Transitioning to a climate-neutral electricity generation in Estonia

Deliverable 7 Report

Action plan

Final Report

Contract details

European Commission – DG Reform
Transitioning to a climate-neutral electricity generation
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Transitioning to a climate neutral electricity generation

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Executive Summary

This executive summary outlines the core results of Deliverable 7 of the project: *Transitioning to a climate-neutral electricity generation in Estonia*. The objectives of Deliverable 7 were to:

- Present a summary of the modelling and other analysis carried out in Deliverable 3, 4, 5 and 6;
- Identify a series of actions that would allow Estonia to potentially follow the modelled pathways; and
- Provide further considerations about the proposed actions, such as their costs, environmental impacts and legal aspects.

The focus of this report are the actions (identified in chapter 4) and the pathway-specific considerations that provide further details on the most relevant actions to support each pathway (presented in chapter 5, 6, 7, 8 and 9). For brevity, chapter 9 includes actions relevant to the three technology-neutral pathways. Table 0-1 provides a summary of the seven pathways considered.

Table 0-1 Pathways and relevant chapters

	Pathway	Description	Chapter
Technology-focused	Renewable electricity + Storage (RES + Storage)	Evaluates a large deployment of **offshore wind** in Estonia (1 GW by 2030, 2 GW by 2035, 3 GW by 2040, and a total of 4 GW by 2050)	5
	Nuclear	Simulates climate-neutral electricity production in Estonia given an addition of 900 MW of Generation III+ **small modular nuclear** capacity by 2040	6
	CCU	Explores the impacts of adding **carbon capture** to two large oil shale generators in Estonia	7
	Renewable gas (RES GAS)	Assumes implementation of 1 GW of **new biogas** generation by 2030	9
Technology competition	All technologies (AT)	The least constrained climate-neutral pathway explored, which allows for the model to endogenously invest in any electricity generation technology based on least-cost optimisation	9
	AT-NIMP (AT-NIMP)	Supplements the All technologies pathway by requiring that Estonia's electricity **imports and exports should approximately offset each other**	9
	1000 MW dispatchable capacity (AT+1000)	Reassesses the All technologies pathway by applying the constraint that Estonia must have **at least 1000 MW of readily dispatchable electricity production** capacity at all times	9

The pathways with the above assumptions have been modelled with an energy system and model and the results have then been fed into a macroeconomic model to understand economic implications for different sectors. Together with inputs from stakeholders and from other deliverables, the modelled technology mix has been used to determine the key actions needed to support the deployment of each pathway. All quantitative results presented here are based results for the "S1" pathways (pathways modelled with higher wind sensitivity).

Table 0-2 present a summary of how different pathways perform across a series of criteria set by the consultant, and identifies the recommended ones. While criteria are not weighted, they are ranked according to the consultant's view (i.e., criteria in the rows at the top are more important than criteria at the bottom). The importance of every criteria is not "absolute", but depends on how the indicators were calculated for the project. For example, while the level of CO_2 emissions in 2050 is paramount, all scenarios achieve carbon neutrality by design (carbon neutrality was a constraint imposed to the model), and the difference in CO_2 emitted is low. Similarly, while reducing biomass use will have positive environmental impacts, biomass use in the power sector is not the only driver of bioenergy use, so a reduced use for electricity consumption may be compensated by an increased use for heat. As this analysis does not allow to understand this effect, the indicator is considered less relevant when it comes to choosing the best scenario. According to this analysis, three scenarios are recommended, two are considered good (viable), while two are not recommended. This result is obviously dependent on the indicators chosen, but it is the relative weight given by the authors that determines the outcome. Adding more indicators is unlikely to change the outcome, as the preference in terms of stakeholders preference, socioeconomic impacts, security of supply and implementation challenge is clear.

