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Decarbonization of the electricity sector – barriers and policies. Case in Latvia

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ABSTRACT

Decarbonizing the electricity sector is not an easy task. To reach the decarbonization of the electricity sector in Latvia by 2050, there are a lot of barriers that need to be addressed. To reduce or completely remove different social, technical, economic, administrative, and other barriers, a set of policies needs to be defined. Research results show that there is a combination of policy instruments that would allow for complete decarbonization of the electricity sector, however, it is crucial to implement the whole set of policies, not just one or two of them, and implement them as soon as possible to gain the maximum effect.

Keywords: renewable energy, electricity supply, system dynamics, decarbonization, energy policies

NOMENCLATURE

Abbreviations	
EU	European Union
RES	Renewable energy sources
EIA	Environmental impact assessment
SD	System dynamics
NECP	National Energy and Climate Plan
CN	Climate neutrality
DH	District heating

1. INTRODUCTION

The European Union's (EU) Energy Roadmap 2050 concludes that decarbonization of the energy sector is technically and economically feasible [1]. It is important to increase the share of renewable energy and make more efficient use of all forms of primary energy resources and types of energy. In the current situation, in which energy demand and imports of fossil fuels are rising, dependence on imported energy resources is increasing. This poses a risk to the security of the energy system and the uninterrupted supply of energy if it is not possible to reach a political or economic consensus with the energy supplier [2].

There are various obstacles to the full implementation of renewable energy source (RES) technologies, both in terms of technology and social aspects. There are technical barriers, like the insufficient current level of development of technologies and technical skills, as well as the lack of infrastructure required to support RES technologies [3]. There are administrative barriers that hinder the rapid increase in the capacity of RES technologies, like the time-consuming process of project coordination. For example, the installation of wind turbines can take several years from the idea to the construction of the plant, as it is necessary to carry out an environmental impact assessment (EIA) and coordinate the technological solutions of the project with various stakeholders. The common denominator in the conversation about the social barriers to the implementation of RES technologies is people's concern about the changes in the environmental landscape when installing RES technologies. Fear of change can worsen people's quality of life. It is crucial to promote public acceptance to enable a smooth transition toward a carbon-neutral energy system [4]. It should also be considered that the lack of knowledge and awareness of RES technologies and systems among rural communities is another challenge in the development of RES. There is a need to raise awareness of renewable energy in communities and to focus on the necessary good socio-cultural practices [5]. Probably the most obvious and widespread barrier to the implementation of RES technologies is cost. In particular, capital costs or initial investments are required, for example, for the construction and installation of solar and wind farms. As with most RES, the operating costs of solar and wind energy technologies are low – this resource is “free”, and maintenance is usually minimal, so most of the costs are incurred for construction and installation [6].

Policy instruments promoting the use of renewable and local energy resources are one of the key conditions for the transition to low-carbon energy sectors because they allow to reduce or completely remove existing barriers, however, those policy instruments must be sustainable and justified [7].

The goal of the study is to find the set of policies that would allow to remove the barriers to renewable energy integration and help to decarbonize the electricity sector in Latvia by 2050.

2. METHODOLOGY

The system dynamics approach was used in modeling the development of the electricity sector in Latvia. The model was built in Stella Architect 2.1.5. software.

System dynamic (SD) is a method of studying the dynamic development of complex systems. SD theory is based on the study of the relationship between the behavior of the system and the underlying system structure. This means that by analyzing the structure of the system, a deeper understanding of the causes of the behavior of the system is formed, which allows to better address the problematic behavior of the observed system [8].

SD was established in the mid-1950s by Professor Jay Wright Forrester of the Massachusetts Institute of Technology. SD was originally designed to help business leaders improve their understanding of production processes, but its application is now much wider, including policy analysis and development in both the public and private sectors.

2.1 Electricity supply sector model

The basic structure of the model was based on the authors' previously built models for electricity and district heating (DH) sectors. Structure for capacity building of fossil and renewable technologies (Fig. 1) as well as tariff calculation can be found in the authors' previous articles [9, 10].

