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REKK

GASIFICATION PLANS AND BUILDING HEATING OPTIONS IN NORTH MACEDONIA

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The contents of this study represent the views of the authors and is their sole responsibility.

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EXECUTIVE SUMMARY AND KEY FINDINGS

- How much does the gas infrastructure cost? In the last few years, huge increase in gas infrastructure cost occurred, therefore in our lower estimate ~35% CAPEX increase to be expected compared to the gas master plan. Cost of the network envisaged in the gas master plan could reach up to 791-1086 MEUR CAPEX without land use costs and additional compressor investment.
- What is the financial plan for construction, commissioning and maintenance of gas infrastructure at the national level. Assuming the principle that system users are to pay for the development and operation of the network, network tariffs were set based on the investment cost and potential flows on the network. As such, a network tariff of 12-26.6 EUR/MWh was estimated. Current gas network tariffs applicable for households make up 6 EUR/MWh.
- What other energy alternatives could be developed with the same funds, focusing on renewable energy alternatives? The investment cost estimated was divided up to three distinct energy efficiency investment in detached and semi-detached houses. We quantified the share of such households in the total building stock which can be targeted with a 90% support, 10% own financing scheme. Ultimately, 49% of detached and semi detached houses may install solar PV from such funds. 40% of detached and semi-detached households may install air-to-air heat pumps to replace inefficient heating solutions. A complex energy efficiency investment can be made for 15% of these households.
- Assessment of cost of gas for households. Cost of gas in the current regulation is mainly driven by wholesale price on TTF. Network costs are under-estimated in current regulation. If the network is to be developed and network users have to pay for this investment, the end-user price of gas may increase to 55-79 EUR/MWh depending on gasification scenario.
- Gas prices predictions and analysis in the gas hubs for the Western Balkans. A short review of Bulgarian and Greek gas exchanges revealed that these markets are moving in unison with the dutch TTF market, with lower volatility. Therefore if the main drivers of TTF price are identified, we can easily assess the prices for the Western Balkans. TTF prices are determined by global LNG market, level of European demand and level of Russian pipeline gas to Europe. Modelling these scenarios with the natural gas market model EGMM, we found that the global LNG market has the strongest effect on the price levels, followed by the European demand. Russian volumes have limited effect on price outcomes.
- To analyze the possibilities for use/production of hydrogen, planned to be transported via gas pipelines in the future. Green hydrogen is

a potential part of the solution for decarbonisation. However, due to the physical qualities of the hydrogen molecule and due to high losses in energy conversion, it is not expected to be utilised in household heating (rather to be used in industrial circumstances and hard-to-decarbonise sectors). For this reason, the scenarios for hydrogen use in buildings are to be omitted.

- Natural gas pipelines may be repurposed to transmit hydrogen and new infrastructure may be commissioned hydrogen-ready. Repurposing can be done at the fraction (15-20%) of dedicated new hydrogen pipeline investment, while new hydrogen pipelines are somewhat more expensive than natural gas infrastructure. However, without a coherent hydrogen strategy investment in such costly network items is deemed risky.
- A detailed model of household decision was set up based on publicly available statistics and assumptions on building stock. Households made a single decision of switching from current heating mode to another based on the cost of investment, the total cost of operation and efficiency of the equipment. The model was fit to the actual energy balance of North Macedonia. Households were allowed to switch to gas only in municipalities which were to be connected according to the gas master plan.
- The modelling revealed that if households and other users are to pay the total cost of investment in the network, the network tariffs would be so high that none of the households would switch to gas.
- As our results were strongly affected by our assumption on energy costs, investment costs, efficiencies and such. In the past years, witnessed huge changes in market outcomes. Therefore, it is important to conduct sensitivities. All sensitivities are ceteris paribus, i.e. changing only one parameter while other are not affected.
- Price of natural gas relative to other fuels. Households would not switch to gas at the current 100 EUR/MWh price level. If the price of gas for households would change on a scale of 5-200 EUR/MWh, households would start switching to gas at 65-90 EUR/MWh consuming 0.5-1 TWh/year and reach a peak consumption of 2 TWh/year at 65 EUR/MWh. This means that the gas consumption levels envisaged in the gas master plan can only be realised if gas is relatively cheap compared to other fuels.
- Switching rate: Switching rate of households was considered to be 100%, that is all households were allowed to change their heating equipment. However, the heating equipment and installation may be prohibitively high for many North Macedonian households. As such we constrained the switching to 20-40-60-80% (corresponding to the income quintiles) of households. At 20% switching, gas demand would reach at most 0.5 TWh/year at low relative gas prices. This means that if the affordability dimension is considered, household switching is more limited. One-time investment support may alleviate this issue, but without additional funding, not all households could offer the new heating appliances.
- Changes in energy demand of households: Household energy demand was set to represent and fit the energy balance. However, due to non-market procurement of firewood (e.g. collecting or non-reported trade) the energy balance may under-estimate the real use of firewood for heating. If we adjust our unitary energy consumptions to better reflect the energy use reported by data collection of other institutes, energy consumption would increase considerably in households. However, the modelled switching behaviour is identical to the one modelled in our base scenario, i.e. households would switch to electricity-based heating (heat pumps).
- Alternative firewood prices: Firewood is sold by the state-owned forestries at a low relative regulated price compared to other fuels. However, firewood is not necessary available at the regulated price and free market price of firewood tends to be higher than the regulated one. It is apparent that a 50% higher effective firewood

price would make gas heating preferrable to wood heating in central heating households. Firewood heating would be crowded out in most households by electricity heat pumps and gas heaters. If firewood prices are 30% higher than current regulated prices, some firewood switching would occur but at a smaller extent than our base case scenario.

- **Switching of district heating households:** Some households have switched from district heating to individual room heating in the city of Skopje. In this calculation we constrained this possibility. If the district heating consumers would be allowed to switch from district heating, they would do so if the total investment cost and the fuel cost would be lower than the current bill they are paying. This is not the case in with the parameters set in our analysis, so even if the switching would be relaxed for district heating consumers, they would stick with the current solution based on costs.
- **Relative prices of fuels are highly determining the outcome of modelling.** Price of natural gas skyrocketed in the crisis, but the price of regulated electricity for households in North Macedonia did not follow this development. The low relative cost of gas compared to electricity drives switching behaviour of households towards gas. Based on the pre-crisis levels of fuels, 2.4 TWh of annual household demand would be realized.

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ABBREVIATIONS

ACER	European Union Agency for the Cooperation of Energy Regulators
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas turbine
CEER	Council of European Energy Regulators
DSO	Distribution system operator
ENTSOG	European Network of Transmission System Operators for Gas
FCRT	Full cost recovery of investment
OPEX	Operating Expenses
PV	Photovoltaic
TCO	Total Cost of Ownership
TSO	Transmission system operator
UIC	Unit investment cost
WB6	West Balkan Six (Bosnia and Herzegovina, Serbia, North Macedonia, Kosovo*, Albania, Montenegro)

*This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ opinion on the Kosovo declaration of independence.

1 INTRODUCTION

REKK was commissioned by Eko-svest to perform a series of short analyses regarding the gasification plans in North Macedonia. The questions related to the gasification and residential heating solutions were targeting the following topics:

- How much does the gas infrastructure cost?
- What is the financial plan for construction, commissioning and maintenance of gas infrastructure at the national level (credits, grants, state contribution, etc.).
- What other energy alternatives could be developed with the same funds, focusing on renewable energy alternatives?
- Assessment of cost of gas for households
- Gas prices predictions and analysis in the gas hubs for the Western Balkans
- To analyze the possibilities for use/production of hydrogen, planned to be transported via gas pipelines in the future.

In order to answer these topics, the following logic was utilised:

- reviewing existing studies and information on the gasification plans and current situation of the natural gas networks in North Macedonia
- performing an update on the existing cost estimates
- constructing a simple model for household choice in heating technologies and quantifying costs

The study is structured along the topics posted by Eko-svest and each chapter contains all the information used for analysis.

We are thankful for expert Dejan Zrmanovski (local energy consultant) for his insights on our input assumptions an data sources and to Liljana Alceva (Habitat for Humanity North Macedonia) for an interview on the building stock in North Macedonia.

2

HOW MUCH DOES THE GAS INFRASTRUCTURE COST?

This chapter quantifies the total cost of investment in gas infrastructure for various setups. The chapter will reflect on the EBRD study "Gas distribution network in North Macedonia" as well as the REKK study "Building sector gasification in the WB6". Methodology for quantifying network costs will consider the FCRT logic discussed in the REKK study. This means an explicit estimate of distribution network length based on road networks.

Costs of network development will consider the real estimated length of the network as well as additional compressor station costs. Unit investment costs of ENTSOG and ACER will be considered for making this estimate.

Natural gas infrastructure developments are characterised by the high up-front CAPEX and low costs of long-term operation. Costs are therefore driven by the size of the network, which essentially means the total pipeline length and other infrastructure elements needed to operate the network.

To determine the cost of designing and installing a new natural gas network (including pipelines, compressor stations, metering and regulation stations and other necessary infrastructure as well as the needed control and maintenance) two main approaches were used predominantly (Perrotton & Massol, 2018):

- Engineering approach, painstakingly listing all needed investment elements and applying the necessary cost items. This approach is highly technical and has considerable data need.
- Econometric/benchmarking approach based on existing networks to estimate a cost function based on historical data. Data availability issues persist in this case as well.

The total cost of network development in North Macedonia was already performed in 2014 and 2020. EBRD commissioned an update of the 2014 gas network feasibility study. The new study considered (EBRD, 2020) 8 scenarios for network development and estimated the cost of developing the distribution network. The EBRD study listed the investment need for each municipality by medium- pressure and low pressure network, including the additional cost of gas meters and service lines as well. However, investment costs were based on 2010-2015 benchmarks of Greek network developments. As of 2023, these costs need to be reviewed and updated. Our approach is to use the network development assumptions of (EBRD, 2020) and provide a new estimate for the total investment cost of the network using the scenarios identical with the (EBRD, 2020) study. Additionally, two scenarios will be considered for analysis based on the routing of the gas network.

2.1. CURRENT STATE OF NATURAL GAS NETWORKS IN NORTH MACEDONIA

Natural gas as a source of space heating is not a widespread option for households: according to the 2021 Census, altogether 550 dwellings were using gaseous fuels as central or stove heating (Figure 3). Gaseous fuels are more widespread in urban areas (Figure 1) than in rural areas (Figure 2). As the distribution network is less developed, only urban households along the main existing gas network in Skopje, Gostivar, Kumanovo, Prilep, Shtip and Bitola may have access to piped natural gas. Rural households and households reporting gaseous fuel consumption may utilise non-piped gas in containers for heating.

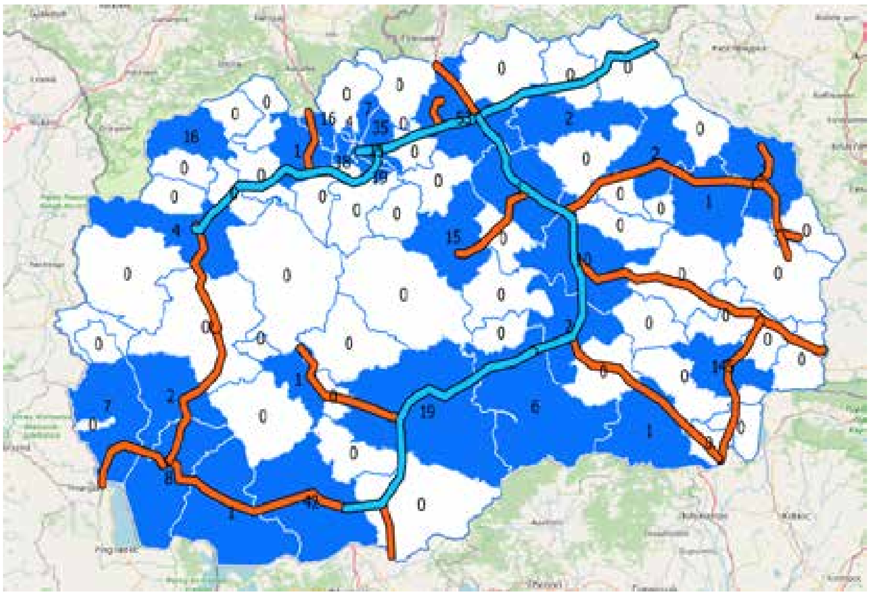


Figure 1.
Number of Urban households using gaseous fuels as central or stove heating

Blue lines: Existing gas transmission networks. Orange lines: planned gas transmission networks
Source: State Statistical Office, Census of Population, Households and Dwellings, 2021, own visualisation

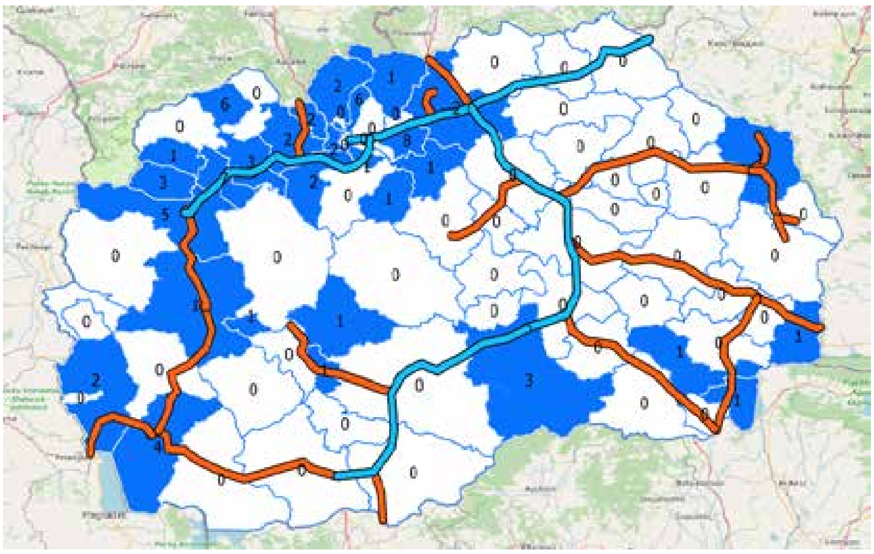


Figure 2.
Number of Rural households using natural gas as central or stove heating

Blue lines: Existing gas transmission networks. Orange lines: planned gas transmission networks
Source: State Statistical Office, Census of Population, Households and Dwellings, 2021, own visualisation

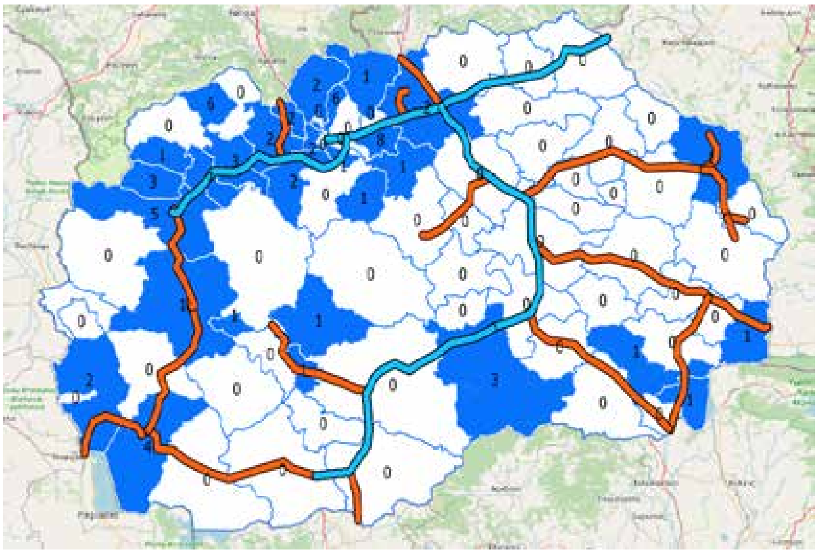


Figure 3. Number of Total households using gaseous fuels as central or stove heating

Blue lines: Existing gas transmission networks. Orange lines: planned gas transmission networks
Source: State Statistical Office, Census of Population, Households and Dwellings, 2021, own visualisation

Natural gas networks are owned and operated by Nomagas, the natural gas TSO and DSO in North Macedonia. According to Nomagas website (Figure 4), the gas network is made up of the following sections:

- Main existing pipeline from Bulgaria to Skopje, 98 km of DN 500 steel pipe
- Gas Ring made up of DN 500 pipes

Section Klechovce
(Lot-1, blue line on Figure 4)

Section Tetovo-Gostivar
(Lot-5, yellow line on Figure 4)

Section Negotino-Shtip
(Lot-1, purple line on Figure 4)

Section Negotino (Kavadarci) -Bitola
(Lot-2, green line on Figure 4)[1]

- Branching pipelines from the gas ring are planned to be made of DN 200 pipelines
    - Sveti Nikola-Veles pipeline
- Interconnector with Greece to be made of DN 700 pipeline

1 Last pipeline welding of Negotino-Bitola occurred 04.2021.

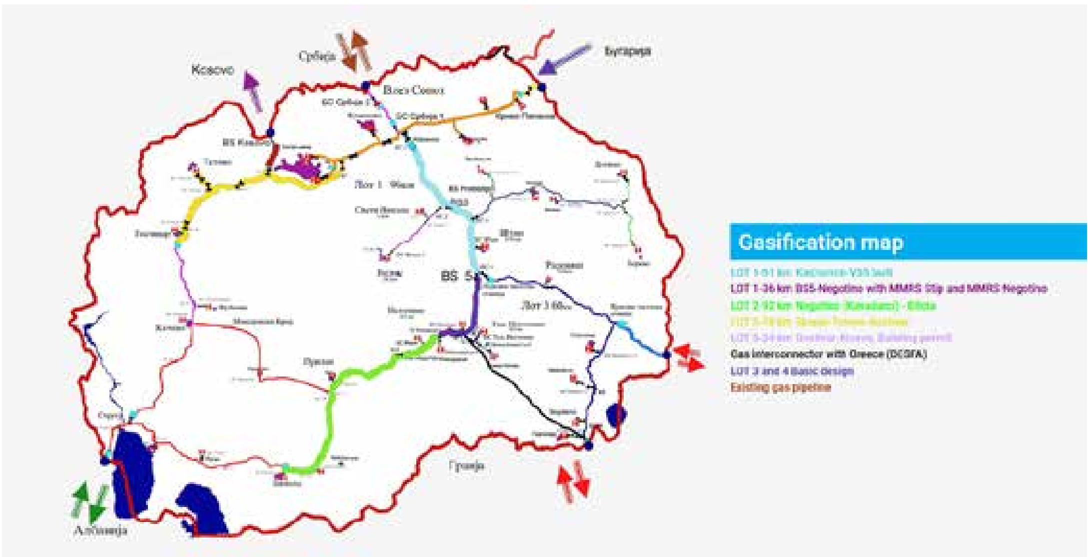


Figure 4. Gas transmission and distribution Network development plan of North Macedonia

Source: Nomagas website

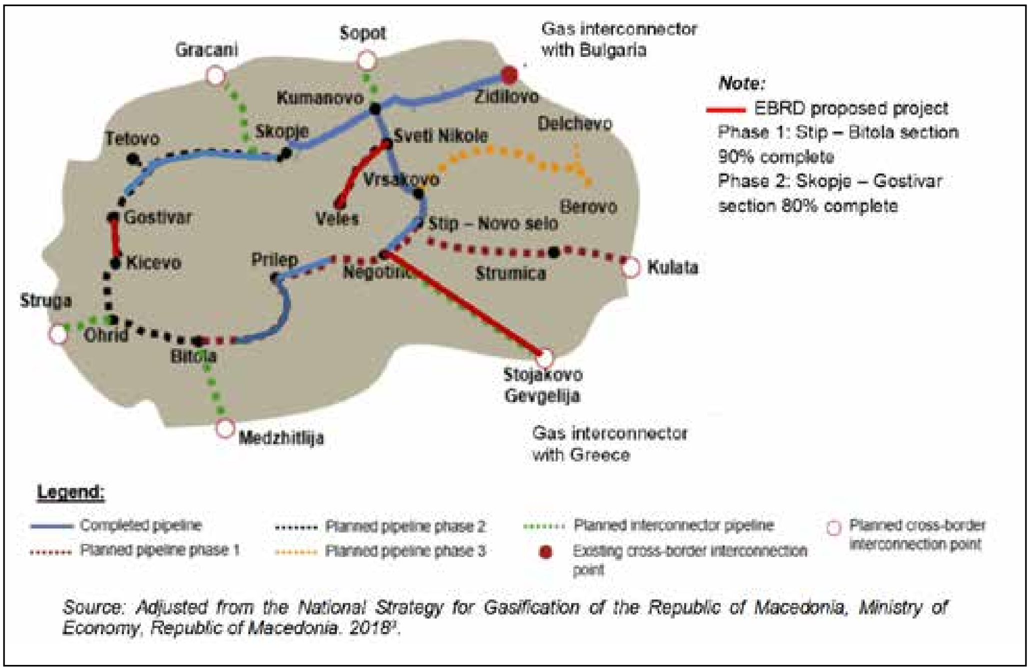
A 2022 update on the Gasification plan of North Macedonia[2] mentions the following sections have been completed:

- Interconnector with Bulgaria (Zidilovo-Skopje)
- Kumanovo-Sveti Nikole-Shtip complete
- Skopje-Tetovo-Gostivar 80% complete
- Shtip-Negotino-Prilep-Bitola 90% complete

2 Ecoline International: North Macedonia Regional Gasification Project: Environmental and social assessment, non-technical summary. pg 4 https://mer.com.mk/Upload/Documents/NMacedonia%20Gas%20Project%20-%20NTS%20Final%20for%20Disclosure%20%2811Sept%202022%29_EN%282%29.pdf

Figure 5. Gasification network plan for North Macedonia

Source: (EBRD, 2022)



Based on this information, the current state of the gas network in North Macedonia as of October 2023 can be characterised as the following:

Table 1. Natural gas pipeline network and plans as of 2023

Source: REKK based on Gasification plan, Nomagas and other sources

Section	Length (km)	Diameter (mm)	State
Main (Zidilovo-Skopje)	98	500	Operating
Skopje-Tetovo-Gostivar	67	500	Completed
Kumanovo-Sveti Nikole-Shtip	96	500	Completed
Shtip-Negotino-Prilep-Bitola	92	500	Completed
Sveti Nikole-Veles	29	200	Under construction
Greece-North Macedonia interconnector	57	700	Under construction
Gostivar-Kicevo	34	500	Planned
Bitola-Ohrid	60	500	Planned
Kicevo-Ohrid	48	500	Planned
Shtip-Strumica-Kulata	78	200	Planned
Vrsakovo-Berovo	102	200	Planned

2.2. UPDATE ON UNIT INVESTMENT COSTS

2.2.1. MEDIUM PRESSURE PIPELINE COSTS

Natural gas medium pressure network to be developed in North Macedonia (DN500 steel pipelines) is technically identical to transmission pipelines operated by TSOs. Therefore a review of recent transmission pipeline investment costs is needed.

