DEVELOPMENT AND EVALUATION OF A STRATEGY FOR MACEDONIAN ENERGY TRANSITION

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Abstract: This paper analyzes the possibility of energy transition in Macedonia within the framework of the energy development strategy up to 2040. Namely, a detailed review of the current state of the Macedonian energy system is provided. Additionally, the analysis takes into account the early effect of COVID-19 on the consumption in the energy system, which is reflected on the projections of the macroeconomic parameters and energy demand in different sectors. Global trends, as well as policies and measures at European level were taken into account while planning the development of the energy system, with a special attention to the Energy Community guidance. For that purpose, three scenarios were defined: reference, moderate transition and green scenario. A methodology which integrates two modeling tools MARKAL and EnergyPLAN was developed. In that regard, the pathways presented in this paper follow good EU practices of renewable energy sources and energy efficiency policies, as well as decarbonisation, taking into consideration targets and trajectories with realistic dynamics that are adjusted to domestic specifics and priorities. The results show reduction of energy consumption, and GHG emissions while increasing GDP and increasing the share of renewable energy sources, which will enable the import dependence not to increase from the 2019 level. These results can be achieved at a cost of the energy system which is lower compared to the price in a scenario in which there are smaller investments in energy efficiency and RES.
Key words: Energy transition, Macedonia, Renewable energy sources, power plants

1. INTRODUCTION

Climate change threats and the need to save resources are one of the main drivers for fostering energy transition everywhere in the world, including Europe. In response, the European Commission in 2019 announced its plan to address such challenges, namely the Green Deal. This plan aims to transform Europe “into a modern, resource-efficient and competitive economy, ensuring: no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use, no person and no place left behind. Additionally, this plan is considered to help deal with the Covid-19 pandemic, as one third of the investments in the NextGenerationEU Recovery Plan and the seven-year EU budget will fund this green agreement. Almost two years after the announcement of the green agreement, EU published a report on the progress towards the energy transition. This report shows promising trends, such as that renewables overtook fossil fuels as the number one power source in the EU for the first time in 2020, generating 38% of electricity, compared to 37% for fossil fuels [1]. However, although in 2020 the total GHG emission savings are 31% compared to 1990 (10% decrease in emissions compared to 2019), to achieve the goal of 55% emission reduction by 2030 and climate neutrality in 2050, such as under the green agreement, more efforts will have to be made. The current spikes in energy prices around the world, mainly caused by the increased gas price, although expected to be temporary, further emphasize the importance of the energy transition, which will improve energy security, not allowing increase in the energy import. The challenge of achieving Europe's climate neutrality by 2050 has also attracted much attention in the literature. Namely, in [2] analyzes which policies, technological developments and societal attitudes can realize the green agreement, analyzing several different scenarios. Another, interesting approach has been applied in [3] which also analyzes possible paths for climate neutrality by 2050, but shows that a sustainable climate neutral energy system in the EU is feasible using well-known technologies, primarily through renewables, energy efficiency and electrification. Other studies show the role that certain technologies, such as photovoltaics, can play in successfully meeting Europe's climate ambitions [4]. Analyzes towards climate neutrality are also done at the country level by the countries in Europe, such as the analyzes in [5] for the German energy transition, in [6] for Italian energy transition, in [7] which compares the France and Sweden systems for guiding the future energy transition, etc. And the countries that are not members of the EU, but are members of the Energy Community (EnC) whose key objective is to extend the EU internal energy market rules and principles to countries in South East Europe, the Black Sea region and beyond, make various analyzes of the possibilities for following these European trends. For example, for a vision of transition from a lignite-based energy system is presented in [8] where as a case study Serbia is analyzed, the decarbonization of the residential building sector of Serbia is analyzed is [9], and [10] analyzes the electricity production from renewable energy sources in the Western Balkans.

The Republic of North Macedonia is also a Contracting Party of the Energy Community (EnC) and a country that has begun the process of EU pre-accession. Additionally, Macedonia as a non-Annex I party to the United Nations Framework Convention on Climate Change (UNFCCC) has signed in 2015 and ratified in January 2018 the Paris Agreement, which is the leading and most important legally binding international document on climate change. As a non-Annex I party, North Macedonia does not have quantified commitments, but despite this fact, it is voluntarily attempting to incorporate Annex I principles as much as possible.