Also, it is important to recall that all pathways meet the main objectives set for the Estonian power system, and that all estimates are subject to wide uncertainty over the time period considered (30 years). For this reasons, the analysis presented in this report should be used as a guide to support the necessary political decisions, not as an absolute conclusion about the potential for a specific technology in Estonia. CCU, Nuclear and Biogas plants (to be used for backup only), which do not appear convenient based on the assumptions used to carry out this study, may well be the best option for Estonia under a different set of assumptions and value judgment.

Table 0-2 Pathways ranked according to criteria

	1.RECOMMENDED			2.VIABLE		3.NOT RECOMMENDED	
Criteria	**RES + Storage**	**Renewable Gas**	**All technologies (AT)**	**No net imports**	**1000 MW dispatchable capacity**	**Nuclear**	**CCU**
Stakeholders' preference	++	+	++	-	0	-	--
Socioeconomic impacts	++	++	0	++	0	-	--
Security of supply	++	0	0	0	++	+	--
Main implementation challenges	0	0	++	0	0	--	-
Risk analysis	0	++	++	--	++	--	--
Limit of fossil use (fossil gas gen. in 2050)	++	++	-	--	-	++	--
Sensitivity analysis	++	++	0	++	0	++	--
Avg. electricity prices in 2050	-	+	+	+	+	++	--
Total cumulative investment costs (2022-2050)	--	--	0	0	0	--	++
Renewable subsidies costs in 2030	--	0	0	--	0	0	++
CO_2 emissions by 2050	0	0	0	-	0	0	++
Electricity from Biomass in 2050	--	--	--	++	--	0	++

There is an important clarification necessary concerning the *Renewable gas* scenario. While the scenario is overall positive, an analysis of capacity and utilisation of different technologies shows that the large (1GW) of biogas capacity is barely used. Therefore, if the decision to implement the biogas scenario is taken, the amount of biogas capacity should be significantly reduced in favour of other cheaper dispatchable technologies.

Table 0-3 and Table 0-4 instead rank pathways according to a set of criteria chosen by the Ministry. Considering these indicators in 2050, the *Nuclear* pathway emerges at the top, while the *No Net imports* slides towards the bottom of the ranking. Other high-scoring pathways are the *All technologies* and the *1000 MW dispatchable capacity*. This result is more deterministic, and obviously more dependent on the indicators chosen – i.e., selecting different indicators will result in a different pathway being selected, given that no weight is applied.

Table 0-3 Key indicators, absolute values in 2050

Criteria	Nuclear	RES + Storage	All technologies (AT)	Renewable Gas	1000 MW dispatchable capacity	No net imports	CCU
Investment cost (€bn)	12.3	14.6	9.2	11.7	10	10.6	4.1
Electricity price in 2050 (€/kwh)	0.088	0.139	0.097	0.101	0.103	0.107	0.149
GDP (output changes compared to reference, €bn)[1]	10.9	13.8	0.4	8.5	4.1	4.9	-12.0
Jobs created (2030 to 2050)	20,074	19,511	16,321	16,629	14,964	15,699	7,332
Share of domestic generation in 2050	146%	142%	119%	110%	122%	119%	29%

Table 0-4 Key indicators, alternative ranking based on 5 criteria

Criteria	Nuclear	RES + Storage	All technologies (AT)	Renewable Gas	1000 MW dispatchable capacity	No net imports	CCU
Investment cost	6	7	2	5	3	4	1
Electricity price in 2050	1	6	2	3	4	5	7
GDP (output changes compared to reference, €bn)[1]	2	1	6	3	5	4	7
Jobs created (2030 to 2050)	1	2	4	3	6	5	7
Share of domestic generation in 2050	1	2	4	6	3	5	7
Total score	**11**	**18**	**18**	**20**	**21**	**23**	**29**
Aggregate ranking	**1**	**2**	**2**	**4**	**5**	**6**	**7**

A final comparison is provided below in section Pathways comparison.