Unit investment cost-based estimate on pipeline investment does not include the cost of land use. As the footprint of natural gas pipelines is low (i.e. only a small section of land is to be procured by the owners) it may not considerably affect the cost of investment compared to the cost of pipeline and land works.

In a review for CEER, consultant SUMICSID presented a simple function of natural gas pipeline investment as of length and diameter (SUMICSID, 2019). Costs for pipeline investments include:

- Cost of material supply
  - pipeline costs, depending on diameter, and taking into consideration the location of pipeline (rural, urban or suburban areas);
  - Pipeline external coating (17-25 €/m2)
  - pipeline internal coating (10 €/m2)
  - Miscellaneous supply (3% of total pipeline cost)
  - Transport to site, unloading and storage (12% of total pipeline costs)
- Cost of pipeline installation and commissioning (12.5 €/"/m, taking into consideration major crossings, not ideal conditions);
- Cost of miscellaneous works (project management, engineering, surveys, work supervision, etc. 5 €/"/m);
- Cost of damage during installation and operation (1.2 €/"/ m, no cost of land or right-of-way included!)
- In-line stations costs (no compressor station costs!)
  - sectionalizing valve station for every 20 km
  - pig launcher and pig receiver for every 100 km
  - cathodic protection station for every 40 km

With all these costs elements, pipeline construction costs can be expressed merely as the function of pipeline diameter and length.

$$\textit{Pipeline construction cost}\left(\frac{€}{km}\right) =$$
$$= 420.3693\ D2\ (“) + 12126.1250\ D(“) + 100432.6361$$

For DN500 pipelines, which would make the backbone of the North Macedonian gas network this would result in ~510 EUR/m pipeline investment cost.

The authors compared their results with ACER's 2015 study on pipeline invertment costs (ACER, 2015). ACER's study estimated higher costs for pipelines, due to the fact of including additional network elements (such as metering and pressure regulation stations, interconnection stations, remote control and command of pipeline system - SCADA and telecommunications).

As the 2019 study relied on 2010-2015 data for estimating the costs, an update was needed. ACER has repeated its data collection on UIC of energy infrastructure in 2023. As investment in natural gas pipelines is not supported by European policy due to the decarbonisation goals, the benchmarking done by ACER only focused on hydrogen pipelines. 5 hydrogen-ready natural gas pipelines were assessed for 40" (Table 2. UIC indicators for hydrogen-ready pipelines of 40 inch (DN 1000) diameter EUR/km). Average investment cost of these pipelines realised in 2017-2021 ranged from 2.2 – 2.3 m€/km. For DN500 pipelines, this would mean 934 EUR/m investment cost.

Table 2. UIC indicators for hydrogen-ready pipelines of 40 inch (DN 1000) diameter EUR/km

Source: (PWC-ACER, 2023)

	Mean	Interquartile range	Median	# of assets	Period
Hydro-gen-ready pipeline, 40"	2 271 347	2 215 636-2 299 253	2 243 254	5	2017-2021

We conducted a data collection of pipeline projects commissioned from 2017-2022 based on ENTSOG TYNDP documents. Altogether we managed to collect 22 pipeline projects, listed in Table 3 and Figure 6. Pipeline projects commissioned 2017-2022. Compared to the gasification plans of North Macedonia, these pipelines are of bigger diameter or are related to offshore investment, therefore they might indicate higher overall costs.

Figure 6. Pipeline projects commissioned 2017-2022

Source: (ENTSOG, 2022)

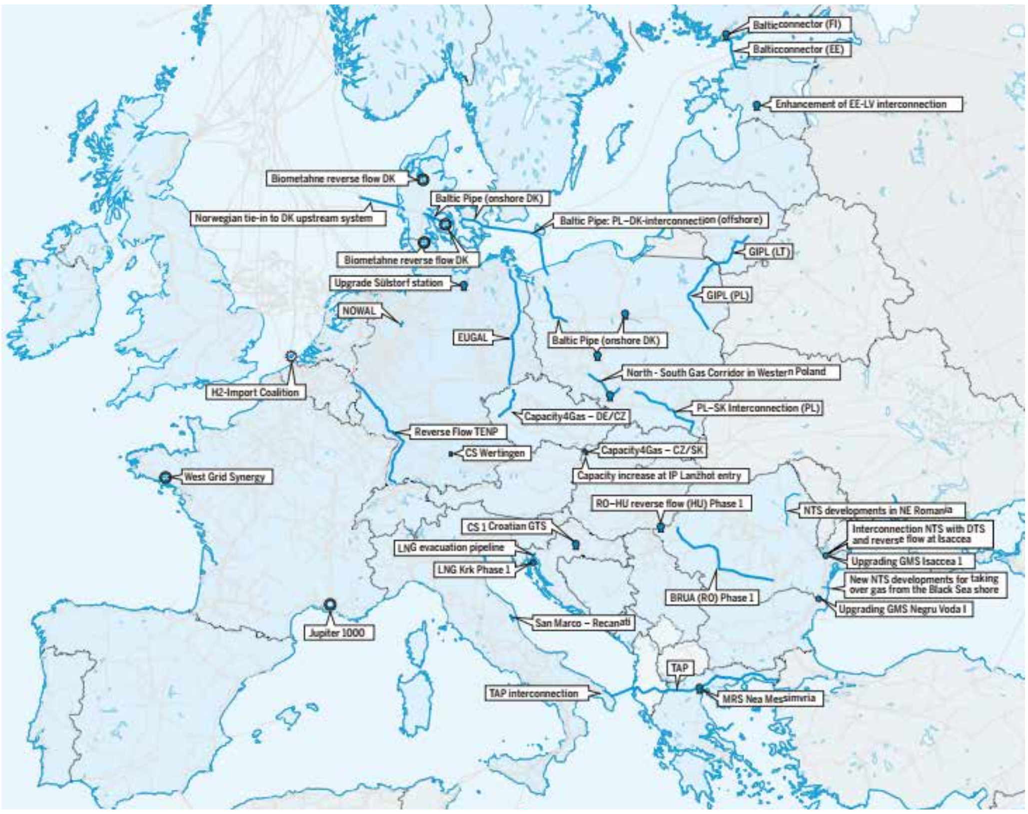


Table 3. List of pipeline projects completed 2017-2021

Source: REKK based on ENTSOG. Pipeline CAPEX is net of compressor costs.

Project code	Project name	Short name	Length (km)	Diameter (mm)	CAPEX	UIC
			km	mm	MEUR	MEUR/km
TRA-F-51	Trans Adriatic Pipeline	TAP	878	1,200	4216	4.8
TRA-F-90	LNG evacuation pipeline Omišalj - Zlobin (Croatia)	HR LNG pipe	18	800	27	1.5
TRA-F-139	Interconnection of the NTS with the DTS and reverse flow at Isaccea	TransBalcan reverse flow	66	813	50	0.8
TRA-F-190	Poland - Slovakia interconnection	PL-SK (SK)	106	1,000	143	1.4
TRA-F-275	Poland - Slovakia Gas Interconnection (PL section)	PL-SK (PL)	381	1,000	680	1.8
TRA-F-212	Gas Interconnection Poland-Lithuania (GIPL) - PL section	GIPL (PL)	343	700	379	1.1
TRA-F-341	Gas Interconnection Poland-Lithuania (GIPL) (Lithuania's section)	GIPL (LT)	165	700	136	0.8

Project code	Project name	Short name	Length (km)	Diameter (mm)	CAPEX	UIC
			km	mm	MEUR	MEUR/km
TRA-F-291	NOWAL - Nord West Anbindungsleitung	NOWAL	26	1000	4	0.2
TRA-F-298	Modernization and rehabilitation of the Bulgarian GTS	BG	120	700	276	2.3
TRA-F-329	ZEELINK	ZEELINK	227	1,000	502	2.2
TRA-F-357	NTS developments in North-East Romania	NTS RO	165	711	117	0.7
TRA-F-358	Development on the Romanian territory of the NTS (BG–RO-HU-AT)-Phase I	BRUA	479	800	390	0.8
TRA-F-378	Interconnector Greece-Bulgaria (IGB Project)	IGB	182	813	201	1.1
TRA-F-592	Necessary expansion of the Bulgarian gas transmission system	BG Balkan-stream	485	1,200	1213	2.5
TRA-F-752	Capacity4Gas – DE/CZ	Capacity4Gas	152	1,400	436	2.9
TRA-F-763	EUGAL - Europaeische Gasanbindungsleitung (European Gaslink)	EUGAL	485	1,400	2383	4.9
TRA-F-895	Balticconnector	Balticconnec-tor EE	95	500	99	1.0
TRA-F-928	Balticconnector Finn-ish part	Balticconnec-tor FI	60	500	96	1.6
TRA-F-964	New NTS develop-ments for taking over gas from the Black Sea shore	RO Offshore	25	508	9	0.4
TRA-F-1193	TAP interconnection	TAP IT	55	1,400	183	3.3
TRA-F-937	Nord Stream 2	NS2	1,200	1,153	8000	6.7

A simple fitting of pipeline length to investment cost was performed, resulting in a good fit of R2=0.97 (Figure 7). The equation estimated on these projects is a simple function of a quadratic and linear term of pipeline length:

$$Pipeline\ construction\ cost\left(\frac{€}{km}\right) =$$
$$= 93.354 + 0.0058\ lenght\ (km)^2 - 0.3359\ lenght\ (km)$$

However, there are only two projects similar to the pipelines intended to build up the medium pressure network in North Macedonia: Balticconnector projects (see TRA-F-895 and TRA-F-928 in Table 3) having a 1-1.6 MEUR/km investment cost and developments in Romania connecting the offshore production costing 0.4 mEUR/km (see TRA-F-964 in Table 3). The simple estimation is somewhat over-shooting the Romanian investment cost of 0.4 MEUR/km which may be much more indicative of North Macedonian investment costs. Therefore, the investment cost for the estimation of network is set at 0.4 MEUR/km (or 400 EUR/m).

Figure 7. Investment cost as a function of pipeline length, MEUR

Source: REKK based on ENTSOG

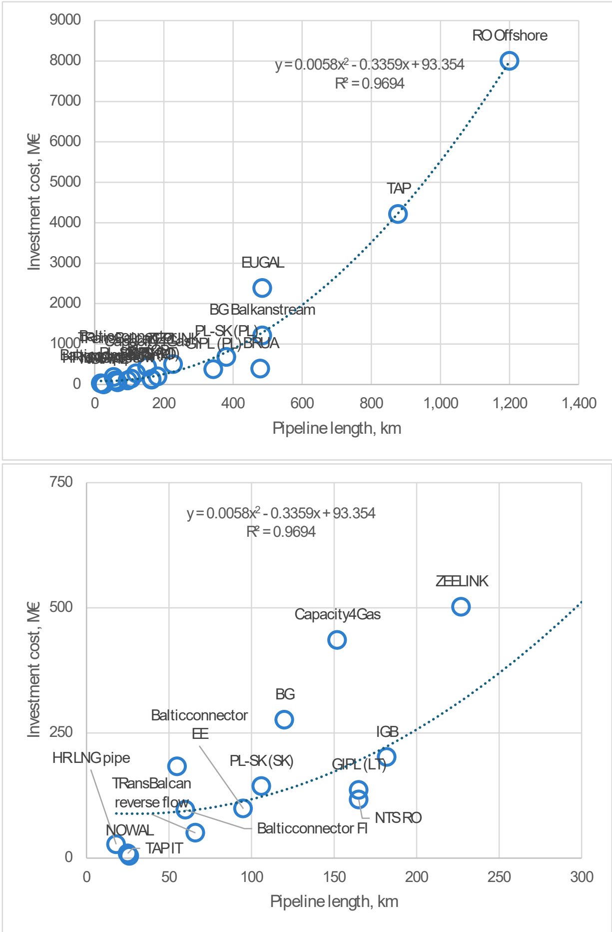


Table 4. Unit investment costs for transmission pipeline

Source: REKK compilation

Project code	Year	EUR/m
(ACER, 2015)	2015	511
(PWC-ACER, 2023)	2023	900
(EBRD, 2020) Base	2020	259
(EBRD, 2020) BAFPOL	2020	181
REKK	2021	511
(ENTSOG, 2022)	2022	370-1600
REKK low	**2023**	**400**
REKK high	**2023**	**1000**

To sum up, we have selected a lower and higher unit investment cost for transmission pipelines, the lower being 400 EUR/m and the higher being 1000 EUR/m.

2.2.2. LOW PRESSURE PIPELINE COSTS

Agrell and Bogetoft analysed the cost drivers for natural gas DSOs in Germany (Agrell & Bogetoft, 2007) and in Belgium (Agrell & Bogetoft, 2011).

In Belgium, 17 DSOs were operating at the gas sector. The goal of the study was to estimate total costs of operation (TOTEX) based on drivers such as network length, number of compressor stations, number of users. TOTEX was defined as the sum of

1. Fees paid for energy transmission to TSO
2. Taxes, fees and direct charges to public authorities (excluding fines)
3. Costs for public service obligations (PSO: distributed generation, renewables, protected clients, certificates)
4. Transfers from earlier years

The best model fitted included number of pressure stations, number of connections (medium and low pressure) and length of pipelines (medium and low pressure).

For the German model, data of 488 gas DSOs were reviewed. The best model fitted includes the following variables: total service area (km2), total number of connections, total distributed energy (Nm3) and total peak output, meaning the maximum hourly output of the entire system (Nm3/h).

There are several other variables, covering different geographical and demographic attributes, that are proved to have a significant effect on costs, though these are not included directly in the cost benchmarking model, partly because some of them are covered partly by other, already included variables. These further variables are dominant soil type of the operator multiplied with the area, population in the area served, energy input of the system in former years and degree of sealed grounds.

As these studies are mainly focusing on the cost benchmarking of existing, mature systems and are good for setting the regulated asset base and similar exercises, in our case a more engineering-focused approach is fitting. This focuses on the needed line length and locational issues more. Therefore we opted to use a single investment cost for pipeline investment per km, as suggested by gas master plans in North Macedonia (EBRD, 2020).

Gas distribution networks have been recently developed in Portugal. The three DSOs active in Portugal have published their network development plans including the investment cost of network and length of networks. The Portuguese Energy Regulator ERSE reviewed and accepted the network development plans of the DSOs and provided benchmark costs for the distribution networks. Investment cost for connecting new consumers as well as installing metering equipment and construction of distribution network were reported 11 companies[3].

3 Grupo GGND, Portgas and Sonorgas. Grupo GGND was formed as a merger of Lisboagás, Lusitaniagás, Setgásm Tagusgás, Beiragás, Duriensegás, Medigás, Dianagás, Paxgás.

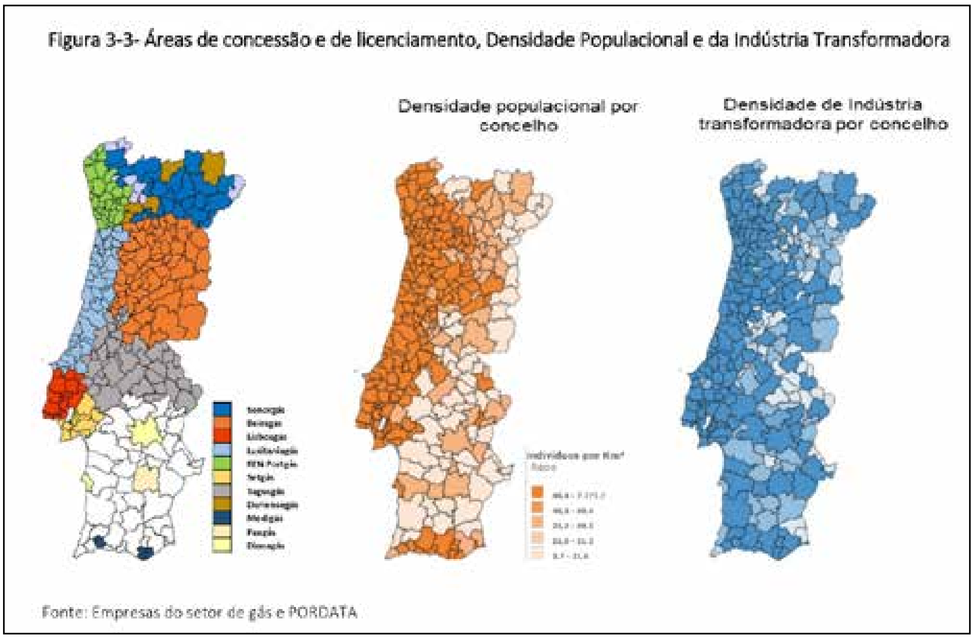


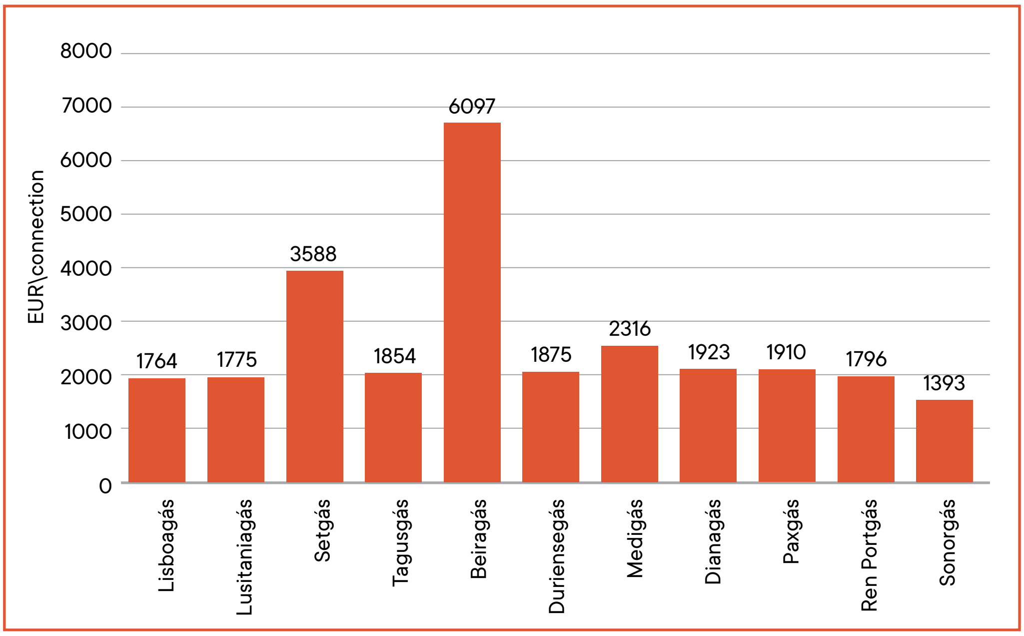
Figure 8. Distribution area of DSOs in Portugal (Left), population density (middle) and indusrty density (Right)

Source: ERSE benchmarking report (PROPOSTAS DE PDIRD-G 2022 Planos quinquenais de desenvolvimento e investimento das redes de distribuição de gás para o período de 2023 a 2027 (PDIRD-G 2022))

The 2022 benchmarking report of the regulator showed investment cost of 1393-6097 EUR/connection. Cost of connection ranged for most DSOs between 1750-2000 EUR/consumer, for sparsely populated regions served by companies Setgas, Medigas and Beiragas this proves to be considerably higher.

Figure 9. Cost of connecting new consumers in Portugal, EUR/consumer (2022

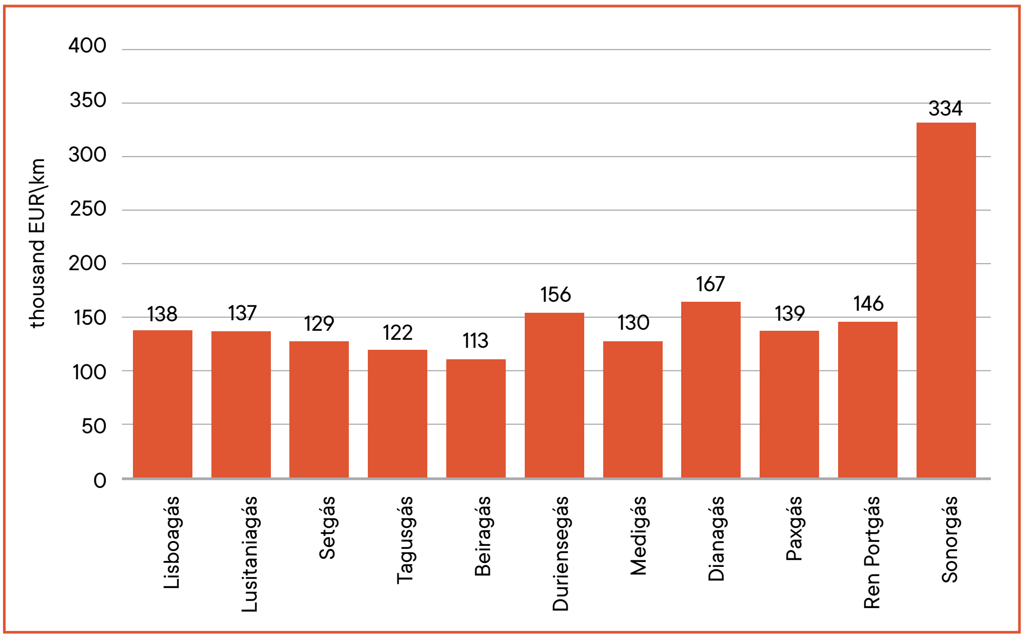
Source: ERSE benchmarking report (PROPOSTAS DE PDIRD-G 2022 Planos quinquenais de desenvolvimento e investimento das redes de distribuição de gás para o período de 2023 a 2027 (PDIRD-G 2022))



Investment cost was directly proportional to the length of the network commissioned. Unitary investment cost per km ranged from 113-334 000 EUR/km, with most DSOs reporting 113-146 000 EUR/km investment cost.