Therefore, a reliable, efficient, environmentally friendly and competitive energy system that is able to stimulate the sustainable economic growth is the vision of the development of North Macedonia, which foresees reduction of energy consumption, but at the same time increasing GDP and increasing the share of renewable energy sources. However, the way, but also the pace at which such a vision can be achieved needs to be explored. Therefore, it is necessary to develop different models and simulations, including different technologies on the generation and consumption side in order to understand the alternatives for the future development of energy systems. Such alternatives, packaged in different scenarios, allow policy makers to assess the effects of taking certain actions and the direction in which such decisions will lead.

This is exactly the purpose of this paper, to make an analysis of the possibilities for energy transition in Macedonia within the framework of the energy development strategy up to 2040 [11], [12]. The results show reduction of energy consumption by 27%, but at the same time increasing GDP and increasing the share of renewable energy sources from the current 18% to 45% in 2040. This will allow the import dependence not to increase compared to the 2019 level. The predicted transformation of the energy sector also contributes to a reduction of greenhouse gas emissions from the energy sector by 55% in 2040 compared to the emissions in 1990. All this can be achieved at the cost of the energy system which is lower compared to the price in a scenario in which there are smaller investments in energy efficiency and RES.

2. MACEDONIAN ENERGY SECTOR

In order to be able to create scenarios for energy development that will incorporate appropriate policies that meet the national conditions, it is necessary to make a detailed review of the current state of the Macedonian energy system as well as the trends from the previous period.

Historical data on primary energy consumption in Macedonia in the period 2005-2019 show a significant change in the distribution of different fuels Figure 1. Until 2014, the share of coal dominates in the mix of primary energy. The reduction of electricity production from thermal power plants (TPPs) leads to this significant reduction in coal consumption, whose share of 50%, decreases to about 35% in the period after 2015. Variations in coal consumption are also due to the production of electricity from renewable energy sources, primarily hydropower plants (HPPs). Additionally, with the reduction of coal consumption, the total consumption of primary energy decreases, with the average consumption in the period 2005-2014 being 2.92 Mtoe, and in the period 2015-2019, decreasing by about 8% and amounting to 2.7 Mtoe.

Consumption of natural gas recorded the largest increase in the analyzed period, and in 2019 is about 4 times higher compared to 2005. The import of electricity is mainly constant during the entire analyzed period, with the exception of the last three years, primarily due to the non-operation of some industrial capacities, which mainly uses electricity from imports.

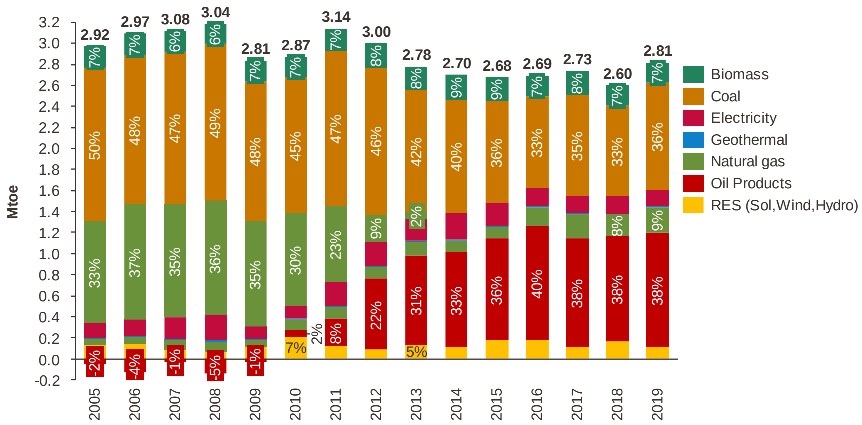

Figure 1. Primary energy consumption

The final energy consumption in 2019 has increased by about 11% compared to 2005, but in the period from 2012-2018 it is almost constant and is around 1.85 on average. What is most noticeable is the drastic increase in diesel consumption, which in 2019 is almost double compared to 2005. The increase is most noticeable after 2012, because of the allowing of import of used vehicles. On the other hand, there is a noticeable decrease in heavy fuel oil (HFO) consumption, which is three times lower in 2019, compared to 2005. A big change in the distribution of final consumption by sectors can be noted. On the one hand, there is a drastic increase in consumption in the Transport sector, which corresponds to the increase in diesel consumption. On the other hand, there is a drastic reduction in the final energy consumption in the Industry, because of the implementation of environmental standards.

