ENERGY TRANSITION OF A DEVELOPING COUNTRY FOLLOWING THE PILLARS OF THE EU GREEN DEAL

by

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Original scientific paper
https://doi.org/10.2298/TSCI2202317D

Utilization of efficient technologies, renovation of buildings and construction of new passive buildings, replacement of coal, natural gas, and nuclear power plants with "clean" technologies such as photovoltaics and wind, transition to 4-D in industry, and electrification are parts of the objectives set out in the Green Deal of the EU. The Green Deal foresees a transformation to a "green" economy while maintaining economic growth, as well as creating new "green" jobs. To meet these goals, each country needs to develop its own strategic documents that will guide the transition, taking into account its own specific conditions, the current state of the energy sector as well as geographical location. This paper aims to present a vision for the energy transition of a developing country, a member of the Energy Community, and a country that expects to join the EU. The vision of the development of the energy system of North Macedonia foresees a transformation from a system based on fossil fuels, where the share of RES in the gross final energy consumption is about 18%, to a 43% share of RES in 2040, while maintaining import dependence at the current level and guaranteeing the security of energy supply. For exploring the way and the pace at which such a vision can be achieved it is necessary to develop different models and simulations, including different technologies on the generation and consumption side. Such alternatives, packaged in different scenarios, allow policymakers to assess the effects of taking certain actions and the direction in which such decisions will lead.

Key words: *energy transition, developing country, RES*

Introduction

Climate change threats and the need to save resources are 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 Next Generation EU Recovery Plan and the seven-year EU budget will fund this green agreement. Almost two

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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 an increase in energy import. The challenge of achieving Europe's climate neutrality by 2050 has also attracted much attention in the literature. Namely, [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, and 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 French and Swedish systems for guiding the future energy transition, *etc.* 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, a vision of transition from a lignite-based energy system is presented in [8] where as a case study Serbia is presented, the decarbonization of the residential building sector of Serbia is analyzed in [9], and the authors in [10] analyze the electricity production from renewable energy sources in the Western Balkans.

The Republic of North Macedonia is a developing country, a Contracting Party of the 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 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.

Therefore, a reliable, efficient, environmentally friendly and competitive energy system that is able to stimulate sustainable economic growth is the vision of the development of North Macedonia, which foresees a reduction of energy consumption, but at the same time increasing GDP and increasing the share of renewable energy sources [11, 12]. 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 policymakers 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 the energy transition in Macedonia, considering the national specific conditions and following the main pillars of the Green Deal. Therefore, the paper first gives a short overview of the Macedonian energy system, including an analysis of the early effects of the COVID-19 crisis on the Macedonian energy sector. In the next chapter, the methodology which is used is explained, together with a presentation of the most important input data. Three scenarios with different intensities and dynamics of the energy transition have been developed: Reference, Moderate transition and Green scenario, and a general overview of the scenarios is presented in section *Scenarios for the energy transition*. Finally, the results are presented using six indicators that are in line with the five dimensions of the EU Energy Union, followed by a conclusion of the paper.

Macedonian energy system

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, fig. 1. Until 2014, the share of coal dominates in the mix of primary energy. The reduction of electricity production from thermal power plants (TPP) 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 (HPP). 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.

