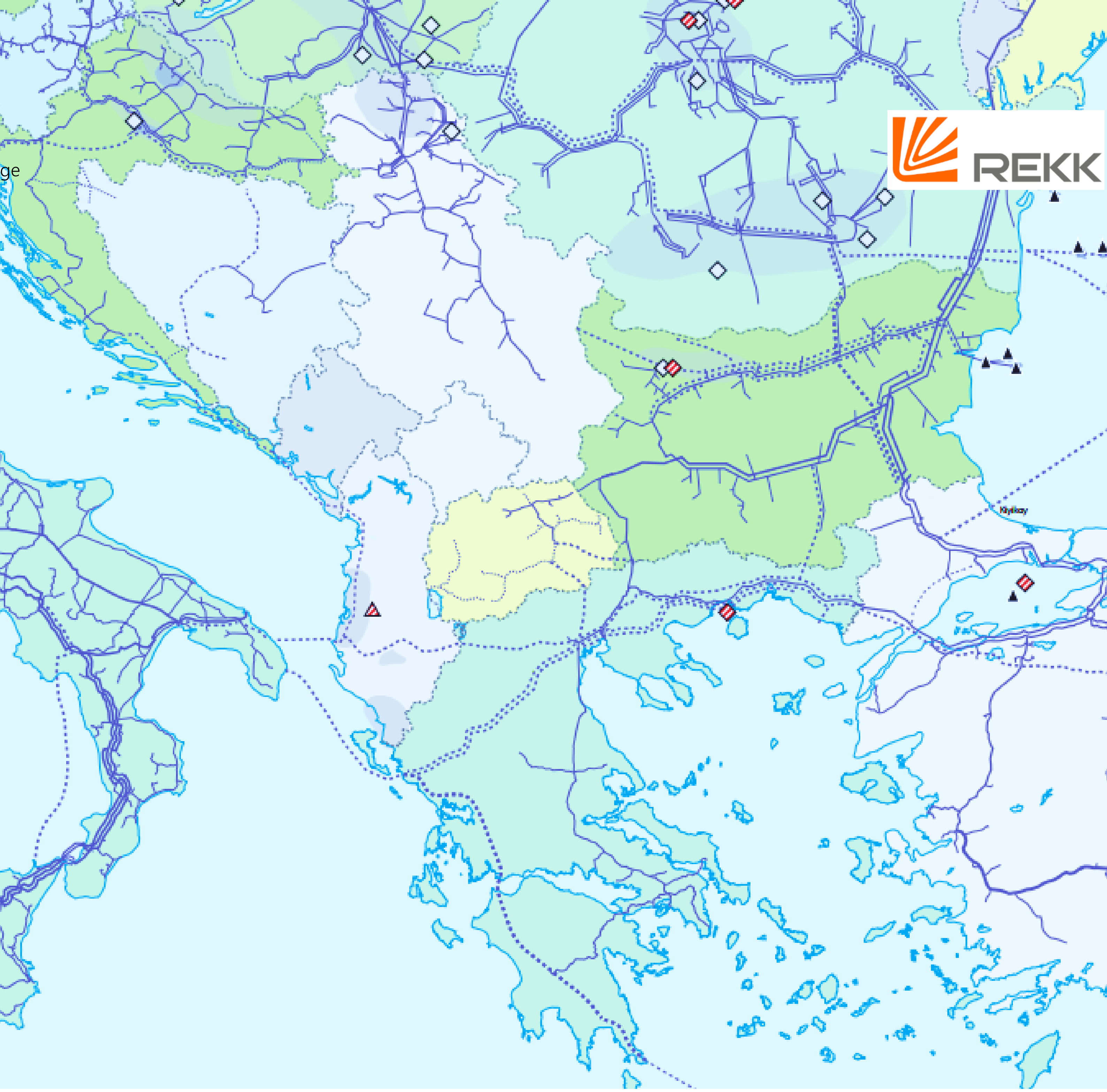

BUILDING SECTOR GASIFICATION IN THE WB6

Final study

REKK

2021

Building sector gasification in the WB6

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Commissioned by European Climate Foundation.

Project lead: Péter Kotek

E-mail: peter.kotek@rekk.hu

Authors: Péter Kotek, Adrienn Selei, Borbála Takácsné Tóth

Cover: ENTSOG Transmission capacity map 2019

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ABBREVIATIONS

ACER	Agency for Cooperation of Energy Regulators
bcm	billion cubic meter
DH	District Heating
ECF	European Climate Foundation
ECS	Energy Community Secretariat
EPBD	Energy Performance of Buildings Directive 2010/31/EU
FID	Final Investment Decision
FCRT	full-cost recovery tariff
LAU	local administrative units
mcm	million cubic meter
NECP	National Energy and Climate Plan
NRA	National Regulatory Authority
OPEX	Operating expenditures
PECI	Project of Energy Community Interest
TAP	Trans-Adriatic Pipeline
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan

Country codes

AL	Albania
BA	Bosnia and Herzegovina
KO*	Kosovo*
ME	Montenegro
MK	North Macedonia
RS	Serbia
WB6	West Balkan 6: Albania, Bosnia Herzegovina, Kosovo*, Montenegro, North Macedonia, Serbia

*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

In a previous fact-finding study conducted for ECF in 2020[1] on natural gas networks and markets in the Western Balkans we found that the WB6 has strong ambitions in gas network development. It is envisaged that about 27.2 bn € would be spent on gas transmission infrastructure development on the Balkans up until 2030, out of which 7.6 bn € are already reserved funds for projects with a final investment decision (FID). A further 13 bn € is planned to be spent in the next few years on advanced projects.

The rationale for these gas network development infrastructure plans was the prognosis of substantial gas demand in all consumption sectors outlined in the countries' national plans. The growth in gas demand in their view would originate on the one hand from coal to gas switching in electricity generation, and on the other the expected increase for buildings and industry sector heat demand.

The historical gas consumption of WB6 in 2018 totalled 3 bcm. Out of that 0.4 bcm was consumed by the heat and electricity production sector. We must note here that Serbia, Bosnia and Herzegovina and North Macedonia have already natural gas in their energy mix, while Albania has almost none but has a new connection to the recently commissioned Trans Adriatic Pipeline (TAP)[2]. Kosovo* and Macedonia have no own connection to the gas network yet and no gas market at all.

Based on the national plans of the countries about 3.5 bcm/yr demand growth is envisaged by 2030 (REKK, 2020)

Modelling studies (IRENA, E3M) do not confirm the optimism of the countries on gas demand growth in the power and heat sector. E3M models a slight gas demand drop in the gas consumption of WB6 by 2030 and a 0.9 bcm/ year increase by 2040. We found no evidence for the demand growth in the industry sector either. The task of this study was to build a simple calculation tool that could help to assess the potential natural gas demand growth of the household sector in the WB6.

The poor quality of buildings, and the lack of investment into maintenance explain the low energy efficiency that results in a massive amount of heating need. When assessing the potential for household natural gas consumption there is a specific obstacle that cannot be neglected in the WB6, which is underheating. This phenomenon means that not all the useful floor area of the building is heated, only a proportion of it. The amount of underheating can only be estimated. Like previous studies did ((Feiler, et al., 2016) this study will attempt to estimate underheating based on difference between calculated heating demand and the primary energy balances.

Another important characteristic for the WB6 region is the historical dominance of fossil heating (coal, lignite and oil) and biomass (fuel wood). (Kambovska, 2021). The fuel wood heating

[1] REKK 2020: ECF SEE GAS MARKET REVIEW, final study (ppt) 15.11. 2020

[2] TAP is part of a large transmission route called the Southern Gas Corridor, that connects the Azeri gas fields via Georgia, Turkey, Greece Albania and an offshore pipeline to Italy. TAP is the section between Greece and Italy.

occurs in old and inefficient furnaces with low efficiency. Biomass heating is the cheapest available option, therefore any switch from this fuel source to natural gas would need to have strong additional value for the users. This could be both the increased comfort level and the better air quality. Heat pumps provide an even more expensive option but a better solution from a climate perspective.

Natural gas infrastructure development and the switching of heating mode in the building sector would create a considerable lock-in effect for several years. For this reason, it should be considered whether gas is the best option from total cost perspective for the building sector (including network development and individual household investment, fuel and O&M costs), as well as from a climate perspective (based on the long-term decarbonization strategies). This study reviews the gas potential from the viewpoint of residential buildings and owners of these buildings. No optimization from a system perspective was performed.

The first part of the study estimates the cost of building the transmission and distribution network in the WB6 to support gasification of the household heating sector. The tariff components that should be paid by the users are a considerable part of the gas bill – in the EU on average network costs account for almost 27% of the bill. (ACER/CEER, 2020)

In the second part of the study the full cost of switching to gas (including the system cost, gas cost and the investment needed on the household side) is compared to other heating alternatives. With the help of a simplified model that builds on datasets available on the building stock important drivers of the total cost (cost of fuels, underheating, learning curves of technologies) are tested as sensitivities to assess the potential level of gas demand of the household sector in the WB6.

2. ASSESSING GAS NETWORK INVESTMENT COSTS

2.1. LITERATURE REVIEW

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.

In our study we used a combination of these two. Network length was measured using a GIS software, and main network element costs were estimated using the parameters found in the econometric studies. Missing technical data was substituted by best estimates and benchmarks from literature.

2.1.1. GAS DSO NETWORK 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 (km^2), total number of connections, total distributed energy (Nm^3) and total peak output, meaning the maximum hourly output of the entire system (Nm^3/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 the region (for details see Chapter 2).

2.1.2. GAS TSO NETWORK COSTS

2.1.2.1. PIPELINE COSTS

A similar review was performed by the same team in 2019 for CEER on the cost benchmarking of natural gas transmission infrastructure (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.

$$Pipeline\ construction\ cost\ \left(\frac{€}{km}\right) = 420.3693\ D^2('') + 12126.1250\ D('') + 100432.6361$$

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).

2.1.2.2. GAS TSO COMPRESSOR COSTS

Compressor costs are driven by compressor capacity and the type of compressor drive (reciprocating compressors driven by gas or centrifugal compressor driven by gas/electricity). Throughout the study, investment cost for electricity driven compressors was used (where P is the capacity of the compressor in kW).

$$Cost(P_{elec})(€) = 3000\ P(kW)$$

2.1.2.3. GAS TSO PRESSURE REGULATION AND METERING STATION COSTS

Investment costs on pressure regulation and metering stations is a function of total flow rate:

$$Reg\&meterning = 799.84Q^{0.5503}(Nm^3/h)$$

2.1.2.4. COSTS FOR CONTROL CENTERS

A control center servicing 5000 km pipeline, storage facilities and international trade was valued 2.5 M€. (SUMICSID, 2019)

2.1.2.5. OPERATION AND MAINTENANCE COSTS

OPEX was estimated as a function of capital costs. The table below lists OPEX costs suggested by the study. For our estimation of OPEX costs, these relative shared of CAPEX were applied.

TABLE 1. ASSUMED OPEX COSTS

Network element	OPEX (% of CAPEX)
Pipeline	2
Compressor electricity	3.5
Metering & pressure regulation	3.5
System supervision	7

Source: (SUMICSID, 2019, old.: 75)

2.2. METHODOLOGY

A uniform approach was selected for all the WB6 countries to calculate an approximate network development cost of both transmission and distribution systems. First, we assessed the available gas master plans and system development plans to see whether there is information on network costs. All WB6 countries had some estimation on the network investment costs, but the level of detail and the time of assessment varied between the studies. The table below lists the available gas master plans, network development plans and strategies used for reference.

The next chapter details how distribution and transmission network development cost were estimated what this resulted in applicable tariffs.

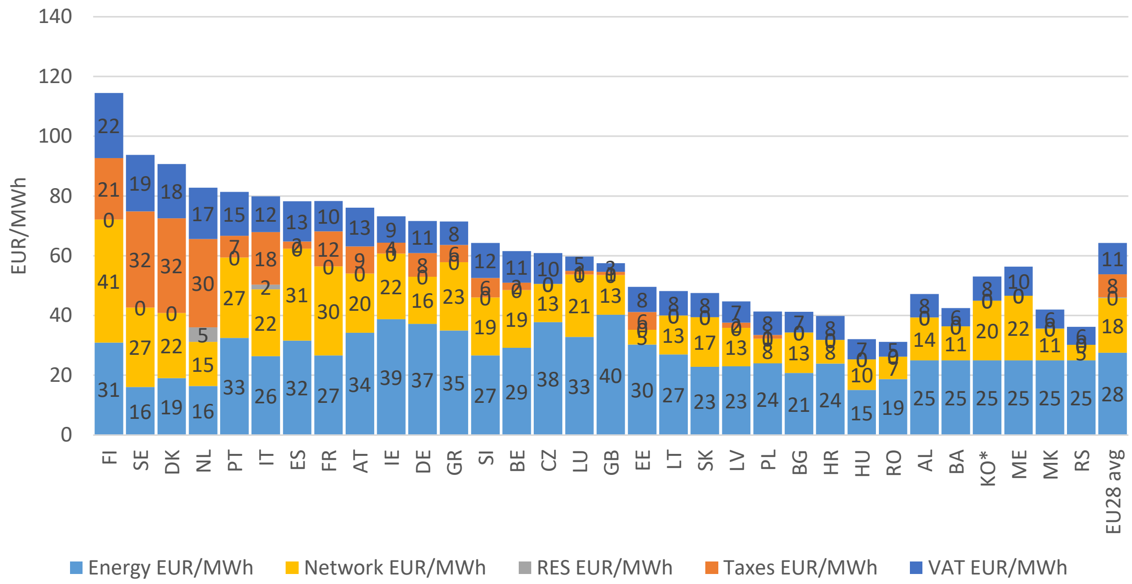
TABLE 2. MAIN INDICATORS FROM GAS MASTER PLANS IN THE WB6

		AL	BA	KO*	ME	MK	RS
Document		Gas Master plan	Energy strategy 2017-2035	Natural gas development strategy	Gas Master Plan Montenegro	Gas distribution network in North Macedonia	TYNDP Transport-gas Srbija 2020-2029
Year of study		2016	2017	2003	2015	2020	2019
Gas demand, 2040, TWh/yr	Residential and services	5.7	n.a.	n.a.	1.7	n.a.	23.8
	Industry & other	4.9	n.a.	n.a.	2.0	n.a.	15.3
	Power & heat	7.9	n.a.	n.a.	3.5	n.a.	4.6
	Total	18.5	n.a.	n.a.	7.2	9.1	43.8
CAPEX, MEUR	Distribution	439.0	n.a.	566	134.7	690.0	n.a.
	Transmission	216.0	n.a.		117.7	n.a.	n.a.
Tariff, EUR/MWh	Distribution	13.0	n.a.	n.a.	18.3	8.6	3.2
	Transmission	1.3	0.2	n.a.	3.3	2.0	1.9

Source: REKK data collection, TSO and ministry websites

Comparing the network fees with the tariffs applicable in the EU28 we can see that the WB6 tariffs or prospective tariffs are close to the EU28 average. Network costs are higher in markets without gas system (AL, KO*, ME).

FIGURE 1. GAS END USER TARIFFS FOR HOUSEHOLDS IN THE EU28 AND THE WB6, EUR/MWH



Source: REKK based on (ACER/CEER, 2020) and gas master plans. Based on household offers for 11,000 kWh gas demand/year.

2.2.1. DISTRIBUTION SYSTEM DEVELOPMENT COSTS

Methodology of the DSO system development costs was based on the Gas Master Plan of Albania (COWI - IPF, 2016). The study identified 4 reference cities (Zall-Herr, Gjirokaster, Kamez, Tirana) in Albania, and linked all other cities and towns in these 4 categories based on population. Required network length in the reference cities was measured using a GIS software. Network length in other cities was estimated based on population. CAPEX of pipeline investment was based on line length, using a unitary cost of 128 EUR/m. OPEX for distribution networks was estimated at 3% of CAPEX. Investment and operational costs were to be recovered by users of the network. Assuming a discount rate of 7% and a lifetime/payback period of 20 years, the study calculated a so-called full-cost recovery tariff (FCRT).

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

Cities and towns were ranked ascending based on FCRT, connecting the least-cost areas first.

REKK recreated the logic of the Albanian gas master plan for all the WB6 with some modifications:

a) Required network length was measured for all cities and towns

b) Estimated gas consumption was based on population of the cities and towns

c) Only more populated cities were considered for gasification, not all municipalities.

TABLE 3. TOTAL POPULATION OF THE WB6 (IN 2021) AND URBAN POPULATION ASSESSED FOR GAS NETWORK DEVELOPMENT

		AL	BA	KO*	ME	MK	RS	Total WB6
A	Total population (million)	2.83	3.49	1.80	0.62	2.07	6.87	17.68
B	Assessed population (million)	1.44	2.50	0.64	0.51	1.50	4.73	11.33
C	Population in gas master plan (million)	1.31	1.72	0.59	0.49	1.50	4.38	10.00
B/A	Assessed/total	51%	72%	36%	82%	73%	69%	64%
C/B	Plan/assessed	91%	69%	92%	96%	100%	92%	88%

Source: statistical offices[3]

[3] AL (2021): http://www.instat.gov.al,
BA (2019): https://bhas.gov.ba/data/Publikacije/Bilteni/2020/DEM_00_2019_TB_0_HR.pdf
KO* (2020): https://ask.rks-gov.net/media/6114/vjetari-statistikor-2021f.pdf
ME (2021): https://www.monstat.org/eng/page.php?id=234&pageid=48
MK (2020): https://www.stat.gov.mk/KlucniIndikatori_en.aspx
RS (2020): https://publikacije.stat.gov.rs/G2021/PdfE/G202127010.pdf

The table above shows that we assessed 64% of the WB6 population, who may theoretically have access to natural gas (either by already having access or by network expansion).

Distribution system lengths were estimated by measuring actual residential street lengths in major cities of the WB6 countries. The freely available OpenStreetMap database was used to extract the exact length of residential area streets.[4] The length of all these roads then was added within the administrative boundaries (LAU2) of cities and towns. Since no detailed division and shape file existed for the LAU2 mapping of Bosnia and Herzegovina, Kosovo*, and Montenegro, boundaries were mapped by REKK covering all the residential roads within the local administrative unit. A detailed description of the methodology can be found in the annexes in 0.

2.2.2. TRANSMISSION SYSTEM DEVELOPMENT COST

Transmission system development was linked to the geographical location of cities and settlements to be gasified and the outline of network presented in the Gas Master Plans. Total pipeline length was estimated using QGIS software. Uniform cost for pipeline installations was used, as suggested by the literature review in Chapter 2.1.2. Cost of pipeline investment was estimated with the following equation (using 20" pipeline diameter as a design dimension):

$$Pipeline\ construction\ cost\ \left(\frac{€}{km}\right) = 420.3693\ D^2('') + 12126.1250\ D('') + 100432.6361 = 511102\ \left(\frac{€}{km}\right)$$

Besides pipeline investment, cost of compressors, pressure regulation and metering as well as cost of a system control center was added, if there was no pre-existing gas network.

Electric drive compressor costs were used for estimating investment cost, applying the formula (assuming a 10 MW compressor for AL, BA and 5 MW units for KO*, MK, ME, RS):

$$Cost(P_{elec})(€) = 3000\ P(kW)$$

For pressure regulation and metering stations, maximum flow rate of the system was driving the investment costs. Peak demand was estimated based on total annual system load, divided by 8760 hours of the year and multiplied by 2 to indicate winter peak load.

$$Reg\&meterning = 799.84Q^{0.5503}(Nm^3/h)$$

A system control center costing 2.5 MEUR was added for every 5000 km of pipeline (i.e. in markets without gas network we considered the costs, in other markets we omitted).

[4] Query for OpenStreetMap requested the highway shapes with residential attribute, which covers all „roads which serve as an access to housing, without function of connecting settlements. Often lined with housing".

2.3. GAS NETWORK INVESTMENT COST AND NETWORK TARIFF ESTIMATION RESULTS

2.3.1. ALBANIA

2.3.1.1. PREVIOUS STUDIES ON SYSTEM COSTS

The Gas Master Plan reviews a number of scenarios for the gasification of Albania. We have selected one of the scenarios to calculate investment costs and tariffs related to the network development.

On distribution network level, the connection of industrial, residential and services sector consumers is assumed to be the most widespread at tariff level 0.15 EUR/cm, allowing for a gas demand on the distribution level of 927 mcm/year by 2040. For comparison, current gas demand in Albania is 40-50 mcm/year.

On transmission level, the demand is highly dependent on three sets of assumption:

- Whether IAP is operational and transiting gas?
    - IAP is in place
    - IAP is not in place
- Whether KO* and MK consumers are supplied from Albania?
    - ALKOGAP to Kosovo* and a branch to North Macedonia is constructed to supply the consumers in South-Western part of North Macedonia
- What is the financing of IAP?
    - IAP is not in place
    - IAP is in place and owned and operated by the Albanian TSO. This implies that investment and operational costs need to be recovered by AL tariffs
    - IAP is in place and owned and operated by an international company. Albania is allowed to use the infrastructure, but no need to recover the costs.

TABLE 4. NATURAL GAS FLOWS ON THE ALBANIAN TRANSMISSION SYSTEM IN THE DIFFERENT SCENARIOS OF THE GAS MASTER PLAN, MCM/YR

	AL market	IAP	KO*	MK	Yearly flow	CAPEX	Tariff
	Mcm/yr	Mcm/yr	Mcm/yr	Mcm/yr	Mcm/yr	MEUR	EUR/m3
Scenario 1	2082	4000	1000	756	7838	133	0.02
Scenario 2	2082	4000			6082	52	0.02
Scenario 3	2082		1000	756	3838	216	0.04
Scenario 4	2082				2082	95	0.03

Source: (COWI - IPF, 2016)

This gives several scenarios to consider, with different level of gas demand and consequently different investment costs and tariffs. In 2020 the revision of the TEN-E regulation proposed by the Commission suggests that no further gas infrastructure should be supported by EU funds. As part of the decarbonization package we do not expect that this proposal will fail in the comitology procedure. Without CEF support IAP is not a realistic option, so for this reason, we opted to use the scenarios without IAP. Furthermore, the supply of consumers in Macedonia and Kosovo* could be a realistic option – Scenario 3. In this scenario, total investment cost of the transmission infrastructure (with ALKOGAP and MK interconnection, but without IAP) is 216 MEUR, resulting in a tariff of 0.04 EUR/cm on the transmission level.

FIGURE 2. GASIFICATION PLAN OF ALBANIA

Figure 3–4: Municipalities viable for further screening for gasification

Figure 5–1: Pipeline sections

Source: (COWI - IPF, 2016)

2.3.1.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of Albania were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m^3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential "supply curve" of distribution network costs, linking potential consumption with distribution tariffs.

Cost of transmission system development was estimated based on the network layout of the gas master plan.

TABLE 5. TOTAL GAS NETWORK INVESMENT COST FOR ALBANIA

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	355.4	10.7	377.5	7.6	733.0	18.2
Compressor	0.0	0.0	30.0	1.1	30.0	1.1
Metering and regulation	0.0	0.0	0.4	0.0	0.4	0.0
System supervision	0.0	0.0	2.5	0.0	2.5	0.0
Total	355.4	10.7	410.4	8.6	765.9	19.3

Source: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

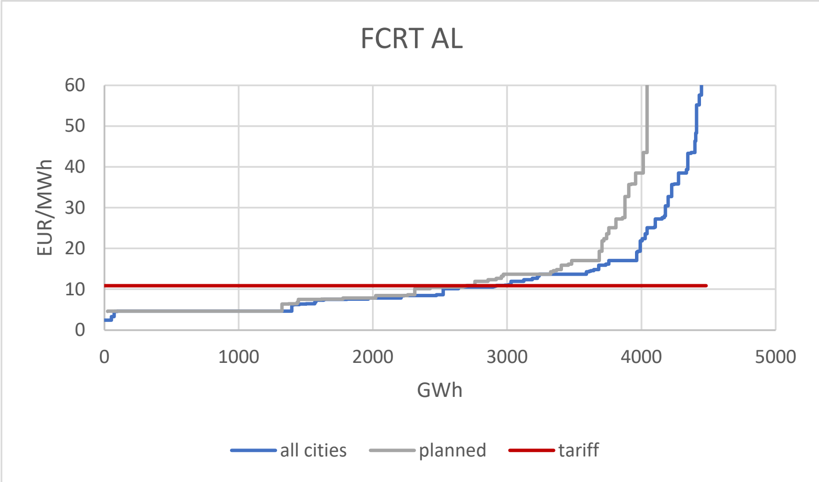
TABLE 6. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN ALBANIA

		TWh/year
DSO	Consumption on distribution level	4.07
TSO	Total consumption	16.87
		EUR/MWh
DSO	Distribution tariff	10.87
TSO	Transmission tariff	2.81

Source: REKK calculation

Figure 3 shows the cost and the potential of the Albanian system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected, while the grey line shows the cost for cities which are part of the Gas Master Plan. The tariff only relates to the line length on distribution level. The red line shows the tariff of the planned distribution network after equalization, i.e. all consumers paying the same distribution tariffs throughout the country.

FIGURE 3. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR ALBANIA



Source: REKK calculation

2.3.2. BOSNIA AND HERZEGOVINA

2.3.2.1. PREVIOUS STUDIES ON SYSTEM COSTS

There is an existing network providing gas supply to the Sarajevo area, and some cities along the line. No detailed strategy for the increased gasification of the country exists. The energy strategy does not indicate actual volumes of gas consumption and does not specify the cost of network investment, or any tariff effects related to that. Currently tariffs are not regulated at country level.

The network expansion is planned via three main directions:

1. Northern part from Croatia, Slobodnica-Brod-Zenica area
2. Western part from Croatia, Trzac-Bosanska Krupa
3. Southern part from Croatia, Posusje-Travnik with a branch to Mostar

Considerable network development is needed on the Croatian side for the Southern (IAP) and Western interconnections.

FIGURE 4. SYSTEM DEVELOPMENT PLAN IN BOSNIA AND HERZEGOVINA

Figure 3.2 Options for interconnections between BiH and Croatia

Source: (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2018)

2.3.2.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of Bosnia were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m^3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential "supply curve" of distribution network costs, linking potential consumption with distribution tariffs.

Cities with already existing distribution network were omitted.

Cost of transmission system development was estimated based on the network layout of the gas master plan.

TABLE 7. TOTAL GAS NETWORK INVESMENT COST FOR BOSNIA AND HERZEGOVINA

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	206.21	9.77	310.52	8.03	516.73	17.80
Compressor	0.00	0.00	30.00	1.05	30.00	1.05
Metering and regulation	0.00	0.00	0.55	0.02	0.55	0.02
System supervision	0.00	0.00	0.00	0.00	0.00	0.00
Total	206.21	9.77	341.07	9.10	547.27	18.87

Source: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

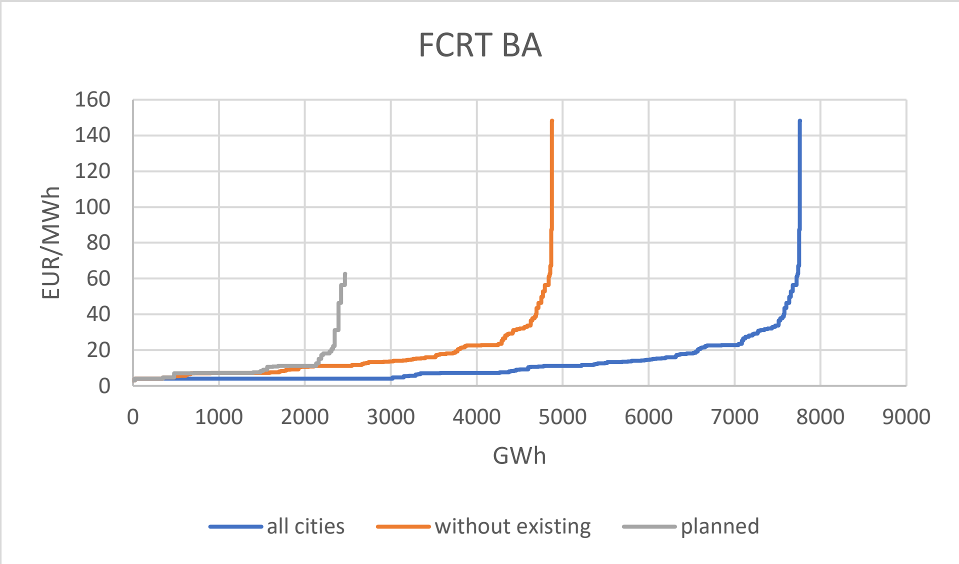
TABLE 8. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN BOSNIA AND HERZEGOVINA

		TWh/year
DSO	Consumption on distribution level	5.36
TSO	Total consumption	10.71
		EUR/MWh
DSO	Distribution tariff	5.46
TSO	Transmission tariff	3.86

Source: REKK calculation

Figure 5 shows the cost and the potential of the Bosnian system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected. The orange line disregards the cities which have already been connected to the gas network. Finally the grey line only lists cities which are part of the gas master plan. The tariff only relates to the line length on distribution level.