Regarding the production of electricity, in the analyzed period a significant change can be noticed in the share of different production technologies (Figure 2). Namely, in 2005, 64% of the production was from thermal power plants, 17% from hydropower plants, and the rest was from imports. On the other hand, in 2019, with the construction of natural gas fired CHP, wind, solar and biogas plants, there is a high variety. In parallel with the introduction of new technologies for electricity production, there is a significant reduction in electricity production from thermal power plants, which reduces their share to 46% in total electricity production in 2019. The introduction of new technologies, especially after 2014, as well as the reduction of the price of natural gas, contributed the domestic production of electricity to be maintained at a level of about 5600 GWh.

In terms of installed capacity, in Macedonia there are about 2080 MW, i.e. for a 10 years period 480 MW were built. A significant increase in installed capacity is made possible by the feed-it tariff (FiT) as a support mechanism. In 2019, with the help of this mechanism, a total of 141 MW were installed, of which 80 MW small hydropower plants, 17MW PV, 37 MW wind, 7 MW biogas and 0.6 MW biomass power plants. Electricity production from these power plants in 2019 is 350 GWh which is 5% of the total domestic electricity production.

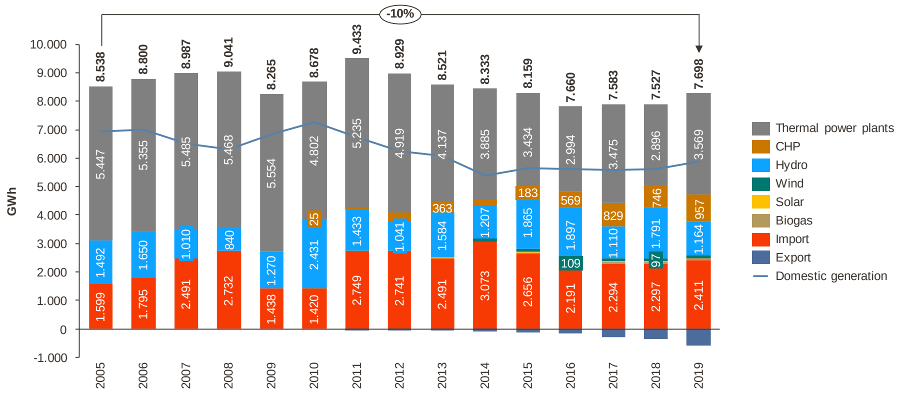

Figure 2. Electricity supply

Regarding the GHG emissions from the Energy sector, the largest share of emissions is from the Energy Industries category, but its share has decreased from 66.0% in 1990 to 51.5% in 2016. On the other hand, the largest increase in the share is in the Transport sector, from 8% in 1990 to 28% in 2016.

2.1. Early Effects of the COVID-19 Crisis on the Macedonian Energy Sector

The initial effect that COVID-19 had on the energy sector in Macedonia is also made in this paper. It can be noticed that in the total electricity consumption in Macedonia there are no drastic changes in the first eight month of 2020 compared to 2018 and 2019. The analysis shows that in the first eight months of 2020, electricity consumption in households increased by 2%, compared to the same period in 2019. This is primarily a result of the restrictive measures due to Covid-19, with which many employees work from home. On the other hand, for the same reasons (but with the opposite effect) there is a decrease in electricity consumption in all other sectors in the analyzed period. This means that the forecasts should not have any drastic deviations in terms of total consumption, but only small differences in redistribution between sectors.

Covid-19 did not affect domestic production. The unfavorable hydrological conditions in 2020, the defect that occurred in REK Bitola, as well as the increase in the number of consumers who do not buy electricity from the universal supplier contributed the domestic production to decrease by 11% compared to the same period in 2019 (Figure 3). At the same time, electricity imports increased by 15% in the same period, while exports decreased by 11%. The Covid-19 crisis affected to some extent the export of electricity, which is primarily due to lower consumption in the region, but also a decline in electricity prices on the power exchanges in the region.