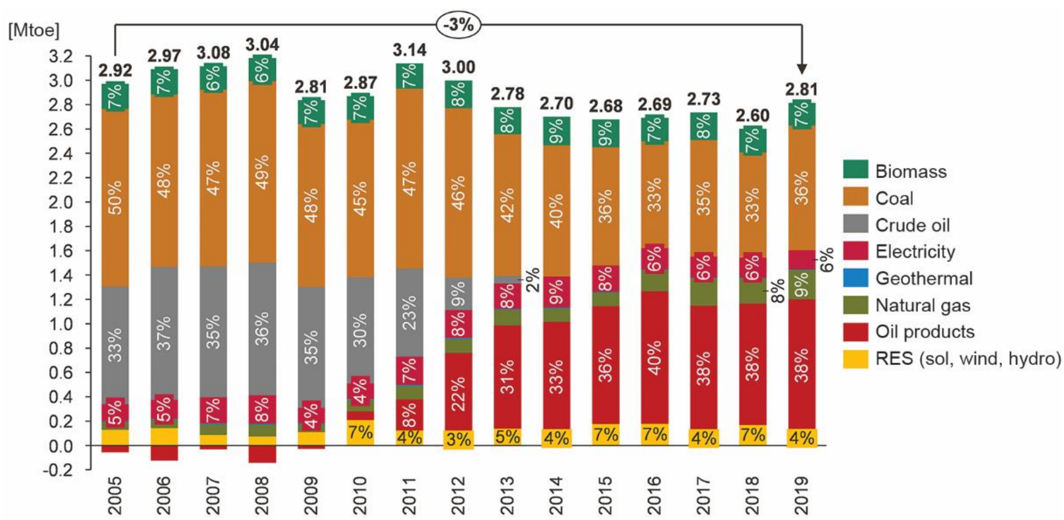

Figure 1. Primary energy consumption (*for color image see journal web site*)

Consumption of natural gas recorded the largest increase in the analyzed period, and in 2019 is about four times higher compared to 2005. The import of electricity is mainly constant after 2011, with the exception of the last three-four years, primarily due to the non-operation of some industrial capacities, which mainly use electricity from imports and the higher electricity production from domestic gas-fired combined heat and power plant (CHP).

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 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 electricity supply, in the analyzed period a significant change can be noticed in the share of different production technologies, fig. 2. Namely, in 2005, 64% of the supply was from TPP, 17% from HPP, 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 TPP, which reduces their share to 46% in total electricity supply 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.

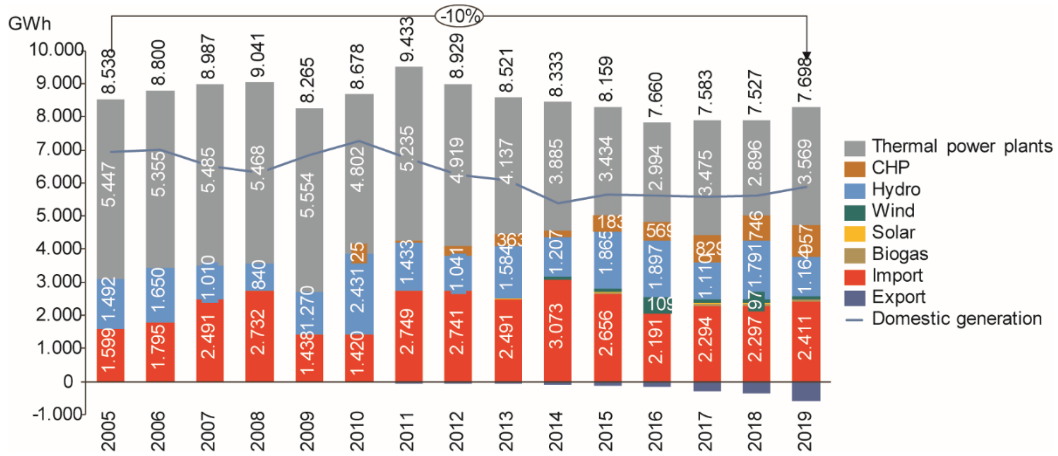

Figure 2. Electricity supply (*for color image see journal web site*)

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-in 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 HPP, 17 MW 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.

Regarding the GHG emissions from the energy sector, according to the latest GHG inventory, 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.

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 months 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 de*via*tions in terms of total consumption, but only small differences in redistribution between sectors.

The Covid-19 did not affect domestic electricity production. The unfavorable hydrological conditions in 2020, the defect that occurred in TPP 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, fig. 3. At the same time, electricity imports increased by 15%, 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 TPP 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).

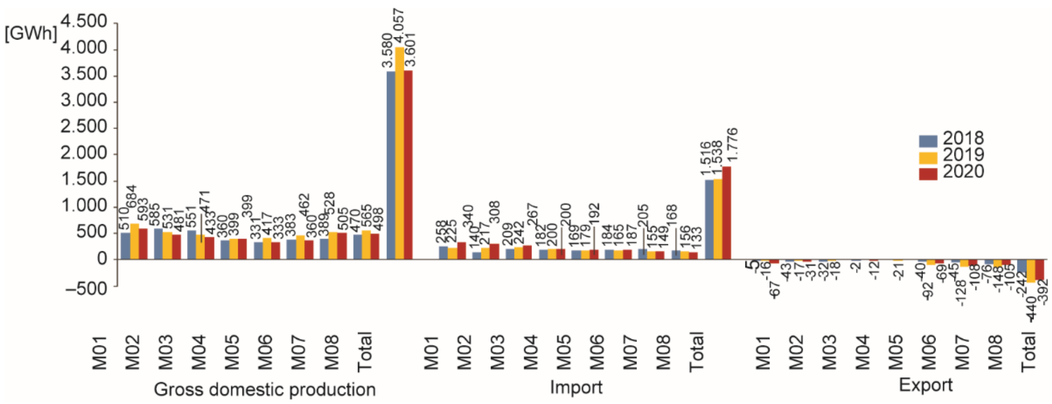

Figure 3. Electricity supply, Jan.-Aug. 2018-2020 (*for color image see journal web site*)