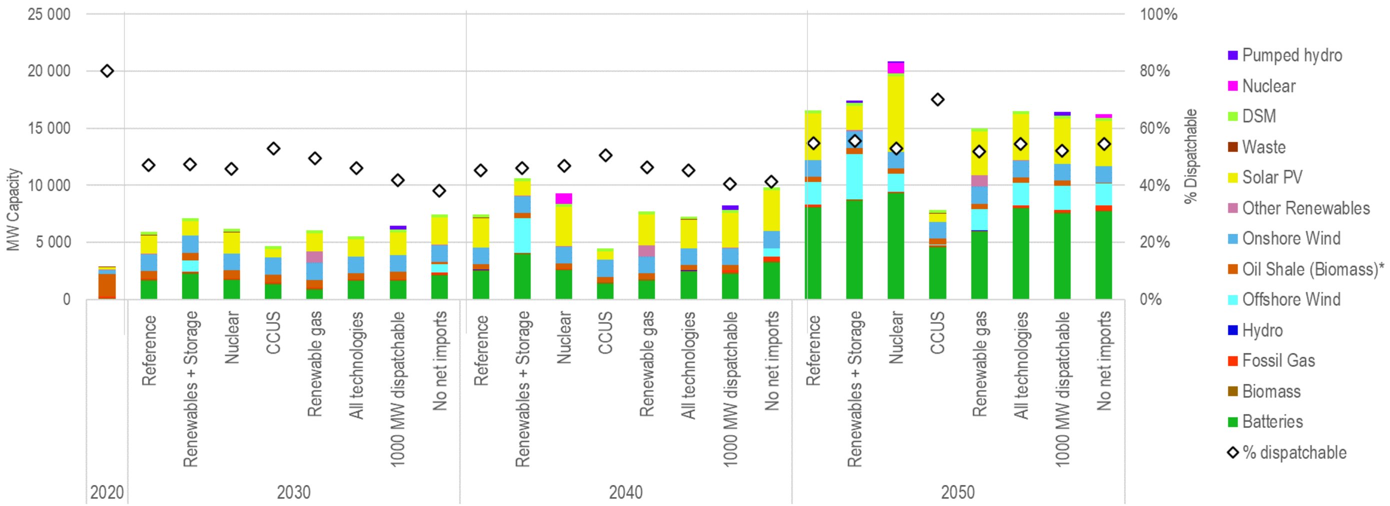
Key insights from other deliverables

According to the energy modelling results, installed power generation and storage capacity increases from 2020 to 2050 for all pathways. In 2050, highest capacities are deployed in the *Nuclear* and *RES + Storage* pathways, and the lowest in the *CCU* pathway (see Figure 3-1). For most pathways, the increase in capacity is driven by batteries (for storage) as well as solar PV and wind power. In 2050, the capacity of offshore wind energy increases in all pathways except the *CCU* pathway, while nuclear energy capacity emerges only in the *Nuclear* and *AT-NIMP* pathways. Some technologies, such as onshore wind and DSM, reach full deployment potential by 2030 in all pathways. For all the pathways, over half of the electricity generation and storage capacity is dispatchable by 2050. A summary of this

[1] GDP output includes tax revenues

analysis if presented in Section 3, while the full results, including the results of the sensitivity analysis, are presented in Deliverable 3 and Deliverable 6 of this assignment. Annex A provides capacity and generation by technology and pathway in 2030 and 2050.

Figure 0-1 Comparison of installed capacity and percent dispatchable for all pathways by technology, 2020-2050, MW[2]



Note: After 2030, oil shale plants are converted to run on biomass in all pathways except CCU. In CCU, the oil shale plants continue to use oil shale as a fuel.

The analysis of socio-economic impacts showed that the *AT-NIMP*, *RES GAS*, *RES + Storage* and *Nuclear* pathways offer the most positive outcomes. The analysis considered economic impacts (impact on GDP), employment, electricity prices and distributional impacts. A summary of this analysis if presented in Section 3, while the full results, including the results of the sensitivity analysis, are presented in Deliverable 4 and Deliverable 6 of this assignment.