Figure 10. unitary investment cost of portuguese gas distribution networks, thousand EUR/km

Source: ERSE benchmarking report (PROPOSTAS DE PDIRD-G 2022 Planos quinquenais de desenvolvimento e investimento das redes de distribuição de gás para o período de 2023 a 2027 (PDIRD-G 2022))



To sum up, a distribution pipeline investment cost of 130 EUR/m is suggested.

Table 5. Unit investment costs for distribution pipelines, EUR/m

	Year	Distribution pipeline cost, EUR/m
(Agrell & Bogetoft, 2007)	2007	n.a.
(Agrell & Bogetoft, 2011)	2011	n.a.
MK gas master plan Base	2020	94
MK gas master plan BAFPOL30	2020	66
REKK 2021	2021	128
PT distribution	2022	113-146
REKK 2023	2023	130

2.3. INVESTMENT COST ESTIMATE

EBRD commissioned an update of the 2014 gas network feasibility study. The new study considered (EBRD, 2020) 8 scenarios for network development and estimated the cost of developing the distribution network. Demand is estimated at 9.11 TWh/year (including industry) with full gasification of all the 80 municipalities in North Macedonia. If only those municipalities are connected which were deemed feasible at the 2014 study, the demand drops to 8.85 TWh/year (BA-FPOL). A more conservative scenario sees a 50% penetration in urban areas and a 20% penetration in rural areas (BA_U50_R20), resulting in 4.2 TWh/year demand. In these scenarios, tariffs range from 8.61 to 9.3 EUR/MWh.

Table 6. List of scenarios for the gas distribution network development in North Macedonia

Source: (EBRD, 2020)

Scenario name	Scenario description	Max demand	CAPEX Distribution	Distribution Tariff	Transmission tariff 2035
		TWh/yr	MEUR	mm	EUR/MWh
BASELINE	All 80 municipalities and 100% of the network is built. This scenario may be used for a direct comparison with the 2014-FS as all municipalities are considered.	9.11	744.92	9.3	2
CAPEX30	As in BASELINE but with a reduction in unit costs by 30% This scenario may be also used for a direct comparison with the 2014-FS as all municipalities are considered.	9.11	552.15	6.91	2
BA-FPOL	Networks are built only at the feasible municipalities of the 2014-FS and at non-feasible municipalities with a high level of airborne emissions. Unit costs are as in the baseline	8.85	690.43	8.61	2
BA_U50_R20	In Urban municipalities only 50% of the network is constructed (50% mid pressure and 50% low pressure network; 50% of demand is met). In rural municipalities only 20% of the network is constructed (20% mid pressure and 20% low pressure network;20% of demand is met). Unit costs are as in the baseline	4.20	334.83	9.04	2
BA_combo	Combination of Scenarios BA-FPOL and BA_U50_R20	4.15	323.36	8.8	2
CAPEX30_COMBO	Combination of Scenarios CAPEX-30, BA-FPOL and BA_U50_R20	4.15	240.68	6.57	2
BA_INCREASED_WACC	Baseline with increased WACC	9.11	744.92	10.38	2
BA_LIQUIDITY	Baseline but with loan repayments adjusted according to project liquidity. Grace period is 7 years and repayment period is set to 20 years	9.11	744.92	9.3	2

The EBRD study assessed demand by assuming unitary heating and cooking demand per detached houses, multi-family houses and other consumers, and multiplying this with the number of connections by the full gasification. Total energy demand was determined for Individual Residential Facilities (Detached houses, facilities with no more than 4 separate residential units) Collective Residential Facilities (multi-family houses and apartment blocks) and other facilities (service sector, institutions and businesses).

Table 7. Energy load and consumption by consumer category according to the 2014-FS

Project code	Heating	Cooking	Total
	kWh/yr	kWh/yr	kWh/yr
IRF	31,449	5400	36,849
CRF	10,483	1800	12,283
OF	360,360	0	360,360

Source: (EBRD, 2020) page 53, Table 16

Total investment cost was assessed using unitary investment for each infrastructure element (pipes, meters, etc). Investment cost used was based on the 2010-2015 cost of Greek distribution companies. We consider these costs out of date for the future due to the inflation of materials and have performed a review of recent (2017-2022) gas infrastructure projects (See Chapter Update on unit investment costs). Based on our assessment of pipelines commissioned in Europe, natural gas transmission pipelines of DN500 range from 400-1000 EUR/m. Gas distribution pipelines for Portuguese DSOs showed and average cost of 130 EUR/m. Cost of other network elements such as pressure reduction stations and risers/meters was not adjusted. OPEX was estimated as 3% of CAPEX.

Table 8. Investment cost for network elements

		EBRD 2020	REKK low	REKK high
DN 500 medium pressure pipeline	EUR/m	259	400	1000
Pressure reduction station	EUR/unit	45000	45000	45000
DN 20 low pressure pipeline	EUR/m	94	130	130
Service line IRF/CRF	EUR/unit	1880	2600	2600
Service line OF	EUR/unit	4490	6209	6209
Riser / Meter IRF/CRF	EUR/unit	370	370	370
Riser / Meter OF	EUR/unit	500	500	500

Necessary investment was published by the EBRD study for each municipality, including the length of medium and low pressure pipelines as well as the cost of meters and service lines.

Table 9. Investment need of the gas network per municipality

Source: (EBRD, 2020)

Municipality	Urban/rural	Medium pressure pipeline	No of pressure reduction stations	Low pressure pipeline	Service lines			Risers/meters		
					IRF	CRF	OF	IRF	CRF	OF
		m	#	m	#	#	#	#	#	#
Aerodrom	U	17,451	2	79,500	2,802	2,118	484	2,802	21,175	484
Butel	U	16,270	2	70,500	2,121	128	152	2,121	1,283	152
Gazi Baba	U	32,396	4	112,500	2,698	312	495	2,698	3,117	495
Gjorche Petrov	U	18,385	2	64,500	3,117	238	324	3,117	2,383	324
Karposh	U	26,527	3	76,500	2,357	843	278	2,357	8,433	278
Kisela Voda	U	32,870	3	105,000	4,845	578	423	4,845	5,775	423
Saraj	R	2,470	1	4,500	498	-	8	498	-	8
Centar	U	20,441	2	57,000	1,021	1,925	1,299	1,021	19,250	1,299
Chair	U	14,882	1	31,500	1,702	743	145	1,702	7,425	145
Shuto Orizari	R	4,250	1	18,000	572	-	19	572	-	19
Arachinovo	R	2,299	1	22,500	253	-	4	253	-	4
Zelenikovo	R	6,370	1	22,500	202	-	8	202	-	8
Ilinden	R	14,037	3	85,500	387	-	865	387	-	865
Petrovec	R	9,966	1	24,000	84	-	438	84	-	438
Sopishte	R	7,250	1	31,500	202	-	4	202	-	4
Studenichani	R	8,850	2	39,000	993	-	23	993	-	23
Chucher Sandevo	R	10,220	2	40,500	354	-	4	354	-	4
Berovo	R	6,395	1	4,500	240	11	14	240	107	14
Bogdanci	U	10,905	1	16,500	364	20	195	364	199	195
Bosilovo	R	2,580	1	3,000	603	-	22	603	-	22
Valandovo	U	5,132	1	6,000	604	4	186	604	40	186
Vasilevo	R	1,938	1	3,000	616	-	17	616	-	17
Veles	U	12,966	2	81,000	3,283	830	357	3,283	8,296	357
Vinica	U	7,200	2	34,500	647	18	120	647	179	120
Gevgelija	U	11,606	2	72,000	1,560	122	607	1,560	1,223	607
Gradsko	U	2,711	1	4,500	115	-	35	115	-	35
Delchevo	U	6,720	1	22,500	578	57	72	578	568	72
Demir Kapija	U	3,490	1	7,500	168	-	65	168	-	65
Dojran	U	4,995	1	7,500	135	6	32	135	58	32
Zrnovce	R	1,378	1	1,500	63	-	6	63	-	6
Kavadarci	U	14,935	2	55,500	565	252	177	565	2,518	177
Karbinci	R	862	1	1,500	35	-	-	35	-	-
Konche	R	1,320	1	1,500	71	-	1	71	-	1
Kochani	U	13,030	2	58,500	1,880	83	137	1,880	829	137

Municipality	Urban/ rural	Medium pressure pipeline	No of pressure reduction stations	Low pressure pipeline	Service lines			Risers/meters		
					IRF	CRF	OF	IRF	CRF	OF
		m	#	m	#	#	#	#	#	#
Kratovo	U	2,963	1	1,500	365	7	11	365	73	11
Kriva Palanka	U	7,833	1	12,000	560	33	62	560	332	62
Kumanovo	U	13,090	3	73,500	5,287	339	145	5,287	3,388	145
Lipkovo	R	2,456	1	9,817	533	-	7	533	-	7
Lozovo	R	899	1	1,500	60	-	4	60	-	4
Makedonska Kamenica	R	1,904	1	3,000	209	21	16	209	209	16
Negotino	U	6,380	1	18,000	640	19	57	640	194	57
Novo Selo	R	2,570	1	3,000	296	-	12	296	-	12
Pehcevo	U	2,750	1	1,500	188	4	10	188	45	10
Prilep	U	19,744	4	121,500	7,418	466	418	7,418	4,658	418
Probishtip	U	5,380	1	13,500	577	89	60	577	886	60
Radovish	U	6,680	1	22,500	730	30	68	730	295	68
Rankovce	R	736	1	1,500	66	-	2	66	-	2
Rosoman	R	1,852	1	3,000	122	-	9	122	-	9
Sveti Nikole	U	13,865	1	28,500	875	16	86	875	164	86
Staro Nagorichane	R	2,792	1	1,278	69	-	1	69	-	1
Strumica	U	-	-	-	2,153	174	255	2,153	1,741	255
Chashka	R	1,227	1	3,000	77	-	5	77	-	5
Cheshinovo Obleshevo	R	8,696	1	3,000	287	-	9	287	-	9
Shtip	U	20,236	2	61,500	3,027	324	203	3,027	3,240	203
Bitola	U	25,088	5	136,500	5,317	1,972	885	5,317	19,716	885
Bogovinje	R	7,295	1	6,000	1,883	-	59	1,883	-	59
Brvenica	R	3,272	1	3,000	963	-	8	963	-	8
Vevchani	R	1,680	1	4,500	81	-	5	81	-	5
Vrapchiste	R	4,504	1	4,500	2,240	-	31	2,240	-	31
Gostivar	U	18,252	4	114,000	3,262	176	197	3,262	1,759	197
Debar	U	5,273	1	22,500	982	23	45	982	234	45
Debarca	R	4,526	1	8,482	445	-	1	445	-	1
Demir Hisar	R	2,390	1	9,000	144	-	14	144	-	14
Dolneni	R	297	1	556	29	-	0	29	-	0
Zhelino	R	4,208	1	1,500	609	-	7	609	-	7
Jegunovce	R	3,835	1	7,186	375	-	32	375	-	32
Kichevo	U	15,078	2	43,500	3,885	136	112	3,885	1,361	112
Krivogashtani	R	4,030	1	1,500	114	-	1	114	-	1
Krushevo	U	4,470	1	10,500	315	0	29	315	4	29
Mavrovol Rostushe	R	2,386	1	4,471	231	-	6	231	-	6

Municipality	Urban/rural	Medium pressure pipeline	No of pressure reduction stations	Low pressure pipeline	Service lines			Risers/meters		
					IRF	CRF	OF	IRF	CRF	OF
		m	#	m	#	#	#	#	#	#
Makedonski Brod	R	2,435	1	6,000	483	1	20	483	6	20
Mogila	R	1,352	1	3,000	103	-	0	103	-	0
Novaci	R	3,135	1	1,670	89	-	3	89	-	3
Ohrid	U	30,330	4	109,500	3,496	440	302	3,496	4,401	302
Plasnica	R	1,995	1	3,000	104	-	-	104	-	-
Resen	U	3,686	1	13,500	521	14	15	521	139	15
Struga	U	12,045	2	55,500	3,353	713	221	3,353	7,132	221
Tearce	R	8,579	1	16,076	849	2	9	849	20	9
Tetovo	U	25,151	3	99,000	4,964	1,133	286	4,964	11,334	286
Centar Zhupa	R	2,025	1	752	39	-	1	39	-	1

Applying these investment costs and the rate of gasification proposed by the EBRD study for each scenario, the investment costs may be easily updated. Costs include the following cost items:

- DN 500 medium pressure transmission network
- DN 20 low pressure distribution network
- Pressure reduction stations
- Service lines (residential and other consumers)
- Meters (residential and other consumers)

Table 10. CAPEX and Updated CAPEX of the distribution and transmission network

Source: (EBRD, 2020) and REKK

	CAPEX MEUR		
	EBRD basse	REKK updated (low)	REKK updated (high)
Baseline	745	1016	1424
CAPEX30	551	739	1026
BA-FPOL	690	939	1296
BA_U50_R20	334	455	629
BA_combo	323	439	603
CAPEX30_COMBO	240	321	436
REKK estimate*	-	791	1086
REKK estimate with Bitola*	-	791	1086

Lower investment costs indicate a 35% cost increase compared to the original estimate of EBRD, while the higher investment cost would mean 90% increase.

Tariffs are calculated based on full cost recovery of tariffs. This logic means that the total costs of the investment must be covered by the system users by their consumption. For this calculation, total volume of gas consumption is needed. EBRD estimated gas demand based on Table 7 and number of consumers. REKK estimation was based on the assumptions of:

- full gasification of municipalities which are already connected to the gas network and will be connected to the gas network in the future
- gas being the cheapest heating alternative
- with the exception of households connected to district heating network, all households are connected to the gas network
- heat demand of households takes into account underheating and heating characteristics of households

Table 11. Total natural gas demand, TWh/year

Source: (EBRD, 2020) and REKK

	DEMAND TWH		
	EBRD base	REKK up-dated (low)	REKK up-dated (high)
Baseline	9.1	7.2	7.2
CAPEX30	9.1	7.2	7.2
BA-FPOL	8.8	6.8	6.8
BA_U50_R20	4.2	3.2	3.2
BA_combo	4.1	3.1	3.1
CAPEX30_COMBO	4.1	3.1	3.1
REKK esti-mate	-	4.5	4.5
REKK esti-mate with Bitola		7.3	7.3

Non-residential gas consumption was not explicitly modelled, but extrapolated based on residential demand (i.e. residential demand made up 58% of total gas demand in all EBRD scenarios, as such non-residential demand was added as proportional to residential demand).

Two additional scenarios are assessed: in the first case, network costs and consumption are estimated based on REKK assumptions. In the second case, the Bitola lignite power station is replaced by a new 250 MW unit gas fired power plant , as suggested by the capital projects investment plan of ESM (ESM, 2022). With 54% efficiency and 68% of annual utilisation this would result in an additional annual gas demand of 2.8 TWh/year.

3

WHAT IS THE FINANCIAL PLAN FOR CONSTRUCTION, COMMISSIONING AND MAINTENANCE OF GAS INFRASTRUCTURE AT THE NATIONAL LEVEL

- Full cost recovery of investments over 20 years of lifetime, financed by the network users (FCRT). In this model, only network users are providing financing for the investment. This results in the highest tariffs for natural gas use, but is considered just and efficient economically, as the network users are paying the cost.
- Major anchor loads like fertiliser industry or power plants can considerably change the cost structure of networks. For this reason, a 500 MW CCGT investment will be considered. The consumption of such plant will definitely drive down network tariffs and help the connection of households.
- State contribution for the investment may be justified, if the household consumers lack the funds for connecting to the gas network. The state may subsidize the investment cost by the central budget. This reduces the network tariffs but in the same time makes taxpayers who are not necessary consuming natural gas cross-finance another investment.
- International financing via grants or credits: the investment may secure grants or other support of international green financial institutions, provided the investment can deliver decarbonisation goals. This can indeed reduce the end-user tariffs.

Investment and operational costs were to be recovered by users of the network. The tariff shown below covers the investment cost as well as the operation costs of the network. Assuming a discount rate of 5% and a lifetime/payback period of 20 years, the tariff was calculated as follows:

$$\text{FCRT} = \frac{\text{NPV(CAPEX + OPEX)}}{\text{NPV (gas volume)}}$$

Compared to the original EBRD estimation, two factors of our estimate increased the tariff:

- by increasing the denominator, higher investment cost
- by lowering the denominator, of gas consumption due to limitations on connecting sparsely populated rural areas and households already connected to district heating networks

Compared to the EBRD baseline, these two effects may increase the tariffs by 70-80% assuming the lower investment cost and 135-145% using the higher investment cost for transmission pipelines.

If one unit of Bitola power station is replaced with gas fired unit it highly decreases the FCRT tariff.

To sum up:

- The EBRD estimation of ~10 EUR/MWh network tariff may be 11-26 EUR/MWh due to increased costs of investments and lower potential consumption. Costs have considerably increased compared to the 2020 EBRD study.
- Lower unitary costs are related to projects in CEE with similar parameters, therefore the estimations using the lower unitary costs are more realistic for the region

Table 12. Total Tariffs calculated at FCRT logic, EUR/MWh

	FCRT, EUR/MWH		
	EBRD	REKK (low)	REKK (high)
Baseline	9.0	15.6	21.9
CAPEX30	6.7	11.3	15.8
BA-FPOL	8.6	15.2	21.0
BA_U50_R20	8.8	15.6	21.5
BA_combo	8.6	15.4	21.1
CAPEX30_COMBO	6.4	11.2	15.3
REKK estimate	-	19.4	26.6
REKK estimate with Bitola	-	12.0	16.4

Table 13. TSO tariffs calculated at FCRT logic, EUR/MWh

	FCRT TSO		
	EBRD	REKK (low)	REKK (high)
Baseline	2.1	4.1	10.3
CAPEX30	1.5	2.9	7.2
BA-FPOL	1.9	3.8	9.5
BA_U50_R20	2.0	3.9	9.8
BA_combo	1.9	3.8	9.5
CAPEX30_COMBO	1.3	2.6	6.6
REKK estimate	-	4.8	11.9
REKK estimate with Bitola		2.9	7.4

Table 14. DSO tariffs calculated at FCRT logic, EUR/MWh

	FCRT DSO		
	EBRD	REKK (low)	REKK (high)
Baseline	6.9	11.5	11.5
CAPEX30	5.2	8.5	8.5
BA-FPOL	6.7	11.4	11.4
BA_U50_R20	6.8	11.6	11.7
BA_combo	6.7	11.6	11.6
CAPEX30_COMBO	5.1	8.6	8.6
REKK estimate	-	14.6	14.7
REKK estimate with Bitola		9.0	9.1

4

WHAT OTHER ENERGY ALTERNATIVES COULD BE DEVELOPED WITH THE SAME FUNDS, FOCUSING ON RENEWABLE ENERGY ALTERNATIVES?

Developing gas infrastructure is a costly investment, creating stranded assets for decades. Using the cost estimates for various scenarios, we assess how many buildings/households can be targeted by

- energy efficiency investment (deep retrofit of existing building stock),
- solar PV installations or
- heat pump installations

These estimates are provided as a simple indication, by dividing the total investment in gas network with the applicable costs of alternative measures. No further optimisation of costs is performed.

During the determination of the costs of each alternative, we also took into account the cost of the investment and the cost of the installation. The values are determined to cover the costs of investments for an average family household. It is worth noting that these costs can differ significantly for apartments, but at the same time they may be suitable for illustrating the ratios and for presenting alternatives for the use of the budget allocated for the development of the gas network. The unit costs are summarized in the following table:

Table 15. Indicative costs for renewable investment and energy efficiency

Source: REKK

COST/HOUSEHOLD (EUR)	
3 kW solar rooftop system and installation	4 000 EUR
Air-to-air heat pump, 4 units and installation	5 000 EUR
Building envelope insulation, 10 cm	13 000 EUR

Regarding the financing side of the investments, we used the following simple assumption: all investments are realized with 10% own-source and 90% support.

Along the individual consumption and cost scenarios in the following proportions of detached and semi-detached households can be reached compared to the total number of detached and semi-detached households:

Table 16. The proportion of detached and semi-detached households implementing 3 kW solar rooftop system, %

Source: REKK

	EBRD	REKK (low)	REKK (high)
Baseline	47%	63%	89%
CAPEX30	34%	46%	64%
BA-FPOL	43%	59%	81%
BA_U50_R20	21%	28%	39%
BA_combo	20%	27%	38%
CAPEX30_COMBO	15%	20%	27%
REKK estimate	-	49%	68%

Table 17. The proportion of detached and semi-detached households implementing Air-to-air heat pump (4 units), %

Source: REKK

	EBRD	REKK (low)	REKK (high)
Baseline	37%	51%	71%
CAPEX30	28%	37%	51%
BA-FPOL	34%	47%	65%
BA_U50_R20	17%	23%	31%
BA_combo	16%	22%	30%
CAPEX30_COMBO	12%	16%	22%
REKK estimate		40%	54%

Table 18. The proportion of detached and semi-detached households implementing Building envelope insulation, %

Source: REKK

	EBRD	REKK (low)	REKK (high)
Baseline	14%	20%	27%
CAPEX30	11%	14%	20%
BA-FPOL	13%	18%	25%
BA_U50_R20	6%	9%	12%
BA_combo	6%	8%	12%
CAPEX30_COMBO	5%	6%	8%
REKK estimate		15%	21%

Based on our assumptions, the cost of the gas network could finance significant renewable energy investments: supplying 49% of detached and semi-detached houses with solar rooftop or 40% with air-to-air heat-pumps or 15% of building envelope insulation can be financed from the budget (with a 10% own source).