The Covid-19 crisis mainly influenced the consumption of oil products, but the consumption of lignite and natural gas are not evidently affected. The lignite consumption corresponds and is correlated to the production of electricity from the thermal power plants and is decreased by 14% in the first eight months of 2020 compared to 2019. The consumption of oil is mainly influenced by the Covid-19 crisis and the final energy consumption is reduced by 12% in the first eight months of 2020 compared to 2019. This is mainly due to the reduced transit of vehicles through the country, as well as the reduced mobility of the citizens (due to work from home, lockdowns).

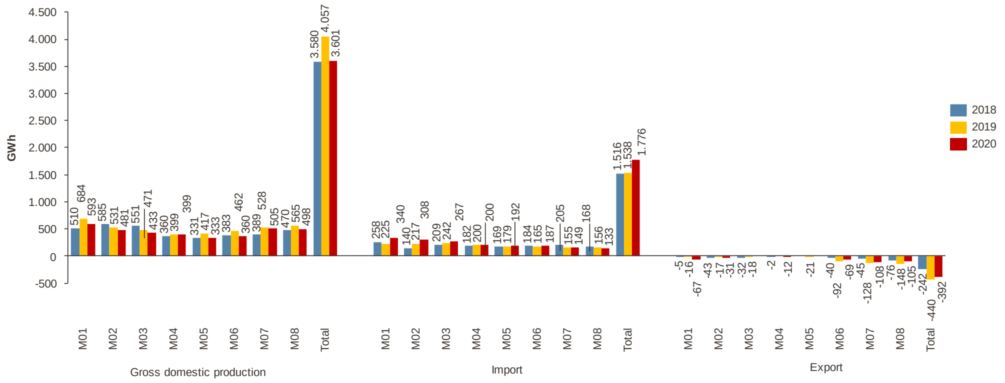

Figure 3. Electricity supply, Jan-Aug 2018-2020

3. METHODOLOGY AND INPUT DATA

The methodology used for developing different scenarios for energy transition is composed of two software tools: MARKAL and EnergyPLAN. The objective of the MARKAL model is to define the optimal development of the overall energy system based on least cost principle, usually over a long period of 20-50 years. It is energy/economic/environmental optimization tool, based on linear programming, therefore the aim of the model is to find optimal value of the objective function taking into account the imposed policy and physical constraints [13]. The objective function is the total discounted system costs over the entire planning horizon. In MARKAL the entire energy system is modeled and is represented as a network of connected blocks through which energy flows, starting from resource extraction, through energy transformation and end-use devices, to demand for useful energy services – as many as desired, in the desired units [14]. The links in this network are associated with certain technical characteristics (capacity, availability, efficiency), environmental characteristics (CO2, SOx, NOx, etc) and economic factors (costs). The MARKAL model does not have a build-in database, so the user should insert all the necessary, but the level of details that will be inserted are mainly defined from the user. For example, the annual load curve, and so each annual variable can be detailed by the desired number of time slices, which is user-defined at three levels: seasonal (or monthly), week days – weekends, and hour of the day.

The MARKAL model is used for long-term planning of the energy system, but for detailed hourly analysis of the balance between electricity production and demand the EnergyPLAN models is used. It is a simulation model for analyzing one year time period, at hourly resolution [15]. The main focus of the model is to analyze the integration of renewable energy sources into the system, taking into account their intermittencies. In this way, the model provides the opportunity to investigate the hourly, daily, weekly and seasonal mismatch between the demand and production.

These two models perfectly fit together, and that is why in this paper both are combined in order to plan the development of the Macedonian energy transition. Figure 4 show how these models are integrated. For selected years, the output of the MARKAL model is used as input into the EnergyPLAN model (such as the installed capacity and demand for that year).

