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Analysis of alternatives to coal-based district heating for the Bitola region in North Macedonia

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Executive summary

The largest coal-fired power plant in Bitola, North Macedonia has been operational for 40 years and has never included a district heating component, although this has often been discussed. The plant operator started taking more concrete steps towards the construction of a district heating system only after the Energy Strategy for North Macedonia concluded that phasing out coal within this decade is not only possible, but actually a necessity. Work towards this district heating system and discussions around it have intensified with the energy crisis in 2021 and 2022. Putting a coal-based district heating system into operation goes against the country's energy strategy and could potentially delay the coal phase-out by a decade. To ensure there are no delays in the coal phase-out plans, this study analyses possible alternatives to the planned coal-based district heating system in the Bitola region.

The study examines the current heating situation in the Bitola region (covering the municipalities of Bitola, Mogila and Novaci), followed by an analysis of the techno-economic potential for using decentralised heating solutions that are also in line with the country's environmental protection commitments. The analysed heating options provided in this study are both economically and environmentally sustainable alternatives to the planned district heating system, not only in the long term, but also as immediate solutions.

The analysis suggests that the most feasible heating option would be photovoltaic systems coupled with inverter air conditioning units for the two types of dwellings: apartments and individual houses. Considering that the current regulation enables households to act as prosumers, this proposed system could produce surplus energy that would be sold to the grid. Our analysis included different scenarios using the suggested technologies, but with differing input variables, including the price at which surplus household energy is sold to the grid and the level of government subsidies in the proposed system. The analysis suggests that without government support, the payback period for the proposed system would be more than 10 years. With certain legislative changes and with government subsidies of 30 or 50 per cent, the payback period can decrease to seven years.

By focusing on alternative heating sources to a thermal power plant, this study outlines the possibilities of promoting local and sustainable heating solutions by adopting a tailored, contextualised approach instead of focusing on large projects with an immense environmental footprint, low economic viability and high potential for corruption, all at the expense of fossil fuel dependency.

Aside from presenting techno-economic reasoning for establishing a citizen-led energy community, this study also includes the potential for establishing a municipal energy community within the municipality of Bitola, considering the different institutions that are managed by the municipality. The municipal energy community will ensure greater municipal participation in the energy transition, increased local energy production and improved energy independence, as well as decreased fossil fuel emissions and increased local labour market opportunities. An energy community formed by different institutions that the municipality manages also has the potential to generate profits from decentralised energy production.

In order for these changes in the heating practices of the municipalities of Bitola, Mogila and Novaci to be as efficient and cost-effective as possible, some changes in the legislation must take place. The government has to make changes in the remuneration equation so that prosumers benefit appropriately from the

investment in photovoltaic systems, and to enable and simplify the administrative procedures for prosumers and energy communities. It also has to establish a National Energy Efficiency Fund that among other things can be used to support and subsidise households to switch to sustainable heating practices.

The local authorities can also play an important part in the energy transformation by implementing renewable-based heating systems in all buildings managed by the municipalities. They can also support households via different support schemes and grants to make the switch to more efficient heating systems.

Citizens can play a pivotal role in the energy transformation of any country, and by investing in their own energy and financial security, they can become active participants in the energy system. They can gain even more from this process if the authorities support them, so they must proactively request better conditions, financing options and streamlined administrative procedures.

Disclaimer:

The analysis presented in this study was conducted from July to October 2022. It takes into account the latest energy policy changes and electricity prices valid at that time. The conversion rate used is EUR 1 = MKD 61.5.[1]

[1] The exchange rate used is the average exchange rate for the period when the analysis was conducted, July to October 2022, according to InforEuro.

Contents

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1. Background

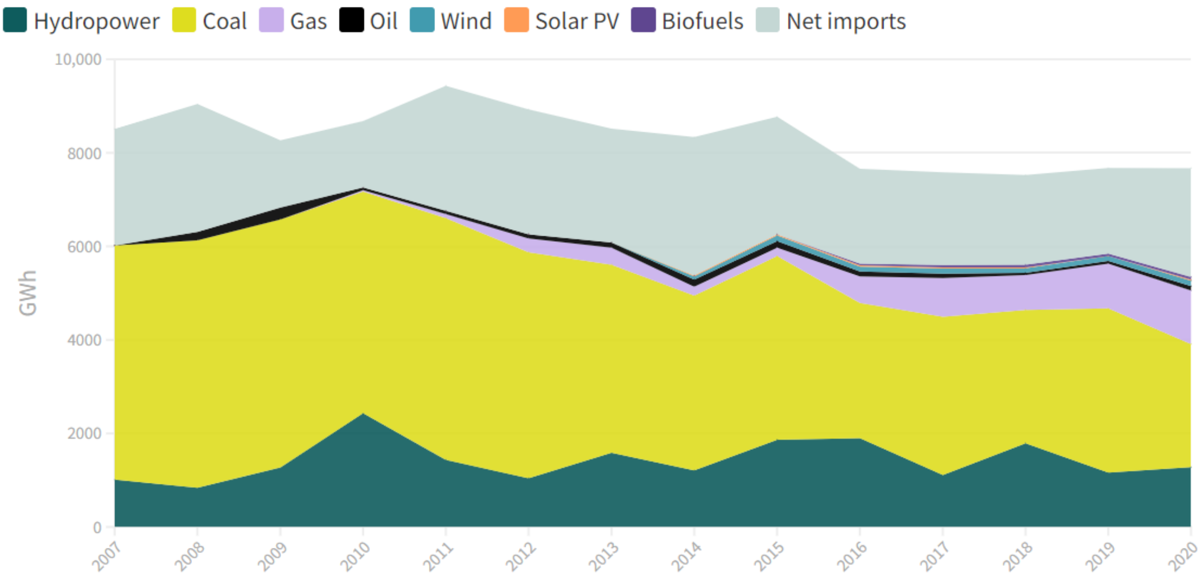
The Republic of North Macedonia is a landlocked country located on the Balkan peninsula with a total area of 25,713 square kilometres (km)[2]. As an energy-dependent country, North Macedonia relies predominantly on fossil fuels (mostly low-grade lignite and imported natural gas). The country's electric power production system includes two coal power plants with a total installed capacity of 825 megawatts (MW) that produce approximately 55 per cent of the electricity the country consumes every year. The country's coal supply comes mainly from the two open pit lignite mines that have a total capacity of around 7 million tons/year, with estimated coal reserves of less than 15 years. The electricity mix of North Macedonia also includes several hydro power plants with a total installed capacity of more than 690 MW, a combined heat and power plant, a heavy oil power plant and a few solar, wind and biogas plants. The evolution of the electricity mix in the country over the past 15 years is presented in figure 1, taking into account imports in the final energy consumption statistics.

In the early 2000s, the state-owned power company was unbundled and partially privatised. Electricity distribution is currently managed by the Austrian utility company EVN, while transmission and generation are state-owned through Makedonski Elektroprenosen Sistem Operator (MEPSO) and Elektrani na Severna Makedonija (ESM) respectively. Until 2018, MEPSO also organised the national electricity market in terms of power control and balancing, as well as being responsible for the transmission network. In 2018, Nacionalen Operator na Pazar na Elektrichna Energija (MEMO) was established, taking over MEPSO's role of operating the national electricity system and regulating the market. MEMO's vision[2] is to organise a transparent, efficient and competitive electricity market that is connected to neighbouring electricity markets in an efficient and economical manner. Moreover, MEMO's focus includes aligning national legislation with European energy legislation and strengthening the integration of the national electricity market with other markets in Southeast Europe and the Western Balkans. As such, MEMO's core responsibilities include:

- Balancing the national grid
- Controlling the national electricity market for bilateral agreements
- Cross-border energy trading

[2] За Нас, *MEMO*, accessed 18 November 2022.

