Cost-Benefit and Multi-Criteria Analysis of Wind Energy Parks Development Potential in Latvia

Liga ROZENTALE¹*, Dagnija BLUMBERGA²

¹,² Institute of Energy systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV-1048, Latvia

Abstract – In the last decade the European Union (EU) has been steadily increasing its’ ambition regarding the climate policy. Considering the linkage between the climate targets and energy sector’s greenhouse gas emissions, the EU’s member states are respectively adjusting their energy policies. One of the current trends in the EU is to increase the renewable electricity generation by roll-out of onshore and offshore wind parks. This research aims at evaluating the potential of large-scale wind parks in Latvia by using the cost-benefit and multi-criteria analysis from financial, technical, climate and administrative perspectives as well as considering the impact on security of energy supply. The results of the research show a good potential for onshore wind park development in Latvia without any state aid, while offshore wind parks are in a much worse position and would not be beneficial for the project promoters without any kind of EU or state aid.

Keywords – Cost-benefit analysis; energy policy; multi-criteria analysis; offshore wind; wind energy; wind parks

1. INTRODUCTION

As has been stated by the EU’s statistical office Eurostat, all the EU’s member states in 2019 generated 3.8 billion tonnes of carbon dioxide (CO₂) equivalents, which is the most emitted greenhouse gas (GHG) in the EU [1]. The EU’s energy sector is the area of economic activity with the highest share of GHG emissions. There is a continuous increase in demand of electricity due to the growth of population and the interlinked growth of economy [2]. The EU’s ambition towards climate neutrality is a major driving force for the EU’s member states to adjust their energy policies and provide other means of electricity production.

Considering both the costs and the necessity to ensure security of energy supply, the transition from fossil fuels to renewable energy sources is neither easy nor quick. The EU’s member states have different approaches to moving towards increased usage of renewable energy, however one of the major common trends is to stimulate the development of wind energy – onshore as well as offshore for the member states which have access to the sea.

This research firstly looks at two different methods of analysis – cost-benefit and multi-criteria analysis, which have been widely used for evaluating wide range of projects. Then these methods are applied for evaluating two theoretical case studies for potential offshore and onshore wind parks in Latvia. The aim of the research is not only to evaluate the financial feasibility of different types of wind parks but also to understand their impact on climate, both the administrative and technical prerequisites for developing a wind park in
Latvia as well as the impact of such wind parks on the security of energy supply considering the possible reduction of electricity imports.

2. METHODS AND PROCEDURES

2.1. Cost-Benefit Analysis

Cost-benefit analysis (CBA) is an instrument that provides the possibility to compare the costs of a certain project with the benefits that this project provides in order to check if the benefits outweigh the costs [3]. CBA thus allows for the project promoters and all other interested parties to draw conclusions, whether the project is feasible. To do that, the costs and benefits must be monetized and expressed as the net present value (because the costs generally appear before the benefits, so the different points in time would actually impact the values) [4].

Though the costs and benefits should be monetized to make the financial analysis in the CBA, setting value can only be one of the tools to express the social costs and benefits of the project to evaluate the impact on the social welfare [5]. In the case of a wind park, the success of the project cannot only be defined by the amount of electricity that has been sold into the electricity grid, because it could be possible to set a feed-in subsidy tariff that would foster the wind park project without increasing social welfare if the feed-in tariff costs had to be compensated by the electricity end-users.

The social welfare impact is not easy to evaluate as it is a rather subjective criterion, but many researchers use the concept of Pareto efficiency entailing that social welfare for a project can be defined as positive if someone benefits without making it worse for others [6]. However, this criterion can easily undermine the results of a CBA if, for example, only one person complains about the visual degradation of the environment due to a wind park project. Another criteria for measuring social welfare is the Kaldor-Hicks compensation test, which entitles that social welfare of a project is positive in case the benefits of a project are so big that the project promoters would be able to compensate the costs for those who have loses due to the project. It is important to stress that the compensation would not actually have to be paid, it is just a way to measure the social welfare benefits [6].

