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RIGA TECHNICAL
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Līga Rozentāle

ELECTRICITY AND CLIMATE POLICY MEASURES: THE UNKNOWN KNOWN

Summary of the Doctoral Thesis

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RIGA TECHNICAL UNIVERSITY
Faculty of Electrical and Environmental Engineering
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ELECTRICITY AND CLIMATE POLICY MEASURES: THE UNKNOWN KNOWN

Summary of the Doctoral Thesis

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DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR THE PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF SCIENCE

To be granted the scientific degree of Doctor of Science (Ph. D.), the present Doctoral Thesis has been submitted for the defence at the open meeting of RTU Promotion Council on 6 June 2022, at 14:00, at the Faculty of Electrical and Environmental Engineering of Riga Technical University, 12/1 Azenes Street, Room 116.

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Science (Ph. D.) is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Līga Rozentāle ……………………………. (signature)
Date: ………………………

The Doctoral Thesis has been written in English. It consists of an introduction, 3 chapters, conclusions, 21 figures, 6 tables, and 9 appendices; the total number of pages is 151, including appendices. The bibliography contains 76 titles.

TABLE OF CONTENTS

Topicality of the Doctoral Thesis

European Union's (EU) energy and climate policy has been one of the major priorities on the EU agenda for the last decade. While the EU member states try to implement the goals and rules stipulated in EU level documents, new legislative proposals keep coming up and member states need to elaborate new national actions to fulfil the common EU targets. Some of the national actions are more developed and incentivized than others due to political, economic, practical reasons and also because of the lack of knowledge.

The topicality of this research comes not only from the EU climate targets but also considering the review of the National Energy and Climate Plan that is coming up in 2023 for all EU member states, as well as the increased energy prices in years 2021–2022 that have urged many electricity consumers to switch to electricity generation for self-consumption. This has been further promoted also by the EU level legislation that has been trying to impower the electricity consumers to produce their own electricity and to cooperate with other self-consumers. Moreover, increased local electricity generation is also an important aspect of energy independency, which is a topical issue in the geopolitical context. Thus, electricity policy measures from a climate perspective are as topical as never before.

The Aim and Tasks of the Doctoral Thesis

The aim of the Thesis is to research those Latvian electricity policy areas which are underdeveloped or overlooked in the current electricity policy framework in order to define the possible improvements from the perspective of achieving climate targets.

The following tasks were defined to achieve the aim of the Thesis:

1. To evaluate the current electricity policy measures in Latvia and the role of climate aspects in it.
2. To assess the economic and technical prospects for accelerating electricity generation from solar panels and wind parks in Latvia while considering these capacities as the potential for creating energy communities.
3. To analyse the possibilities of decreasing the consumption of fossil fuels by taking into account the energy intensity in manufacturing in Latvia as well as the possible benefits from railway electrification while also considering the overall electricity consumption reduction by involvement of aggregators.
4. To propose new electricity policy measures for the National Energy and Climate Plan of Latvia based on the conclusions from Tasks 2 and 3 while providing quantitative assumptions on the effect of these measures.

Hypothesis of the Doctoral Thesis

Additional overlooked electricity policy measures in the National Energy and Climate Plan of Latvia can play an important role in the way towards achieving climate neutrality.

Methodology of Research

The Thesis utilizes seven different types of methodologies for evaluating the electricity policy measures that are not covered or at least not fully covered by the National Energy and Climate Plan (NECP) of Latvia. As has been summarized in Fig. 1, six of the methodologies are united by the final research using theory-based approach. Methodologies for researching the electricity policy measures were chosen based on the aim of each research – if the aim was to understand the financial side of the measure, more mathematical approaches were used, while if the aim was to understand if and how the policy measure is being implemented in the national legislation – a qualitative analysis was used. At the same time, when using theory-based approach, all previously explored policy measures received a quantifiable evaluation.

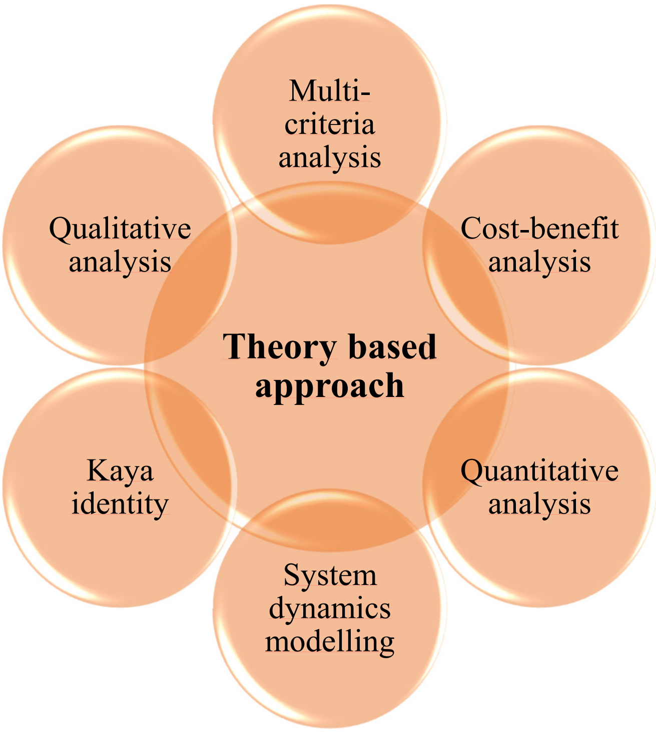

Fig. 1. Research framework uniting seven different methodologies.

Scientific Significance of the Doctoral Thesis

The research is of scientific significance in terms of comprehensive and systematic analysis of the underdeveloped electricity policy measures with different methodological approaches coming down to the final theory-based approach to integrate all parts of the research.

The research is focused on linking theory on electricity policy to practical electricity policy results, while providing a cross-cut approach in combining energy, economic, social research aspects for specific electricity policy improvements from climate perspective.

The overall study is based on multiple methodologies to evaluate electricity policy from different angles, thus, it provides a separate investigation of each potential policy measure before utilizing theory-based approach to combine the research results.

Practical Significance of the Doctoral Thesis

The practical significance of the research is that it provides practical proposals for the improvements in the review of NECP in 2023. The current NECP of Latvia has served for two years now, and it has been possible to compare the Latvian NECP with the NECP of other EU members states and to assess what are the missing aspects that could provide measurable benefit for Latvia (in the form of CO_2 reduction) if included in the NECP.

At the same time, as part of the research, a practical model has been developed that can be used as a tool for estimating the return of investments in solar panels. At the same time a system dynamics model was created to evaluate the impacts of railway electrification that can be applicable also to other countries.

Structure and Description of the Doctoral Thesis

The Doctoral Thesis is based on thematically linked 9 scientific publications, which are published in various scientific journals and are accessible on different scientific databases available for citation. Eight of the publications research different electricity policy measures, and the ninth publication provides a summary and proposals for the National Energy and Climate Plan of Latvia considering the aspects that have been reviewed in the previous publications.

The Doctoral Thesis comprises an introduction and three chapters:

1. Literature review.
2. Research methodologies.
3. Results and discussion.

The introduction provides the aim of the Doctoral Thesis, which is followed by the tasks for achieving the aim. The introduction also provides a hypothesis and describes the scientific and practical significance of the Thesis. This is followed by the information on approbation of the research results by participating in international scientific conferences and published scientific publications.

The literature review in Chapter 1 consists of an overview of the area of research, i.e., the electricity policy in Latvia and the relevant policy measures discussed in the author's publications. Chapter 2 describes the methodology that was used in all of the publications in order the evaluate the different electricity policy measures that are currently underdeveloped in the Latvian electricity policy. Chapter 3 provides the results of the research based on the previously mentioned methodology, which allows the author to finalise the Doctoral Thesis with conclusions.

The structure of the Thesis is displayed in Fig. 2, showing that, firstly, the current electricity policy measures are evaluated, then, the focus is turned to additional electricity production measures, additional electricity consumption measures and additional measures in switching from fossil fuels to electricity. Policy measures in these three groups are researched by 7 different methodologies that allow to apply theory-based approach in the end to assess the practical potential of these measures in the review of National Climate and Energy Plan in 2023.