FIGURE 5. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR BOSNIA AND HERZEGOVINA



Source: REKK calculation

2.3.3. KOSOVO*

2.3.3.1. PREVIOUS STUDIES ON SYSTEM COSTS

For Kosovo*, no detailed gas master plan exists. The EBRD provided funding for the Gas Development Plan and Regulatory Framework Review and Assistance, which was under preparation in 2019.[5] The energy strategy and outlooks by Kosovo* ministries did not foresee the uptake of natural gas in the country.

A short paper from the Energy Office of the Provisional Institutions of Self-Government of Kosovo* - dated 2003 - details the ambitions and plans on network development. (PISG (KO*), 2003)

The gas network in Kosovo* is to be constructed in five phases.

- Phase I sets up the transmission network originating either from Serbia or from North Macedonia, reaching the consumers in Pristhina, Ferizaj and Mitrovica. District heating plants in Pristhina and Mitrovica as well as the switching of Kosovo A power plant to gas will serve as an anchor load. The network in uni-directional at this stage.
- Phase II connects the major cities Peje and Prizren in the Western part of the country.
- Phase III makes interconnection and bidirectionality possible on the main pipeline.
- Phase IV connects Peje and Prizren in the west, serving Gjakove and adding district heating possibility.

[5] https://www.wbif.eu/storage/app/media/Library/12.Meetings/2.%20Project%20Financiers%20Group/27th%20PFG/WBIF-27thPFG-Minutes-of-Meeting-update.pdf

- Phase V connects Podujeve, Kamenica in the East from the main transmission line

FIGURE 6. GASIFICATION PLAN FOR KOSOVO*

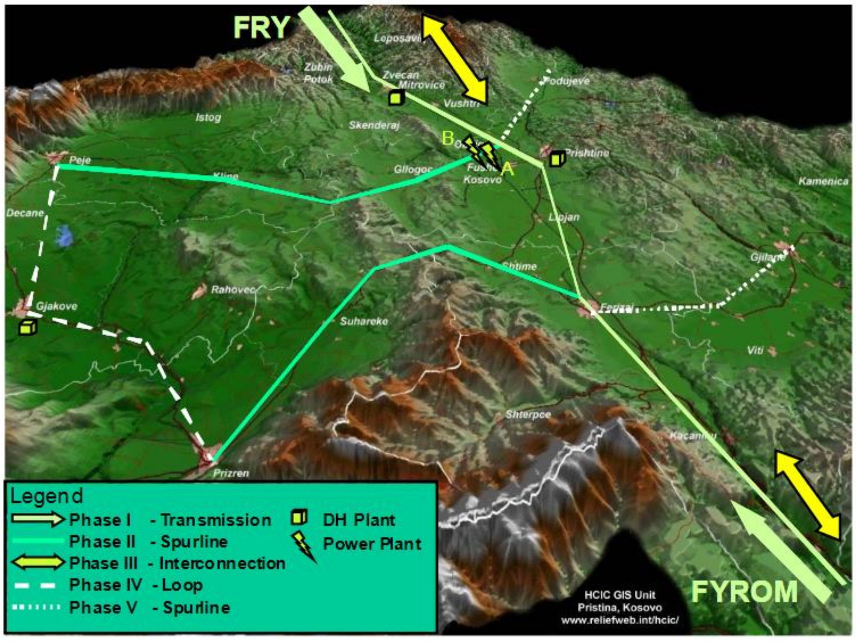


Figure 1. Gas network development

Source: (PISG (KO), 2003)*

No indication on the level of gas demand was presented. Total investment cost for distribution and transmission level was estimated at 566 MUSD (in 2003). Adjusting for inflation, in 2021 purchasing power this would mean 828 MUSD, ~699 MEUR.

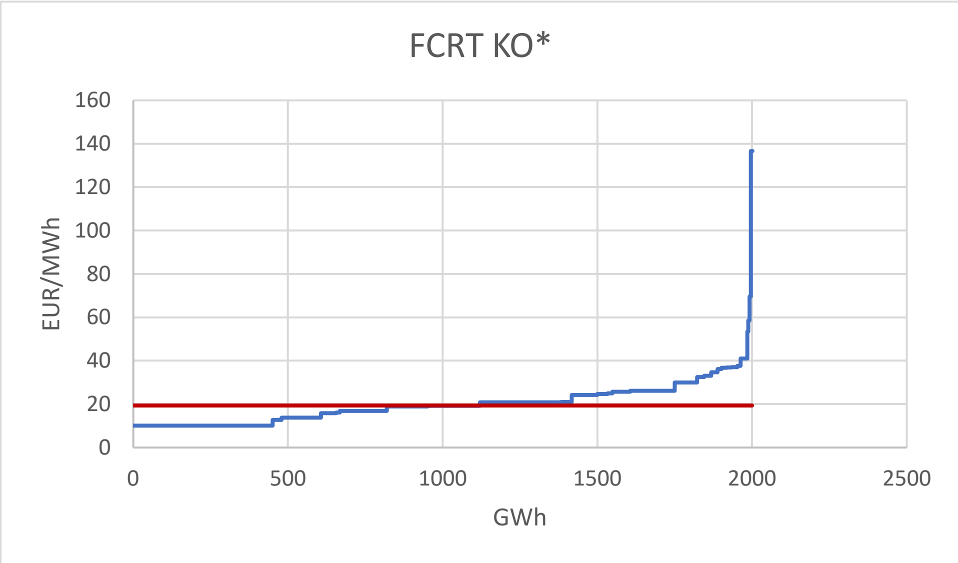
Additional investment at residential level (replacement of heating equipment, boilers, cookers, installation of central heating system) totalled 250 MUSD (in 2003) ~211 MEUR.

2.3.3.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of Kosovo* were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m^3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential "supply curve" of distribution network costs, linking potential consumption with distribution tariffs.

Figure 7 shows the cost and the potential of the Kosovo* system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected. The tariff only relates to the line length on distribution level. The red line shows the tariff of the planned distribution network after equalization, i.e. all consumers paying the same distribution tariffs throughout the country.

FIGURE 7. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR KOSOVO*



Source: REKK calculation

Additionally, cost of building up the transmission network was calculated using the routing of the Gas Master Plan and connecting cities mentioned in the plan. Investment cost for pipeline, compressor and other costs were included. Only cities connected to the transmission network were considered to be part of the demand, bringing down the potential consumption to 1.84 TWh/year on distribution level (indicated by red line on the figure).

TABLE 9. TOTAL GAS NETWORK INVESMENT COST FOR KOSOVO*

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	284.24	8.53	268.54	5.37	552.79	13.90
Compressor	0.00	0.00	15.00	0.53	15.00	0.53
Metering and regulation	0.00	0.00	0.27	0.01	0.27	0.01
System supervision	0.00	0.00	2.50	0.02	2.50	0.02
Total	284.24	8.53	286.31	5.92	570.56	14.45

Source: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

TABLE 10. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN KOSOVO*

		TWh/year
DSO	Consumption on distribution level	1.84
TSO	Total consumption	3.68
		EUR/MWh
DSO	Distribution tariff	19.24
TSO	Transmission tariff	8.96

Source: REKK calculation

2.3.4. NORTH MACEDONIA

2.3.4.1. PREVIOUS STUDIES ON SYSTEM COSTS

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 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 11. LIST OF SCENARIOS FOR THE GAS DISTRIBUTION NETWORK DEVELOPMENT IN NORTH MACEDONIA

Scenario name	Scenario description	Max demand	CAPEX Distribution	Distribution Tariff	Transmission tariff 2035
		TWh/yr	MEUR	EUR/MWh	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

Source: (EBRD, 2020)

Transmission system development cost was not explicitly assessed by the EBRD study in 2020. 2 EUR/MWh tariff from NER Skopje[6] (National Energy Resources) was used as an input. There is no information on the CAPEX of the transmission system.

2.3.4.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of North Macedonia were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential "supply curve" of distribution network costs, linking potential consumption with distribution tariffs. Cities where gas distribution already existed (Skopje, Kumanovo, Shtip) were omitted.

FIGURE 8. GASIFICATION PLAN FOR NORTH MACEDONIA

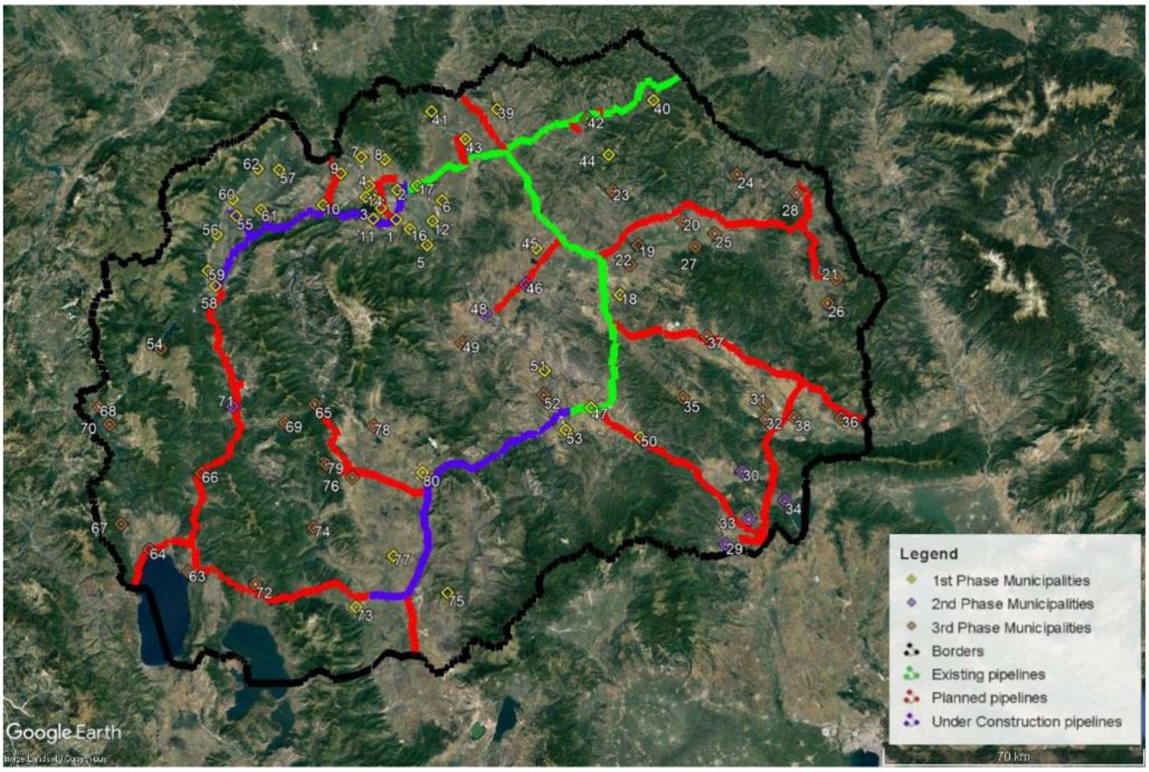


Figure 1 Map of current and future transmission system in North Macedonia

Source: (EBRD, 2020)

Cost of transmission system development was estimated based on the network layout of the gas master plan. (Figure 8)

[6] https://mer.com.mk/en-US

TABLE 12. TOTAL GAS NETWORK INVESMENT COST FOR NORTH MACEDONIA

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	198.2305	5.946914	377.66	6.02	575.89	11.97
Compressor	0	0	15.00	0.53	15.00	0.53
Metering and regulation	0	0	0.43	0.02	0.43	0.02
System supervision	0	0	2.50	0.02	2.50	0.02
Total	198.2305	5.946914	395.59	6.58	593.82	12.53

Source: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

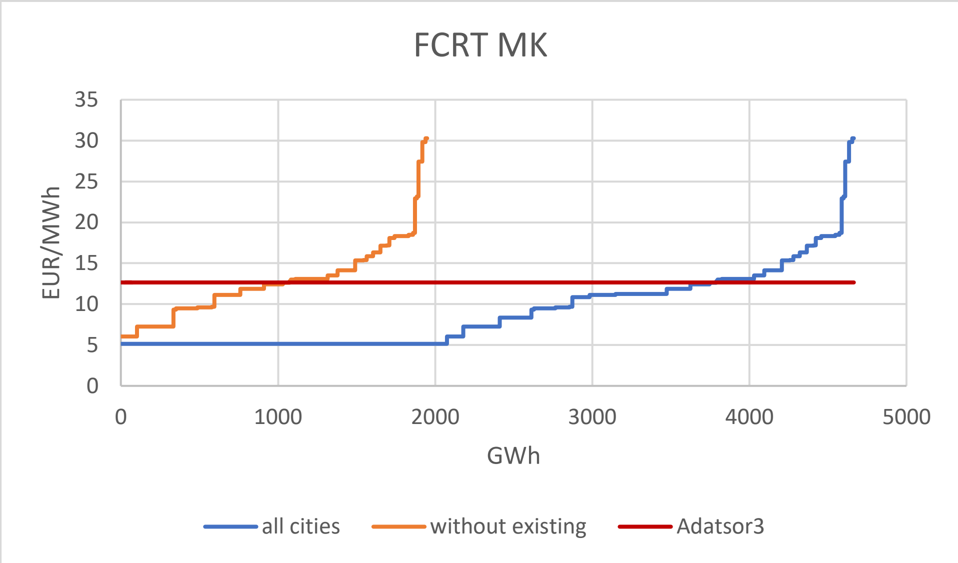
TABLE 13. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN NORTH MACEDONIA

		TWh/year
DSO	Consumption on distribution level	1.95
TSO	Total consumption	8.85
		EUR/MWh
DSO	Distribution tariff	12.65
TSO	Transmission tariff	4.96

Source: REKK calculation

Figure 9 shows the cost and the potential of the North Macedonian system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected. The orange line disregards the cities which have already been connected to the gas network. The tariff only relates to the line length on distribution level. The red line shows the tariff of the planned distribution network after equalization, i.e. all consumers paying the same distribution tariffs throughout the country.

FIGURE 9. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR NORTH MACEDONIA



Source: REKK calculation

2.3.5. MONTENEGRO

2.3.5.1. PREVIOUS STUDIES ON SYSTEM COSTS

Gas Master Plan was prepared by COWI in 2015, financed by an EBRD grant (COWI - IPF, 2015). The plan set out three main scenarios for gasification:

- Scenario 1 gasification of all municipalities in Montenegro
- Scenario 2 gasification of all municipalities in Montenegro and supply to Kosovo*
- Scenario 3 gasification of all municipalities in Montenegro and supply to Kosovo* and southern Rozaje

We opted to use data from Scenario 1, as the Kosovo* gasification plans do not prefer supply from Montenegro.

The system is to be connected from Albania, first connecting the coastal cities, then moving into the mainland towards Podgorica. Two main branches will spread to Niksic and Berane (See Figure 10 for reference). Based on level of gasification and pipeline options, a number of investment scenarios were drafted. Tariffs range on transmission level from 0.01 to 0.11 EUR/m^3, while on distribution level tariff of 0.21 EUR/m^3 was set.

We selected the full gasification on transmission level and without IAP scenario, so transmission tariffs are 0.04 EUR/m^3 while distribution tariffs are 0.21 EUR/m^3.

TABLE 14. GASIFICATION PLAN FOR MONTENEGRO

Transmission/distribution	Area	With/without IAP	CAPEX MEUR	OPEX MEUR	Tariff EUR/m3
Transmission	Coastal area	Without IAP	19.693	0.661	0.08
Transmission	Coastal area + Podgorica	Without IAP	62.85	1.463	0.11
Transmission	Coastal area + Podgorica + Niksic	Without IAP	82.438	1.963	0.11
Transmission	Coastal area + Podgorica + Niksic + large anchor consumers	Without IAP	82.438	2.04	0.04
Transmission	No network	IAP	110.453	1.852	0.01
Transmission	Coastal area	IAP	130.146	2.173	0.02
Transmission	Coastal area + Podgorica	IAP	173.303	2.975	0.02
Transmission	Coastal area + Podgorica + Niksic	IAP	192.891	3.474	0.02
Transmission	Coastal area + Podgorica + Niksic + large anchor consumers	IAP	192.891	3.552	0.02
Distribution	Coastal area		51.2		0.21
Distribution	Central area		124.5		0.21

Source: (COWI - IPF, 2015)

FIGURE 10. GAS MASTER PLAN OF MONTENEGRO

Source: (COWI - IPF, 2015)

2.3.5.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of Montenegro were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m^3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential “supply curve” of distribution network costs, linking potential consumption with distribution tariffs. Gas network is widespread, cities where gas distribution already existed were omitted from the calculation, as well es cities which were not selected as part of the gasification.

Cost of transmission system development was estimated based on the network layout of the gas master plan. (Figure 10)

TABLE 15. TOTAL GAS NETWORK INVESMENT COST FOR MONTENEGRO

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	127.1373	3.814118	299.1	6.0	426.28	9.80
Compressor	0	0	15.00	0.53	15.00	0.53
Metering and regulation	0	0	0.233478	0.008172	0.23	0.01
System supervision	0	0	2.5	0.0175	2.50	0.02
Total	127.14	3.81	316.87	6.53	444.01	10.35

Cost: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

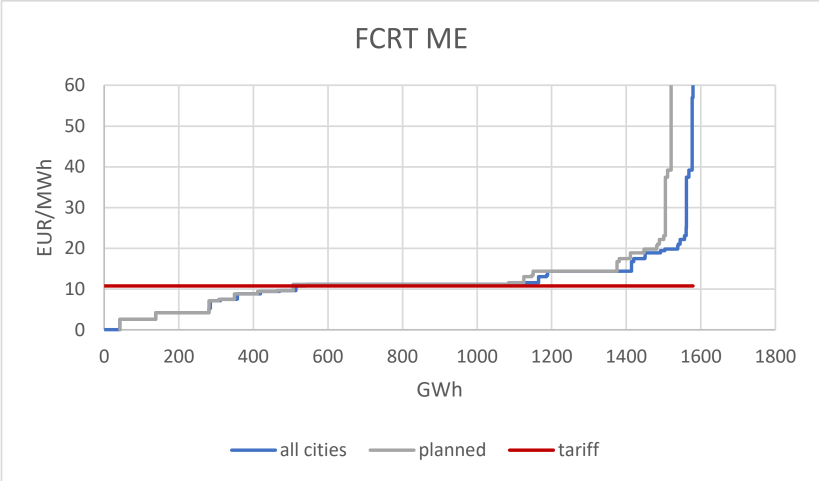
TABLE 16. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN MONTENEGRO

		TWh/year
DSO	**Consumption on distribution level**	1.52
TSO	**Total consumption**	7.02
		EUR/MWh
DSO	**Distribution tariff**	10.40
TSO	**Transmission tariff**	5.19

Cost: REKK calculation

Figure 11 shows the cost and the potential of the Montenegrin system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected. The tariff only relates to the line length on distribution level. The red line shows the tariff of the planned distribution network after equalization, i.e. all consumers paying the same distribution tariffs throughout the country.

FIGURE 11. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR MONTENEGRO



Cost: REKK calculation

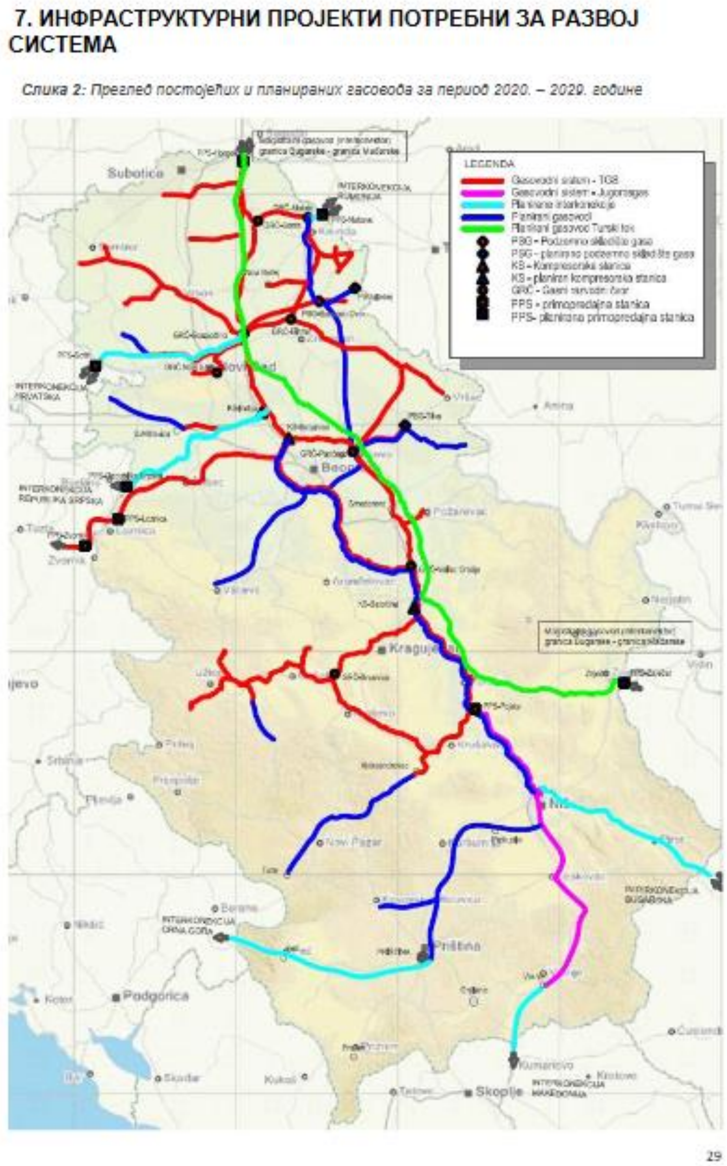
2.3.6. SERBIA

2.3.6.1. PREVIOUS STUDIES ON SYSTEM COSTS

As the gas market is well-developed compared to the other WB6 countries, no gas master plan exists. Transmission network development is performed by the gas TSO Transportgas Srbija and detailed in its TYNDP.

No indication in given on the investment need, but volume of consumption by 2029 and needed system developments are listed in the TYNDP.

FIGURE 12. EXISTING AND PLANNED GAS TRANSMISSIO NETWORK IN SERBIA, 2020-2029



Existing network: Red, green and purple lines

Planned network: Cyan and blue lines

Source: (Transportgaz Srbija, 2020)

2.3.6.2. CALCULATION OF SYSTEM COSTS AND TARIFFS

Major cities and towns of Serbia were listed and mapped. Distribution system length was estimated using QGIS software, based on the total length of residential streets. Using a uniform CAPEX (128 EUR/m), investment and O&M cost for distribution systems was calculated. Potential residential gas consumption was set based on population (300 m^3/person/year). Lifetime of the network was calculated for 20 years, assuming 7% discount rate. Using these parameters, distribution system tariff was calculated assuming full cost recovery, so the system users in the specific settlement were paying for their own network development costs. Cities and towns then were ranked based on the FCRT tariff. This created a potential "supply curve" of distribution network costs, linking potential consumption with distribution tariffs. Gas network is widespread, cities where gas distribution already existed were omitted from the calculation, as well es cities which were not selected as part of the gasification.

Cost of transmission system development was estimated based on the network layout of the gas master plan. (Figure 12)

TABLE 17. TOTAL GAS NETWORK INVESMENT COST FOR SERBIA

	DSO		TSO		Total	
	CAPEX	OPEX	CAPEX	OPEX	CAPEX	OPEX
	mEUR	mEUR/yr	mEUR	mEUR/yr	mEUR	mEUR/yr
Pipeline	135.57	37.09	373.95	30.15	509.5	67.2
Compressor	0.00	0.00	13.20	0.46	13.2	0.5
Metering and regulation	0.00	0.00	0.78	0.03	0.8	0.0
System supervision	0.00	0.00	0.00	0.00	0.0	0.0
Total	135.57	37.09	387.93	30.64	523.5	67.7

Source: REKK calculation

Investment costs were divided up amongst system users. DSO costs were to be financed by households, while TSO costs were financed by all system users.

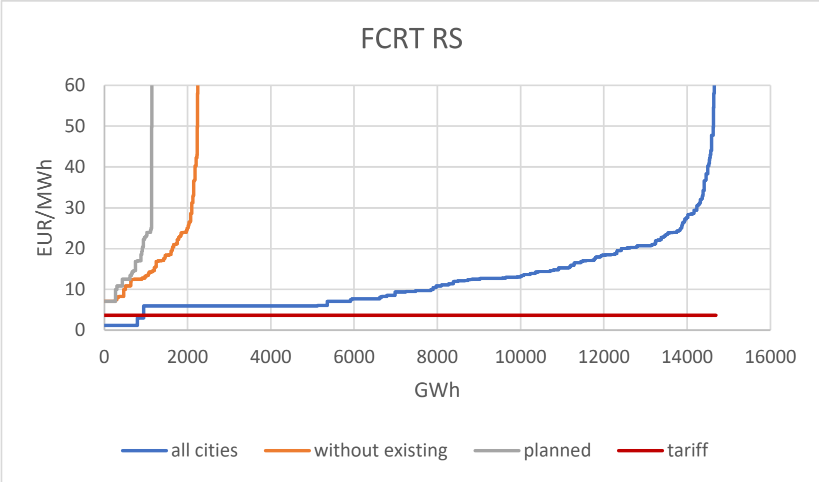
TABLE 18. ESTIMATED DISTRIBUTION AND TRANSMISSION TARIFFS IN SERBIA

		TWh/year
DSO	Consumption on distribution level	13.59
TSO	Total consumption	33.49
		EUR/MWh
DSO	Distribution tariff	3.67
TSO	Transmission tariff	2.01

Source: REKK calculation

Figure 13 shows the cost and the potential of the Serbian system to be developed. The horizontal axis shows the volume of gas to be supplied and consumed in the cities in GWh/year, while the vertical axis shows the applicable tariff (calculated in FCRT logic). The blue line indicates the cost for all cities to be connected. The orange line disregards the cities which have already been connected to the gas network. The tariff only relates to the line length on distribution level. The red line shows the tariff of the planned distribution network after equalization, i.e. all consumers paying the same distribution tariffs throughout the country.

FIGURE 13. DISTRIBUTION TARIFF AND ESTIMATED HOUSEHOLD POTENTIAL FOR SERBIA



Source: REKK calculation

2.4. COMPARISON OF TARIFFS ESTIMATED WITH PREVIOUS STUDIES

We have presented a simplified methodology to assess the network cost element (including transmission and distribution) of the gas supply. Tariffs were available in a number of scenarios when gas master plans were drafted (Albania, Montenegro, North Macedonia), but lacking in Kosovo* and in countries with already existing gas networks (Bosnia and Herzegovina, Serbia). Therefore, the comparison is possible, but limited.

For Albania, we managed to re-create the costs indicated in the Gas Master plan. Montenegro distribution tariffs are considerably lower in our estimation.

The reason for this may be the fact that uniform investment cost of 128 EUR/m was used for distribution system development, while the Gas Master Plan of Montenegro included investments ranging from 122-145 EUR/m.

Estimated Macedonian tariffs over-shoot the gas mater plan distribution and transmission tariffs as well. This may be caused by different assumption on gas demand.

In case of Serbia, operating costs of the existing network and investment plus operating costs of new network were considered. This proved to be less than half of the current tariffs. Serbian existing tariffs may include the investment cost of Balkan Stream, which was not considered in our calculation.

TABLE 19. COMPARING CALCULATED TARIFFS WITH GAS MASTER PLANS AND EXISTING TARIFFS

		AL	BA	KO*	ME	MK	RS
Calculated	DSO tariff	10.87	5.46	19.24	10.40	12.65	3.67
Calculated	TSO tariff	2.81	3.86	8.96	5.19	4.96	2.01
GMP	DSO tariff	13.00	n.a.	n.a.	18.30	8.60	5.50
GMP	TSO tariff	1.30	0.20	n.a.	3.30	2.00	7.30
Calculated	Tariff CALC	13.68	9.31	28.20	15.59	17.61	5.68
GMP	Tariff GMP	14.30	n.a.	n.a.	21.60	10.60	12.80

Source: REKK calculation, Gas Master plans

2.5. SENSITIVITY FOR TARIFFS

2.5.1. INVESTMENT COST SENSITIVITY

Effect of variable investment cost had a direct linear effect on tariffs, namely 1% higher investment costs resulted in 1% higher tariffs on both transmission and distribution side.

2.5.2. DISCOUNT RATE SENSITIVITY

Discount rate of 7% was used in the study. We checked the sensitivity of the tariff change to discount rate in the range between 0-15%. Calculated gas network tariffs for the DSOs and TSOs did not change significantly. Lowering the discount rate to 0% or raising it to 15% had an effect lower than 0.5% on distribution and transmission tariffs.

2.5.3. GAS CONSUMPTION PER CAPITA SENSITIVITY

Average gas consumption / capita of 300 m^3 was used in the study. We checked the sensitivity of the tariff change to different gas consumption / capita in the range between 150-450 m^3/capita. Calculated gas network tariffs for the DSOs and TSOs changed proportionally to the consumption. This means that assuming 150 m^3 / capita gas consumption would double the network costs, whereas 450 m^3/capita gas consumption would cut the network costs to 2/3.