5 ASSESSMENT OF COST OF GAS FOR HOUSEHOLDS

Total cost of replacing the heating technology in North Macedonian households may involve retrofitting the heating system (e.g. from individual heating to central heating), replacing the boiler and preparing the connection point (e.g. installing meter, building distribution pipe to the household). Besides these one-time costs, households need to pay network costs, energy costs and other tariffs for the use of natural gas. To provide a sound assessment, cost of gas will include connection costs, network costs and other components for households, not only the cost of the energy. The study will explicitly show:

- the cost of connection and network use as part of the network tariff (as part of the network tariff. This will include the meter, the relevant part of the distribution grid, etc.)
- the cost of equipment (natural gas boiler)
- the cost of gas
- VAT and other taxes
- Other potential cost components (e.g. CO_2 costs or environmental taxes in the future)

5.1. INVESTMENT DECISION OF HOUSEHOLDS

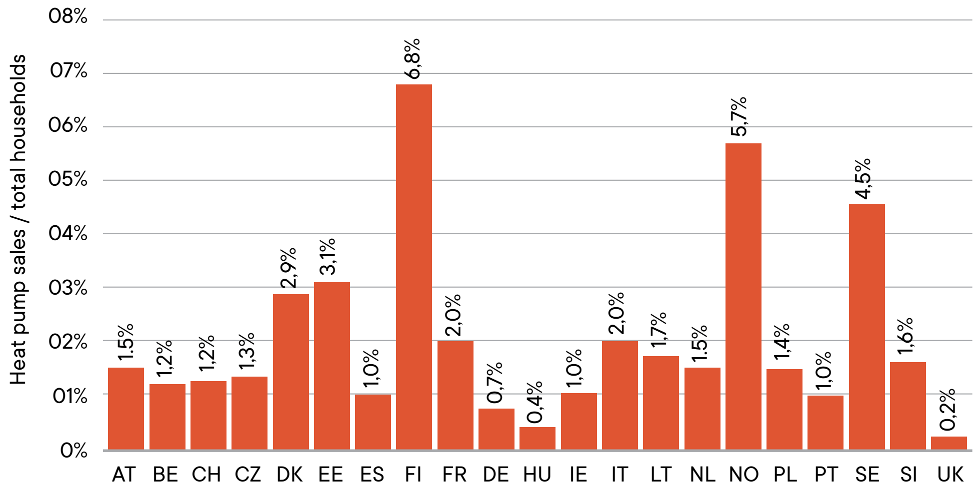
European Heat Pump Association (EHPA, 2022) claimed that households based their decision on the replacement of heating appliance on short-term investment costs of the appliance rather than the total cost of ownership (TCO) which would account for operating costs and investment costs alike. TCO perspective reveals a significant cost advantage for heat pumps compared to other technologies, due to the high efficiency of the technology.

The European Heat Pump Association reported total heat pump sales per country in 2022.[4] Comparing this figure to the total number of households[5] in each European country we can see that on average 1.4% of households were purchasing heat pumps in 2022.

4 https://www.ehpa.org/market-data/
5 Eurostat: Number of households by household composition, number of children and working status within households (1 000) [lfst_hhnhwhtc_custom_8331069], 2022 data

Figure 11. Heat pump sales proportional to the number of households

Source: REKK based on EHPA and Eurostat



A 2021 study surveyed 3000 households in Germany, France, Italy, Bulgaria and Poland who have installed heating appliances in the past 5 years. The study showed that 59.7% of households installed boilers, 27% installed heat pumps and the remaining other hybrid technologies. In most cases, the new appliance replaced an older heating appliance, which broke down (64.3% of replacements were due to appliance faults). It must be noted that 73% of respondents did not change the technology with the replacement: these respondents purchased the same type of appliance – a new boiler or a new heat pump. Of the 3000 respondents, 7.7% switched from boilers to heat pumps.

The study surveyed the main aspects of consumer decision when choosing a heating appliance. Respondents were asked to rank several aspects on a 5 point scale. The most important aspects, ranked over 4 on the 5-point scale when choosing heating appliance were the following: Energy consumption (4.3), Running costs - Energy costs (4.21), Energy class/energy efficiency (4.16), Purchase and installation costs (4.13).

Based on this information, we can conclude that:

- Households base their decision on costs and cost-related aspects of the investment, taking the running costs and up-front installation costs into consideration
- Investment decision is often driven by a broken down or faulty appliance
- Household decision is heavily dependent on existing technology: replacing a boiler with a new boiler is more common than switching technologies
- If there is a technology switch, the most common is from boilers to heat pumps

Figure 12. Replacement behaviour

			New heating appiliance			
			Boiler	Heat pump	CHP system	Hybrid system
			65.9%	21.3%	6.4%	6.4%
Old heating appliance	**Boiler**	70.7%	**58.5%**	7.7%	2.4%	2.1%
	Heat pump	15.7%	3.3%	**10.3%**	1.3%	0.8%
	CHP system	5.6%	1.1%	1.3%	**2.1%**	1.1%
	Hybrid system	3.4%	0.5%	0.4%	0.4%	**2.1%**
	Other	2.9%	1.7%	1.0%	0.1%	0.1%
	Don't know	1.8%	0.9%	0.6%	0.1%	0.2%

Base = respondents who purchased the heating appiliance to replace an old one (N=2181)

5.2. COST OF GAS IN NORTH MACEDONIA FOR HOUSEHOLDS

Based on the 2021 Census, 550 households were using gaseous fuels as a source of space heating.

State statistical office data report regulated prices for household consumers on a semi-annual basis from 2017. Tariffs were the same for users in consumption category D1 (<20 nm3) and users D2 (20-200 nm3). Cost of energy made up nearly 75-80% of the end-user cost for households. Network costs accounted for ~10%. In 2022, energy component in North Macedonia made up 81-82% of total end user price, while network costs accounted for 3-4%. The low cost of the network component indicates that networks are not developed and/or network costs are not necessarily covered in the tariffs. In comparison, network costs for European Union Member States with more developed transmission and distribution networks ranged from 7% to 27% of the total cost in 2022.[6]

End-user price of natural gas for households in North Macedonia strongly correlated with the TTF averages. A simple linear regression model resulted in a strong fitting (R2=0.78), therefore it can be concluded that TTF prices are a good indicator of natural gas price in North Macedonia.

National regulator ERC has worked out the by-laws and regulations[7] for setting the allowed revenue of the transmission and distribution system operator. TIRZ DIREKCIJA and JP KUMANOVO GAS are license holders developing the distribution grid in local urban areas.[8]

6 ACER MMR 2023 pg 43, fig 33

7 https://www.erc.org.mk/page_en.aspx?id=372

8 https://www.erc.org.mk/page_en.aspx?id=314

Figure 13. Natural gas tariffs for household consumers in North Macedonia, MKD/GJ

Source: State statistical office, REKK figure

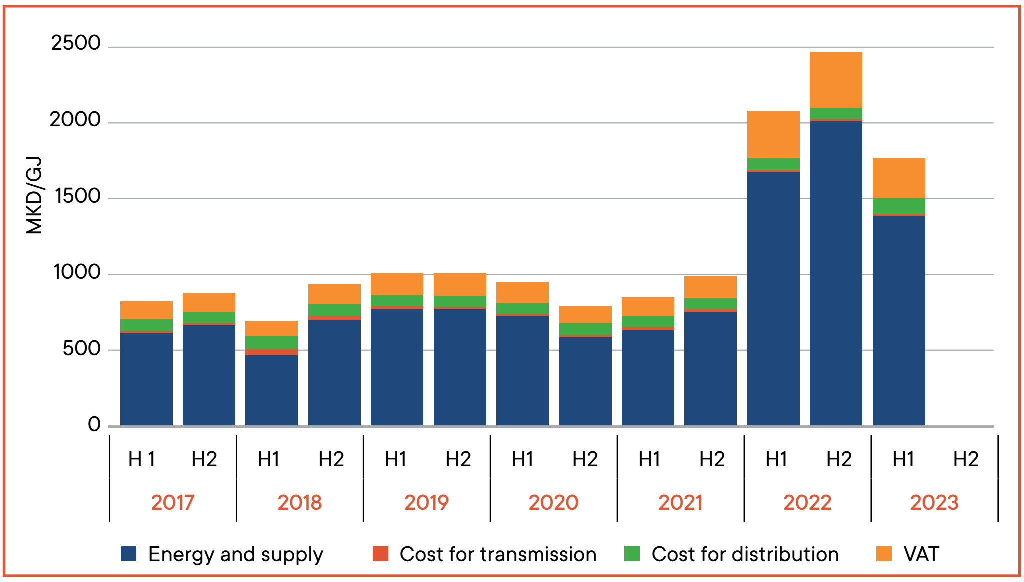
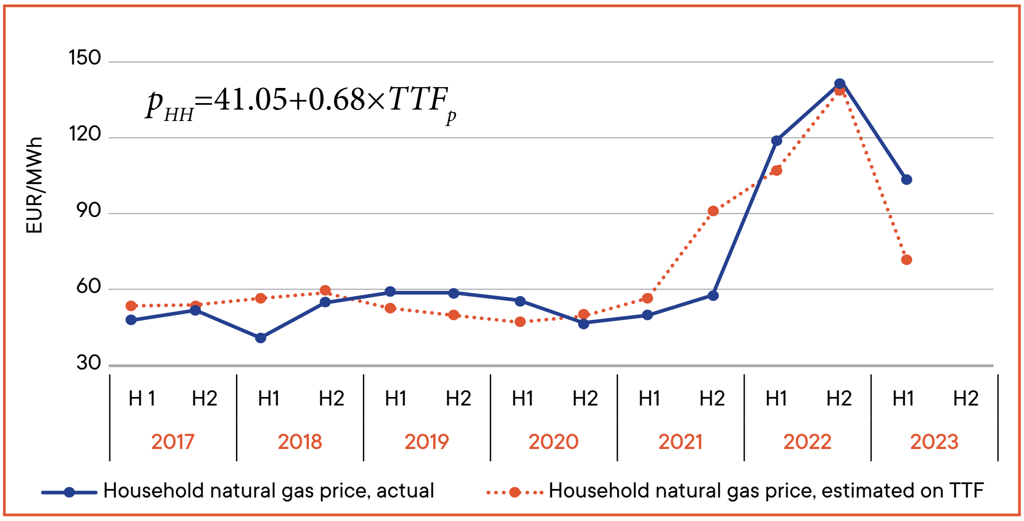


Figure 14. End-user household natural gas price (including network costs and VAT) and estimated end-user natural gas price based on ttf indexes

Source: REKK calculation



5.3. ESTIMATING HEATING DEMAND OF HOUSEHOLDS

Heat demand modelling of country-level building sector usually relies on creating a building typology and estimating heat consumption taking into account the floor area, the heat exchange of building envelope, the efficiency of heaters as well as behavioural factors (such as preferred indoor temperature, time of use and heated floor area). Buildings in every country are highly diverse, but simplified building typologies are commonly applied to make high-level modelling and policy advice possible. Such building typologies exist for EU Member states, for instance the European Building Observatory or the TABULA project. Such detailed database does not yet exist for North Macedonia.

The logic of the modelling exercise is the following:

1. A detailed dataset of residential buildings is created based on publicly available data of the State Statistical Office in North Macedonia containing the type (detached, semi-detached house, multi-family building or apartment block), vintage, heating source and location of the building by municipality.
2. The heat demand modelled using this detailed dataset is validated by comparing the total energy need and fuels used to the final energy consumption of households in the energy balance of North Macedonia
3. Households are allowed to switch from the initial heating technology to alternative heating. Households consider the total cost approach, i.e. investment costs as well as fuel costs during the total lifetime of the appliance are compared.
4. Calculation and switching behaviour is heavily dependent on the input parameters, therefore a detailed description of main driver variables and sensitivities are presented.

5.3.1. RESIDENTIAL BUILDING STOCK DATA FOR NORTH MACEDONIA

As we mentioned earlier. no detailed assessment of the North Macedonian building stock exists, however, there are two sources of information that are worth starting from: Habitat for Humanity has surveyed over 5000 residential buildings in North Macedonia covering 36 municipalities of the 80[9] and the State Statistical Office provides aggregate data on a number of topic related to housing and living conditions:

- The type of dwellings: single-family/detached houses, terraced or semi-detached houses, multi-family houses and apartment blocks.
- Total number of occupied dwellings per municipality is reported
- Type of heating technology used

No information is available on the vintage of the building stock. As a proxy of building vintage, the vintage representative of Serbia is applied.[10]

Although these data are not inter-linked, they do provide detailed information which can be used to compile a building typology for North Macedonia. These data are not result of primary data collection, rather making use of all publicly available information.

Buildings are categorised into 4 types (detached, semi-detached, multi-family house and apartment block) and 6 vintages (before 1945, 1946-1960, 1961-1970, 1971-1980, 1981-1990, 1990-2011, 2011-), resulting in 24 representative buildings. The representative buildings are characterized by floor area (m2) and unitary heating energy consumption (kWh/m2/year).

9 https://buildingmanagementweb.azurewebsites.net/

10 https://episcope.eu/fileadmin/tabula/public/docs/brochure/RS_TABULA_TypologyBrochure_FA-UB.pdf. As the Serbian typology was published in 2013, it contained the vintage up to 2011. Weights were used and re-allocated to reflect new builds in North Macedonia.

Table 19. Indicative floor area of representative buildings

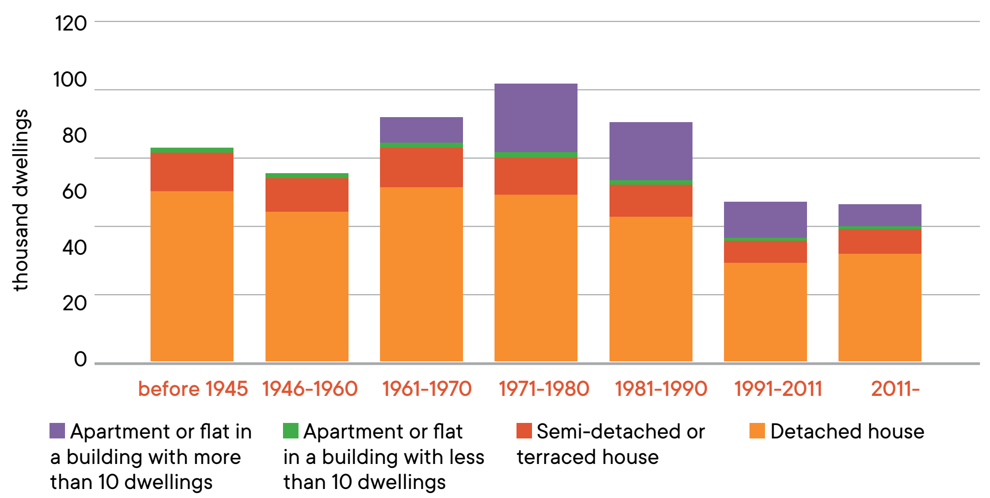
		Floor area, m²			
		1	2	3	4
		Detached house	Terraced	Multi family	Apartment block
A	before 1945	60	60	75	75
B	1946-1960	75	75	75	75
C	1961-1970	100	100	75	75
D	1971-1980	120	120	75	75
E	1981-1990	130	130	75	75
F	1991-2011	150	150	75	75
G	2011-	150	150	75	75

Table 20. indicative energy consumption of representative buildings

		Energy consumption, kWh/m²/yr			
		1	2	3	4
		Detached house	Terraced	Multi family	Apartment block
A	before 1945	280	280	250	250
B	1946-1960	244	244	219	219
C	1961-1970	221	221	189	189
D	1971-1980	190	190	158	158
E	1981-1990	174	174	126	127
F	1991-2011	159	159	100	100
G	2011-	143	143	100	100

Figure 15. Building stock in North Macedonia by type of building and vintage: Assumptions

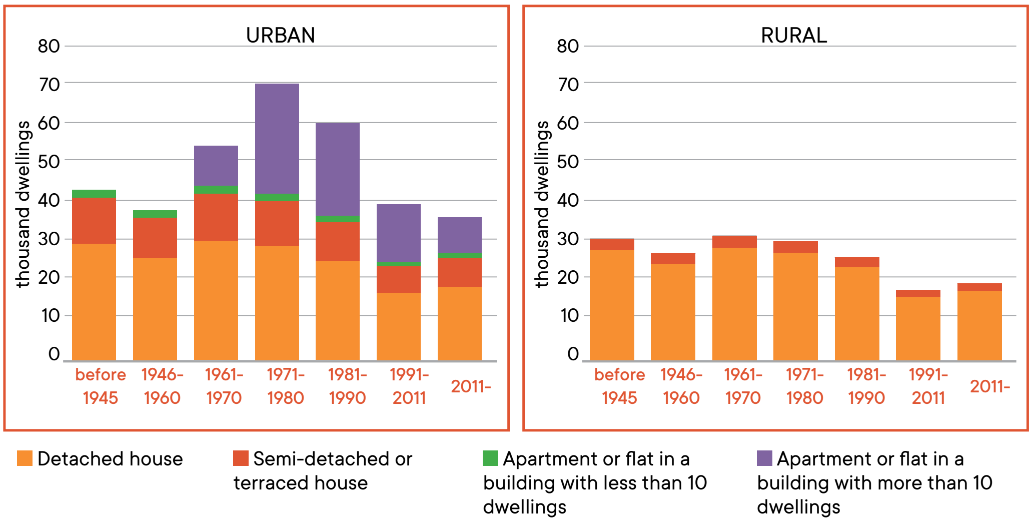
Source: REKK assumptions based on State Statistical Office tables (DSOOM19)



Multi-family buildings and apartment blocks are assumed to be located in rural areas, whereas detached and semi-detached houses can be present in both urban and rural areas.

Figure 16. Distribution of dwellings by urban and rural areas: Assumptions

Source: REKK assumptions based on State Statistical Office tables (DSOOM19)



Dwellings are further divided into categories and municipalities, using the data of the State Statistical Office. For each of the 80 municipalities, we indicate the number of buildings in the 24 representative building types.

The 2021 Census provided detailed data by municipalities on the heating type. Households heating with oil, coal and other fuels were merged into CH other and RH other categories.

As some households use secondary heating, some adjustments were made to fit the heating types to the representative dwelling types:

1. The total number of households heating with other fuels and indicating no heating were omitted (Other& no heating row of 58 013 dwellings)
2. Electricity and firewood stoves for room heating are often used as interchangeable heating and may be secondary in some cases. To account for

Table 21. Households by type of household heating and type of settlement, by municipalities, Census 2021

Source: State Statistical Office, T2006P21

		Number of dwellings	%	%	%
District heating			45772	8%	8%
Central heating	CH electricity	23856	4%	20%
	CH firewood	59179	10%	
	CH pellet	22961	4%	
	CH gaseous fuels	346	0%	
	CH other	13498	2%	
Stove Heating	RH electricity	40717	7%	51%
	RH firewood	253158	42%	
	RH pellet	10628	2%	
	RH gaseous fuels	204	0%	
	RH other	766	0%	
Air conditioning		69534	12%	12%
Other & no heating		58013	10%	10%
Total		**598632**	**100%**	**100%**

each dwelling in every municipality, the room heating with electricity and firewood were adjusted to represent the total number of dwelling for the municipality.