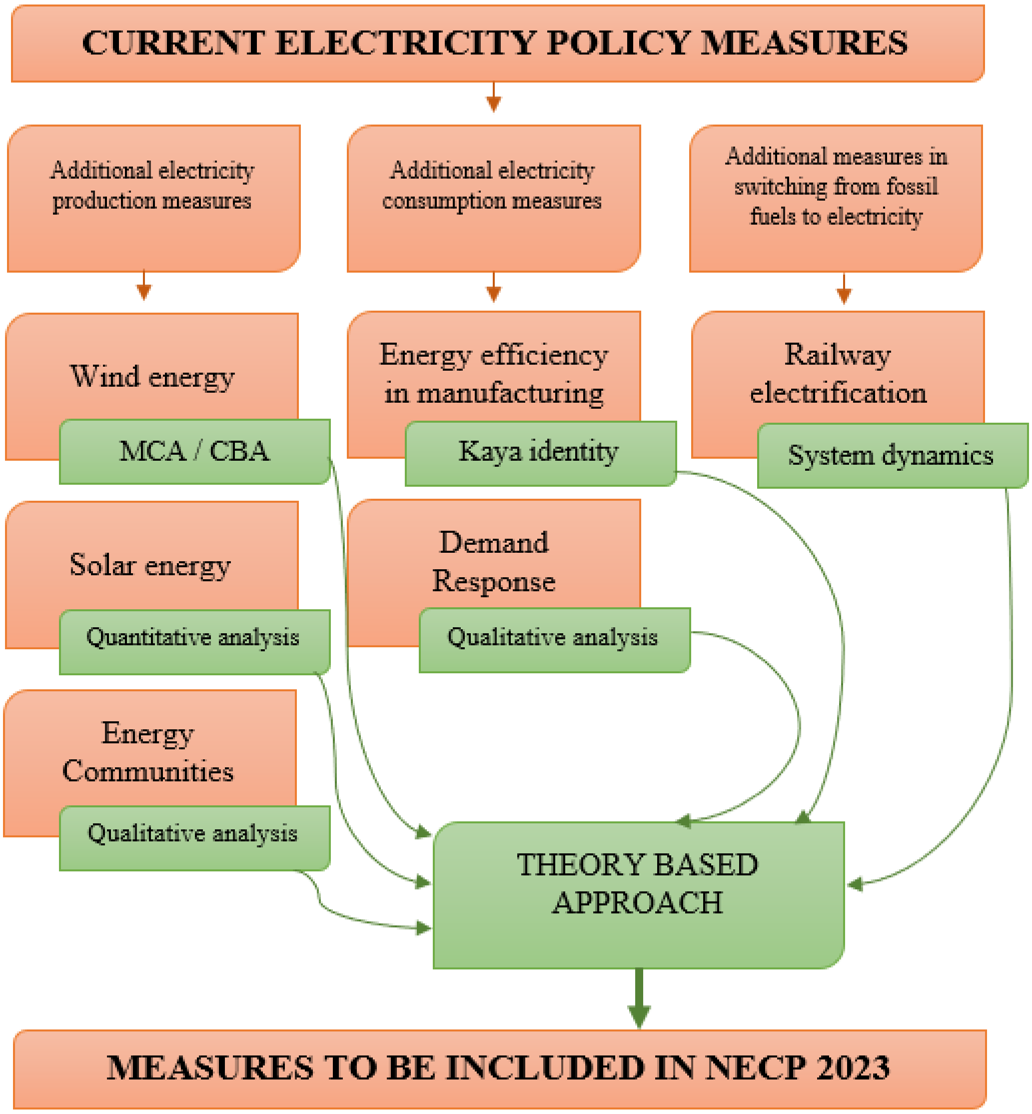

Fig. 2. Structure of the Thesis.

Approbation of the Research Results

The research results have been approbated in 8 international scientific conferences and 9 full-length articles; 8 articles have been published (7 articles are indexed in SCOPUS database and 6 in ISI Web of Science database) and 1 recent article is under review.

Reports at International Scientific Conferences

1. Rozentale L., Blumberga D. Potential role of energy communities in the way towards climate neutrality // 62th International Scientific Conference on Power and Electrical Engineering, Riga Technical University, 2021.

2. Rozentale L., Blumberga D. Cost-benefit and multi-criteria analysis of wind energy parks' development potential in Latvia // International Scientific Conference of Environmental and Climate Technologies – CONECT 2021, Riga Technical University, 2021.

3. Rozentale L., Blumberga D. Aggregator as a new electricity market player. Case study of Latvia. // 61th International Scientific Conference on Power and Electrical Engineering, Riga Technical University, 2020.

4. Rozentale L., Mo G., Gravelsins A., Rochas C., Pubule J., Blumberga D. System Dynamics Modelling of Railway Electrification in Latvia. // International Scientific Conference of Environmental and Climate Technologies – CONECT 2020, Riga Technical University, 2020.

5. Rozentale L., Blumberga D. Energy Intensive Manufacturers in State Economy: Case study of Latvia. // 60th International Scientific Conference on Power and Electrical Engineering, Riga Technical University, 2019.

6. Rozentale L., Blumberga D. Methods to Evaluate Electricity Policy from Climate Perspective. // International Scientific Conference of Environmental and Climate Technologies – CONECT 2019, Riga Technical University, 2019.

7. Rozentale L., Lauka D., Blumberga D. Accelerating Power Generation with Solar Panels. Case in Latvia. // Vilnius Gediminas Technical University 21st Conference of Lithuanian Junior Researchers "Science – Future of Lithuania. Environmental protection engineering", Vilnius, Lithuania, 2018.

8. Rozentale L., Lauka D., Blumberga D. Accelerating Power Generation with Solar Panels. Case in Latvia. // International Scientific Conference of Environmental and Climate Technologies – CONECT 2018, Riga Technical University, 2018.

Publications by the Author

1. Rozentale L., Blumberga D. Electricity policy solutions in Latvia from climate perspective // 2022 – Article submitted for review.
2. Rozentale L., Blumberga D. Potential role of energy communities in the way towards climate neutrality. Case study of Latvia // 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), IEEE – 2021, pp. 1–6. DOI: https://doi.org/10.1109/RTUCON53541.2021.9711724.
3. Pakere I., Gravelsins A., Bohvalovs G., Rozentale L., Blumberga D. Will Aggregator Reduce Renewable Power Surpluses? A System Dynamics Approach for the Latvia Case Study // Energies (EISSN 1996-1073) – 2021. DOI: https://doi.org/10.3390/en14237900.

4. Rozentale L., Blumberga D. Cost-benefit and multi-criteria analysis of wind energy parks' development potential in Latvia // Environmental and Climate Technologies – vol. 25, no. 1, 2021, pp. 1229–1240. DOI: https://doi.org/10.2478/rtuect-2021-0093.
5. Rozentale, L., Blumberga, D. Aggregator as a new electricity market player. Case study of Latvia. // 61th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), IEEE – 2020, pp. 1–6, DOI: 10.1109/RTUCON51174.2020.9316486.
6. Rozentale L., Blumberga, D. Energy Intensive Manufacturers in State Economy: Case study of Latvia. // 60th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia, IEEE – 2019, pp. 1–6. DOI: https://doi.org/10.1109/RTUCON48111.2019.8982318.
7. Rozentale L., Mo G., Gravelsins A., Rochas C,. Pubule J., Blumberga D. System Dynamics Modelling of Railway Electrification in Latvia. // Environmental and Climate Technologies – 2020. Vol. 24, No. 2, pp. 247–257. DOI: https://doi.org/10.2478/rtuect-2020-0070.
8. Rozentale L., Blumberga D. Methods to Evaluate Electricity Policy from Climate Perspective. // Environmental and Climate Technologies (ISSN 1691-5208) – 2019, Vol. 23, No. 2, pp. 131–147. DOI: https://doi.org/10.2478/rtuect-2019-0060.
9. Rozentale L., Lauka D., Blumberga D. Accelerating Power Generation with Solar Panels. Case in Latvia. // Energy Procedia (ISSN 1876-6102) – 2018, Vol. 147, pp. 600–606. DOI: https://doi.org/10.1016/j.egypro.2018.07.077.

1. OVERVIEW OF THE AUTHOR'S RESEARCH ON ELECTRICITY POLICY MEASURES

A well-functioning internal energy market is crucial to provide Europe with secure, sustainable and affordable energy supplies [1]. To ensure such internal energy market, it is necessary to implement a sound national electricity policy, which may include development of national legislation, regional cooperation, and different political decisions (such as development of national and cross border infrastructure). All these actions are closely related to different monetary investments both from the national and EU financial resources. The EU internal energy market can be related to both electricity and gas market; however, to narrow down the research, the Thesis focus is on the internal electricity market. All the actions performed to ensure a well-functioning internal energy market can be viewed and evaluated from different perspectives: How much will it cost? Will it be sustainable? What political or technical problems of the internal electricity market will it solve? etc.

In this time of climate change and ever-increasing EU-level ambitions for mitigating these climate changes until 2030 by reducing the greenhouse gas emissions, by increasing the usage of renewable energy, and by improving the energy efficiency [2], it would be essential to evaluate both the political and technical actions in the electricity sector from the climate perspective, i.e., to measure the impact on the climate.