While wind has no fuel costs, there are several key parameters that define the costs of a wind park:

- Investment costs (also known as capital costs or CAPEX), which include the turbine costs, construction works, grid connection costs and other capital costs including administrative costs, designing costs etc.;
- Operation and maintenance costs (OPEX that can be fixed or variable);
- Capacity factor (the output of the turbine affects the rate of return);
- Economic lifetime;
- Cost of capital (i.e. the expected return) [7].

For the CBA of an electricity infrastructure project European Network of Transmission System Operators for Electricity (ENTSO-E) identifies three categories for assessment that are reflected in Table 1 [8].

Costs and benefits in this research will be analyzed by a linear cost model (LCM) that allows to calculate CAPEX and OPEX [4]. For a wind park, the basic CAPEX would be defined by number of cables, substations and turbines. This would include also the costs of materials and construction. The costs would vary depending on the length of cables and the capacity of the wind turbines, which would create a linear function.
OPEX for a wind park are relatively low compared to fossil energy sources, for which around 40–70 % of costs are related to fuel as well as operation and maintenance during the whole life cycle [9].

2.2. Multi-Criteria Analysis

Multi-criteria analysis (MCA) is a widely known research method, which has various techniques and ways of application, but in general it uses several objectives and criteria to solve decision-making problems [10]. MCA is a well appreciated instrument in the decision-making process regarding transition of energy policy. MCA is continuously chosen as a good tool for energy policy as it can cover different relevant actors and criteria [11].

In order to apply MCA analysis, it is necessary to develop criteria and set their corresponding importance. The criteria in this study will be ranked by Analytic hierarchy process (AHP) providing specific score for each criteria, showing the importance of the criteria in comparison to other criteria (1 – equally important, 9 – much more important than other criteria) [12]. After that, the evaluation of the case study projects will be made by using Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) method. The concept of TOPSIS is that the best alternative is the one which is closer to the ideal solution and the farthest away from the worst solution. Thus, when the best and worst values for criteria are defined, alternative with the highest value will be the best one [13], [14].

Both CBA and MCA are applied to the case study in order to evaluate the potential of developing wind parks in Latvia from different perspectives. Both analysis complements each other.

3. Case Study

3.1. Energy and Climate Policy of Latvia

The share of renewable energy sources (RES) utilized in Latvia is rather high, in accordance with the data of 2017, when RES in final consumption was 39.01 %. This is mostly due to the hydroelectric power plants, which produce most of the electricity produced in Latvia, as well as the high usage of biomass for the fuel considering Latvia’s advantage of highly afforested lands [15]. Meanwhile, the National Energy and Climate Plan (NECP) provides a target that the RES share should be 50 % by 2030. Moreover, NECP also stipulate that by 2030, there should be installed 800 MW capacity wind parks offshore and 800 MW capacity wind parks onshore [16]. It’s important to mention that currently there are no offshore wind parks in Latvia and rather few onshore wind parks, mostly small scale that are connected to the distribution grid (70 wind parks with the total generation capacity of 51 MW are connected to the distribution grid, showing that the average capacity of a wind park is far below 1 MW) [17]. The current total wind energy capacity in Latvia is 78 MW, which include the above mentioned small wind parks, wind micro-generators (i.e. generators that have capacity
of up to 11.1 kW) and wind parks that are connected to the transmission system operator’s grid. Thus, large scale wind parks have a very underdeveloped sector in Latvia. The reasoning for that is partly because there are no state grants or feed-in tariff possibilities as the state’s position is that the electricity producers have to compete on market-based rules.

At the same time, taking into account the RES targets, Latvian and Estonian government in collaboration are working on a common offshore wind park ‘ELWIND’ with the total capacity of about 1000 MW (to be determined during the feasibility studies). In September 2020 both governments signed a memorandum of understanding and have begun active work on the project that could be ready by 2030 [18].