These assumptions allowed the setting up of a data table containing the number of dwellings by type and vintage for each municipality by urban and rural area, as well as the primary mode of heating for each municipality. As an example, the municipality of Gazi Baba is displayed:

Table 22.
Dwellings by heating type in the municipality of Gazi Baba (Example)
Source: REKK assumption and calculations based on State Statistical Office

					Avg floor area	Total dwellings	DH	CH Electricity	CH firewood	CH pellet	CH gas	CH other	RH Elec	RH firewood	RH pellet	RH gas	RH other	Air conditioning
Municipality	Area	Code	Type	Vintage	m^2	#	#	#	#	#	#	#	#	#	#	#	#	#
Gazi Baba	Urban	A1	Detached house	before 1945	60	1013	309	48	32	36	2	3	285	38	14	1	1	244
Gazi Baba	Urban	B1	Detached house	1946-1960	75	890	272	43	28	32	2	3	248	34	12	1	1	214
Gazi Baba	Urban	C1	Detached house	1961-1970	100	1038	317	50	33	37	2	3	291	39	14	1	1	250
Gazi Baba	Urban	D1	Detached house	1971-1980	120	990	302	47	31	36	2	3	278	37	14	1	1	238
Gazi Baba	Urban	E1	Detached house	1981-1990	130	858	262	41	27	31	2	3	240	32	12	1	1	206
Gazi Baba	Urban	F1	Detached house	1991-2011	150	583	178	28	18	21	1	2	164	22	8	1	0	140
Gazi Baba	Urban	G1	Detached house	2011-	150	637	195	30	20	23	1	2	179	24	9	1	0	153
Gazi Baba	Urban	A2	Terraced	before 1945	60	402	123	19	13	14	1	1	113	15	6	0	0	97
Gazi Baba	Urban	B2	Terraced	1946-1960	75	353	108	17	11	13	1	1	99	13	5	0	0	85
Gazi Baba	Urban	C2	Terraced	1961-1970	100	412	126	20	13	15	1	1	115	16	6	0	0	99
Gazi Baba	Urban	D2	Terraced	1971-1980	120	393	120	19	12	14	1	1	112	15	5	0	0	94
Gazi Baba	Urban	E2	Terraced	1981-1990	130	341	104	16	11	12	1	1	96	13	5	0	0	82
Gazi Baba	Urban	F2	Terraced	1991-2011	150	231	71	11	7	8	0	1	65	9	3	0	0	56
Gazi Baba	Urban	G2	Terraced	2011-	150	253	77	12	8	9	0	1	71	10	4	0	0	61
Gazi Baba	Urban	A3	Multi family	before 1945	75	69	21	3	2	2	0	0	20	3	1	0	0	17
Gazi Baba	Urban	B3	Multi family	1946-1960	75	61	19	3	2	2	0	0	17	2	1	0	0	15
Gazi Baba	Urban	C3	Multi family	1961-1970	75	71	22	3	2	3	0	0	20	3	1	0	0	17
Gazi Baba	Urban	D3	Multi family	1971-1980	75	68	21	3	2	2	0	0	20	3	1	0	0	16
Gazi Baba	Urban	E3	Multi family	1981-1990	75	59	18	3	2	2	0	0	17	2	1	0	0	14
Gazi Baba	Urban	F3	Multi family	1991-2011	75	40	12	2	1	1	0	0	11	2	1	0	0	10
Gazi Baba	Urban	G3	Multi family	2011-	75	44	13	2	1	2	0	0	12	2	1	0	0	11
Gazi Baba	Urban	A4	Apartment block	before 1945	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Urban	B4	Apartment block	1946-1960	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Urban	C4	Apartment block	1961-1970	75	352	108	17	11	13	1	1	98	13	5	0	0	85
Gazi Baba	Urban	D4	Apartment block	1971-1980	75	967	295	46	31	35	2	3	272	36	13	1	1	232
Gazi Baba	Urban	E4	Apartment block	1981-1990	75	814	249	39	26	29	1	2	228	31	11	1	1	196
Gazi Baba	Urban	F4	Apartment block	1991-2011	75	506	155	24	16	18	1	2	141	19	7	1	0	122
Gazi Baba	Urban	G4	Apartment block	2011-	75	313	96	15	10	11	1	1	88	12	4	0	0	75
Gazi Baba	Rural	A1	Detached house	before 1945	60	1240	0	30	132	68	0	15	189	614	37	0	5	150

					Avg floor area	Total dwell-ings	DH	CH Elec-tricity	CH fire-wood	CH pellet	CH gas	CH other	RH Elec	RH fire-wood	RH pellet	RH gas	RH other	Air condi-tioning
Munici-pality	Area	Code	Type	Vintage	m^2	#	#	#	#	#	#	#	#	#	#	#	#	#
Gazi Baba	Rural	B1	Detached house	1946-1960	75	1089	0	26	116	60	0	14	167	539	32	0	4	131
Gazi Baba	Rural	C1	Detached house	1961-1970	100	1271	0	30	135	70	0	16	194	630	38	0	5	153
Gazi Baba	Rural	D1	Detached house	1971-1980	120	1213	0	29	129	67	0	15	185	601	36	0	5	146
Gazi Baba	Rural	E1	Detached house	1981-1990	130	1050	0	25	111	58	0	13	161	520	31	0	4	127
Gazi Baba	Rural	F1	Detached house	1991-2011	150	713	0	17	76	39	0	9	109	353	21	0	3	86
Gazi Baba	Rural	G1	Detached house	2011-	150	780	0	19	83	43	0	10	119	386	23	0	3	94
Gazi Baba	Rural	A2	Terraced	before 1945	60	133	0	3	14	7	0	2	20	66	4	0	1	16
Gazi Baba	Rural	B2	Terraced	1946-1960	75	117	0	3	12	6	0	1	20	58	3	0	0	14
Gazi Baba	Rural	C2	Terraced	1961-1970	100	136	0	3	14	7	0	2	22	67	4	0	1	16
Gazi Baba	Rural	D2	Terraced	1971-1980	120	130	0	3	14	7	0	2	19	64	4	0	1	16
Gazi Baba	Rural	E2	Terraced	1981-1990	130	113	0	3	12	6	0	1	18	56	3	0	0	14
Gazi Baba	Rural	F2	Terraced	1991-2011	150	77	0	2	8	4	0	1	13	38	2	0	0	9
Gazi Baba	Rural	G2	Terraced	2011-	150	84	0	2	9	5	0	1	12	42	3	0	0	10
Gazi Baba	Rural	A3	Multi family	before 1945	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	B3	Multi family	1946-1960	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	C3	Multi family	1961-1970	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	D3	Multi family	1971-1980	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	E3	Multi family	1981-1990	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	F3	Multi family	1991-2011	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	G3	Multi family	2011-	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	A4	Apartment block	before 1945	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	B4	Apartment block	1946-1960	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	C4	Apartment block	1961-1970	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	D4	Apartment block	1971-1980	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	E4	Apartment block	1981-1990	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	F4	Apartment block	1991-2011	75	0	0	0	0	0	0	0	0	0	0	0	0	0
Gazi Baba	Rural	G4	Apartment block	2011-	75	0	0	0	0	0	0	0	0	0	0	0	0	0

Households do not utilise all their useful floor area. We assume that:

- dwellings in multi-family houses and apartment blocks are heating all their floor area (100%)
- detached and semi-detached houses in Skopje and cities (Bitola, Veles, Gostvar, Kumanovo, Ohrid, Strumica, Tetovo, Shtip) are heating 50% of their useful floor area
- detached and semi-detached houses in other municipalities are heating 25% of their useful floor area

Overall, this results in a 50% under-heating in the total building stock.

Efficiency of the technologies is identical across building types. Efficiency in this context means how much useful heating energy is converted by using one unit of fuel or energy source. For example, to deliver 1 kWh of useful heating energy, 1 kWh of electricity is needed if resistance type room heating is used. In case of firewood room heating, 1.18 kWh of firewood is used (Table 23).

Table 23.
Assumed efficiency of heating technologies
Source: REKK assumptions

DH	CH Elec	CH fire-wood	CH pellet	CH gas	CH other	RH Elec	RH fire-wood	RH pellet	RH gas	RH other	Air condi-tioning	Oth-er&no heat-ing
100%	300%	85%	90%	110%	90%	100%	85%	90%	95%	90%	200%	90%

Energy consumption of each household can be calculated as:

$$\textit{Heating Energy Consumption (kWh/year)} = \textit{Floor area } (m^2) \text{ X } \textit{Unitary energy consumption} \left(\frac{kWh}{m^2/year}\right) \text{ X } \textit{Underheating}(\%)/\textit{efficiency}(\%)$$

where

Floor area is the total floor area of the dwelling in m^2 (Table 19)

Unitary energy consumption is the (Table 20)

Underheating represents that limited floor area is heated in the households, due to consumer decision.

Efficiency means how much heating energy is produced by using one unit of energy or fuel (Table 23).

Heating energy consumption by each building type and heating mode is then calculated for every municipality and aggregated by municipality level. The building typology and the classification of the heating mode allows us to calculate the heating energy need of each households and this can be compared to the consumption of the residential sector in the energy balance. Figure 17 shows this comparison. As households are using electricity for other purposes than heating (e.g. lighting and appliances consumption), the annual demand for electricity is adjusted by this volume (~1.5 TWh/year)[11]. This shows that our simple model captures the residential part of the North Macedonian final energy balance and shows the weight of various fuels correctly.

11 See Eurostat: Disaggregated final energy consumption in households - quantities [nrg_d_hhq_custom_8181652]

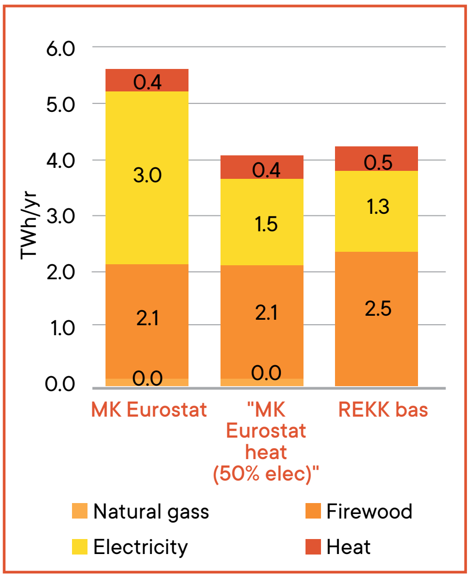


Figure 17.
Final energy consumption of the residential sector and calculated consumption of households

5.3.2 SWITCHING OPTIONS AND POTENTIAL OF THE NORTH MACEDONIAN HOUSEHOLDS

After constructing the building stock database, a simple model of household decision is set up: given the opportunity, each household may decide to switch from their currently used heating technology to another. Decision is made on the basis of full information and long-term cost minimisation: this means that:

- switching means the change of heating appliance. Dwellings pay a one-time investment cost for the switching pay the fuel cost accordingly for the new technology.
- switching does not alter consumer behaviour, i.e. the rate of underheating and energy consumption is the same for the dwelling before and after the switching. This means that the heat demand delivered for households is the same before and after switching, but due to the different efficiency of technology this may result in lower overall final energy consumption.

- all households know the prices of energy and cost of investment for switching.
- all households have ample funds for any kind of switching.
- as the cost of switching from room heating to central heating are extremely high compered to the change of heating technology, switching between the various heating modes (between district heating, central heating and room heating) is not allowed. This means that
  - dwellings with district heating do not switch;
  - dwellings with central heating can switch to other central heating technologies ;
  - dwellings with room heating can switch to other room heating technologies and air conditioning;
  - dwellings with air conditioning can switch to room heating technologies.
- dwellings will choose the technology to switch to with the lowest overall cost (investment + overall fuel cost), assuming 20 years of lifetime and 10% discount rate.
- all households urban households which are located in municipalities which are part of the gas master plan are allowed to switch to gas. Rural households are not allowed to switch to gas heating.
- all dwellings have sufficient funds to switch.

Cost of switching included the cost of equipment as well as installation. As households were assumed not to switch from room heating to central heating no additional cost for piping and other heat exchangers was included. Installation cost of 1000 EUR/central heating equipment was added. For room heating equipment, no installation cost was added in case of resistance heaters, pellet stoves and solid stoves while 100 EUR/heater was added for air conditioners and gas convectors. Four units of room heaters were assumed for each households.

Table 24. investment cost of central heating options

Source: REKK assumptions

	CH Elec	CH firewood	CH pellet	CH gas
	Air-to-Air heat pump	Solid stove central	Pellet boiler central	Condensing gas boiler central
				
Efficiency (%)	300%	85%	90%	110%
Equipment cost EUR	10000	1200	5000	2000
Installation cost EUR	1000	1000	1000	1000
# units	1	1	1	1

Table 25. Investment cost of Room heating option

Source: REKK assumptions

	RH Elec	RH firewood	RH pellet	RH gas	Air-to-air heat pump
	Electric resistance heater	Solid stove single room	Pellet stove	Gas convector	Air conditioning
					
Efficiency (%)	100%	85%	90%	95%	200%
Equipment cost EUR	300	1000	1200	400	1000
Installation cost EUR	0	0	0	250	250
# units	4	4	4	4	4

Table 26. Overall cost (installation + equipment) for swithcing per household, EUR

Source: REKK assumptions

CH Elec	CH firewood	CH pellet	CH gas	RH Elec	RH firewood	RH pellet	RH gas	Air conditioning
11000	2600	6000	3000	1200	4000	4800	2600	5000

Main outputs of this exercise are the total final energy consumption of households and the cost of switching. For this reason, a number of different scenarios will be presented to show the effects of these drivers.

Switching behaviour is driven by the relative cost of fuels as well as the efficiency of the heating equipment. Cost of fuels is set by the 2023 H1 prices reported by State Statistical Office.

District heating is supplied by BEG and Skopje Sever to households, we used 2023 data reported by Energy And Water Services Regulatory Commission Of The Republic Of North Macedonia (ERC)[12] for BEG consumers (3 MKD/kWh, ~0.04 EUR/kWh).

Average electricity price reported by State Statistical Office for H1 2023 was applied as electricity tariff, including network charges and VAT (6.74 MKD/kWh, ~0.11 EUR/kWh).

Firewood price is regulated, state forestry services has increased the price of firewood by 20% in August 2022.[13] Oak was selling for 3564 MKD/m^3, which would mean 0.06 EUR/kWh considering an energy density of 2100 kWh/m^3. Firewood is not available in all municipalities at the regulated price and black-market price of firewood might be higher than the regulated one. Own collection of firewood and use of other solid fuels not procured on the market may decrease the actual cost of the fuel.

Pellet prices were not reported by the state statistical office. As a proxy of pellet prices, 2023 October prices reported by the German Pellet Organisation were used at 0.07 EUR/kWh.[14] Pellet price includes transport within 50 km, VAT in Germany and other costs incurred, calculated at 5 kWh/kg NCV.

Gas prices were reported by the State Statistical office for household consumers consumption category D1.

12 https://www.erc.org.mk/page_en.aspx?id=289
13 https://www.erc.org.mk/page_en.aspx?id=289
14 https://www.depi.de/pelletpreis-wirtschaftlichkeit

Figure 18. . Historical prices in North Macedonia

Source: REKK data collection

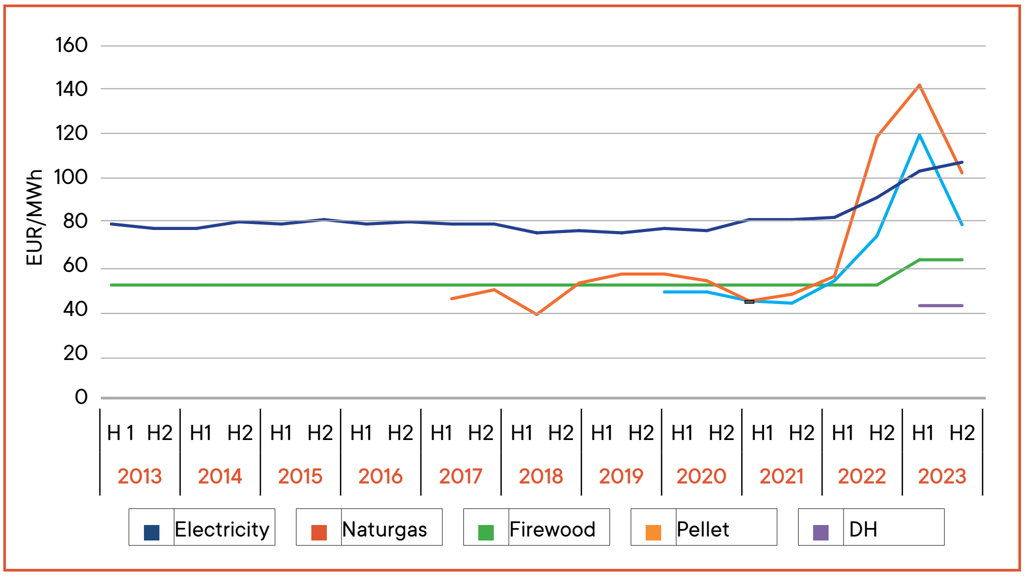


Table 27. Fuel prices assumed for modelling

Source: REKK based on State Statistical Office and other sources

		District Heating	Electric-ity	Fire-wood	Pellet	Gas
Energy	EUR/kWh	-	0.06		-	0.08
Network&transport	EUR/kWh	-	0.04		-	0.01
Fuel, other taxes	EUR/kWh	-	-	-	-	-
VAT	EUR/kWh	-	0.01		-	0.02
Total fuel cost	EUR/kWh	0.04	0.11	0.06	0.07	0.10

5.3.3. RESULTS

Assuming the parameters presented above, the following behaviour is modelled:

- Households with central heating switch to solid fuel central heaters, due to the low overall cost of firewood compared to other fuels.
- Households with district heating do not switch
- Households with room heating switch to air-to-air heat pumps (air conditioning) and resistance heaters from firewood
- Overall energy consumption in households will decrease due to the higher efficiency of heat pumps compared to firewood burning

Figure 19. Switching behaviour of households

Source: REKK modelling

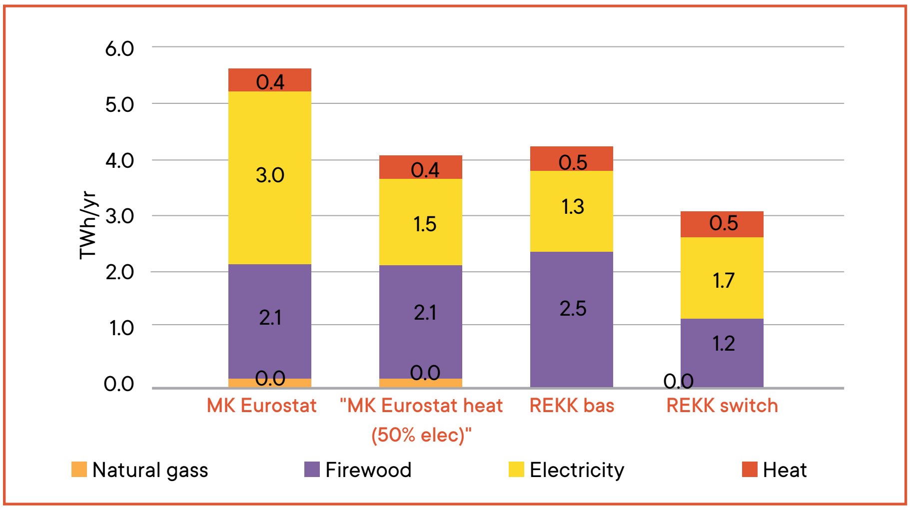


Figure 20. Share of heating technologies before and after switching

Source: REKK modelling

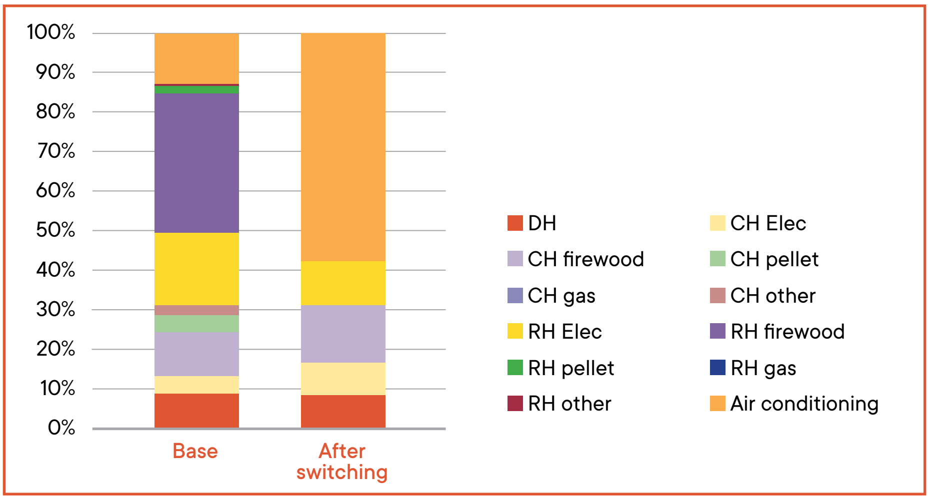


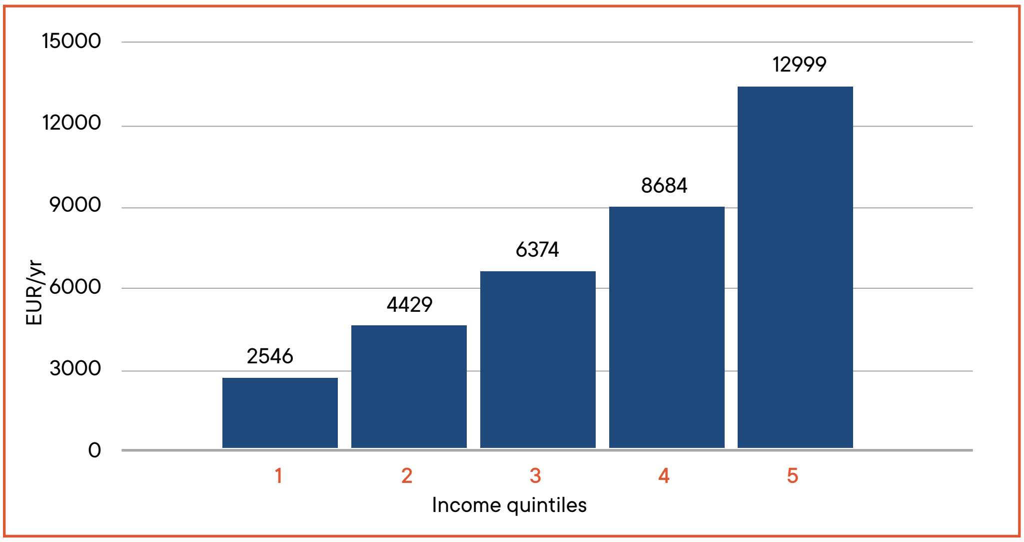
Table 28. Household switching

	Before switching	Change	After switching
DH	45768	0	45768
CH Elec	23805	-23402	403
CH firewood	59147	59987	119134
CH pellet	22895	-22895	0
CH gas	270	-270	0
CH other	13420	-13420	0
RH Elec	97174	-5838	91336
RH firewood	188685	-188685	0
RH pellet	10563	-10563	0
RH gas	127	-127	0
RH other	610	-610	0
Air conditioning	69504	205823	275327
Other&no heating	0	0	0
Total	531968	0	531968

Cost of switching for a household to air conditioning based heating would mean 5000 EUR (installing 4 air conditioning units). Annual disposable income of households in North Macedonia in the 3rd quintile was 6374 EUR/year in 2020, and 12999 EUR/yr for the 5th quintile. Even at the highest quintiles, switching of heating technology would cover nearly 38% of household disposable income. This suggests that without support, replacing the heating equipment is not possible for most households.

