost of heat production. From a previous weighted-average tariff of UAH 654/Gcal, or UAH 545/Gcal before VAT, it increased to UAH 1,041/Gcal, or UAH 868 before VAT (MERT, 2016; MinReg, 2016)—while the cost of heat production with the new gas price is around UAH 1,150/Gcal. Thus, although the gas sold to DHCs is no longer subsidized, there is still an implicit subsidy on heat at around 25% (see Figure 11).

After the gas subsidy removal and bringing the tariffs to the import parity, the last main step remaining to complete the gas reform is to deregulate the price setting, a move expected to happen either in 2016 or 2017, and allow private players to compete with Naftogaz.

3.3 Implicit natural gas subsidies

As mentioned above, due to the fact that it has been possible to use domestic state-controlled production to satisfy a large portion of household consumption, it is necessary to differentiate between two different forms of implicit subsidies: a subsidy through an actual financial loss created by reselling imported gas to households at a discount and a subsidy in the form of Naftogaz's foregone revenues from selling the domestic gas at below the import price.

Figure 12: Implicit gas subsidies compared to the Ukrainian budgetary deficit, 2012–2015

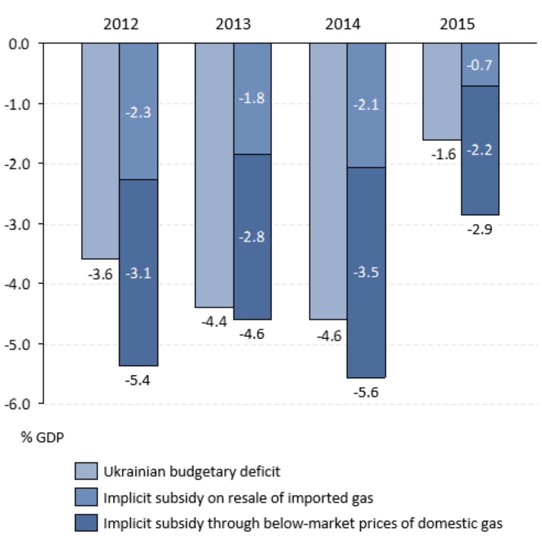
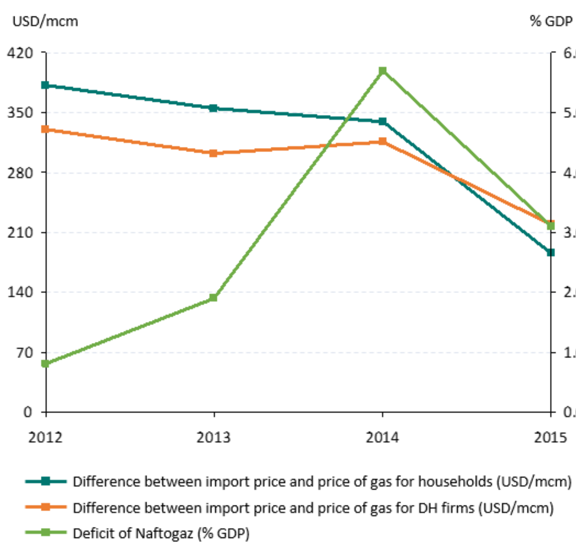


Figure 13: Differences between import gas price and gas prices for the population, 2012–2015



Source: CASE Ukraine (2016), Naftogaz (2015a, 2015c & 2016a), Repko et al. (2015), World Bank (2016), news reports, and authors' estimates.

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[11] Since the final gas price for DHCs does not include the supply tariff, it was set slightly lower than the one for households and, as of May 1, 2016, amounted to UAH 6,810/mcm (MERT, 2016).

Table 1: The size of the Ukrainian implicit gas subsidies

	Household & DH consumption, bcm	Import price, USD/mcm	Weighted-average price of gas as a comm., USD/mcm	Naftogaz's loss, USD bn	Naftogaz's loss, GDP
2012	26	425	61	9.5	5.4%
2013	25	397	59	8.5	4.6%
2014	22	379	47	7.3	5.6%
2015	17	277	81	3.4	2.9%

Source: see Figure 12 and Figure 13. Naftogaz's loss is calculated by V*(Pi-Ps).

To use an example, in 2014 households (including DHC) consumed 22.1 bcm of natural gas out of which 13.9 bcm came from Ukrainian domestic production by UGV, which had to sell it at subsidized prices to Naftogaz, and 8.2 bcm came from imports (Naftogaz, 2015c). Given that the weighted-average price of gas as a commodity for DHCs producing heat for households and the price of gas as a commodity for direct household use equaled USD 47/mcm,[12] and that the weighted-average import price throughout the year equaled USD 379/mcm, the 2014 implicit subsidy through Naftogaz's foregone revenues on domestically produced gas can be estimated at USD 4.6bn, or 3.5% of GDP (Figure 12). In addition, reselling the 8.2 bcm of imported gas at USD 47/mcm generated a direct financial loss of USD 2.7bn, or 2.1% of GDP,[13] bringing total subsidies' size to 5.6% of GDP (Table 1). Finally, DHCs selling heat at below the production cost constituted an additional cost of UAH 7.6bn in 2014, or 0.5% of GDP.

Together these three implicit subsidies had been constantly larger than the total Ukrainian budget deficit, vividly visualizing the scale of the problem. It is also important to recognize that since the implicit subsidies applied indiscriminately to each household, the more gas and heat a household consumed—the larger the subsidy became. Consequently, affluent Ukrainian households tended to benefit more than the poor ones (cf. Mitra & Atoyan, 2012).

In Figure 13 above, the deficit of Naftogaz is plotted against the difference between import prices and the price of gas for households. At first glance, we would expect that Naftogaz's deficits as a share of GDP should largely exhibit covariance with this difference (as the differential of prices goes up, we would expect that the Ukrainian state needs to use more money to refinance Naftogaz). This is not the whole picture, however. The size of the transfers as a share of GDP which Naftogaz needs each year to finance its operations will crucially depend on three factors other than the price differential:

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[12] Household price of gas as a commodity equaled at the time UAH 473/mcm, or USD 39/mcm, while price of gas as a commodity for DHCs producing heat for households equaled UAH 756/mcm, or USD 63/mcm (Naftogaz, 2015a).

[13] Please note that our calculations yield somewhat higher cost of sales of imported gas and thus a higher subsidy level than Naftogaz's own calculations (2015c). In 2014, Q1 weighted-average import price was substantially lower than in the remaining quarters (USD 269/mcm versus 472 in Q2, 353 in Q3, and 360 in Q4) and it appears that in its accounting Naftogaz assumed that all gas imported in Q1 was resold to households. This leads to a lower cost of sales to households as compared to the industry, which "bought" the more expensive gas imported in the other quarters. We, on the other hand, assume a constant and proportional fraction of sales between households and industry throughout the year.

first, the size of Naftogaz's debt and thus its interest repayments, second, the value of the Ukrainian currency in relationship to the currency in which Naftogaz repays its debt and, third, the total size of the Ukrainian economy. First, Naftogaz was amassing dollar-denominated debt in the years up to 2014, which incurred larger yearly interest rate payments. Second, when the Ukrainian hryvnia started depreciating in 2014, losing 50% of its value against the dollar in just a year, this led to a massive currency-related loss, estimated by Naftogaz at UAH 45bn in 2014 (around USD 3.75bn assuming UAH 12 per USD 1, or equivalent to 2.9% of Ukrainian GDP; Naftogaz, 2015a). Third, the Ukrainian economy contracted by around 7% in 2014, while gas consumption and the import to household price differential was relatively constant, also driving Naftogaz's deficit as a share of Ukrainian GDP up. In 2014, as Naftogaz's deficit was approaching 6% of Ukrainian GDP, the situation became critical. The system of heavily subsidized domestic gas consumption, necessitating the Ukrainian state to transfer several percentage of GDP on a yearly basis in order to cover Naftogaz's deficit, had become untenable. Aggravated by the severe currency depreciation as well as the GDP contraction, gas subsidies had developed into a matter of vital importance to the entire Ukrainian public finances, threatening to cause a Ukrainian default on its debts, with wide and far-reaching implications for the real economy.

In order to assess the effect of the removal of the implicit gas and heat subsidies on the Ukrainian natural gas demand, we will estimate the household gas and household heat price elasticities of demand. Having done that, we will be able to establish a precise relationship between the gas tariffs, its consumption and the elimination of the subsidies. At the same time, it is important to note that these three implicit subsidies are not the only subsidies present in the household gas and heat markets. Households also receive direct non-cash subsidies in the form of social assistance and benefits which further lower their gas and heat bills. The state transfers these direct household subsidies directly to the companies distributing gas and heat to compensate them for corresponding revenue losses. The way in which such explicit subsidies affect our estimates is discussed in Section 9.2.

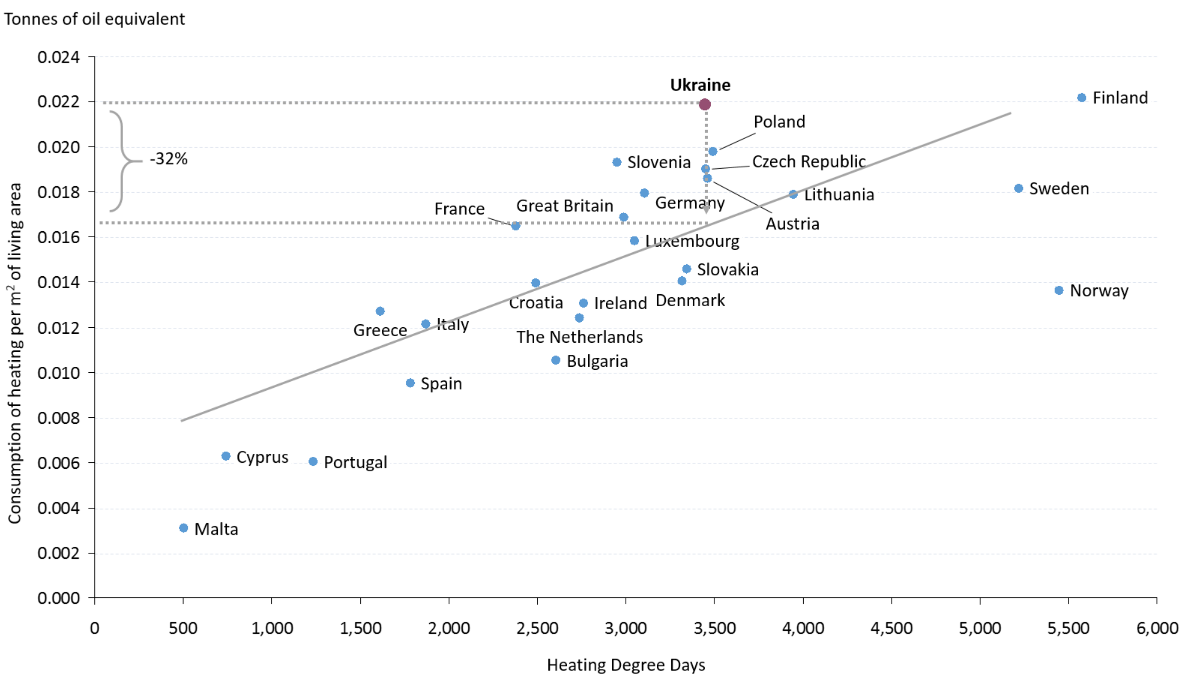
4 Energy efficiency

Energy efficiency is a function of the price of energy, state policies, legislation, and societal norms and knowledge about energy preservation. This paper tries to determine the effect from the subsidy removal on gas consumption. It is a difficult task: as the prices for gas increase, so do the incentives for households to invest in energy saving equipment and the incentives for companies to provide energy saving products. Simultaneously, in Ukraine, the reform of gas prices is coupled with an effort by the state and international financial institutions to increase the financial support for households and district heating companies to make energy-saving investments. Most of these changes, which are mainly caused by the price increase for natural gas, will be taking place over a ten-year period, only partially visible in our price elasticity estimate. This section provides an overview of where Ukraine is today in terms of energy efficiency and what type of changes, with the resulting savings, can be expected in the short and long run.