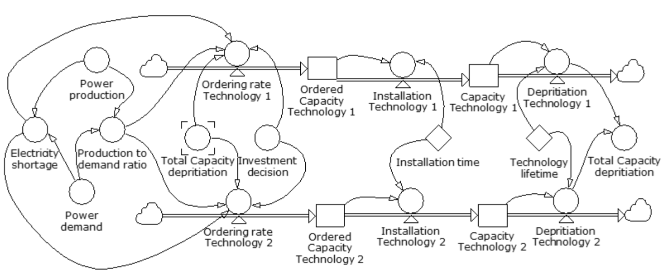

Fig. 1 Structure of capacity building [10]

The model structure was supplemented with different policies to examine the possibility of decarbonizing the electricity sector. Each of the policies was targeted toward specific barriers in the system.

Support policies were targeted toward economic barriers that hinder the development of renewables in the system. Funding and subsidies are important in promoting renewable technologies in the electricity sector, especially in the early stages, when there are no existing capacities of specific technologies, or the capacity level is low. Figure 2 shows the structure of the funding sub-model. The structure is built to represent the real-life system with interruptions in available funding. In Latvia funding for renewable energy integration comes mostly from EU funds. EU funding is not continuous, because there is some time between different planning periods, therefore availability of funds is strongly dependent on the start and end times of planning periods. Also, if all available funding is not used within the planning period in which it was granted, the unused funding is lost, and not transferred to the next planning period. All of this is considered in figure 2.

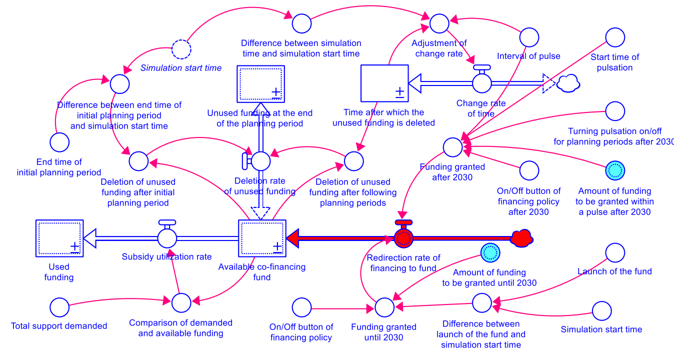

Fig. 2 Structure of funding sub-model

The social barrier related to the lack of knowledge and awareness is addressed by implementing an information campaign policy (Fig. 3). This policy allows to increase social acceptance and decreases the inconvenience costs arising from lack of knowledge. For an information campaign, there are two crucial parameters – information campaign strength and quality. If the information campaign is comprehensive, but lacks quality, or has high quality, but is poorly disseminated, the expected effect will not be achieved. Only a combination of both parameters can produce the best result.

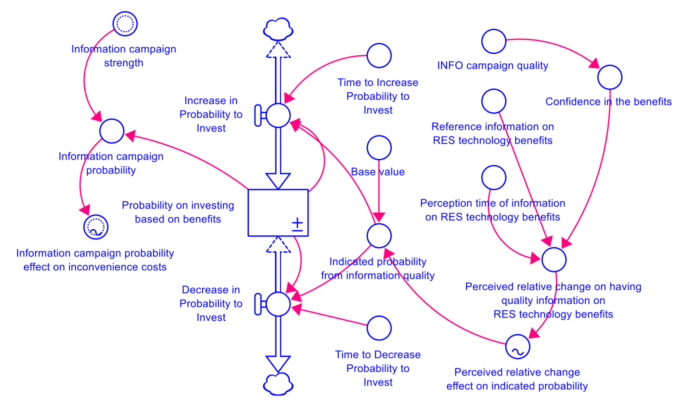

Fig. 3 Structure of information campaign sub-model

Technical barriers can be reduced by investing in research and development (R&D). This would allow to improve technologies, develop necessary solutions for renewable energy integration in the system and move the energy system towards decarbonization. Investing in R&D would also allow to increase necessary technical skills within the country. The model structure used in modeling the investment in R&D is displayed in figure 4.