EU Regulation 2018/1999 [3] determines that each EU member state must draw up a NECP for the period 2021–2030 in order to achieve targets in the above-mentioned areas. This study further on focuses on the measures that are more or less overlooked in Latvian current NECP, while being an important trend in the EU, creating concern, why Latvia is not putting more emphasis on those areas and what would be the impact if we did include these electricity policy measures in the NECP that will be reviewed in 2023 providing an excellent possibility for improvements.

The researched electricity policy measures can be divided into 3 categories:

- Electricity policy measures for producing more electricity (solar energy, wind energy, and energy communities combining both);
- Electricity policy measures for reducing energy consumption (energy efficiency measures in manufacturing and demand response);
- Electricity policy measures fostering the consumption switch from using fossil fuels to electricity (railway electrification).

1.1. Electricity generation policy measures

The electricity generation policy measures that are reviewed in the Thesis are wind energy and solar energy policies that are also closely linked to energy communities. NECP of Latvia sets a target that the RES share in gross final consumption should be 50 % by 2030. However, 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 (as of the beginning of 2022, 90 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) [4]. The current total wind energy capacity in Latvia is 78.6 MW (for instance, Lithuania has more than 500 MW [5] and Estonia more than 300 MW [6]).

Meanwhile, the usage of solar energy in Latvia could be described as underdeveloped. The Central Statistical Bureau of Latvia does not include solar energy in the statistics of national energy mix because it is less than 0.1 %. The current installed solar capacity for microgenerators is 13.9 MW (as of December 2021) and for solar power plants – 6.9 MW. Thus, the total installed solar capacity is 20.8 MW. In comparison, the current installed solar capacity in Lithuania is around 150 MW [7], while in Estonia around 130 MW [6], showing that in the Baltic region Latvia is largely lagging in this policy area.

In the context of electricity generation from wind and solar energy, EU has provided a new legal framework for additional promotion of renewable energy – energy communities. With the increase of decentralized electricity production, creation of energy communities has become more and more topical considering the economic benefit that appears when a group of people engage in an activity that is considered to be more expensive if exercised individually [8]. The concept of energy communities has been developing for more than ten years, and there are already operating pilot projects in Europe [9]. Energy communities provide the opportunity for consumers to be empowered at different community sizes and forms, produce their own electricity (or other type of energy) and consume it collectively with little or no involvement of an electricity supplier [10], [11].

The electricity transmission system operator (TSO) of Latvia has modelled the possible electricity demand up to year 2030 in three scenarios, where the first one is the most conservative and the last one is the most optimistic and provides the highest increase in electricity consumption in Latvia [12]. All three scenarios show that the electricity consumption in Latvia in the next years will only rise. The TSO has also compared this demand with the possibilities to provide the necessary capacity from the existing power plants and import. In the base scenario, Latvia would be capable to cover peak demand up to 2024, after that there would be electricity deficit in Latvia [12]. This means that additional electricity generation installations will be needed, and energy communities is a way to foster it.

Neither the onshore wind energy, nor solar energy or energy communities have specific goals that should be achieved in accordance with the NECP of Latvia.

1.2. Electricity consumption reduction measures

There were two aspects covered under the electricity consumption reduction measures – energy efficiency in manufacturing and demand response.

Manufacturing industry is sometimes considered to be the backbone of a country’s economy. Some of the main benefits include such aspects as increased employment, country’s gross domestic product (GDP), and technological advancement [13]. However, it is assumed that large manufacturing also comes together with high energy intensity and high level of greenhouse gas emissions. Energy intensity in Latvia is quite above average in the EU, however, in the recent years the gap is narrowing down.

As researched in the study, there is no specific NECP target defined in terms of reducing energy (electricity) intensity in the manufacturing sector in Latvia. The measures are descriptive and aimed at assessing whether entrepreneurs should be obliged to compare different technological alternatives (e.g., manufacturing facilities with higher and lower energy consumption) when making investment decisions regarding development. NECP also requires policy planners to amend legal acts that cover the EU funding rules to determine certain energy efficiency requirements, as well as requires additional studies to be made, e.g., regarding possible review of the scope of current energy efficiency obligations. Currently, energy intensive manufacturers must carry out an energy audit (once every 4 years) or implement a certified energy/environmental management system. Energy intensive manufacturers must implement at least 3 energy efficiency improvement measures that provide energy savings. However, neither the pre-NECP legislation, nor NECP implement any specific measurable energy saving goals for energy intensive manufacturers.

As regards demand response, it provides a range of flexibility mechanisms provided by the agreggators at different electricity market segments, where aggregator can act as a facilitator for providing flexibility of electricity consumption where needed – for electricity distribution or transmission systerm operators or for the balance responsible parties (electricity suppliers) [14]. Demand response can be described as changes in the usual pattern of electricity consumption by the final consumer [15]. Latvia's NECP does include vision of aggregators, prescribing the need for legislation that would set the rights and duties of the aggregators, however, there are no specific goals for their actions, e.g., yearly electricity savings.

1.3. Electricity policy fostering electrification

Railway transport is one of the most promising modes of land transport, both in safety and in environmental terms. In Latvia's land transport, the share of rail freight is approximately 39 %, while passenger transport is 7 %. In the structure of rail freight transport, 85 % is transit traffic, mainly from Russia and Belarus to ports in Latvia (East-West transit corridor), inland transport is about 11 % [16].

The total length of Latvia's rail network is about 1860 km, of which only about 14 % is electrified (this is substantially lower than the EU average of 55 %). However, at present, electric trains can only be used for passenger transportation, while freight is only carried by diesel trains [17].

According to the European Environment Agency rail transport produces 3.5 times less CO_2 emissions per tonne-kilometre than road transport [18]. However, currently diesel is the main energy source both for truck and railway freight, which is also the main source of emissions (mostly CO_2) in the land transport sector.

The NECP goals in transport sector in Latvia include electrification of certain railway lines by 2023. However, NECP does not explain, what will be the electrified percentage of the railway, and there is no specific goal for 3030.

1.4. Summary of the literature review

All the electricity policy measures evaluated in the literature review can have their own policy targets, however, this is not the case for the NECP of Latvia, which is either missing or the target is not sufficient in these policy areas. The literature review provides an insight about all these policy measures, showing the current situation in Latvia regarding renewable energy generation, consumption, and measures that would allow certain activities to switch from the consumption of fossil fuels to the consumption of electricity. All the fields are closely interlinked and complement each other. The literature review also shows the know-how and experience of other EU member states.

2. RESEARCH METHODS

Seven study areas were covered by seven types of methodologies. Figure 2.1 shows the areas that were researched in the Thesis. Electricity policy from climate perspective is the overarching theme linking together all the other areas of research.

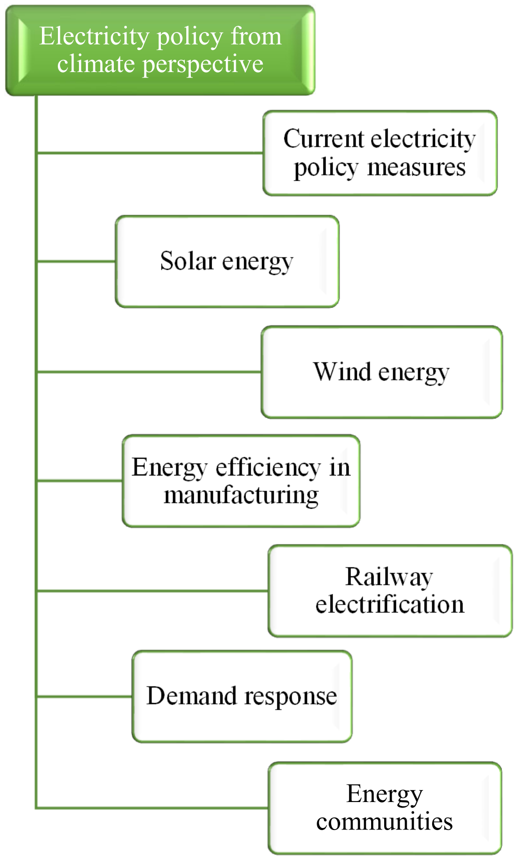

Fig. 2.1. Research topics covered by the study.

2.1. Multi-criteria analysis

Multi-criteria analysis (MCA) was used in the research of two topics – the current electricity policy measures to evaluate their focus on climate and for the first part of the research on the potential of wind parks.

2.1.1. Multi-criteria analysis on existing electricity policy measures

Several current electricity policy measures were chosen for the MCA. The criteria for evaluating these projects are different modes of benefits – benefits for electricity consumer, for electricity producer, for electricity seller, for transmission and distribution system operators, for the state, and, finally, for the climate. These benefits had different weights – benefit for consumer is the most important, followed by the benefit for producer, benefit for climate, benefit for state, benefit for seller, and the benefit for the electricity system operators.