3. BUILDING SECTOR MODELLING

3.1. LITERATURE REVIEW

We prepared a short overview of heating sector related studies, which focused also on gas network development in WB6.

A recent review of WB6 building sector (Kambovska, 2021) noted that: (i) nearly 97% of district heating supply is fossil based in the WB6 (ii) decentralised heating uses biomass or fossil coal (iii) EU and local governments are pushing for gas infrastructure development as a bridging/transition fuel. The study suggests that no major gas network developments should be done, as it would only lock in another fossil technology. Rather, RES heating and energy efficiency solutions should be supported.

The Commission (European Commission, 2020) mentions the development of a low-emission natural gas network, which will improve air quality and lower emissions. The Commission set out the following flagship projects under the transition from coal goal:

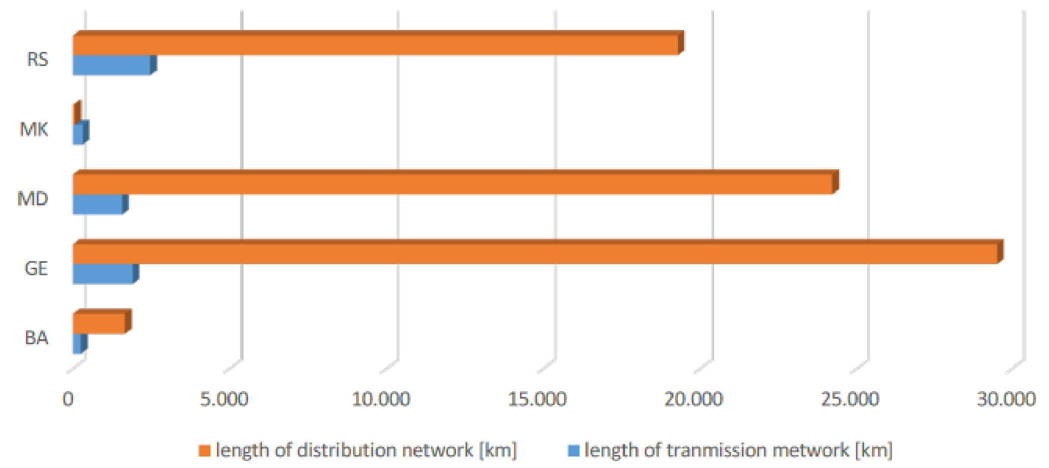
- Fier-Vlora gas pipeline in Albania (not PECI)
- Gas-interconnector Bosnia and Herzegovina –Croatia (not PECI)
- North Macedonia – Kosovo Gas Interconnection (on PECI list)
- North Macedonia – Serbia Gas Interconnection (on PECI list)

Another flagship project is the renovation wave. Building sector accounts for 40% of total energy consumption in the WB6. The gas network is seen future-proof as the network is to allow decarbonised gases to be injected. The building sector is to experience a renovation wave similar to the EU. With the coordination of the Energy community, renovation rate is set to triple, new buildings are expected to meet nearly zero energy and emission standards.

The main challenges and possibilities for the WB6 were described in a discussion paper of the Energy Community Secretariat (Energy Community Secretariat, 2021). Energy efficiency in the building sector is quite low, potentials for savings were estimated at 50% of the sector' energy consumption. The high share of multi-apartment buildings in the region hampers investment, as ownership issues and energy poverty make the support for renovation difficult. Similarly, barriers for the residential sector are: i) small project size and relatively high transaction costs, (ii) low energy tariffs, (iii) affordability, (iv) weak homeowner associations' (HOAs') decision-making processes and regulations, (v) lack of creditworthiness of HOAs/homeowners, (vi) norm-based billing systems for heating, (vii) limited access to affordable financing, (viii) informal or illegal construction, including unregistered building additions, and (viii) short investment horizons by homeowners (i.e. desire for short payback periods).

The EnC secretariat reviewed the current gas transmission and distribution networks to estimate methane leakage in 2021, this gives an indication on the current state of networks in WB6.

FIGURE 14. LENGTH OF GAS TRANSMISSION AND DISTRIBUTION NETWORKS IN THE ENC CONTRACTING PARTIES



(Čegir, 2021) pg 19 Diagram 5

3.2. BUILDING TYPOLOGY

To assess the costs and options for different heating technologies, we needed to have information on the actual building stock, the type of heating and similar characteristics. For Albania, Montenegro and Serbia, the SLED project created a detailed database. In case of Kosovo* and Bosnia and Herzegovina, a similar detailed building typology for the residential buildings was used. For North Macedonia, no such database existed as of 2021, but is already being prepared by the Habitat for Humanity and due to be published in 2022. To show approximate results for the North Macedonian residential sector, we opted to use the distribution of Serbia regarding the type of residential buildings and the year of building.

TABLE 20. DATA AVAILABILITY AND STUDIES USED TO REVIEW THE BUILDING SECTOR OF THE WB6

	Residential	Public
AL	SLED (2016) (Feiler, et al., 2016)	SLED (2018) (Simaku, et al., 2016)
BA	GIZ 2016 (Arnautović-Aksić, et al., 2016)	2018 (Nisandzic, 2018)
KO*	GFA based on TABULA, 2018 (Ministry of Environment and Spatial Planning of Kosovo*, 2018)	-
MK	- (Currently being prepared by Habitat for Humanity)	-
ME	SLED (2016) (Novikova, et al., 2015)	-
RS	SLED (2016)	Schools, kindergartens and gyms (Jovanović Popović, et al., 2019) (Jovanović Popović, et al., 2018) (Jovanović Popović, et al., 2018)

Source: REKK data collection

A complete database of non-residential buildings is non-existent for the region. Some data on public buildings exists for Albania, Bosnia and Herzegovina and Serbia, but this does not cover the entire building sector in any of the countries. For this reason, no detailed calculation on the non-residential building stock was performed.

The typologies and statistics of the residential building stock show the total floor area, the type of building, year of construction, the heat demand, the fuels used and average underheating as well. Coding and data content of the typologies differs somewhat (e.g. type C3 in Serbia denotes multi-family buildings constructed 1961-1970, while in Montenegro C3 denoted apartment blocks constructed in 1971-1990), for this reason a joint re-coding was performed based on the Serbian typology.

Using this joint typology, a short summary for the building stock of the WB6 is presented.

TABLE 21. CODING OF RESIDENTIAL BUILDING TYPES

		AL	BA	KO*	ME	MK	RS
DH	A1	DH before 1960	DH before 1945	DH before 1960	DH before 1945	DH before 1945	DH before 1945
	B1	-	DH 1946-1960	-	DH 1946-70	DH 1946-1960	DH 1946-1960
	C1	DH 1961-1980	DH 1961-1970	DH 1960-1969	-	DH 1961-1970	DH 1961-1970
	D1	-	DH 1971-1980	DH 1970-1979	DH 1971-90	DH 1971-1980	DH 1971-1980
	E1	DH 1981-1990	DH 1981-1990	DH 1980-1999	DH 1991-2000	DH 1981-1990	DH 1981-1990
	F1	DH 1991-2000	DH 1991-2014	DH 2000-2017	DH 2001-2011	DH 1991-2011	DH 1991-2011
SDH, TH	A2	SDH before 1960; TH before 1960	TH before 1945	TH before 1960	-	TH before 1945	TH before 1945
	B2	-	TH 1946-1960	-	-	TH 1946-1960	TH 1946-1960
	C2	SDH 1961-1980; TH 1961-1980	TH 1961-1970	TH 1960-1969	-	TH 1961-1970	TH 1961-1970
	D2	-	TH 1971-1980	TH 1970-1979	-	TH 1971-1980	TH 1971-1980
	E2	SDH 1981-1990; TH 1981-1990	TH 1981-1990	TH 1980-1999	-	TH 1981-1990	TH 1981-1990
	F2	SDH 1991-2000; TH 1991-2000	TH 1991-2014	TH 2000-2017	-	TH 1991-2011	TH 1991-2011
MFH	A3	MFH before 1960	MFH before 1945	MFH before 1960	MFH before 1945	MFH before 1945	MFH before 1945
	B3	-	MFH 1946-1960	-	MFH 1946-70	MFH 1946-1960	MFH 1946-1960
	C3	MFH 1961-1980	MFH 1961-1970	MFH 1960-1969	-	MFH 1961-1970	MFH 1961-1970
	D3	-	MFH 1971-1980	MFH 1970-1979	MFH 1971-90	MFH 1971-1980	MFH 1971-1980
	E3	MFH 1981-1990	MFH 1981-1990	MFH 1980-1999	MFH 1991-2000	MFH 1981-1990	MFH 1981-1990
	F3	MFH 1991-2000	MFH 1991-2014	MFH 2000-2017	MFH 2001-2011	MFH 1991-2011	MFH 1991-2011
AB, ABP, HR	A4	-	AB, ABP, HR be-fore 1945	-	-	AB before 1945	AB before 1945
	B4	-	AB, ABP, HR 1946-1960	-	-	AB 1946-1960	AB 1946-1960
	C4	-	AB, ABP, HR 1961-1970	AB 1960-1969	-	AB 1961-1970	AB 1961-1970
	D4	-	AB, ABP, HR 1971-1980	AB 1970-1979	AB 1971-90	AB 1971-1980	AB 1971-1980
	E4	-	AB, ABP, HR 1981-1990	AB 1980-1999	AB 1991-2000	AB 1981-1990	AB 1981-1990
	F4	-	AB, ABP, HR 1991-2014	AB 2000-2017	AB 2001-2011	AB 1991-2011	AB 1991-2011

DH: Detached house; SDH: Semi-Detached house, TH: Terraced house, MFH: Multi-family house, AB: Apartment block, ABP: Apartment block (prefabricated), HR: High-rise apartment

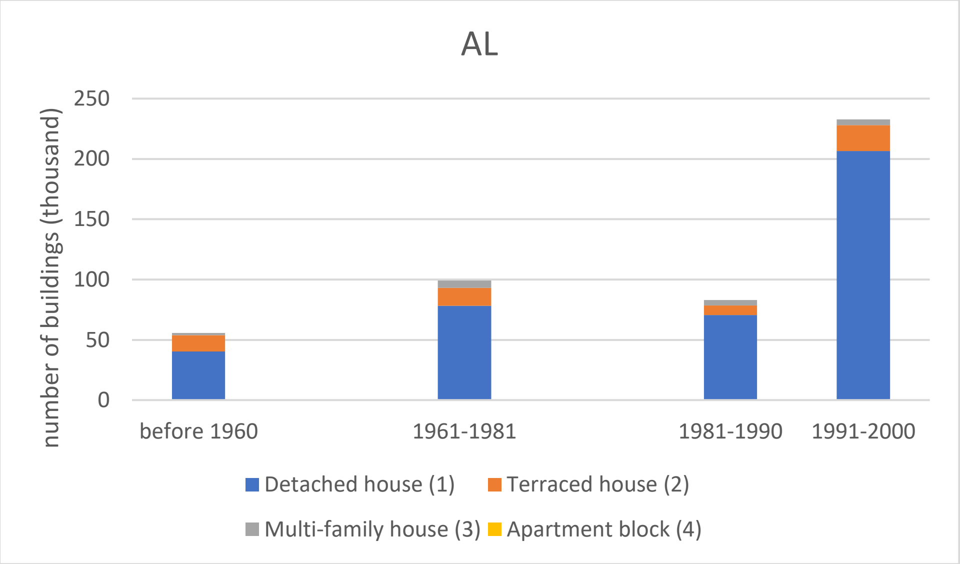
Source: REKK categorization

3.2.1. ALBANIA

Data on the Albanian building stock were derived from the SLED study (Feiler, et al., 2016). Over 96% of the building stock is comprised of detached or semi-detached/terraced housing. Nearly 50% of the buildings were constructed after 1990. (Figure 15)

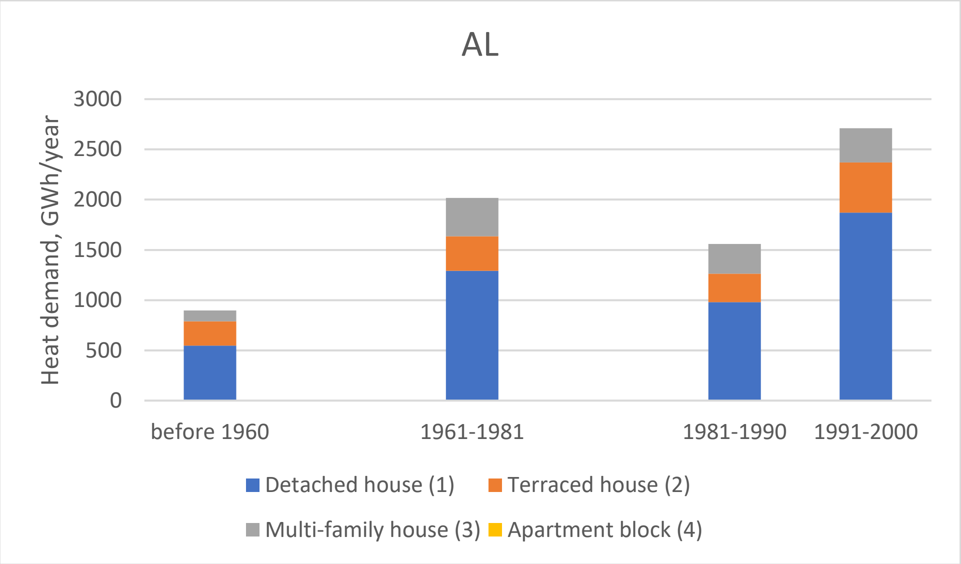
84% of the building sector heat demand is consumed in detached or terraced housing. 60% of the heat demand is concentrated in buildings built after 1981. (Figure 16)

FIGURE 15. NUMBER OF RESIDENTIAL BUILDINGS IN ALBANIA, THOUSAND BUILDINGS



Source: REKK based on SLED 2016

FIGURE 16. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN ALBANIA, GWH/YEAR



Source: REKK based on SLED 2016

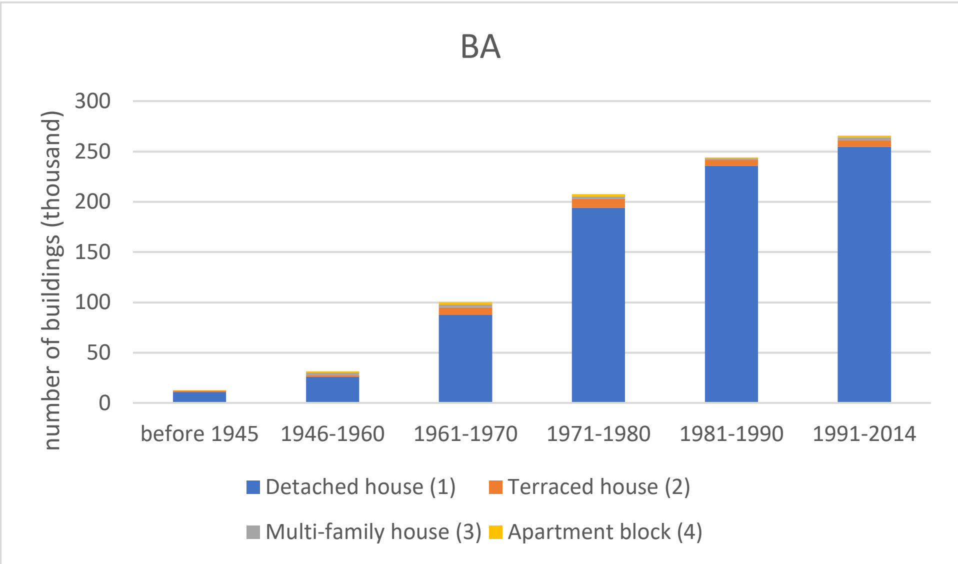
3.2.2. BOSNIA AND HERZEGOVINA

Data on the Bosnian building stock were obtained from the detailed assessment of the sector commissioned by GIZ (Arnautović-Aksić, et al., 2016).

98% of residential buildings are detached houses. 60% of the building stock was constructed after 1980. (Figure 17)

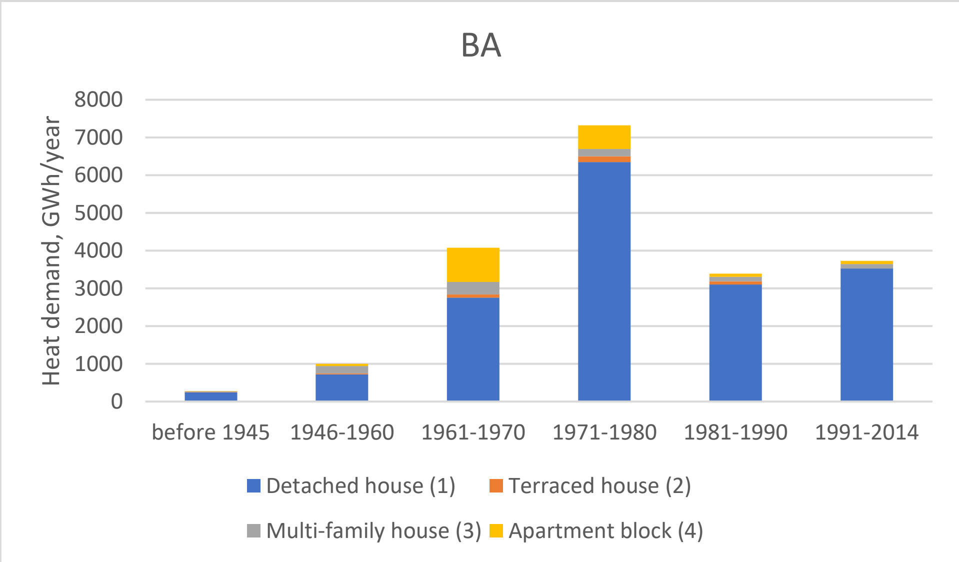
Most of the residential building sector heat demand is in detached or terraced housing (86%). 64% of the heat demand is consumed in old, low energy efficiency buildings built before 1980. (Figure 18)

FIGURE 17. NUMBER OF RESIDENTIAL BUILDINGS IN BOSNIA AND HERZEGOVINA, THOUSAND BUILDINGS



Source: REKK based on GIZ 2016

FIGURE 18. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN BOSNIA AND HERZEGOVINA, GWH/YEAR



Source: REKK based on GIZ 2016

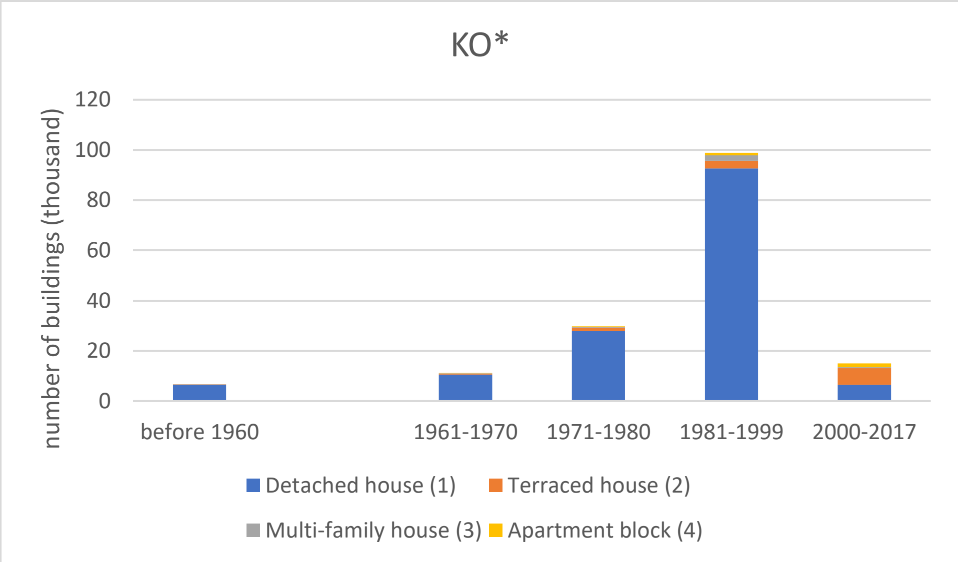
3.2.3. KOSOVO*

Data on Kosovo* building stock were collected from a review of the Kosovo* government to meet the EPBD directive (Ministry of Environment and Spatial Planning of Kosovo*, 2018).

96% of the buildings are detached or terraced houses. The building stock is relatively new, 71% of buildings were constructed after 1981. (Figure 19)

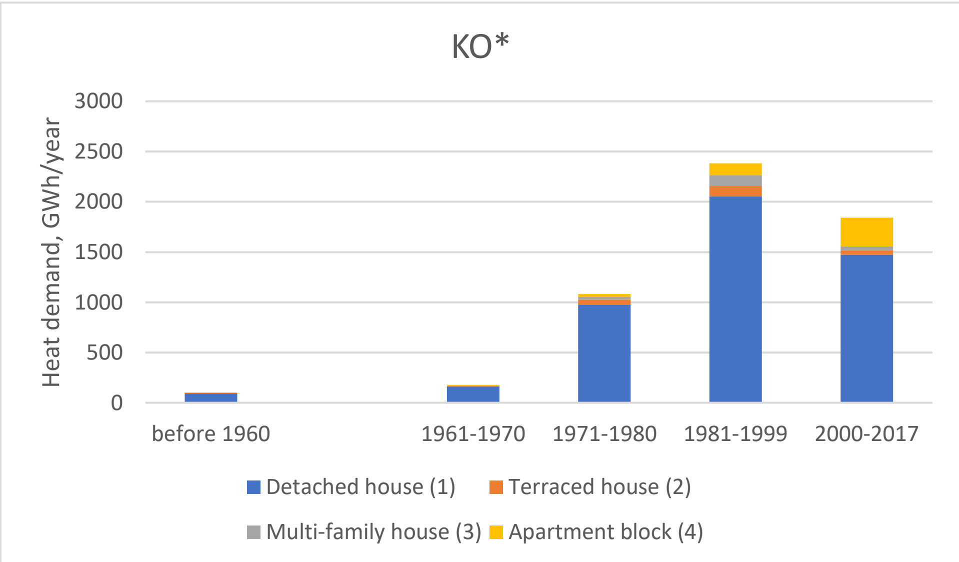
90% of heat demand is consumed in detached or terraced houses, and 76% of the demand is used in buildings constructed after 1981. (Figure 20)

FIGURE 19. NUMBER OF RESIDENTIAL BUILDINGS IN KOSOVO*, THOUSAND BUILDINGS



Source: REKK based on GFA 2018

FIGURE 20. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN KOSOVO*, GWH/YEAR



Source: REKK based on GFA 2018

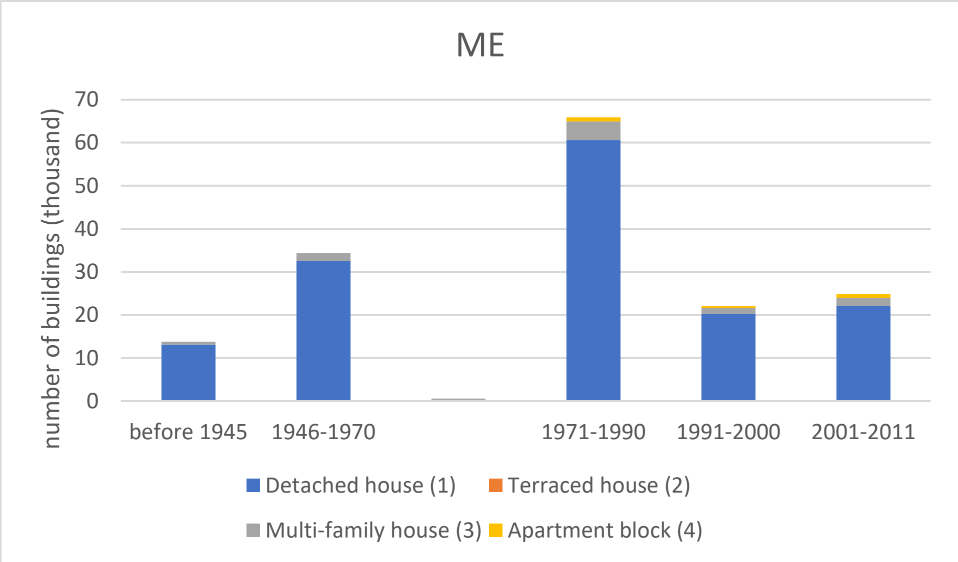
3.2.4. MONTENEGRO

Building sector data were collected from SLED project (Novikova, et al., 2015).

92% of the buildings are detached houses, and over 70% of the stock was constructed before 1990. (Figure 21)

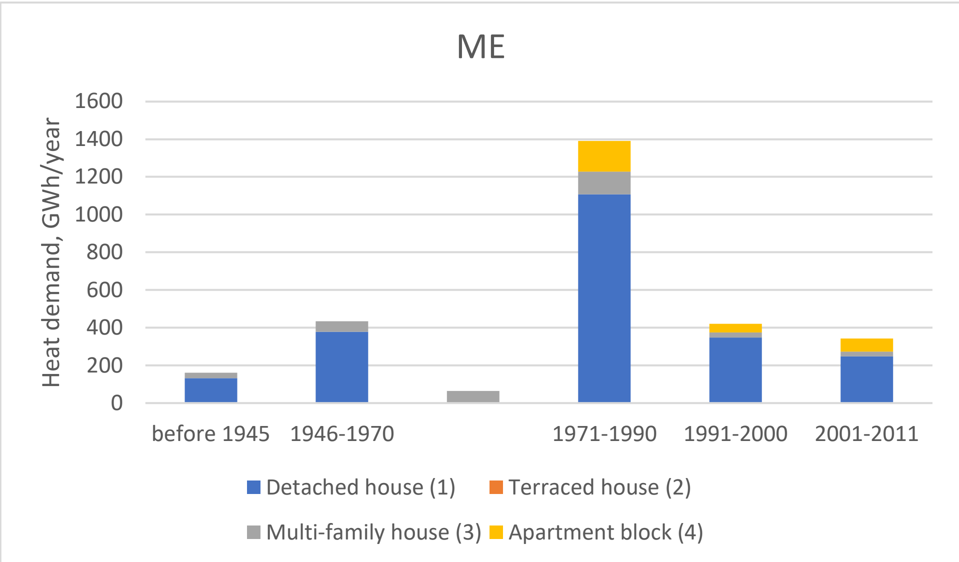
Over 70% of the heat demand is related to these buildings. (Figure 22)

FIGURE 21. NUMBER OF RESIDENTIAL BUILDINGS IN MONTENEGRO, THOUSAND BUILDINGS



Source: REKK based on SLED 2016

FIGURE 22. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN MONTENEGRO, GWH/YEAR

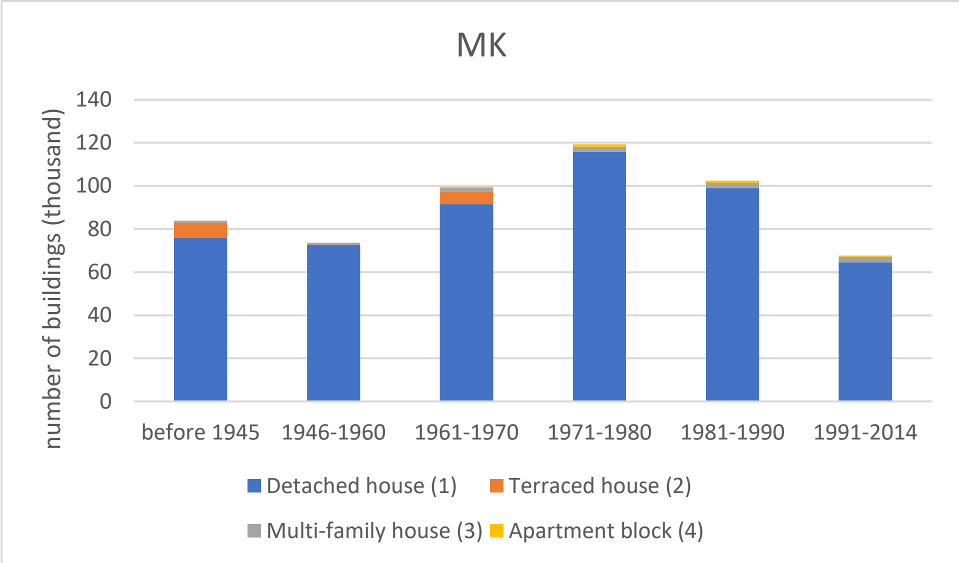


Source: REKK based on SLED 2016

3.2.5. NORTH MACEDONIA

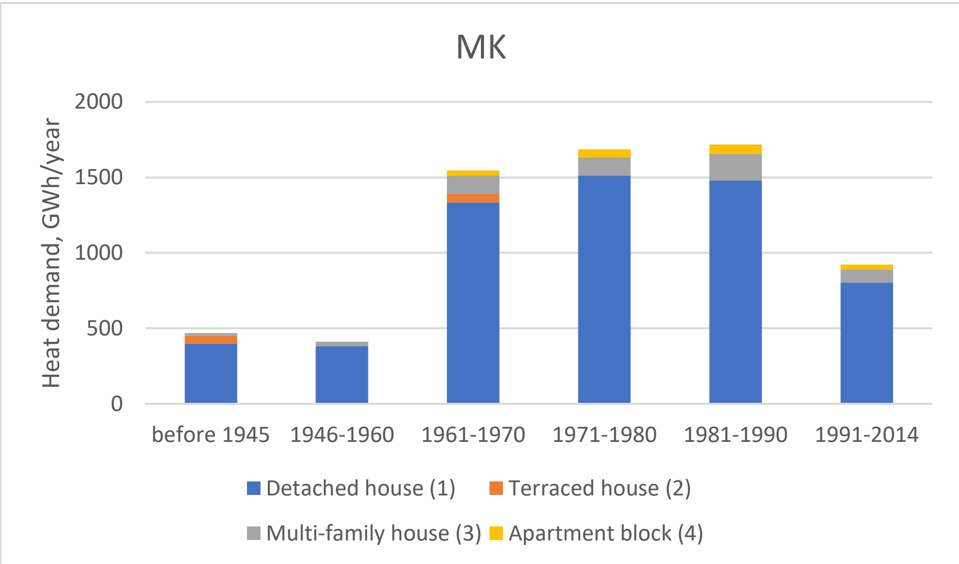
No detailed assessment of the North Macedonian building stock exists. For this reason, we used the Serbian building stock as a proxy. The ratio of households in North Macedonia and Serbia is 1:4, so using this as a rough estimation we made a theoretical building stock for North Macedonia, accompanied with a heat demand. It must be stressed that all our results are based on this make-up figures. The methodology applied can be easily adjusted once the building stock survey of Habitat for Humanity is completed for North Macedonia.