Stakeholders have identified the following main barriers:

- Lack of focus and clarity on government strategy. While the government has published relevant strategic documents, stakeholders do not believe the government is actually committed to them, and not sufficiently is being done to implement them.
- The planning process suffers from bottlenecks and inefficiencies in the process.
- Negative public opinion of renewable generation (in particular, local opposition to onshore wind farms).
- Developers and investors require support to manage some risks beyond their control and reduce the premium they require on their investment.

The above barriers discourage developers and investors from considering opportunities in Estonia, or if they do they require higher return on their investment to compensate for the extended development time and the chance that the project will not reach construction stage. A summary of this analysis is presented in Section 2, while the full results, including the results of the sensitivity analysis, are presented in Deliverable 5 of this assignment.

[2] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 0-5 describes how the results of deliverable 3 to 7 provided inputs for the definition of the pathway-specific action plans.

Table 0-5 how the different deliverables fed in the action plans

Deliverable	Main insights gained	Input to action plans
D3 Pathway modelling	Preliminary prognosis on capacities and generation, electricity price	The results of the pathway analysis provided the main basis of the action plans, i.e. defining which technologies are expected to come online at which point in time. This deliverable also provides relevant inputs on technology, sources of storage and flexibility, imports, and dispatchable capacity.
D4 Socio-economic impact assessment	Socio-economic impacts, impacts on employment, GDP, investments	The socioeconomic impact assessment provides investment needs by technology. In the action plan, this is used to identify which policies/actions would support these investments, and the strength/focus of these actions
D5 Risk analysis	Stakeholders perceived risk associated with different pathways, main barriers to their deployment and potential actions to solve them	Actions proposed in the action plans attempt to address the risks identified here. For some pathway, no action can completely eliminate the risks, which is why the risk assessment still is considered as part of final evaluation. For example, the risk that nuclear technology development is slower than expected is a considered a very high risk. Actions to mitigate this risk (dedicated regulator, skill academy, international cooperation) are proposed, but the risk remains high.
D6 Sensitivity analysis	Re-modelled D3 pathways: S1-S4 Sensitivities on wind granularity, higher dispatch of nuclear, high prices of biomass, batteries and storage Socio-economic impacts re-evaluated for S1-S4	The sensitivities, in general, confirmed the robustness of the original pathways of D3. However, the new wind availability curves were deemed a more reliable estimate and used as the new main scenarios, providing the main inputs for the action plan and superseding the results of deliverables 3 and 4.
D7 Action plan	Definition of actions	In order to identify relevant actions and recommend a pathway, new analysis was performed in D7: • Review of current key policies and strategic documents. This includes an analysis of renewable deployment expected to be supported via the planned renewable auctions • Analysis of key stakeholders' policy statements and plans • Analysis of environmental impacts and mitigation strategies associated with the technologies considered • Summary of key barriers identified by stakeholders • Other specific analysis requested by the client (e.g. land requirement, potential issues that may arise with Estonian legal system, regional impacts, investment in transmission infrastructure and so on)

Actions considered

Based on discussions with stakeholders and literary sources (in particular, sources describing how other Member States have approached similar issues), this report identifies a series of actions that would allow Estonia to see the emergence of a technology mix as modelled in the pathways analysis. Given the assumptions used, there are limited differences between the technology mix required by the different scenarios. For this reasons, it was deemed appropriate to first identify the actions that would support a certain technology deployment, then provide further considerations only for the most relevant actions at pathway level. The main actions identified are listed in Table 0-6 and cover seven different areas (actions sets). Some additional minor actions are also recommended for specific pathways, but these do not figure in the main list.