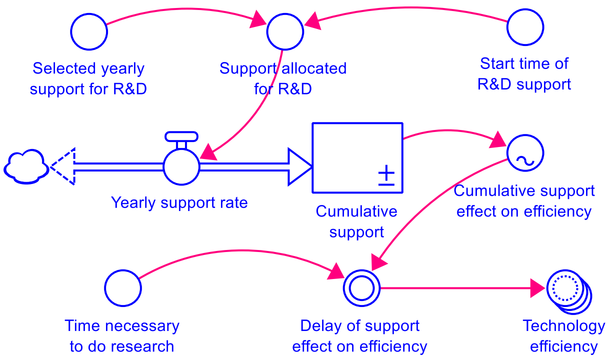

Fig. 4 Structure of R&D sub-model

All the policies used in the model are described in section 2.2. There are different available fundings for different purposes, but all of the use the same structure displayed in figure 2.

2.2 Scenarios for the modeling

Three different scenarios were tested in this research. Policy measures used in each scenario are depicted in Table 1. The baseline scenario describes the current situation without additional policy tools. In the baseline scenario, only policy measures and support already in place were considered. The Baseline scenario includes current fossil tax rates and natural resources tax rates. The Baseline scenario incorporates the existing regulation on the Mandatory procurement component and includes the approved subsidy amounts until 2022.

To meet the EU's new energy and climate targets for 2030, Member States were required to establish a 10-year NECP (National Energy and Climate Plan) for the period from 2021 to 2030. The 2nd scenario, therefore, was the NECP scenario, which included the policy measures set in the National Energy and Climate Plan of Latvia. The support in this scenario was granted according to the values specified in NECP and the support period was till 2030. No additional support was given after 2030. Some policies, like regulations or improved procedures, continued also after 2030 as they were already set in place. This was done to test whether the inertia of the NECP 2030 policies was enough to transform the electricity sector towards full decarbonization.

The last scenario was the climate neutrality (CN) scenario. This scenario was built around the NECP scenario, but with additional support after 2030, with stronger procedural policies and some additional policy measures to boost the transition.

Input data related to the resources installed technology capacities and energy consumption, used in the model is described in the previous article of the authors [11]. Technology data, like costs, efficiencies, etc. are taken from Danish Energy Agencies' technology catalogues [12].

Table. 1 Policies used in scenarios

Policy	Base scenario	NECP scenario	Climate neutrality scenario
Excise tax on natural gas	1.65 EUR/MWh	Additional increase rate of 10 % per year to 2030	Additional increase rate of 10 % per year to 2050
Natural resource tax on CO_2 emissions	4.5 EUR per tCO_2 with increase to 15 EUR per tCO_2 in 2022		
Price of CO_2 emission allowance in the ETS sector	Increase to around 50 EUR per allowance in 2040[1]	22 EUR per tCO_2 with an increase rate of 3 % per year	
Subsidies for the development of DH	49,5 MEUR from 2017 to 2022	275 MEUR with a support intensity of 40 % to 2030	550 MEUR with a support intensity of 40 % to 2050
Support RES in the centralized electricity production	Not applicable	750 MEUR for offshore wind parks with a support intensity of 50 % to 2030	750 MEUR for all technologies with a support intensity of 30 % to 2050
Support for solar PV for end-users	Not applicable	15 MEUR with a support intensity of 40 % to 2030	30 MEUR with a support intensity of 40 % to 2050
Support for R&D	Not applicable	292 MEUR to 2030	584 MEUR to 2050
Support for biogas and biomethane production	Not applicable	80 MEUR to 2030	160 MEUR to 2050
Information campaign on the use of RES	Not applicable	Reaches 70% of the target audience	Reaches close to 100% of the target audience
Net payment system for RES electricity	Net payment system for households	Net payment system for legal persons and households, increasing the share of self-produced electricity	

[1] According to European Commision recommendations

Virtual netting	Not applicable	Introduction of a net payment system for households, increasing the share of self-produced electricity	
Power to heat	Not applicable	Integration of RES electricity surpluses in DH using heat pumps	
Power to hydrogen	Not applicable	Not applicable	The use of renewable electricity surpluses to produce hydrogen for the transport sector
Accelerated procedure (including permits)	Not applicable	Improved coordination of wind and solar parks, reducing the implementation time	

This paper provides the results for the policy combinations described in the scenarios (see Table 1), however, during the research phase, each policy measure and policy measure combinations were also tested separately and compared to reference and base scenarios to determine the individual and combined impact of policies on the energy system. The full set of policies for the CN scenario was chosen based on individual analysis, and only policies with measurable impact were included in the final scenario. This paper focuses on the impact of policy combinations and on the comparison of different scenarios rather than on the impact of the individual policies, therefore, although analyses on the individual impacts of the policies are carried out to define the optimal CN scenario, they are not included in the result section of the paper.