FIGURE 23. NUMBER OF RESIDENTIAL BUILDINGS IN NORTH MACEDONIA, THOUSAND BUILDINGS (ESTIMATED, NOT DATA)



Source: REKK assumptions

FIGURE 24. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN NORTH MACEDONIA, GWH/YEAR (ESTIMATED, NOT DATA)



Source: REKK assumptions

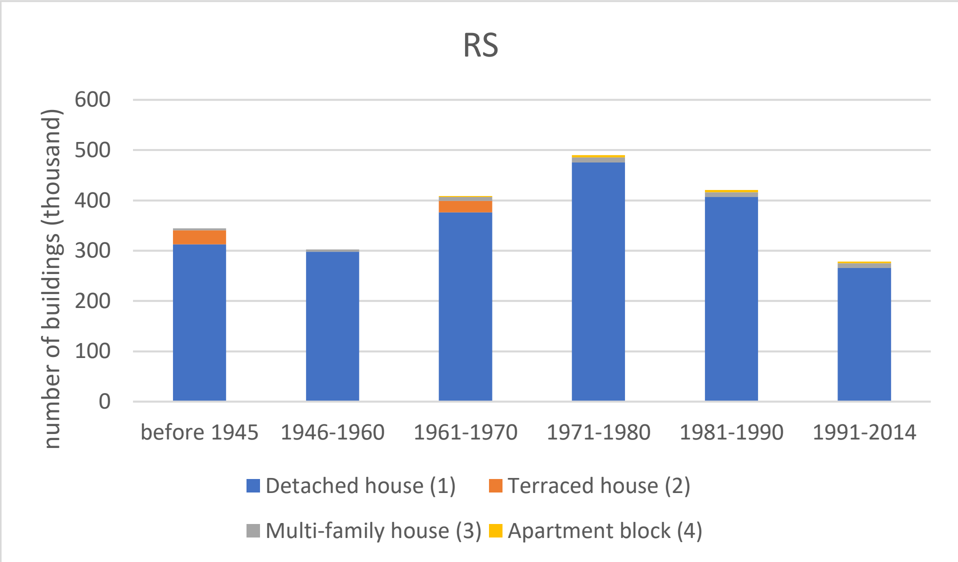
3.2.6. SERBIA

Building sector data were obtained from SLED project (Feiler, et al., 2015).

95% of buildings are detached or terraced houses. Around 70% of the buildings was built before 1980. (Figure 25)

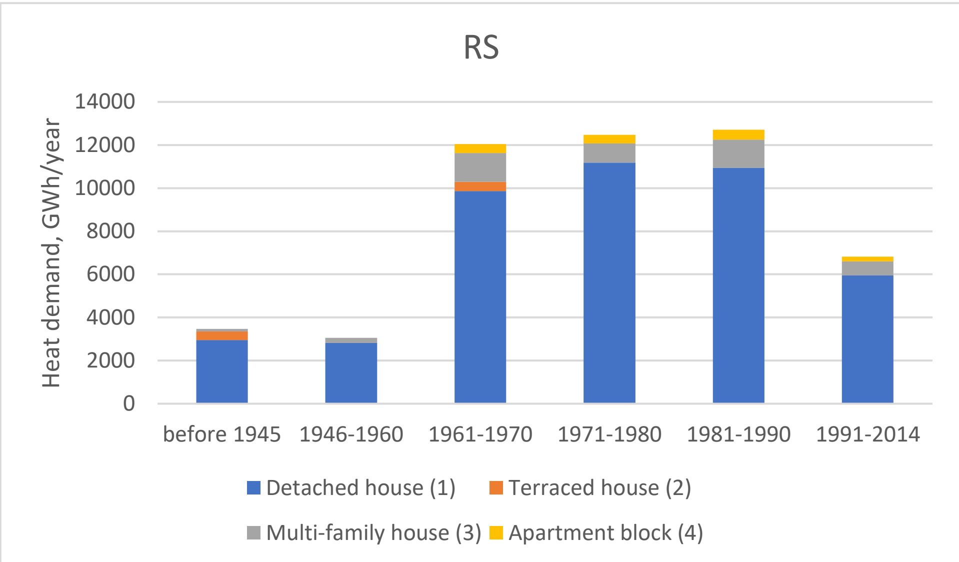
Heat demand is concentrated in detached housing (88% of total heat demand). 60% of heat consumption of the total residential building sector is related to buildings constructed before 1980. (Figure 26)

FIGURE 25. NUMBER OF RESIDENTIAL BUILDINGS IN SERBIA, THOUSAND BUILDINGS



Source: REKK based on SLED 2016

FIGURE 26. HEAT DEMAND IN RESIDENTIAL BUILDINGS PER BUILDING TYPE AND AGE IN SERBIA, GWH/YEAR



Source: REKK based on SLED 2016

3.3. MODELLING FRAMEWORK

A simplified Excel calculation tool was developed to quantify different scenarios and show the cost of alternative heating technologies. The tool aims at showing the cost of different heating modes as well as the potential gas demand stemming from the residential building sector. The simple and straightforward formulation allows for quick generation of results, as well as creating a number of sensitivity cases. Although this approach is rather simplistic, it allows for highlighting the main drivers and most important parameters.

As a first step, the different building types are listed for each of the WB6 countries. The building types are characterised by the year and type of building and climate zone. The calculation sets up a base case, which shows the current state of the residential building sector, listing the fuels used for heating.

In the second step, the total heat demand is met with different heating options (see below in table rows a-g). The variable costs of the various heating options are listed (including energy component, network cost, taxes and VAT) and added up with an annualised variable investment component. The variable investment component is calculated as the investment cost divided by the total energy delivered under the (perceived) lifetime of the investment.

TABLE 22. CALCULATING HEATING OPTIONS FOR RESIDENTIAL BUILDINGS

	electricity	wood	gas	distrit heating	coal	oil	heat pump
0	40%	23%	7%	-	5%	1%	-
a	100%	-	-	-	-	-	-
b	-	100%	-	-	-	-	-
c	-	-	100%	-	-	-	-
d	-	-	-	100%	-	-	-
e	-	-	-	-	100%	-	-
f	-	-	-	-	-	100%	-
g	-	-	-	-	-	-	100%

In the third step, the most cost-effective solution is picked and all heating is "switched" to this mode of heating. A comparison of all technologies regarding the costs is displayed, as well as the energy balance of the sector is presented.

3.3.1. PARAMETERS

Parameters listed under this chapter are valued which can be adjusted easily in the calculation framework. These allow for sensitivity and scenario runs. The initial setting of the parameters was based on studies and calibration of the energy consumption of the buildings in the energy balances.

Initial value of the parameters is listed in each case.

- Heating appliance installation cost (I), EUR: investment cost for the installation of a new heating system. At the time of investment, the household compares the switching to an alternative heating system (or keeping the same technology, but replacing the existing one with a new appliance). Installation cost is uniform across the modelled countries. Investing in biomass boilers is only possible in detached houses or terraced houses, while district heating was considered only for multi-family buildings. Investment costs were obtained from the SLED project assumptions.

TABLE 23. HEATING APPLIANCE INSTALLATION COST (I), EUR

	Investment cost, heating appliance, EUR						
	electricity	wood	gas	district heating	coal	oil	heat pump
A1	400	3000	1500	-	2000	2500	6000
A2	400	3000	1500	-	2000	2500	6000
A3	800	-	3500	4000	2000	2500	12000
A4	800	-	3500	4000	2000	2500	12000
B1	400	3000	1500	-	2000	2500	6000
B2	400	3000	1500	-	2000	2500	6000
B3	800	-	3500	4000	2000	2500	12000
B4	800	-	3500	4000	2000	2500	12000
C1	400	3000	1500	-	2000	2500	6000
C2	400	3000	1500	-	2000	2500	6000
C3	800	-	3500	4000	2000	2500	12000
C4	800	-	3500	4000	2000	2500	12000
D1	400	3000	1500	-	2000	2500	6000
D2	400	3000	1500	-	2000	2500	6000
D3	800	-	3500	4000	2000	2500	12000
D4	800	-	3500	4000	2000	2500	12000
E1	400	3000	1500	-	2000	2500	6000
E2	400	3000	1500	-	2000	2500	6000
E3	800	-	3500	4000	2000	2500	12000
E4	800	-	3500	4000	2000	2500	12000
F1	400	3000	1500	-	2000	2500	6000
F2	400	3000	1500	-	2000	2500	6000
F3	800	-	3500	4000	2000	2500	12000
F4	800	-	3500	4000	2000	2500	12000

Source: (Feiler, et al., 2015) page 51 tables 12-13

- Heating appliance efficiency (η), %: rate at which 1 kWh of energy of a specific fuel is converted into useful energy for heating. This relates to the total efficiency of the heating system (i.e. piping, boiler and control efficiency all together).

TABLE 24. HEATING APPLIANCE EFFICIENCY, %

	Heating appliance efficiency, %						
	electric-ity	wood	gas	distrit heating	coal	oil	heat pump
A1	100%	79%	93%	-	75%	75%	300%
A2	100%	79%	93%	-	75%	75%	300%
A3	100%	-	93%	100%	75%	75%	300%
A4	100%	-	93%	100%	75%	75%	300%
B1	100%	79%	93%	-	75%	75%	300%
B2	100%	79%	93%	-	75%	75%	300%
B3	100%	-	93%	100%	75%	75%	300%
B4	100%	-	93%	100%	75%	75%	300%
C1	100%	79%	93%	-	75%	75%	300%
C2	100%	79%	93%	-	75%	75%	300%
C3	100%	-	93%	100%	75%	75%	300%
C4	100%	-	93%	100%	75%	75%	300%
D1	100%	79%	93%	-	75%	75%	300%
D2	100%	79%	93%	-	75%	75%	300%
D3	100%	-	93%	100%	75%	75%	300%
D4	100%	-	93%	100%	75%	75%	300%
E1	100%	79%	93%	-	75%	75%	300%
E2	100%	79%	93%	-	75%	75%	300%
E3	100%	-	93%	100%	75%	75%	300%
E4	100%	-	93%	100%	75%	75%	300%
F1	100%	79%	93%	-	75%	75%	300%
F2	100%	79%	93%	-	75%	75%	300%
F3	100%	-	93%	100%	75%	75%	300%
F4	100%	-	93%	100%	75%	75%	300%

Source: based on (Marchetti, 2019) page 75, Table 17

- Underheating (U), %: many households choose not to heat the total floor area of the buildings, this may be due to costs-saving decisions or changing family structure (e.g. older people without children not heating the vacant rooms). Under-heating values were obtained from SLED studies or calibrated to reflect the consumption of the energy balances. Under-heating of 30% means that only 30% of the heat demand is met.

TABLE 25. UNDER-HEATING ASSUMED IN THE WB6, %

	AL	BA	KO*	ME	MK	RS
A1	40%	90%	48%	48%	48%	50%
A2	40%	90%	48%	48%	48%	50%
A3	40%	90%	48%	48%	48%	50%
A4	40%	90%	48%	48%	48%	0%
B1	40%	90%	48%	48%	48%	50%
B2	40%	90%	48%	48%	48%	0%
B3	40%	90%	48%	48%	48%	50%
B4	40%	90%	48%	48%	48%	0%
C1	40%	90%	48%	48%	48%	50%
C2	40%	90%	48%	48%	48%	50%
C3	40%	90%	48%	48%	48%	80%
C4	40%	90%	48%	48%	48%	100%
D1	40%	90%	48%	48%	48%	50%
D2	40%	90%	48%	48%	48%	0%
D3	40%	90%	48%	48%	48%	50%
D4	40%	90%	48%	48%	48%	50%
E1	40%	90%	48%	48%	48%	50%
E2	40%	90%	48%	48%	48%	0%
E3	40%	90%	48%	48%	48%	50%
E4	40%	90%	48%	48%	48%	50%
F1	40%	90%	48%	48%	48%	50%
F2	40%	90%	48%	48%	48%	0%
F3	40%	90%	48%	48%	48%	50%
F4	40%	90%	48%	48%	48%	50%

AL, BA, KO, ME: calibrated for primary energy balances*

MK: (State Statistical Office of the Republic of North Macedonia, 2021) T-02

RS: (Feiler, et al., 2015)

- Energy cost, (p_{en}) EUR/MWh: cost of different fuels used for heating, related to the energy component.

TABLE 26. ENERGY COMPONENT OF FUELS, EUR/MWH

	Energy cost, EUR/MWh						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	52.6	23.0	25.0	54.1	40.0	45.0	52.6
BA	37.6	23.0	25.0	54.1	40.0	45.0	37.6
KO	26.4	23.0	25.0	54.1	40.0	45.0	26.4
ME	45.9	23.0	25.0	54.1	40.0	45.0	45.9
MK	43.7	23.0	25.0	54.1	40.0	45.0	43.7
RS	24.6	23.0	25.0	54.1	40.0	45.0	24.6

Source: electricity: (ACER/CEER, 2020), gas: Average 2021 price (Jan-aug) TTF spot DA price ; wood: (Stojadinovic, Bortoli, & Baldini, 2017) page 50 fig 29 coal and oil: (Stojadinovic, Bortoli, & Baldini, 2017) page 52 fig 31, district heating: BA regulated DH reference price

- Network cost (p_{net}): cost of different fuels used for heating, related to the network component. No network or additional transportation cost component for wood, coal and oil was calculated.

TABLE 27. NETWORK COMPONENT OF FUELS, EUR/MWH

	Network cost, EUR/MWh						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	17.8	-	14.3	14.1	-	-	17.8
BA	36.1	-	11.4	14.1	-	-	36.1
KO	30.0	-	20.0	14.1	-	-	30.0
ME	37.6	-	21.6	14.1	-	-	37.6
MK	21.9	-	10.6	14.1	-	-	21.9
RS	31.9	-	5.2	14.1	-	-	31.9

Source: Electricity (ACER/CEER, 2020); Gas: see Chapter 3. Assessing gas network investment costs; district heating: BA regulated DH reference price

- VAT (p_{VAT}): value added tax paid by households for different fuels, based on network and energy costs and applicable VAT rates for 2021.

TABLE 28. VAT RATE FOR FUELS, % (OF ENERGY AND NETWORK COMPONENT)

	VAT, %						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	20%	20%	20%	20%	20%	20%	20%
BA	17%	17%	17%	17%	17%	17%	17%
KO	6%	18%	18%	6%	18%	18%	6%
ME	21%	21%	21%	21%	21%	21%	21%
MK	18%	18%	18%	18%	18%	18%	18%
RS	20%	10%	10%	10%	20%	20%	20%

Source: vatupdate.com[7]

- Other taxes (p_{TAX}): excise duties and other taxes paid by households for different fuels. 2 EUR/MWh "convenience" tax was added on the cost of fuelwood.

TABLE 29. EXCISE DUTIES AND OTHER TAXES ON FUELS, EUR/MWH

	Taxes, EUR/MWh						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	0.0	2.0	-	-	-	-	0.0
BA	1.1	2.0	-	-	-	-	1.1
KO	0.0	2.0	-	-	-	-	0.0
ME	4.9	2.0	-	-	-	-	4.9
MK	6.1	2.0	-	-	-	-	6.1
RS	5.1	2.0	-	-	-	-	5.1

Source: Electricity (ACER/CEER, 2020); for other fuels, no excise duty or other taxes were considered

- Lifetime, years (t): Lifetime and optimisation horizon of the household. The model allows for differentiation. As a starting point we assumed an identical 20 years across countries and technologies.

[7] https://www.vatupdate.com/2021/05/26/vat-rates-in-albania/;
https://www.vatupdate.com/2021/04/18/vat-rates-in-bosnia-and-herzegovina/;
https://www.vatupdate.com/2021/05/12/vat-rates-in-kosovo/;
https://www.vatupdate.com/2021/05/13/vat-rates-in-montenegro/;
https://www.vatupdate.com/2021/05/12/vat-rates-in-north-macedonia/;
https://www.vatupdate.com/2021/04/18/vat-rates-in-serbia/

TABLE 30. ASSUMED LIFETIME OF TECHNOLOGIES, YEARS

	Lifetime, years						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	20	20	20	20	20	20	20
BA	20	20	20	20	20	20	20
KO	20	20	20	20	20	20	20
ME	20	20	20	20	20	20	20
MK	20	20	20	20	20	20	20
RS	20	20	20	20	20	20	20

- Discount rate (r), %: Discount rate applied for assessing the variable investment cost. Literature shows 2%-30% discount rates for household energy efficiency and heating investment.

TABLE 31. DISCOUNT RATE APPLIED, %

	Dis-count rate
AL	5%
BA	5%
KO	5%
ME	5%
MK	5%
RS	5%

Source: (Andersen, Wiese, Petrovic, & Russell, 2020)

3.3.2. DATA AND CALCULATION

- Country: code for WB6 countries considered in the analysis
- Climate zone: Coastal, Central or Mountain region differentiated for AL, ME. Only one central region is considered for BA, KO*, MK, RS.
- Building Type: as listed in Table 21.
- Type code: as listed in Table 21.
- Construction period: as listed in Table 21.
- Floor area, m^2 (total): total floor area for the specific building type
- Number of buildings: total number of buildings of the specific building type
- Floor area, m^2 (average): average floor area for the specific building type

- Heat demand (Q_{HD}), kWh/year/building: heat demand for the specific building type, calculated by SLED and other building surveys based on the floor area, year of building and physical characteristics of the building.
- Heat demand with underheating (Q_{HDU}), kWh/year/building: Q_{HD}*U (see U as Under-heating in Parameters)
- Demand per source (%)/(kWh/year/building): share of different fuels used for heating. Based on surveys of SLED and calibration of shares to meet the residential sector energy consumption in the energy balances.
- Delivered energy per source (QD): calculated as Q_{HDU}/η. Lists the delivered energy as the default heating modes. (See η as efficiency of heating system in parameters)
- Variable total energy cost (p_{tot}): sum of variable energy costs considering efficiency $p_{tot}=(P_{en}+p_{net}+p_{vat}+p_{tax})/ \eta$
- Variable investment cost p_{inv}: investment cost divided by the discounted value of the total energy delivered. $P_{inv}=I/(Q_D/(1+r)^t)$

3.4. RESULTS

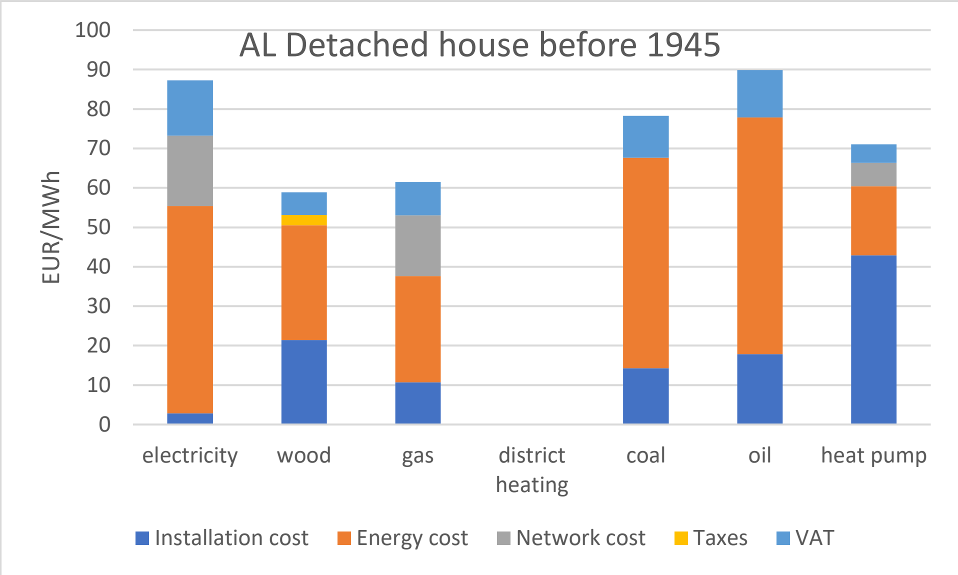
Our main results focus on the cost-competitiveness of natural gas with other modes of heating, and the total potential of gas demand. This is compared and contrasted with the gas demand estimated in the Network investment cost assessment.

3.4.1. COST OF GAS RELATIVE TO OTHER MODES OF HEATING

Applying the methodology described above, a cost comparison for all technologies and for all building types was performed. Variable type of costs (p_{en}, p_{net}, p_{vat}, p_{tax}) were identical for all building types within the same country, while annualised investment costs (p_{inv}) were diverse for the building types, related to the floor area mainly. The figure below gives an example for the cost of heating options for detached houses built 1981-1990 in Albania. It is apparent that fuelwood is the most cost-efficient option, followed by natural gas, heat pumps, coal, electricity and finally oil. (Figure 27)

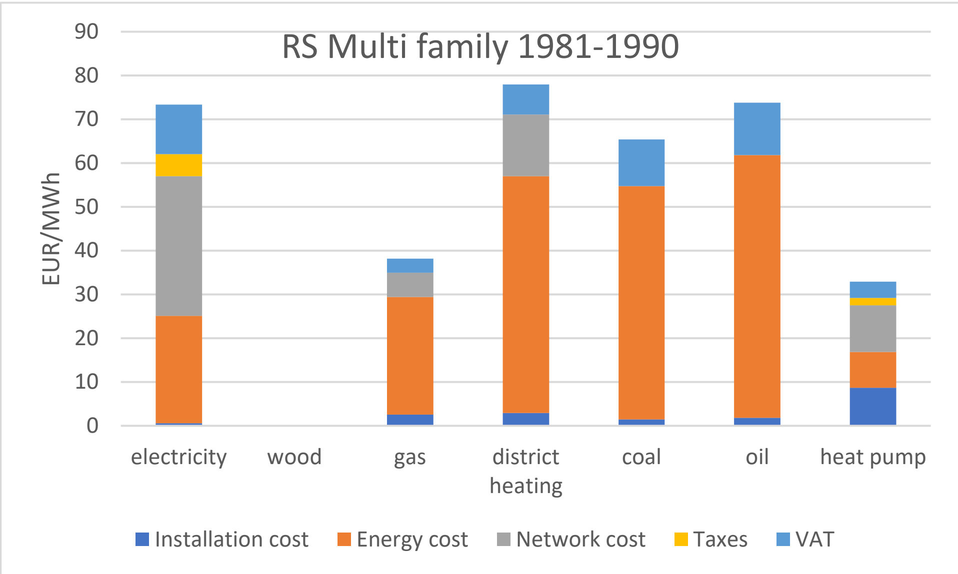
The same calculation was performed for all building types, the "merit order" of fuels differs for countries, building types (detached house, multi-family or apartment block), as well as year of construction. For illustration, see Figure 28.

FIGURE 27. HEATING COSTS FOR A SELECTED BUILDING TYPE IN ALBANIA



Source: REKK calculation

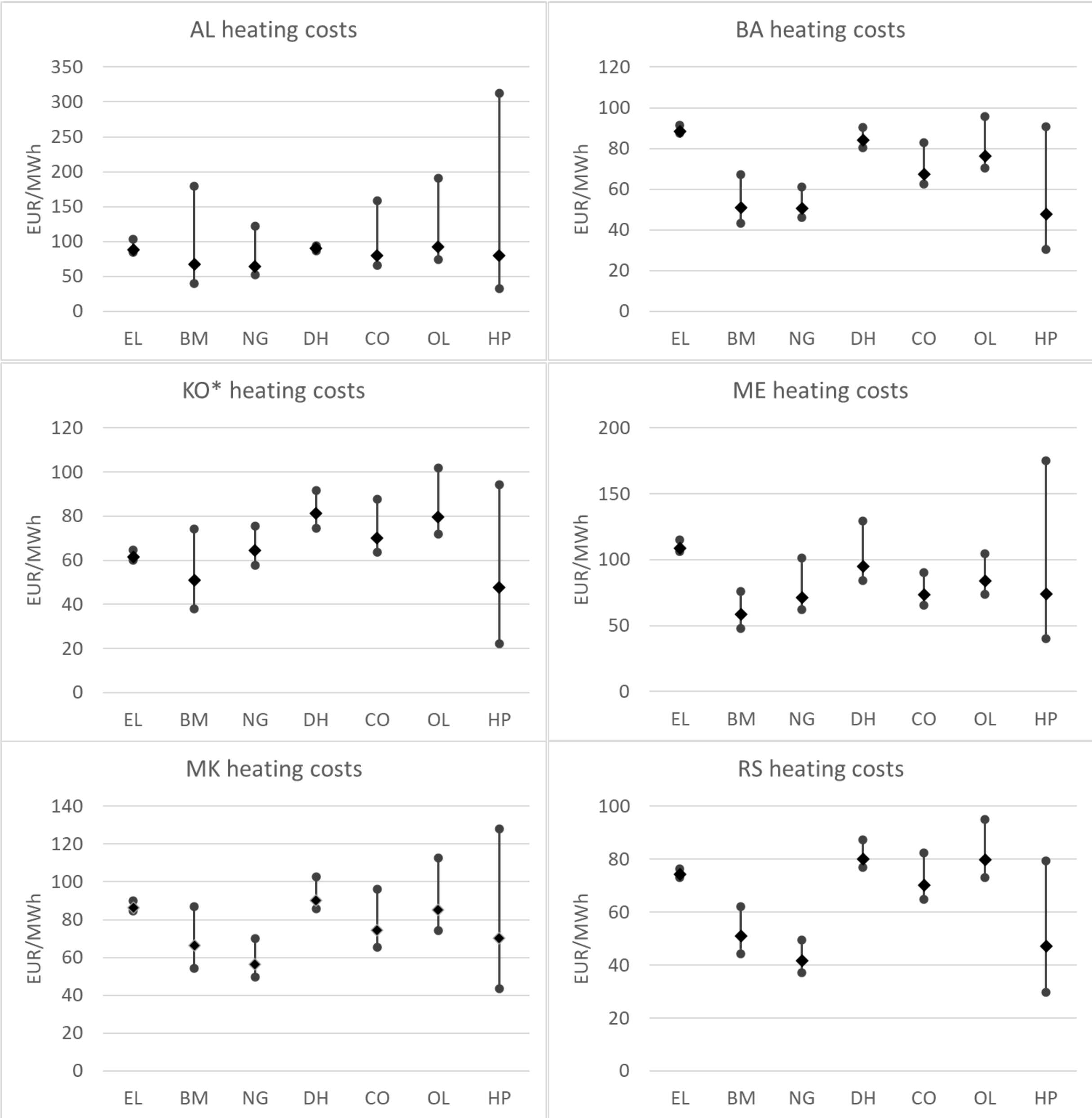
FIGURE 28. HEATING COSTS FOR A SELECTED BUILDING TYPE IN SERBIA



Source: REKK calculation

The same calculation was performed for all building types. This gives us a range of costs displayed in Figure 29. The figure shows minimum, maximum and average cost of the different technologies (including fuel, network and variable investment cost as well).