Figure 21. Total disposable household income, by types and quintile groups, average per household, 2020 (0.016 EUR/MKD exchange rate)

Source: MAKSTAT



Surveys of the Macedonian households indicate that they have little disposable income for energy efficiency or other up-front investment: a 2019 survey of Habitat for Humanity showed that 95% of respondents of a survey in Gjorche Petrov and 65% in Veles could not pay any up-front energy efficiency investment. Those who indicated that they are willing and able to invest in Veles could afford on average a 600 EUR investment. (Habitat for Humanity North Macedonia, 2019)

A 2023 study surveyed (Indago, 2023) the attitudes of households towards natural gas were overall positive: 73% of respondents noted that natural gas is cheaper than other fuels; 67% claimed that they would find natural gas more suitable for heating than firewood. If given the opportunity, 75% of respondents would connect to the gas network immediately. Still, 70% of households would invest only under 300 EUR for connection to the gas network. Even if connection fee is not charged, the purchase of gas convectors and installing them could cost easily over 2000 EUR. This suggests that low costs associated with natural gas are based on the under-developed network and current regulation, which could change if the costs of the expanded network are to be paid by system users.

5.3.4. SENSITIVITIES

Outcomes of the modelling are driven by the relative prices of fuels and cost of investment. If the cost of gas relatively to other fuels changes ceteris paribus, we see different outcomes. Moreover, households may have limited funds for switching and thus the original structure of the building heating sector may not change for this reason.

5.3.4.1. SENSITIVITY ON THE PRICE OF NATURAL GAS

Price of natural gas has changed on a wide range in the past 5 years: in the model formulation, gas price was set at 105 EUR/MWh for households. At this price, households would choose rather electricity or firewood as a source of heating. It must be stressed that the price of gas was at parity with electricity and twice as expensive as firewood in 2023 H1, which served as a basis for our parameters. In the past years, electricity was nearly priced at double compared to natural gas. The figure below shows the effects of different gas price levels while other prices are unchanged. Gas would enter the mix as a source of heating at the end-user price of 65-90 EUR/MWh, resulting in ~0.5-1 TWh/year residential demand.

If the end-user price dropped to 65 EUR/MWh (including network costs and VAT alike), residential consumption would increase to 2.5 TWh/year.

However, if costs of the network development are accounted for, then households would need to pay 12-26.6 EUR/MWh network costs, as well as VAT. This leaves little margin for the molecule costs, and such it is not realistic that such a scenario will be realised. If a carbon tax is to be introduced on electricity and gas, the additional costs of carbon would make gas even less competitive to electricity.

5.3.4.2. SENSITIVITY ON SWITCHING RATE

The gasification plans of North Macedonia assume high conversion rates of household to natural gas. However, switching from current heating solution to natural gas is based on the decision of households. These can be incentivised with direct monetary transfers, setting lower price for gas or other regulatory incentives or information campaigns. Economic viability of a gasification campaign thus depends on the financial background of households and state support.

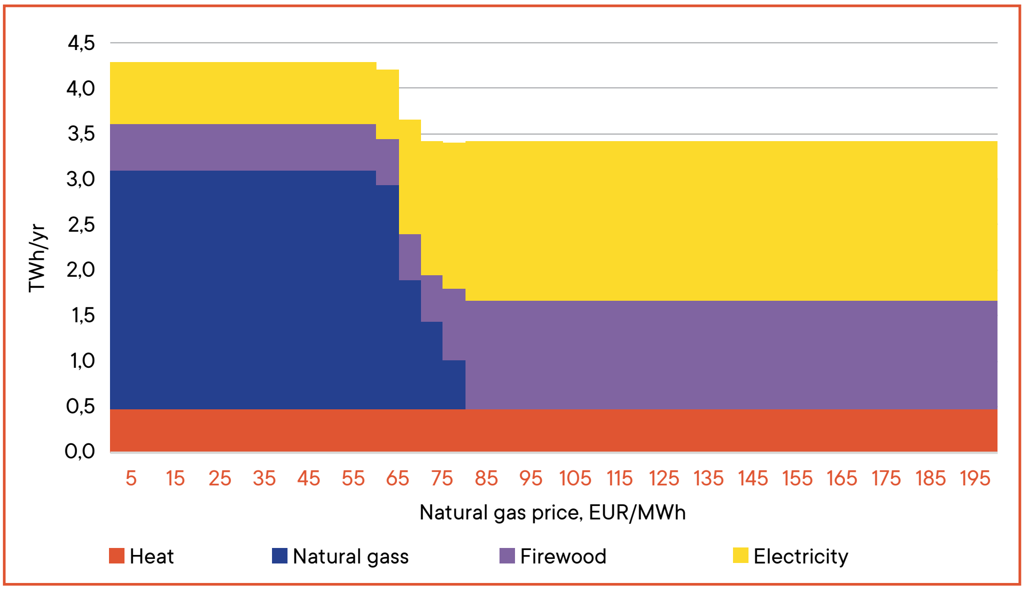
Households may lack the sufficient funds for any switching activity. Considering the high up-front cost of investment for new heating technologies and the available income of households, four alternative scenarios were modelled:

- only the highest quintile households are able to switch (20%)
- the highest two quintiles are able to switch (40%)
- the highest three quintiles are able to switch (60%)
- all but the lowest quintile is able to switch (80%)

Constraining the households switching behaviour highly decreases the potential residential gas consumption:

Figure 22. Final energy consumption of residential buildings as a function of gas price, TWh/year

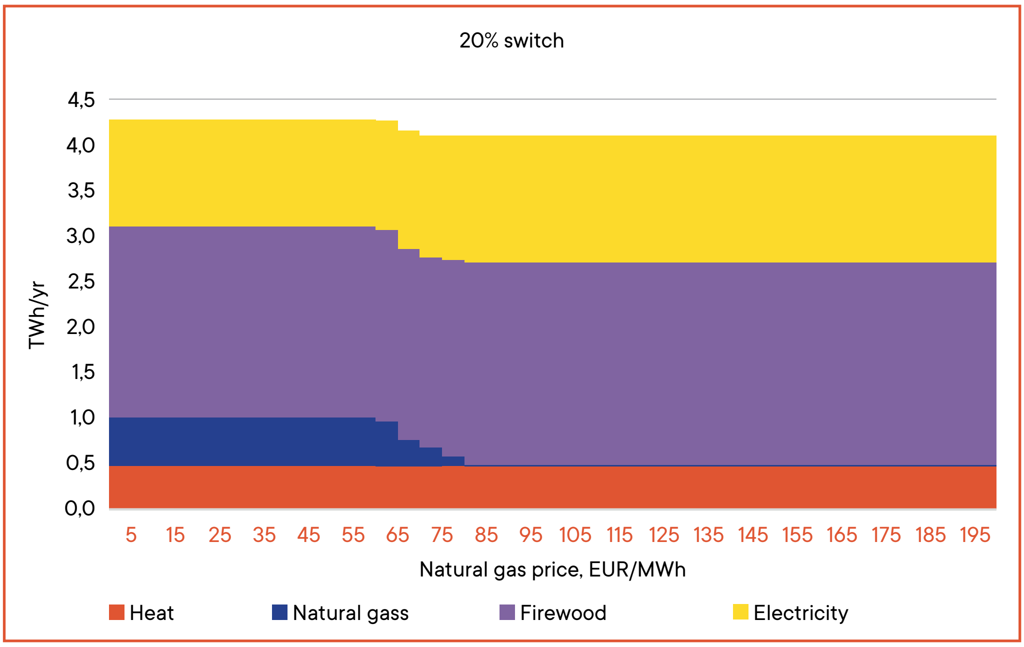
Source: REKK modelling

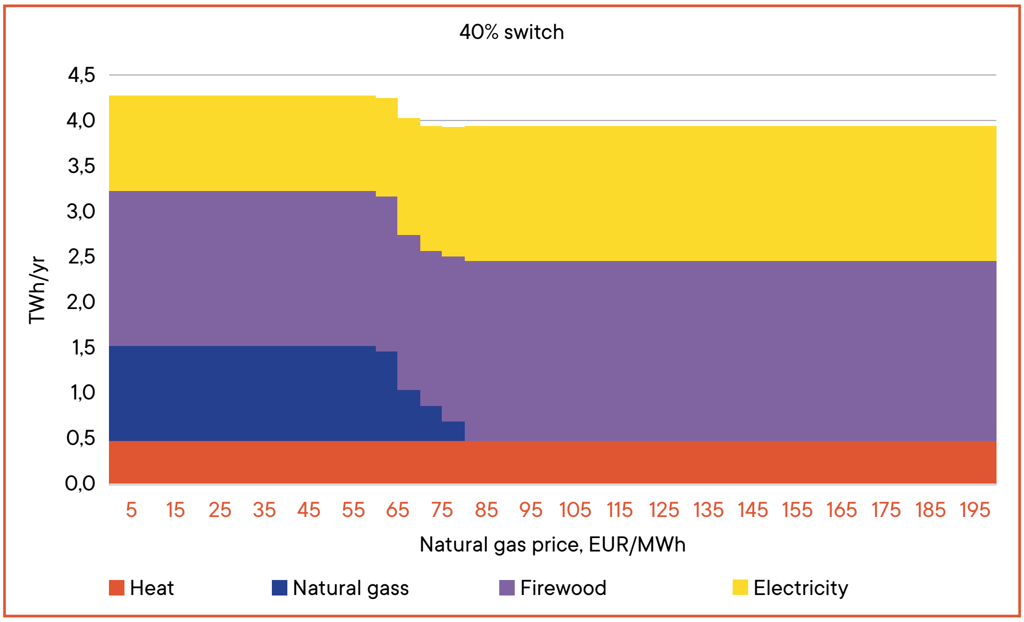


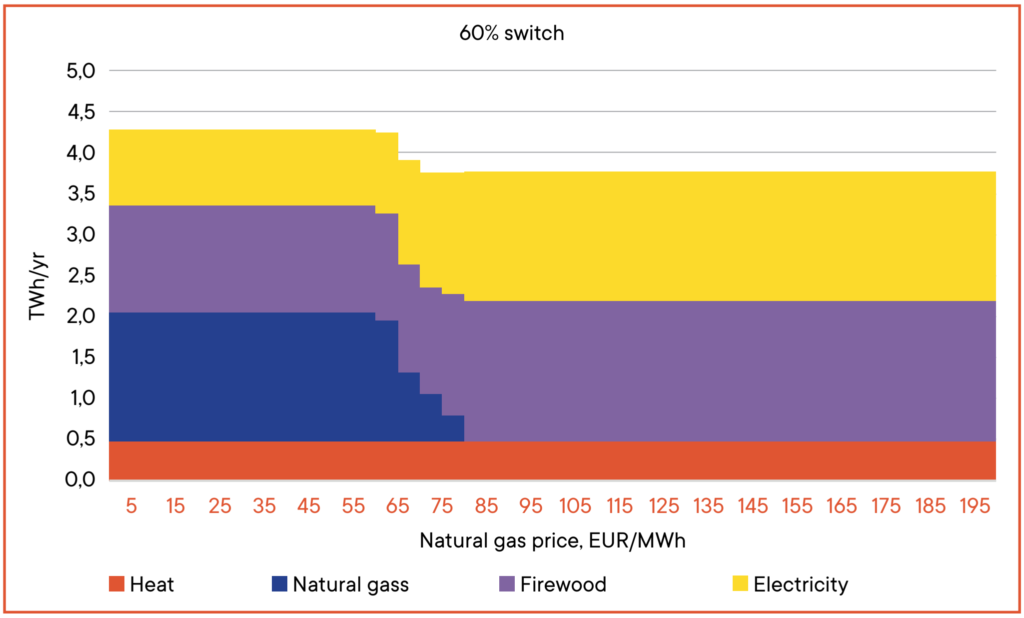
- at 20% switching, only 0.5 TWh/year gas demand is modelled at 20 EUR/MWh
- at 40% switching, 1 TWh/year gas demand is modelled at 20 EUR/MWh
- at 60% switching, 1.5 TWh/year gas demand is modelled at 20 EUR/MWh
- at 80% switching, 2 TWh/year gas demand is modelled at 20 EUR/MWh (identical with 100% switching)

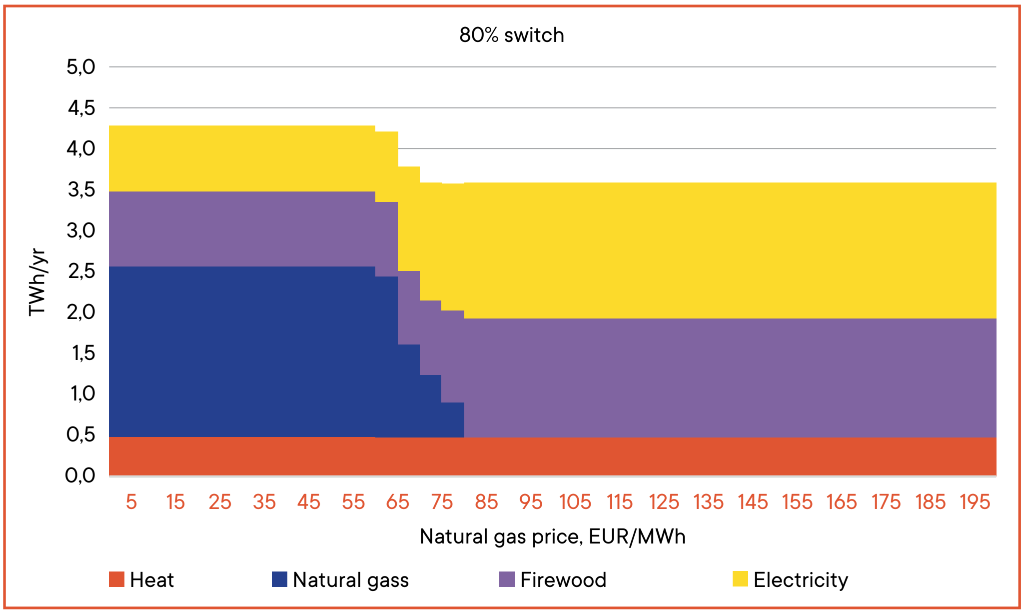
Figure 23. Sensitivity on switching rate

Source: REKK modelling




40% switch
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
TWh/yr
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Natural gas price, EUR/MWh
Heat
Natural gass
Firewood
Electricity


60% switch
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
TWh/yr
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Natural gas price, EUR/MWh
Heat
Natural gass
Firewood
Electricity


80% switch
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
TWh/yr
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Natural gas price, EUR/MWh
Heat
Natural gass
Firewood
Electricity

5.3.4.3. SENSITIVITY ON ENERGY CONSUMPTION OF BUILDINGS

An ongoing review of the North Macedonian building stock conducted by Habitat for Humanity contained detailed actual data on the energy consumption of buildings. Compared to our assumptions, average energy consumption of households were around 50 kWh/m2/year higher.

Table 29. Indicative Energy consumption of representative buildings, sensitivity assumptions

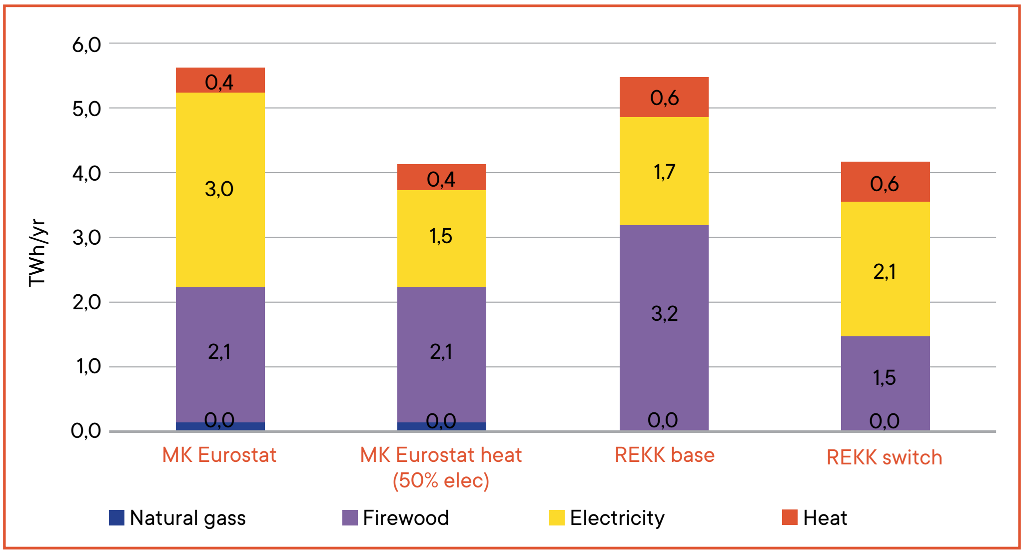
Applying this to our calculation, the following changes occurred:

		Energy consumption, kWh/m2/yr			
		1	2	3	4
		Detached house	Terraced	Multi family	Apartment block
A	before 1945	60	60	75	75
B	1946-1960	75	75	75	75
C	1961-1970	100	100	75	75
D	1971-1980	120	120	75	75
E	1981-1990	130	130	75	75
F	1991-2011	150	150	75	75
G	2011-	150	150	75	75

Applying this to our calculation, the following changes occurred:

- total energy demand increased to above 5.6 TWh/year
- Switching behaviour is identical to the one modelled in our base scenario, i.e. households would switch to electricity-based heating (heat pumps)

Figure 24. Switching behaviour of households, energy consumption sensitivity



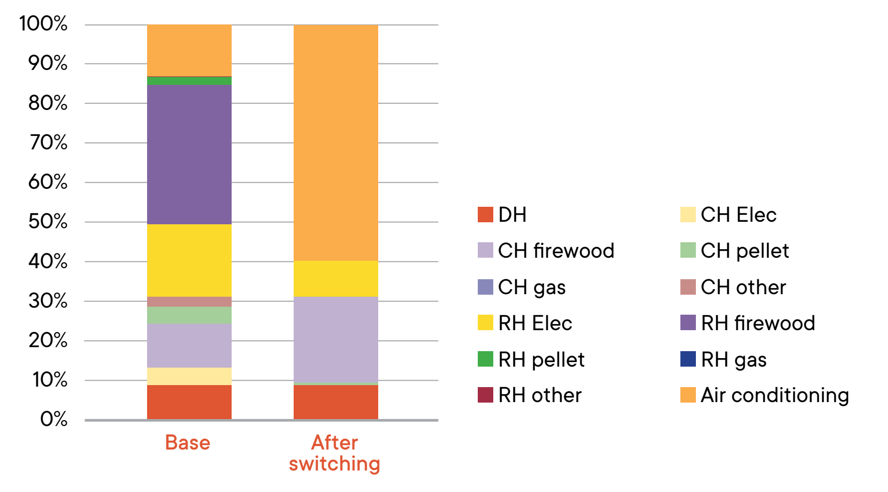


Figure 25. Share of heating technologies before and after switching, energy consumption sensitivity

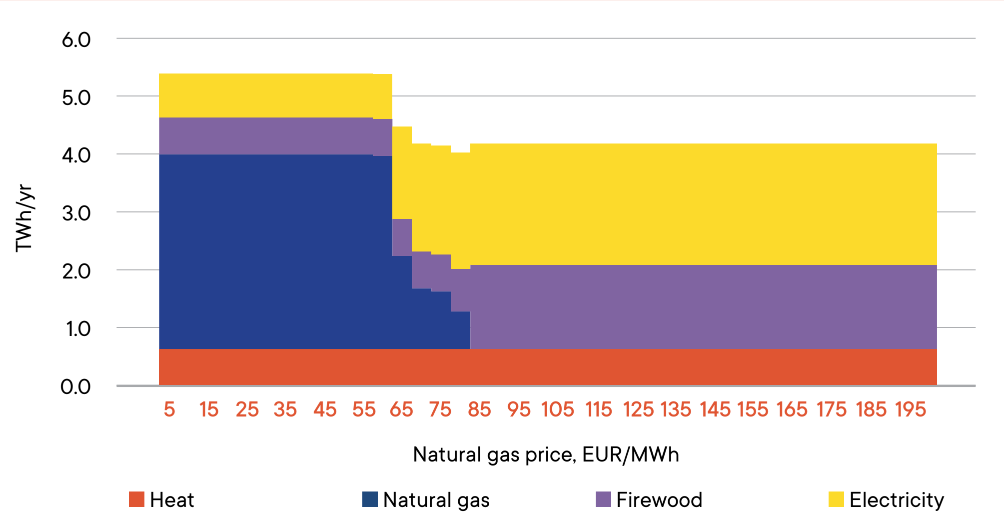


Figure 26. Final energy consumption of residential buildings as a function of gas price, energy consumption sensitivity

5.3.4.4. SENSITIVITY ON FIREWOOD PRICE

Firewood costs assumed in our calculations were based on the regulated firewood price announced by the national forest company.[15] As the regulated firewood price did not follow the high price uptake in electricity and natural gas prices, households turned to firewood which caused scarcity and the regulated price as such may not be indicative of the real cost of households.

For this reason, firewood price was assumed to be 50% higher than the regulated price.

It is apparent that a 50% higher effective firewood price would make gas heating preferrable to wood heating in central heating households. Firewood heating would be crowded out in most households by electricity heat pumps and gas heaters.