3. RESULTS AND DISCUSSION

The goal of the study was to find the set of policies that would allow decarbonizing the electricity sector. Three different scenarios with a different set of policies were tested to see the effect on electricity supply. In figure 5 all three scenarios are compared based on the RES share achieved. All the scenarios are exhibiting an upward trend.

The baseline scenario indicates that even without support measures in the long-term renewable technologies will continue to penetrate the system and increase the renewable energy share. This happens mostly due to assumptions made about global fossil fuel price increases and renewable technology price decreases in the future. However, in the baseline scenario pace of transition is slow, and the transition rate is below the target set by European Union, therefore additional policy measures are necessary to reach the targets set for 2030 and 2050. By implementing the NECP scenario, which utilizes policies set under National Energy Climate Plan for Latvia until 2030, significant improvement in renewable energy share can be observed. The biggest changes between the baseline and NECP scenario are observed in the period between 2022 and 2030, which was expected because the policy measures in the NECP scenario were mostly focused on this specific period. Although most of the support measures end after 2030 in the NECP scenario, due to inertia, renewable energy share still keeps increasing. This scenario allows to reach the targets set for 2030, however, it still falls short of the target of full decarbonization of the electricity sector in 2050. Additional support and policy measures included in the climate neutrality scenario, however, allow reaching the full decarbonization of the electricity supply side.

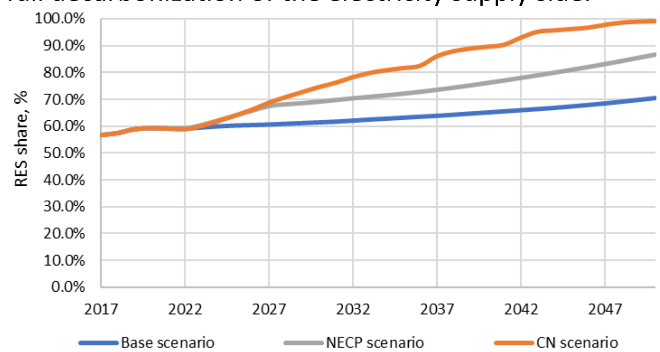

Fig. 5 Renewable energy share

The main contributors to decarbonization in the climate neutrality scenario are solar and wind energy. For solar energy, the difference in production between baseline and NECP scenarios is noticeable but not huge. This means that additional policies of virtual netting, expanding the net payment system to include legal entities, information campaigns, procedure simplification, and granting support for individual producers, resulted in increased solar PV capacity. However, the best result was reached in the climate neutrality scenario, when sector coupling was enabled, and support for centralized production was granted also for solar technologies. This allowed increasing the solar production by almost 100 % when compared to the NECP scenario (Fig. 6).

For wind energy, the difference between scenarios is even more significant. Although for solar energy a significant development was observed in the baseline scenario, mainly due to individual producers, this is not the case with wind energy. For individual producers, this is not a viable option, while for centralized production, although market indications are positive, there are too many barriers for wind energy to develop. The main barrier is the time-consuming process of project coordination, which can take from 7 up to 10 years to finalize the project. When this barrier is removed, we can see a significant increase in wind energy production in the NECP scenario. Investment in R&D and taxation of fossil resources and CO2 emissions also gives a boost to wind technology development. Although there is also funding available, it is granted only for offshore wind farm development, which in the NECP scenario still proved to be too expensive, when combining the costs of wind turbines, infrastructure, and construction. The most significant difference again is between NECP and the climate neutrality scenario. The main difference between scenarios is enabling sector coupling between several sectors and granting the support also for onshore wind farm development. This allows for increased wind energy production by almost 300 % when compared to the NECP scenario.