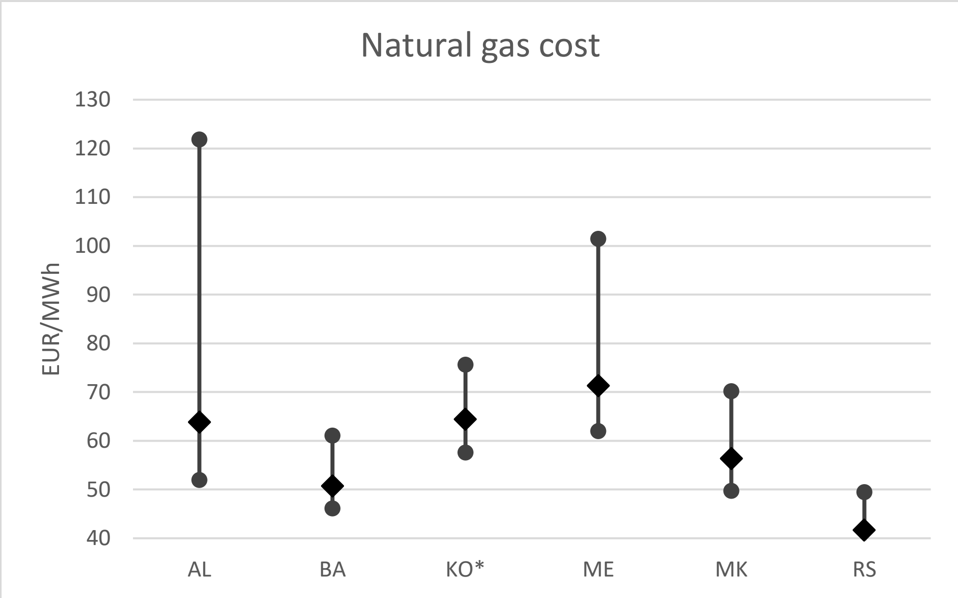
FIGURE 29. RANGE FOR DIFFERENT COSTS OF HEATING IN ALL BUILDING TYPES IN THE WB6, EUR/MWH



Source: REKK calculation. EL: electricity; BM: biomass (fuelwood); NG: natural gas DH: district heating; CO: coal; OL: heating oil; HP: heat pump

Cost of natural gas for households (Figure 30) has a narrower range in countries with existing gas network (RS, BA, MK), while the range and the level of costs is high in countries without existing gas networks (AL, KO*, ME). This is due to the cost of the network component, to be paid by system users, if gas network is to be developed.

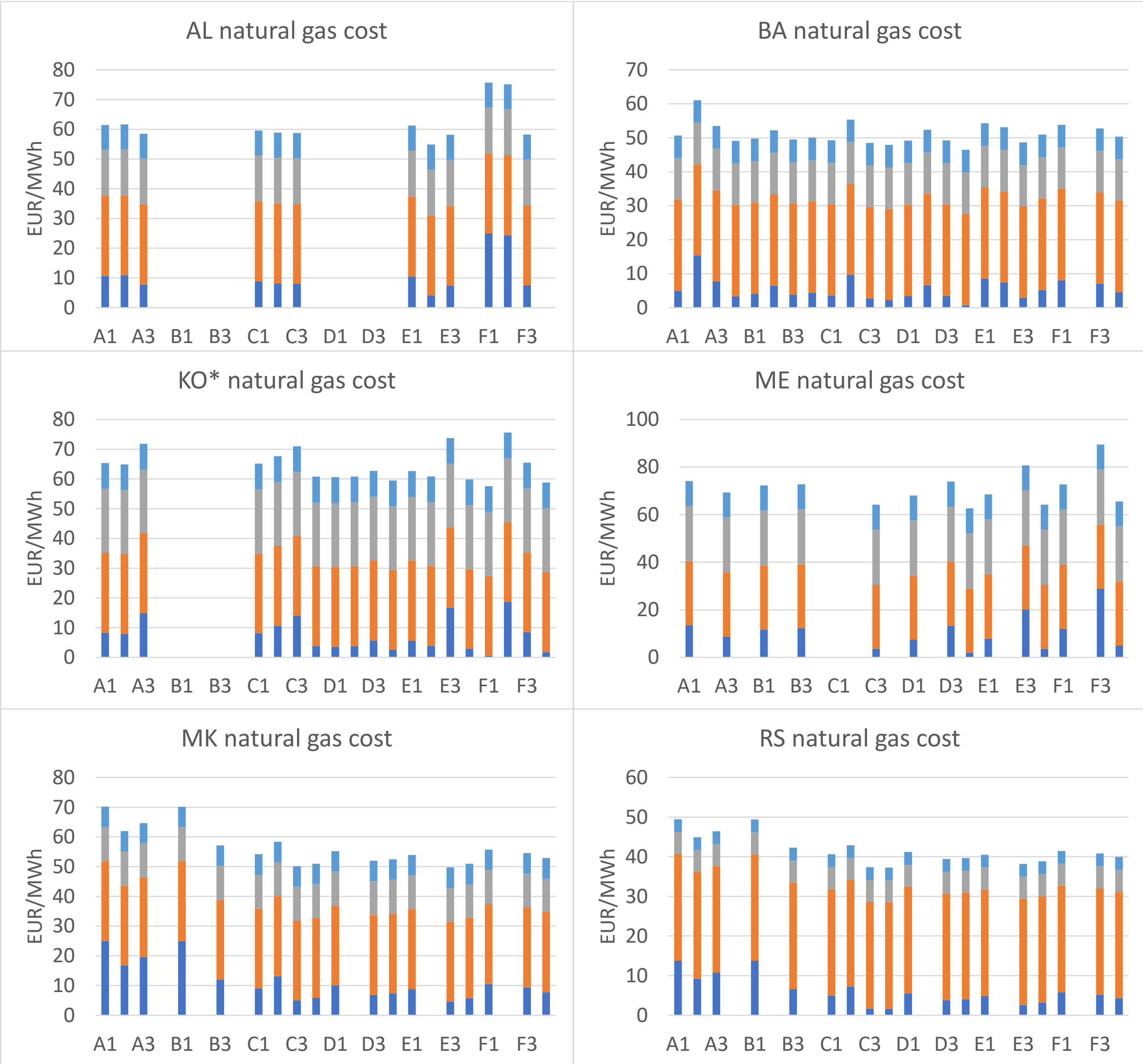
FIGURE 30. RANGES FOR ALL BUILDING TYPES IN THE WB6 FOR NATURAL GAS, EUR/MWH



Source: REKK calculation

Next figure (Figure 31) shows that throughout the WB6 countries the cost of natural gas for household heating is most economic in multifamily and apartment buildings, that are more typical for cities.

FIGURE 31. DETAILED COST BREAKDOWN OF GAS HEATING IN THE WB6 IN ALL BUILDING TYPES



Source: REKK calculation

3.4.2. OPTIMAL TECHNOLOGY FOR EACH BUILDING TYPE

By listing the cost of heating for each building type, it is possible to select the least cost option and calculate a cost-minimizing energy mix of each country (See Figure 32). This methodology has its drawbacks as it assumes instant conversion to an alternative heating technology (i.e. all households switching one at the time), but can be considered as a theoretical maximum in the residential building sector's natural gas demand.

FIGURE 32. ILLUSTRATION FOR SELECTING THE LEAST COST TECHNOLOGY

				Ranking					
Country	Building Type	Type code	Construction period	1	2	3	4	5	6
code				€	€	€	€	€	€
RS	Detached house	A1	before 1945	gas	wood	electricity	heat pump	coal	oil
RS	Detached house	B1	1946-1960	gas	wood	electricity	heat pump	coal	oil
RS	Detached house	C1	1961-1970	gas	heat pump	wood	coal	electricity	oil
RS	Detached house	D1	1971-1980	gas	wood	heat pump	coal	electricity	oil
RS	Detached house	E1	1981-1990	gas	heat pump	wood	coal	electricity	oil
RS	Detached house	F1	1991-2011	gas	wood	heat pump	coal	electricity	oil
RS	Terraced	A2	before 1945	gas	wood	heat pump	electricity	coal	oil
RS	Terraced	B2	1946-1960	-	-	-	-	-	-
RS	Terraced	C2	1961-1970	gas	wood	heat pump	coal	electricity	oil
RS	Terraced	D2	1971-1980	-	-	-	-	-	-
RS	Terraced	E2	1981-1990	-	-	-	-	-	-
RS	Terraced	F2	1991-2011	-	-	-	-	-	-
RS	Multi family	A3	before 1945	gas	heat pump	coal	electricity	oil	district hea
RS	Multi family	B3	1946-1960	gas	heat pump	coal	electricity	oil	district hea
RS	Multi family	C3	1961-1970	heat pump	gas	coal	electricity	oil	district hea
RS	Multi family	D3	1971-1980	heat pump	gas	coal	electricity	oil	district hea
RS	Multi family	E3	1981-1990	heat pump	gas	coal	electricity	oil	district hea
RS	Multi family	F3	1991-2011	gas	heat pump	coal	electricity	oil	district hea

3.4.3. POTENTIAL ENERGY MIX OF THE RESIDENTIAL BUILDING SECTOR

Figure 33 shows three indicators for each WB6 country. Balance column shows the final energy consumption of the residential building sector based on the 2018 energy balances by fuels. Model shows a base case calibration of final energy demand in our calculation. Our aim was to recreate the 2018 energy balance as close as possible. Best estimate shows the energy mix in the building sector, if the cheapest option is selected by all households. Table 32 lists the volumes of fuels in the best estimate scenario for the WB6. It is apparent that three technologies compete in the mix: biomass, natural gas and heat pumps. Electricity, coal and oil are phased out on an economic basis. District heating fuelled by fossil gets at the end of the merit order.

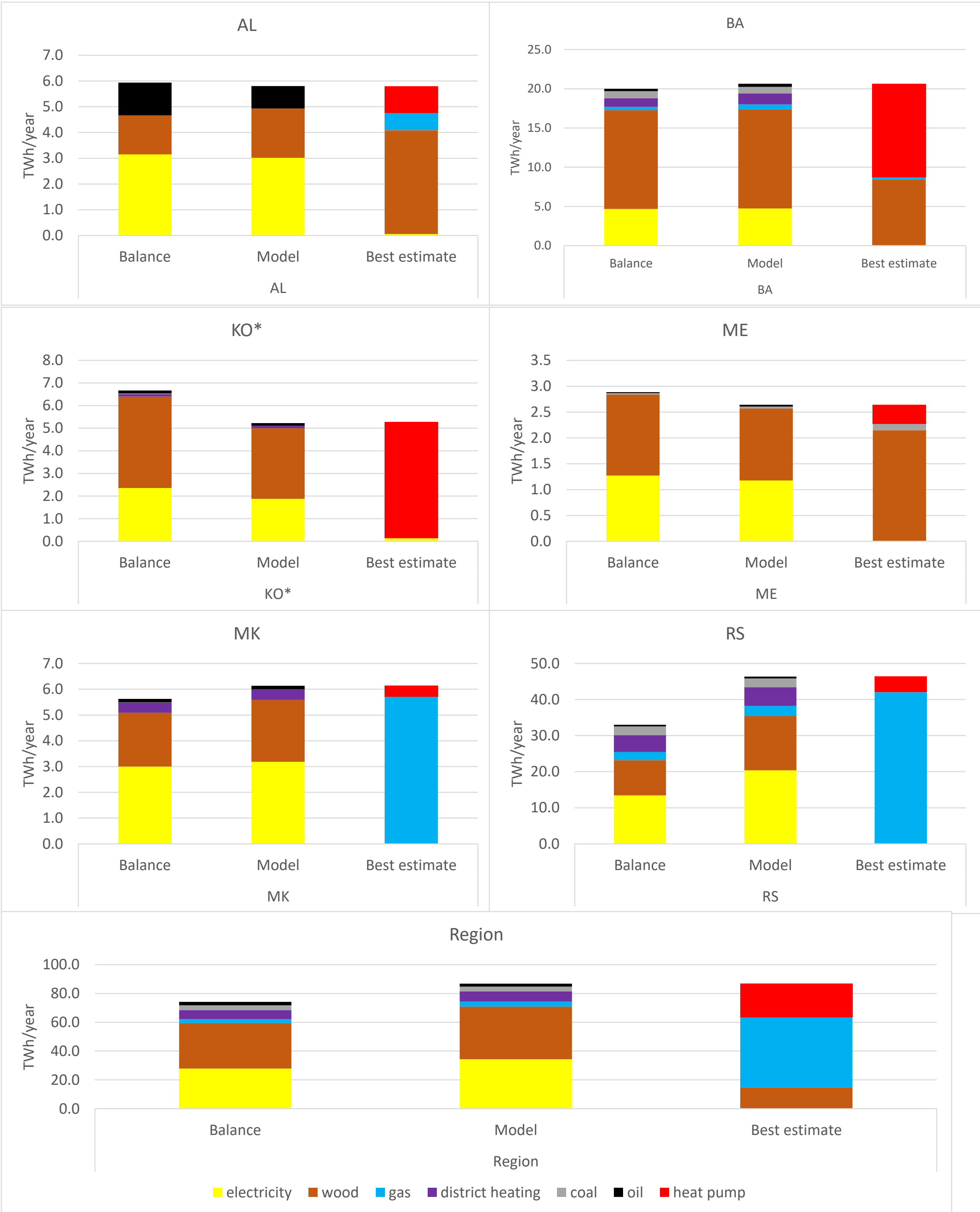
Natural gas is not in the mix of countries where the network is yet to be commissioned (AL, KO*, ME, BA), as network costs make gas unfavourable. In these countries, biomass and heat pumps still prevail.

Natural gas has a potential growth in Serbia and North Macedonia, as network costs are lower and make gas more competitive.

On a regional level, 48.6 TWh/year gas demand is envisaged from residential buildings. In 2018, gas consumption of the WB6 residential sector was 2.7 TWh/year. This means that gas may account for 55% of residential building energy demand in WB6, followed by heat pumps (26%). Fuelwood drops to 17% from 43%. Electricity based heating, previously 38% would disappear from the mix.

Our results are sensitive to the main assumptions (investment costs, fuel costs, taxes, etc.). For this reason, a number of scenarios and sensitivities were carried out in the next chapters.

FIGURE 33. ENERGY MIX OF HEATING



Source: REKK calculation

TABLE 32. ENERGY MIX OF HEATING IN THE WB6, "BEST TECHNOLOGY" (TWH/YEAR)

	Building sector (best technology)							
	electricity	wood	gas	distrit heating	coal	oil	heat pump	Total
AL	61	4 027	676	0	0	0	1 033	5 797
BA	0	8 452	230	0	0	0	11 957	20 640
KO*	131	4	0	0	0	0	5 142	5 277
ME	0	2 146	0	0	129	0	368	2 643
MK	0	0	5 709	0	0	0	426	6 135
RS	0	0	42 034	0	0	0	4 348	46 382
Region	0.2	14.6	48.6	0.0	0.1	0.0	23.3	86.9

Source: REKK calculation

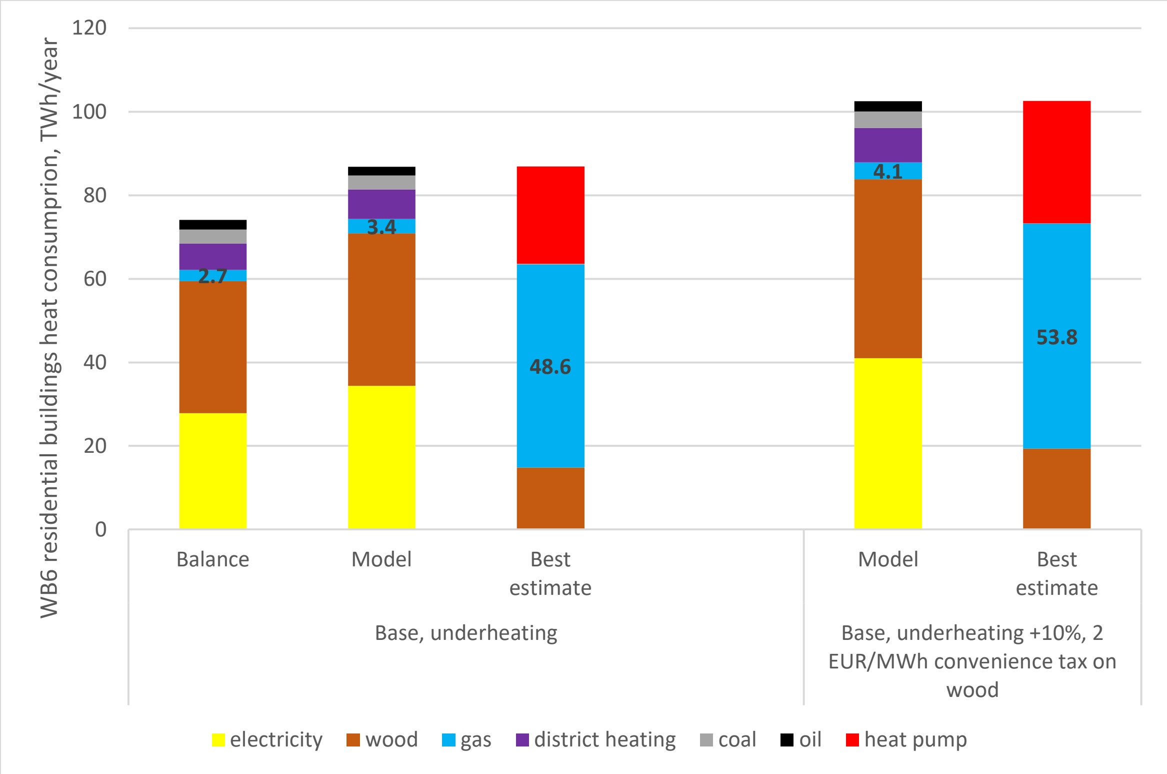
3.4.4. SCENARIOS

3.4.4.1. UNDER-HEATING AND ENERGY EFFICIENCY

Under-heating is prevalent in the region. In most countries, only 50% of the floor area is heated, thus resulting in lower energy demand as the insulation and characteristics of the building would suggest. Huge efforts target deep building renovation and energy efficiency improvement of the building stock of the WB6 (European Commission, 2020). As households may engage in energy-efficiency related investments, heat demand may drop. Energy efficiency investments may cause on the one hand (i) a reduction in energy consumption, if the household keeps its current comfort level and chooses not to heat additional rooms or increase the average temperature, or (ii) an increase in energy consumption (so-called rebound effect), as the household may afford higher level of comfort with the same amount of spending on heating. To account for this phenomenon, we increased the share of floor area heated in this scenario by 10% (to show the effect of an energy-efficiency investment with rebound).

The demand increase of 10% was met with the same mix of fuels, but with a 10% increased demand for gas in the residential building sector.

FIGURE 34. GAS DEMAND IN THE WB6 WITH UNDERHEATING ASSUMED, WITH 10% HIGHER HEATING IN ALL COUNTRIES



Source: REKK calculation

3.4.4.2. HEAT PUMP INVESTMENT COST (LEARNING CURVE)

High investment cost attributed to heat pumps might be constraining the application of this technology. Assuming a lower investment cost from the point of households (either by efficiency gains/learning effect on the technology or by direct government support on investment) we considered alternative cost ranges up to -50% with 5% steps. Gas prices were plotted on a 20-30 EUR/MWh range.

Considering these scenarios, the table below shows the total natural gas demand modelled for the region. It is apparent that reduction in investment costs accompanied with higher gas price levels gives an advantage for heat pumps. (Table 33) The gas demand ranges between 0-67 TWh/year.

If investment costs drop by 25% for heat pumps, gas demand drops to 18 TWh/year in the WB6 residential sector and heat pumps would account for 66% for the heat demand.

A 20% increase in gas prices, assuming identical investment cost, would also help the spread of heat pumps to 50% of heat demand and curb the gas demand in the region from 48.6 TWh/year to 7.1 TWh/year.

Heat pumps become a dominant technology at lower investment costs (4500 EUR for detached houses). (Table 34)

TABLE 33. NATURAL GAS DEMAND OF THE RESIDENTIAL BUILDING SECTOR IN THE WB6 AS A FACTOR OF HEAT PUMP INVESTMENT COST AND NATURAL GAS PRICES

Regional gas demand, TWh/yr												
		Gas price, EUR/MWh										
		20	21	22	23	24	25	26	27	28	29	30
Heat pump investment cost, EUR	3000	23.2	7.3	6.6	6.6	6.2	6.2	6.1	3.5	0.7	0.7	0.7
	3300	45.4	13.6	7.3	6.9	6.7	6.3	6.2	6.2	6.1	6.1	0.7
	3600	56.3	51.7	15.4	7.3	6.9	6.8	6.6	6.2	6.2	6.2	6.1
	3900	58.1	57.2	45.5	15.9	8.5	7.3	6.8	6.7	6.2	6.2	6.2
	4200	59.2	58.4	57.1	37.7	17.2	9.9	7.9	6.8	6.7	6.6	6.2
	4500	60.1	58.7	58.4	57.1	36.2	18.0	9.3	7.2	6.7	6.7	6.5
	4800	61.0	59.2	58.4	57.3	55.5	28.5	14.8	7.2	7.1	6.7	6.7
	5100	61.2	60.4	58.8	57.9	55.5	47.9	25.4	12.7	7.2	7.1	7.0
	5400	62.1	60.5	60.1	58.1	56.1	47.9	34.6	23.0	12.7	7.1	7.1
	5700	63.4	61.2	60.1	58.8	56.3	48.5	44.7	32.4	23.1	7.1	7.1
	6000	66.8	61.3	60.4	59.6	56.7	48.6	44.8	42.6	23.3	7.1	7.1

Source: REKK calculation

TABLE 34. SHARE OF HEAT PUMPS IN THE RESIDENTIAL BUILDING SECTOR IN THE WB6 AS A FACTOR OF HEAT PUMP INVESTMENT COST AND NATURAL GAS PRICES

Share of heat pumps in regional energy demand,%												
		Gas price, EUR/MWh										
		20	21	22	23	24	25	26	27	28	29	30
Heat pump investment cost, EUR	3000	73%	92%	92%	92%	93%	93%	93%	96%	99%	99%	99%
	3300	48%	84%	91%	92%	92%	92%	92%	92%	93%	93%	99%
	3600	34%	39%	80%	90%	90%	90%	90%	91%	91%	91%	91%
	3900	31%	32%	45%	79%	88%	89%	89%	90%	90%	90%	90%
	4200	30%	30%	32%	54%	77%	85%	86%	88%	88%	88%	88%
	4500	28%	30%	30%	31%	53%	66%	75%	75%	75%	75%	75%
	4800	27%	29%	30%	31%	31%	53%	65%	71%	71%	72%	72%
	5100	27%	28%	29%	30%	31%	31%	53%	65%	71%	71%	71%
	5400	25%	27%	27%	28%	29%	29%	41%	52%	64%	70%	70%
	5700	23%	25%	26%	27%	28%	28%	29%	40%	51%	63%	63%
	6000	19%	24%	25%	25%	26%	27%	28%	28%	50%	50%	50%

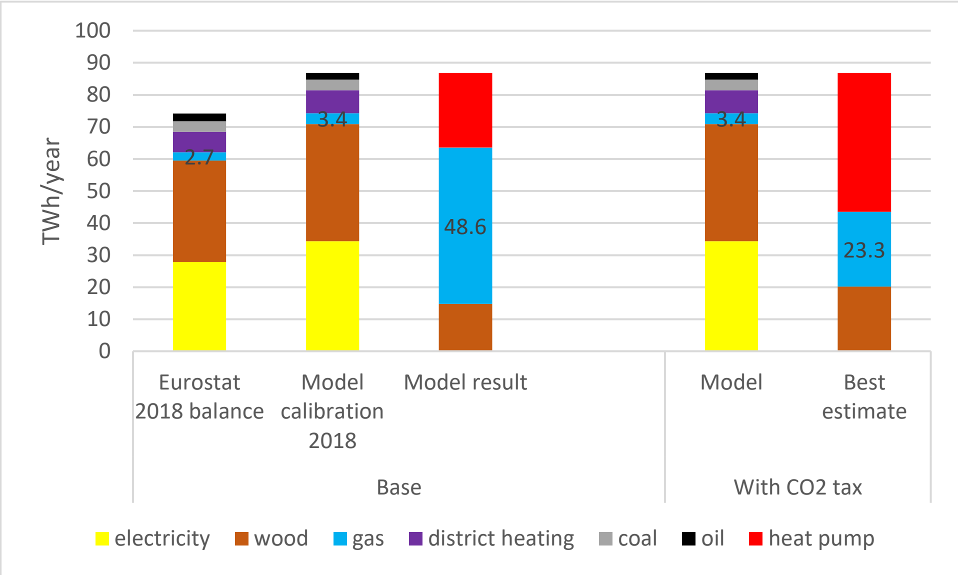
Source: REKK calculation

3.4.4.3. INTRODUCTION OF EU ETS AND CARBON PRICING FOR THE BUILDING SECTOR

On the long term, climate policies may be implemented in the WB6 countries in the building sector. This may affect the competitiveness of fossil fuels as opposed to biomass and RES based heating solutions. To account for this effect, we applied a carbon tax on natural gas, coal and oil assuming a 20 EUR/t CO_2 tax (which is reflecting 2018-2019 EU ETS price level). Emission factors were obtained from IPCC (IPCC, 2006). Biomass was considered to have 0 kg/TJ CO_2 emission.

Applying these factors, natural gas was demand in the region when considering the least cost option ("best estimate") dropped from nearly 50 TWh/year to 23 TWh/year. (Figure 35) Therefore, if WB6 countries plan to introduce any kind of carbon taxation on the building sector, it would adversely affect the development of their potential gas demand and give and advantage for heat pumps and to a smaller extent to biomass.

FIGURE 35. EFFECTS OF INTRODUCING CARBON TAXATION IN THE WB6 FOR THE BUILDING SECTOR FOSSIL FUELS



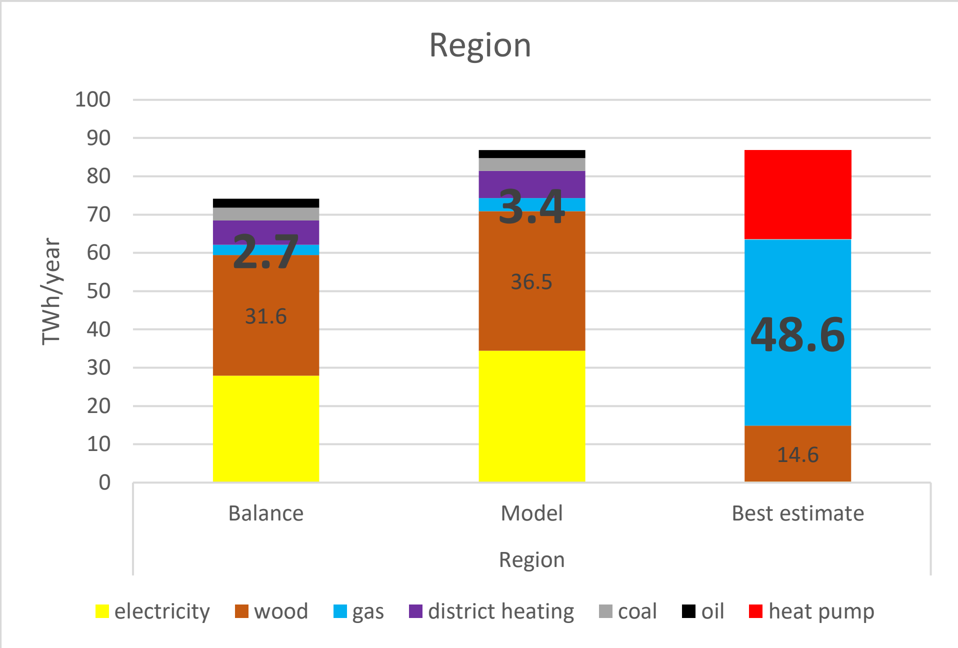
Source: REKK calculation

3.4.5. SENSITIVITIES

3.4.5.1. GAS PRICE AND WOOD PRICE

The relationship of biomass and natural gas prices has a strong effect on the total gas demand of the region and the spread of gas-based heating. In our reference case, fuelwood costs were set at a lower price (23 EUR/MWh) compared to natural gas (25 EUR/MWh). Additionally, fuelwood had a convenience tax of 2 EUR/MWh. Considering transmission, distribution and other costs for gas, even after accounting for higher efficiency, gas-based heating was more competitive than biomass in most building types – resulting in 48.6 TWh/year natural gas consumption and 14.6 TWh/year biomass consumption.

FIGURE 36. TOTAL ENERGY MIX OF THE RESIDENTIAL BUILDING SECTOR (23 EUR/MWH WOOD PRICE AND 25 EUR/MWH NATURAL GAS PRICE)



Source: REKK calculation

We have plotted the sensitivity of the regional gas consumption to the price of these fuels in the table below.