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 the least-cost principle, usually over a long period of 20-50 years. It is an energy/economic/environmental optimization tool, based on linear programming, therefore the aim of the model is to find the 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 modelled 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 the 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 (CO_2, SO_x, NO_x, *etc.*) and economic factors (costs). The MARKAL model does not have a built-in database, so the user should insert all the necessary data, but the level of details that will be inserted is mainly defined by 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), weekdays – 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 model 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 shows 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).

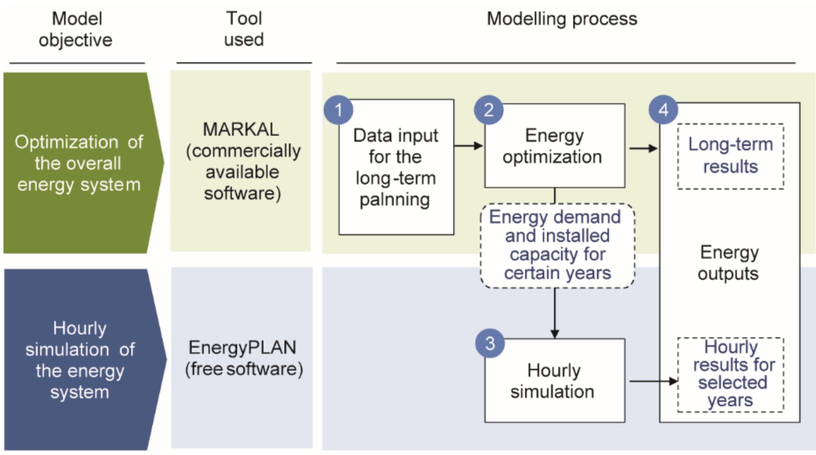

Figure 4. Modelling framework

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 to define this parameter. The 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. Besides the 2020th recession, additional transitions are forecasted in the periods between 2025/2026, 2030/2031, 2034/2035, and 2037/2038, fig. 5.

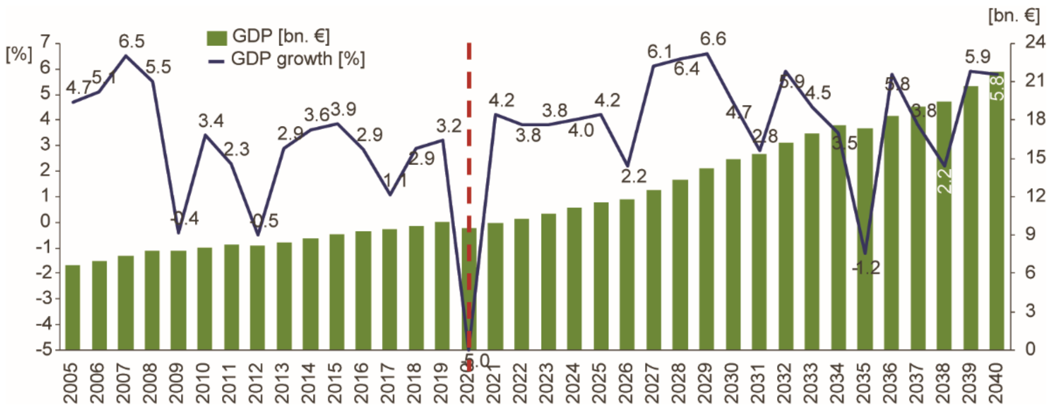

Figure 5. The GDP and GDP growth – historical and projected values up to 2040 in Macedonia
(*for color image see journal web site*)

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

Scenarios for the 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 the energy transition, but with different intensity and dynamics, and a general overview of the scenarios is presented in fig. 6. 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 the carbon price, carbon and fuel price projections, as well as the dynamics of policy penetration of the EU Directives, especially for EE and RES.

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 dependence, GHG emissions, RES share, total system costs, and legal and regulatory compliance.