Ukraine is one of the least energy efficient countries in the world. Measured as energy usage per unit of GDP, in 2013 Ukraine consumed 3.8 times the European average (Radeke & Kosse, 2013). A large share of this inefficiency is driven by a lack of incentives for energy-saving investments due to highly subsidized cheap gas. A comparison of the energy efficiency of the Ukrainian housing stock with

European countries yields similar results: Ukrainian households consume around 32% more heat per square meter than the European average, controlling for heating degree days (HDDs; see Figure 14). When compared with other Central and Eastern European (CEE) countries with similar amounts of HDDs, Ukraine has an energy consumption 10% higher than Poland, 15% higher than the Czech Republic and 50% higher than Slovakia. It is important to note that this underestimates Ukraine's energy efficiency problems as Ukraine is also lagging behind other countries in other aspects such as the efficiency of generating heat from gas or heat transmission losses.

Figure 14: Heating usage per square meter of living area in Ukraine, comparison with European countries, 2013



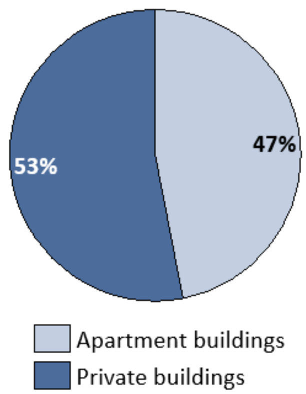
Source: Adapted from Repko (2015).

Most of the 18.6 bcm gas consumed by households and the public sector are used for heating purposes, and that is also where the most energy is wasted, as compared to most European countries. If Ukraine was to reach the current EU average level of efficiency in energy generation, then 11.4 bcm of gas could be saved, a whopping 61% of the total gas consumption for that purpose (MinReg, 2016). The real potential for savings is much harder to estimate and depends on the success of legislation reforms, availability of financing for energy efficiency investments, behavioral changes reducing waste, and the pricing of natural gas. For our purposes, we estimated the most likely scenario for energy efficiency gains, which we will employ in the demand estimation section of the paper. The following provides an overview of the type of measures and the associated energy savings possible for, on the one hand, private houses and blocks of flats and, on the other hand, district heating companies (DHCs).

4.1 Energy efficiency in private buildings and blocks of flats

Blocks of flats make up 47% of Ukraine's total housing stock, measured in square meters, but only 3.7% of the total amount of buildings (Figure 15). Around 50% of Ukraine's total housing stock was built between 1946 and 1970, which is a relatively high number compared to for example Czech Republic and Lithuania (see Table 2). Very few of these buildings have been renovated since construction and they have very low standards of energy efficiency.

Figure 15: Breakdown of housing stock by type (total of 1,066 million m^2)



Source: MinReg (2016).

Table 2: Breakdown of buildings by the year of construction, comparison European countries

Period of construction	Ukraine	Germany	Czechia	Lithuania
Until 1919	5%	14%	11%	6%
1919–1945	13%	14%	14%	23%
1946–1970	51%	46%	25%	33%
1971–1980	16%	13%	22%	18%
After 1981	15%	13%	28%	20%

Source: MinReg (2016).

Most of the blocks of flats are connected to district heating network which supplies them with both heat and hot water from DHCs. The private buildings, on the other hand, often have separate gas boilers which provide them with hot water and heating.

There are three main types of measures which can be done to improve the energy efficiency of blocks of flats and private houses. First, meters for consumption of heat, water, and gas can be installed. This is a measure which gives households incentives to modify their consumption when prices rise and thus induces behavioral changes to save energy. The second type of measure includes the use of more efficient gas boilers used for producing heating or hot water. The third measure involves investment in thermo-modernization, including insulating roofs, walls and basements, and replacing windows and doors. These measures can be introduced both for private houses and blocks of flats.

Private houses and blocks of flats connected to DHCs often lack meters for heating and hot water consumption (see Table 3). This has serious implications for people's incentives to use heating efficiently, making individual savings pointless (since household bills are not based on the individual level of consumption). As of January 2016, only 51% of blocks of flats were equipped with building-level heat meters, up from 40% in 2014 (MinReg, 2016). Such meters were being rapidly introduced during 2015 and this will continue in 2016, with a goal of 80% of buildings being equipped with meters at the end of the year (MinReg, 2016). The fraction of metered buildings differs widely between regions, with rather high fractions of metering in *oblast*s [provinces] like Lviv (73%), Kyiv (70%) and Mykolaiv (68%) but very low in *oblast*s like Ternopil (7%) and Poltava (24%; MinReg, 2016). Buildings without meters cannot locally control the temperature since they lack a building level substation (heating decisions are taken centrally by DHCs). In practice, households in such buildings regulate the temperature by opening the windows (if it is too hot) or using alternative sources of heating, such as electric heaters, if it is too cold. For hot water, the average fraction of metering is higher, at 64% of all buildings, with the highest in Zhytomyr and Kirovohrad (100%) and the lowest in Odessa (19%) and Luhansk (23%). Such meters can reveal if households were being overcharged or undercharged, by allowing transparency in billing. This can potentially have large effects: a research report estimates heat supply norms to be set around 8% too high (at 0.14 Gcal/m3 compared to actual 0.129; MinReg, 2016). Thus, the introduction of meters will not only induce behavioral changes to save energy but also lead to "savings" due to previously unreasonably high norms. Thus, the introduction of meters will not only induce behavioral changes to save energy but also lead to "savings" due to previously unreasonably high norms.

Table 3: Metering of different types of consumption

	Services provided by DHCs		**Services provided by *Oblgaz*es**		
Type of consumption	Heating (building level)	Hot water (household level)	Gas for heating	Gas for cooking/ hot water	Gas for cooking
Share of metered households, 2015	51%	64%	~100%	72%	27%

Source: MigNews (2015), Minreg (2016), and Naftogaz (2015c).

Metering for direct gas consumption by households used for heating and hot water is much higher, almost at 100% (Minreg, 2016). Households using gas only for cooking have a much lower fraction of meters, at 27% in 2015 (MigNews, 2015). Altogether, 93% of the volume of gas sold was metered in 2015 (MigNews, 2015). If current legislation which requires all household gas consumption in Ukraine to be metered before January 1, 2018 is implemented, we should expect this fraction to increase even further (Naftogaz, 2015c).

After metering and replacement of boilers, thermo-modernization offers the highest potential for energy savings. Thermo-modernization includes envelope upgrades, such as insulating roofs, walls and basements, and replacing windows and doors. These measures are more expensive than the previous options considered but have larger potential in terms of savings of energy. In a comparative study looking at different types of initiatives from CEE and CES countries, the Alliance to Save Energy (2007) finds that utility bill savings of 40–60 percent can be achieved through comprehensive thermo-modernization.

4.2 Energy efficiency of district heating companies

The district heating system of Ukraine is, in terms of energy efficiency, lagging far behind comparable countries. The largest inefficiencies result from large energy losses during the production and distribution of hot water by the district heating companies (DHCs), with an estimated 59% of the total energy lost (German Advisory Group to Ukraine, 2013). A comparable number for German DHCs is 32%, which indicates that huge savings could be made.

In Ukraine, district heating is either produced by smaller gas boiler houses, or by larger cogeneration plants, producing both electricity and heat at the same time. The latter are predominantly used in urban areas. The largest potential for energy efficiency gains for district heating comes from rehabilitating boiler houses which are old and inefficient and increasing the efficiency of transmission of gas by replacing old network pipes. The regulated very low prices for heating in Ukraine have resulted in DHCs acquiring large losses, covered by the Ukrainian authorities, but also resulting in an inability to finance energy-efficiency saving investments. Thus, both the production and transmission of heat is done inefficiently, which often also leads to low service quality, especially in the stability of heat delivery and the temperature of the delivered heat to the end consumer (Semikolenova, Pierce & Hankinson, 2012). The Ministry for Regional Development (MinReg, 2016) estimates that 23% of the total length of heating networks is worn-out and unsafe, and in some areas this number is as high as 51% (Odessa), resulting in large losses of heat as well as unreliable service. So far, unfortunately, only limited number of transmission network renovations have been carried out. There has been some replacement of boilers, on the other hand, with 480 out of 30,000 boiler houses modernized in 2015, with a resulting decrease in gas consumption of around 28 mmcm/year (MinReg, 2016). A separate mechanism resulting from the price increases of gas is that boilers are being redirected to alternative fuels. As of 2015, 801 boiler houses were redirected to other fuels, 70% out of them to wood, representing 50 mmcm/year in decreased gas consumption, so far a small amount (MinReg, 2016).

Building on the content of this section, Section 7 provides an overview of different scenarios for energy savings, with estimates of the particular effects of different energy efficiency measures on gas consumption in Ukraine.

5 Method

This study seeks to estimate the effect of a recent Ukrainian implicit subsidy reform on the household gas demand. As previously outlined, we will specifically be answering the following research question:

> What effect will the removal of implicit natural gas and heat subsidies have on the household demand for gas?

5.1 Literature review of price elasticity of demand

When a subsidy is removed and the prices for the consumers subsequently rise, the effect therefrom will depend on how responsive household demand for natural gas is to price changes. The most common measure used for this type of analysis is the price elasticity of demand (PED). It is usually calculated as the percentage change in the quantity demanded in response to a one percent change in price. Normal goods have a negative value of the price elasticity (as the price increases, demand declines). A good is said to be inelastic if the PED<1 and elastic if PED>1. In an overview of the literature, Yoo, Lim & Kwak (2009) find that the results of studies on short-run elasticities range from –0.03 to –0.9, while the long-run values range from –0.2 to as high as –4.6. For Germany, Rehdanz (2007) estimates price elasticities of household demand for gas-fired heat in the range of –0.44 and –0.63. The latest study looking into natural gas price elasticity of demand in Ukraine is a 2012 study by the IMF (Mitra & Atoyan, 2012). It employed a cross-section analysis on the 2010 Household Living Conditions Survey data from the State Statistics Service of Ukraine to derive the elasticities of both gas and heat consumption among the population. The study controlled for various household characteristics influencing gas and heat demand and estimated the short-run household heat price elasticity at –0.17 and the gas price elasticity at –0.26, although it also included LPG consumption from cylinders when calculating the latter elasticity. In all studies reviewed, demand for natural gas is found to be price-inelastic in the short run, but may be price elastic, sometimes with the elasticity being much larger than 1 in the long run. The price elasticity is also known to be somewhat dependent on the relative price level. With the historically very low prices for gas in Ukraine as well as rather low levels of metering, we would expect the estimated price elasticity to be somewhat lower than in other comparable countries.