TABLE 35. SENSITIVITY OF REGIONAL GAS CONSUMPTION, TWH/YEAR (WITH CONVENIENCE TAX)

		Regional gas demand, TWh/yr with 2 EUR/MWh convenience tax on wood										
		Gas price, EUR/MWh										
		20	21	22	23	24	25	26	27	28	29	30
Biomass price, EUR/MWh	20	61.1	51.6	48.7	45.7	43.8	24.1	7.4	6.9	6.9	6.3	6.2
	21	62.1	60.3	54.4	49.9	45.9	43.4	23.3	7.3	6.9	6.7	6.2
	22	62.8	60.9	59.8	54.0	49.0	45.6	42.6	32.4	7.3	7.1	6.7
	23	66.8	61.3	60.4	59.6	56.7	48.6	44.8	42.6	23.3	7.1	7.1
	24	67.7	62.2	60.7	60.1	58.5	56.5	48.3	44.8	23.3	23.1	12.6
	25	67.7	63.1	60.9	60.4	59.0	58.1	56.0	48.3	25.5	23.9	12.7
	26	67.7	63.1	61.2	60.6	59.0	58.6	57.3	56.3	32.4	26.6	13.5
	27	68.2	63.2	61.2	60.6	59.1	58.7	57.8	57.7	37.8	32.2	17.9
	28	68.3	63.7	61.2	60.6	59.1	58.7	57.9	57.7	38.3	37.6	25.6
	29	68.5	63.7	61.7	60.7	59.1	58.7	57.9	57.9	38.3	38.1	27.1
	30	69.0	64.1	61.8	61.1	59.3	58.8	57.9	57.9	38.4	38.1	27.5

Source: REKK calculation

Our estimation included a “convenience tax” on wood, which covers the hassle cost and additional work of the household with the handling of fuelwood (chopping, taking out ash, etc). When this “convenience tax” is omitted, the pattern remains the same, but gas may only have

2-3 EUR/MWh premium over biomass at most to deliver 50 TWh/year consumption in the region.

TABLE 36. SENSITIVITY OF REGIONAL GAS CONSUMPTION, TWH/YEAR (WITHOUT CONVENIENCE TAX)

		Regional gas demand, TWh/yr (base) without 2 EUR/MWh										
		Gas price, EUR/MWh										
		20	21	22	23	24	25	26	27	28	29	30
Biomass price, EUR/MWh	20	50.9	46.6	45.3	25.6	8.6	7.8	7.0	6.5	6.5	6.3	6.2
	21	56.5	50.8	47.4	44.9	24.5	8.2	7.0	6.9	6.5	6.3	6.2
	22	61.9	54.9	50.5	47.1	43.8	24.1	7.4	6.9	6.9	6.3	6.2
	23	62.6	60.5	58.1	50.2	45.9	43.4	42.6	7.3	7.3	6.8	6.2
	24	63.6	61.0	60.0	58.0	49.5	45.6	42.6	42.5	12.9	7.1	6.7
	25	67.0	62.0	60.7	59.6	57.4	49.2	44.8	43.3	23.3	12.7	7.1
	26	67.7	62.8	60.8	60.4	58.5	57.1	51.7	46.1	24.1	23.1	12.7
	27	67.7	63.1	61.2	60.4	59.0	58.5	57.1	51.6	28.5	25.3	12.7
	28	67.7	63.1	61.2	60.6	59.1	58.6	57.8	57.1	36.2	28.3	14.8
	29	68.2	63.2	61.2	60.6	59.1	58.7	57.8	57.7	37.8	36.2	17.9
	30	68.3	63.7	61.4	60.6	59.1	58.7	57.9	57.7	38.3	37.6	26.1

Source: REKK calculation

3.4.5.2. LIFETIME AND DISCOUNT RATE

Households have a shorter horizon for deciding on energy efficiency and heat related investments. When calculating the variable investment costs, the main drivers are the lifetime and the discount rate applied. We used 5% discount rate and 20 years of lifetime as a base case. Literature suggests that discount rate ranges from 2% to 30% (Andersen, Wiese, Petrovic, & Russell, 2020). The discount rate and the lifetime of the investment mainly affects the competitiveness of heat pumps. In the tables below we listed the effect of investment cost reduction as well as the change in lifetime and discount rate. It is apparent that the longer the optimisation horizon (lifetime) or the lower the discount rate, heat pumps have better chance and are crowding out the gas.

However, as households have a shorter foresight (which may either be represented by shorter optimisation horizon or higher discount rates), this implies that gas has a better chance compared to heat pumps, bringing gas demand levels in the region to 50-75 TWh/year, irrespective of gas prices and heat pump investment costs.

TABLE 37. SENSITIVITY OF REGIONAL GAS CONSUMPTION, TWH/YEAR ASSUMING 20% DISCOUNT RATE (AS OPPOSED TO 5% IN THE BASED CASE)

Regional gas demand, TWh/yr 20 yrs 20%												
		Gas price, EUR/MWh										
		20	21	22	23	24	25	26	27	28	29	30
Heat pump investment cost	3000	61.9	60.4	58.4	58.2	57.6	57.5	47.0	37.4	20.9	17.1	10.4
	3300	74.5	63.0	61.1	59.7	58.5	58.3	57.6	57.6	47.0	37.3	26.8
	3600	75.6	75.0	63.0	62.5	60.5	59.3	58.5	58.3	57.6	57.1	57.0
	3900	76.0	75.4	75.0	66.8	62.8	62.2	60.4	59.5	58.5	57.8	57.0
	4200	77.9	75.6	75.2	75.0	73.6	63.4	62.3	60.3	58.9	58.0	57.8
	4500	78.3	77.1	75.5	75.2	73.6	63.7	63.0	61.3	60.3	58.6	57.9
	4800	78.3	77.8	75.8	75.5	75.1	64.0	63.2	62.0	60.5	59.7	58.5
	5100	78.3	77.8	77.3	75.7	75.2	65.3	63.4	62.0	61.2	60.0	59.4
	5400	78.3	77.8	77.7	77.2	75.4	65.3	64.7	62.2	61.2	60.4	59.6
	5700	78.4	77.8	77.7	77.6	75.7	65.5	64.7	63.6	61.5	60.6	60.0
	6000	78.4	77.9	77.7	77.6	76.9	65.8	64.9	63.7	62.7	60.8	60.2

Source: REKK calculation

3.4.6. CO2 EMISSIONS

To further elaborate our results, we show the CO2 emissions of the residential building sector related to the different scenarios.

CO2 coefficients were obtained from (IPCC, 2006). CO2 emission of the electricity sector was calculated based on the 2020 generation mix of each WB6 country[8] published on ENTSO-E transparency platform[9], assigning an efficiency factor of 0.36 to solid fossil fuels and 50% to gas fired generation. Emission factor of renewable electricity was set to 0.

[8] For Kosovo*, 2021 generation mix was available.

[9] Actual Generation per Production Type - Aggregated Generation per Type [16.1.B&C]. https://transparency.entsoe.eu

TABLE 38. EMISSION FACTORS FOR ELECTRICITY GENERATION

	kg CO2/TJ NCV	Efficiency of electricity generation
Biomass	112000	36%
Fossil Brown coal/Lignite	101000	36%
Fossil Coal-derived gas	44400	36%
Fossil Gas	56100	50%
Fossil Hard coal	98300	36%
Fossil Oil	74100	50%
Fossil Oil shale	73300	50%
Fossil Peat	106000	36%
Geothermal	0	100%
Hydro Pumped Storage	0	100%
	0	100%
Hydro Run-of-river and poundage	0	100%
Hydro Water Reservoir	0	100%
Marine	0	100%
Nuclear	0	100%
Other	0	100%
Other renewable	0	100%
Solar	0	100%
Waste	100000	100%
Wind Offshore	0	100%
Wind Onshore	0	100%

Source: Emission factor (IPCC, 2006), efficiency: REKK assumptions

TABLE 39. EMISSION FACTOR OF HEATING OPTIONS

	CO2 emission factor, t CO2/MWh						
	electric-ity	wood	gas	district heating	coal	oil	heat pump
AL	0.000	0.510	0.217	0.346	0.485	0.356	0.000
BA	0.699	0.510	0.217	0.346	0.485	0.356	0.233
KO	1.001	0.510	0.217	0.346	0.485	0.356	0.334
ME	0.484	0.510	0.217	0.346	0.485	0.356	0.161
MK	0.779	0.510	0.217	0.346	0.485	0.356	0.260
RS	0.712	0.510	0.217	0.346	0.485	0.356	0.237

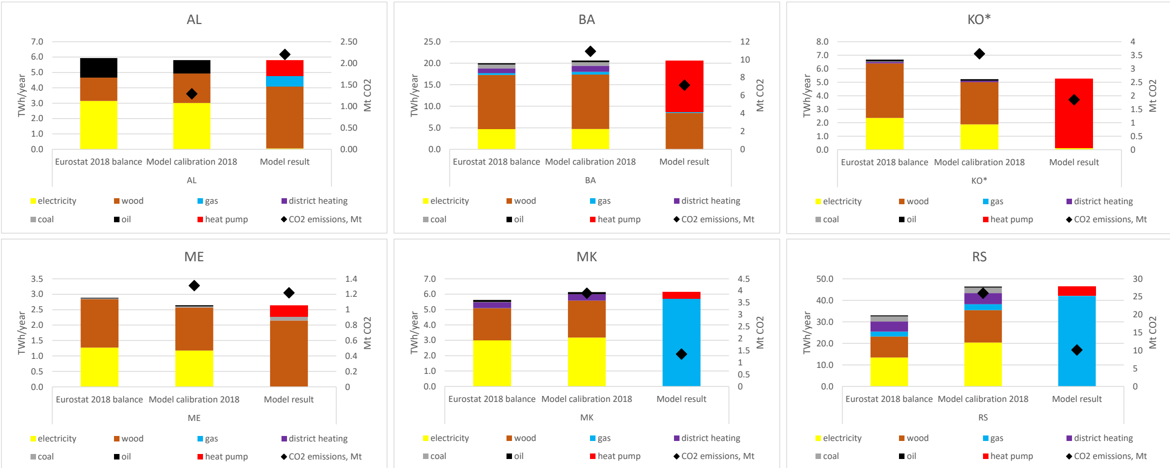
Source: Electricity REKK calculation, other values (IPCC, 2006)

In case of Albania, all generation is based on hydropower and as such there is no CO2 emission related to electricity-based heating. In Kosovo*, the opposite is true, all generation is backed by the lignite-fired local power station, thus the high emission factor of electricity generation. Applying these emission factors, the total CO2 emissions of the residential building sector were estimated.

It must be stressed that we considered the CO2 emissions related to electricity-based heating and heat pumps in the residential sector (which would be reported in the energy and heat sector), so the figures do not necessarily match the statistics of the countries. Moreover, emissions from biomass-based heating are usually accounted as 0, but for this exercise we found it important to show the CO2 emissions related to biomass burning.

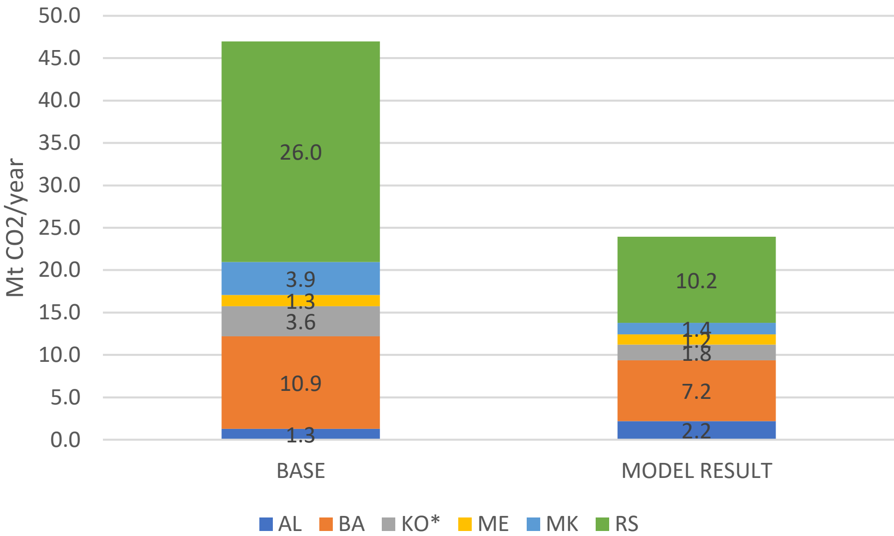
In our base case (see Chapter 3.4.3), CO2 emissions related to the building sector (taking into account the emissions of electricity, district heating and biomass as well) totalled 47 Mt CO2/year. Without the electricity, district heating and biomass-related emissions this number is 3 Mt CO2. As a comparison, total CO2 emissions of the region were 107 Mt CO2. When applying the most cost-effective technology, emissions on a regional level drop to 24 Mt CO2/year (Figure 38).

FIGURE 37. FUEL MIX OF RESIDENTIAL HEATING IN THE WB6 AND CO2 EMISSIONS (BASE CASE AND MODEL RESULTS)



Source: REKK calculation

FIGURE 38. CO2 EMISSIONS OF THE RESIDENTIAL BUILDING SECTOR IN EACH WB6 COUNTRY, MT CO2/YEAR



Source: REKK calculation

In Albania, carbon intensity increased compared to the base case. The reason for this is the fact that Albanian grid electricity is solely based on hydro generation, which causes no CO2 emissions. Switching to biomass and gas increases this relatively clean mix. Nevertheless, on a regional level the increasing Albanian emissions are offset by other countries' reduction.

In Bosnia and Herzegovina heating is mainly switched to heat pumps, which offer a cleaner solution and due to their high efficiency have lower emission factor than other electricity-based technologies. Emissions drop from 10.9 Mt CO2 to 7.2 Mt CO2.

In Kosovo*, all heating is switched to heat pumps, which has a similar effect as in Bosnia. However, it must be pointed out that current emission factor of electricity in Kosovo* is the highest in the region, as all electricity production is based on lignite fired power stations. If the electricity sector is switched to renewables or other, less polluting fuels, the emissions may further decrease.

In Montenegro, electricity-based heating is replaced with biomass and to a lesser extent heat pumps. Emissions are relatively unchanged, decreasing slightly from 1.3 Mt to 1.2 Mt.

In North Macedonia, lower emissions are attributed to switching from biomass and electricity to gas – emissions fall from 3.9 Mt to 1.4 Mt/year.

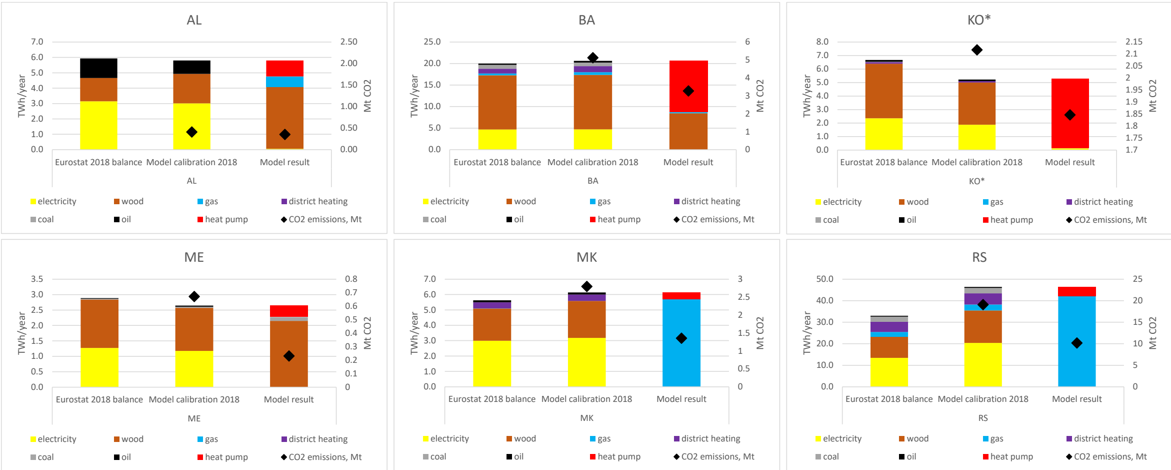
In Serbia, increased gas production and heat pumps crowd out biomass and electricity. This has a positive effect on emissions, falling from 26 Mt CO2/year to 10.2 Mt CO2.

On regional level, 47 Mt CO2 are emitted in the base case, and this drops to 24 Mt CO2/year. The drop in CO2 emissions is mainly attributed to the following factors:

- Increased use of heat pumps consumes less electricity than conventional electricity-based heating solutions and so has a lower carbon footprint.
- Biomass has a relatively high CO2 emission (112 000 kg CO1/TJ, while lignite is 101 000 kg CO1/TJ). In CO2 emission accounting, this value is considered 0. In our calculation we opted to use the actual CO2 emissions and this way show the local effects of CO2 on air quality. As in the base case most homes were heated with biomass and this shifted to gas and heat pumps, the total emission dropped.
- Gas is relatively clean fuel on a carbon basis compared to other fossil fuels. The increase of gas consumption crowded out electricity in Serbia and North Macedonia, where the carbon intensity of electricity generation was high.

Biomass accounting may be subject to scrutiny. If biomass is produced from sustainable sources and we consider only small part (10%) of biomass emissions (due to logging, transport, etc), then total regional emissions amount to 30.2 Mt CO2 in the base case and fall to 17.2 Mt CO2 in the modelled estimate (as opposed to 47 Mt in the base case and 24 Mt in the modelled).

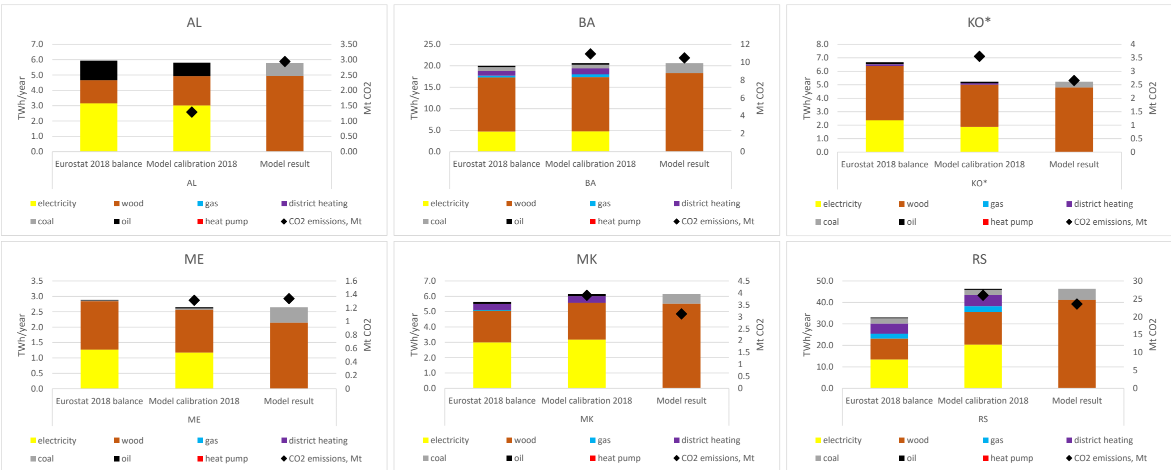
FIGURE 39. FUEL MIX OF RESIDENTIAL HEATING IN THE WB6 AND CO2 EMISSIONS (ASSUMING LOW CO2 EMISSIONS FROM BIOMASS)



Source: REKK calculation

Moreover, when considering the high gas price environment and electricity prices of late 2021, the case for biomass-based heating is stronger. In Late September 2021, gas prices averaged 70 EUR/MWh. Assuming 140 EUR/MWh electricity prices, biomass is the most competitive technology. This results is almost no reduction on regional CO2 emissions, as the switching to gas or heat pumps is prohibited by the high fuel prices.

FIGURE 40. FUEL MIX OF RESIDENTIAL HEATING IN THE WB6 AND CO2 EMISSIONS ASSUMING HIGH GAS (70 EUR/MWH) AND ELECTRICITY (140 EUR/MWH) PRICES



Source: REKK calculation

4. MAIN FINDINGS

In this study, we aimed at quantifying the cost of gas network development in the WB6 and finding a level of potential gas demand. We followed a two-step approach: in the first step, the cost of gas network development was assessed using a uniform GIS-based approach for the WB6. In the second step, strongly building on the results of previous studies, a simplified model was set up to compare the costs of different heating technologies for residential buildings – including fuel, network, investment and other cost elements.

Network costs were strongly affecting the outcome of results, thus in countries without existing gas infrastructure gas turned out to be less favourable. Network costs were the lowest in Serbia and highest in Kosovo*, ranging from 5.68 EUR/MWh to 28.2 EUR/MWh. (Table 40) Tariffs were only sensitive to the volume of gas consumed in the cities connected, having an adversely proportional effect (i.e. the higher the gas consumption, the lower the tariff).

TABLE 40. CALCULATED DISTRIBUTION AND TRANSMISSION TARIFFS FOR THE WB6, EUR/MWH

	AL	BA	KO*	ME	MK	RS
DSO tariff	10.87	5.46	19.24	10.40	12.65	3.67
TSO tariff	2.81	3.86	8.96	5.19	4.96	2.01
Tariff CALC	13.68	9.31	28.20	15.59	17.61	5.68

Source: REKK estimation

Applying these network tariffs on gas fuel cost, we compared the cost of alternative heating options in all residential building types for the WB6.

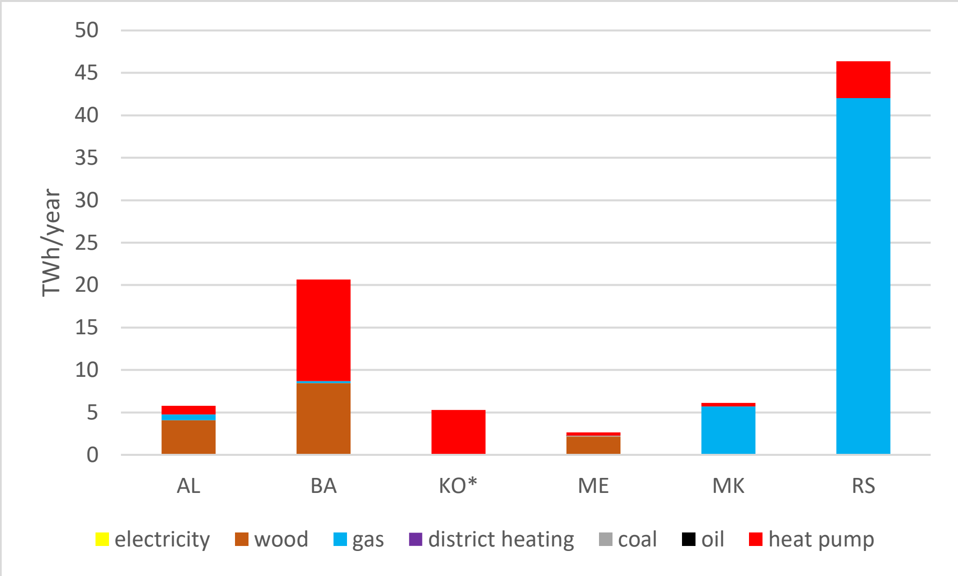
In the base scenario, our results show that comparing potential heating options, gas proved to be an important part of the energy mix of residential space heating, competing with biomass and heat pump. Electricity, coal and oil are phased out on an economic basis. District heating fuelled by fossil gets at the end of the merit order.

Natural gas is not in the mix of countries where the network is yet to be commissioned (AL, KO*, ME, BA), as network costs make gas unfavourable. In these countries, biomass and heat pumps still prevail.

Natural gas has a potential growth in Serbia and North Macedonia, as network costs are lower and make gas more competitive. (Figure 41)

On a regional level, 48.6 TWh/year gas demand is envisaged from residential buildings. In 2018, gas consumption of the WB6 residential sector was 2.7 TWh/year. This means that gas may account for 55% of residential building energy demand in WB6, followed by heat pumps (26%). Fuelwood drops to 17% from 43%. Electricity based heating, previously 38% would disappear from the mix.

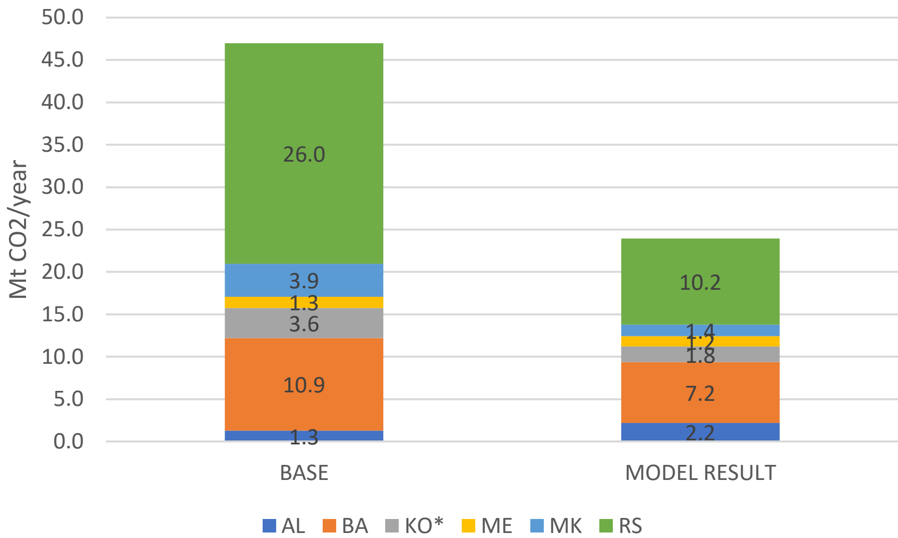
FIGURE 41. MODELLED ENERGY MIX IN THE WB6 RESIDENTIAL BUILDING SECTOR ASSUMING LEAST COST HEATING OPTION



Source: REKK calculation

There is about 50% emission reduction in the base case scenario for the residential sector heating in the WB6 envisaged. This is attributable to three main factors: the rollout of very efficient heat pumps, the switch from biomass to natural gas, and the crowding out of electricity heating in countries where the carbon intensity of electricity generation was high.

FIGURE 42. CO2 EMISSIONS OF THE RESIDENTIAL BUILDING SECTOR IN EACH B6 COUNTRY, MT CO2/YEAR



Source: REKK calculation

Results are sensitive to the cost of biomass relative to natural gas, and to the cost of heat pump investment. When considering the high gas price environment and electricity prices of late

2021, the case for biomass-based heating is stronger. High fuel prices lead to almost no reduction of regional CO2 emissions, as neither switching to gas nor to heat pumps would be economically viable.

Low investment horizon (either modelled with short lifetime or high discount rate) typical for household consumers is in favour of gas-based heating against heat pumps.

Introduction of CO2 taxation for the building sector would help the heat pump investments and hinder the development of gas in the WB6 region.

Based on the above results, the following policy conclusions can be drawn:

- Investment into natural gas infrastructure could only be an option for Serbia and North Macedonia
- The risk of constructing stranded assets is huge: demand for gas is very sensitive to the gas prices, investment costs and other factors. Heat pumps may outcompete gas from the fuel mix when moving forward on the learning curve.
- To avoid building stranded assets, policy measures can be implemented in the transition period (as long as heat pumps are not economic alternative to gas): e.g. tax on fossil fuels or investment support on heat pumps.
- Biomass will still be part of the mix, which might not necessarily be harmful, if the fuelwood is produced in a sustainable manner.
- Energy efficiency measures via building renovation might further curb the heat demand of the building sector, thus gas consumption might even be lower than estimated. This would result in higher network tariffs and make gas heating less competitive compared to other fuels.

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6. ANNEXES

6.1. METHODOLOGY SHOWCASE - THE ALBANIAN GAS MASTER PLAN

In order to show how well-fitting the data used for gas distribution network development are, we have re-calculated the network length in the four selected cities (Zall-Herr, Gjirokaster, Kamez, Tirana) in Albania. First, data from OpenStreetMap referring to highways (roads) which are located next to housing were queried for the four reference cities. The figures below show the gas master plan of Albania and the OpenStreetMap query results respectively. It is apparent that the plotted networks are quite similar.