Table 0-6 list of actions considered across pathways

Action set	Actions	Pathways more closely related
1. Planning	1A. Streamline the infrastructure planning approval process	• All pathways
	1B. Increase administrative resources dedicated to planning and permissions	• All pathways excluding CCU
	1C. Supporting actions to speed-up the approval process	• All pathways excluding CCU
2. Institutional reform	2A. Set up a nuclear regulator	• Nuclear, All technologies
	2B. Review the mandate of the Estonian National Regulatory Agency	• All pathways
	2C. Set up an Energy and Climate Agency	• All pathways
	2D. Increase cross border cooperation	• All pathways
3. Risk reduction instruments	3A. actions to stimulate the uptake of Power Purchase Agreements (PPAs)	• All pathways
	3B. Amendment to the current renewable electricity auction scheme	• All pathways excluding CCU
	3C. Move all or part of the funding for renewable electricity to the fossil gas bill or to other funds	• Renewables + storage (offshore wind) • Nuclear
	3D. Extend the current size of state guarantees provided by the Estonian Business and Innovation Agency | KredEx and develop a broader framework for government guarantees	• All pathways
	3E. Public co-investing and sharing risks	• Nuclear • CCU
4. RES for households and SMEs	4A. Set up an on-site small scale renewable generation support scheme, in combination with other actions to incentivise building renovation	• All pathways excluding CCU
	4B. Allow Households and SMEs to invest in remote renewable electricity generation	• All pathways excluding CCU
5. Power networks	5A. Develop a national flexibility strategy	• All pathways excluding CCU
	5B. Further improve the transparency of the Baltic balancing market	• All pathways • Lower relevance for CCU and nuclear
	5C. Improve batteries' economic viability and access to finance	• All pathways • Lower relevance for CCU and nuclear
	5D. Create a demand side management framework	• All pathways
	5E. Other actions to support storage know-how and reduce barriers	• All pathways
	5F. Consider alternative design models and funding mechanisms for key offshore infrastructure	• Renewables + storage (offshore wind) • All technologies
	5G. Reinforcement to Transmission and interconnection infrastructure	• All pathways
6. Involvement of the civil society	6A. Information campaign to be launched together with a new renewable energy strategy	• All pathways
	6B. Setup One-stop shops	• All pathways
	6C. Local action groups	• All pathways
	6D. Facilitate the uptake of Citizens and Renewable Energy communities	• All pathways
7. Other actions	7A. Support for vulnerable households	• All pathways
	7B. Skills development	• Nuclear

Several actions are relevant across all pathways considered. Some of the more relevant are:

- **Actions to streamline the planning process**, in particular to simplify the administrative requirements, to speed up decision time (by providing more resources and incentives to Local Authorities in charge of taking the decision). Additionally, if these improvements are still not sufficient to stimulate the required technologies in sufficient quantities, planning and approval responsibilities should be transferred to the national level.
- **Actions to facilitate the diffusion of PPAs.** These actions aim at simplifying agreements between contracting parties (generators and consumers) by creating standard contracts and incentives to consumers that decide to sign them.

- **Actions to reduce risks on renewable or low carbon investments**. For the majority of renewables, market risks are the major factor stopping or delaying an investment decision. The recommended mechanism to overcome this barrier is an improvement on the current feed-in premium. Contracts for difference would provide a more balanced risk transfer between generators and consumers, and minimise support if energy prices stay high. Different budgets within the scheme would allow support tailored to the targeted technology mix. Other technologies, such as renewable gas, nuclear energy and CCU will instead need more tailored risk reduction instruments that address technology-specific risks if it is decided that these are desirable for strategic regions (cost:return ratios are otherwise too unattractive for market players to invest).
- **Setup of a market for reserve capacity, flexibility and ancillary services**, open to different technologies, to nearby countries and to prosumers. This would be an important instrument to drive the deployment of batteries or other storage solutions which are needed in every pathway.
- **Actions to support the uptake of Demand Side Management (DSM)**. In all scenarios, all available DSM capacity (261 MW) is exploited, with broadly similar utilisation level in 2030 (between 25 and 29 GWh) and 2050 (between 21 and 27 GWh). DSM should participate in the market for flexibility capacity discussed at the previous point.
- **Setup an Energy and Climate Agency**, in charge of supporting various ministries with the implementation of energy and climate programmes.
- **Increased funding and** limits for guarantees provided by the Estonian Business and Innovation Agency | Kredex, to support developers with low credit rating and to lower risk premiums demanded by investors.
- **Actions to support vulnerable households**. These should include different type of support, including economic, technical, and informational. Some of the pathways considered may have a significant impact on the energy bill, so the most vulnerable consumers should be supported to reduce their consumption and access programmes that can support with the installation of energy efficiency measures.