In our work we make a distinction between demand for heating and demand for gas. In a study of the Swedish households living in blocks of flats, Nässén (2007) estimates the long-run price elasticity of demand for heat over the period 1970–2002 at −0.48. In a more recent study of the Swedish district heating market, Werner (2009) estimates the long-run price elasticity of demand for district heat at −0.35 (using data over the time period 1970–2006). However, the Swedish elasticity for district heating is not easy to transfer to the Ukrainian case. The lack of heat metering in Ukraine fundamentally decreases the possibility and incentives for a household to react to higher prices. These differences make us expect the heat elasticity to be lower in Ukraine than the studies from other countries indicate.

There is a set of specific concerns related to price elasticity studies which we need to consider for the purpose of our study: the distinction between short and long-run elasticities, elasticity when consumers do not have a meter, cross-elasticities—substitution to fuels other than gas, varying elasticities between income quintiles, and regional differences in elasticities.

Short- and long-run elasticities: In the short run, people can often do very little to change their gas consumption. If households rely on gas for heating as well as for cooking, even when there is a price increase, they might not be able to decrease their consumption. In the long run, households can invest in energy-saving technology or shift to other sources of fuel, which often generates much higher price elasticities of demand. The way the short run is defined often depends on the periodicity of the data (usually one year), while the long run often spans over several years. Essentially, an individual judgment has to be made how to construct and interpret the estimated price elasticity, depending on the context of the study (Dahl & Sterner, 1991). In our study, the size of the price increase will drive major long-term changes of consumption due to investments in energy efficiency measures, not yet visible in the data. That is why we are also introducing a separate analysis of the scope for energy efficiency measures in Ukraine, as separate from the elasticity estimation.

Metering: As outlined in Section 4, some types of consumption of gas in Ukraine are largely unmetered. A basic feature of elasticity is that consumers react to changing prices by changing their consumption. If a consumer is given a fixed price for a good, which does not take into account their level of consumption, then the consumer does not have an elasticity in the normal meaning of the word (the consumer faces a choice of either paying a fixed price independent of consumption or entirely resigning from the consumption). Only 27% of the households using gas for cooking and 72% of the households using it also for hot water are metered. We would expect this consumption to have a considerably lower elasticity than for gas consumed with meters. As a result, in our study, we conduct a separate analysis of the elasticity of this type of gas consumption.

Cross price elasticities: Some natural gas demand elasticity studies model the quantity demanded also as a function of substitute fuels. Specifically, these models estimate cross-price elasticities, predominantly for electricity. For example, Beierlein, Dunn & McConnon (1981) find that the cross-price elasticity between gas and electricity for residential housing is 1.70, that is, for each 10% increase in the price of electricity, the demand for gas will rise by 17%. In Ukraine, there is empirical evidence of DHCs substituting wood for gas, as gas-boilers are sometimes refitted to use wood as fuel (MinReg, 2016).[14] There are also indications that households with access to affordable wood and appropriate stoves are substituting some of their gas consumption with wood, particularly in rural and more forested areas (Mitra & Atoyan, 2012). In our study, we are not able to include a variable controlling for this effect due to the lack of data on the pricing and availability of wood across households in Ukraine. This will remain a limitation of our study.

Income effects: In demand elasticity studies in the energy sector it is necessary to simultaneously control for income effects (income elasticity). The reason is straightforward—gas is a normal good, so with increasing/decreasing income the consumption is expected to increase/decrease independently from the pricing of gas. A linear model specification can be used, if it is assumed that the effect of higher income is linear across all income levels. Sometimes other specifications are used, for example interacting income with price elasticity, capturing how the elasticity can vary across different income levels. For example, Alberini, Gans & Velez-Lopez (2011) find that the price elasticity of electricity demand declines somewhat with income. Mitra & Atoyan (2012), studying Ukraine, on the contrary find that the elasticity of gas increases somewhat with higher income, albeit with significant results only in the higher income quintiles. To conclude, it is not clear from the literature if we should expect different elasticities across different income levels but we will test for such a possibility.

[14] Around 575 boiler houses were redirected from gas to wood in 2015, more or less following the degree of the relative percentage of the forest cover in different parts of the country (MinReg, 2016).

Regional differences in elasticity: In case of regional differences in terms of availability and cost of substitutes, we expect to see variance in the price elasticity of gas. For example, differences in regional policies providing different costs for substitutes (for example energy-saving equipment) can affect the elasticity of demand for consumers. Also the perceived value of gas-fired heating might depend on the average temperature differences across regions, which in turn would affect the elasticity (if it is very cold, consumers value heating higher and thus their elasticity is lower). In a study by Bernstein & Griffin (2006), the gas elasticity in the U.S. is estimated at three different levels of aggregation (national, regional and state level). The study finds minor differences between regions in terms of the elasticity for residential gas. The authors' main recommendation for the U.S. Department of Energy is thus to keep the level of analysis for natural gas demand on the national level. In the case of our study, as previously mentioned, the access to substitutes such as wood could vary across regions. We also expect some differences in regional policies, especially when it comes to the degree of implementation of metering of heat consumption. Altogether, although we expect regional differences to be a relevant factor for our model, as there seems to be some differences between the availability of substitutes for gas across Ukrainian regions, we lack sufficient data to control for them in our model. This will remain a limitation of the model.

To conclude, we have derived the following hypotheses:

- **H1**: The short-run Ukrainian price elasticity for gas is expected to be inelastic, ranging between –0.1 and –0.6, probably in the lower bound of that range. The elasticity for heat is expected to be somewhat lower than the average values from other studies, around –0.1 to –0.4.
- **H2**: We expect to see larger price elasticities of gas and heat in the long run than in the short one, mainly due to improvements in energy efficiency.
- **H3:** The lower the level of metering, the less elastic the consumption should be. Accordingly, heat should be less elastic than gas for heating, and gas used for cooking is expected to have even lower elasticity.
- **H4**: The higher the availability of substitutes to gas consumption, the higher the expected price elasticity. Accordingly, in areas with greater access to wood, the elasticity should be lower.
- **H5**: We expect differences in the elasticities for different income levels.
- **H6**: We anticipate that there will be regional differences affecting our estimation, especially through the effect from substitution from gas to other fuels, such as wood.

We expect the elasticity to have changed from the IMF estimates from 2010 (Mitra & Atoyan, 2012) mainly through three key mechanisms. First, real wages increased by 13% from 2010–2014, which should affect the price elasticity (MinFin, 2016). Second, the number of houses with heat meters rose from around 30% in 2010 to 38–40% in 2014, increasing the heat elasticity due to increasing incentives to save as prices rise (MinReg, 2016; NCEPUR, 2015; Semikolenova, Pierce & Hankinson, 2012). Finally, IMF's gas elasticity is a joint elasticity for both natural gas and LPG consumption while we chose to analyze only the former. The next subsection will introduce the dataset used and the specific method chosen.

5.2 Dataset used in the study

Previous empirical studies on natural gas demand can be classified into two different categories, based on the data used in them. The first category of studies uses cross-sectional survey data. An overview of such studies is given in Bohi & Zimmerman (1984) and Zhang (2011). Some of these studies use dynamic demand models assuming lagged reactions to price changes. Others use static models, studying demand only at a snapshot of time. The main benefit from using cross-sectional survey data is that it is usually rich in variables which can be used as controls for household characteristics affecting the demand.

The second category of studies pools the data and uses panel data estimators, often using a time-series of cross-sections. Notable studies in this category include Balestra and Nerlove (1966), Al-Sahlawi (1989) and Maddala, Trost, Li & Joutz (1997). These studies look at aggregate time-series data over countries or regions, often over longer time periods spanning decades. These studies make it easier to compare regions or countries over time and the data required for the studies is generally easier to come by.

This paper uses the Household Living Conditions Survey from the State Statistics Service of Ukraine, kindly provided to us by the Kiev School of Economics. It is a quarterly survey targeted at a sample of between 8,500 and 11,000 Ukrainian households, providing information about social and demographic characteristics, living conditions, structure of actual expenditure, income, state benefits and other indicators relevant for estimating household living standards.[15] The aggregate annual data set is finalized the following year around June, which is why the latest available dataset for this paper is from 2014. The dataset is based on yearly independent cross-sections (they are not completely independent since the surveyed households are partly reused year from year). The dataset is known to be somewhat unrepresentative of the population as a whole as it contains too small number of affluent households. This can be corrected with frequency weights included in the dataset which allow to give greater weight to underrepresented types of households. In 2014, the survey gathered information from 8,814 households, including 467 households from Autonomous Republic of Crimea and Donetsk and Luhansk *oblast*s which we decided to drop because of the Russian annexation of Crimea and the ongoing war in parts of Donetsk and Luhansk.

With this type of data, generally two methods can be used: a static model based on the last available year's data or a model pooling independent cross-sections (IPCS) over time. The static model gives a snapshot of the price elasticity of a particular year. With a sufficient sample size, it often gives an adequate measure of the price elasticity. An overview study found that such elasticity is often best interpreted as "intermediate," with values in between the short and long term price elasticities (Dahl & Sterner, 1991). Pooling the cross-sections and adding indicator variables to control for temporal instability allows to determine changing structural relationships between variables as well as increases the sample size. On the other hand, the correct specification of the model becomes more difficult and the model becomes more susceptible to groupwise heteroskedasticity (Wooldridge, 2015). In Ukraine,

[15] Details and methodology of the survey can be accessed through the website of State Statistics Service of Ukraine (2016a, 2016b).

even in the short term, there have been large changes in both metering, the pricing structure and in the energy efficiency in the natural gas market, only partly covered in our model specification. This becomes a problem when pooling the data. Therefore, we are using a static model with the latest data (2014) to estimate the elasticity.

6 Model

We estimate the natural gas price elasticity through a log-linear function of gas demand for a given household *i*:

$$\ln Q_i = \alpha + \beta_1 \ln P_i + \beta_2 \ln Y_i + \beta_3 \ln area_i + \beta_4 \ln HDD_r + \sum_{d=1}^{4} \delta_d X_d + \varepsilon_i,$$

where Q_i is annual natural gas consumption by a household without a district heating (DH) connection, P_i is the effective price of gas, Y_i is the total yearly household income, $area_i$ denotes the total living area, HDD_r represents the number of heating degree days for the oblast r in which the household was located, and X_k is a vector of 4 dummy variables which define various characteristics of the household, specifically: type of accommodation (house vs. apartment), presence of a gas water heater, presence of an individual heating system and if the house is new (a new building constructed after 1990 or an old one renovated after 2000).

The reason we estimate the gas demand only for households without a district heating connection reflects the fact that we expect households with DH to be mostly inelastic to price variation. Households which obtain heat through a DH network consume gas mostly for cooking purposes, and sometimes for heating water in the bathroom. In 2014, such gas consumption remained largely unmetered and most households paid a flat rate independent of the amount of gas used. Thus, in accordance with hypothesis 3, whichever price such a consumer face, we expect them not to adjust their behavior, at least until metering becomes more commonplace. To verify our expectations, we run a separate regression for such households and find that their consumption's price elasticity in 2014 was statistically insignificant with a coefficient indeed close to perfect inelasticity (Table 4).

Since the household survey data does not provide information about the actual consumption of gas, we calculate the volume based on the households' reported gas expenditure and the gas subsidies it received. The effective price of gas, P_i, in turn, is calculated by dividing the gas bill by the consumed volume of gas, Q_i. This way we can retrace the effective price of the households which received some subsidies or social benefits. Since such households faced a different consumer choice due to a lower price, the difference between their prices and the prices of households which paid the unsubsidized price will help to explain the variation in consumption caused by pricing differences. Due to the fact that 26% of gas-consuming households in our sample received some form of direct gas subsidy or benefit and that its size varies from a minimal amount to as much as a full discount of 100%,[16] a

[16] For instance, households in which there is a disabled war veteran can consume a predefined amount of gas free of charge.

significant variation is introduced to the price-consumption relationship enabling estimation of the price elasticity.