2.1.2. Multi-criteria analysis for the potential of wind parks in Latvia

MCA was also used as one of two methodologies to evaluate the potential of wind parks. In order to be able to compare wind parks of different sizes, the levelized costs per 1 megawatt were used. The MCA results were dependant on several criteria – investments costs, operational and maintenance costs, administrative burden, job creation, capacity factor, import reduction, and levelized cost of electricity. By applying analytic hierarchy process method [19], the criteria received specific weight.

2.2. Cost-benefit analysis

Moving forward with wind park analysis, cost-benefit analysis (CBA) was an instrument that provided the possibility to compare the costs of two case studies with the benefits that these projects provide that allowed to see if the benefits outweigh the costs. CBA 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) [20].

In case of wind parks, both MCA and CBA are applied to a case study in order to evaluate the potential of developing wind parks in Latvia from different perspectives. Both analyses complement each other.

2.3. Quantitative analysis

The potential of solar energy was calculated by a quantitative analysis based on the model developed by the author. It was essential to develop a functional model, which would allow to determine the necessary actions to maximise the usage of solar panels in Latvia. The model first of all included data that forms the electricity bill of a household:

1) electricity tariff;
2) distribution tariff;
3) compulsory procurement component;
4) Value Added Tax.

To further develop the model, specific data was collected from 15 households that have installed solar panels across the territory of Latvia. It was important to obtain data from different parts of Latvia to evaluate the amount of solar irradiation and also to make the research reliable, because it shows situation in the whole Latvia. In total, respondents were asked to reply to 13 questions regarding their solar panel system.

2.4. System dynamics modelling

There are different approaches for modelling, but the research on railway electrification was focused on system dynamics modelling, which is an approach to figuring out the nonlinear behaviour of complex systems over time using stocks, flows, internal feedback loops, table functions and time delays [21].

To understand the impact electrification has on the environment as well as the energy supply and production, the model considers the current situation of the electrical supply system and the future development of the system. In the model there are four main factors that must be considered:

- emissions;
- power usage;
- transport opportunities;
- economic influence.

The model is developed from an explanatory model that highlights the problem model is going to show.

2.5. Kaya identity

It is important to research not only the possibilities of increasing renewable electricity generation but also to assess the energy efficiency measures that can be improved. The case study involved data on gross domestic product (GDP), energy consumption, and greenhouse gas emissions in Latvia to evaluate the development tendencies of this data. Further on, the Kaya identity was applied to analyse more thoroughly the allowed carbon intensity. The Kaya identity can be expressed as:

$$\mathrm{CO_2} = Pop \times \frac{\mathrm{CO_2}}{E} \times \frac{E}{GDP} \times \frac{GDP}{Pop}, \tag{2.1}$$

where

CO_2 – the total amount of carbon emissions;

E – the total energy consumption;

GDP – the gross domestic product;

Pop – the population [22].

The Kaya identity facilitates the understanding of the mechanism that determines the changes in emissions. The Kaya identity is applied for the case study in Latvia. The results are calculated for the years 2020 and 2030 based on the increase or decrease of the data (population, GDP per capita, energy intensity) relative to 1990.

2.6. Qualitative analysis

The focus of qualitative analysis were two electricity policy concepts that are rather new – energy communities and aggregators that work with demand response.

2.6.1. Qualitative analysis of energy communities

As regards energy communities, the research focused on analysing and comparing the EU legal framework with the appropriate legislative proposals in Latvia to evaluate if the national legal framework is properly transposing the EU legislation without creating barriers for the introduction of energy communities in Latvia.

The author researched the two EU directives that set the legal framework for energy communities. One of them introduces the term "citizen energy community" (CEC), but the other one introduces the term "renewable energy community" (REC). The main difference between CEC and REC is that CEC is specifically meant for electricity production (or storage, aggregation, sharing, etc.), and this electricity can also be non-renewable, while REC concerns all types of renewable energy (these can be renewable electricity installings, but they can also be heat pumps, biomethane facilities, etc.). Thus, if a group of people makes an energy community to collectively produce electricity from solar panels for their own needs, it will simultaneously be a REC (because of renewable energy) and CEC (because of electricity). Both CEC and REC are created as a legal voluntary entity. Energy communities are controlled by their members, and their main aim has to be creation of benefits for the members of the energy community (instead of gaining financial profit) [23].

As per the data of distribution system operator [24], by the end of June 2021 the installed solar capacity for microgenerators (capacity up to 11.1 kW) was 9.12 MW, while the capacity of solar power plants (above 11.1 kW) was 4.44 MW, which adds up to 13.56 MW of solar capacity connected to the distribution grid in Latvia. Since in January 2022 the capacity was 20.8 MW, the solar energy capacity in half a year has increased by 35 %. The concept of energy communities can stimulate this tendency.

2.6.2. Qualitative analysis of demand-response

As regards aggregators, the study is based on researching the legal and economic aspects of demand response and aggregation, and applying them to the situation in Latvia. As has been noted in a research by J. K. Juffermans [25], it is hard to predict how much of the conventional generation will be able to aid in providing flexibility in the future, because it can be thoroughly based on political decisions on whether these conventional generation units will continue to operate (e.g., cogeneration plants from natural gas). Thus, a bigger role will be played by the demand side response.

In growing demand of electricity, this can replace part of the generation that will be needed to fulfil this future demand. The demand side management types show us all the options an aggregator can use – it is not only load shifting to another period of time, but also decrease in electricity consumption in general by using the consumer's appliances more efficiently and thus providing benefits also for the EU's climate policy and climate targets [26].

2.7. Theory based approach

As was discussed before, the main idea of the research is to propose additional measures for the NECP of Latvia. In order to summarize the previously used methodologies, a theory-based approach is used for finalizing the study. As the author has summarized in Fig. 2.2, electricity policy is one of the gears in the NECP that plays an important role in the amount of GHG emissions in the energy sector.

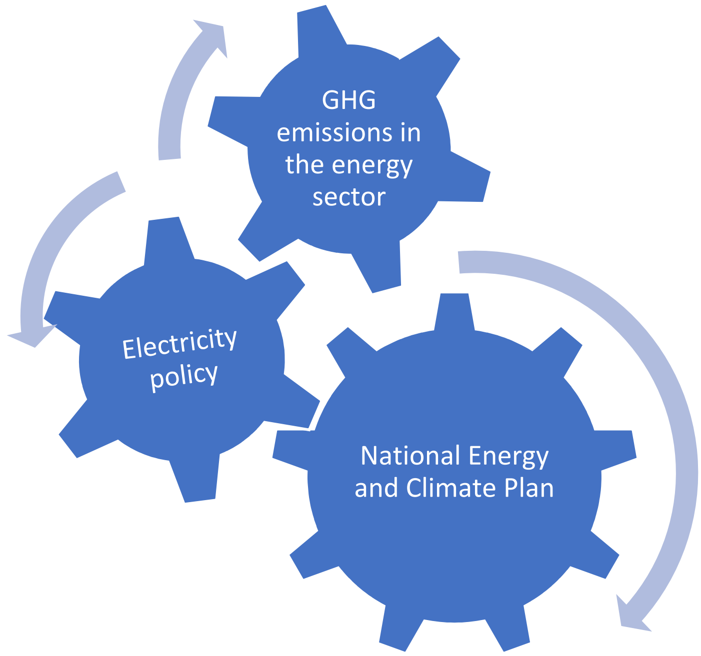

Fig. 2.2. Causal relationship between the GHG emissions and the NECP.

NECP has been devised in several dimensions with specific targets in each of the dimensions, as can be seen in Fig. 2.9. There is a wide range of activities under each of the dimensions, and they are closely interlinked.

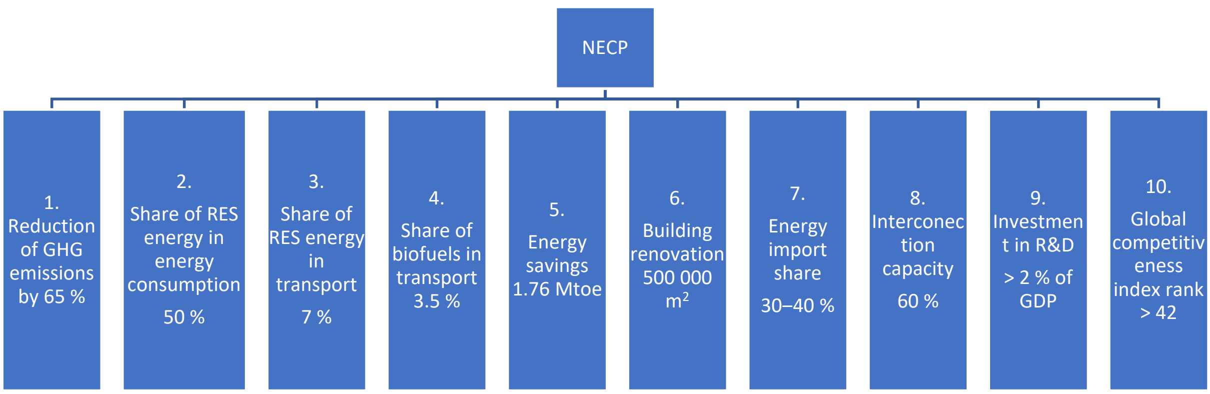

Fig. 2.3. Different dimensions and their targets in NECP of Latvia.