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 them. For the household sector, final energy consumption is 31% lower compared

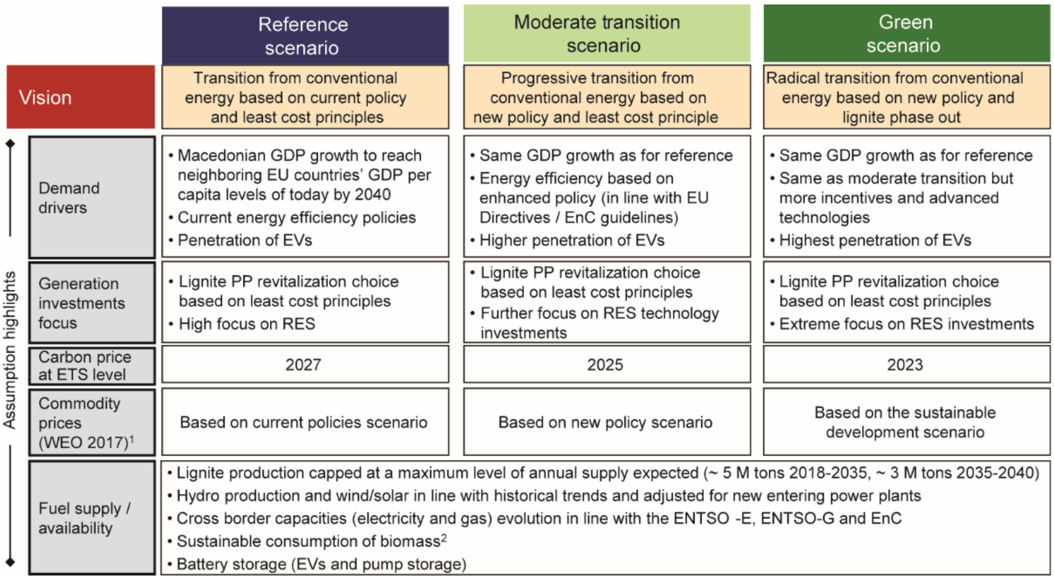

Figure 6. Overview of scenarios for the development of Macedonian energy system until 2040

to useful energy consumption in 2040 under the Green scenario, fig. 7. 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.

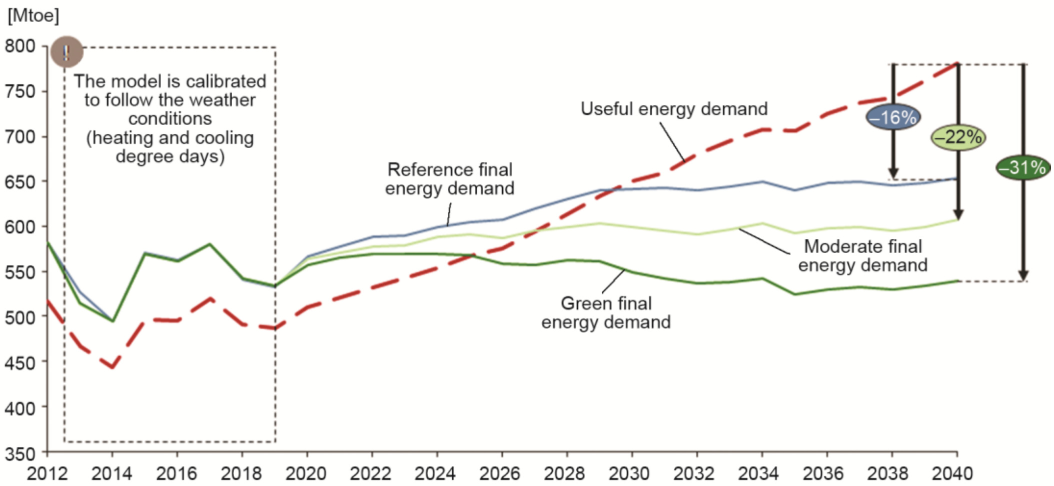

Figure 7. Useful *vs.* final energy consumption in the household sector, by scenario

In all three scenarios, electricity and diesel will remain key commodities to satisfy the final energy needs. However, their consumption will be reduced in the Moderate transition scenario, resulting in 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 in coal consumption is the main driver for the reduction of primary energy consumption. The primary energy consumption in the Reference scenario is projected to grow by 44% by 2040, driven by coal consumption. However, due to higher CO_2 prices, 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.