The *total income* of a household, Y_i, represents the sum of cash income, the value of self-produced consumption, and the subsidies and social benefits of all the households' members. Importantly, the main specification of our model assumes a homogeneous price elasticity across different income groups and thus evaluates the price elasticity at average income. We also constructed an alternate specification of our model allows for heterogeneous elasticities between different income quintiles. *Area* is measured as square meters of floor area (excluding balconies and terraces) of a given household and captures the increased need for gas used for heating as the size of your house increases.

The *HDD* variable represents the total 2014 heating degree days (HDDs) with the base temperature of 18°C. Since the heat consumption is largely influenced by the prevalence of cold temperature, the *HDD* variable is expected to control for weather-induced changes in heat demand. The only location information provided by the survey dataset for a given household is the *oblast j* in which it is located. Thus, the HDDs are obtained from the most reliable weather station in that *oblast*, such as an airport in the main city, and then applied to each household located in that *oblast*.[17]

The dummy for *apartment* shows the structural differences between the consumption of gas between a separate house and an apartment. The most important difference is the ratio between the surface area and the housing area—heating constitutes the largest share of gas consumption and heating dissipates through the building envelope, more so for houses than for apartments. Apartments are also less equipped with gas meters than houses, giving higher than real norms for consumption of gas (see energy efficiency section) as well as inducing behavioral changes to save gas, which will also be represented in this variable, since it is not picked up directly in any other variable.

For households using gas for heating their houses, the level of energy efficiency, especially the thermal efficiency of a house, will influence the gas consumption of the household. Ideally, a variable measuring energy efficiency directly and specifically for each household should be included. Lacking such data on the household level, a dummy *new house* has been created, including separate houses built after 1990 or houses renovated in 2001 or later. It picks up the effect from energy efficiency differences between houses which are newly built and/or have undergone major renovations as compared with other houses. The dummy for *gas water heater* further separates the additional effect from households which also use gas for heating water. The dummy for an *individual heating system* controls for the effect on gas consumption from using gas also for heating.[18]

The heat price elasticity is estimated through a similar log-linear function:

[17] Due to lack of data for Ternopil and Kirovohrad *oblast*s, the HDDs from Khmelnytskyi oblast (Khmelnytskyi airport) are used for Ternopil, and Lozovatka airport's HDDs are used for Kirovohrad (Lozovatka lies at the border of Kirovohrad oblast).

[18] This variable will also capture some other variation. An individual heating system can use also other fuels, including biomass, electricity and coal. In our dataset, 92% of the households who have an individual heating system are also connected to the gas network and a large fraction of them will be using gas for heating (but not all).

$$\ln Q_i = \alpha + \beta_1 \ln P_i + \beta_2 \ln Y_i + \beta_3 \ln area_i + \beta_4 \ln HDD_j + \delta_1 \text{ post-1980}_i + \varepsilon_{i,}$$

where Q is annual heat and hot water consumption is provided by a district heating company to a given household *i* and P_i is the effective heat price. As with the natural gas demand, Q_i is estimated by taking the data on household's bills and the value of relevant social benefits and subsidies, and dividing its sum by the weighted-average final household price of heat. The effective price, in turn, is obtained by adjusting the weighted-average heat price by the value of social benefits and subsidies.

Since all the households in the sample which are connected to the district heating network live in blocks of flats, we exclude the variable describing the type of housing. The variable *post-1980* includes blocks of flats built after 1980. This variable encompasses some energy efficiency differences in the housing stocks before and after 1980 as stricter building norms and better materials were used prior to 1980 (Mitra & Atoyan, 2012, p. 13).

7 Results

7.1 Regression results

In line with the first hypothesis (H1), we find that the gas demand by households without a district heating connection has a price elasticity of –0.20 while the heat demand shows price elasticity of –0.15 (Table 4 and Table 5). In other words, for every 10% price increase of heat, its consumption falls by 1.5%, while for gas a 10% price increase leads to 2.0% less demand. In accordance with our third hypothesis (H3), we find that the price elasticity for gas consumption by households with a district heating connection is almost perfectly inelastic (these households use gas only for cooking and hot water). This result is insignificant, mostly as a result of the majority of these households' consumption not being metered, making it hard to find evidence of them having any elasticity (Table 4). The differences in elasticities reflect not only a strong difference in the proportions of metered volume between the three consumptions but also the differences between the types of goods in terms of substitutability and household demand functions.

Our results are somewhat lower than in other studies looking at gas and heat elasticities. In accordance with our second hypothesis (H2), correctly interpreting the results requires an evaluation of the degree to which they also incorporate long-run changes. In a comparative study, Dahl & Sterner (1991) found that the elasticity from cross-sectional estimates was best interpreted as "intermediate," meaning being in between the short and the long run. This can be interpreted as a couple of years, if the data has a one-year periodicity (Dahl & Sterner, 1991). Thus, our elasticity results are most valid for the coming years, while the long-run effects of this policy will also include effects from increasing energy efficiency investments, as estimated in Section 8.

Table 4: Natural gas demand regression results

VARIABLES	(1) Gas volume w/o DH	(2) Gas volume w/ DH
ln_eff_gas_price	-0.201***	-0.0174
	(0.0257)	(0.0671)
ln_income	0.215***	0.317***
	(0.0156)	(0.0268)
ln_area	0.274***	0.332***
	(0.0224)	(0.0368)
ln_hdd	0.247***	
	(0.0812)	
apartment	-0.468***	-1.718***
	(0.0222)	(0.279)
new_house	-0.0411**	
	(0.0183)	
gaswaterheater	0.0775***	0.424***
	(0.0171)	(0.0351)
indheatsystem	0.336***	
	(0.0283)	
Constant	-3.878***	-4.042***
	(0.748)	(0.565)
Observations	3,786	2,281
R-squared	0.336	0.180

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Heat demand regression results

VARIABLES	(1) Heat volume
ln_eff_heat_price	-0.149***
	(0.0306)
ln_income	0.108***
	(0.0142)
ln_area	0.566***
	(0.0209)
post1980	0.0428***
	(0.0153)
ln_hdd	1.507***
	(0.114)
Constant	-10.50***
	(1.005)
Observations	2,539
R-squared	0.316

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Apart from establishing the price elasticities, the model measures the extent to which other relevant variables influence both the heat and gas demand. All of the coefficients have the expected sign and are statistically significant. Some of the findings:

1. Gas demand is more sensitive to income changes, for the same reasons as it is more sensitive to variation in price. For every 10% increase in income, gas demand rises by 1.6% while heat demand rises only by 1.1%.
2. Area is more than twice as important for heat consumption as it is for the gas demand. This stems from the fact that while the amount of heat consumed is directly proportional to the total living area, the demand for gas is less so as it is also consumed for cooking and preparing hot water.
3. Due to better energy efficiency of newer buildings, the newer or more recently renovated the house is, the less gas is consumed. We see the opposite result for heat demand in blocks of flats. If a block of flat was built post-1980, it will on average consume more heat.
4. The presence of a gas water heater and an individual heating system drive the volume of gas demanded by 8% and 34%, respectively.
5. Despite the fact that HHDs were measured on an *oblast* level, their effect is statistically significant at the 1% level. For every 10% increase in HDDs, heat consumption rises by 15% while gas consumption rises by 2.5%. The effect for heat reflects the fact that more heat is supplied in *oblast*s which have colder weather. The size of the effect is smaller for gas as many households use gas only for cooking, which they do independently of the weather.

As discussed in hypothesis 5, it is possible that different income groups exhibit different price elasticities. In order to verify if that is the case, we checked the robustness of the above model by creating a separate regression model based on the assumption of income-based heterogeneity. Instead of a single homogeneous price variable, we employed interaction terms between the effective price and five different income subsets, created with the help of the survey weights, which allow to identify possible differences in elasticities between such groups. As indicated by our regression results (Appendix A) the elasticities do not differ economically between the quintiles for both the gas and heat demand. We further confirmed this by performing Wald tests which did not allow us to reject the hypothesis that the elasticities between the income quintiles significantly differed between one another.

7.2 Limitations

The above model gives a good estimate of the price elasticity of demand for both gas and heat but there are some areas where it faces certain limitations. Generally, the validity of a model and its results is based on the extent to which the model represents reality. This will depend on the right method being chosen, using high quality data and including all relevant variables in the model. The following will give an overview of the validity of our model, judging from these factors.

First, an elasticity is usually defined either as a point elasticity, measuring the elasticity at one specific point on the demand curve, or as an arch elasticity, measuring the average elasticity over a range of points on the demand curve. Regardless of the method utilized, the value of the elasticity will be different at different places on the demand curve (typically with lower elasticity when the good is comparatively cheap and higher elasticity as it grows relatively more expensive; Griffiths & Wall, 2008). As a result, our estimated elasticity will be most accurate when estimating the effects from price changes around the average prices of gas paid by consumers in 2014. As the price increase becomes large, it shifts consumption to another point on the demand curve, decreasing the validity of our estimated elasticity. Consequently, we get a larger expected error of our coefficients when we estimate the effects of a very large price increase, as has been the case in Ukraine.

Second, the sample itself shows some limitations. As is often the case with survey data, our dataset does not perfectly resemble the population and somewhat over-represents low-income households. This can pose a problem when extracting summary statistics from the dataset. Fortunately, the dataset contains frequency weights which can be assigned to each household in order to make it representative of the population as a whole. When performing regressions, however, whether differential sampling becomes an issue will depend on the source of the differences between the sample and the population. A problem occurs when there is a so-called endogenous sampling. If the sample and population differ only because of selection on factors that are exogenous within the model, then there is no need to apply weights (O'Donnell & Wagstaff, 2008). Another way to say this: if determinants of gas consumption which are not part of the model (they are in the error term) are uncorrelated with income, conditional on the variables controlled for in the model, then there is no need to apply weights. One way of determining the prevalence of endogenous sampling is by comparing the results of the unweighted regression and the weighted regression. When those regressions yield diverging results, that is often a sign that there is a problem, such as endogenous sampling (Friedman, 2013). In our regressions, applying the weights yield very similar results on all variables except the regional HDD variable which we have added to the dataset (see Table 17 and Table 18 in the Appendix A for the result with weights). We interpret this as an indication that our model does not suffer from endogenous sampling.

Third, there is a war in the eastern parts of Ukraine. This poses a problem insofar as direct warfare often leads to a large insecurity of the population, people fleeing their homes, and public utilities not functioning, including natural gas deliveries. The areas close to the front are most directly affected by the above mentioned disturbances and thus pose the greatest problems. For this reason, we have decided to exclude the entire *oblast*s of Donetsk and Luhansk from our sample in order to minimize effects from direct warfare on our estimates. For the rest of Ukraine, the war should mostly affect households through economic decline and bleak future prospects, after controlling for real income changes, not further affecting our estimation. In Section 8, when estimating the size of the market, the areas in Donetsk and Luhansk *oblast*s not controlled by separatists are included in the analysis, assuming that their elasticity as a whole is more or less equivalent to the rest of the population. This is a limitation if the demand functions for natural gas are indeed somewhat different in those regions.