Figure 1 – Electricity mix of North Macedonia



Source: Bankwatch[3]

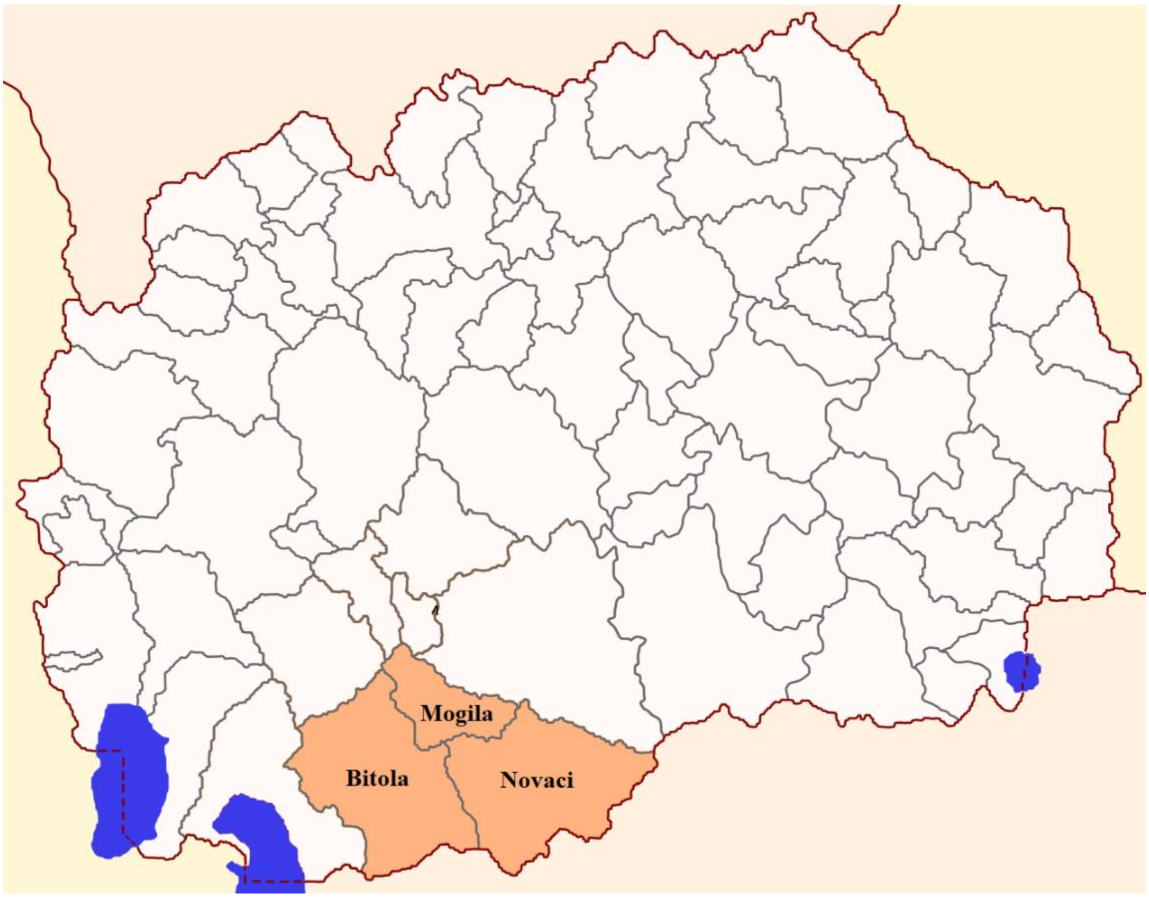
The Energy Strategy for North Macedonia[4] considers several scenarios that take into account different transition pathways and efforts. Among these scenarios is the green scenario, which foresees the closure of the largest coal power plant in the country (REK Bitola) and its transition towards using renewable energy sources and natural gas in a combined heat and power plant (CHP). The energy strategy paves the way for phasing out coal by the end of this decade, outlining the possibilities for transitioning towards an energy mix that will predominantly include renewable energy sources. However, ESM has announced its plan to operationalise a decades-long idea: a coal-based district heating system for the cities and municipalities of Bitola, Mogila and Novaci using the country's largest coal power plant, located in Novaci. In the short- to medium-term, it is foreseen that one block of the power plant will be transformed from lignite- to natural-gas-powered, providing a cleaner energy production alternative.

Considering the plan to create a district heating network using heat from REK Bitola, the medium- to long-term strategy for district heating in the municipalities of Bitola, Mogila and Novaci is based on imported fossil fuels.

[3] The energy sector in North Macedonia, *CEE Bankwatch Network*, accessed 18 November 2022.

[4] Government of the Republic of Macedonia, Стратегија за развој на енергетиката во република северна македонија до 2040 година, *Government of the Republic of Macedonia*, 28 December 2019.

Figure 2 – The municipalities of Bitola, Mogila and Novaci



Source: Author's own adaptation

As the introduction of this fossil-fuel-based district heating network will inevitably create tension due to the country's energy strategy and its decarbonisation efforts, the purpose of this study is to provide a techno-economic analysis of alternatives to the proposed district heating plans in terms of using both coal and natural gas as input resources. The aim of this study is to provide alternatives that are readily available, scalable and based on renewable energy. The suggestions will include more efficient technologies that are applicable to the given context and are in line with North Macedonia's energy strategy, coal phase-out and decarbonisation efforts.

2. The current heating situation in the Bitola region

The current heating situation in Bitola, Mogila and Novaci is dominated by two main energy sources: wood/solid biofuel and electricity. According to the information provided by the municipality of Bitola, households in the region have individual heating systems, but in 1999 a small district heating system with a network length of under 10 km[5] was built and began to operate. This system has a capacity of 27.75 MW,

[5] Топлификација, *Municipality of Bitola*, accessed 18 November 2022.

connecting six different fossil liquid fuel boilers that serve more than 60 collective housing units with an area of more than 130,000 square metres $(m)^2$, as well as more than 60 businesses.

According to the latest census data for Bitola, 6,734 apartments (households) have their own hot water heating installation, 2,629 apartments have a hot water heating installation that is connected to the district heating grid, and 34,361 have no hot water heating installation. According to these data, the census registers a total of 43,724 apartments which is the same as the general information on apartments from the census. The census data also shows that 14,138 apartments have their own air conditioning units, whereas 28,743 apartments have no air conditioning unit. The census data does not specify the percentage of these units that are inverter air conditioning. Using this information, the census registered a total of 42,881 apartments, showing a slight discrepancy between these figures and the previous data. No official data in terms of household heat energy demand is available, but the results of this study suggest that demand exceeds 200 gigawatt hours (GWh) per year.

To gain a different perspective on the fuels and systems currently used for heating in the analysed region, informal unstructured interviews with more than 80 residents of Bitola, Mogila and Novaci were conducted in July 2022. These interviews were also used to determine whether residents intended to change their current heating system (applicable on a case-by-case basis). The results of this research approach show that residents living in collective residential buildings typically use some form of electric heating unit (radiation or convection-based units), or they rely on an air conditioning system, either an inverter or a classic system. Almost all residents of collective resident buildings that use some form of electric heating system other than an inverter air conditioning unit expressed their willingness to switch to this system, as it is the most efficient heating/cooling system available on the market and is also suitable for apartment living. Almost all respondents living in individual housing units said their heating system uses solid biofuels. When asked about the amount of fuel they consume on a yearly basis, respondents' answers ranged from 4 to 5.5 m^3 per year.

In response to a freedom of information request, the municipality of Bitola provided information about the current heating situation of the region's kindergartens, primary schools and secondary schools. The data shows that 13 kindergartens within the two municipal institutions use heating oil, which cost more than MKD 4.9 million (more than EUR 79 500) during the winter heating period of 2020-2021. Eleven of Bitola's primary schools use heating oil and only one uses electricity; two of the 11 primary schools that use heating oil also have a combined heating system that uses solid biofuel (wood). Total heating costs during the winter heating period of 2020-2021 were just over MKD 14 million (EUR 227 596). The region's six secondary schools use heating oil, which cost more than MKD 7.3 million (EUR 118 675) during the winter heating period of 2020-2021. All data (in Macedonian) is available on request.

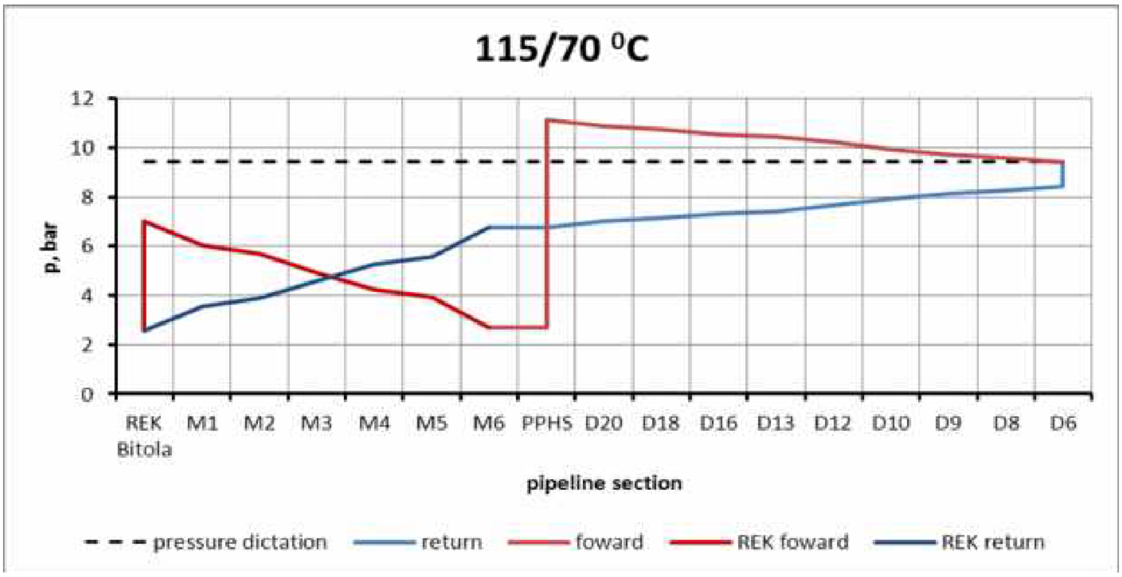
3. District heating in Bitola region: current and planned activities

The construction of a district heating system in Bitola that relies on the country's largest power plant as its energy source is a decades-long idea. Using low-to-medium energy steam taken from the last stages of the steam turbine during the electricity production process, this project is meant to reduce the consumption of electricity and biofuels for heating in Bitola, consequently reducing the environmental impact. Over the past four decades, various technical and feasibility studies have looked at the potential of establishing a district heating system in Bitola. A pre-feasibility study conducted in 2011 by Norsk Energi and the Centre for Climate Change, then a subsequent feasibility study conducted by Ekonerg in 2012 provided the required techno-economic rationale for the development and implementation of the district heating idea.

