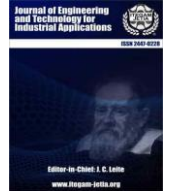




ISSN ONLINE: 2447-0228



RESEARCH ARTICLE

OPEN ACCESS

LONG-TERM SUSTAINABLE ENERGY PLAN TO REDUCE AIR POLLUTION IN THE REPUBLIC OF MOLDOVA

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ARTICLE INFO

Article History

Received: February 02th, 2021

Accepted: April 01th, 2021

Published: April 30th, 2021

Keywords:

Energy plan,
Sustainable energy,
Carbon footprint,
Pollution-based energy sources,
Moldova

ABSTRACT

This paper is an energy system analysis of current energy systems in the Republic of Moldova. By recognizing the adverse health effects of pollution-based energy sources, a new energy plan for the Republic of Moldova is introduced. This sustainable energy plan is based on three main renewable energy sources: wind power, solar energy, and pumped hydropower. In addition, the amount of energy produced for electricity and heat, transportation and other residential, commercial, and industrial purposes is assessed and calculated. Then, based on the accessibility of these three main sustainable energy sources in Moldova, a feasible redistribution of the amount of energy accordingly is suggested. This long-term energy plan would serve as a geo-political strategy that also provides Moldova with the opportunity to reduce air pollution and increase their quality of life.



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I. INTRODUCTION

Moldova is a small landlocked country in Eastern Europe located in between Romania and Ukraine. Although it is an independent country since 1991, it has always been under the political, economic, and sometimes military influence of countries like Russia and Ukraine [1][2]. The country's aspirations for the future are towards the west, joining the European Union and rising its economic level to a European standard. But they cannot do so, with the continuous influence of foreign regional superpowers, especially regarding the country's energy use.

Most of the country's energy production comes from natural gas and petroleum, both of which are sources imported by other countries in the region, mainly Russia and Ukraine [1][2]. Finding a way to make the Republic of Moldova produce its energy from its own resources, would be crucial and would make a huge impact in its geo-political position in the region. Fortunately, there are a lot of renewable sources of energy available in Moldova where the three most important ones include wind power, solar energy, and pumped hydropower [3]. Based on these sources of energy is possible to create a sustainable energy plan that would cover all the energy needs of the country. Through using the

available renewable energy sources such as wind, solar energy and filling the gaps with hydropower and biomass energy, Moldova would be able to cut the import of natural gas and petroleum by more than half. This would result in a more stable and self-dependent economy, which would create more possibilities for Moldova to reduce air pollution and increase their quality of life.

II. MATERIALS AND METHODS

This paper is an energy system analysis of current energy systems in the Republic of Moldova. The main discourse of the paper revolves around the Energy Flow Charts created by the Lawrence Livermore National Laboratory in Canada for the Department of Energy's National Nuclear Security Administration. To calculate the amount of energy produced for residential, commercial, and industrial purposes, the energy Flow Chart of the Republic of Moldova was assessed. Then, a renewable energy plan for the year 2050 is introduced based on three main sustainable energy sources available in the region: wind power, solar energy and pumped hydropower.

To find out what energy sources were feasible for implementation, official governmental websites of the Republic of Moldova were reviewed. Energy data was collected from the Flow

m/s, which means that in general we would be able to generate about 2 W/m² [6].

III.2 THE PLAN

By 2050 the republic of Moldova will be able to produce 140 PJ which is 2 PJ more than what it produced in 2011. If we would incorporate solar energy and wind power in the energy system by 2050, Moldova will be able to cut its natural gas imports by almost 62 PJ. This amount corresponds to the amount being used to produce electricity and heat. In this case the energy plan illustrated in this paper suggests that the republic of Moldova will be able to produce all its electricity and heat from domestic renewable resources. Compared to its current use of petroleum, the plan doesn't change anything because petroleum, indeed is one of the most needed source of energy for vehicles and automobiles. For a developing country like Moldova will be very hard to replace all the cars, buses and airplanes that run on petroleum, with hybrid or electric automobiles. From the amount of petroleum imported in 2011 (35 PJ), 16 PJ was used for transportation and 13 PJ was used for residential purposes. By implementing this plan, the Republic of Moldova will be able to reduce the amount of petroleum produced by 18 PJ. Petroleum consumed in residential settings is mainly used for heating, and cooking [7]. By implementing this plan, the 18 PJ that comes from petroleum will be able to come in the form of electricity and heat from renewable resources.