TABLE 41. GAS DISTRIBUTION NETWORK OF ZALL-HERR IN THE GAS MASTER PLAN OF ALBANIA AND OPENSTREETMAP ESTIMATION

GAS MASTER PLAN ALBANIA

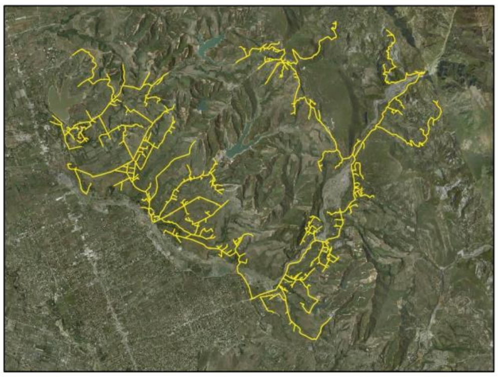


Table 4-3 Proposed city distribution network of Zall-Herr

OPENSTREETMAP

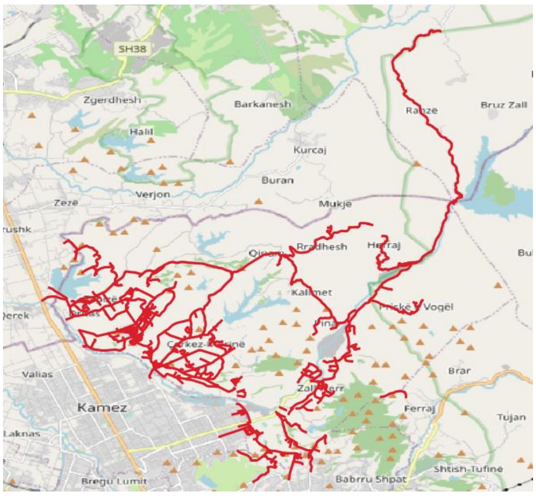


TABLE 42. GAS DISTRIBUTION NETWORK OF GJIROKASTER IN THE GAS MASTER PLAN OF ALBANIA AND OPENSTREETMAP ESTIMATION

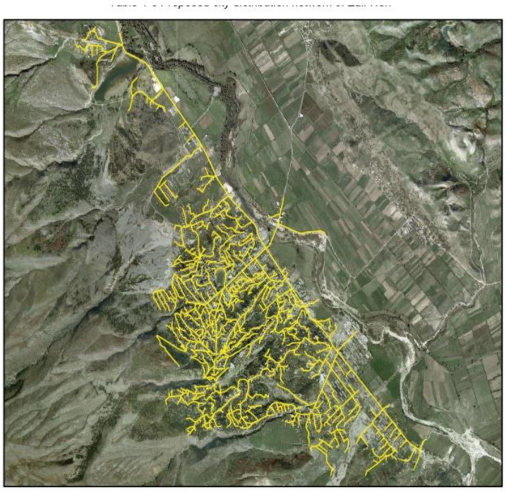
GAS MASTER PLAN ALBANIA	OPENSTREETMAP
 *Table 4-4 Proposed city distribution network of Gjirokaster*	

TABLE 43. GAS DISTRIBUTION NETWORK OF GJIROKASTER IN THE GAS MASTER PLAN OF ALBANIA AND OPENSTREETMAP ESTIMATION

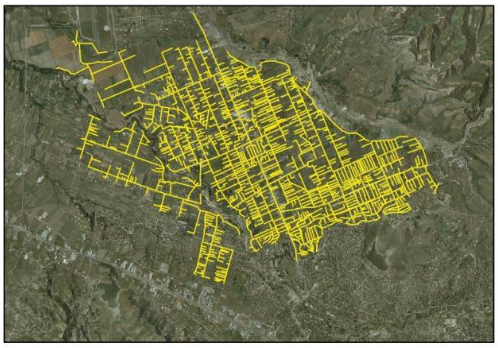
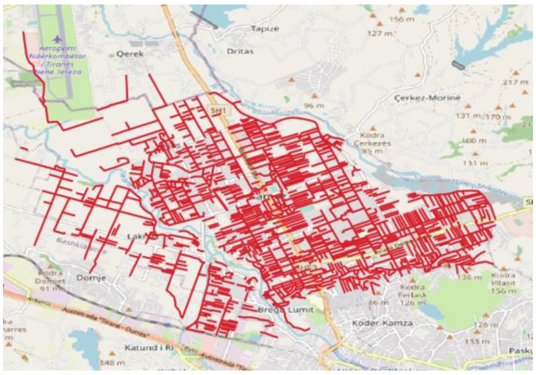
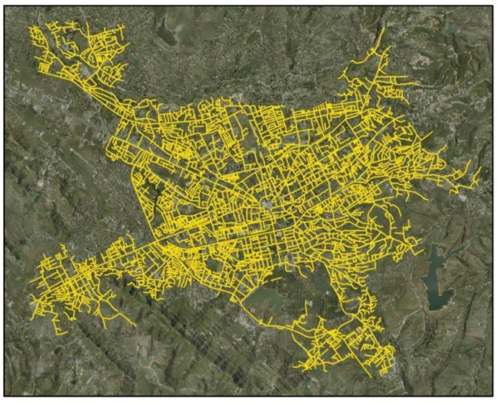
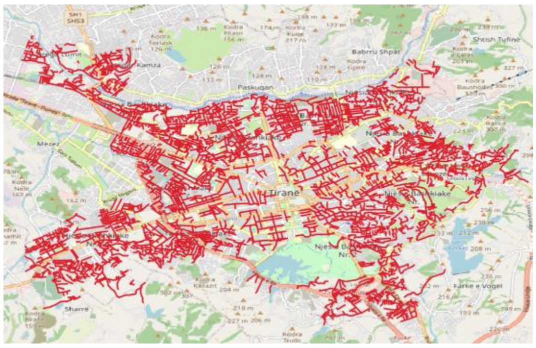
GAS MASTER PLAN ALBANIA	OPENSTREETMAP
 *Table 4-5 Proposed city distribution network of Kamez*	

TABLE 44. GAS DISTRIBUTION NETWORK OF TIRANA IN THE GAS MASTER PLAN OF ALBANIA AND OPENSTREETMAP ESTIMATION

GAS MASTER PLAN ALBANIA	OPENSTREETMAP
 Table 4-6 Proposed city distribution network of Tirana	

The network length were then compared with the actual estimates of the gas master plan. In case of Tirana and Zall-Herr, the difference was below 10%, while for Gjirokaster and Kamez the two datasets differed significantly (+/- 30%).

TABLE 45. COMPARISON OF GAS MASTER PLAN ALBANIA (COWI) AND OPENSTREETMAP (OSM) DISTRIBUTION NETWORK LENGTHS

	Pipeline COWI (m)	Pipeline OSM (m)	DIFF OSM/COWI (%)
Zall-Herr	99 761	106 895	7%
Gjirokaster	77 294	55 608	-28
Kamez	226 671	280 334	24%
Tirana	481 149	461 102	-4%

Source: REKK calculation

6.2. MAPPING GAS DISTRIBUTION NETWORK LENGTHS

A simple graphical example is given to indicate how the distribution network length was estimated. Using the OpenStreetMap database, three GIS layers were queried:

1) Highway: residential database, which shows all the roads lined with housing
2) List of major cities and towns in North Macedonia
3) LAU2 division of administrative units

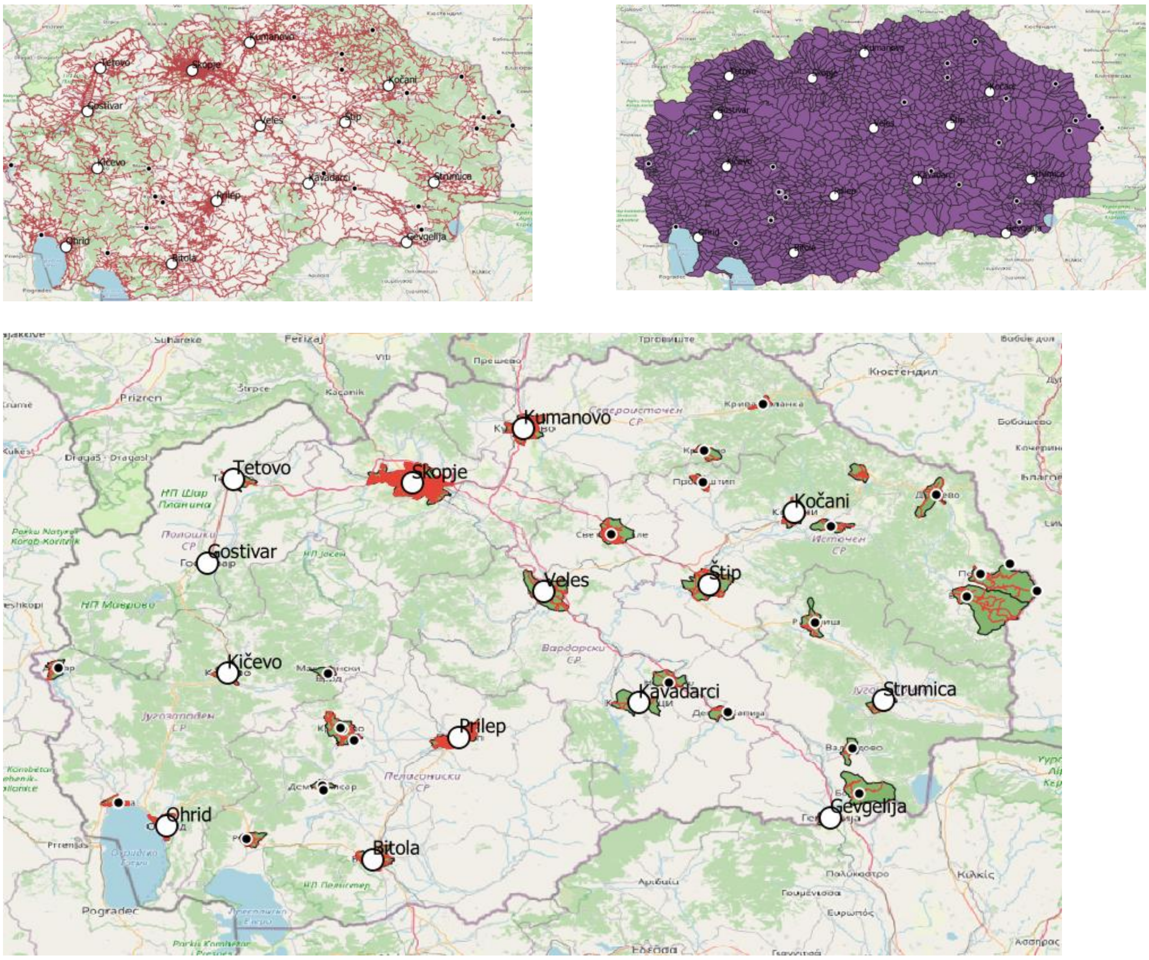
These three layers were merged to a single one, in two steps:

1) LAU2 units with major cities and towns were selected

2) Length of roads within the shape of these administrative units was measured

The figure below illustrates the process for North Macedonia.

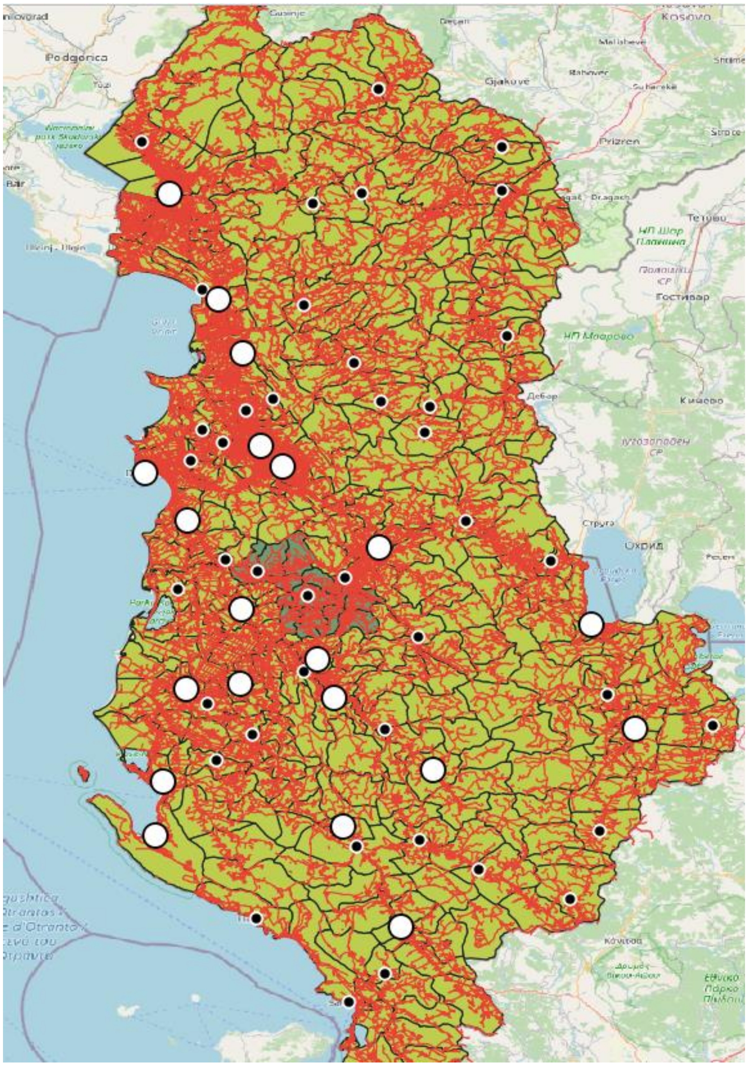
FIGURE 43. MEASURING THE DISTRIBUTION NETWORK LENGTH IN NORTH MACEDONIA



Source: REKK and © OpenStreetMap contributors

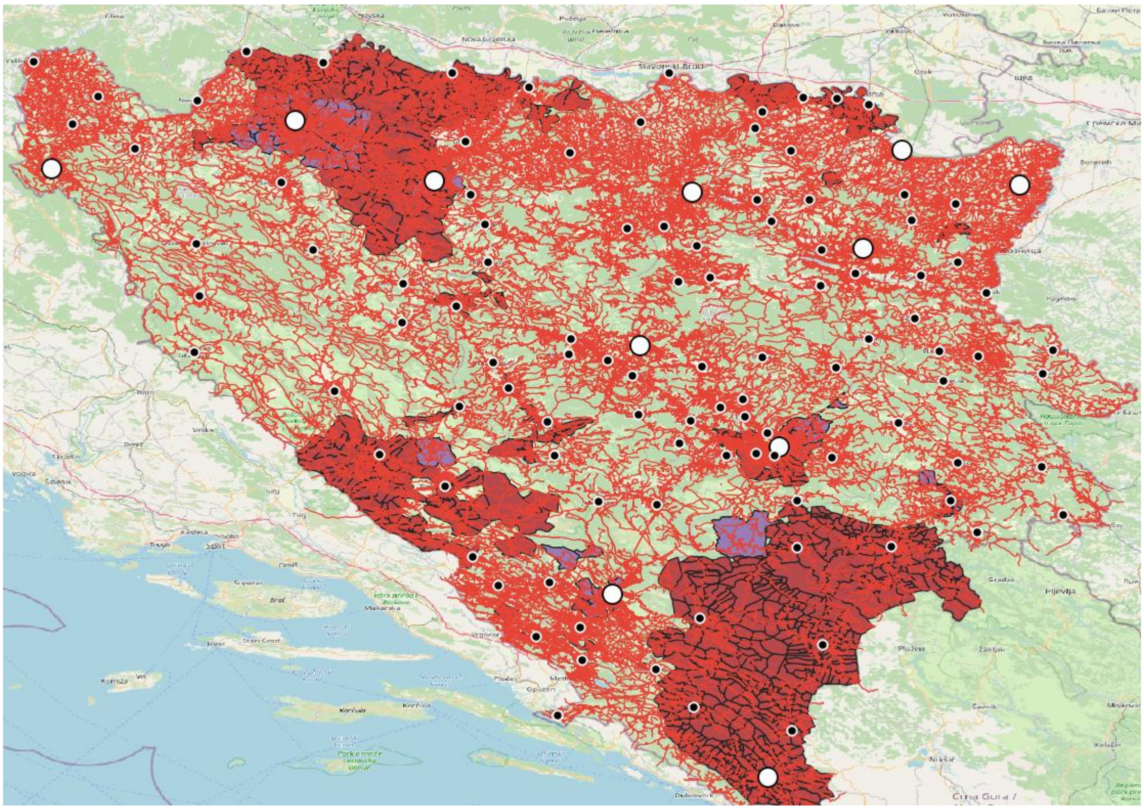
This process was performed for all the WB6 countries. A single map is provided for reference to show the road network, the cities and administrative boundaries applied. LAU2 division was not available for Bosnia and Herzegovina, Kosovo* and Montenegro, in these cases the outlines of cities were added manually.

FIGURE 44. MAJOR CITIES AND TOWNS, ADMINISTRATIVE BOUNDARIES AND ROAD NETWORK IN ALBANIA



Source: REKK and © OpenStreetMap contributors

FIGURE 45. MAJOR CITIES AND TOWNS, ADMINISTRATIVE BOUNDARIES AND ROAD NETWORK IN BOSNIA AND HERZEGOVINA



Source: REKK and © OpenStreetMap contributors

FIGURE 46. MAJOR CITIES AND TOWNS, ADMINISTRATIVE BOUNDARIES AND ROAD NETWORK IN KOSOVO*

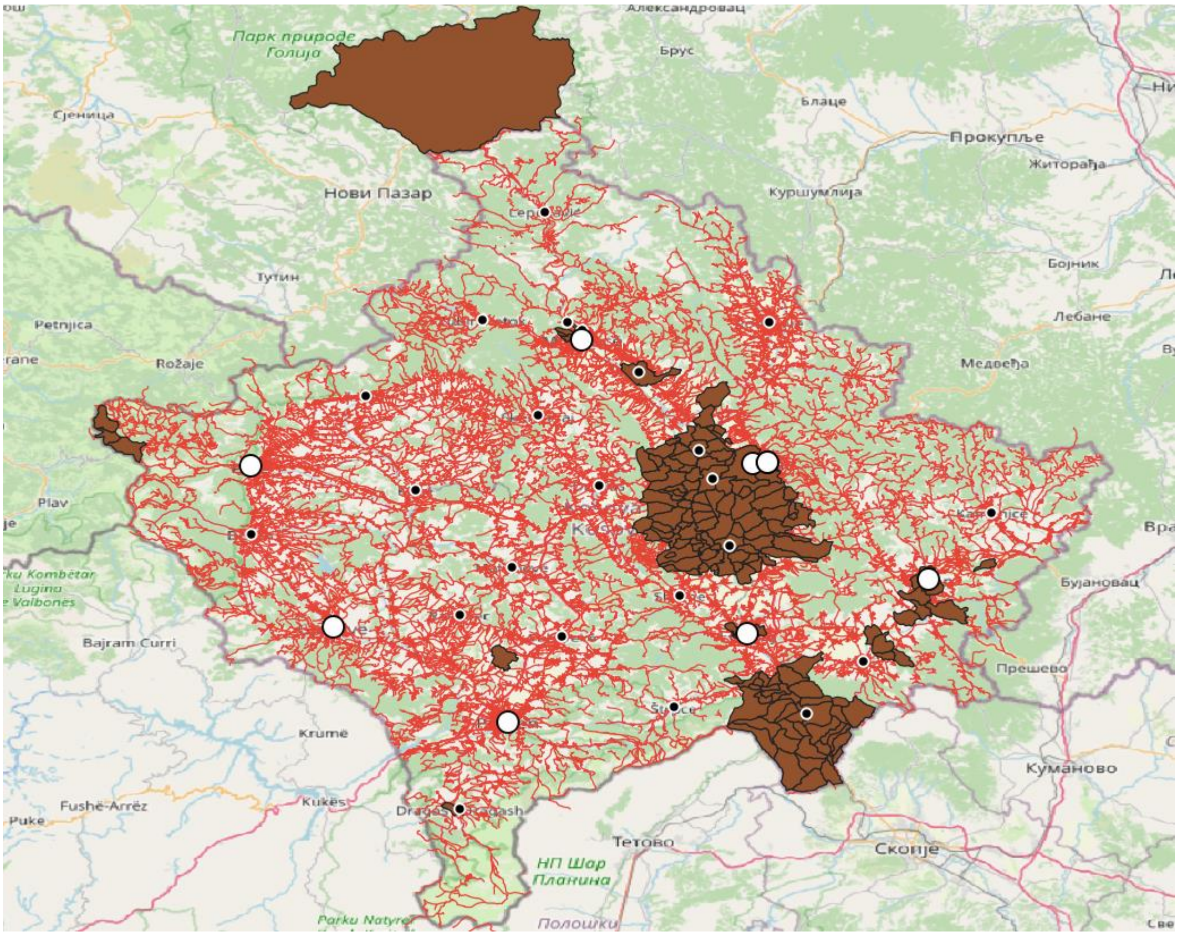


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FIGURE 47. MAJOR CITIES AND TOWNS, ADMINISTRATIVE BOUNDARIES AND ROAD NETWORK IN MONTENEGRO

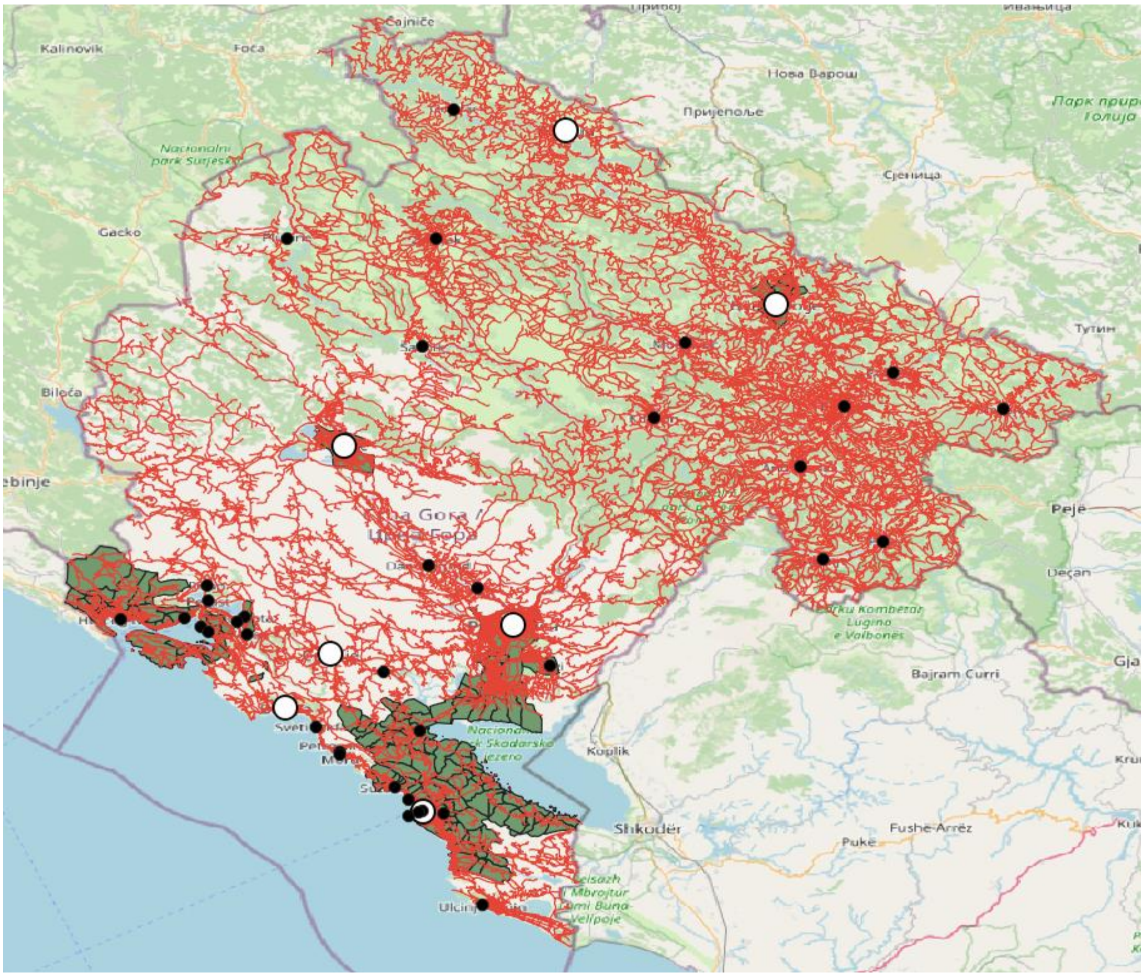

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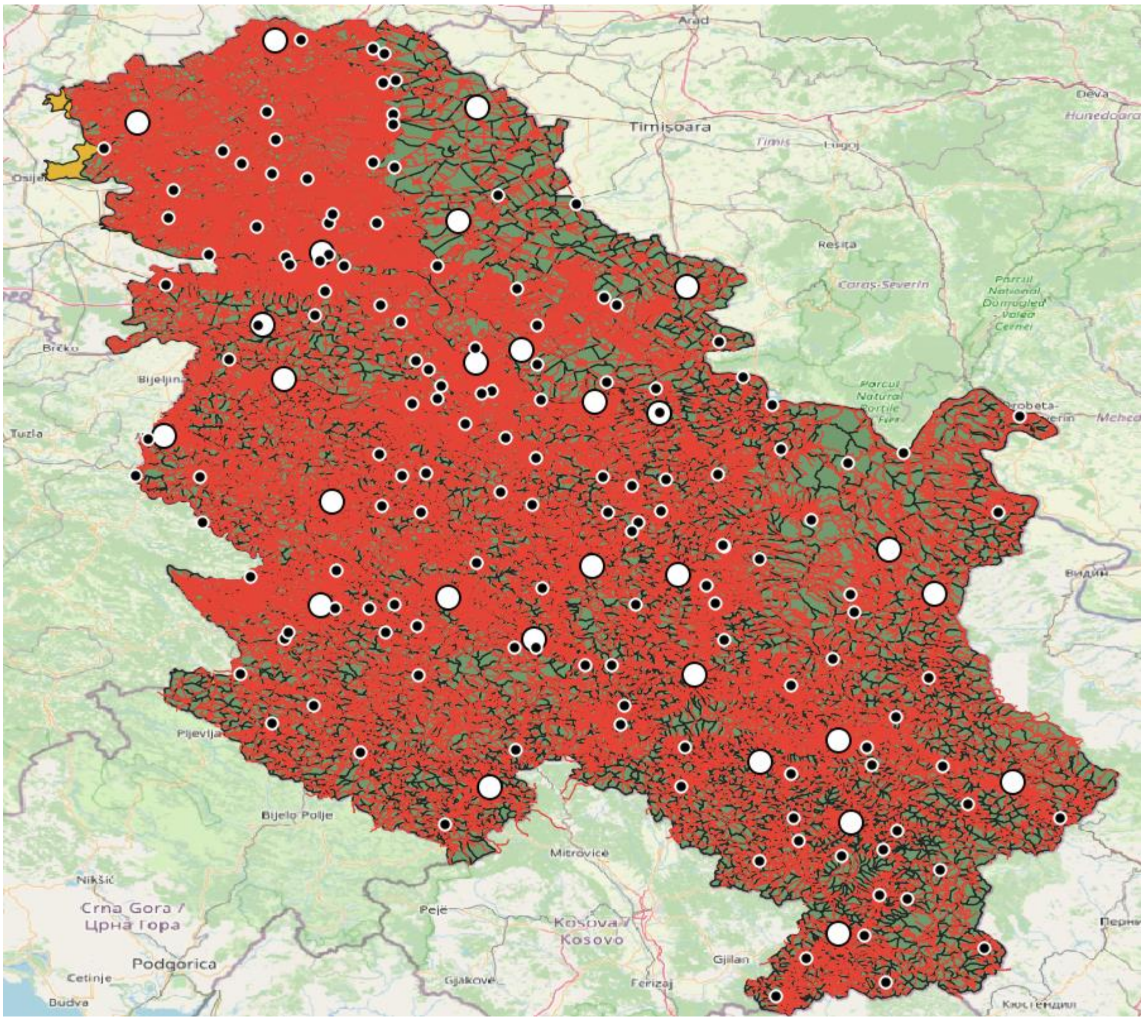
FIGURE 48. MAJOR CITIES AND TOWNS, ADMINISTRATIVE BOUNDARIES AND ROAD NETWORK IN SERBIA



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The tables below list the detailed road length and population data for the settlements. Population data was obtained from national statistical agencies (usually referring to 2011 census).