Some further details at action set level are provided in Table 0-7 Action sets details while further below an indicative timeline for the proposed actions is presented.

Table 0-7 Action sets details

Action sets	Objective	Timeline	Responsible	Other key stakeholders	Cost/ resources
1.Planning process reform	Speed up approval process and reduce developers' risks	Short term (2023 - 2030)	Central government	Local administrations	Low cost, mostly human resources
2.Institutional reform	Provide more independent and dedicated resources	Medium term (2023 - 2035)	Central government		Low cost. Mostly resources transfer and reallocation of responsibilities
3.Risk reduction instruments	Reduce developers and investors risk	Award: short term (2023 - 2030) Implementation: medium/long term (2023-2040)	Central government	Financial institutions Large electricity users	Costs vary significantly with pathway and will depend on future energy prices
4.Support for households and SMEs	Reduce network reinforcement costs; exploit	Medium term (2023 - 2035)	Central government		Costs vary significantly with pathway

	low-cost opportunities; raise private finance				and will depend on future energy prices
5.Power networks	Allow integration of renewables at the lowest system cost	Medium term (2023 – 2035)	TSO	Central government	Financed via energy bills
6.Civil society	Reduce public opposition to renewables	Short term (2023 - 2030)	Central government		Low cost
7.Other actions	Avoid negative effect on households; ensure skills are available	--	Central government		Varies with scenario and macroeconomic factors

Figure 0-2 Indicative timeline and roles of the proposed actions (1/2)