15 http://www.mkd-sumi.com.mk/admin/documents/cenovnik_za_utvrduvane_na_cen-ite_na_glavnite_sum-proizvodi_na_jp_na-cionalni_sumi_po_skop-je.pdf

Figure 27. Switching behaviour of households, Firewood price sensitivity

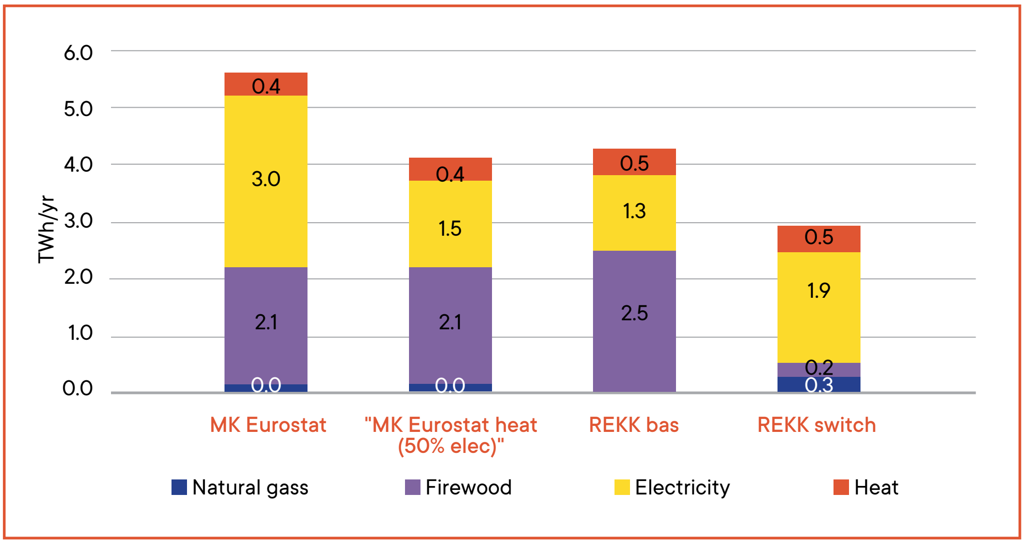


Figure 28. Share of heating technologies before and after switching, energy consumption sensitivity

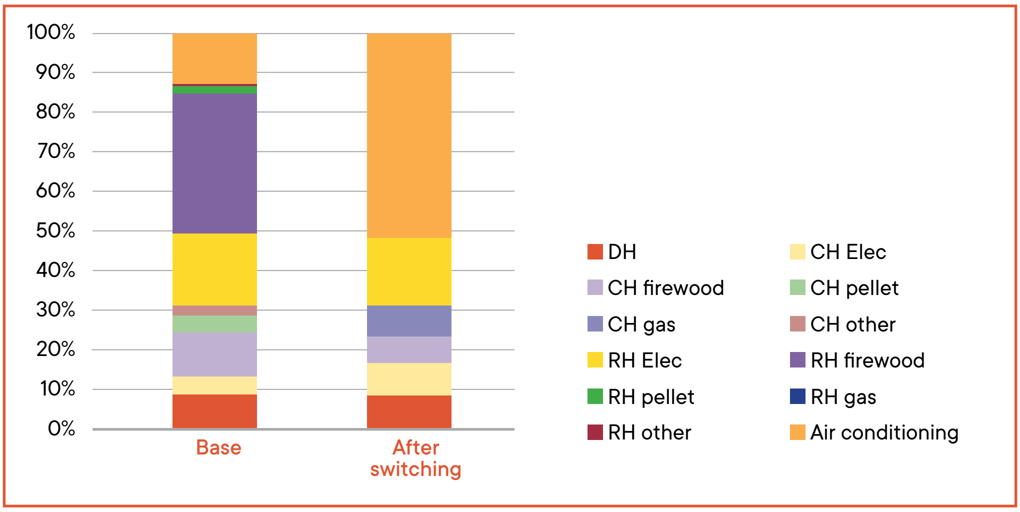
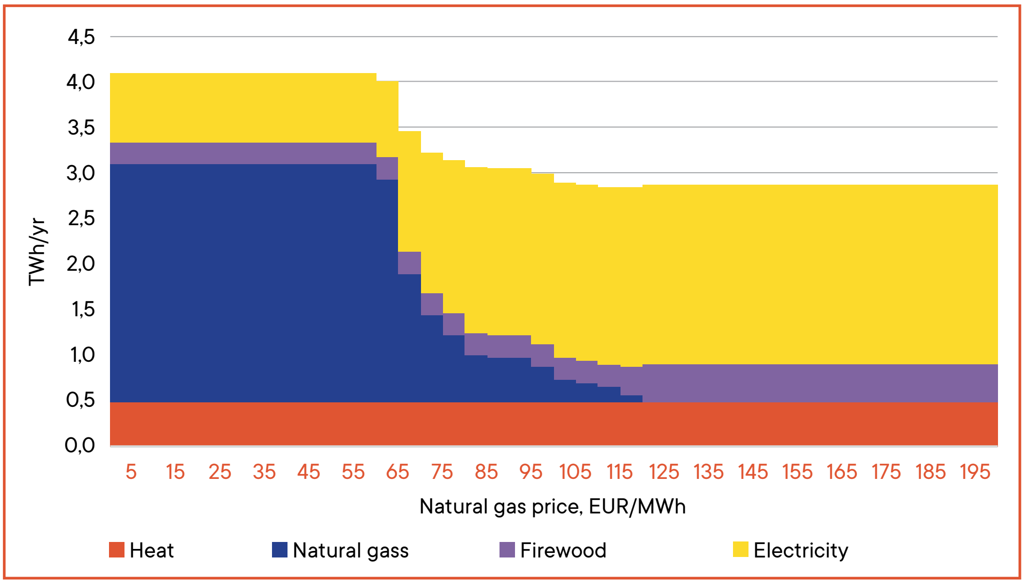


Figure 29. Final energy consumption of residential buildings as a function of gas price, Firewood price sensitivity (50% higher prices)



5.3.4.5. SENSITIVITY ON DISTRICT HEATING SWITCHING

Some households have switched from district heating to individual room heating in the city of Skopje. In this calculation we constrained this possibility. If the district heating consumers would be allowed to switch from district heating, they would do so if the total investment cost and the fuel cost would be lower than the current bill they are paying. This is not the case in with the parameters set in our analysis, so even if the switching would be relaxed for district heating consumers, they would stick with the current solution based on costs.

Switching behaviour of households may not only be caused by the prices but comfort and other factors which are not part of this analysis.

5.3.4.6. SENSITIVITY ON PRE-CRISIS PRICE LEVELS

Relative prices of fuels are highly determining the outcome of modelling. Price of natural as skyrocketed in the crisis, but the price of regulated electricity for households in North Macedonia did not follow this development. Therefore, a sensitivity with the following parameters was performed:

Table 30. Cost of fuels assumed, EUR/MWh pre-crisis price sensitivity

District heat	Electricity	Firewood	Pellet	Natural gas
EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh
44,21	76,31	52,61	50,00	50,00

The low relative cost of gas compared to electricity drives switching behavior of households towards gas. Based on the pre-crisis levels, 2,4 TWh of annual household demand would could be realized.

Figure 30. Switching behaviour of households, Pre-crisis price sensitivity

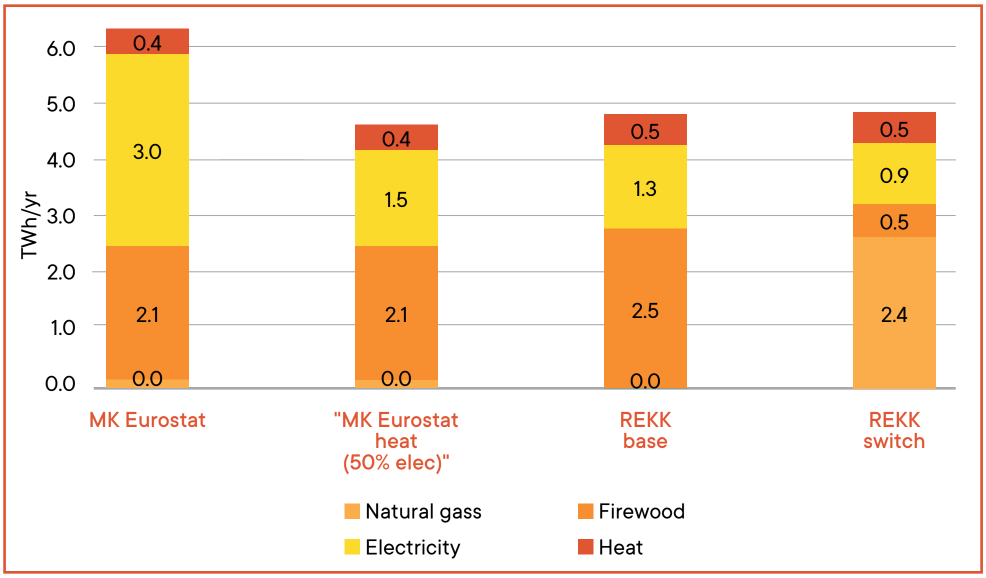


Figure 31. Share of heating technologies before and after switching, pre-crisis sensitivity

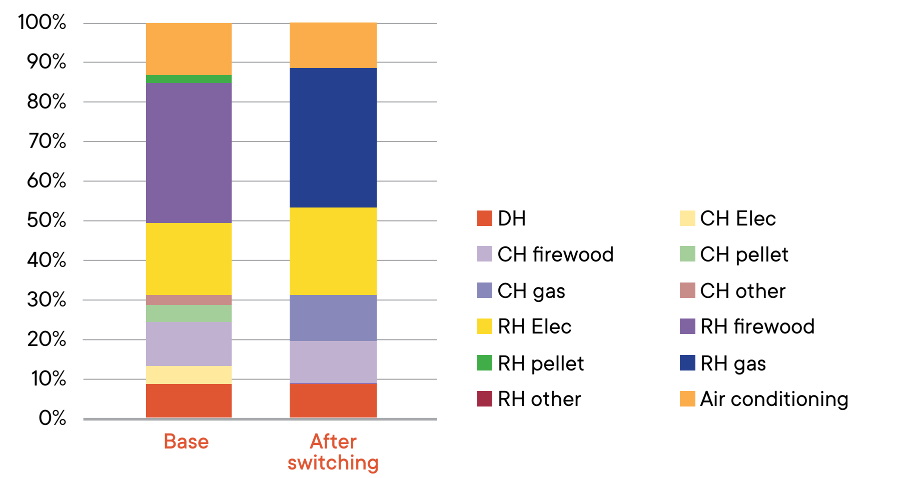
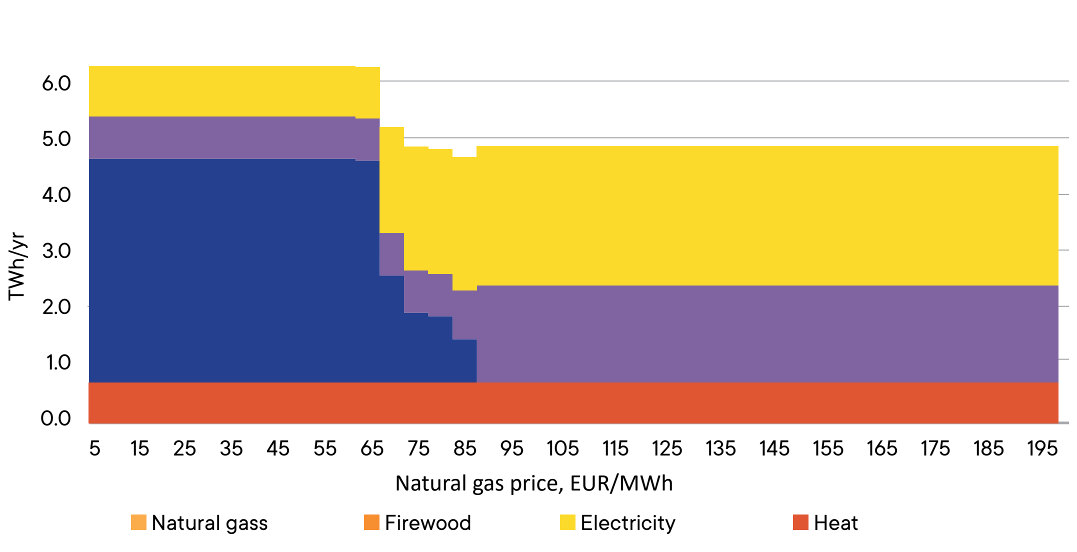


Figure 32. Final energy consumption of residential buildings as a function of gas price, Pre-crisis price sensitivity



5.3.4.7. SENSITIVITY ON CO2 TAX

From 2027 on, the household sector will be part of the EU ETS2 scheme, which means that households need to pay carbon costs after their energy end-use. Although this is not required for Macedonian households, as not part of the ETS regulation, in the future such a climate scheme may alter the cost of household fossil-based heating. Fossil fuels such as oil, gas are subject to the taxation, while in the current state of the regulation firewood is excluded, as biomass related emissions are considered to be offset by the CO2 absorbed by the growth of the forests.

Emission factor of gas was assumed to be 56.1 t CO2/TJ.[16] Considering a carbon price of 30, 60 or 90 EUR/t this results in a CO2 tariff for households of 0.01-0.02 EUR/kWh on gas.

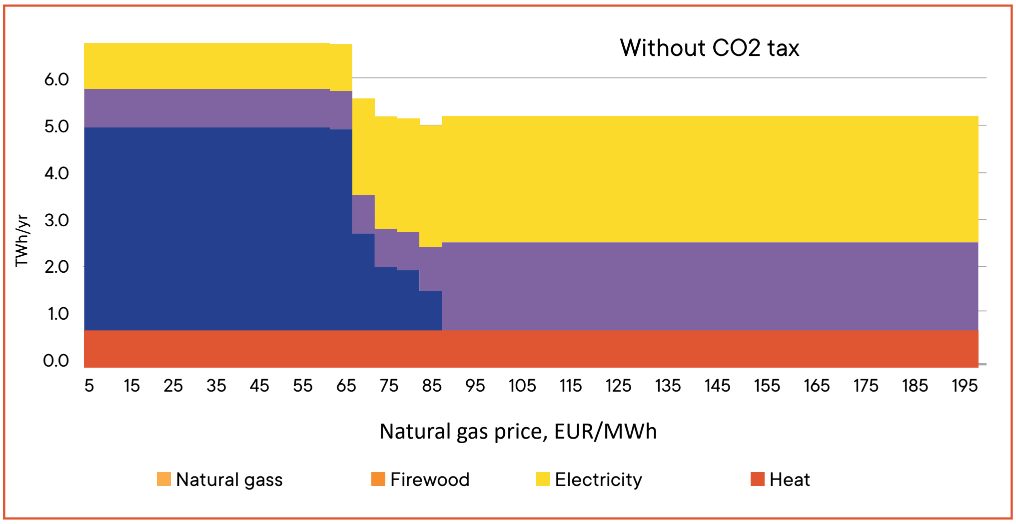
16 PCC guidelines on residential source emissions. Table 2.5 DEFAULT EMISSION FACTORS FOR STATIONARY COMBUSTION IN THE RESIDENTIAL AND AGRICULTURE/FORESTRY/FISHING/FISHING FARMS CATEGORIES (kg of greenhouse gas per TJ on a Net Calorific Basis)

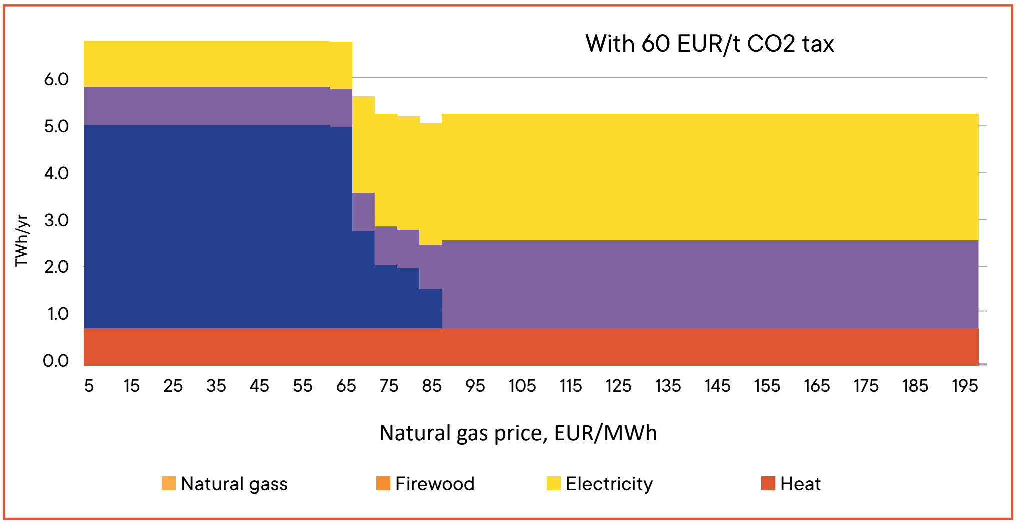
For each sensitivity concerned, the CO2 tax decreases the volume of gas demand as other fuels turn out to be more competitive compared to our base case. This means that to reach the same level of gas demand, the end-user price net of the CO2 tax must be considerably lower at higher CO2 tax levels. In other words, to reach 2.5 TWh/year gas demand:

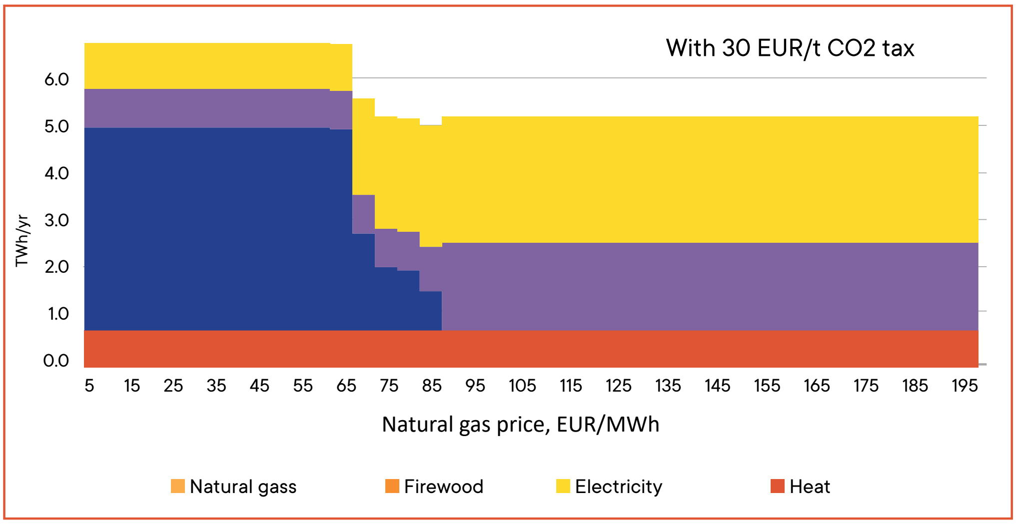
- With no CO2 tax, 2.5 TWh/year residential gas demand may be realised at 65 EUR/MWh end-user price
- With 30 EUR/t CO2 tax, the same 2.5 TWh/year gas demand is reached at 60 EUR/MWh gas price
- With 60 EUR/t CO2 tax, 2.5 TWh/year gas demand is reached at 50 EUR/MWh gas price
- With 90 EUR/t CO2 tax the 2.5 TWh/year gas demand is reached at 45 EUR/MWh gas price.

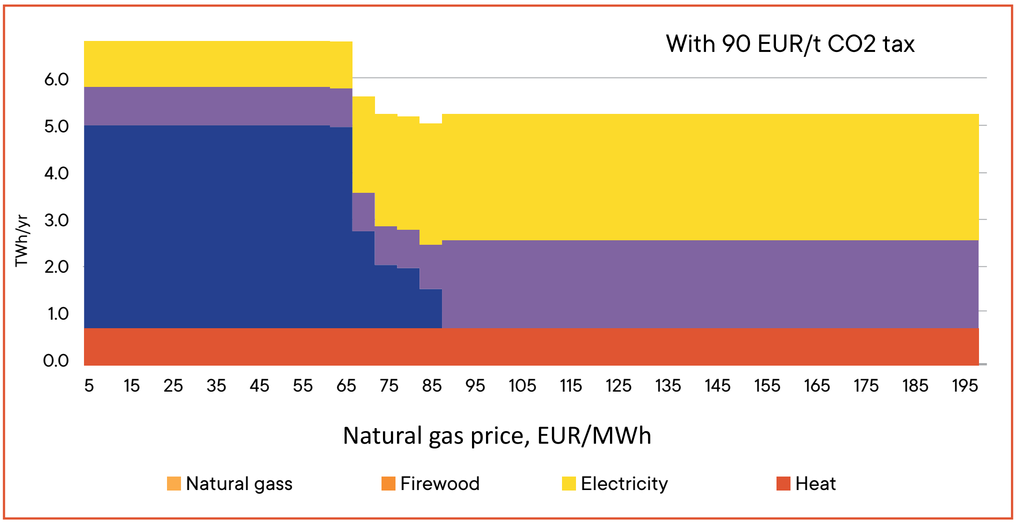
Figure 33. Sensitivity of gas demand on CO2 tax

Source: REKK modelling









5.3.4.8. SENSITIVITY ON HOUSEHOLD DECISION MAKING

In our exercise, households made their decision on the total cost of investment and 20 years of operation costs. However, household decision can be more short-sighted, focusing on shorter term pay-back periods, or completely disregarding operation costs and considering only the one-time cost of investment.

For this reason, two distinct sensitivities are presented:

- Households only consider the cost of operation (i.e. the relative fuel prices)
- Households only consider the cost of equipment and installation (i.e. investment cost and no fuel prices

In the first case, households would switch to the more efficient and relatively cheap heat pumps. The high price of heat pump installation may hamper the widespread use of this technology.