3.2. Administrative Procedures for Developing Wind Park in Latvia

The Law on Environmental Impact Assessment prescribes in which cases an environmental impact assessment is necessary. In case of wind parks, an environmental impact assessment is necessary for the construction of the wind parks if there are 15 turbines or more, or if the total generation capacity of the wind park is 15 MW. The initial environmental impact assessment is necessary for the construction of a wind park if there are 5 turbines or more, or if the total generation capacity is 5 MW or more. If the initial assessment ends with a decision that the full impact assessment is not necessary, the electricity producer receives just the technical rules for implementing the power plant. If the initial assessment prescribes the full environmental assessment, it must be done by the project promoter and the final document is evaluated by the government institution, which will issue an approval decision. While the initial assessment is made by the government institution and takes only 20 days, the full impact assessment is a much longer procedure with specific program and public consultations that will take at least 10 months [19].

For any electricity generation plant (above 11.1 kW) to be allowed to operate in Latvia, the potential electricity producer has to receive a permit from the Ministry of Economics of Latvia in accordance with Rules of the Cabinet of Ministers No.559 (adopted 2 September 2020) ‘Regulations Regarding Permits for Increasing Electricity Production Capacities or the Introduction of New Electricity Production Equipment’. If the electricity generation installation is above 1 MW, the potential electricity producer has to provide:

- Fulfilled application indicating the legal information of the entrepreneur and the basic data of the power plant – type of power plans, generation capacity, location and point of connection to grid;
- Detailed description with technical data of the power plant;
- Blueprint of the power plant;
- Ownership documentation for the property;
- Technical rules for implementation of the power plant in accordance with environmental guidelines (if the technical rules in the specific case have been deemed necessary according to the legal acts in the field of environment);
- Approval decision after the environmental impact assessment (if the assessment in the specific case has been deemed necessary according to the legal acts in the field of environment);
- Caution money (178 EUR for a power plant up to 1.99 MW capacity, 267 EUR for a power plant up to 2.99 MW capacity, 356 EUR for a power plant up to 3.99 MW capacity and 50 EUR more for each MW above 4 MW capacity).
The Ministry of Economics of Latvia provides a permit within one month and defines several rules for the power plant – it has to begin construction of the power plant within 6 months (submission of the construction permit is enough, actual construction works are not a prerequisite) and it has to finish the construction works within 5 years. Otherwise the permit will be cancelled [20].

It is important to stress that there is a very different additional procedure for construction in the sea, where a license from the government is necessary in accordance with the Rules of Cabinet of Ministers No. 631 (adopted 14 October 2014) ‘Construction Regulations for Structures in the Internal Waters, Territorial Waters and Exclusive Economic Zone of the Republic of Latvia’. This procedure may take at least 6 months [21].

After receiving the permit from the Ministry of Economics, the potential electricity producer must turn to the system operator to receive technical rules for building the electricity connection between the power plant and the system operator’s grid. The distribution system operator can connect to the grid power plants with the generation capacity of up to 10 MW. Above this threshold, it is usually a connection to the transmission system operator’s grid [22]. For a wind park to receive an authorization from the transmission system operator for a grid connection, the potential electricity producers have to comply with the Commission’s Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators [23]. Decision No. 1/6 (adopted 22 February 2012) of the Board of the Public Utilities Commission ‘Regulation Regarding System Connection for Electricity Producers’ define prerequisites for a system connection and the methodology for the calculation of a connection fee for electricity producers. The system operator will provide technical rules within 60 days. The electricity producer is then responsible for designing the connection in accordance with those rules, but the system operator is responsible for the construction of the connection (the electricity producer pays for that) [22].