Fourth, there are several variables that could be important for determining gas and heat consumption but which we have not been able to include in the model. First, we lack data on whether a household has meters for gas and heat consumption or not. According to our hypothesis 3 (H3), we would expect households with meters to have a higher elasticity since they have more incentives to change their consumption when prices change. Since we cannot include this in our regression, we add it as a separate effect in the energy efficiency analysis, using an estimate of the behavioral change from introduction of metering based on Naftogaz's analysis (2015a). Second, anticipating a price hike for natural gas, there is a legal possibility for households to report an increased level of consumption of gas during the months prior to the price increase, in order to decrease the consumption under the new, higher pricing regime. This phenomenon might have been prevalent during 2014, as households were anticipating the price increase of 2015 (Maslichenko, 2016). This will lead to a bias in the estimated elasticity as households report a higher consumption of gas prior to a price change and then a lower consumption after the price change. This is not accounted for in our model. Third, as outlined in our hypothesis 4 and 5, differing access to substitutes to gas will be important in determining the elasticity. For example, if you have access to a wood stove and access to cheap wood, you can substitute gas consumption with wood. We do not have access to data on prices and availability of substitutes in different regions of Ukraine and thus our model will not show the separate effect of this phenomenon. Last, prevalence of non-payment of consumed gas, when at a large scale and occurring specifically as a reaction to rising prices for gas, will have an effect on the price elasticity. Where such a possibility exists and the rate of non-payment changes over time with price increases, we would expect the price elasticity in the short run to be lower than when such a possibility does not exist. We are not able to include non-payment into our model.

Last, there are long-term changes in the structure of gas demand which our model does not take into account. First, our model does not cover the effect from higher prices on increased incentives for investments aimed at energy efficiency improvements. As a result of the price increase, in the long term, there will be an increased level of investments in energy efficiency measures, decreasing consumption more than shown in the price elasticity estimate, as outlined in Section 4. Second, higher prices might also create a different legislative and political environment, where the government for example chooses to subsidize loans with the purpose of increasing energy efficiency, change the requirements for gas metering or change the centralized norms of consumption. For instance, such changes all occurred in 2015 alone, which will affect the elasticity of demand but is not controlled for in our model. Last, as arbitrage opportunities diminish through higher prices of gas, we should expect to see less household gas being whisked away for corrupt purposes. In our model, a decreased level of corruption will show up as an upward bias of the price elasticity, since part of the measured decrease will capture a decreased reclassification of gas consumption previously illicitly resold towards other uses.

8 Estimating demand for gas in Ukraine

This section will apply the results from the previous sections in order to estimate the effect on demand for natural gas in Ukraine in 2020. The most important variables affecting the total size of demand will be identified and expected effects on gas consumption in bcm in 2020 will be derived. This will be done by using three different scenarios, using different assumptions about the development of the Ukrainian import price, the size of explicit gas subsidies introduced, the size of actual energy efficiency savings as well as other variables affecting the size of demand.

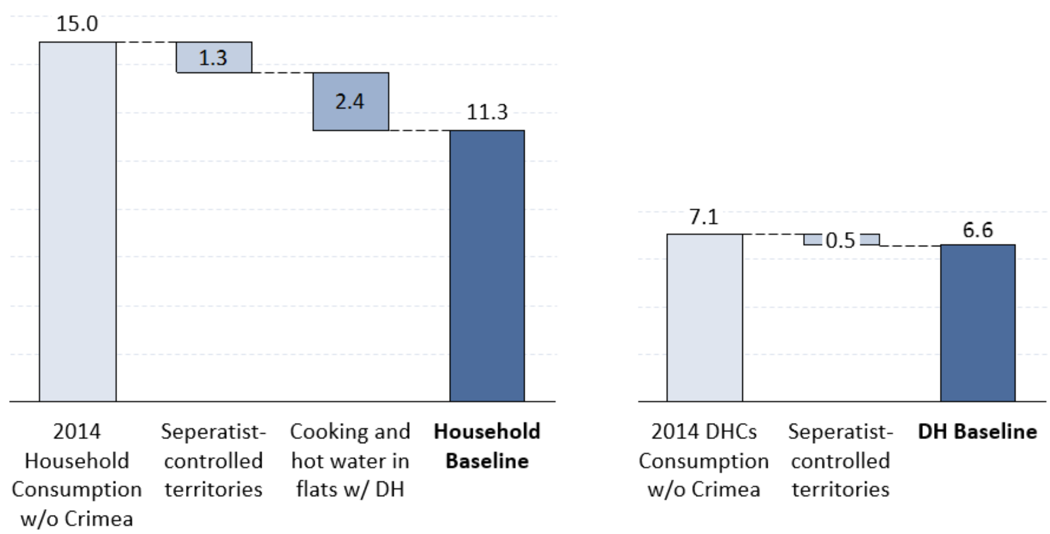
8.1 Estimation of the effect from a full subsidy removal

In this subsection, first, a measure of the required price increases to reach full subsidy removal is calculated. Then the baseline upon which the consumption change should be based is derived. Finally, applying the elasticity measures, estimates of decrease in the size of the market due to the subsidy cancellation is presented.

In 2014, the household tariff for gas on average equaled UAH 1,030/mcm, or USD 86/mcm, out of which the price of gas as a commodity was UAH 473/mcm, or USD 39 (Naftogaz, 2015a). Assuming that the 2017–2020 import price was to equal USD 200, which is roughly the May 2016 forward price for December 2017 at the German NGC hub together with transportation costs to Ukraine, the 2014 *price of gas as a commodity* would have to increase by 407% to reach import parity, holding explicit subsidies, inflation, and currency exchange rate constant. Given no change in transportation, distribution and supply tariffs, and adjusting for the size of VAT and the 4% surcharge, this would translate into the *final price* of gas having to increase by 237% from the 2014 level to reach the import-parity level. Applying our elasticity results of 2.0% decrease of demand for each 10% increase in price, we estimate direct gas consumption to fall by 48% as a result of a full implicit subsidy removal. This estimate changes to 39% and 56% if we assume the import price to change to USD 170/mcm and USD 230/mcm respectively.

The 2014 weighted-average consumer heat tariffs including VAT, in turn, equaled UAH 390/Gcal, while the DHCs' total heat production costs equaled on average UAH 509/Gcal. To reach import-parity of USD 200/mcm, the gas component of the UAH 390/Gcal tariff would have to increase by 315%. Assuming no change in the transportation tariffs, other costs, and adjusting for the size of the VAT, the final price of heat would have to increase by 148% from the 2014 level to reach the cost-recovery level, translating into a 22% fall in consumption from a full subsidy removal. With USD 170/mcm and USD 230/mcm import prices the fall would be 19% and 25% respectively.

Figure 16: Consumption baselines for estimating the subsidy removal's effect, bcm



Source: Own estimates based on Naftogaz (2015c & 2016a).

The percentages of the predicted fall in the consumption should be applied to correct consumption baselines (see Figure 16). The official figures reported by agencies include Crimean consumption for the first two months of 2014 so we excluded them. Furthermore, households in territories controlled by separatists (ATO Zone) are not affected by the Ukrainian reforms and thus their consumption will not react to the subsidy removal and hence we exclude an estimate of their consumption from our baseline.[19] How the consumption in the ATO Zone is reacting to the ongoing conflict is a topic for a separate research, especially as those territories are now partly supplied with gas from Russia. In addition, our household consumption baseline, as suggested by our regression results, excludes households connected to the district heating, since they exhibit no price elasticity in their gas demand. For the baseline of gas consumption by the DHCs producing heat for the population, we only need to exclude the 2014 consumption in Crimea and the ATO Zone. This results in a baseline of 11.3 bcm for direct household gas consumption and 6.6 bcm for heat consumption.

Table 6: Consumption decline due to the subsidy removal, three scenarios

	USD 170 import	USD 200 import	USD 230 import
Gas baseline, bcm	11.3	11.3	11.3
Tariff increase for import-parity	194%	237%	281%
Gas price elasticity	(0.20)	(0.20)	(0.20)
Change in consumption, bcm	(4.4)	(5.4)	(6.4)
Heat baseline, bcm	6.6	6.6	6.6
Tariff increase for import-parity	129%	148%	167%
Heat price elasticity	(0.15)	(0.15)	(0.15)
Change in consumption, bcm	(1.3)	(1.5)	(1.6)
2014 market w/o Crimea and ATO	22.0	22.0	22.0
Total consumption change, bcm	(5.7)	(6.8)	(8.0)
Total consumption change	(26%)	(31%)	(36%)

Source: Own estimates.

Applying our elasticity regression results (Table 6), a 48% decline in household consumption due to the removal of the subsidy translates into a 5.4 bcm decrease in gas consumption, while the other import price scenarios result in 4.4 and 6.4 bcm decreases. The DHCs' gas consumption would fall by 1.5 bcm under the medium import price scenario and 1.3 and 1.6 bcm with a low and high import prices. Altogether, we expect the market to decline by 5.7–8.0 bcm (26–36%), with the most likely medium scenario indicating a 6.8 bcm (31%) decline.

8.2 Estimation of the effect from changes in explicit natural gas and heat subsidies

In order to correctly estimate the actual effect on demand from removing the gas subsidies in Ukraine, the actual price increase for the average consumer needs to be calculated. The Ukrainian government is planning to expand current explicit subsidies for the population, thus partly offsetting the price increases. This subsection tries to derive an estimate of the actual price increases for the consumers, assuming different scenarios of changes in explicit subsidies.

Explicit subsidies for housing and utility services (HUS) in Ukraine are targeted governmental payments designed to ease the burden of payment on both the poorest citizens and the ones with special status. Contrary to implicit subsidies, explicit subsidies are not applied indiscriminately and

[19] Ukrainian authorities do not provide official information on gas consumption in the ATO Zone and thus our numbers are rough approximations based on historical figures.

thus better fulfill the social purpose of protecting the vulnerable. Normally, the explicit subsidies are disbursed to the utility companies which then deliver the subsidized services to the households, which simply receive a lower bill. In 2015, only 2% of the explicit subsidies were directly paid to the households (Pavlyuk, 2016). Unfortunately, it is commonplace that the utilities do not actually receive the necessary funding. In 2015, a third of explicit subsidies ended up as budgetary debt (MinReg, 2016). At the same time, however, the absence of comprehensive gas and heat metering allows utility firms to overstate household consumption in order to illicitly capture part of the state subsidies (Pavlyuk, 2016).

It is important to note that the estimation in Subsection 8.1 assumes no change, from 2014 onward, in the percentage of household gas and heat expenditures covered by explicit governmental subsidies and thus the absolute value of the subsidies is assumed to grow proportionally with the price increase. This is in line with Ukraine's governmental plan of rolling out a more extensive system of targeted explicit subsidies. The plan, which is developed with the IMF assistance, strives to ease the burden of the implicit subsidy removal on the vulnerable citizens. According to the IMF, as much as 27% of all Ukrainian households are supposed to be shielded from the tariff increases (IMF, 2014, p. 21). This change in explicit gas subsidies needs to be taken into account when estimating the size of the demand of gas in 2020.

In 2014, the Ukrainian budget provided around UAH 6bn for various HUS subsidies (MinReg, 2016). Since gas subsidies accounted for around 46% and heat subsidies for roughly 30% of the total value of the HUS subsidies,[20] we estimate their 2014 value at UAH 2.8bn and UAH 1.8bn, respectively. Assuming a constant portion of gas and heat bills covered by the explicit subsidies, the scenarios from Subsection 8.1 imply that the gas and heat subsidies would grow to UAH 9.3bn and UAH 4.5bn (in 2014 hryvnia), respectively, with import price of USD 200/mcm.