3.1. Technical characteristics of the district heating system

Heat input for the district heating system will be provided by taking steam from turbines 2 and 3, which will be taken to a steam-water heat exchanger. The hot water will be transported 12.61 km along the towns of Novaci and Logovardi to Bitola, through fertile agricultural soil with a temperature profile of 115/70 °C. The pressure profile of the heating system is presented in figure 3 below.

Figure 3 – Pressure profile of the proposed heating system



Source: ESM – Development & Investment Sector[6]

The first phase of the district heating system includes the following subsystems:

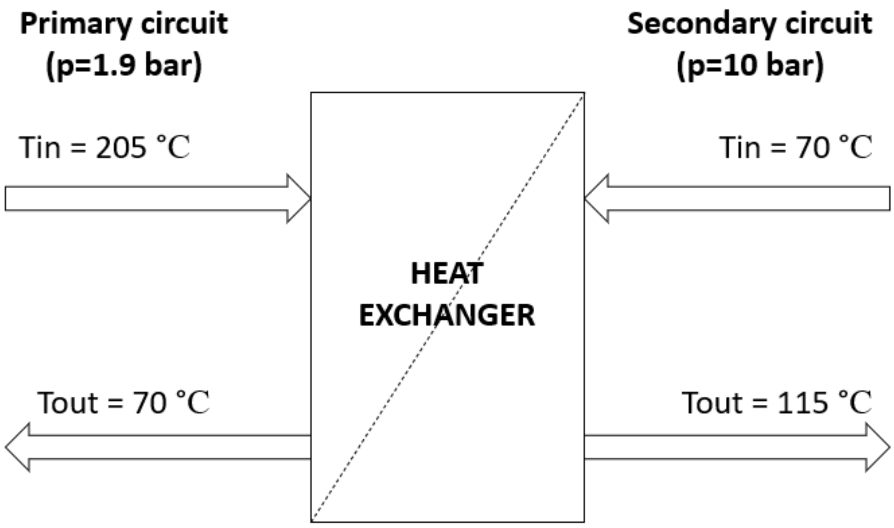
- Heat production subsystem
- Transport pipeline
- Primary pump-thermal station in Bitola
- District heating distribution network
- Heat substations in buildings

The first phase of the project includes the construction of the transport pipeline between the power plant and the city of Bitola, with connectors for distribution networks in Novaci, Mogila and Logovardi. However, this phase does not include the construction of a distribution network within these municipalities, as the need to connect to the heating system must be proven by a techno-economic feasibility study. It is expected that the extension of the district heating grid in these three municipalities will not be feasible from a techno-

[6] Elektrani na Severna Makedonija, Проект топлификација на Битола, Новаци и Могила – I фаза, *Elektrani na Severna Makedonija*, 2019.

economic perspective due to the low number of housing units there. The 100 MW heat production will rely on two 50 MW heat exchangers. The relevant heat exchanger data is provided below in figure 4.

Figure 4 – Characteristics of the heat exchanger



Source: Author's design

In the first phase, the distribution network in Bitola should be built and connected with the transport pipeline. Considering that the city already has a very limited distribution system from a district heating system built several decades ago that is currently not functioning, as described earlier in this report, the first phase of the project will aim to connect as many consumers as possible from the old and the new distribution networks (not only private consumers such as households and businesses, but also public organisations). However, in order to operationalise the existing limited distribution system in Bitola, extensive technical inspections of the entire system are necessary. This will extend the timeline for implementation by an unknown amount of time.

The project's feasibility study[7] forecasts a specific **loss of potential electricity production between 18.4 and 25.3 per cent from the steam** that will be indirectly used in the district heating network. However, these losses are projected for a district heating system of up to 80 MW. As the district network expands in the future, the use of small local burners to reach the desired temperature profiles will inevitably lead to greater losses. As such, the specific loss of heat, electricity and efficiency will be considerably higher in reality than estimated in the feasibility study and will far outweigh the transportation and distribution losses that would come with an electric system, which casts doubt on the overall economic/financial feasibility of the project. Furthermore, no transmission and distribution heat losses are taken into account in the project's description, which means the losses and associated costs will be greater than anticipated.

[7] Elektrani na Severna Makedonija, Проект топлификација на Битола, Новаци и Могила – I фаза.

3.2. Foreseen investments

The first phase of the district heating project will cost EUR 46 337 000. German investment bank KfW has provided a EUR 39 million loan for this purpose to ESM with an interest rate of 1.5 per cent.[8] The cost breakdown is provided in table 1.

Table 1 – Phase 1 cost breakdowns

Costs	**EUR**	**Percentage of total budget**
Studies, design, expropriation	1 900 000	4
Construction works	29 787 000	64
Equipment	9 735 200	21
Consultants	964 000	2
Unforeseen costs	3 950 000	9
Sum	46 337 000	100

4. Analysis of alternative heating solutions

Analysing possible alternatives to the district heating network requires us to consider heating systems and technologies that are appropriate for the region. Our choice of systems and technologies that warrant detailed consideration and techno-economic analysis is based on preliminary research that looks at existing technologies, relevant fuels, the availability and quality of data, and the social and environmental context. The preliminary analysis included technologies and systems such as municipal waste incineration and heat recovery for electricity production, including agricultural biomass collection, selection and use; inverter heat pumps; and geothermal technologies as standalone solutions or as part of a fourth-generation district heating concept. The preliminary analysis included field visits to the three selected regions (Bitola, Mogila and Novaci) and resulted in the selection of systems and technologies for further analysis. A lack of data and poor data integrity (accuracy, completeness and consistency), as well as some technologies being inappropriate for the region, meant we considered only inverter heat pumps – either as standalone solutions or coupled with photovoltaic systems – to be viable alternatives to the proposed district heating system.

4.1. Input Data

This section presents the input data used to conduct the techno-economic analysis of the selected technologies. In most cases, readily available data from reliable databases (both domestic and

[8] Ministry of Finance of the Republic of North Macedonia, Потпишани договори за реализација на проектот за топлификација на Битола, *Ministry of Finance of the Republic of North Macedonia*, 29 December 2019.

international) were used. However, certain information that was missing from these databases was gathered through primary research.

Number of housing units and current heating systems

To determine the number of housing units by type (individual versus collective), the latest census data was used. However, as discussed in section 2, there is a discrepancy in the number of apartments in the municipality of Bitola, an issue that is further complicated by the fact that not all apartments are occupied or used. For that reason, only the 27,661 apartments that are actively used have been considered in this research, and the division of the number of apartments in collective housing versus the number of individual houses is based on various study approaches, including desktop analysis, field visits and publicly available data. In short, the 65 per cent occupancy rate means there are 27,661 used apartments, of which 24,342 are apartments in collective housing units, while 3,319 are individual houses.

As the latest census data does not provide any specific information about the number of collective housing buildings and individual houses, assumptions based on various research approaches allow us to estimate that there are 2,680 collective housing buildings, each with an average of 16 apartments with an area of 60 m^2 across four floors (including the ground floor). This is an estimate of the total number of apartments, not just occupied ones. There are 3,319 individual houses (with less than three floors) that have an average area of 100 m^2.

Determining the type of heating systems currently used in these municipalities had to be done using primary research, as such data is not available from the latest census data. The unstructured interviews with citizens of Bitola, Mogila and Novaci show that most individual houses use some type of biomass (wood) for heating, with some examples of hybrid heating oil and biomass systems, as well as biomass coupled with an air conditioning unit. However, in both cases, biomass was the primary heating source. For this reason, all of the individual houses are considered to use some form of a biomass heating system.

In collective housing units, electricity is the predominant energy source for heating purposes. Different types of electric heating devices are used, and 50 per cent of respondents stated that they use some form of a conventional radiation/convection heating system. Roughly 35 per cent of apartments use air conditioning systems, while the rest (15 per cent) use inverter air conditioning systems. Table 2 summarises the heating systems used by households in Bitola, Mogila and Novaci.