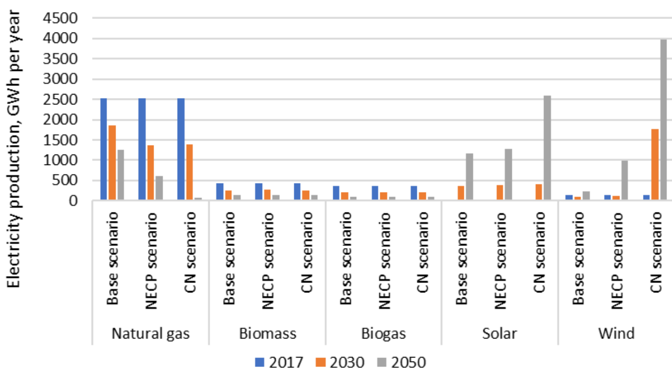

Fig. 6 Electricity production by resource type

Financial support was crucial for both solar and wind technologies to increase the production amount, however, sector coupling is the main culprit for such a high level of production. In the climate neutrality scenario, the regulatory framework is put in place, so that electricity from variable renewable energy sources can be easily used in other sectors, like DH, transport, hydrogen, and biomethane production, when there is a high renewable energy surplus, which exceeds the electricity consumption. Increased supply of renewable electricity, which is relatively cheap at peak production hours, increases the demand for electricity in other sectors. Demand dictates the optimal level of production capacity to install, and the higher the demand, the higher will be the optimal capacity, if increasing demand is covered with local resources, not imported energy. Figure 7 shows the increase in total demand followed by an increase in solar and wind energy production.

An increase in renewable energy production, coupled with the electrification of other sectors allows to reduce the dependency on imported electricity and allows to increase self-sufficiency.

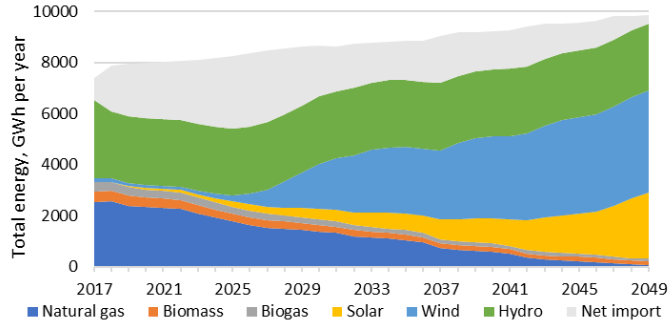

Fig. 7 Electricity production by resource type (CN scenario)

It is clear that financial support is necessary to reach the decarbonization of the electricity sector, however, a lot of development happens also without the support. Figure 8 shows that investment in renewable technologies is made even in the baseline and NECP scenarios when there is no support for centralized electricity generation technologies.

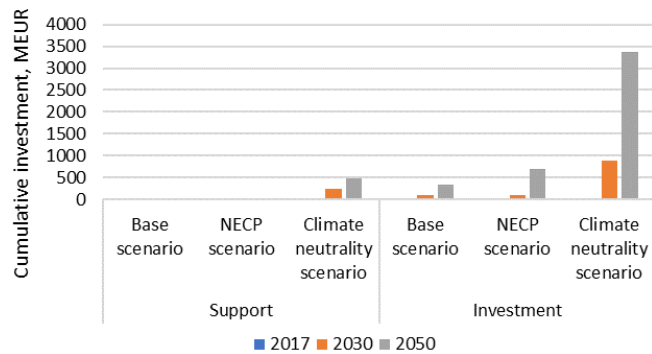

Fig. 8 Cumulative support and investment in RES

Even in the climate neutrality scenario total investment made until 2050 is significantly higher than available support for centralized generation technologies. The support granted in the climate neutrality scenario accounted for only 14.6% of the total investment in renewable energy technologies. As support intensity was 30%, a lot of investment was made without receiving support.

Therefore, results indicate that the goal of the electricity sector decarbonization is viable if the correct set of policy instruments are being applied.

4. CONCLUSIONS

Research proved that the decarbonization target in the electricity sector is achievable, and it is feasible. Removal of administrative and social barriers is important to increase the renewable energy share, however, full decarbonization cannot be reached without financial support. Nonetheless, financial support is only necessary as a boost, because solar and wind technologies in the last few years have experienced a significant decrease in cost and already are competitive with fossil technologies in the electricity sector, and the same trend is expected also in the future.

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