Provided we assume a full realization of the IMF's proposal to protect 27% poorest households from an implicit subsidy removal by keeping their gas and heat prices at an average 2014 effective price—that is the actual price taking into account both the implicit and explicit subsidies, and increased the prices to the import-parity only for the remaining 73%, we coincidentally find that this would increase the cost of the explicit subsidies almost precisely to the levels assumed in Subsection 8.1.[21] In particular, if we raise the gas and heat prices to the import-parity only for the 73% of richest households, we find that the total decrease in the overall gas consumption with USD 200/mcm import price is expected to equal 6.7 bcm, marginally different from the 6.8 bcm stated in the previous subsection. It is uncertain, however, if the governmental explicit subsidy program will be that extensive. With less than 27% of households shielded from the price increase, more families will face higher prices and thus the consumption will fall further. Table 7 shows this full scenario as well as two other scenarios: assuming only 18.5% and 10% households being protected from the tariff increase.

[20] Estimates based on data from the 2014 household living condition survey.

[21] Importantly, we assume that the poorest 27% households consume around 23% of the total gas consumption (estimates based on Naftogaz, 2015f).

Those scenarios result in 7.4 and 8.0 bcm decrease in consumption, respectively, if the import price is USD 200/mcm.

Table 7: Consumption decline, scenarios based on the extent of the explicit subsidies

Share of households protected from the price increase	10% of households			18.5% of households			27% of households		
Import price per mcm, USD	150	180	220	150	180	220	150	180	220
2014 market w/o Crimea, bcm	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Total consumption change, bcm	6.7	8.0	9.3	6.2	7.4	8.6	5.7	6.7	7.8
Total consumption change	31%	37%	42%	28%	34%	39%	26%	31%	36%

Source: Own estimates.

Last but not least, the predictions of the changes in gas and heat demand derived from our model do not fully take into account the effects from depreciation of the hryvnia. Estimating how the depreciation will affect the consumption is difficult, since it also depends on the influence from inflation and income changes. Generally, hryvnia depreciation leads to a rising price of imports. If, however, depreciation was to be perfectly matched by CPI inflation (including gas and heat prices), the real price of gas and heat would not change—only real income would decrease. If, however, the depreciation is not fully matched by inflation, as has been the case in 2014–2015, the market price of gas and heat will be rising in real terms, shadowing the difference between inflation and depreciation. Predicting the way these factors will interact up until 2020 is complex which is why in our estimation of demand for gas and heat we will only include the effect from the expected changes in income over time and will not attempt to predict the future Ukrainian discrepancy between depreciation and inflation.

8.3 Estimation of the effect from changes in energy efficiency

In this subsection, an estimate of the size of savings of gas resulting from energy efficiency investments will be derived. Five areas of savings were outlined in the energy efficiency section: behavioral savings from metering of heat, hot water and gas, savings from more efficient boilers, savings from thermo-insulation investments and savings from more efficient heat generation and transmission among DHCs. Several estimates of the potential gas savings in Ukraine from these types of measures have previously been done (Semikolenova *et al.*, 2012; Naftogaz, 2015d; and Minreg 2016). We base our analysis on these estimates, using 2014 as the baseline (in terms of energy efficiency, very little has happened since 2015, so either year could be used). The analysis will make a distinction between the short and the long term, defined as the period until 2020 for the short term and 2020–2025 for the long term.

The scenarios start from a baseline of the total potential gas savings from energy efficiency related measures, estimated at 11.8 bcm, or a 63% reduction from the 2015 levels of consumption. In Table 8, the total gas savings and required investments for our three different scenarios are outlined, as well as the total potential.

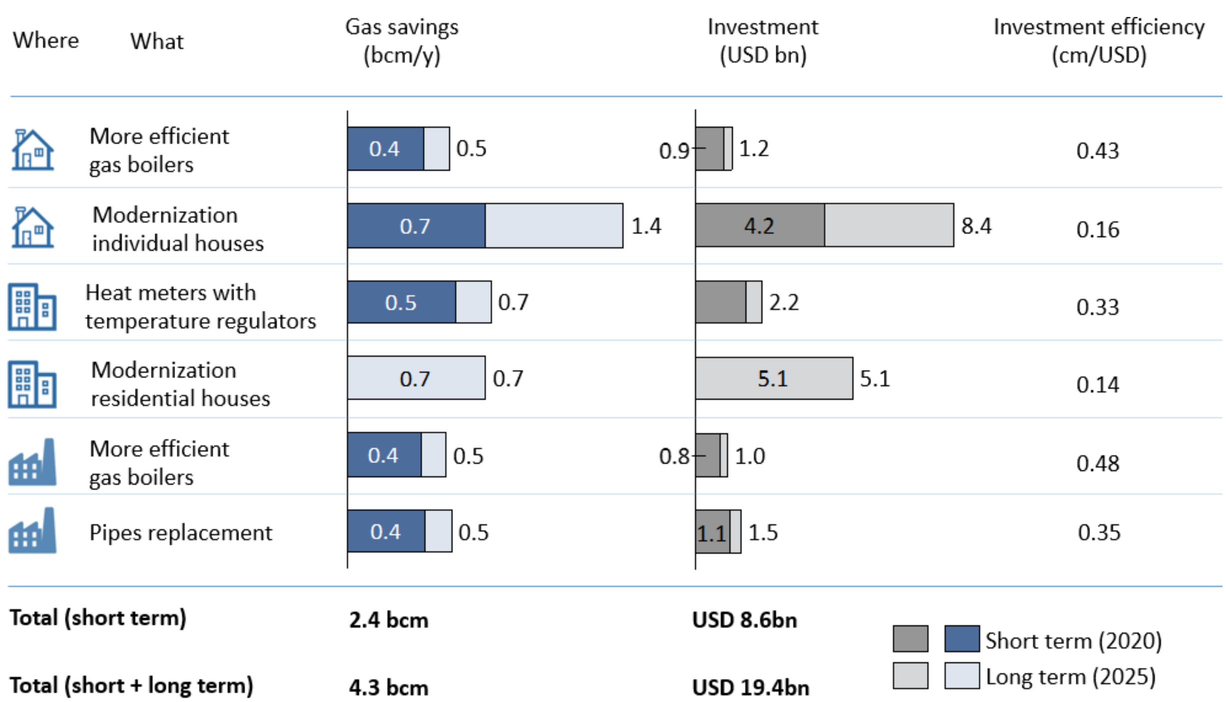
Table 8: Energy savings possible under different scenarios, short term (2020)

	Low scenario		Medium scenario		High scenario		Total potential	
	Short	Long	Short	Long	Short	Long	Short	Long
Total gas savings, bcm/y	1.6	2.5	2.4	4.3	3.3	6.3	6.0	11.8
Total investment, USD bn	5.3	10.2	8.6	19.4	12.7	29.3	23.3	57.4

Source: Own scenario estimates based on Minreg (2016) and Naftogaz (2015d).

In Table 9, our medium scenario for the development of Ukrainian energy efficiency measures is outlined more in detail (medium scenario). In a similar fashion, the low scenario and the high scenario are outlined in more detail in the appendix in Table 19 and Table 20.

Table 9: Estimate of gas savings in a medium scenario, long and short term



Source: Own scenario estimates based on Minreg (2016) and Naftogaz (2015d).

The medium scenario in Table 9 has been created by separately evaluating the probable extent of implementation of each possible energy efficiency measure, weighing the probabilities according to:

- If it already started in 2015, such as metering and replacement of boilers in DHC, the measure gets a high estimate of implementation (around 80% in scenario 2);
- If it has a comparatively high investment efficiency in terms of saved cm/USD, it will get a higher estimate of implementation (between 40–50% in the medium scenario for measures gas boilers for individual houses and district heating companies);

- If the measures require legal changes or requires large investments, it is deferred to the long term and given a quite low estimate of implementation, for example thermo-modernization of blocks of flats estimated at 30%, and only in the long term.

To conclude, in the medium scenario it is assumed that the easily available and relatively economically efficient measures are undertaken to a large extent, namely investments in more efficient gas boilers for households, heat meters for blocks of flats[22] and investments in more efficiency in generation and transmission of DHCs. Thermo-modernization of the housing stock is assumed to be done only to 30% of its potential, even in the long term, due to the legal and financial hurdles to overcome, as well as its relatively low rate of return compared to the other measures. The total savings from energy efficiency measures is estimated at 2.4 bcm in the short run and at 4.3 bcm in the long run, the latter representing 19.5% of the total consumption in the sector in 2014.

8.4 Estimation of the effect from income changes

Another important factor that will affect the development of gas and heat demand in the upcoming years is income. In accordance with theory, all other things equal, we expect that the richer the Ukrainian households get, the more gas and heat they will consume, and vice versa. As found by our model, for each 10% increase/decrease in income, the gas and heat demand is expected to grow/fall by 2.2% and 1.1%, respectively.

Due to the ongoing economic crisis, Ukrainian real GDP fell in 2015 by 9.9% but according to the IMF prediction is expected to rebound by 1.5% in 2016 and by a further 2.5% in 2017 (IMF, 2016). If the 2.5% growth were to continue until 2020, real GDP would be almost 1% higher than in 2014. Even if the growth path will not be realized to such an extent or, on the contrary, will surprise us by its pace, the 2020 real GDP in high likelihood will lie within ±7% of the 2014 level and, for simplicity, we expect the same for the real income. As seen in Table 10, such changes in income will have a very small expected effect on both gas and heat demand.

Table 10: Consumption decline, scenarios based on different income changes

	Low growth	Medium growth	High growth
2017–2020 annual change in real GDP	1.0%	2.5%	4.0%
2020/2014 total change in real GDP	(4.8%)	0.9%	7.0%
Change in gas consumption, %	(1.0%)	0.2%	1.5%
Change in heat consumption, %	(0.5%)	0.1%	0.8%
Total change, bcm	(0.15)	0.03	0.22

Source: Own estimates.

[22] Heat meters are not strictly speaking an energy efficiency measure, since the efficiency gains are achieved entirely through behavior changes, leading to lower energy consumption. They are included here since they require investments (in meters) and will lead to less gas being consumed in Ukraine.

9 Scenarios for demand

There are numerous factors which will determine the household natural gas demand in Ukraine in 2020. In the upcoming few years, the most important factor will be households adjusting themselves to the removal of the implicit subsidies—a mechanism which has already created a strong downward pressure on gas consumption. At the same time, we expect to see simultaneous investments in the energy efficiency measures, stemming from increased prices and governmental efforts, which will further drive the decrease. Third, the Ukrainian government promised to shield the poorest from the effects of the subsidy removal and thus the extent of this help will also change the predicted size of the market. Finally, we expect changes in household income to play only a minor role, as we anticipate similar income in 2020 as in 2014. A summary of the factors can be seen in Table 11 below.

Table 11: Summary of changes in the overall household gas demand depending on various determinants

2020 import price/mcm	USD 170			USD 200			USD 230		
Effect of the implicit subsidy removal, bcm[23]	(5.7)			(6.8)			(8.0)		
Households protected from the price increase	10.0%	18.5%	27.0%	10.0%	18.5%	27.0%	10.0%	18.5%	27.0%
Additional change from explicit subsidy, bcm	(1.1)	(0.5)	0.0	(1.2)	(0.5)	0.0	(1.3)	(0.6)	0.2
Total change from subsidy removal, bcm	(6.7)	(6.2)	(5.7)	(8.0)	(7.4)	(6.7)	(9.3)	(8.6)	(7.8)

Energy efficiency by 2020	low	medium	high
Total change, bcm	(1.6)	(2.4)	(3.3)

Annual GDP growth (2017–2020)	1.0%	2.5%	4.0%
Total change from income, bcm	(0.2)	0.0	0.2

Source: Own estimates. Numbers may not add up due to rounding.