As defined in Rules of Cabinet of Ministers No. 500 (adopted 19 August 2014), ‘General Construction Rules’, a power plant with generation capacity above 20 kW is considered a third group engineering construction [24]. Meanwhile, the Rules of Cabinet of Ministers No.573 (adopted 30 September 2014) ‘Construction Rules for electricity generation, transmission and distribution facilities’ defines the documentation that has to be submitted for obtaining the building permit. The building permit is issued within one month [25]. The cost of a construction permit for engineering construction for legal entities is 51.22 euro. The construction permit is valid for five years for construction that had qualified for environmental impact assessment and 8 years if the environmental impact assessment was not needed. The cost of prolonging a construction permit for legal entities is 21.32 euro.

It can be summarized that the administrative state fees do not put any dramatic burden on the potential electricity producer, but all the administrative procedures take time and depending on the location of the wind park (onshore/offshore), all the process starting from the environmental impact assessment and ending with the construction permit can take from about 1 year up to 2.5 years.

### 3.3. Scenarios for Case Study

In order to evaluate a wind park’s real potential, it is important to look at specific wind park projects, which could provide both estimate financial costs as well as the feasibility of the project from the technical, administrative and environmental perspectives. To have a broader view it is important to evaluate projects of different scope. Thus, this research focuses on wind parks of two different sizes and different locations (onshore and offshore):
Wind park with the generation capacity of 100 MW, located onshore in the western part of Latvia (in the region of Kurzeme);
− Wind park with the generation capacity of 500 MW, located offshore in the territorial sea of Latvia (in the Gulf of Riga).

In both case scenarios the life span of the wind park technologies is 20 years. Though different generation capacities make the comparison between the scenarios impossible, it is important to stress that the aim of the research is not to choose one of the two scenarios as the best option, but to evaluate these 2 scenarios as different possibilities for Latvia. The generation capacities assumed by the authors are based on the practical experience on the real-life wind park projects that have been developed or are in planning stage in Latvia.

3.4. Wind and Electricity Grid Potential in Latvia

The wind speed not only differs depending on the region, but also depending on the height. Latvian researchers have gathered average wind speed statistics for the height of 10 meters, 50 meters and 100 meters [26]. European Commissions Joint Research Center has distinguished between small wind turbines with the height of 35 m (250 kW generation capacity) and larger wind turbines with the height of 80 m (3 MW generation capacity) [27]. Considering that in both case studies the generation capacities are 100 MW or more, they would use large wind turbines. In the last years the technologies become more and more advanced and the average height of the turbines is increasing above 100 meters. In this research we would assume that the wind turbine would be about 100 meters high, thus the relevant wind speed would also be for the height of 100 meters, which has been showed in Fig. 1.

Fig. 1. Average wind speed in Latvia at the height of 100 meters [26].
It is important to stress that not only the wind power is different in different regions of Latvia, but also the electricity grid capacity and the possibilities of the electricity system operator to connect new wind parks to the grid. Considering the generation capacity in both case study scenarios, it can be assumed that both wind parks would be connected to the transmission system operator’s grid. As was mentioned in subchapter 3.2., the potential energy producer shall receive technical rules from the system operator, which will define what are the technical solutions that shall be implemented in order for the system operator to be able to connect the new wind park to the grid. Thus, depending on the location of the new wind park, the grid requirements will differ.

As can be seen in Fig. 2, the grid is most developed in the region Kurzeme with the recently finished ‘Kurzeme ring’ project providing 800 MW grid capacity, however, here the capacity is also the most demanded, thus the grid capability is not unlimited and for large new generation capacities, the grid would have to be improved. Meanwhile, the grid is rather flexible in the Latgale region, where there is less demand for new generation capacities to be connected to the grid [28].

Fig. 2. Latvian transmission network [28].

As regards the sea, it has been researched that the Baltic seas common wind energy capacity could be more than 93 and the Baltic Sea has a potential to locate 187 wind parks with each capacity of 500 MW (which is also the capacity that was assumed for the offshore wind park case scenario). Furthermore, if narrowed down to the potential of Latvia in the Baltic sea – Latvian territorial sea could contain 29 wind parks with the total capacity of 15.5 GW, that could produce 49.2 TWh per year [16].
4. RESULTS

4.1. Cost-Benefit Analysis of the Case Study

As has been calculated by the International Renewable Energy Agency (IRENA), the breakdown of the share of costs for a typical onshore wind park can be seen in Fig. 3.