Table 2 – Heating systems by household

Heating system (source)	Number of households
Solid biomass-based heating system (wood)	3,319
Radiation/convection-based heating system (electricity)	12,171
Air conditioning units (electricity)	8,520
Inverter air conditioning units (electricity)	3,651

Solar radiation and photovoltaic potential

The geographical location of North Macedonia is favourable when it comes to using photovoltaic systems for electricity production. The region of Bitola, as shown in figure 5 below, has a specific yield of between 1,200 and 1,400 kilowatt hours / kilowatt peak (kWh/kWp). Specific yield is one of the most common performance metrics for solar systems, showing how much electrical energy (kWh) is produced for every kWp of photovoltaic capacity installed over the course of an actual year. When considering the installation of these systems, aside from the specific yield, the solar elevation and the solar azimuth angles need to be considered for the specified location. This data for the selected region is provided in figure 6.

To determine the actual electricity production from photovoltaic systems within the considered region, we use publicly available data from the Global Solar Atlas,[9] the US National Renewable Energy Laboratory (NREL)[10] and the European Photovoltaic Geographical Information System (PVGIS).[11] The optimal mounting angle for photovoltaic modules in this region is 33°.

Considering the solar radiation and the angle of the slope, for a theoretical photovoltaic system composed of modules with a total capacity of 6 kW, yearly energy production would be between 7,800 and 8,000 kWh (with a system loss of 14 per cent). Figure 7 shows the monthly average energy production, with July and December having the highest and lowest outputs respectively.

Figure 5 – Long-term average of annual totals of photovoltaic power potential

Source: Global Solar Atlas[12]

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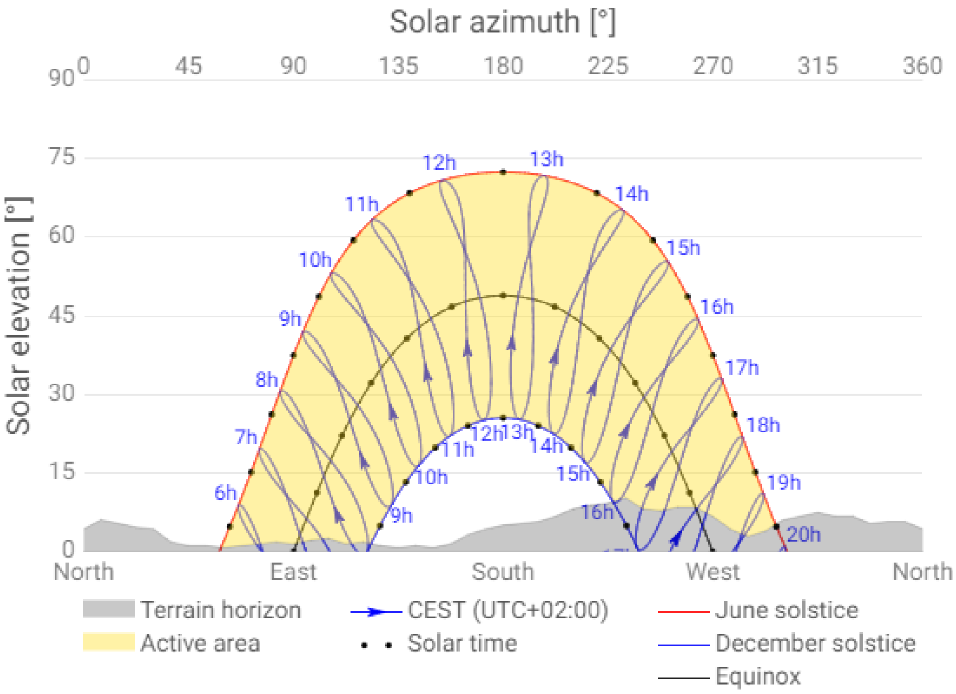
[9] World Bank, ESMAP, Solargis, Global Solar Atlas, accessed 18 November 2022.

[10] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy and the Alliance for Sustainable Energy, National Renewable Energy Laboratory, accessed 18 November 2022.

[11] European Commission, Photovoltaic Geographic Information System, *European Commission*, accessed 18 November 2022.

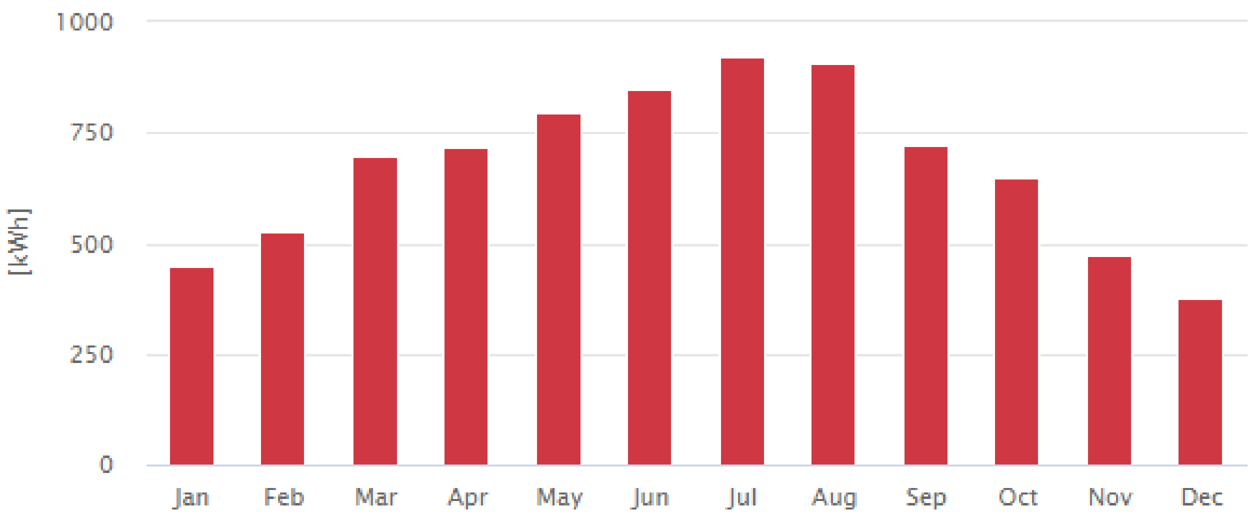
[12] World Bank, ESMAP, Solargis, Global Solar Atlas.

Figure 6 – Horizon and sun path



Source: Global Solar Atlas

Figure 7 – Monthly averages of power output (kWh)



Source: Global Solar Atlas

Focusing on the specific hour outputs of a photovoltaic system provides insight into the operation and management of the system and the possibilities of off-grid solutions. For the chosen region of Bitola and a theoretical photovoltaic system of 6 kW, figure 8 provides hourly profiles across the year.

Figure 8 – Average hourly outputs of a theoretical 6 kW PV plant (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					0	0	0					
5 - 6			0	0	0	0	0	0	0			
6 - 7		0	0	1	1	1	1	1	1	0	0	
7 - 8	0	1	1	2	2	2	2	2	2	1	1	0
8 - 9	1	2	2	2	3	3	3	3	2	2	2	1
9 - 10	2	2	3	3	3	3	3	3	3	3	2	2
10 - 11	2	3	3	3	3	4	4	4	3	3	2	2
11 - 12	2	3	3	3	3	4	4	4	3	3	3	2
12 - 13	2	3	3	3	3	3	4	4	3	3	2	2
13 - 14	2	3	3	3	3	3	3	3	3	2	2	2
14 - 15	2	2	2	2	2	2	3	3	2	2	1	1
15 - 16	1	1	1	1	2	2	2	2	1	1	0	0
16 - 17	0	0	1	1	1	1	1	1	1	0		
17 - 18			0	0	0	0	0	0	0			
18 - 19					0	0	0					
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	14	19	22	24	26	28	30	29	24	21	16	12

Source: Global Solar Atlas

In recent months, regulation changes in North Macedonia have enabled the installation of individual small-scale renewable energy systems (solar and wind) with an installed capacity behind the meter of up to 6 kW for households and up to 40 kW for companies.[13] Moreover, the government aims to subsidise 30 per cent of the cost of individual renewable energy power systems up to MKD 62 000 (approximately EUR 1 000) per household. To further promote the installation of small-scale renewable energy technologies, the government has also introduced the possibility for households and small consumers to become prosumers by selling the surplus energy they produce back to the grid. According to the latest documents that regulate this matter,[14] including the recent changes,[15] households will be paid for the excess electricity they produce according to the following formula:

[13] Government of the Republic of North Macedonia, Бектеши: Со новиот Правилник за обновливи извори создадовме услови секое домаќинство и деловен субјект да може да постави фотоволтаик на својот покрив и да ја продава произведената струја, *Government of the Republic of North Macedonia*, 15 June 2022.

[14] Ministry of Economy of the Republic of North Macedonia, Правилник за обновливи извори на енергија, *Ministry of Economy of the Republic of North Macedonia*, 30 October 2018.