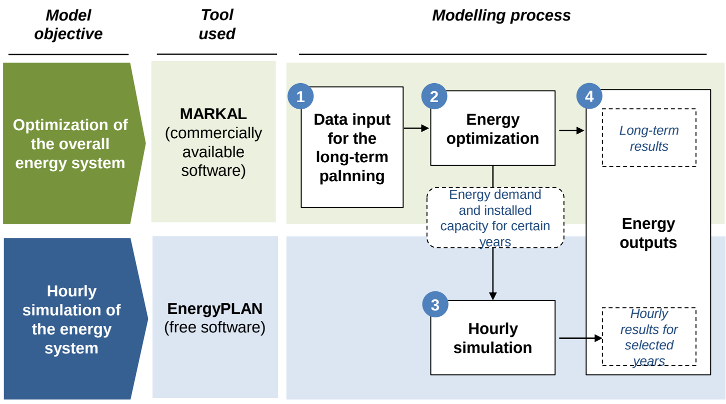

Figure 4 Modelling framework

The forecast of the annual growth rates of GDP is one of the most important indicators which is used as input to the MARKAL model. A detailed economic analysis is made in order define this parameter. Average annual GDP growth rate of 3.8%, positioning North Macedonia in 2040 at today's level of GDP per capita of the Central and East European countries is foreseen and it is supposed that through the period 2020 – 2040, the economies will run through 5 business cycles, namely: in 2020 (the current recessions), in the transition between 2025/2026, 2030/2031, 2034/2035 and 2037/2038.

Based on the United Nations (UN) data, constant fertility scenario, the population is expected to decline by 0.2% in 2040 compared to 2017.

4. SCENARIOS FOR ENERGY TRANSITION

In order to examine the different possibilities for energy system development, three scenarios have been developed: Reference, Moderate transition and Green scenario. All three scenarios are in the direction of energy transition, but with different intensity and dynamics, and general overview of the scenarios is presented in Figure 5. Although the three scenarios were developed taking into account the same GDP projections, the main differences in the scenarios are in the year of introduction of carbon price, carbon and fuel price projections, as well as the dynamics of policy penetration of the European Union Directives, especially for EE and RES.

5. RESULTS

The modeling results are presented using six indicators that are in line with the five dimensions of the EU Energy Union: energy efficiency, energy dependance, GHG emissions, RES share, total system costs and legal and regulatory compliance. =

	Reference scenario	Moderate Transition scenario	Green scenario
Vision	**Transition from conventional energy based on current policy and least cost principles**	**Progressive transition from conventional energy based on new policy and least cost principle**	**Radical transition from conventional energy based on new policy and lignite phase out**
Assumption highlights			
Demand drivers	• Macedonian GDP growth to reach neighboring EU countries' GDP per capita levels of today by 2040 • Current energy efficiency policies • Penetration of EVs	• Same GDP growth as for reference • Energy efficiency based on enhanced policy (in line with EU Directives / EnC guidelines) • Higher penetration of EVs	• Same GDP growth as for reference • Same as moderate transition but more incentives and advanced technologies • Highest penetration of EVs
Generation investments focus	• Lignite PP revitalization choice based on least cost principles • High focus on RES	• Lignite PP revitalization choice based on least cost principles • Further focus on RES technology investments	• Lignite PP revitalization choice based on least cost principles • Extreme focus on RES investments
Carbon price at ETS level	2027	2025	2023
Commodity prices (WEO 2017)[1]	Based on current policies scenario	Based on new policy scenario	Based on the sustainable development scenario
Fuel Supply / Availability	• Lignite production capped at a maximum level of annual supply expected (~ 5 M tons 2018-2035, ~ 3 M tons 2035-2040) • Hydro production and wind/solar in line with historical trends and adjusted for new entering power plants • Cross Border Capacities (electricity and gas) evolution in line with the ENTSO-E, ENTSO-G and EnC • Sustainable consumption of biomass[2] • Battery storage (EVs and pump storage)		

Figure 5 Overview of scenarios for the development of Macedonian energy system until 2040

5.1. Energy Efficiency Indicator

In all three scenarios, North Macedonia will use less resources to cover the same needs. Even though the useful energy consumption is projected to grow, the final energy consumption does not follow this trend since more efficient technologies are being implemented in each of the. For the household sector final energy consumption is 31% lower compared to useful energy consumption in 2040 under the Green scenario. The decoupling of the energy consumption curves starts from 2020 for all scenarios, but with different rates per scenario. In all three scenarios, the final energy consumption will increase, but at considerably lower rates in the Moderate transition and Green scenarios. The industrial and the transport sectors are the main drivers of the final energy consumption.