Considering the fields of previous studies, the author paid attention to whether the NECP dimensions have specific electricity policy goals for 2030 in the following areas:

- ✓ electricity production from solar panels;
- ✓ electricity production from wind energy;
- ✓ electricity saving requirements for energy intensive manufacturers;
- ✓ railway electrification;
- ✓ electricity savings by aggregation (demand response);
- ✓ RES electricity production in energy communities.

If such goals were not set or the goals were vague and only in relation to other activities, the author of the Thesis provided the possible goals based on the experience, knowledge and best practise in other EU member states arising from the previously researched topics.

3. RESULTS OF THE STUDY

The results of the methodologies applied and reviewed in previous section are summarized in this chapter. The results are linked together as different electricity policy measures that should be part of the NECP of Latvia.

3.1. The focus of current electricity policy measures

While developing electricity policy, the policymakers often think of amending obscure provisions, to implement clearer ruling and the new projects can sometimes be beneficial for a rather small audience.

The EU level projects for electricity field are mostly intended to improve the climate and, moreover, they are intended for a large group of beneficiaries, so the results in the research were the highest for these measures. Moreover, one of the highest scored national projects is based on requirements from the EU, which also explains the versatile and relatable content for different involved sides. And there is a certain pattern – the climate benefits only in cases where all other sides (consumer, producer, traders, etc.) have benefits. So, it could be argued either it is a problem or a gain, but the system best works in a complex framework.

At the same time, it is important to stress, that in most projects, the most gains go to consumers, and it is essential that the policy planners concentrate their effort on consumers, which is the basis for society. There is also a tendency that consumer, state, and climate are the criteria, which are thought of in almost all projects. Electricity producers and traders receive much less support, even though it could seem surprising considering that Latvia has an established system of mandatory procurement component that the consumers pay for the green energy and high efficiency cogeneration energy produced in Latvia. But this only means that the policy makers are slowly moving away from this rather unsustainable support system and focus more on the electricity consumer while developing new concepts for supporting renewable energy in Latvia without such high costs.

3.2. Potential of the wind parks in Latvia

The results of both MCA and CBA analysis are summarized in this subchapter. For MCA, 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 (Wind Park A). In general, the offshore wind park (Wind Park B) is not an optimal solution both due to the initial capital costs and the related levelized cost of electricity (LCOE) value. The results of MCA are summarized in Table 3.1.

Table 3.1

MCA Results for the Potential of Wind Parks

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	

As regards CBA, 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 parks would not be rentable in normal market conditions as they were at the beginning of 2021. 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 project's 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 close to actual market value of the electricity at the beginning of 2021. At the same time, the offshore project's LCOE was 110.17 EUR/MWh, which is close to the market value in 2022, but as the price spikes eventually drop, the project will become less rentable.

Table 3.2

CBA Results for the Potential of Wind Parks

	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

3.3. Potential of solar energy development in Latvia

The average efficiency rate for solar panels from case studies was about 16.92 %. The average costs for installing the system were almost 5000 EUR. Based on the collected data, the average monthly electricity bill was calculated before installing the solar panels. Based on the electricity produced by panels and the amount of electricity fed into the grid and collected from grid, the average monthly electricity bill after installing solar panels was calculated. The difference between the electricity bill before and after installing the solar panels are the savings per month. The total invested amount of money in the solar panel's system is divided by the yearly savings resulting in return of investments period, which on average was about 13 years.

A deeper research was done for the first case study – a household with a consumption of 293 kWh/month. Before the solar panels were installed, the household paid EUR 35.87 per month for electricity. The solar panel system with the efficiency of 16.88 % was able to produce about 243 kWh/months. Considering the amount of electricity the household fed into the grid and took from the grid, the new electricity bill came down to EUR 12.63 per month. The reduction of the electricity bill, which is almost three times lower, can be better viewed in Fig. 3.1.

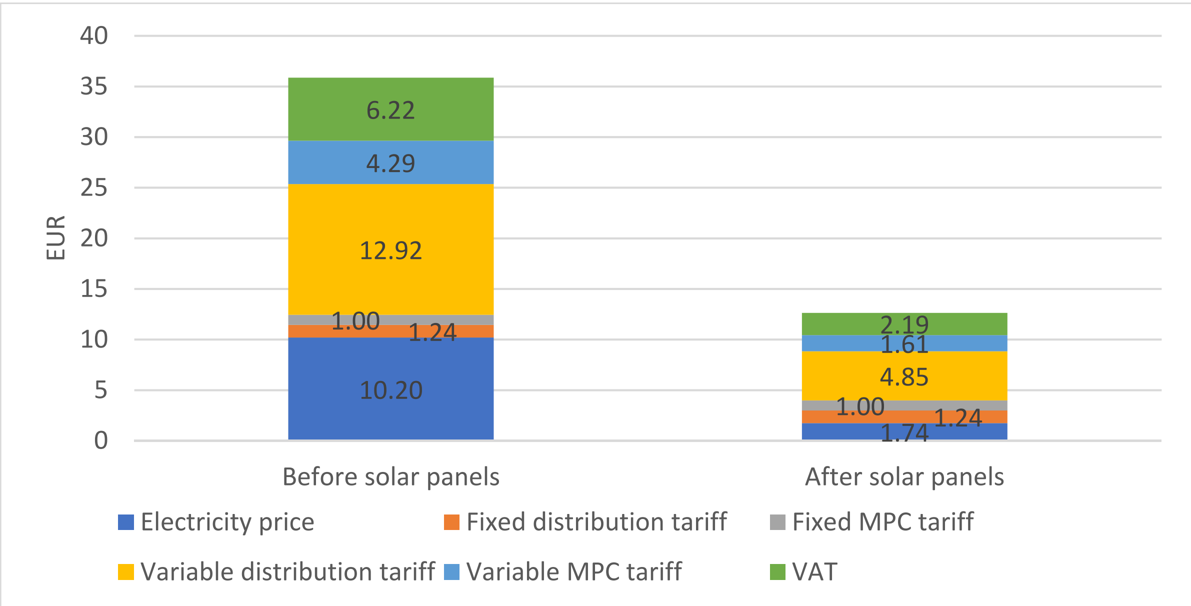

Fig. 3.1. Monthly electricity bill before and after installation of solar panels (293 kWh consumption).

3.4. Impact of railway electrification on climate

Railway electrification was reviewed in seven different scenarios depending on the level of electrification spanning from 0 % electrification to 100 % electrification from renewable energy sources. In the scenarios, where the only thing that is changed is emissions per tonne, the only results that change are the emissions, as seen in Fig. 3.2.

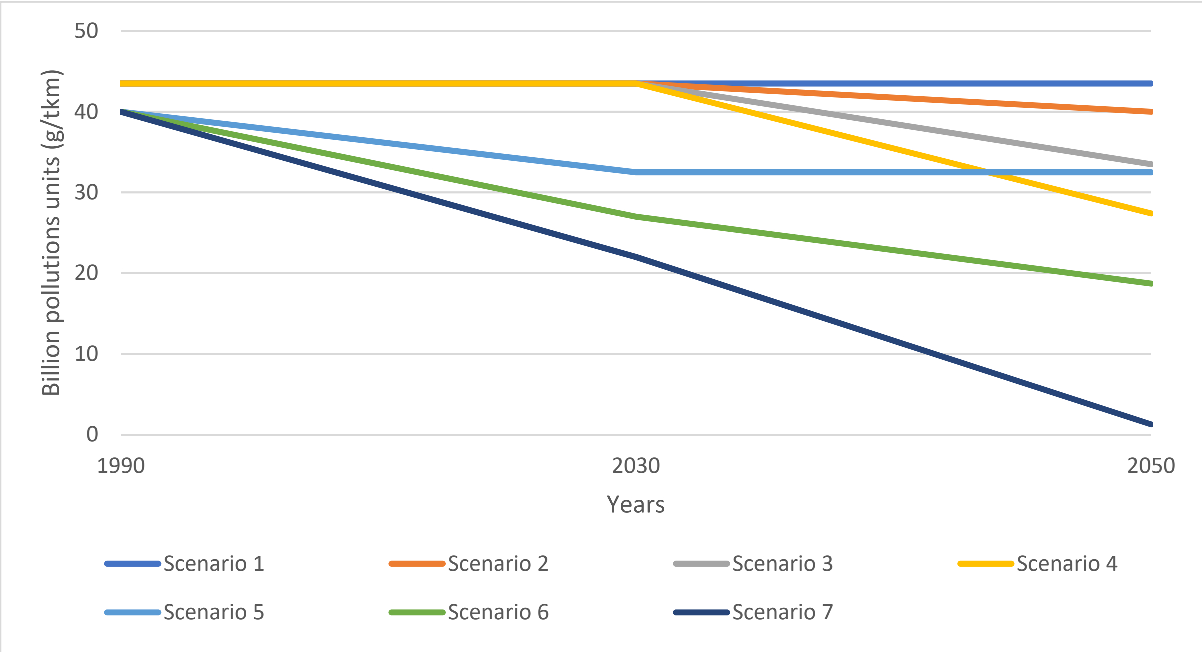

Fig. 3.2. Results of the system dynamics modelling.