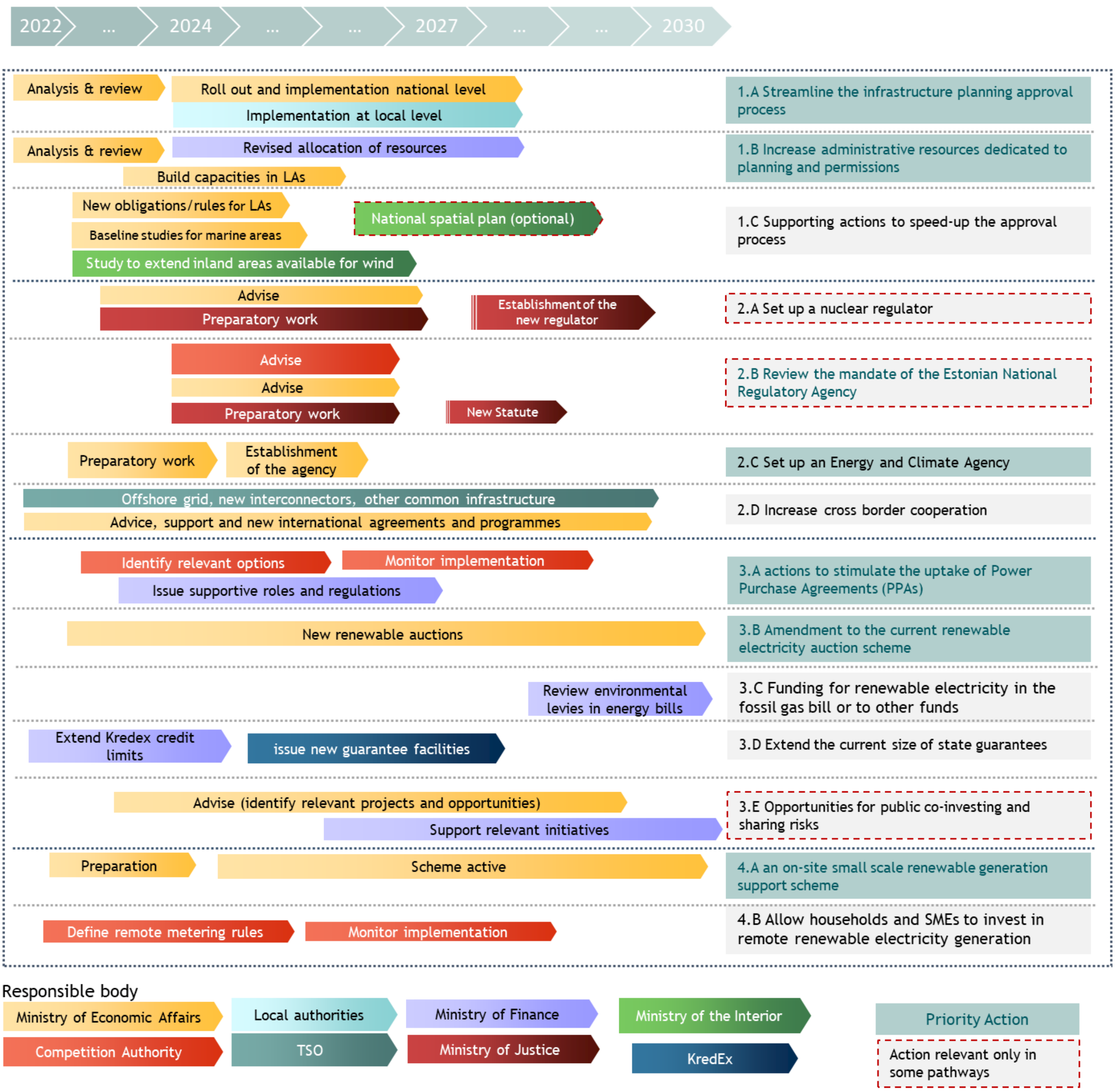
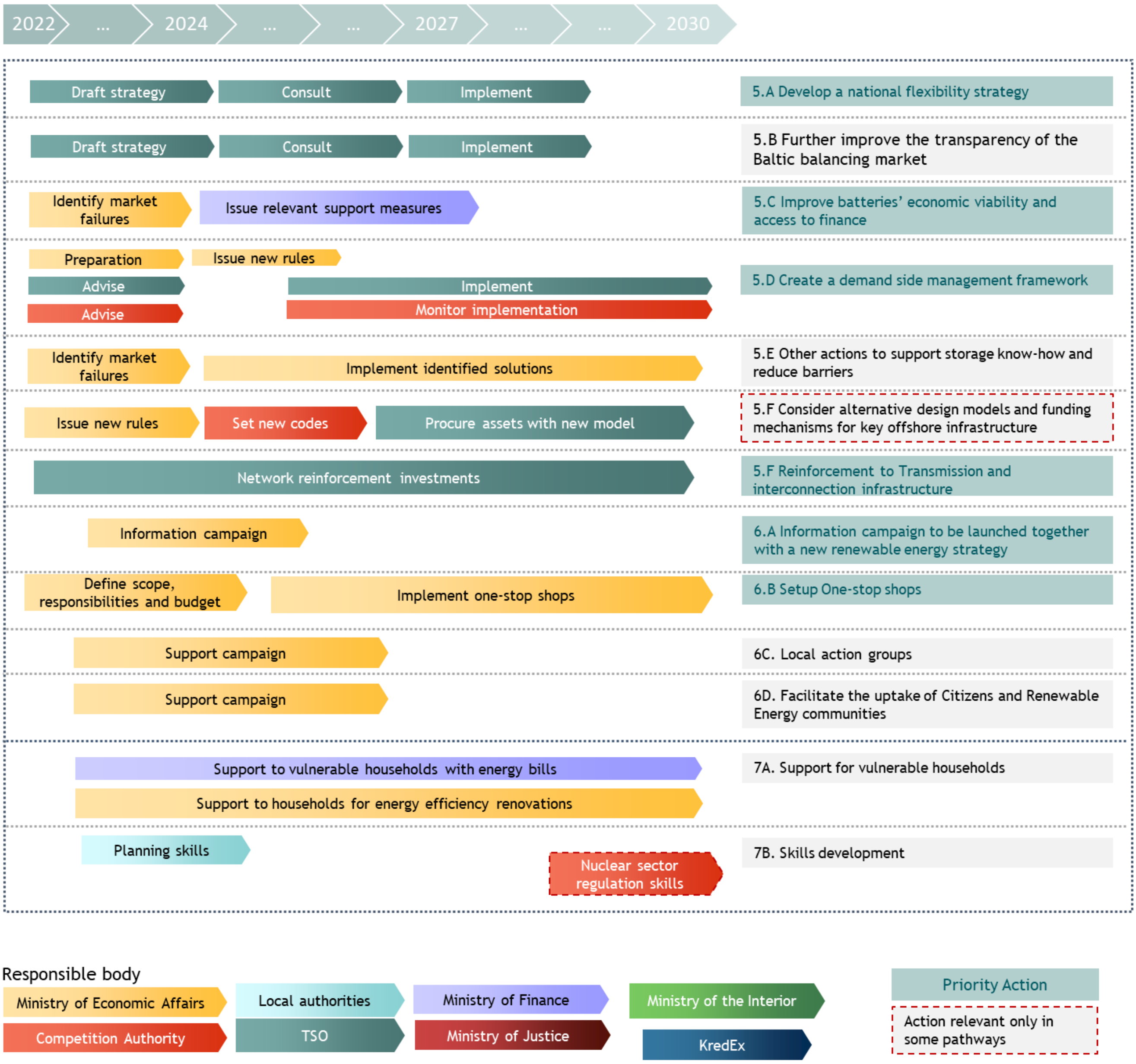