[15] Ministry of Economy of the Republic of North Macedonia, Правилник за изменување и дополнување на правилникот за обновливи извори на енергија, *Ministry of Economy of the Republic of North Macedonia*, 15 June 2022.

C = PCE*0.9 if Ei >= Ep

C = PCE*0.9*Ei/Ep

Where:

Ei – total electricity (kWh) supplied to the prosumer by the supplier

Ep – total electricity (kWh) supplied to the network by the prosumer

PCE – average price (MKD/kWh) of electricity that the prosumer pays to the supplier for the purchased electricity, without compensation for using the network (network fee) and other fees and taxes

Electricity tariffs

Starting in July 2022, the Energy and Water Services Regulatory Commission of the Republic of North Macedonia introduced different blocks (levels) of high electricity tariffs for consumers on the regulated market (households) that are supplied by the universal supplier (as shown in table 3). Considering the looming energy crisis and the associated effects in terms of electricity price increases and lack of primary fuel for electricity production, the introduction of new levels of high electricity tariffs is intended to improve the efficiency of using domestic energy resources.[16]

Table 3 – Household electricity prices and intervals

Product	Price (MKD/kWh)	Monthly interval (kWh)
High tariff 1	4.3484	Up to 210
High tariff 2	4.7017	211-630
High tariff 3	5.2877	631-1,050
High tariff 4	14.1025	Above 1,050
Low tariff	0.6193	/

Source: Energy and Water Services Regulatory Commission of the Republic of North Macedonia[17]

Aside from the introduction of the different blocks (levels) within the high tariff system, the new regulation also separated the transportation and distribution costs from the electricity tariff, outlining them as separate elements with their unique price. The current transportation and distribution costs for households is 3.3742 MKD/kWh.

[16] Energy and Water Services Regulatory Commission of the Republic of North Macedonia, Нов тарифен систем за универзалениотснабдувач, *Energy and Water Services Regulatory Commission of the Republic of North Macedonia*, 27 June 2022.

[17] Energy and Water Services Regulatory Commission of the Republic of North Macedonia, Цени: електрична енергија, *Energy and Water Services Regulatory Commission of the Republic of North Macedonia*, accessed 18 November 2022.

Heat consumption profiles

One important aspect that needs to be considered when analysing heat supply technologies and systems is monthly and yearly consumption profiles. According to the analysis conducted by the Energy and Water Services Regulatory Commission of the Republic of North Macedonia, a 60 m^2 apartment would need on average 6,480 kWh of energy for heating.[18] Monthly heat consumption is provided in table 4 below.

Table 4 – Monthly heat consumption as a percentage of total yearly heat consumption

Month	Percentage of yearly heat consumption
October	10
November	13
December	27
January	27
February	13
March	10

4.2. Alternative heating systems

Analysing possible alternative heating systems for both individual and collective housing requires different input data that is not always available. As this research considers two main technologies that would constitute the heating systems for the analysed regions – inverter heat pumps with a coefficient of performance (COP) of 4 coupled with a photovoltaic system – the initial analysis finds that the investment cost of inverter heat pumps with two internal units per apartment in collective housing would be EUR 1 000, whereas for individual houses, an inverter heat pump with three internal units would cost EUR 1 500 per house. Photovoltaic installation would cost EUR 1 000 per kW. Electricity consumption for heating is modelled as a 90/10 per cent profile across the high/low electricity tariffs, whereas other monthly electricity consumption taken as 300 kWh for apartments and 450 kWh for houses is modelled as a 70/30 percent profile across the high/low electricity tariffs. The roof area of collective housing units is considered to be only half usable for installing photovoltaic systems (making the maximum theoretical photovoltaic capacity 24 kW)[19], whereas for individual houses, the 6 kW limit for individual small renewable energy installations is considered. The PCE (average electricity price supplied to the prosumer by the supplier as shown in section 4.1) is considered to be 48 EUR/MWh.[20] Moreover, the analysis considers that every household, regardless

[18] Note: does not correspond to the electricity consumption for heating

[19] The analysis considers photovoltaic modules of 5 m^2/kW

[20] Орце Костов, 'И Ковачевски и ЕВН согласни: Струја по сегашната цена само до Нова година', *A1on*, 6 September 2022.

of whether it is part of a collective housing unit or an individual house, will use the proposed heating systems.

Results of the analysis

The analysis was conducted by considering monthly values of consumption and costs, despite the six-month heating season. This means that heating costs are spread across 12 months, as is the case with billing for district heating in Skopje. The following tables show the results of the analysis by considering the two heating systems for the two general types of housing: apartments of 60 m^2 and houses of 100 m^2. Apartments in collective housing units are considered to be constituents of the type of legal entity that is allowed to install up to 40 kW of renewable energy capacity with the costs and potential earnings being shared equally.

Table 5 – Results for inverter heat pump systems

	Apartment	House
Yearly heat consumption (kWh)	6,840	10,260
Monthly electricity for heating (kWh)	142.5	213.75
90 per cent of electricity consumption for heating in high tariff (kWh)	128.25	192.38
10 per cent of electricity consumption for heating in low tariff (kWh)	14.25	21.38
Other monthly electricity in high tariff (kWh)	210	315
Other monthly electricity in low tariff (kWh)	90	135
Total monthly electricity consumption (kWh)	442.5	663.75
Monthly distribution cost (MKD)	1 491	2 237
Monthly electricity costs without distribution (MKD)	1 579	2 406
Monthly electricity + distribution costs (MKD)	3 070	4 643
VAT (5 per cent) (MKD)	153.5	232.15
Air conditioner inverter installation cost per apartment/house (MKD) per month for 10 years	500	750
Total monthly electricity costs (MKD)	**3 723.5**	**5 625.15**

Table 6 – Results for inverter heat pump system coupled with a photovoltaic system

	Apartment	House
Roof area (m^2)	120	100
Photovoltaic module (kW)	24	6
Photovoltaic installation costs per apartment/house (MKD)	92 250	369 000
Photovoltaic installation costs per apartment/house (MKD) per month for 10 years	768.75	3075
Air conditioner inverter installation cost per apartment/house (MKD)	60 000	90 000
Air conditioner inverter installation cost per apartment/house (MKD) per month for 10 years	500	750
Monthly production (kWh)	2,619.08	654.75
Monthly production (kWh) per apartment/house	163.69	654.75
Remuneration per kWh (MKD/kWh)[21]	2.6568	2.66
Monthly income from sold electricity per household (MKD)	434.90	1739.54
Monthly electricity costs + monthly photovoltaic and inverter air conditioning installation cost (MKD)	4 492.25	8 700.15
Total monthly costs (MKD)	**4 057.35**	**6 960.61**

The results suggest that after a 10-year period in which heating systems with an inverter heat pump coupled with a photovoltaic system have been paid off, the total monthly costs for electricity will drop to MKD 2 789 for apartments and MKD 3 135 for houses (if all considered elements remain the same).

4.3. Analysis of possible scenarios

The aim of this section is to outline different scenarios and identify the most favourable one, taking into account expected rises in electricity prices and possible government subsidies by analysing heating systems that use an inverter heat pump coupled with a photovoltaic system. The table below shows the total monthly costs for apartments and houses comparing different scenarios with the baseline: using an inverter heat pump for heating.

[21] Considering C = PCE*0.9 as shown in section 4.1

Table 7 – Analysis of scenarios

Scenarios	Total monthly costs (MKD) [EUR]	
	Apartment	*House*
Scenario 0 (baseline): → inverter heat pump → no photovoltaic system	3 723.50 [60.5]	5 625.15 [91.5]
Scenario 1: → inverter heat pump → photovoltaic system → C = EUR 48 /MWh → no government subsidy for the heating system	4 057.35 [66]	6 960.61 [113.2]
Scenario 2: → inverter heat pump → photovoltaic system → C[22] = EUR 60 /MWh → no government subsidy for the heating system	3 948.63 [62.2]	6 525.73 [106.1]
Scenario 3: → inverter heat pump → photovoltaic system → C = EUR 48 /MWh → 30 per cent government subsidy for the heating system	3 676.73 [59.8]	5 813.11 [94.5]
Scenario 4: → inverter heat pump → photovoltaic system → C = EUR 60 /MWh → 30 per cent government subsidy for the heating system	3 568 [58]	5 378.23 [87.5]
Scenario 5: → inverter heat pump	3 314.25 [53.9]	4 613.23 [75]

[22] C = PCE

→ photovoltaic system → C = EUR 60 /MWh → 50% government subsidies for the heating system		
Scenario 6: → inverter heat pump → photovoltaic system → C = EUR 60 /MWh → 50 per cent government subsidies for the heating system	3 253.85 [52.9]	4 371.62 [71]

The results suggest that there are several favourable scenarios that provide a 10-year period of 'shock absorption' for price fluctuations and a considerable decrease in monthly costs after this period. As such, investment in individual heating systems composed of an inverter heat pump coupled with a photovoltaic system can easily be regarded as a suitable heating alternative to the proposed district heating solution, considering the price stabilisation and protection that this system provides compared to the fossil fuel dependency of the planned large-scale heating project.