In Scenario 2, the variables mimic the current Latvian railway electrification scenario. The pollution from the railway drops significantly – from 43.5 billion pollution units (PU) to 40 billion PU, this is a drop of 8.05 %. It is important to remember that in this scenario, the energy sector has not been incorporated into the model giving the electric locomotives a fuel source that is fossil. Meanwhile, in Scenario 7, the railway is 100 % electrified and energy supply is fully renewable. As could be expected, here the emissions have been reduced the most. The emissions drop according to the locomotive changes, the emissions start at 40 billion PU and drop under 10 billion PU in 2050. The emissions from the diesel locomotives also drop alongside the locomotive changes.

When looking from the perspective of climate change and the possibilities to reduce that, it would be enough to implement Scenario 2 in order to already decrease the PU by more than 8 % that can be reached already before 2050.

3.5. Carbon intensity of energy intensive manufacturers

Table 3.3 shows the results of the calculations for the optimal carbon intensity in 2020 and 2030 under the assumptions of forecasted GDP, population, and energy intensity.

Table 3.3

Results of Kaya Identity Calculations

Criteria	**Years**		
	1990	**2020**	**2030**
CO_2 emissions	100 %	43 %	45 %
Population	100 %	72 %	63 %
GDP per capita	100 %	168 %	215 %
Energy intensity	100 %	72 %	64 %
Carbon intensity	100 %	49 %	52 %

Table 3.3 shows that the carbon intensity in Latvia in 2020 should be 49 % (i.e., the reductions should be by 51 %) and 52 % in 2030 (i.e., the reduction should be by 48 %) in order to achieve the National Energy and Climate Plan's targets in reduction of CO_2 emissions. The Kaya identity allows to work with the data and understand how much, for example, the reduction of energy intensity would lower the carbon intensity. If the energy intensity is lowered by 5 % annually beginning from 2020, the carbon intensity reduction by 2030 would only need to be 20 %. Thus, the necessity to reduce carbon intensity would drop by half. This example proves that it is necessary to urgently develop manufacturing with much lower energy intensity than now.

About 15–25 % of costs for energy intensive manufacturers are composed of costs for energy consumption [27]. Such a large energy consumption is not only unsustainable and against the energy and climate goals of Latvia but is also very expensive for the manufacturer and may lead to bankruptcy. This situation not only leaves negative impact on the GDP, but has other side effects such as increased energy tariffs for the rest of the energy consumers.

When analysing the energy intensity (and CO_2 intensity), it is important to link it with the concept of decoupling. There are two types of decoupling – resource and impact decoupling, which can be further categorized as relative or absolute decoupling. Resource decoupling would be a reduced usage of energy per unit of economic activity (GDP), so the production amount is the same, but with less energy resources, which can be labelled as increased resource productivity. Impact decoupling means that the economic output must be increased while reducing the negative environmental consequences such as CO_2 emissions, so the production volume is larger (not at the same level as in case of resource decoupling), but the energy resources are used at the same level as before or less, so it can be labelled as increased eco-efficiency [28]. In case of Latvia, both of the options would be acceptable from the point of view of country's economic growth.

3.6. Concept of energy communities

The EU member states are free to choose the best ways how to transpose rules set in the EU directives in the national regulations. Each member state is trying to provide its own interpretation for a logical mechanism. The concept proposed in Latvia is summarized by the author in Fig. 3.3. The following interpretation of the EU legislation provides that there are three types of active customers: renewables self-consumers, jointly acting renewable energy self-consumers and energy communities. Jointly acting renewables self-consumers and energy communities can use the electricity sharing option (sharing is not considered trade), while single renewables self-consumers (both households and legal entities) can use net-metering scheme. All three types are allowed to participate in peer-to-peer trade.

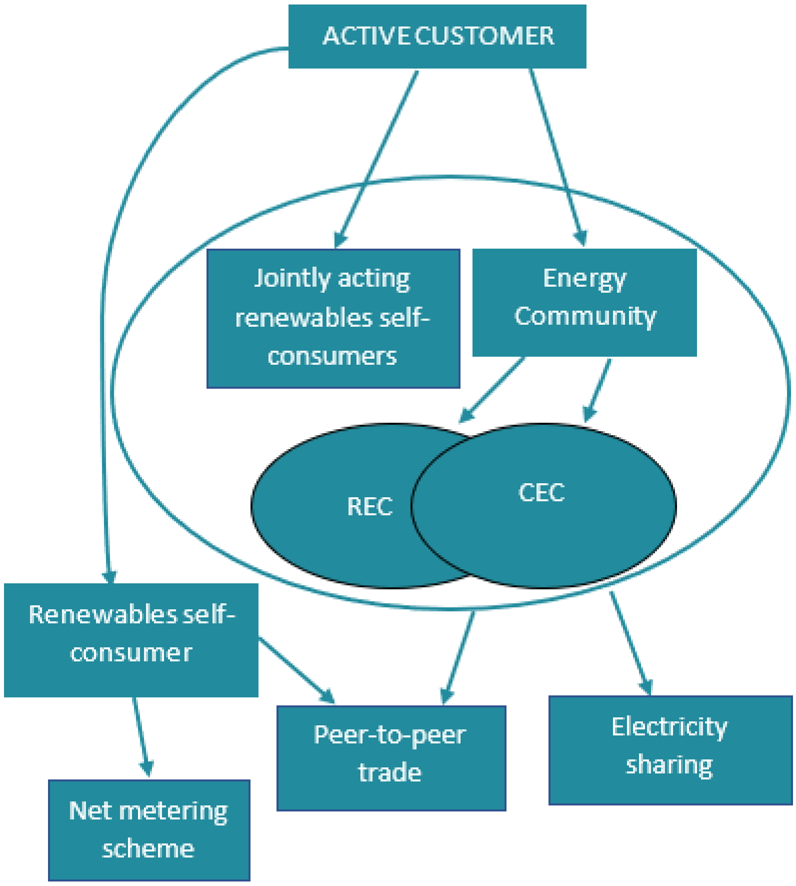

Fig. 3.3. Legislative framework for renewable energy self-consumption.

Though according to the EU legislation, the primary target shall not be gaining financial benefit from energy community, the legislation does not forbid energy communities to receive income, e.g., for the electricity that has been produced in the energy community and has been sold in peer-to-peer trade as the residual electricity that was not necessary for the consumption of the members in the energy community at that time. Thus, energy communities can have income that could be used to pay off the assets and to maintain electricity production installations, which has been stressed by the society as one of the important aspects for the energy community to be cost-efficient.

3.7. Role of aggregators in the electricity market

In the household sector an aggregator needs to have about 10 000 consumers who save 5 kWh a day to make it a profitable business. For instance, general review of online offers for electrical appliances provides that on average a central air conditioner/heat pump consumes around 5–15 kW per hour, so reduction of electricity consumption by 5 kWh a day is actually not so much considering that part of the amount of electricity would still be consumed, but at different time of day, when the electricity prices are lower. Fig. 3.4 shows the demand of electricity in Latvia on 3 August 2020. The red line is the actual demand, but the blue line has been drawn by the author to show how an aggregator could level out the demand in peak hours by shifting it to a different time of the day.