From 140 PJ energy that will be produced by 2050, the republic of Moldova will be able to stop using and importing coal. In 2011, 4.3 PJ was imported from countries such as Russia and Ukraine and 4.1 PJ was produced within the Republic of Moldova [1][2]. Almost 90% of the amount produced from coal was used in industrial settings and about 10% was used in residential settings. Although it might be difficult to substitute coal with other types of energy in industrial settings, it would be beneficial for business to eventually move away from these sources of energy and start using natural gas which is more environmentally friendly and relatively

cheaper, as well as electricity, that after the implementation of this sustainable energy plan will come 100% from renewable resources.

There are three technologies that this energy plan includes, solar energy, wind power and the pumped hydropower energy. Moldova has a lot of potential to use solar energy for electricity production and that is why, among a lot of different technologies in the solar section, this plan encompasses the use photovoltaics solar panels. Moldova gets about 240 sunny days throughout a year period, which is pretty good for a North-Eastern European country. According to literature, Moldova sometimes is also called "the sunny land", and yet so far there is 0 PJ energy coming from this clean and renewable source of energy. From the global horizontal irradiation map created by GeoModel Solar and illustrated in Figure 2, its pretty clear to see parts of Moldova that get about 1400 kWh/m² annually [6]. This means that photovoltaics could produce about 3.83 kwh/day/m² [8][9]. Although it is a small area that could produce this amount of energy, the rest of the south produces a similar amount that differs by 0.1 kwh/day/m² which is not that much of a difference. Installing photovoltaics in the South of Moldova energy would be able to be produced at about 32 PJ annually. Installing photovoltaics to produce this amount of energy would require an area of 6417 km². (The 32 PJ set to be produced by photovoltaics was divided with 3.83 kwh/day which is the amount that some regions of Moldova can produce in 1 m².) Photovoltaics could be installed either in the roofs of the houses and buildings in the south (although there are not many major cities), but most likely they could be installed in large fields.

There would be economic and technological challenges in storing this huge amount of energy that will be produced by implementing solar panels, so the most possible and feasible solution would be to use this energy throughout the day when the demand is high [10]. There might be issues with the solar energy considering weather patterns, and that is the reason why this plan suggests the implementation of wind power and pumped hydroelectric technologies that will fill in the gaps and will make sure that the supply meets the demand.



Figure 2: Horizontal Irradiation Map of Moldova.

Source: [6].

The republic of Moldova has a lot of potential to implement wind energy in its future sustainable energy plan. That is why the

energy plan 2050 in this paper gives a lot of considerations to this technology. As you can see from this Wind Map by 3Tier in figure

3, there are many areas in the Republic of Moldova where the wind speed reaches about 5-6 m/s [6]. Most of these areas are in the south, but there are a lot of other areas across the country where we can actually generate electricity from the wind speed. To generate electricity, we need at least 5 m/s of wind speed, which Moldova has in addition to many areas where the wind speed goes even

higher. According to this plan, the Republic of Moldova will be able to generate 20 PJ of energy annually by the year 2050. All this energy will go towards producing electricity and heat for residential, commercial, industrial as well as transportation purposes.