Fig. 3. Breakdown of costs for an onshore wind park in 2012 [7].

The costs of wind turbines include the costs of generator, transformer, power converters, gearbox, rotor blades, tower and other additional costs. However, in the last decade the costs of the wind turbine have largely decreased. The tables have changed now and according to the newest IRENA report on renewable power generation costs in 2019, average onshore wind turbine costs would be 580 000 EUR/MW. The rest of the costs (grid connection, planning, foundation construction) on average comprise around 649 000 EUR/MW [29], so the additional costs now are higher than the wind turbine costs. Operational and maintenance costs for onshore projects on average in Europe are 37 000 EUR/MW/year, which also includes the labour force.

Offshore wind projects cost more. The average total costs of wind park are 3 171 000 EUR/MW, where offshore turbines take about 50 % of these total costs and the other 50 % are for the grid connection and other additional costs would make around 80 000 EUR/MW/year.

TABLE 2. COSTS AND BENEFITS OF THE WIND PARK CASE STUDIES

| Costs and benefits | Wind park A | Wind park B |
|--------------------|-------------|-------------|
| 1 Wind turbine costs (total EUR) | −58 000 000 | −792 970 000 |
| 2 Grid connection and other costs (total EUR) | −64 900 000 | −792 970 000 |
| 3 Operation and maintenance costs (total EUR in 20 years, 2 % OPEX growth, 8 % discount rate) | −37 352 254 | −403 634 155 |
| 5 Revenues from electricity sales (using average NordPool power exchange price for Latvian area in February 2021–59.15 EUR/MWh, 8 % discount rate for output) | +163 599 233 | +1 067 939 438 |
| Total | +3 308 091 | −921 634 717 |
If we calculate the costs and benefits from the project promoters point of view regarding the financial perspective, it can be seen that the onshore wind park can be beneficial if the produced electricity is sold by the current average electricity exchange price. These results were calculated by taking into account the possible OPEX growth (2% annually) as well as the discount rate and the interlinked net present value of the costs and net present value of the electricity output. The results also provide that offshore wind park is currently not rentable. For clearer understanding of the circumstances, when the offshore wind park would be rentable, the authors calculated the levelized cost of electricity (LCOE), which is the selling price of electricity that is required so that the projects revenues would at least equal the costs. LCOE was calculated by using the total project costs (over the 20-year lifetime, including OPEX with 2% annual growth rate), capacity factor, 20-year lifetime, the respective electricity output in 20 years and the cost of capital (assumed discount rate 8%).

For onshore project the LCOE value was 57.9 EUR/MWh, which is rather close to the current actual market value of the electricity. At the same time, the offshore project’s LCOE was 110.17 EUR/MWh, almost double the market price. Thus, without project grants or feed-in tariffs, the authors of the research don’t see, how such a project could be introduced.

If we look as social welfare part of cost-benefit analysis, it could be argued that the benefits outweigh the costs. For both of the case studies, we can see several benefits:

- Increased security of supply due to the decrease of imports. In February 2021, Latvia had a net import of 40,831 MWh. The onshore wind park could produce for Latvian market 25,920 MWh/month, so it could reduce this net import by more than a half (if the electricity is sold for the national market). The offshore wind park could produce 169,200 MWh/month fully covering the deficit of electricity in Latvia.
- Reduction in CO₂ emissions – introduction of wind parks reduces the carbon footprint on average be 600 g/kWh [30]. Thus, the onshore wind park could reduce the CO₂ emissions by 15,552 tons/month, while the offshore wind park could even reduce the CO₂ emissions by 101,520 tons/month.
- A step towards achieving the targets set in NECP of 800 MW onshore and offshore. The offshore target would easily achievable by 2 large scale wind parks.
- Increased employment – different research studies suggest that on average around 5 jobs per wind energy MW are created in the world [31]. Of course, this does not mean so many employees in Latvia on the specific wind park, but that is the number of workers, who would be employed to develop designs, come up with engineering solutions, produce wind park’s turbines and all other parts, as well as this includes the workers that are necessary to maintain the wind park. So, the onshore project could provide work for 100 people around Europe (or around the world, depending on the country that produces parts for the wind park) and the offshore project could provide even 500 jobs. If we look locally, the onshore park would provide around 2 work places, while the offshore park would need around 5 employees.