TABLE 46. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN ALBANIA

	Road length, residential km	Population
Tiranë	375.35	418 495
Durrës	301.51	113 249
Vlorë	163.62	79 513
Elbasan	120.75	78 703
Shkodër	127.31	77 075
Kamëz	221.83	66 841
Fier	82.13	55 845
Korçë	75.83	51 152
Berat	71.94	36496
Lushnjë	72.25	31 105
Pogradec	26.15	20 848
Kavajë	43.06	20 192
Gjirokastër	47.67	19 836
Fushë-Krujë	138.79	18 477
Sarandë	84.36	17 233
Laç	52.99	17 086
Leskovik	8.08	17 086
Kukës	28.30	16 719
Patos	84.67	15 937
Lezhë	19.31	15510
Peshkopi	16.05	13 251
Kuçovë	31.33	12 654
Krujë	33.93	11 721
Vorë	76.05	10 901
Burrel	15.42	10862
Rrëshen	56.22	8 803
Belsh	74.56	8781
Gramsh	12.02	8440
Bulqizë	17.57	8177
Shëngjin	98.03	8 091
Klos	66.49	7 873
Ballsh	6.79	7657
Shijak	21.44	7 568
Ura Vajgurore	22.80	7 232
Rrogozhinë	30.76	7 049
Librazhd	11.38	6 937
Cërrik	18.64	6695
Manëz	71.59	6 652
Peqin	4.11	6 353
Bilisht	23.55	6250
Krumë	35.66	6 006

	Road length, residential km	Population
Përmet	12.92	5 945
Përrenjas	40.68	5847
Delvinë	30.95	5754
Orikum	61.83	5 503
Bajram Curri	6.43	5340
Roskovec	22.88	4 975
Tepelenë	11.19	4 342
Poliçan	9.12	4 318
Maliq	18.28	4290
Çorovodë	8.44	4051
Ersekë	7.68	3 746
Koplik	28.67	3 734
Pukë	10.12	3 607
Himarë	45.76	2 822
Këlcyrë	14.46	2 651
Memaliaj	3.52	2 647
Fushë-Arrëz	12.36	2 513
Selenicë	8.32	2 235
Konispol	19.20	2 123
Martanesh	17.28	1836

Source: REKK calculation

TABLE 47. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN BOSNIA AND HERZEGOVINA

	Road length, residential km	Population
Sarajevo	545.50	696731
Banja Luka	313.98	221106
Zenica	129.05	164423
Tuzla	310.08	142486
Mostar	83.43	104518
Bihac	102.84	75641
Ilidza	282.25	63528
Bugojno	38.55	41378
Brcko	171.49	38968
Bijeljina	86.02	37692
Prijedor	113.13	36347
Trebinje	85.75	33178
Travnik	55.40	31127
Doboj	40.18	27235
Cazin	45.12	21741
Velika Kladusa	40.61	19330
Busovaca	19.88	18488
Visoko	44.23	17890
Gorazde	19.38	17650
Konjic	41.75	15950

	Road length, residential	Population
Gracanica	42.98	15758
Gradacac	54.07	15659
Bosanska Krupa	26.96	15193
Mrkonjic Grad	38.43	14737
Foca	41.63	14615
Zavidovici	50.91	14380
Zivinice	150.04	13641
Sanski Most	82.55	13551
Gradiska	76.13	13346
Bileca	35.11	13257
Kakanj	66.22	12406
Lukavac	75.60	12061
Livno	34.81	11748
Odzak	31.97	11621
Sipovo	13.61	10738
Prozor	47.48	10349
Modrica	91.56	10137
Novi travnik	16.34	10006
Ljubuski	27.43	9987
Kozarska Dubica	61.67	9959
Derventa	34.72	9773
Jajce	23.96	9763
Siroki Brijeg	33.93	9370
Brod	27.18	9249
Novi Grad	26.76	8920
Sokolac	37.24	8842
Zepce	21.28	8502
Kiseljak	19.31	8475
Bratunac	43.34	8359
Fojnica	16.86	8244
Milici	13.44	8210
Vogosca	49.05	8180
Vitez	52.24	8140
Prnajavor	53.28	8120
Zvornik	11.92	8026
Donji Vakuf	35.02	7955
Capljina	12.67	7923
Tomislavgrad	4.76	7737
Stolac	15.94	7733
Lukavica (RS)	25.70	7597
Tesanj	17.94	7550
Drvar	77.32	7506
Pale	63.27	7458
Maglaj	27.63	7399
Srbac	40.49	7380
Nevesinje	20.33	7313
Kljuc	24.29	7245

	Road length, residential	Population
Buzim	8.00	7229
Vlasenica	31.93	7228
Banovici	21.62	7211
Vares	8.88	7193
Hadzici	18.65	7173
Knezevo	18.04	6866
Rogatica	23.84	6855
Kladanj	19.65	6783
Celinac	47.57	6670
Laktasi	62.66	6464
Teslic	36.11	6405
Posusje	27.62	6386
Sekovici	14.80	6315
jablanica	17.36	6209
Visegrad	25.38	6087
Ilijas	32.18	5855
Gacko	17.21	5784
Tomislavgrad	23.24	5760
Citluk	16.43	5718
Samac	26.65	5390
Kotor Varos	37.31	5068
Ugljevik	31.39	4155
Domaljevac	26.56	4152
Kostajnica	16.16	4047
Orasje	23.78	3614
Grude	9.73	3528
Bosansnki Petrovec	44.88	3427
Breza	22.26	3014
Neum	18.86	3013
Kupres	22.55	2883
Ljubinje	16.00	2744
Lopare	12.28	2709
Srebernica	7.70	2607
Cajnice	7.77	2401
Petrovo	14.41	2322
Kalesija	24.42	2039
Han-Pijesak	8.30	2018
Olovo	12.30	2000
Gornji Vakuf Uskoplje	24.43	2000
Celic	34.08	2000
Sreberniki	57.85	2000
Rudo	6.83	1949
Glamoc	22.45	1885
Sapna	5.59	1807
Kresevo	5.62	1433
Kalinovik	1.17	1093
Trnovo	6.75	1018

	Road length, residential	Population
Bosankso Grahovo	10.36	651

Source: REKK calculation

TABLE 48. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN KOSOVO*

	Road length, residential, km	Population
Prishtina	285.68	145149
Prizren	344.25	85119
Gjilan	203.50	54239
Peje	160.98	48962
Mitrovice	235.22	46230
Ferizaj	156.92	42628
Gjakove	108.93	40827
Vushtrri	127.03	26964
Podujeve	137.23	23453
Fushe Kosove	92.76	18515
Rahovec	48.75	15892
Suhareke	50.05	10422
Kacanik	42.54	10393
Skenderaj	23.19	9372
Kamenice	47.15	7331
Shtime	45.89	7255
Lipjan	46.35	6870
Obiliq	54.93	6864
Drenas	44.27	6143
Kline	39.72	5542
Istog	24.85	5115
Viti	35.45	4924
Decan	26.74	3803
Leposavic	11.64	3702
Malinove	24.86	3395
Zubin Potok	45.93	1724
Zvecan	14.79	1297
Skrpce	13.16	1265
Dragash	14.89	1098

Source: REKK calculation

TABLE 49. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN MONTENEGRO

	Road length, residential, km	Population
Podgorica	404.97	185937
Niksic	203.69	72443
Bijelo Polje	37.98	46051
Herceg Novi	15.81	30864

	Road length, residential, km	Population
Ulcinj	34.36	19921
Cetinje	30.94	16757
Tivat	26.41	14000
Kotor	0.18	13510
Bar	19.69	13503
Budva	30.15	13338
Tuzi	43.23	11742
Berane	42.61	11000
Rozaje	32.57	9567
Mojkovac	12.07	8622
Dobrota	17.25	8189
Danilovgrad	17.43	6852
Plav	16.06	3717
Bijela	13.97	3691
Kolasin	22.85	2989
Risan	4.41	2034
Sutomore	14.64	2004
Stari Bar	6.09	1864
Zabljak	7.07	1723
Gusinje	6.16	1673
Petrovac	6.30	1398
Gradac	1.35	1308
Prcanj	1.67	1128
Andrijevica	2.74	1048
Savnik	2.29	570
Petnjica	5.99	539
Virpazar	1.36	277
Rijeka Crnojevica	0.61	175
Stevi Stefan	1.93	100

Source: REKK calculation

TABLE 50. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN NORTH MACEDONIA

	Road length, residential km	Population
Skopje	670.92	668500
Struga	38.94	33000
Bitola	105.56	74550
Shtip	105.67	65000
Krushevo	10.01	5507
Veles	80.89	43716
Kavadarci	54.87	29320
Krushevo OT	10.05	5330
Strumica	76.22	36000
Tetovo	115.07	53000
Kumanovo	230.37	105000

Kichevo	71.80	31000
Delchevo	40.57	17505
Ohrid	94.29	38940
Kriva Palanka	34.47	14010
Demir Hisar	6.48	2593
Bogdanci	22.07	8707
Prilep	169.08	66246
Gevgelija	54.49	20664
Gostivar	99.21	36000
Radovish	49.96	16690
Kratovo	20.79	6924
Sveti Nikole	40.89	13220
Debar	46.31	14561
Negotino	44.82	13390
Makedonska Kamenica	17.25	5147
Vinica	37.36	10590
Kochani	103.67	29000
Resen	31.54	8750
Valandovo	16.05	4402
Makedonski Brod	16.72	3740
Demir Kapija	14.81	3275
Probishtip	43.79	8190
Berovo	37.74	6490
Pehchevo	19.13	3237

Source: REKK calculation

TABLE 51. POPULATION AND LENGTH OF DISTRIBUTION NETWORKS BASED ON ROAD LENGTH IN SERBIA

	Road length, residential km	Population
Belgrade	1551.50	1344844
Nis (Medijana)	58.35	255901
Novi Sad	323.55	215400
Kragujevac	365.25	147473
Cacak	220.83	117072
Subotica	403.09	100000
Leskovac	130.73	94758
Novi Pazar	118.09	85996
Kraljevo	150.89	82846
Zrenjanin	237.56	79773
Pancevo	141.50	76654
Krusevac	89.32	75256
Uzice	106.36	63577
Smederevo	173.52	62000
Valjevo	149.01	61035
Vranje	132.44	56199

	Road length, residential km	Population
Sabac	119.50	55114
Zajecar	125.90	49800
Trstenik	28.59	49043
Sombor	156.39	48454
Borca	182.19	46086
Kikinda	111.45	41935
Pozarevac	163.00	41736
Pirot	85.85	40678
Bor	63.62	39387
Sremska Mitrovica	98.90	39084
Vrsac	104.42	36300
Jagodina	78.95	35589
Ruma	75.34	32229
Backa Palanka	79.98	29449
Prokuplje	91.79	27673
Smederevska Palanka	89.86	27000
Barajevo	125.35	26798
Indjija	64.46	26025
Vrbas	65.72	25907
Becej	119.98	25774
Knjazevac	62.35	25000
Arandjelovac	86.67	24797
Gornji Milanovac	91.06	23982
Mladenovac	48.10	23609
Lazarevac	84.43	23551
Cuprija	57.66	20585
Senta	116.37	20302
Temerin	70.76	19661
Loznica	45.47	19212
Futog	67.33	18641
Apatin	57.00	18320
Kula	70.09	17866
Negotin	72.18	17612
Obrenovac	46.67	16821
Aleksinac	55.80	16685
Stara Pazova	58.37	16217
Velika Plana	69.21	16088
Vlasotince	52.92	15882
Priboj	23.57	14920
Sid	49.04	14893
Kovin	67.56	14250
Sjenica	65.28	14060
Petrovaradin	77.03	13917
Prijepolje	32.25	13330
Kursumlija	37.57	13200
Pozega	31.70	13153
Novi Becej	72.91	13133

	Road length, residential km	Population
Surcin	117.22	12575
Sremska Kamenica	91.76	12273
Srbobran	63.82	12009
Ivanjica	22.79	11715
Surdulica	31.11	10888
Bela Crkva	29.73	10675
Vrnjacka Banja	43.63	10207
Kanjiza	54.93	10200
Tutin	26.30	10094
Majdanpek	14.71	10071
Kostolac	39.47	9569
Ada	56.81	9564
Lebane	33.43	9272
Svilajnac	42.02	9198
Crvenka	36.31	9001
Kladovo	49.48	8869
Sremski Karlovci	58.98	8839
Odzaci	30.84	8811
Nova Varos	21.25	8795
Bajina Basta	22.01	8533
Zabalj	31.09	8503
Grocka	66.24	8441
Bela Palanka	32.43	8143
Vladicin Han	29.32	8030
Sokobanja	48.62	7982
Mol	49.60	7950
Beocin	34.78	7839
Palic	66.66	7771
Dobanovci	29.82	7592
Svrljig	25.84	7553
Starcevo	32.41	7473
Petrovac na Mlavi	33.03	7447
Lapovo	44.69	7422
Kovacica	32.97	7357
Backi Petrovac	37.31	7229
Bogatic	21.84	7225
Sevojno	39.20	7101
Kacarevo	25.08	7100
Arilje	18.46	6762
Raska	17.78	6590
Banatski Karlovac	16.73	6319
Dimitrovgrad	22.69	6278
Aleksandrovac	12.11	6228
Titel	25.19	6227
Ub	18.51	6191
Paracin	72.13	6000
Veliko Gradiste	41.53	5825

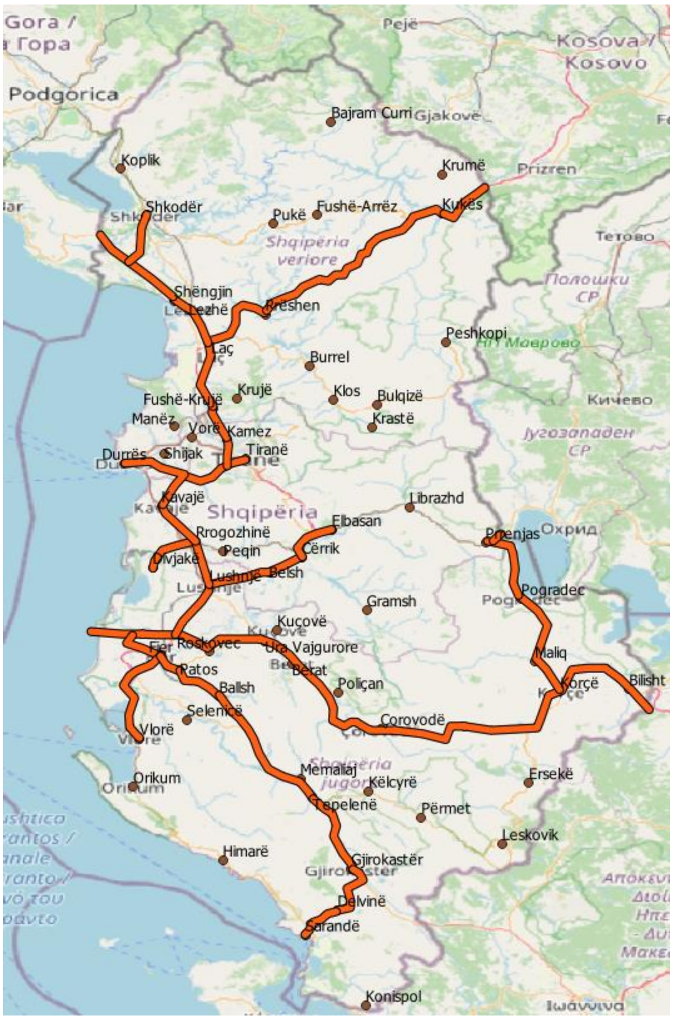
	Road length, residential km	Population
Batocina	36.48	5804
Backi Jarak	18.19	5687
Umka	24.98	5618
Coka	16.81	5414
Bac	25.82	5399
Vranjska Banja	24.59	5347
Blace	19.97	5253
Banja Koviljaca	26.45	5151
Topola	25.92	4973
Mali Idjos	38.98	4890
Cicevac	33.43	4667
Brus	13.13	4636
Babusnica	15.97	4601
Krupanj	15.83	4429
Irig	28.25	4415
Mali Zvornik	15.74	4407
Niska Banja	19.86	4380
Ostruznica	18.12	4218
Despotovac	20.57	4197
Kosjeric (town)	18.06	3992
Kucevo	28.33	3944
Ljubovija	10.19	3929
Mavanska Mitrovica	18.67	3837
Beli Potok	17.54	3621
Lucani (town)	10.41	3387
Cajetina	19.91	3336
Boljevac	15.86	3333
Lajkovac (Town)	12.16	3249
Ljig	16.12	3226
Pinosava	17.64	3151
Bojnik	13.37	3100
Presevo	52.58	3080
Alibunar	14.11	3007
Mataruska Banja	12.66	2950
Zitiste	15.96	2903
Vucje	14.47	2865
Medvedja	6.61	2860
Zlatibor	70.67	2821
Bujanovac	25.48	2624
Bosilegrad	29.69	2624
Raca	8.81	2603
Zagubica	21.74	2590
Donji Milanovac	19.85	2410
Jasa Tomic	19.57	2373
Knic	23.23	2181
Grdelica	6.04	2136
Resavica	4.34	2035

	Road length, residential km	Population
Sopot	9.09	1920
Trgoviste	7.12	1855
Guca	4.63	1755
Golubac	10.69	1653
Ribnica	7.95	1642
Mionica	6.12	1620
Rekovac	12.91	1587
Gadzin Han	4.77	1223
Zabari	8.64	1174
Bogovina	17.89	1151
Crna Trava	2.36	434
Zitoradja	19.89	363

Source: REKK calculation

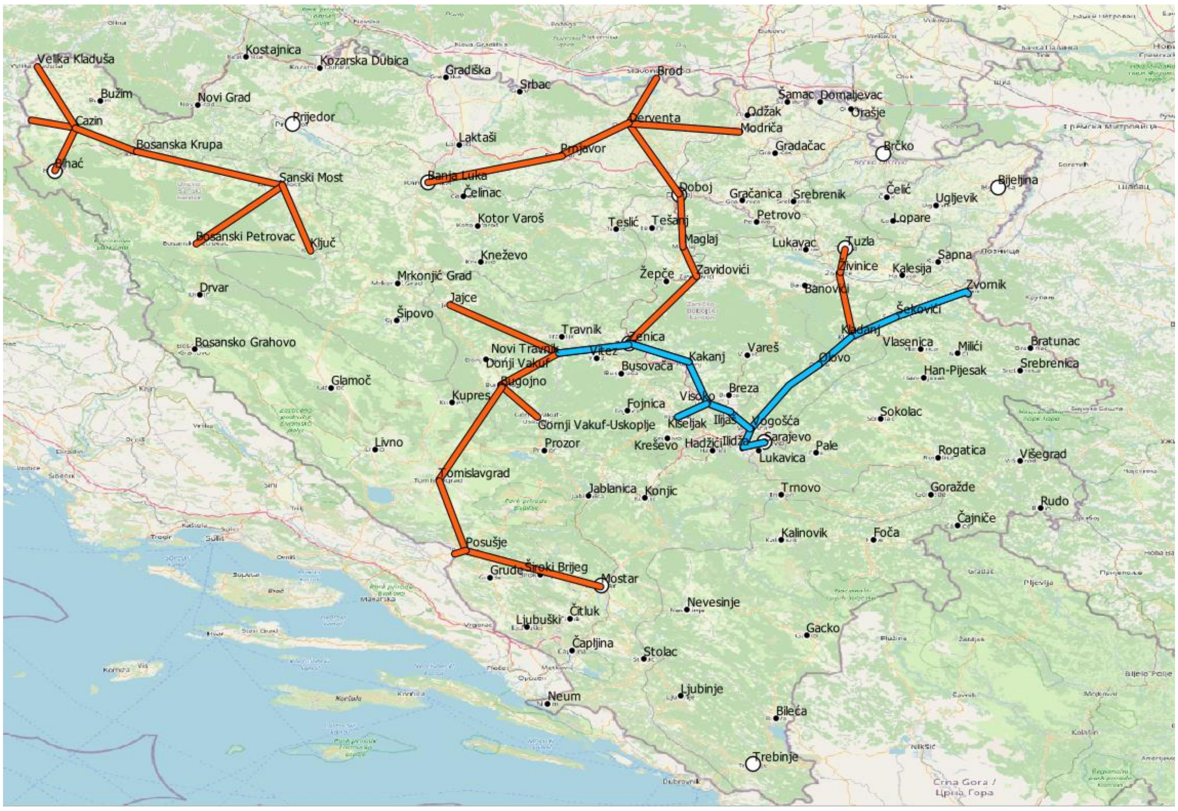
6.3. MAPPING GAS TRANSMISSION SYSTEM LENGTH

FIGURE 49. STYLISED MAP OF THE PLANNED ALBANIAN GAS TRANSISMISSION NETWORK



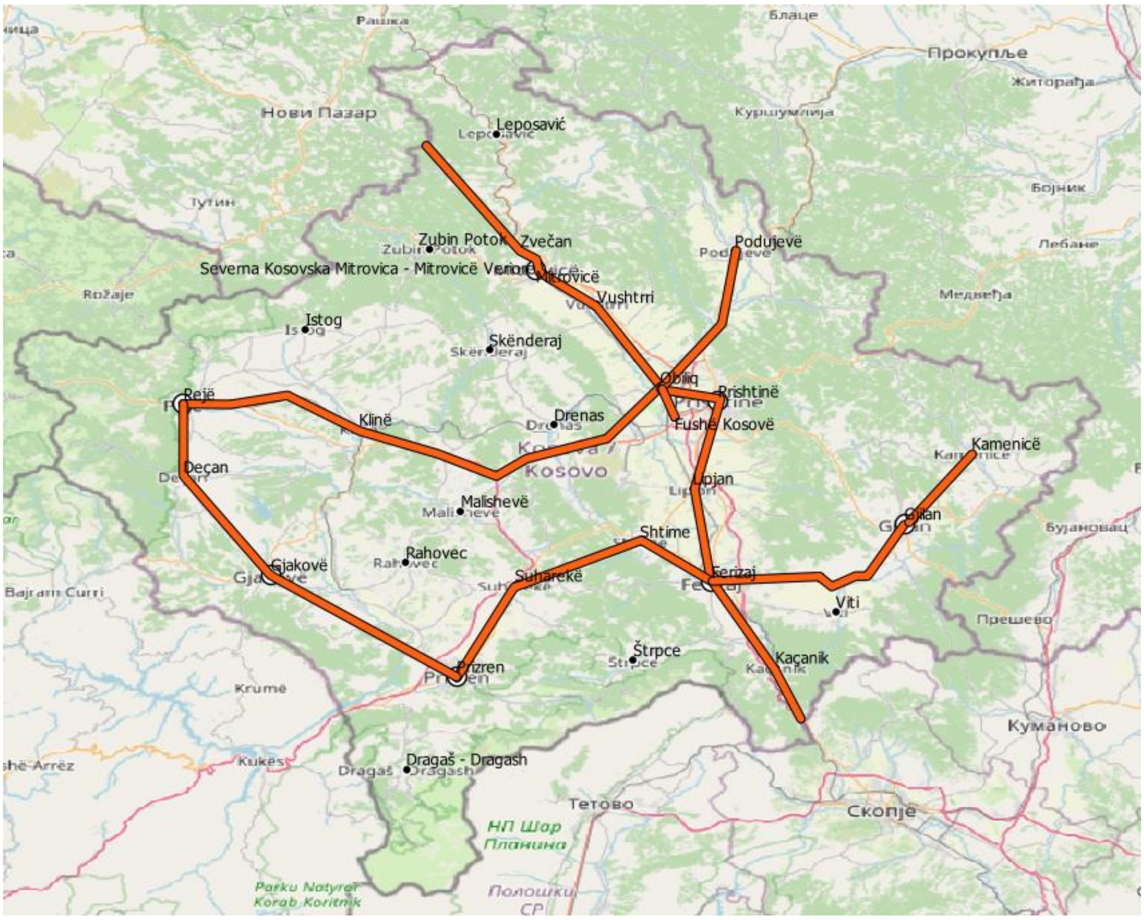
Source: REKK based on (COWI - IPF, 2016) and © OpenStreetMap contributors

FIGURE 50. STYLISED MAP OF THE EXISTING (BLUE) AND PLANNED (ORANGE) BOSNIAN GAS TRANSISMISSION NETWORK



Source: REKK based on (Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina, 2018) and © OpenStreetMap contributors

FIGURE 51. STYLISED MAP OF THE PLANNED KOSOVO* GAS TRANSISMISSION NETWORK



Source: REKK based on (PISG (KO), 2003) and © OpenStreetMap contributors*

FIGURE 52 STYLISED MAP OF THE PLANNED (ORANGE) MONTENGRO GAS TRANSIMISSION NETWORK

Source: REKK based on (COWI - IPF, 2015)

FIGURE 53. STYLISED MAP OF THE EXISTING (BLUE) AND PLANNED (ORANGE) SERBIAN GAS TRANSIMISSION NETWORK

Source: REKK based on (Transportgaz Srbija, 2020)

6.4. ESTIMATING THE CONNECTION OF POPULATION AND GAS DEMAND

While using city-level data, no information on the actual building stock or gas demand could be found for all the WB6. The only exception is when gas master plan was available, in that case municipality level gas consumption was published (for Albania, Montenegro and North Macedonia). For this reason, a simple proxy for gas consumption needed to be formulated.

To find an easy to reproduce proxy, we plotted gas consumption of different sectors in the EU28 and WB6 for the 2009-2017 period. Average annual gas consumption for the households&services, industry and power sectors was plotted against the HDD and the total population of each country. Correlation of population and gas consumption was strong in all sectors.

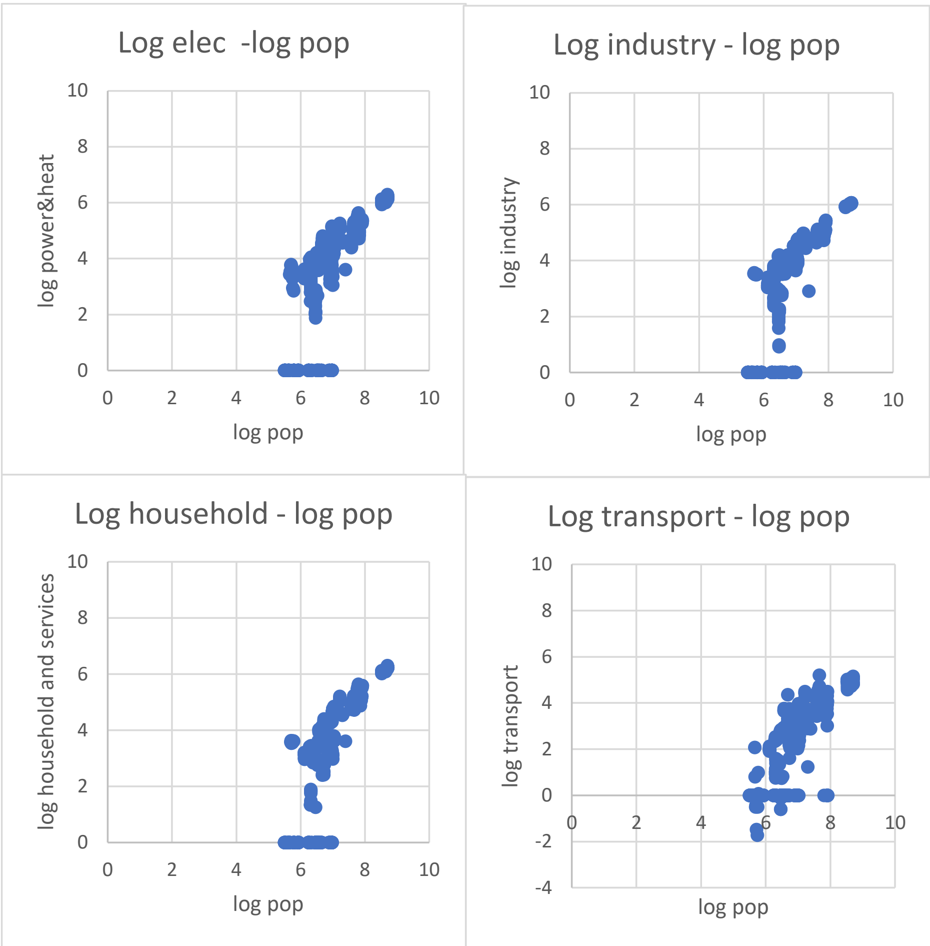
FIGURE 54. CORRELATION OF SECTORAL NATURAL GAS CONSUMPTION AND POPULATION (2009-2017, EU28 + WB6)

	Correlation
Electricity, heat and energy sector	0.982
Industry and non-energy use	0.994
Households and services	0.990
Transport and other	0.886

Source: REKK calculation based on Eurostat

The logged plots below indicate the high correlation as well.

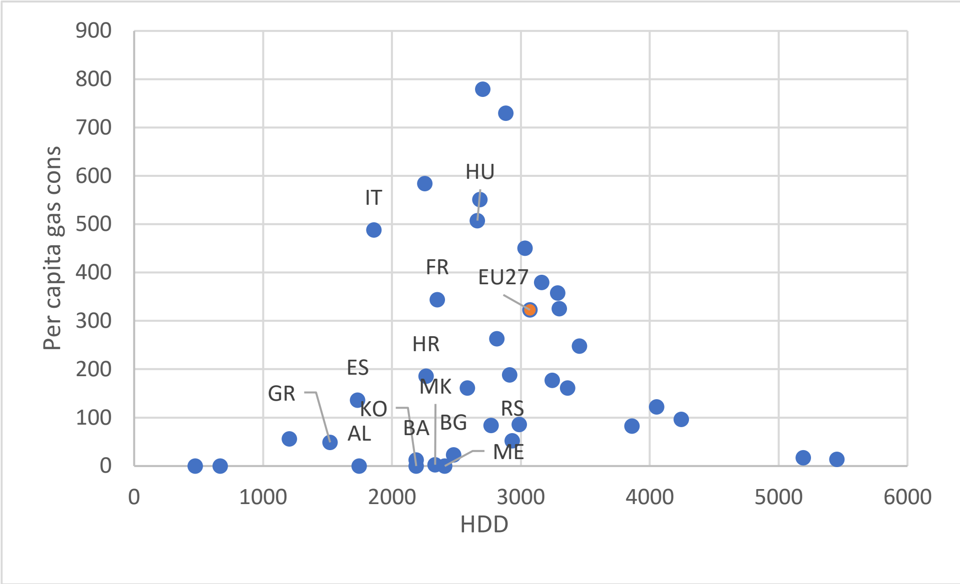
FIGURE 55. CORRELATION OF LOGARITHMIC SECTORAL CONSUMPTION WITH LOGARITHMIC POPULATION (2009-2017, EU28 + WB6)



Source: REKK calculation based on Eurostat

Additionally, per capita gas consumption was plotted against the heating degree days for each country. We chose to use an EU28 average per capita gas consumption (~300 m^3/capita).

FIGURE 56. HDDS AND PER CAPITA GAS CONSUMPTION



Source: REKK calculation based on Eurostat