Based on our estimates, we have constructed three scenarios which exemplify different possibilities of how the demand could develop (see Table 11). Scenario 2 is constructed as our most likely scenario, with the values of variables chosen in order to represent our estimates of what we think is most likely to happen. Scenario 1 and Scenario 3 provide scenarios with likely developments which give a low and high estimate respectively.

[23] Assuming a stable relative share of explicit subsidies. For more details, see Subsection 3.3 on implicit natural gas subsidies.

Scenario 1: low import price of USD 170, extensive protection of vulnerable households through explicit subsidies covering 27% of all households, low energy efficiency investments, and 2.5% annual GDP growth from 2017 onwards. Under this scenario, the import price will be low—resulting in lower domestic gas prices. As a consequence, the increases of the 2014 price of gas and heat necessary for establishing import-parity will be relatively low. This, in turn, will not stimulate energy efficiency as strongly as with high prices and thus we assume low energy efficiency investments in this scenario. At the same time, due to low prices it will prove cheap for the government to provide vulnerable households with explicit subsidies easing the burden of higher prices and thus we assume a full coverage of 27%. All in all, under such circumstances we predict a fall in the household market size of only 33%, or 7.2 bcm, to a level of 14.8 bcm of household gas consumption in 2020.

Scenario 2: medium import price of USD 200, extensive protection of vulnerable households through explicit subsidies covering 27% of all households, medium energy efficiency investments, and 2.5% annual GDP growth from 2017 onwards. In this scenario, import prices will be at the same level as in the first half of 2016 and thus will put more pressure on energy efficiency investments than in Scenario 1. Although funding explicit subsidies will be more expensive, it should still be possible to provide them in the full proposed scope, especially given the promise of the IMF to provide loans towards that end (MinReg, 2016). In such a case, we see the demand fall by around 41%, or 9.1 bcm, to 12.9 bcm of gas consumption.

Scenario 3: high import price of USD 230, medium protection of the vulnerable households through explicit subsidies covering 18.5% of all households, high energy efficiency investments, and 2.5% annual GDP growth from 2017 onwards. In this final scenario, we assume a high import price of USD 230 which will make gas very expensive to households given the import-parity pricing. This will drive their consumption down and exert a large pressure to implement energy efficiency measures. Correspondingly, the size of explicit subsidies needed to shield the poorest will grow considerably and we assume only 18.5% of households to be protected from the price increases. In this scenario, we expect the demand to fall the most, possibly by as much as 54%, or 11.9 bcm, to a very low level of 10.2 bcm demand in 2020.

Table 12: Scenarios for the overall household gas demand changes

	Scenario 1	**Scenario 2**	**Scenario 3**
2014 market w/o Crimea	22.0	22.0	22.0
Total change in consumption, bcm	(7.2)	(9.1)	(11.9)
Total change in consumption, %	(33%)	(41%)	(54%)
2020 household market size, bcm	14.8	12.9	10.2

Source: Own estimates.

Overall, the import price has the largest effect on the final predicted consumption, with up to 2.3 bcm difference between a USD 170/mcm and a USD 230/mcm import price. This is explained by the fact that with the higher import price, the consumer prices of gas and heat will have to increase by 88 and 44 percentage points more from the 2014 price levels than with the low import price. When applying our elasticity results, differences in import prices result in large effects on consumption. Additionally, the different scenarios for energy efficiency investments lead to quite large differences in the results:

1.7 bcm more savings in Scenario 3 than in Scenario 1. Last, after adding the effect from different levels of explicit subsidies, the total range of our three scenarios add up to a difference of up to 4.6 bcm in final household and DHCs gas consumption. Our main prediction of the market in 2020 is Scenario 2, where we expect the market to be 12.9 bcm, down 41% from the baseline (Table 12).

In addition to the effects outlined in Table 12, there will be an additional 1.9 bcm/year of gas savings from long term energy efficiency investments until 2025, according to Scenario 2 (Table 9). The majority of these additional savings come from thermo-modernization of private houses and residential buildings, which will happen only over the long term. Thus, the total demand for gas in 2025 is estimated at 11 bcm in Scenario 2.

9.1 Effects on the Ukrainian state budget from a decrease of subsidies

For Ukraine, the previously highly subsidized gas consumption for households was increasingly costly for the state budget. As we calculated in Section 3, the average implicit subsidy for gas consumption paid by the Ukrainian state has been 1.7% of GDP in the period from 2012–2015. When the pricing reforms have been fully implemented, this type of subsidy will disappear entirely. Simultaneously, the implicit subsidy will be partly exchanged by explicit subsidies, in 2014 at USD 0.4bn (0.3% of 2014 GDP) and following our Scenario 2, rising to USD 1.15bn (0.87% of 2014 GDP). The net effect of the reform will thus, according to our medium estimate, amount to yearly savings of around USD 1.5bn (1.14% of 2014 GDP; see Table 13).

Table 13: Yearly budgetary savings from changes in subsidies

	2014	**2020**
Implicit subsidy (USD bn)	2.27	0
Explicit subsidy (USD bn)	0.38	1.15
Total yearly savings from 2016 onwards (USD bn)	1.5	

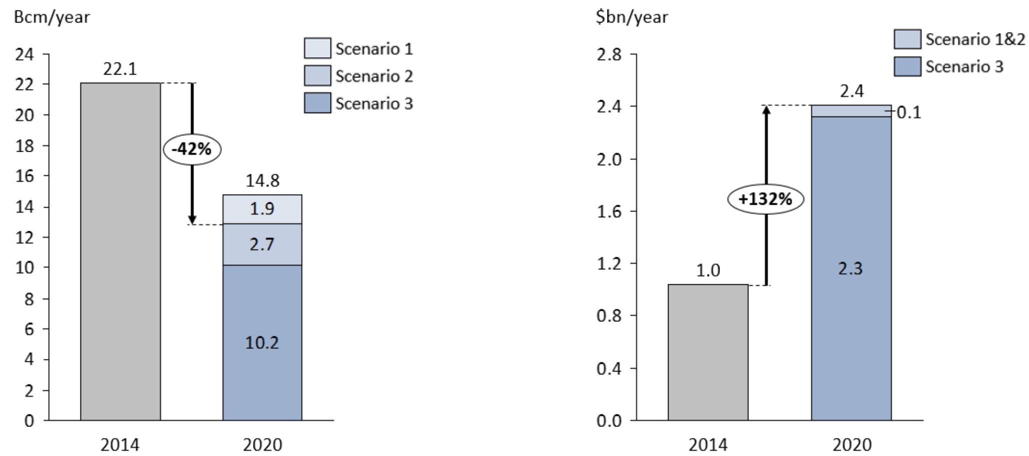
Source: Own calculations. All numbers refer to the 2014 exchange rate of 12 UAH/USD.

This should be seen as the lowest estimate of the effect on the Ukrainian budget. In reality, the Ukrainian state has had to cover Naftogaz's deficits of several percentage points of GDP per year, in 2014 as much as 6% of GDP, in addition to the implicit subsidies also covering deficit related to currency losses, repayment of outstanding debt and non-payment by DHCs. The new pricing system should provide more stability to the Ukrainian state budget, minimizing the large payment fluctuations seen in previous years. Additionally, the new pricing system will create increasing tax revenues from taxes and royalties on domestic production of gas, now sold at import-parity prices rather than at low, subsidized prices. Last, using the same (or less) money, targeted subsidies provide the same or better support for the most vulnerable parts of the Ukrainian population, as compared to the system with an across-the-board implicit price subsidy.

9.2 Effects on the household natural gas market from a decrease of subsidies

The increasing revenues caused by the price increase of gas does not only affect the Ukrainian national budget through the lower level of subsidies. The increased prices for household gas will also give Naftogaz, mainly through its gas production company Ukrgazvydobuvannya, significantly increased revenues from supplying the Ukrainian market. But the change in the size of the market is relevant to all companies who supply the domestic Ukrainian market. In Figure 17, the estimated size of the 2020 market for natural gas is presented.

Figure 17: Increased size of the natural gas market for households and DHCs, 2020



Source: own estimates. Note that the scenarios assume different import-parity prices for gas (Scenario 1: USD 150/mcm, Scenario 2: UDS 180/mcm, and Scenario 3: USD 220/mcm.)

In Figure 17, we note that in Scenario 2, the most likely scenario, the decrease in the volume of gas sold from the 2014 level is 42%, while the dollar value of the market increases by 132%, to USD 2.4bn. However, the real attractiveness of the market will depend on the profitability and access to the market. The profitability will, besides investment and operational costs and the sales price, mainly depend on the royalty levels and the corporate tax levels imposed by the Ukrainian government. The royalty levels for UGV, defined as a percentage of the selling price, have been fluctuating markedly over the last years, increasing from 20% in 2014, to 70% in 2015 and then down to 50% from April 1, 2016 (Naftogaz, 2015c).[24] The royalties for private producers of gas have also been changing, from 55% to 29% for wells less than 5 km deep and from 28% to 14% for wells deeper than 5km (Afendikov & McGrath, 2016). The fluctuating royalty rates have made the business environment uncertain for production companies, but the recent changes of the tariff structures seem to indicate that the Ukrainian government wants to make the business environment somewhat more attractive going forward.

Importantly, together with both households and DHCs gas tariffs, the tariff which UGV receives for the gas it produces was also strongly increased. From a previously very low level of UAH 1,590/mcm, which led to underinvestments, it was raised threefold to UAH 4,849/mcm, out of which half will go to the state budget in the form of royalties (MERT, 2016). The government hopes that this will

[24] Simultaneously with the increase in 2015, the price for gas increased. Naftogaz (2015c) still estimates that the high royalty had severe consequences for UGV's profitability.

stimulate state-controlled gas production to grow from the current 14.5 to 20 bcm/y by 2020 (Naftogaz, 2016d; MERT, 2016), possibly allowing the overall Ukrainian production to rise up to 27–30 bcm/y (RIA Novosti, 2016).

10 Conclusion

In the last three years, Ukraine underwent a profound reform of its natural gas market. A country which for a decade had been a prime example of how a dysfunctional energy subsidy can cause wasteful energy usage, high financial costs for the state budget and declining domestic production, has been able to become one of the few success stories of implementing an energy subsidy reform. In 2014, Ukrainian households and DHCs paid a gas tariff whose gas as a commodity component stood at only 10% and 17% of the average import price, respectively. Furthermore, the cost of heat for the population, produced by DHCs mostly out of the subsidized gas, was subject to a second stage of subsidization—as households paid for heat less than 2/3 of DHCs' already low production cost. By May 1, 2016, the implicit gas subsidies for both households and DHCs had been fully removed, leaving behind only the implicit heat subsidies, now providing households with around 25% discount on the heat tariff.