The costs of the social welfare are harder to express in numbers. These costs are mostly comprised of the complaints about the aesthetic view in the environment, threat to health. Different researches show that there is not threat to human health (besides there is a security protection zone set by the law defining the necessary construction distance from houses and other objects). Thus, from the social welfare point of view, if we consider the previously explained Kaldor-Hicks method, the benefits outweigh the costs.
4.2. Multi-Criteria Analysis of the Case Study

In this case study, the MCA is done to compare an offshore and onshore wind park. In order to be able to compare wind parks of different sizes, the levelized costs per 1 MW are used. The chosen input data (criteria) for the wind park are defined in Table 1. As there has been a research showing that increased wind energy share does not necessarily mean that there will be decrease in electricity prices [32], impact on electricity price was not considered as a criteria for MCA. Meanwhile, the previously calculated LCOE is included between the criteria. The capacity factor shows the energy output from a wind park per year as a share of wind parks maximum possible output that is influenced by the wind speed and the used technologies. By applying AHP method, the criteria received specific weight.

| Criteria | Weight | Wind park A | Wind park B |
|----------|--------|-------------|-------------|
| C1 All investment costs, EUR/MW | 15 % | 1 229 000 | 3 171 000 |
| C2 Operation and maintenance costs, EUR/MW/year | 13 % | 37 000 | 80 000 |
| C3 Administrative burden, months | 5 % | 12 | 24 |
| C4 Job creations, number of workers | 6 % | 2 | 5 |
| C5 Capacity factor % | 25 % | 36 | 47 |
| C6 Import reduction, % | 8 % | | |
| C7 LCOE, EUR/MWh | 28 % | 57.9 | 110.17 |

The input data was normalized by dividing criteria value by the sum of criteria value. Table 4 shows the results of the MCA.

| Criteria | Wind park A | Wind park B | Best values |
|----------|-------------|-------------|-------------|
| C1 All investment costs, EUR/MW | +0.042 | −0.108 | Min |
| C2 Operation and maintenance costs, EUR/MW/year | +0.041 | −0.089 | Min |
| C3 Administrative burden, months | +0.017 | −0.033 | Min |
| C4 Job creations, number of workers | −0.017 | +0.043 | Max |
| C5 Capacity factor % | −0.108 | +0.142 | Max |
| C6 Import reduction, % | −0.027 | +0.053 | Max |
| C7 LCOE, EUR/MWh | +0.096 | −0.184 | Min |

Total | −0.149 | −0.176 |

Criteria with the positive factor were added to the criteria with the negative factor (the positive or negative notion was set based on the best value indication column). The results of the MCA provide that in comparison between the two scenarios, some of the criteria have played a big role in determining that the best case study would be the onshore wind park. In general, the offshore wind park is not an optimal solution both due to the initial capital costs and the related LCOE value.
5. CONCLUSIONS

While cost benefit analysis on its own serves as a tool to understand if any of the wind park case study scenarios are feasible from financial and other perspectives, the multi criteria analysis provide a comparison between the two suggested case study projects.

Both of the analysis provided rather similar results, showing that an offshore wind park in the sea is currently not a good business case if there is no state (or EU) support in the form of financial grants or energy policy changes regarding a feed-in tariff for renewable energy. For current situation it is understandable that the only project under real consideration for offshore is the common Estonian-Latvian wind park project that will be able to qualify for the EU grant from Connecting Europe Facility. Other support mechanisms should be further researched that could be applied to private project promoters. At the same time, the research clearly showed a good potential for onshore wind energy development that would not need state support and could operate on market-based principles with a competitive electricity price to provide.