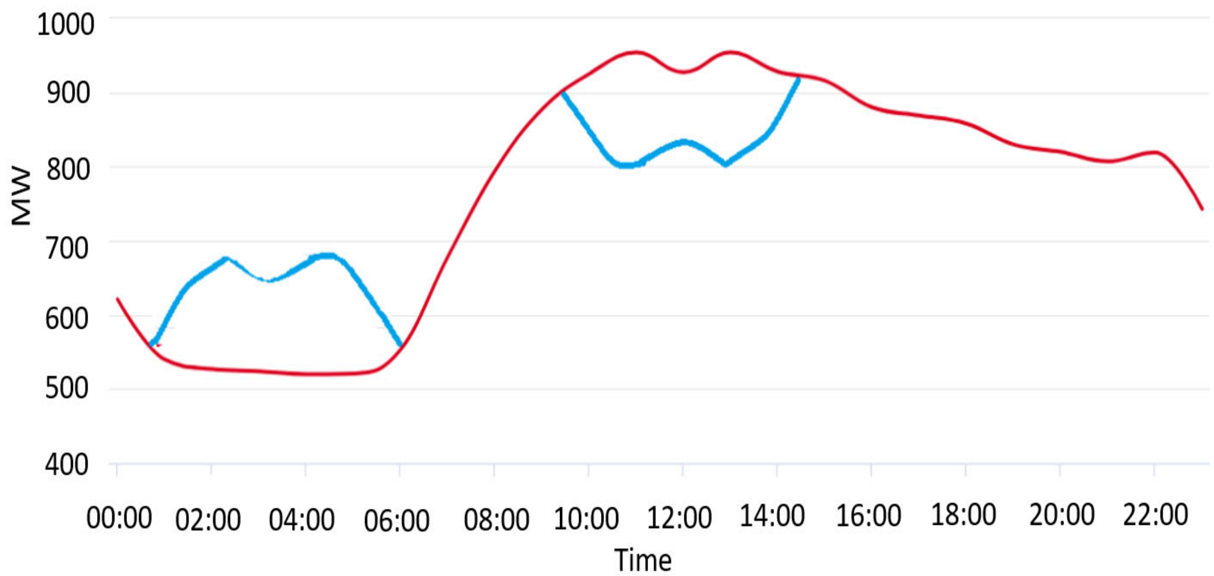

Fig. 3.4. Electricity consumption, MWh/hour, in Latvia on 3 August 2020.

If an aggregator has aggregation agreements with 10 000 consumers that reduce their consumption by at least 1 kWh daily, these are 10 MWh a day or 3650 MWh per year by rough calculations. Latvia's yearly consumption of electricity is around 7 TWh. This means that an aggregator could be capable of reducing the yearly electricity consumption in Latvia by at least 0.05 %. This may not seem much, but for one aggregator it is not a bad result and would also serve as means for achieving national energy and climate targets.

3.8. Electricity policy from climate perspective

All the outside-NECP activities that were researched and reviewed in the previous chapters have been assigned the goal that is shown in Fig. 3.5. If the goals are reached, the activities will have different political impacts, which are also reflected in Figure 3.5. The installed new electricity generation capacities as well as aggregators and battery energy storage system (BESS) will replace import or production of electricity from fossil fuels. Electrified railway will replace the diesel used in rail freight transportation. At the same time energy savings of energy intensive manufacturers will reduce energy consumption in total. Though all outside NECP electricity policy activities have different impacts, they can all be tied together with a common indicator, which is the guiding theme of this research, i.e., reduction of GHG emissions. In this case, GHG emissions have been narrowed down to CO_2 emissions that will be measured in kilotons per year. In case of new electricity generation installations, aggregators and BESS, the reduction of CO_2 emissions is calculated by considering that natural gas would instead create CO_2 in the amount of 185 kg/MWh. Diesel rail freight would create CO_2 in the amount of 18 g/tk. As regards energy intensive manufacturers, weighted average CO_2 emission factor of 101.9 kg/MWh was used to estimate the reduction of CO_2 emissions per year if the electricity consumption is lowered.

The additional goals that are set for the NECP of Latvia are based on the national situation in combination with the experience of the neighbouring countries. For example, the goal for installed solar energy in 2030 is set as 629 MW based on the watts per capita set as goals in Estonia and Lithuania. As regards on-shore wind energy, the target is specified based on the current plan to have 800 MW off-shore wind energy by 2030 in Latvia, as well as by taking into account the grid capacities.

While the solar energy, wind energy, electrification, energy intensity, and aggregation targets arise from previous studies on the capabilities of these measures, additional measure was added in the final step – introduction of BESS. This is due to the volatile nature of renewable energy that should be balanced by either some type of base generation load or storage. Considering that the currently available base generation loads in Latvia are provided by cogeneration plants powered by natural gas, it is important to find new alternative solutions for ensuring balancing and electricity system stability in a sustainable manner.

The results of the outside NECP activities are shown in Fig. 3.5, providing that the total CO_2 savings if the goals are achieved in 2030 would be additional 906.43 kt. For comparison, according to the NECP, total GHG emissions in 2018 were 11 800.2 kt CO_2-eq. It follows that outside NECP activities overviewed in this research could provide the reduction in GHG emissions by around 8 %.

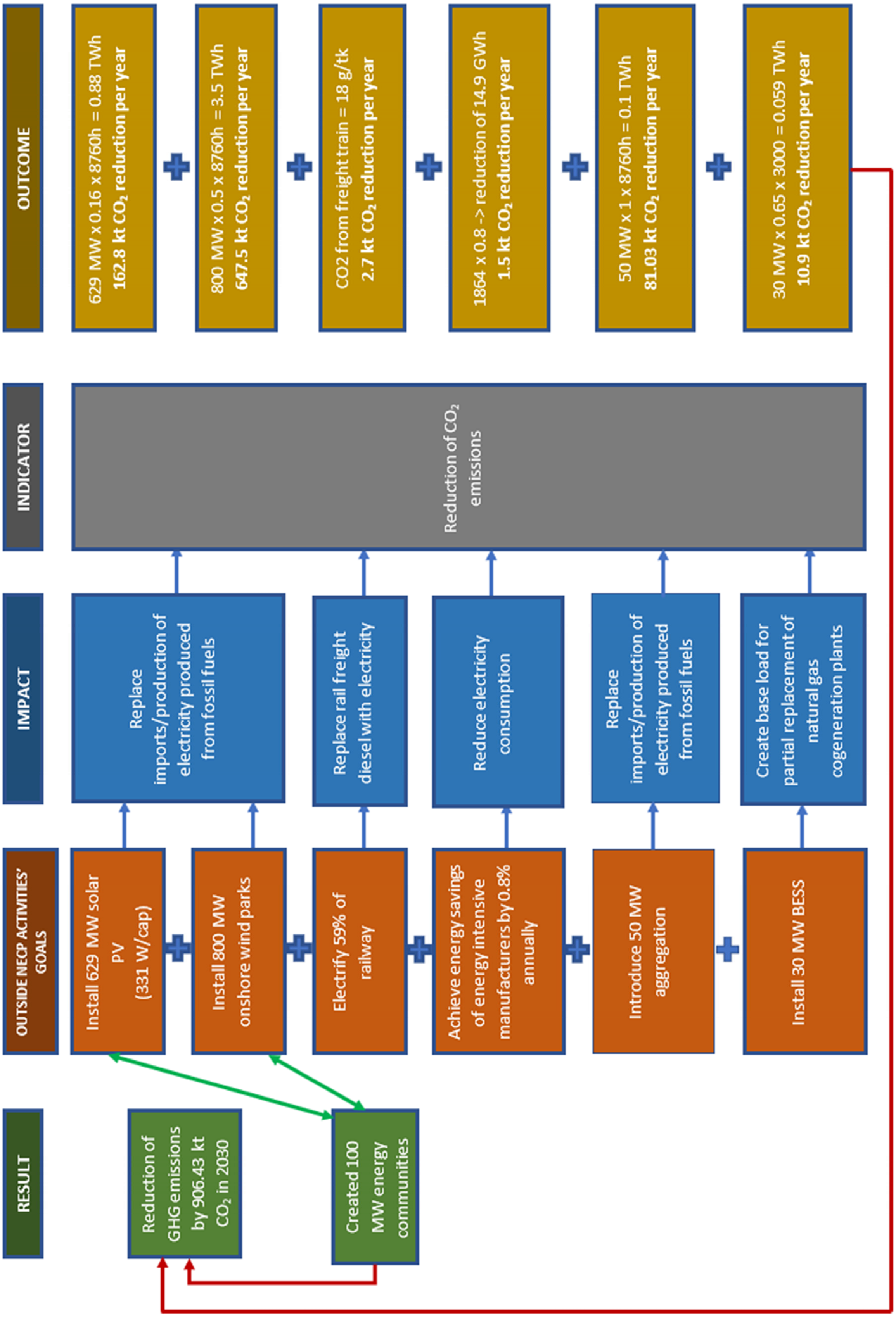

Fig. 3.5. Summary of the results of outside NECP activities and their contribution to the reduction of GHG emissions.