This profound reform meant significant price increases. To assess how the overall gas consumption is going to respond to the subsidy removal, we estimated price elasticities of household demand for both gas and heat in 2014. We found that for every 10% increase in the gas and heat tariffs, households consume 2.0% and 1.5% less of gas and heat respectively. Assuming no change in the USD/UAH exchange rate from its 2014 level, by reaching an import-parity price of gas of USD 200/mcm, we expect households to consume 48% less gas and 22% less heat. The price increase, in turn, together with an increased political ambition, began to stimulate energy efficiency investments. According to our estimates, by 2020, we should see between 1.6 and 3.3 bcm less demand for natural gas due to such improvements, driven mostly by modernization of individual houses and installation of heat meters in blocks of flats. Altogether, depending on the assumptions, we expect to see between 5.7 and 9.3 bcm decline in natural gas consumption, constituting a 26–42% decline from the 2014 baseline. By 2025, we anticipate another 0.9–3.0 bcm decrease due to additional long-run energy efficiency improvements. Importantly, our estimates are in the lower range given the additional effect from hryvnia depreciation, which makes attaining import parity prices more expensive for the households but also due to the effects for the households from the ongoing conflict in the ATO Zone.

One of the problems with the large subsidies was the high costs for the Ukrainian state budget, at around 2% of GDP per year. The subsidy reform entirely removes the implicit gas subsidies, while increasing the explicit subsidies paid to vulnerable households. The net effect from these two measures result in yearly savings of around 1.1% of the 2014 GDP, or USD 1.5bn per year. This is only the direct effect. The reform also decreases the state's exposure to Naftogaz's highly fluctuating deficit, in 2014 amounting to as much as 6% of Ukrainian GDP. The reformed system allows the Ukrainian state to increase its spending on direct gas subsidies to the most vulnerable parts of society, while still providing large savings for the state budget, helping to solve the very grave financial situation of the country. An additional problem for the Ukrainian state has been the way subsidies created ample opportunity for corruption, created by the price differential between household gas and gas used by industry. The removal of the subsidies has the added benefit of decreasing these opportunities, as of

2016 completely eliminating them through market parity pricing, helping to decrease the amount of gas related corruption in Ukraine.

In 2015, Ukraine for the first time since its independence imported less gas than it produced domestically, 16.4 bcm versus 19.9 bcm (Naftogaz, 2016d; 2016e). Ukrainian gas production has been relatively stagnant, so this change in import dependency can be mostly attributed to the fall in consumption. If other consumption and local production remains stable, the household subsidy reform together with the ensuing energy efficiency improvements can make the need to import gas 35–63% smaller in 2020 than in 2014, positively contributing to Ukrainian energy security. Simultaneously, despite the falling consumption of gas, the dollar value of the market will be increasing as a result of higher tariffs. By 2020, the household gas market should be worth around USD 2.3bn, compared to around USD 1.05bn in 2014, a large increase. The new financial conditions for natural gas production could allow UGV and other Ukrainian producers to scale up their production, further decreasing the Ukrainian dependency on imports. From 2014 to 2016, the tariffs for UGV have been increased by three times, in line with the government's ambitious plans to increase domestic production to 27–30 bcm/y by 2020, which, if successful, would make Ukraine a net exporter of gas.

Finally, the successful removal of the subsidies for natural gas and heat in Ukraine can serve as an example for other countries that consider implementing similar reforms. Many former post-Soviet states have similar issues as Ukraine in the form of subsidized energy prices, leading to low energy efficiency, high costs for the state budget and less profitable domestic gas extraction. As an example, in 2015 the domestic final price for natural gas in Moscow, Russia was around USD 80–85/mcm and for gas used for electricity generation still 20% cheaper (Energo Consultant, 2015). This is far from the European hub prices of USD 150–160/mcm in May 2016 (CME Group, 2016). Reformers should take advantage of the currently very low international prices for natural gas by decreasing or removing the price subsidies, while also introducing efforts to increase energy efficiency. The elasticity of demand from this paper, as well as the framework for calculating the effects on the market size for gas, could be used by policy makers seeking to evaluate the effects from a whole or partial subsidy removal of natural gas.

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Appendix A

Table 14: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
gas_vol	8,347	.9078048	1.054882	0	8.15534
heat_vol	8,347	82.23935	138.0662	0	860.8333
effe~s_price	6,154	928.0137	195.3615	0	1030
effe~t_price	2,594	7.617995	1.453777	0	8.304001
totalinc	8,347	48669.35	29008.86	470.4	397857.4
area	8,347	39.86855	18.45092	5	200
hdd	8,347	6361.408	555.2365	4731	7139
dh	8,347	.3377261	.472963	0	1
apartment	8,347	.4698694	.4991212	0	1
post1980	8,347	.3412004	.4741409	0	1
new_house	8,347	.2554211	.4361238	0	1
gaswaterhe~r	8,347	.1556248	.362521	0	1
indheatsys~m	8,347	.4322511	.4954185	0	1

Table 15: Natural gas demand regression results with heterogeneous income elasticities, households without district heating connection

Linear regression

Number of obs	=	3,786
F(11, 3774)	=	127.68
Prob > F	=	0.0000
R-squared	=	0.3353
Root MSE	=	.47932

ln_gas_vol	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
totalinc_quintile# c.ln_eff_gas_price						
1	-.2004138	.0271342	-7.39	0.000	-.2536129	-.1472147
2	-.1982175	.0260326	-7.61	0.000	-.2492569	-.147178
3	-.2044547	.025759	-7.94	0.000	-.2549576	-.1539517
4	-.2002942	.0259448	-7.72	0.000	-.2511614	-.149427
5	-.2004679	.0265776	-7.54	0.000	-.2525757	-.1483601
ln_income	.2154234	.0558365	3.86	0.000	.1059508	.324896
ln_area	.2703266	.0222354	12.16	0.000	.2267321	.3139211
ln_hdd	.2501712	.0813432	3.08	0.002	.0906903	.4096521
apartment	-.4472796	.0196576	-22.75	0.000	-.4858201	-.4087391
gaswaterheater	.0784184	.0170336	4.60	0.000	.0450225	.1118143
indheatsystem	.3342298	.0283221	11.80	0.000	.2787017	.3897579
_cons	-3.912737	.9305682	-4.20	0.000	-5.737202	-2.088271

Table 16: Heat demand regression results with heterogeneous income elasticities

Linear regression	Number of obs	=	2,539
	F(9, 2529)	=	114.04
	Prob > F	=	0.0000
	R-squared	=	0.3167
	Root MSE	=	.39519

ln_heat_vol	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
totalinc_quintile#c.ln_eff_heat_price						
1	-.1434418	.0345027	-4.16	0.000	-.2110981	-.0757854
2	-.153377	.0312345	-4.91	0.000	-.2146249	-.0921291
3	-.1539713	.0318489	-4.83	0.000	-.2164239	-.0915188
4	-.1455272	.0328521	-4.43	0.000	-.209947	-.0811074
5	-.1404493	.0377584	-3.72	0.000	-.2144898	-.0664088
ln_income	.1044047	.0422716	2.47	0.014	.0215142	.1872952
ln_area	.5661315	.0209637	27.01	0.000	.5250237	.6072392
post1980	.0428015	.0154174	2.78	0.006	.0125696	.0730335
ln_hdd	1.51314	.1140264	13.27	0.000	1.289545	1.736735
_cons	-10.52176	1.101453	-9.55	0.000	-12.6816	-8.361921

Table 17: Natural gas demand regression results with weights applied, households without district heating connection

Source	SS	df	MS
Model	714637.035	8	89329.6294
Residual	1385042.02	6,140,322	.225565046
Total	2099679.05	6,140,330	.341948894

Number of obs	=	6,140,331
F(8, 6140322)	>	99999.00
Prob > F	=	0.0000
R-squared	=	0.3404
Adj R-squared	=	0.3404
Root MSE	=	.47494

ln_gas_vol	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_eff_gas_price	-.2026018	.0005765	-351.44	0.000	-.2037317	-.2014719
ln_income	.2373953	.0003848	616.90	0.000	.2366411	.2381496
ln_area	.2861449	.0005324	537.45	0.000	.2851013	.2871884
ln_hdd	-.0431213	.00212	-20.34	0.000	-.0472765	-.0389661
apartment	-.4920134	.0005417	-908.35	0.000	-.493075	-.4909518
new_house	-.0549953	.0004539	-121.16	0.000	-.055885	-.0541057
gaswaterheater	.0681732	.0004435	153.70	0.000	.0673039	.0690425
indheatsystem	.3367011	.0005877	572.89	0.000	.3355491	.337853
_cons	-1.592263	.0199517	-79.81	0.000	-1.631368	-1.553159

Table 18: Heat demand regression results with weights applied

Source	SS	df	MS		
				Number of obs	= 4,645,737
				F(5, 4645731)	> 99999.00
Model	336105.431	5	67221.0862	Prob > F	= 0.0000
Residual	714908.94	4,645,731	.153885135	R-squared	= 0.3198
				Adj R-squared	= 0.3198
Total	1051014.37	4,645,736	.226232048	Root MSE	= .39228

ln_heat_vol	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_eff_heat_price	-.1577423	.0007484	-210.77	0.000	-.1592091	-.1562754
ln_income	.1331984	.0003418	389.74	0.000	.1325286	.1338682
ln_area	.5752555	.0004874	1180.29	0.000	.5743003	.5762108
post1980	.0246986	.0003689	66.95	0.000	.0239755	.0254216
ln_hdd	1.431718	.0024931	574.26	0.000	1.426832	1.436605
_cons	-10.11869	.0223676	-452.38	0.000	-10.16253	-10.07485

Appendix B

Table 19: Estimate of gas savings in the low scenario (1), long and short term

Where	What	Gas savings (bcm/y) – Short term (2020)	Gas savings (bcm/y) – Long term (2025)	Investment (USD bn) – Short term (2020)	Investment (USD bn) – Long term (2025)	Investment efficiency (cm/USD)
	More efficient gas boilers	0.3	0.3	0.6	0.8	0.43
	Modernization individual houses	0.3	0.7	2.1	4.2	0.16
	Heat meters with temperature regulators	0.4	0.6	1.3	1.7	0.33
	Modernization residential houses	0.2	0.2	1.7	1.7	0.14
	More efficient gas boilers	0.2	0.3	0.5	0.7	0.48
	Pipes replacement	0.3	0.4	0.8	1.1	0.35
Total (short term)		**1.6 bcm**		**USD 5.3bn**		
Total (short + long term)		**2.5 bcm**		**USD 10.2bn**		

Short term (2020)
Long term (2025)

Source: Own scenario estimates based on Minreg, 2016 and Naftogaz, 2015d.

Table 20: Estimate of gas savings in the high scenario (3), long and short term

Where	What	Gas savings (bcm/y) – Short term (2020)	Gas savings (bcm/y) – Long term (2025)	Investment (USD bn) – Short term (2020)	Investment (USD bn) – Long term (2025)	Investment efficiency (cm/USD)
	More efficient gas boilers	0.5	0.7	1.2	1.6	0.43
	Modernization individual houses	1.2	2.3	7.0	14.0	0.16
	Heat meters with temperature regulators	0.6	0.8	1.8	2.4	0.33
	Modernization residential houses	1.0	1.0	7.7	7.7	0.14
	More efficient gas boilers	0.5	0.7	1.0	1.4	0.48
	Pipes replacement	0.6	0.8	1.7	2.2	0.35
Total (short term)		**3.3 bcm**		**USD 12.2bn**		
Total (short + long term)		**6.3 bcm**		**USD 31.3bn**		

Short term (2020)
Long term (2025)

Source: Own scenario estimates based on Minreg, 2016 and Naftogaz, 2015d.