4.4. Environmental and social impact of the alternative heating system

The proposed coupling of inverter air-to-air heat pumps with solar photovoltaic systems will have various positive environmental and social impacts, both at societal (macro) and individual (micro) levels. Among the many positive influences, one can expect that the implementation of the proposed system will enable:

- Greater citizen participation in the energy transition, which is recognised as one of the pillars for successfully transitioning to low-carbon societies.
- Increased local energy production, minimising energy imports and improving energy independence.
- Decreased emissions from fossil fuels, both in terms of using coal or natural gas at REK Bitola and using biomass at household levels.
- Increased renewable energy capacity, which directly supports the country's decarbonisation efforts and energy strategy.
- Increased local supply chains, enabling local companies to become part of the installation, operation and maintenance processes.
- Increased labour market opportunities for local technical installation and maintenance companies.
- Increased household comfort due to improved heating distribution across multiple indoor units.
- Protection from energy price fluctuation, which further eases and improves long-term strategy and policy planning.

- Decreased household exposure to price fluctuations, which improves household income security.
- The possibility of introducing innovative business models based on decentralised and citizen-controlled resources.

5. The potential for setting up energy communities in Bitola

5.1. Research rationale

Changing the respective regulation to allow citizens and legal entities to install small-scale individual renewable energy systems is the first step towards enabling a range of stakeholders to contribute to the energy transition and support North Macedonia's government in its decarbonisation efforts. As part of a positive contribution towards the transition,[23] citizens, institutions and businesses can greatly help when it comes to the deployment of renewable energy technologies and the production of low-carbon electricity. Increased policy support backed by cheaper technologies gives greater agency to individuals and groups of prosumers to take varied forms of actions. One way prosumers can increase their role and impact is by taking collective action and forming energy communities. This section of the report provides the techno-economic rationale for enabling such collective practices to become a reality in the context of North Macedonia by changing the respective policies and regulations and introducing support mechanisms that will quickly boost the number of renewable energy communities in the country.

5.2. Researched locations for energy community projects

Within the analysed context, field visits were conducted in several areas of the municipality of Bitola. These locations were chosen due to their composition and the overall geographical positioning of the buildings, which contributes to forming natural building clusters. A primary research approach in the form of an observational study was adopted to analyse the chosen locations, enabling the researcher to determine the following aspects of the identified building clusters:

- Composition of the building stock
- Average distance between different types of housing units
- Number of floors of different types of housing units
- Presence of small-scale individual renewable energy technologies

[23] European Environment Agency, Citizens can contribute to Europe's energy transition, *European Environment Agency*, 1 September 2022.

Table 8 – Characteristics of analysed quarters and parts of Bitola

Municipality of Bitola quarter/part	Share of individual/collective housing (percentage)	Most frequent floor count of individual housing	Most frequent floor count of collective housing	Distinctive buildings	Presence of photovoltaic/wind technologies
Mogila	100/0	GF + 1	N/A	Storage facilities, municipal building	No
Brusnichka	10/90	GF + 2	GF + 3	N/A	No
Lavchanska	10/90	GF + 2	GF + 3	N/A	No
Bukovski Livadi	20/80	GF + 2	GF + 3	Elementary school	No
Bukovo	100/0	GF + 2	N/A	Elementary school	No
Strelishte	50/50	GF + 2	GF + 3	Elementary school	No
Strezhevska	10/90	GF + 2	GF + 3	N/A	No
Novaci	100/0	GF + 2	N/A	Storage facilities, municipal building	No

The analysis of the selected quarters shows that most people live in collective housing units with four floors, with no installed renewable energy capacities, aside from occasional domestic hot water solar thermal installations. When considering the development of a theoretical energy community project, a location dominated by individual housing units should be selected, so as to minimise the issues and costs associated with multiple smart meters.

5.3. Techno-economic feasibility of an energy community in the municipality of Bitola

A theoretical location in the municipality of Bitola that shares the same characteristics as the analysed quarters from the previous table was selected. The most important condition was the number of individual housing units and the number of smart meters found in these houses. The modelled energy community considers 10 individual houses and 10 smart meters, and the share of heat consumption per month is the same as in the previous example. The following table provides the details of energy consumption (both heat and electricity) for a single individual house, as determined in the previous sections using the shares of heat consumption by month [24] provided by the Energy and Water Services Regulatory Commission of the Republic of North Macedonia.

Table 9 – Modelled electricity consumption for a single house

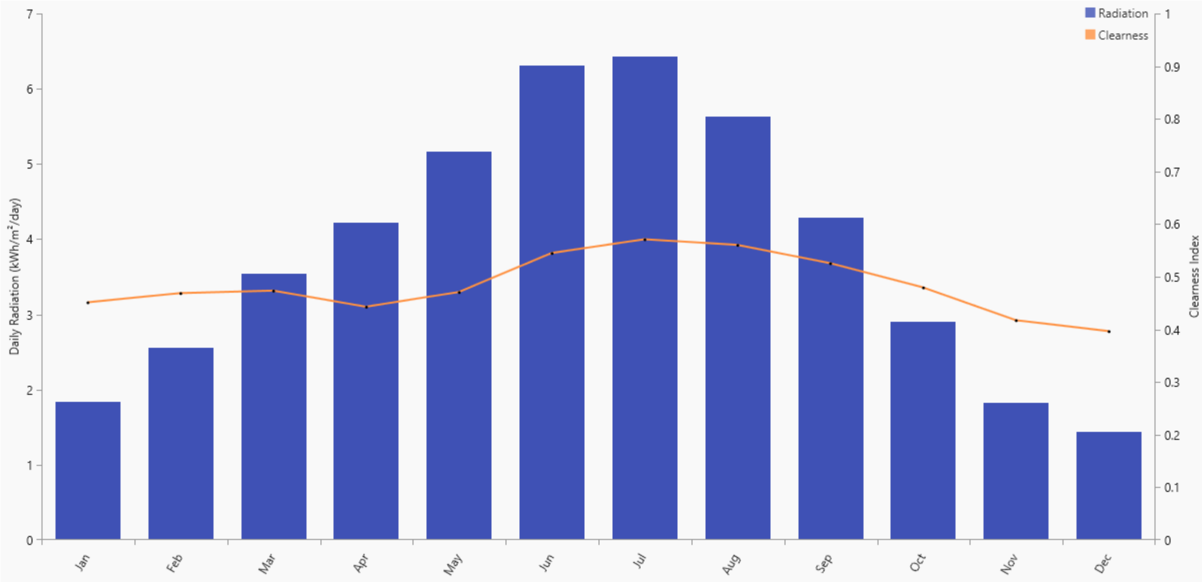
Month	Share of heat consumption by month (percentage)	Heat consumption (kWh)	Electricity consumption for heating[25] (kWh)	Electricity consumption for cooling (kWh)	Other electricity consumption (kWh)	Total monthly electricity consumption (kWh)
January	27	2,770	693	0	450	1,143
February	13	13,334	333	0	450	783
March	10	1,026	257	0	450	707
April	0	0	0	0	450	450
May	0	0	0	0	450	450
June	0	0	0	150	450	600
July	0	0	0	300	450	750
August	0	0	0	300	450	750
September	0	0	0	150	450	600
October	10	1,026	257	0	450	707
November	13	13,334	333	0	450	783
December	27	2,770	693	0	450	1,143

The analysis of the 10-house energy community was performed using HOMER grid optimisation software. The monthly average solar global horizontal irradiance figure is taken from the NASA Prediction of Worldwide Energy Resource (POWER) database, while the following figure outlines irradiance and the clearance index for Bitola.

[24] Energy and Water Services Regulatory Commission of the Republic of North Macedonia, Нов тарифен систем за универзалениотснабдувач.

[25] COP = 4

Figure 9 – Monthly average solar global horizontal irradiance data



The analysis of a theoretical energy community considers four scenarios that include different costs associated with the excess electricity produced by the community and paid for by the universal supplier, as well as a number of energy technology components. One important aspect is that all four scenarios have a 90 per cent share of renewables in their energy/electricity mix, meaning that the other 10 per cent is supplied by the universal supplier. Below are the four scenarios, along with their technical components, monthly electricity production, associated electricity prices and monthly community electricity costs (costs for the whole community composed of 10 individual houses).