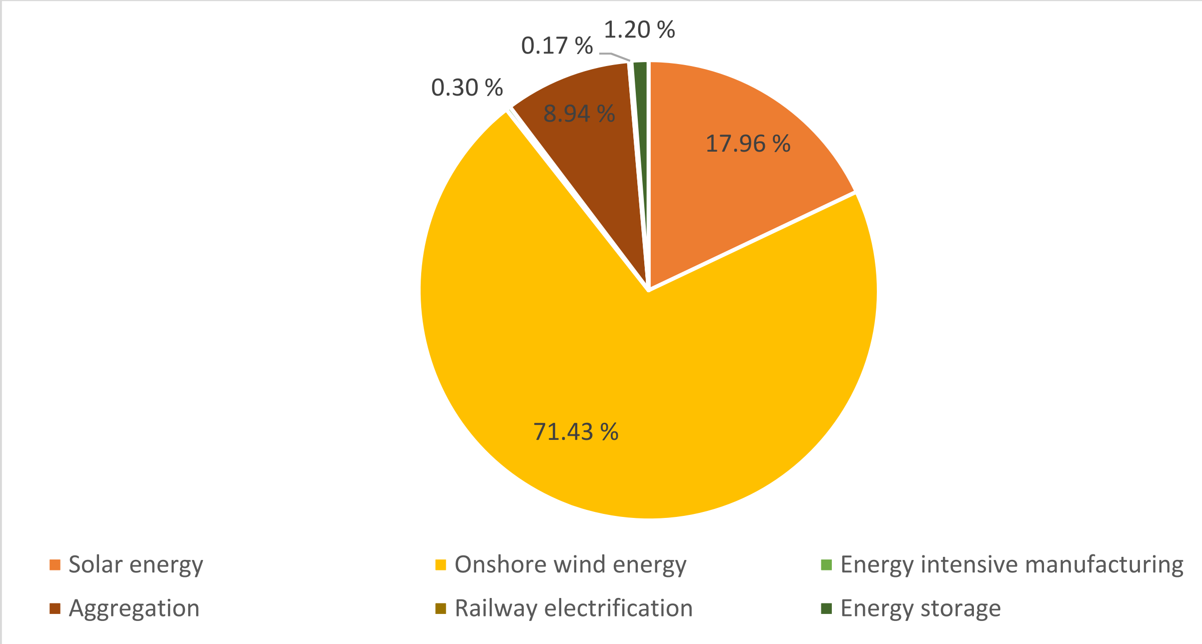

Fig. 3.6. Impact of each outside NECP activity on the reduction of GHG emissions.

If we look at the input of each outside NECP activity, Fig. 3.6 provides a clear view which measures have the most impact on the final CO_2 savings. Onshore wind energy provides the highest potential in reducing GHG emissions as a replacement for electricity generation from fossil fuels. This is followed by the benefits from installing solar energy capacities. Aggregators may also provide an effective amount of CO_2 reductions.

At the same time energy storage, railway electrification, and, finally, the reduction of electricity consumption in energy intensive manufacturing would play a very small role in the efforts of reducing GHG emissions. Nevertheless, these are still important aspects from other angles, i.e., energy storage would play a big role in ensuring the stability of the electricity system, railway electrification would ensure the reduction of energy (fuel) dependency from third countries, and the reduction of electricity consumption in the manufacturing sector would benefit the manufacturer and increase cost-effectiveness and competitiveness.

CONCLUSIONS

While developing a policy in the electricity sector, the climate issues are only tackled in legislative initiatives, which cover a broad spectrum of questions, but not individually as such. Respectively, the outcome of the research confirms that at the national level, the most positive effect for climate comes from the National Energy and Climate Plan.

Both CBA and MCA analysis provided that an offshore wind park is currently not a good business case if there is no support in the form of financial grants or energy policy changes regarding a feed-in tariff for renewable energy. 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 improvement in administrative procedures. Meanwhile, the administrative costs applied at state and municipal level are at acceptable level and should not be viewed as an obstacle for developing wind parks.

Economic situation and technological advancement level in the solar energy sector is adequate enough to achieve a situation in which the instalment of solar panels would pay back in 5 years or less. At the same time, political incentives and changes in current legal framework would be necessary to reduce the payback time for solar panels.

Based on the finding of the research, the price for solar panels in Latvia has been at least two times higher than in other European and non-European countries, which has been a huge barrier for the households to increasingly install the solar panels. Moreover, the prices for solar panels are not aligned with the efficiency, making the solar panels inadequately over-priced.

There are four factors that influence the return of investment period for solar panels – the solar panel system's efficiency rate, the price of the solar panel system, the government support and the components of the electricity bill. Separate actions, such as the reduction of the price of solar panels or an increased efficiency of solar panels gives only partial effect and would not bring the result of a five-year return of investment period. It should be solved by a complex action.

Different scenarios of the system dynamics modelling provided a rather wide range of results showing the real importance of two influential policies – electrification of the railway and switching over to usage of fully renewable energy.

It is important to understand that railway electrification not only provides climate benefits, but also impacts the economy from the side of investments, employment, and indirect economic benefits. Especially in these challenging times of international crisis it is very topical to discuss future investments for the benefit of economic recovery.

Energy intensity is an overarching problem in Latvia's manufacturing industry, while it is also the cornerstone of the country's economy, as it is strongly linked with the GDP.

As the manufacturing industry plays an important role in Latvia's GDP, the manufacturing should not be reduced, but it must be improved by introducing new energy efficient and low energy intensity manufacturing with high added value. To achieve the EU's goals for reduction of carbon emissions, it is important to put effort in restructuring the manufacturing industry. It is essential to minimize the carbon intensity, which is directly dependent on the energy intensity.

The research showed that currently the planned legislation in Latvia provides a solid basic mechanism for energy communities and electricity sharing as well as peer-to-peer trade without harsh restrictions. Considering the future electricity deficit in Latvia, energy communities have a good potential, but further detailed requirements (contracts, electricity data accounting, reporting, balancing) for creating them still must be developed in order to ensure the security of electricity grid.

For further development of the national legislation, it is important to involve society as much as possible to understand the current experiences and possibilities in order to create as efficient legal framework as possible. The research and development of the legislation is complicated also because of the lack of best practice in the EU. Though pilot projects have been launched in many EU countries, the EU legislation has not yet been transposed by the neighbouring countries that otherwise could provide advice.

Financing, such as providing grants, is one of the key measures that would allow energy communities to develop. Financing, appropriate legal framework, cost of technologies and the interlinked payback time, as well as responsiveness of the society will all impact the role energy communities will be able to play in order to avoid electricity deficit from 2024 onwards.

Aggregators and demand response can provide benefits not only for the electricity policy of Latvia, but also can serve for the good of climate policy, when reducing the electricity consumption in Latvia.

However, currently the existing electricity market players have not yet engaged in understanding and using the possibilities currently provided for the electricity suppliers who could combine their role of supplier with the role of aggregator. This model can be financially beneficial under the existing market conditions.

Meanwhile, the model of independent aggregators is yet to be developed in Latvia. Even if the technical barriers in the legislation are resolved, it will not be enough for independent aggregators to immediately enter the electricity market from the economic perspective, as an aggregator would need a rather big client portfolio.

The electricity market is constantly developing, providing new mechanisms, technical opportunities and solutions. The current NECP of Latvia is not using the full potential of these solutions and excludes solutions that could provide a substantial benefit in the work towards reduced GHG emissions. The NECP is not focusing on the electricity policy measures from climate perspective as much as needed or possible.

The research overviewed seven additional activities that are not part of the NECP and provided six new goals that could be added in the reviewed NECP of Latvia. If achieved, three of the goals would create significant input in the reduction of GHG emissions approving the hypothesis of the Thesis.

Though all of the activities could be included in the revised NECP, it is important to take into account the actual added value of each activity when deciding on funding opportunities.

Although the research focused on the reduction of GHG emissions, the discussed outside NECP activities create additional benefits in the energy sector, e.g., if the electricity production by solar or wind energy is increased nationally, Latvia becomes more self-sufficient and avoids electricity imports not only from the EU, but also from the third countries, which is also an issue of energy security. The outside NECP activities allow to create a complex solution for energy security issues considering not only the local electricity production increase but also by including the battery storage and aggregation solutions, which allow to shift the electricity demand.

Outside NECP activities may also provide additional socio-economic benefits considering the employment and investment opportunities, however, these aspects could be further studied in additional studies.

When the NECP is reviewed in 2023, it should focus not only on the improvements of the existing measures in the plan but on all the possible additional activities, i.e., not only the ones reviewed in this research, but also considering other trends and situation in the market in 2023. This would also include using the experience of neighbouring countries to avoid similar circumstances as in the solar energy field, where Latvia is the only EU member state without a solar energy capacity target.

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