In all three scenarios, electricity and diesel will remain key commodities to satisfy the final energy needs. However, their consumption will be reduced in Moderate transition scenario, resulting with 0.2 Mtoe less compared to the Reference scenario. Additionally, other commodities, such as natural gas and renewables, are expected to become more available for final consumption. Therefore, in the

Green scenario, the final energy consumption is 0.4 Mtoe lower than in the Reference scenario, owing to the substitution of coal with gas in the industry.

The decrease of coal consumption is the main driver for reduction of primary energy consumption. The primary energy consumption in the Reference scenario is projected to grow for 44% by 2040, driven by the coal consumption. However, due to higher CO_2 price, new domestic lignite mines will not be a viable option in the Moderate and Green scenario and coal technologies are replaced with more efficient gas and RES technologies. This will reflect on the primary energy consumption, which in the Green scenario in 2040 will be 26% less than the Reference scenario (Figure 6).

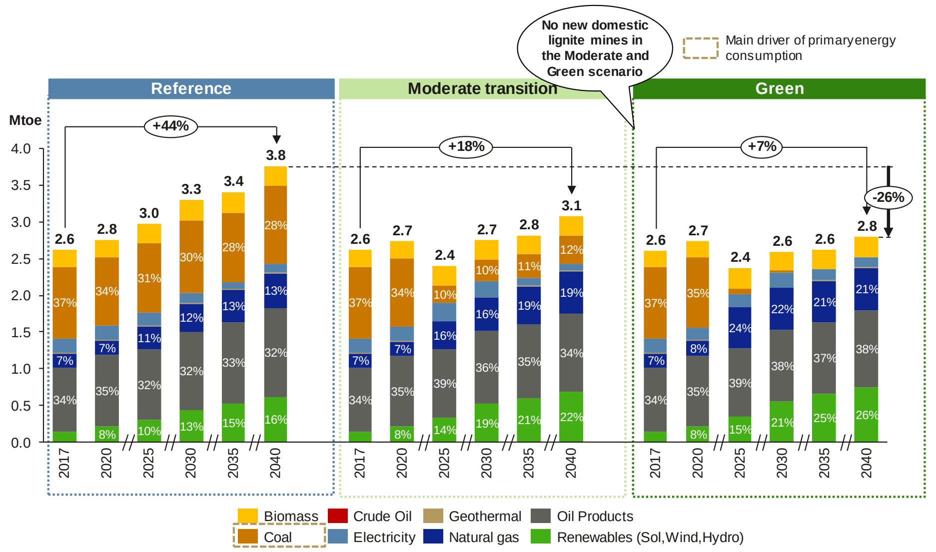

Figure 6 Primary energy consumption per fuel

5.2. Energy Dependance Indicator

Considering the energy dependence, in the Reference and Green scenario the share of net import remains similar to the current level, while in the Moderate transition it increases to ~64% by 2040. From this aspect, in Moderate transition and Green scenarios, a critical year is 2025 when the existing lignite power plants will be decommissioned and the remaining generation capacity in the country will not be enough to satisfy the electricity consumption, so additional import of electricity and natural gas will be needed (increasing its share to above 70%).

5.3. GHG emissions indicator

GHG emission reduction is achieved in two out of three scenarios, driven by the decline in the coal utilization and mining. CO_2 represents the majority of GHG emissions in all three scenarios (~96% of total). In the Moderate transition scenario the CO_2 emissions decrease for nearly 23% in 2040 relative to 2017 and in the Green scenario for 44%.