Energy dependence 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%).

The GHG emissions indicator

The GHG emission reduction is achieved in two out of three scenarios, driven by the decline in coal utilization and mining. The 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 by nearly 23% in 2040 relative to 2017 and in the Green scenario by 44%, fig. 8.

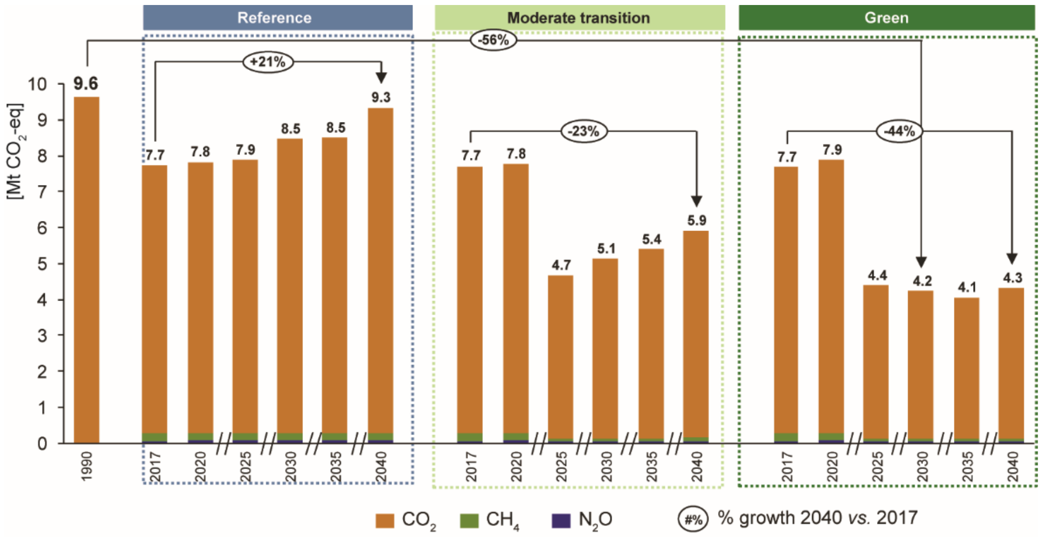

Figure 8. Reduction of GHG emissions by gas (*for color image see journal web site*)

The RES share indicator

The utilization level of RES 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, fig. 9.

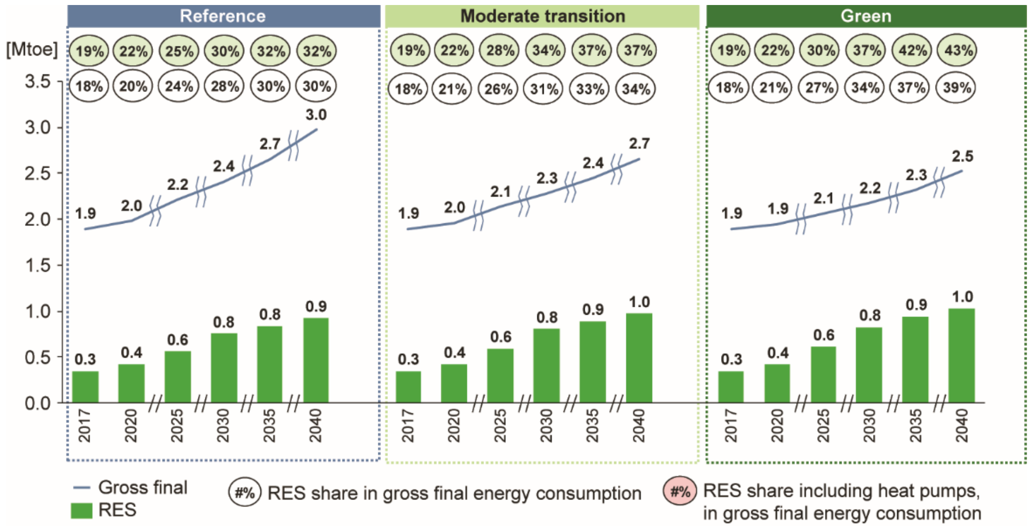

Figure 9. The RES share in gross final energy consumption

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, fig. 10. Also, investments in power generation technologies will occur, especially after 2030.

The Green scenario is the most cost-effective scenario. The cumulative savings in the Moderate transition scenario are estimated at 4.2 billion €, while in the Green scenario the estimate is at 6.2 billion €. 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 € are needed by 2040 (depending on the scenario).