Any large-scale wind park project would effectively contribute to the security of energy supply aspect if the wind energy was not exported but sold locally, which would reduce the imports significantly. At the same time, wind parks cannot provide specific base capacity due to its’ volatile nature.

It could be argued that the administrative procedure for introducing a wind park, especially an offshore wind park, is complicated, takes a lot of time and should be improved so that the new electricity producers would see support from the state at least in the terms of administrative procedures. Meanwhile, the administrative costs in comparison are minimal considering the project costs that circle around several million euros, thus there is no real need to lower the fees and levies from the state side.

In order to fulfil the targets of NECP, it is planned to introduce additional 800 MW of onshore and offshore wind capacity. To be able to do that, it’s also important to develop the electricity grid. Both onshore and offshore project promoters are interested in connecting their wind parks to the transmission grid and mostly in the western part of Latvia (due to the wind speed), the respective electricity grid has to have enough capacity to do that. The necessary grid improvement works should be done as soon as possible.

REFERENCES

[1] Eurostat. Greenhouse gas emission statistics – air emissions accounts, 2021. [Online]. [Accessed 01.04.2021]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emission_statistics_-_air_emissions_accounts&oldid=549000
[2] Kijewska A., Bluszcz A. Analysis of greenhouse gas emissions in the European Union member states with the use of an agglomeration algorithm. Journal of Sustainable Mining 2017:15(4)133–142. https://doi.org/10.1016/j.jsm.2017.02.001
[3] Intrac. Cost-benefit analysis. Oxford: Intrac, 2017.
[4] Avdic Belltheus D.m Stahl P. Cost-Benefit Analysis of an integrated offshore grid in the Baltic sea. Berlin: Baltic InteGrid, 2019.
[5] De Rus G. Introduction to Cost-Benefit Analysis: Looking for Reasonable Shortcuts. Cheltenham: Edward Elgar, 2021.
[6] Mouter N. Cost-Benefit Analysis in Practice. Thesis. Delft: Delft University of Technology, 2014.
[7] IRENA. Renewable Energy Technologies: Cost Analysis series. Wind Power. Abu Dhabi: IRENA, 2012:1(5/5).
[8] ENTSO-E. Guideline for Cost Benefit Analysis of Grid Development Projects. Brussels: ENTSO-E, 2016.
[9] Wind Europe. Wind energy is the cheapest source of electricity generation, 2019 [Online]. [Accessed 20.03.2021]. Available: https://windeurope.org/policy/topics/economics/
[10] Dean M. Chapter Six – Multi-criteria analysis. Advances in Transport Policy and Planning 2020:6:165–224. https://doi.org/10.1016/bs.atpp.2020.07.001
[11] Urošević B. G., Marinović B. Ranking construction of small hydro power plants using multi-criteria decision analysis. Renewable Energy 2021:172:1174–1183. https://doi.org/10.1016/j.renene.2020.03.115
[12] Vamza I, Valters K., Blumberga D. Multi-Criteria Analysis of Lignocellulose Substrate Pre-Treatment. Environmental and Climate Technologies 2020:24(3):483–492. https://doi.org/10.2478/rtuect-2020-0018
[13] Zlaugotne B., et al. GHG Performance Evaluation in Green Deal Context. Environmental and Climate Technologies 2020:24(1):431–441. https://doi.org/10.2478/rtuect-2020-0026
[14] Zlaugotne B., et al. Multi-Criteria Decision Analysis Methods Comparison. Environmental and Climate Technologies 2020:24(3):447–456. https://doi.org/10.2478/rtuect-2020-0015