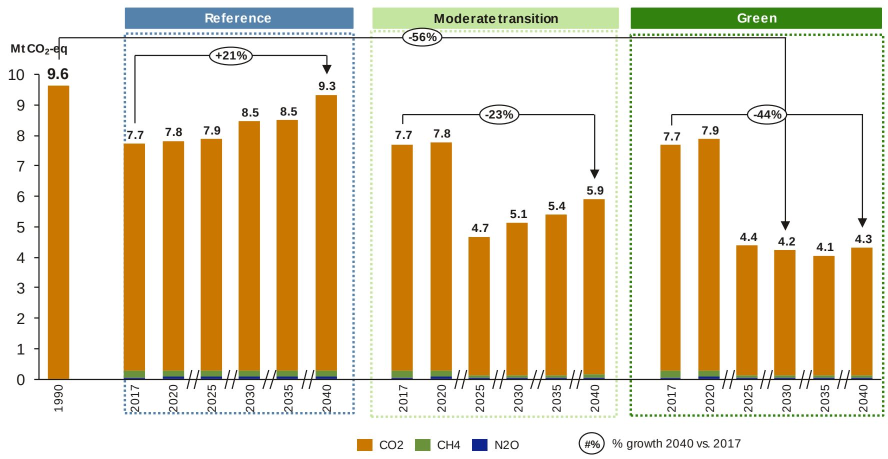

Figure 7 Reduction of GHG emissions by gas

5.4. RES Share Indicator

The utilization level of the renewables as an important factor for decarbonisation of the energy sector, has been considered relevant even in the Reference scenario, where 32% RES share is projected after 2030. By taking into account the heat pumps, the RES share in gross final energy consumption will become even higher, reaching 37% in the Moderate transition scenario and 43% in the Green scenario (Figure 8).

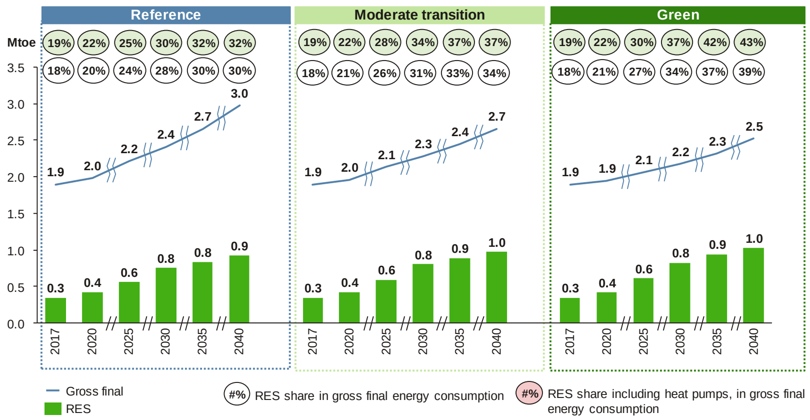

Figure 8 RES share in gross final energy consumption

5.5. TOTAL SYSTEM COSTS INDICATOR

In the Reference scenario, the annual energy system costs will be more than double by 2040. The majority of the annual expenditures in the Reference scenario are investments in the demand technologies and the fuel costs, both consisting 69% of the total costs in 2040. Also, investments in power generation technologies will occur, especially after 2030.

The Green scenario is most cost-effective scenario. The cumulative savings in the Moderate transition scenario are estimated at 4.2 billion EUR, while in the Green scenario the estimate is at 6.5 billion EUR. The main driver for the savings is the lower cost of fuel supply, although more investments in new technologies are needed. It has been shown that in order to achieve the energy transition in

Macedonia, cumulative overnight capital investments in the range of 9.5-19.9 billion EUR are needed by 2040 (depending on the scenario).