Scenario 1 (90 per cent renewable energy)

Table 10 – Scenario 1: technical components and characteristics

Component	**Number of components**	**Total cost (MKD)**
Generic flat-plate photovoltaic (1 kW)	15	1 107 000
Generic lithium ion storage (1 kWh)	0	0
System converter (1 kW)	0	0
Total investment cost (MKD) [EUR]	1 107 000 [18 000]	

Figure 10 – Scenario 1: monthly electricity production

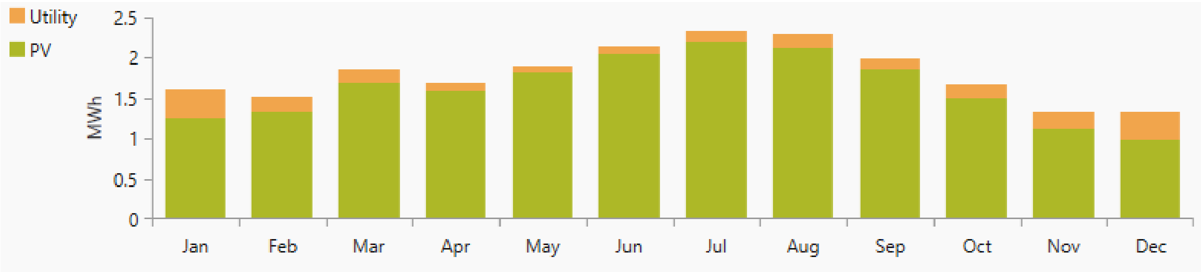


Table 11 – Scenario 1: electricity prices

Type of product	Cost (MKD/kWh)
Utility electricity cost	7.5[26]
Excess electricity cost sold to the network	2.95
Levelised cost of electricity over 25 years	2.67

Table 12 – Scenario 1: monthly community electricity costs

Month	Community electricity purchase (kWh)	Community net electricity purchase (kWh)	Community electricity cost (MKD)
January	345	-723	-562
February	185	-1,001	-2 108
March	174	-1,339	-3 159
April	93	-1,382	-3 655
May	81	-1,607	-4 372
June	99	-1,764	-4 754
July	136	-1,849	-4 837
August	157	-1,762	-4 484
September	135	-1,582	-4 052
October	173	-1,163	-2 643
November	216	-755	-1 244
December	349	-441	288

[26] Calculated as total electricity costs divided by total electricity consumption for the modelled type of house (taken from table 5 without considering the cost of the inverter heat pump).

Scenario 2 (90 per cent renewable energy)

Table 13 – Scenario 2: technical components and characteristics

Component	# of components	Total cost (MKD)
Generic flat-plate photovoltaic (1 kW)	15	1 107 000
Generic lithium ion storage (1 kWh)	0	0
System converter (1 kW)	0	0
Total investment cost (MKD) [EUR]	1 107 000 [18 000]	

Figure 11 – Scenario 2: monthly electricity production

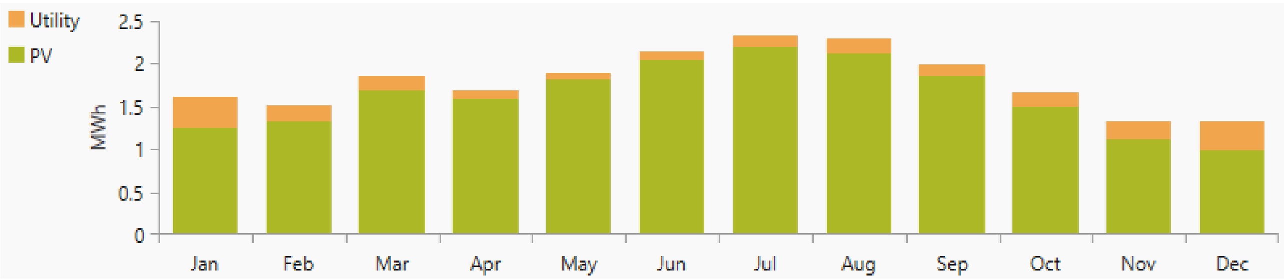


Table 14 – Scenario 2: electricity prices

Type of product	Cost (MKD/kWh)
Utility electricity cost	7.5[27]
Excess electricity cost sold to the network	3.69
Levelised cost of electricity over 25 years	2.07

[27] Calculated as total electricity costs divided by total electricity consumption for the modelled type of house (taken from table 5 without considering the cost of the inverter heat pump).

Table 15 – Scenario 2: monthly community electricity costs

Month	Community electricity purchase (kWh)	Community net electricity purchase (kWh)	Community electricity cost (MKD)
January	345	-723	-1 353
February	185	-1,001	-2 986
March	174	-1,339	-4 279
April	93	-1,382	-4 746
May	81	-1,607	-5 621
June	99	-1,764	-6 133
July	136	-1,849	-6 305
August	157	-1,762	-5 903
September	135	-1,582	-5 323
October	173	-1,163	-3 631
November	216	-755	-1 963
December	349	-441	-296

Scenario 3 (90 per cent renewable energy)

Table 16 – Scenario 3: technical components and characteristics

Component	# of components	Total cost (MKD)
Generic flat-plate photovoltaic (1 kW)	15	1 107 000
Generic lithium ion storage (1 kWh)	0	0
System converter (1 kW)	0	0
Total investment cost (MKD) [EUR]	1 107 000 [18 000]	

Figure 12 – Scenario 3: monthly electricity production

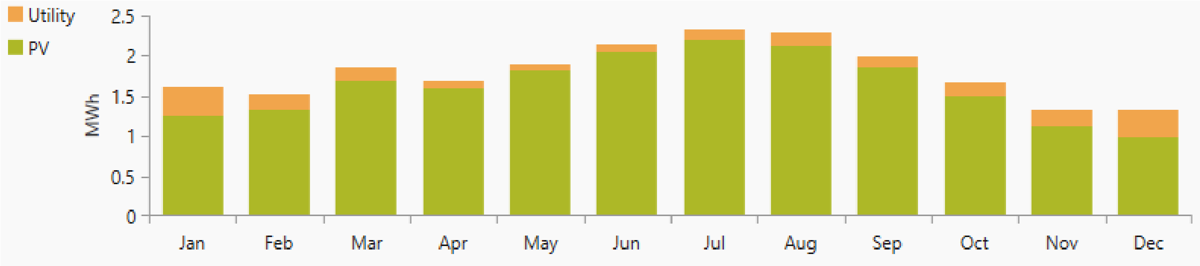


Table 17 – Scenario 3: electricity prices

Type of product	Cost (MKD/kWh)
Utility electricity cost	7.5[28]
Price for excess electricity sold to the network	4.35[29]
Levelised cost of electricity over 25 years	1.54

Table 18 – Scenario 3: monthly community electricity costs

Month	Community electricity purchase (kWh)	Community net electricity purchase (kWh)	Community electricity cost (MKD)
January	345	-723	-2 058
February	185	-1,001	-3 769
March	174	-1,339	-5 277
April	93	-1,382	-5 719
May	81	-1,607	-6 735
June	99	-1,764	-7 363
July	136	-1,849	-7 615
August	157	-1,762	-7 169
September	135	-1,582	-6 456
October	173	-1,163	-4 513
November	216	-755	-2 604
December	349	-441	-818

[28] Calculated as total electricity costs divided by total electricity consumption for the modelled type of house (taken from tab le 5 without considering the cost of the inverter heat pump).

[29] Price for the excess electricity to be equal to the lowest level/category of high electricity tariffs for the regulated market in North Macedonia.

Scenario 4[30] (90 per cent renewable energy)

Table 19 – Scenario 4: technical components and characteristics

Component	# of components	Total cost (MKD)
Generic flat plate photovoltaic (1 kW)	36	2 592 000
Generic lithium ion storage (1 kWh)	1	60 000
System converter (1 kW)	1	15 000
Total investment cost (MKD) [EUR]	2 667 000 [43 365.9]	

Figure 13 – Scenario 4: monthly electricity production

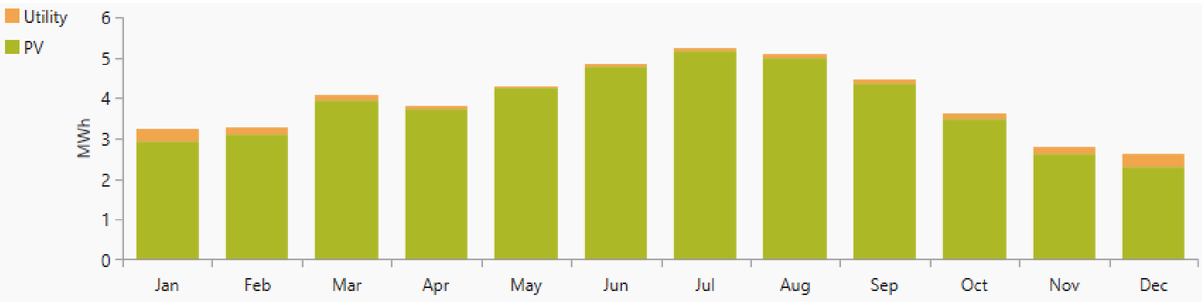


Table 20 – Scenario 4: electricity prices

Type of product	Cost (MKD/kWh)
Utility electricity cost	7.5[31]
Levelised cost of electricity over 25 years	-1.76

Table 21 – Scenario 4: monthly community electricity costs

Month	Community electricity purchase (kWh)	Community net electricity purchase (kWh)	Community electricity cost (MKD)
January	309	-2,404	-18 026
February	163	-2,776	-20 818

[30] This scenario considers net metering.