[15] Kudurs E., et al. Are Industries Open for Renewable Energy? Environmental and Climate Technologies 2020:24(3):447–456. https://doi.org/10.2478/rtuect-2020-0015
[16] Ministry of Economics of Latvia. Nacionālais Enerģētikas un Klimata Plāns (National Energy and Climate Plan) [Online]. [Accessed 04.04.2021]. Available: https://www.em.gov.lv/lv/nacionalais-energetikas-un-klimata-plans (in Latvian)
[17] Ministry of Economics of Latvia. Elektroenerģijas Ražošana (Electricity generation) [Online]. [Accessed 15.03.2021]. Available: https://www.em.gov.lv/lv/elektroenergijas-razosana (in Latvian)
[18] Latvijas Vestnesis. Parakstīts Saprašanās memorands par Igaunijas un Latvijas vēja parka projektu (A Memorandum of Understanding has been signed on the Estonian and Latvian offshore wind farm project) [Online]. [Accessed 15.03.2021]. Available: https://lv portals.it/ dienaskar tiba/320014-parakstit-saprasanas-memorands-par-igaunijas-un-latvijas-atkarstes-veja-parka-projektu-2020 (in Latvian)
[19] Vides eksperti. Ietekmes uz vidi novērtējums (Environmental Impact Assessment) [Online]. [Accessed 10.04.2021]. Available: https://videseksperti.lv/ietekmes-uz-vidi-novertejums-2 (in Latvian)
[20] Cabinet of Ministers Republic of Latvia. Regulations Regarding Permits for Increasing Electricity Production Capacities or the Introduction of New Production Equipment. Latvijas Vestnesis 2020:175.
[21] Cabinet of Ministers Republic of Latvia. Construction Regulations for Structures in the Internal Waters, Territorial Waters and Exclusive Economic Zone of the Republic of Latvia. Latvijas Vestnesis 2014:211.
[22] Sadales tīkls. Elektrostacijas pieslēgums (Power plant connection) [Online]. [Accessed 30.03.2021]. Available: https://sadaletikls.lv/lv/elektrostacijas-pieslsgsana (in Latvian)
[23] Augstsprieguma tīkls. Connections to the transmission grid [Online]. [Accessed 01.04.2021]. Available: https://www.ast.lv/en/content/connections-transmission-grid
[24] Cabinet of Ministers Republic of Latvia. General Construction Regulations. Latvijas Vestnesis 2014:191.
[25] Cabinet of Ministers Republic of Latvia. Elektroenerģijas ražošanas, pārvades un sadales būvniecība (Building regulations for electricity generation, transmission and distribution facilities.), Latvijas Vestnesis 2014:194. (in Latvian)
[26] WindEnergy. Vēja ātrums 100 metru augstumā (The Speed of Wind at a Height of 100 Metres) [Online]. [Accessed 01.04.2021]. Available: http://www.windenergy.lv/map/en/veja-atrums-100-metru-augstuma/
[27] Dalla Longa F., et al. Wind potentials for EU and neighbouring countries. Luxembourg: Publications Office of the European Union, 2018. https://doi.org/10.2760/041705
[28] Augstsprieguma tīkls. Transmission network and substations [Online]. [Accessed 18.03.2021]. Available: https://www.ast.lv/en/transmission-network-info/transmission-network-and-substations
[29] IRENA. Renewable power generation costs in 2019. Abu Dhabi: IRENA, 2020.
[30] Hernandez C. V., Gonzalez J. S., Fernandez-Blanco R. New method to assess the long-term role of wind energy in reduction of CO2 emissions – Case study of the European Union. Journal of Cleaner Production 2019:207:1099–1111. https://doi.org/10.1016/j.jclepro.2018.09.249
[31] Aldieri L., et al. Wind Power and Job Creation. Sustainability 2019:12(1):45. https://doi.org/10.3390/su12010045
[32] Valdmanis G., Bazbauers G. Influence of wind power production on electricity market price. Environmental and Climate Technologies 2020:24(1):472–482. https://doi.org/10.2478/rtuect-2020-0029