Detailed electricity supply results

The results of the electricity generation by type of technology show 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, fig. 11. and the electricity import will be reduced from around 30% in 2017 to 10% in 2040. From the scenario's realization 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 HPP is made. The analyses are made based on the capacities given in the Green scenario. Figure 12 shows 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 electricity demand in North Macedonia.

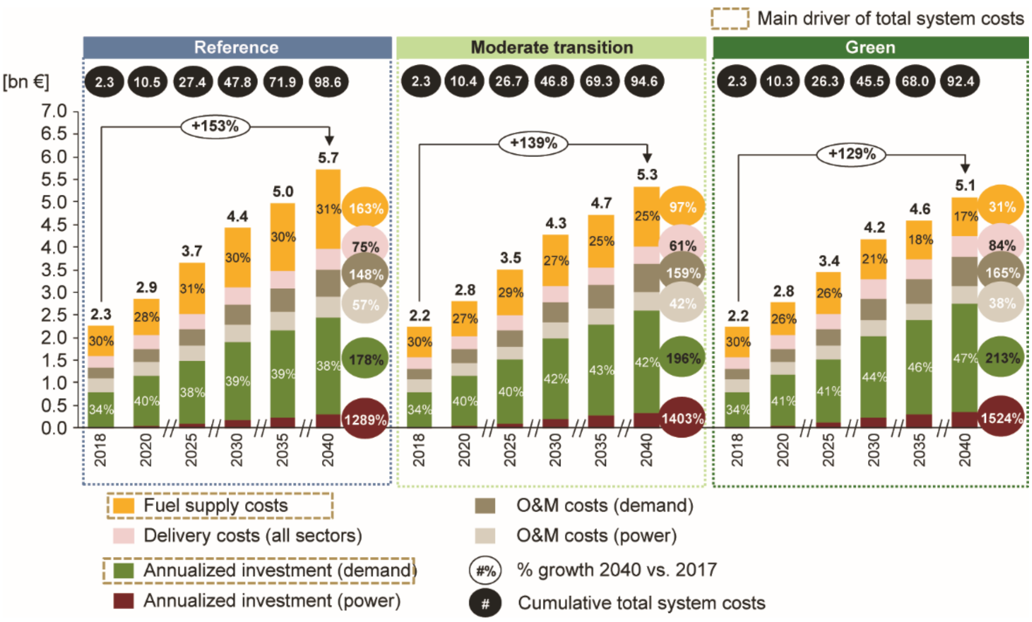

Figure 10. Annual expenditures breakdown (*for color image see journal web site*)

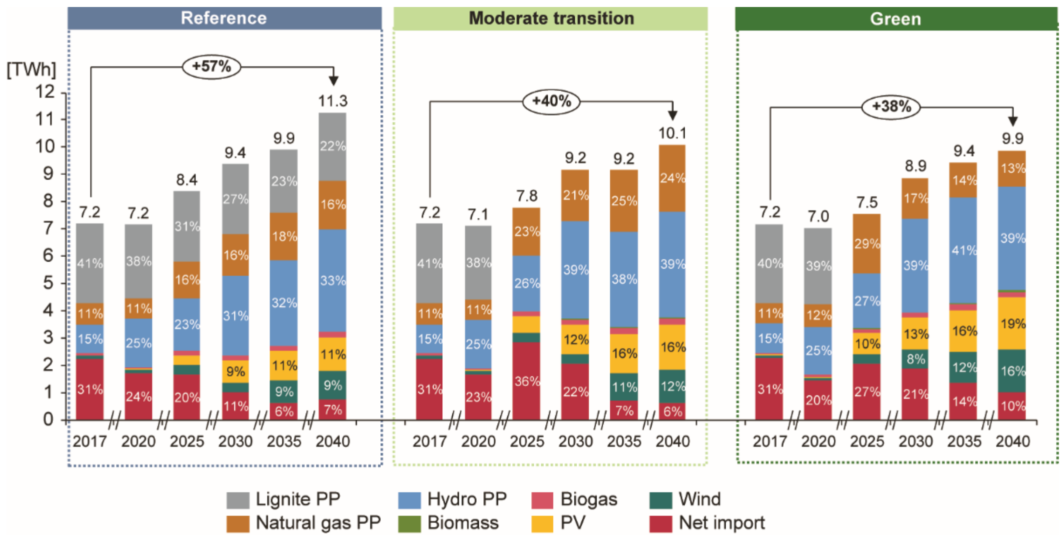

Figure 11. Electricity supply forecast (*for color image see journal web site*)