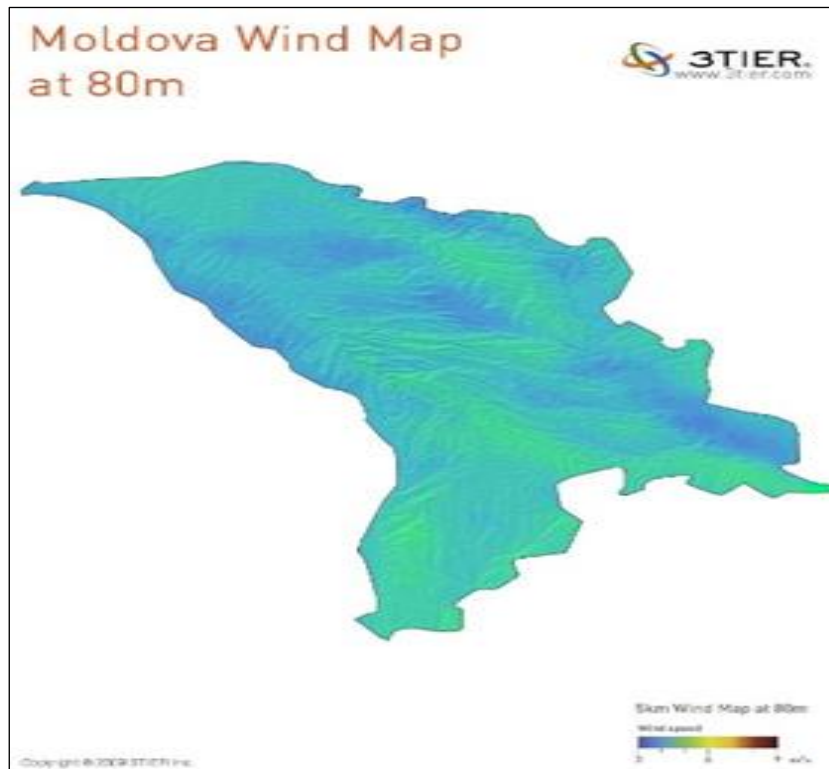


Figure 3: Wind Map of Moldova.
Source: [6].

To generate this amount of energy we would need to build about 18802 windmills with 25 m diameter of blades, which might sound like a lot but the return on investment will be very high in the long run [8][11]. To find out how many windmills were needed the energy that could be produced by a windmill with 25 m blades could produce, which was 816 kwh/day [8][11]. Then 20 PJ was converted into kwh/day and divided by the amount that 1 windmill can produce. According to these calculations we would need an area of 11.8 km², area which could easily be incorporated with the solar panels in the south and with the pumped hydropower facilities in the north. This number was found by firstly calculating how much area its needed for just one of them, which was 625 m², and then through the necessary conversions this number was multiplied with the amount of windmills. The biggest challenge of this technology would be the amount of wind turbines that are needed, but if economies of scale are followed you could build bigger wind turbines that will reduce the number of them that need to be installed and in the same time will keep the energy the same.

The third technology that could be implemented is Pumped Hydropower. Calculations show that Moldova would be able to produce about 36 PJ of energy and all of it could be used to produce electricity and heat. In order to produce this amount of energy, we would need about 380 3MW pumped hydropower facilities where each one of them would be about 2 km². In order to find this number, 36 PJ was divided with the amount of kwh/day that one 3MW pumped hydropower can produce [12].

As a result, implementing the pumped hydropower energy will require 760 km² of area, and facilities would need to be built

mostly in the north and the north east. This area was estimated by multiplying the amount of pumped hydropower facilities with the area that 1 of them. The drawback of using this technology is that more energy is needed to pump the water from the lower reservoir to the higher one, but that process could be done during the night when the demand for energy is low [12]. Also, these reservoirs could be used for raising fish for local consumption.

III.3 ANALYSIS

The implementation of this plan by 2050 comes with a considerable amount of cost, because firstly the Government of Moldova has to manage the construction of all these new technologies. Also, it has to do all the necessary construction to connect them to the existing grid. If the Republic of Moldova sees it as a necessity to upgrade or change the whole grid, then the cost will rise up. However, this plan does not suggest the creation of a new grid, but just simply connecting these three new technologies with one another, in a way so they can be used together in cases when the demand for energy is too high or too low. On the other side the pumped hydropower is a perfect storage technology that would help in cases when there is not enough supply of energy coming from both wind power and solar energy.

The U.S. Energy Information Administration has estimated some simple average of regional values for new generation of resources for plants entering service in 2022. In the absence of finding accurate information about the country of Moldova and the region of Eastern Europe, the US LCOEs were

used as an approximate, even though the prices of incorporating these technologies would be lower in Moldova because there is cheaper labor available as well as less taxes and regulations. Constructing and installing 6417 km² of solar photovoltaics which will produce 36 PJ, will cost around \$756,500,000 USD [13]. To find that, this amount of energy was converted in MWh and then it was multiplied with the LCOE estimated by the U.S. Energy Information Administration. The same approach as to find how

much it costs to construct and install the wind turbines and the pumped hydropower facilities was used. Calculations show that, constructing 18802 wind turbines with 25 m blade diameter will cost about \$356,720,000 USD. On the other side, constructing the 380 pumped hydropower facilities will cost about \$662,000,000 USD. So, to implement this energy plan in total would cost \$1,775,220,000 USD.