[31] Calculated as total electricity costs divided by total electricity consumption for the modelled type of house (taken from tab le 5 without considering the cost of the inverter heat pump).

March	145	-3,588	-26 908
April	68	-3,509	-26 315
May	52	-4,037	-30 275
June	66	-4,497	-33 725
July	97	-4,795	-35 960
August	127	-4,611	-34 581
September	105	-4,071	-30 533
October	148	-3,156	-23 674
November	188	-2,239	-16 794
December	312	-1,748	-13 110

Table 22 – Summary of scenario results

Cost/Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Utility electricity cost (MKD/kWh)	7.5	7.5	7.5	7.5
Excess electricity cost sold to the network (MKD/kWh)	2.95	3.69	4.35	7.5
Levelised cost of electricity for the next 25 years (MKD/kWh)	2.67	2.07	1.54	-1.76
Total investment cost (MKD) [EUR]	1 107 000 [18 000]	1 107 000 [18 000]	1 107 000 [18 000]	2 667 000 [43 365.9]

5.4. Municipal energy community

To determine the heat consumption of public institutions (municipal buildings, kindergartens, primary and secondary schools) in the municipality of Bitola, a freedom of information request was used to gain insight into heating costs per heating season, including the type of heat source and technology used in each public institution.

Table 23 – Volume of heating oil contracted for Bitola institutions (2020-2021)

Public institution	Heating oil
JOUDG Estreja Ovadija Mara	75,000
JOUDG Majski Cvet	50,000
Opshtina Bitola	50,000
OOU Aleksandar Turundziev	20,000
OOU Gjorgji Sugarev	50,000
OOU Goce Delchev	45,000
OOU Dame Gruev	44,000
OOU Elpida Karamandi	40,000
OOU Krste Petkov Misirkov	26,000
OOU Sv Kliment Ohridski	61,000
OOU Kole Kaninski	66,800
OOU Stiv Naumov	20,000
OOU Todor Angelevski	42,000
OOU D-r Trifun Panovski	10,000
SOEU Jane Sandanski	26,000
SOZU Kuzman Shapkarev	25,000
SOU Taki Daskalo	50,000
SOU Gimnazija Josip Broz Tito	30,000
SOTU Gjorgji Naumov	40,000

Source: Extracted from the e-market platform[32]

[32] Електронски систем за јавни набавки, Известување за склучен договор за јавна набавка, *E-nabavki*, accessed 18 November 2022.

The limited answers obtained through this approach had to be complemented by researching publicly available contracts on the e-market platform. A summary of the analysis of the contracts and the information obtained from the municipality (the number of institutions and heating oil consumption) is presented in table 23.

Heating oil consumption was used as the basis for calculating heat consumption across the above-listed institutions, assuming that the oil furnaces used were 70 per cent efficient. The analysis shows that public institutions in the municipality of Bitola consume 6,496,302 kWh of heating energy per heating season. The table below provides details of the electricity consumed by heating and assumptions of electricity consumption for other purposes.

Table 24 – Modelled electricity consumption for the municipal institutions

Months	Share of heat consumption per month (percentage)	Electricity consumption for heating (kWh)	Other electricity consumption (kWh)	Total monthly electricity consumption (kWh)
January	27	438,500	5,000	443,500
February	13	211,130	5,000	216,130
March	10	162,408	5,000	167,408
April	0	0	5,000	5,000
May	0	0	5,000	5,000
June	0	0	5,000	5,000
July	0	0	5,000	5,000
August	0	0	5,000	5,000
September	0	0	5,000	5,000
October	10	162,408	5,000	167,408
November	13	211,130	5,000	216,130
December	27	438,500	5,000	443,500

The analysis shows that using renewable energy technologies (solar photovoltaic systems) to form a municipal energy community is a feasible techno-economic option, considering the public institutions' hours of operation, which coincide with periods of increased solar intensity. Moreover, the optimisation results show that this municipal energy community might be able to reach more than a 99.7 per cent share of renewable energy, decreasing its overall energy reliance on the national grid. In the end, implementing a municipal energy community will strengthen the municipality's independence and will enable the implementation of other strategic projects across the region.

Table 25 – Technical components and characteristics

Component	# of components	Total cost (MKD)
Generic flat-plate photovoltaic (1 kW)	108	7 776 000
Generic lithium ion storage (1 kWh)	0	0
System converter (1 kW)	0	0
Total investment cost (MKD) [EUR]	7 776 000 [126 439]	

Figure 14 – Monthly electricity production

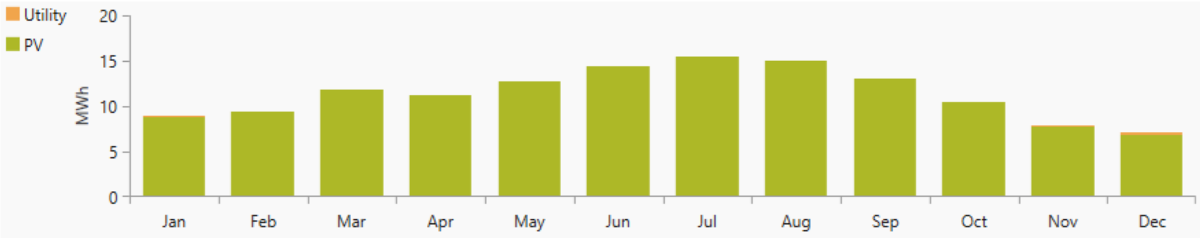


Table 26 – Electricity prices

Type of product	Cost (MKD/kWh)
Utility electricity cost	7.5[33]
Levelised cost of electricity over 25 years	-2.48

Table 27 – Monthly electricity costs

Month	Electricity purchase (kWh)	Net electricity purchase (kWh)	Community electricity cost (MKD)
January	175	-7,808	-58 560
February	21	-8,835	-66 263
March	0	-11,339	-85 046
April	0	-11,152	-83 643
May	0	-12,737	-95 527
June	0	-14,321	-107 404

[33] With net metering

July	0	-15,441	-115 808
August	0	-14,935	-112 009
September	0	-13,049	-97 866
October	4	-10,071	-75 529
November	54	-7,271	-54 535
December	204	-5,737	-43 031

5.5. Environmental and social impact assessment

The proposed establishment of a municipal energy community would have various positive environmental and social impacts, not only at societal (macro) and municipal (meso) levels, but also at individual (micro) levels. Among the many positive influences, one can expect that the implementation of the proposed municipal energy community will enable:

- Greater municipal participation in the energy transition, which is recognised as one of the pillars for successfully transitioning to low-carbon societies.
- Increased local energy production, minimising energy imports and improving the municipality's energy independence.
- Decreased emissions from fossil fuels (heating oil), which are currently used for heating across the municipal institutions.
- Increased renewable energy capacity in the municipality, which directly supports the country's decarbonisation efforts and energy strategy.
- Increased labour market opportunities for local technical installation and maintenance companies in the region.
- Increased office and workplace thermal comfort due to improved heating distribution across multiple indoor units, which is expected to have a positive impact on productivity.
- Protection from energy price fluctuation, which further eases and improves long-term strategy planning.

6. Recommendations

To the national authorities:

- Remove the 10 per cent decrease of the remuneration equation and make sure the price paid to prosumers is at least the lowest level of the high electricity tariff.
- Introduce net metering.
- Simplify the photovoltaic system registration process and speed up connections to the grid.

- Enable collective residential buildings to have the option to use renewable energy solutions for heating purposes in addition to other services (elevators, lighting).
- Enable individual investments in medium and large collective renewable energy projects.
- Empower municipalities to form energy communities.
- Enable citizens to form energy communities.
- Establish a national electricity market.
- Establish the national Energy Efficiency Fund which can be used as the main pillar of financing for the transition of household heating systems from existing non-efficient, unsustainable and polluting systems to clean, renewable and energy efficient systems.

To the local authorities:

- Adopt an action plan to convert the heating systems of all public institutions in the municipalities of Bitola, Novaci and Mogila to inverter air conditioning paired with photovoltaic systems, either individually or as an energy community. The plan has to include a timetable for implementation and sources of financing.
- Establish support schemes for the installation of inverter air conditioning units paired with photovoltaic systems for households.
- Establish a grant programme for the installation of inverter air conditioning units paired with photovoltaic systems in energy poor and low income households.

To the citizens of the Bitola, Novaci and Mogila municipalities:

- The medium and high income households should proactively make decisions regarding their heating solutions, opting for systems based on renewable energy sources with the highest energy and financial savings and least impact on the environment.
- Request that the local and national authorities simplify the administrative procedures and establish support schemes for clean, renewable and energy efficient heating solutions for households.
- Request that the local and national chambers of commerce provide a list of authorised and certified companies for the installation of photovoltaic systems.

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