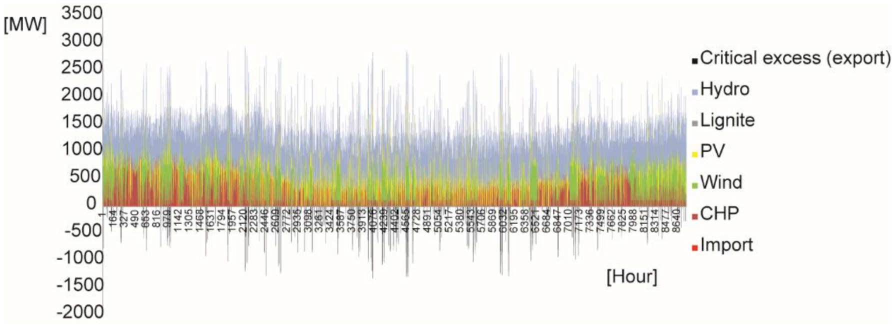

Figure 12. Hourly electricity balancing in 2040 (Green Scenario)
(*for color image see journal web site*)

In order to present the importance of the pumped-storage HPP Chebren has 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, fig. 13.

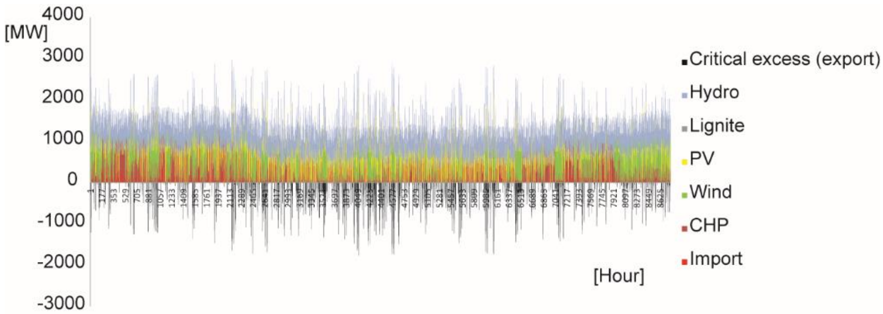

Figure 13. Hourly electricity balancing in 2040 (Green Scenario without Chebren)
(*for color image see journal web site*)

The detailed electricity analyses for 2025 shows that there are almost no critical hours and electricity imports are less than 2% in the Green scenario, as a result of the replacement of TPP Bitola with additional 450 MW CHP in 2025. This means that domestic production can fully meet electricity demand.

Conclusion

The structure of the energy systems that existed 10-15 years ago is slowly but surely being abandoned. It is experiencing the greatest transformation in recent history, driven by the desire for sustainable economic development. Reducing energy consumption and GHG emissions is a global challenge to which every country can and should contribute. Providing the most economically viable solution to make an energy transition is a challenge for any government, and the job of researchers is to point out possible solutions. Therefore, in this paper a methodology was developed, using which the most cost-effective option for the energy transition of the country was determined.

The paper analyzes three scenarios for North Macedonia: Reference, Moderate Transition, and Green. Most funds should be invested in the Green scenario, around 20 billion € in the period 2020-2040. But if we compare the total costs of the whole energy system, it is shown that it is lower compared to the costs in the other two scenarios in which there are smaller investments in energy efficiency and RES. In addition, the results show a reduction of energy consumption by 27%, while increasing GDP, and increasing the share of renewable energy sources in gross final energy consumption from the current 18% to 45% in 2040. This will allow the import dependence not to increase compared to the 2019 level. The predicted transition of the energy sector also contributes to a reduction of GHG emissions from the energy sector by 55% in 2040 compared to the emissions in 1990.

Acknowledgment

This research was made within the project "Building Greener and Safer Future for North Macedonia – Support for Development of Programme for the Implementation of the National Strategy for Energy Development", funded by the UK Government with the support of the British Embassy Skopje. We thank our colleagues from the Macedonian Academy of Sciences and Arts, PWC Skopje and Zagreb, Public Administration International – London, and Centre for Change Management – Skopje who provided insight and expertise that greatly assisted the research.

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Paper submitted: December 22, 2021
Paper revised: January 15, 2022
Paper accepted: February 7, 2022