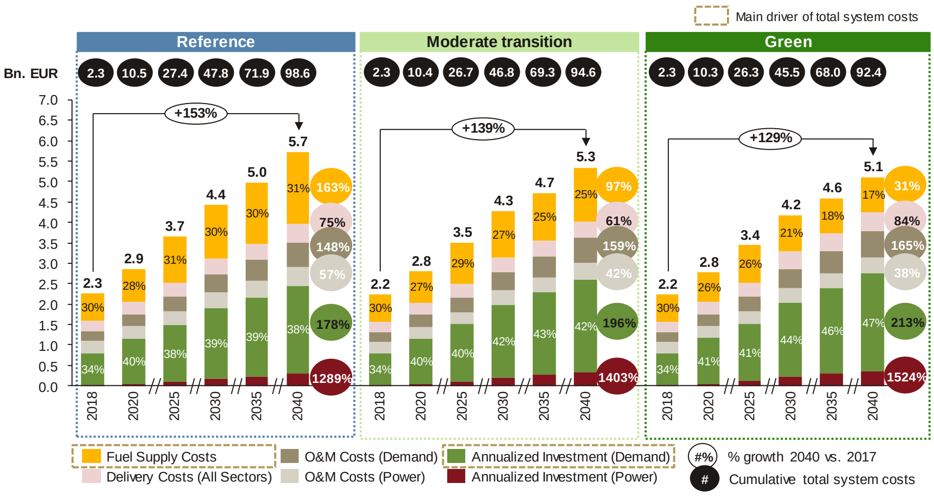

Figure 9 Annual expenditures breakdown

5.6. Detailed electricity generation results

The results of the electricity generation by type of technology shows that the realization of the green scenario means that in 2040, more than 80% of the domestic electricity generation will be from renewable energy sources (Figure 10), and the electricity import will be reduced from around 30% in 2017 to 10% in 2040. From the scenario's realisation perspective, the critical year is 2025, because of the revitalization or decommissioning of TPP Bitola. Because of the high share of RES in 2040 (up to 1400 MW PV and 750 MW wind), in this paper additional hourly analyzes of the needs for balancing and the role of the pumped-storage hydro power plants is made.

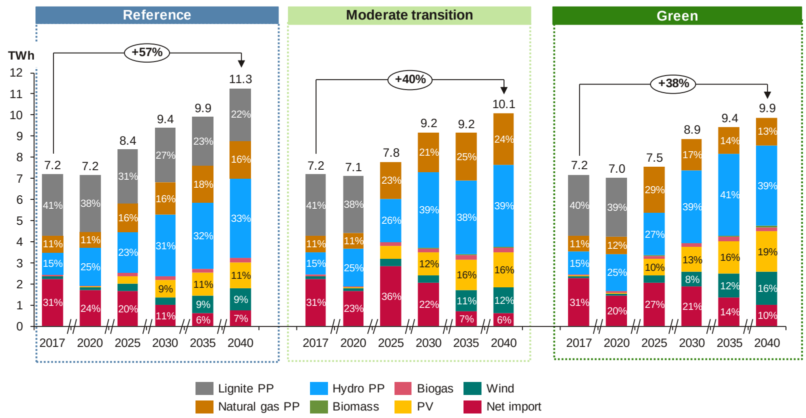

Figure 10. Electricity generation by type of technology

The analyses are made based on the capacities given in the Green scenario. On Figure 11 it can be seen that imports participate with 3%, while the critical excess electricity production hours in the total production participate with about 1% (not including the electric vehicles in these analyzes although they are part of the Green scenario). This means that the capacities projected in the Green scenario can satisfy the demand of the electricity in Macedonia.

In order to present the importance of the pumped hydro PP Chebren have in the future system, a scenario was made in which Chebren is excluded. In this case the balancing of the system is disturbed and the critical excess electricity production increases from 300 GWh to 1100 GWh (Figure 12).

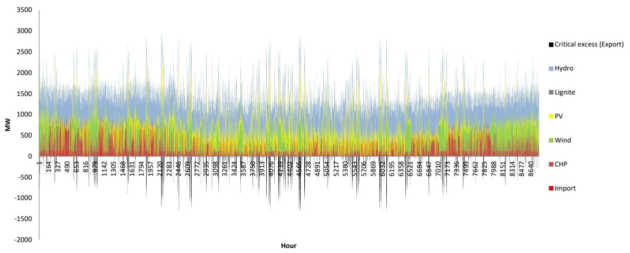

Figure 11. Hourly electricity balancing in 2040 (Green Scenario 2040)

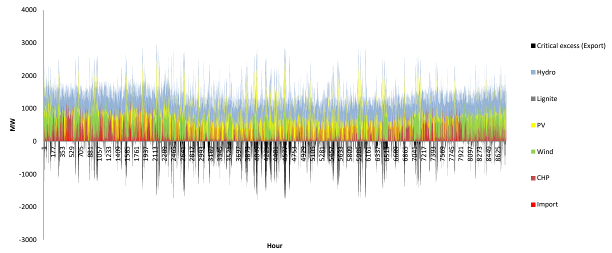

Figure 12. Hourly electricity balancing in 2040 (Green Scenario without Chebren)

For the electricity analyses for 2025, the analysis shows that there are almost no critical hours and electricity imports are less than 2%. This means that domestic production can fully meet electricity demand.

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