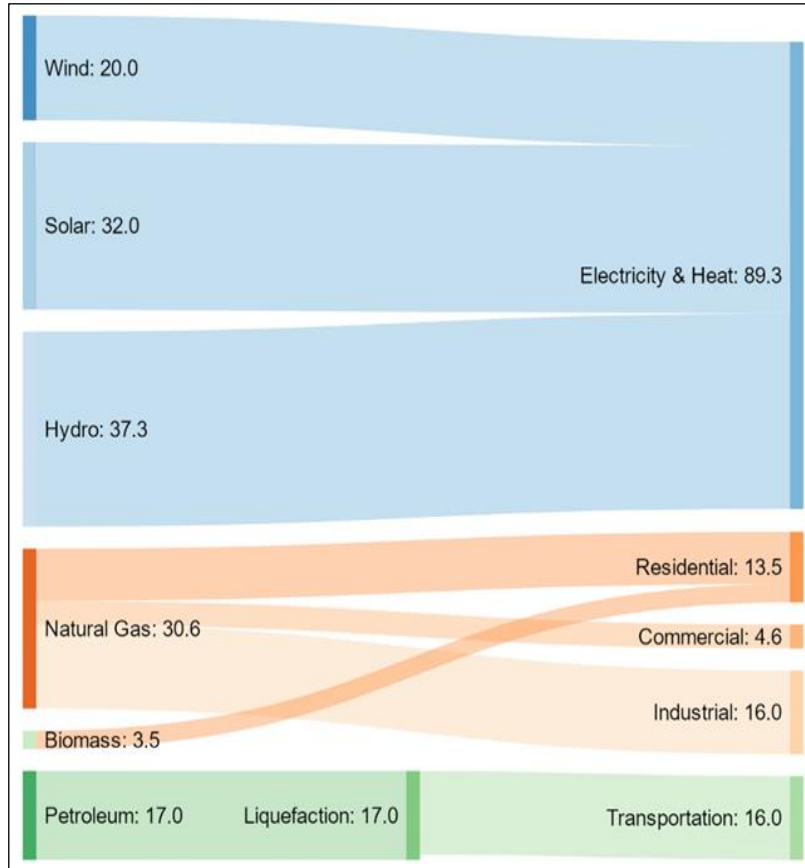


Figure 4: Moldova Energy Flow in 2050: ~ 140.4 PJ.
Source: [14].

According to the Central Intelligence Agency (CIA), Moldova's GDP in 2016 was about \$18.54 billion USD [15]. As calculated, this energy plan would cost about \$1.8 billion USD, amount which the Republic of Moldova has the full capacity to build and implement these new energy facilities. A lot of construction and maintenance jobs will be created, the buying power will rise and therefore the country will set the foundations of a stronger economy in the near future.

IV. CONCLUSIONS

Based on the calculations done in this paper, it makes a lot of sense economically to implement this type of energy plan in the Republic of Moldova. The government has to spend only a small portion of its annual GDP to implement all three technologies that this energy plan is suggesting by also providing so many jobs for the Moldovans as well as other people in that region. According to the Central Intelligence Agency, the unemployment rate in 2016 was 6.3% [15]. Thanks to the creation of these new jobs the unemployment rate will drop considerably. Also, there will be less imports of natural gas and petroleum which will considerably affect the economy of the country as well as its geopolitical position in the region.

In addition, the implementation of a new sustainable energy plan makes sense environmentally because through constructing these new energy facilities and installing these new technologies the country of Moldova will be able to produce 100% of its electricity and heat from renewable resources. There will be a lot of CO₂ emitted in the atmosphere during the time of construction of these facilities but considering the fact that these technologies emit 0 lbs. of CO₂ in the atmosphere, it will pay off in the long run.

The implementation of this energy plan will make a lot of sense socially, because it will provide people the opportunity to get jobs. Most of the population is employed in agriculture and services, but with construction and installation of these new technologies there will be so many other jobs available, from which people will be able to earn more money, afford buying more things and therefore raise their standard of living.

V. ACKNOWLEDGMENTS

The author would like to acknowledge the Sustainable Energy course at Allegheny College as well as the book "Sustainable Energy – without the hot air" from David MacKay for the inspiration to write this scientific paper and for the technical

guidance to conduct the necessary calculations throughout the paper.

VI. AUTHOR'S CONTRIBUTION

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Discussion of results: Erblin Shehu.

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Writing – Review and Editing: Erblin Shehu.

Resources: Erblin Shehu.

Supervision: Erblin Shehu.

Approval of the final text: Erblin Shehu.

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