Figure 34. Switching behaviour of households, fuel cost decision sensitivity

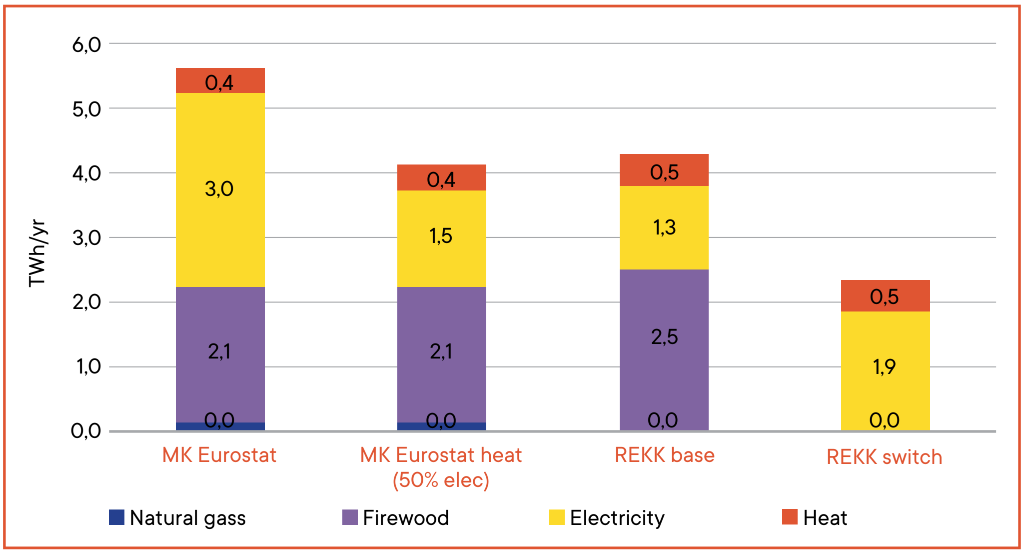


Figure 35. Share of heating technologies before and after switching, fuel cost decision sensitivity

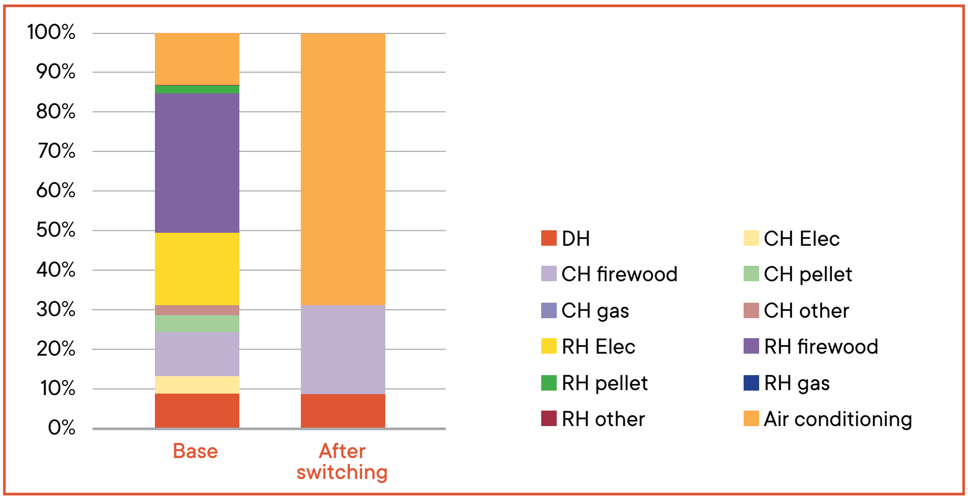
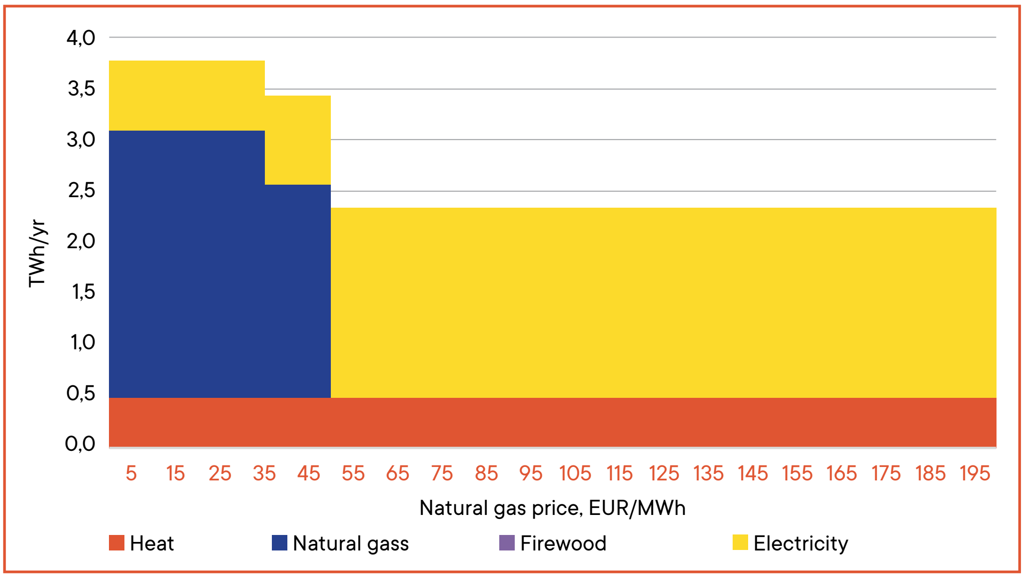


Figure 36. Final energy consumption of residential buildings as a function of gas price, fuel cost decision sensitivity



If households only consider the investment cost, then only the relative cost of equipment and installation as defined in Table 24 and Table 25 are driving the household decision. For this reason, households would switch to resistance air heating in case of room heating and firewood central heating. This means that short-term bias towards investment cost (i.e. the preference of households towards cheaper equipment) may easily result in lower efficiency heating decisions and in the end higher energy consumption.

Figure 37. Switching behaviour of households, investment cost decision sensitivity

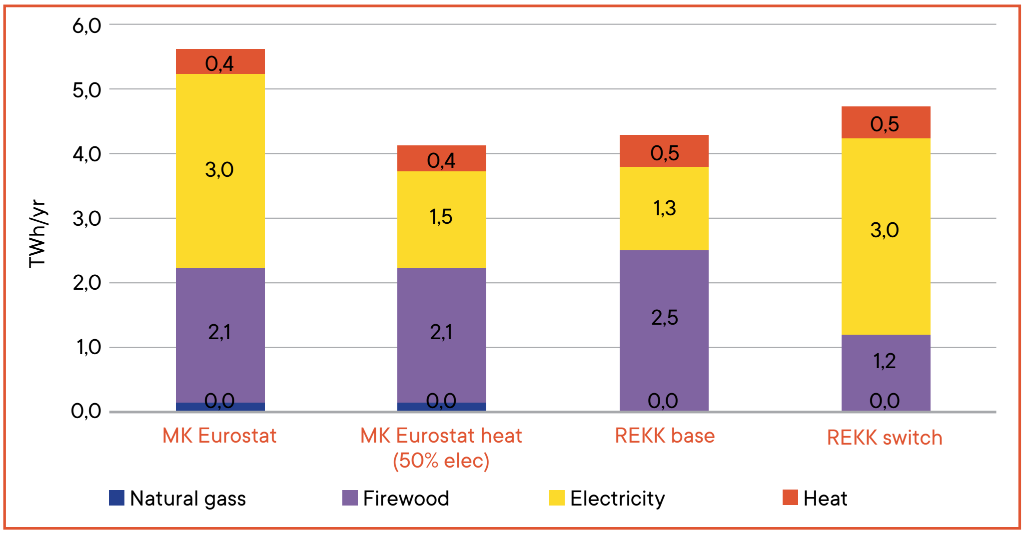
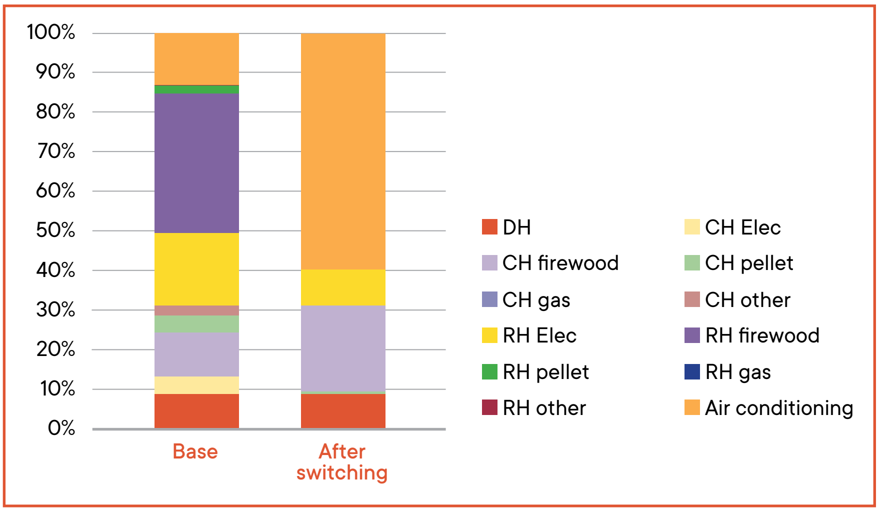


Figure 38. Share of heating technologies before and after switching, investment cost decision sensitivity



6 GAS PRICES PREDICTIONS AND ANALYSIS IN THE GAS HUBS FOR THE WESTERN BALKANS

REKK performs gas price estimations based on scenario analysis for the EU countries and the EnC Contracting Parties. Based on global assumptions like LNG supply, gas deliveries of Russia to Europe, storage level and winter demand, a general indication of price levels in Europe and the Western Balkans will be provided. REKK will use its European Gas Market Model[17] to perform this analysis.

6.1. NATURAL GAS MARKETS IN THE WESTERN BALKANS

Currently two organized marketplaces (energy exchanges) are operating in the neighboring countries of North Macedonia: the Balkan Gas Hub in Bulgaria and the Hellenic Energy Exchange in Greece. The Balkan Gas Hub has been operating since 2021 and offers within-day, day-ahead, weekly and monthly products. Compared to the gas consumption of Bulgaria, 11% of the total gas consumption was traded in 2022 and 41% in 2023 on the exchange, thus in 2023 it can give a good indication of the Bulgarian gas prices. Day-ahead prices in Bulgaria showed a strong correlation with day-ahead prices on the TTF (R2=0.97), but in many cases the high volatility on TTF was not mirrored in BG.

The Hellenic Energy Exchange is primarily an electricity trade platform, started trading natural gas products since 2022 March, offering short term gas products: within-day, da-ahead and 1-2-3 following day gas can be traded. Compared to the gas consumption of Greece, 3% was traded in 2022 and 11% in 2023, thus this exchange does not give a full picture about the gas market in Greece.

In October 2023, Bulgaria introduced a tariff of 10 EUR/MWh on any Russian gas transited on its system. Up to December 2023, Gazprom did not comment on the tax and failed to pay for these tariffs. At the same time Russian deliveries via Bulgaria towards Serbia and North Macedonia were uninterrupted. For the winter 2023/2024, ESM Skopje contracted a Bulgarian company Greystone Bulgaria for the delivery of non-Russian gas (Azeri piped or US LNG) at the price of 56 EUR/MWh.[18]

17 Peter Kotek, Borbála Takácsné Tóth, Adrienn Selei (2023): Designing a future-proof gas and hydrogen infrastructure for Europe – A modelling-based approach, Energy Policy, Volume 180, 113641, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2023.113641.

18 https://www.mkd.mk/node/531244

Figure 39. Volume of day-ahead gas traded on energy exchanges vs monthly consumption

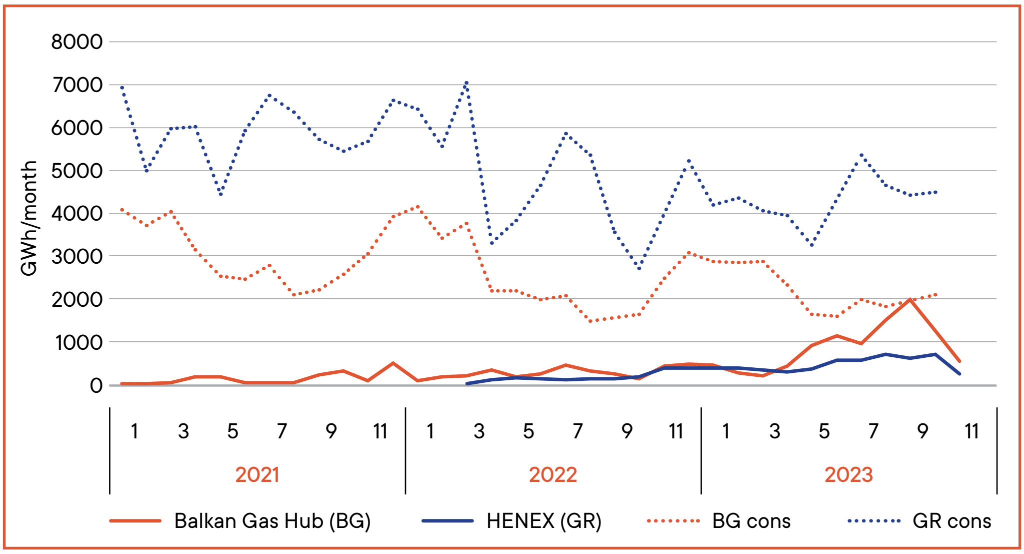
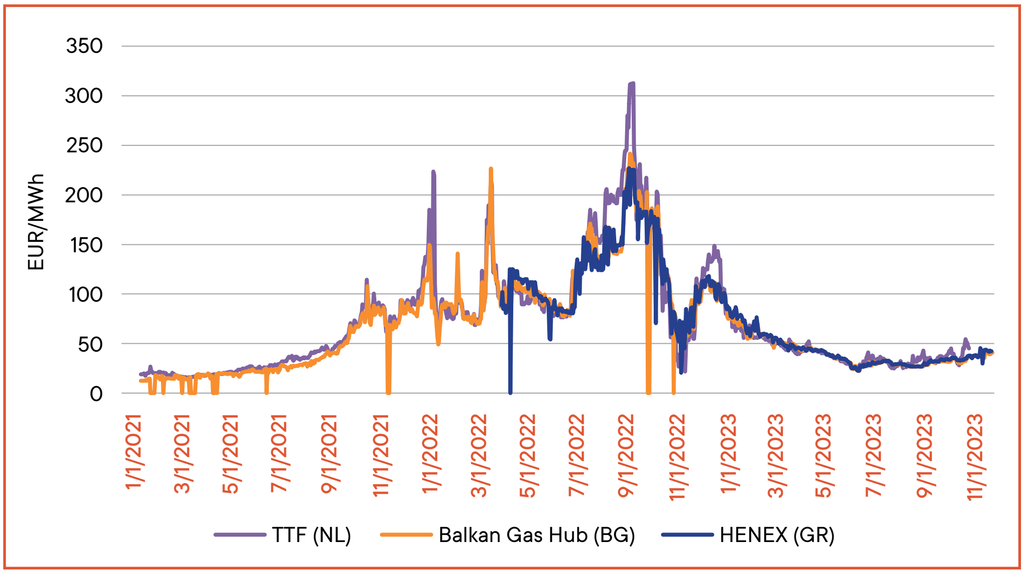


Figure 40. Day-ahead natural gas price in Bulgaria, Greece and the Netherlands



6.2. MODELLING GAS PRICES FOR THE WESTERN BALKANS

As we have indicated, a strong correlation is present between TTF, Bulgarian and Greek wholesale gas prices. The future gas market is modelled using the European Gas Market Model (EGMM). EGMM is a competitive, dynamic, multi-market partial equilibrium model that simulates the operation of the wholesale natural gas market across the whole of Europe. It includes a supply-demand representation of EU28 countries, Switzerland, the Contracting Parties of the Energy Community and Turkey, including gas storage and transportation linkages. Large external markets, including Russia, Norway, Libya, Algeria, Azerbaijan, Iran and LNG exporters are represented exogenously with market prices, long-term supply contracts and physical connections to Europe. Detailed description and mathematical formulation of the model can be found at (Selei & Takácsné Tóth, 2022).

A number of scenarios are presented based on the following drivers:

- Global LNG market tightness: global supply of LNG is characterized by the cost of gas in Asia. The following scenarios will be considered:
  - a low (25 EUR/MWh) Asian price indicates oversupply in LNG markets,
  - a high (75 EUR/MWh) shows a tight market, while
  - a medium (40 EUR/MWh) gives a balanced LNG supply.

- Russian gas flows to Europe have greatly diminished since 2023. However, Russian gas is still and important source of supply for Serbia, Bosnia and Herzegovina and Hungary. Therefore the availability of Russian gas transiting via the TurkStream system highly affects the gas supply of the region. Two scenarios are considered:
  - 30 bcm/yr Russian gas transiting to European markets via the TurkStream system, as well as
  - full cessation of Russian gas supply to Europe
- Level of European natural gas demand is the other driver of prices. The Russian invasion on Ukraine and the limiting of Russian gas to Europe prompted policy response to reduce gas consumption, resulting in ~20% demand reduction. For this reason, we included to scenarios:
  - a before-the-war demand level (~3500 TWh/year for EU27) as well as a
  - lower gas demand delivering the REPOWER targets (~2500 TWh/year for EU27)

The combination of these assumptions gives altogether 12 scenarios. For the year 2030, modelled natural gas prices are the following:

Due to the increased role of LNG in the European supply mix, global LNG market outcomes are driving the European market much stronger than before: in a tight market, TTF prices are at 70-75 EUR/MWh depending on the supply of Russian gas and the level of demand in Europe. As LNG markets are more volatile when tight, more frequent spikes may be expected in the future.

Modelled prices have strong correlation, indicating Europe is a single European gas market. There are little differences between the Dutch, Bulgarian and Greek market in the corresponding scenarios.

Reducing the demand of European consumers (by switching from gas to electricity, energy efficiency investment or demand destruction alike) can reduce the prices by 2-6 EUR/MWh.

The effect of cutting Russian gas supplies from the European mix are low by 2030: the increased LNG regasification capacity is sufficient to supply the European consumers.

Table 31. Modelled natural gas wholesale prices, EUR/MWh 2030

Source: REKK EGMM modelling. Reference demand ~3500 TWh/year; Repower demand ~2500 TWh/year for EU27.:

		2030								
		NL			BG			GR		
		25	40	75	25	40	75	25	40	75
RU0	Reference	26.6	39.1	74.7	28.3	40.1	73.1	28.0	40.4	73.9
	Repower	21.5	35.8	70.2	22.2	36.3	71.2	21.7	36.1	71.2
RU30	Reference	26.5	38.2	74.2	23.6	37.4	72.0	23.1	38.2	73.1
	Repower	21.4	35.7	69.8	21.0	35.7	69.5	21.3	36.0	70.0

7

TO ANALYZE THE POSSIBILITIES FOR USE PRODUCTION OF HYDROGEN, PLANNED TO BE TRANSPORTED VIA GAS PIPELINES IN THE FUTURE

Green hydrogen is a potential part of the solution for decarbonisation. However, due to the physical qualities of the hydrogen molecule and due to high losses in energy conversion, it is not expected to be utilised in household heating (rather to be used in industrial circumstances and hard-to-decarbonise sectors). A meta-analysis of 43 hydrogen scenarios revealed that building sector accounted for only 0.5-1.7% of the total hydrogen demand.[19] Use of hydrogen in industrial sectors or in transport was more widespread result of the hydrogen scenarios.

Energy Community Secretariat commissioned a study on potential implementation of hydrogen in EnC Contracting Parties.[20] The study claimed that there were no specific plans or strategies regarding hydrogen in North Macedonia.

European Hydrogen Backbone initiative estimated the investment cost. For 20" pipelines (which represent the pipeline network to be developed in North Macedonia) costs for new hydrogen pipeline range from 1.4-1.8 MEUR/km. In our estimate for network costs, investment for natural gas pipelines was set at 0.4-1 MEUR/km (See Table 4). Gas pipelines may be repurposed to transmit hydrogen at a fraction of investment costs of a new dedicated hydrogen pipeline. Repurposing the operating natural gas steel pipelines would cost 0.2-0.5 MEUR/km according to the estimates of European Hydrogen Backbone.

If the existing gas transmission network is to be repurposed, and new pipelines are to be commissioned to transmit hydrogen, then the cost of TSO pipeline investment may considerably increase. Applying the UIC costs of the European Hydrogen network, total costs of a hydrogen network in North Macedonia range between 539-799 MEUR CAPEX for pipeline investment. To put tis into perspective,

19 Matia Riemer, Lin Zheng, Johannes Eckstein, Martin Wietschel, Natalia Pieton, Robert Kunze (2022): Future hydrogen demand: A cross-sectoral, global meta-analysis. HYPAT Working Paper 04/2022 https://isi-cmsportal.de/hypat-wAssets/docs/new/publications/HYPAT_Working_Paper_04_2022_Future_hydrogen_demand.pdf

20 https://www.energy-community.org/dam/jcr:512b6d58-70a2-4533-9f04-5cb537058b8e/ECA_E4tech_H2_part3.pdf

the natural gas pipeline network investment was estimated at 269-672 MEUR.

Hydrogen might have a place in the generation of high-temperature heat in industrial locations, where electrification of high-grade heat is not possible. The iron and steel sector is the top consumer of energy, which need high-grade heat for production and may drive hydrogen demand. However, siting of the electrolysers and production of hydrogen is more cost-effective closer to the demand. For this reason, the need for long-distance hydrogen transport may not be justified if the hydrogen demand is low.

Power sector RES targets are related to hydropower and PV rather than hydrogen. The intermittent PV and wind capacities are to be balanced by pumped storage units rather than hydrogen.[21]

21 https://www.energy-community.org/dam/jcr:512b6d58-70a2-4533-9f04-5cb537058b8e/ECA_E4tech_H2_part3.pdf

Use of hydrogen in the transport sector is limited due to the more cost-competitive nature of electrification of transport. Hydrogen fuel cells may be used in long-haul transport sector.

Summing up these factors there is little rationale for developing a hydrogen network in North Macedonia.

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