Figure 0-3 Indicative timeline and roles of the proposed actions (2/2)



Pathways comparison

Chapter 10 provides Conclusions and general recommendations, including which pathways appear the most promising according to different criteria. Table 0-8 summarises the main outcomes emerging from the analysis across key indicators, while Table 0-9 provides the final comparison, including a qualitative summary and the ranking according to a set and the two methods proposed (five key criteria and the consultant's assessment).

Table 0-8 summary results by pathways

Pathway	Cumulative investments to 2050 (€m)[3]	Network reinforcement cost (€m)	Expected public support (in 2030)	CO_2 emissions by 2050 ($ktCO_2$)	Electricity costs (LCOE-based in 2050 €/MWh)	GDP impact	Job impact
Renewable electricity + Storage (RES + Storage)	14,293	355	€105-209M	79 $ktCO_2$	139 EUR/MWh	Very positive	Neutral
Nuclear	12,089	230	€39-78M	30 $ktCO_2$	88 EUR/MWh	Neutral	Neutral
CCU	3,966	135	€28-55M	-147 $ktCO_2$	149 EUR/MWh	Negative	Negative
Renewable gas (RES GAS)	11,577	141	€37-73M	68 $ktCO_2$	101 EUR/MWh	Very positive	Very positive
All technologies (AT)	9,025	155	€36-71M	167 $ktCO_2$	97 EUR/MWh	Positive	Negative
AT-NIMP (AT-NIMP)	10,454	135	€94-189M	324 $ktCO_2$	107 EUR/MWh	Very positive	Very positive
1000 MW dispatchable capacity (AT+1000)	9,868	155	€41-82M	199 $ktCO_2$	103 EUR/MWh	Positive	Negative

The results of Deliverable 3, 4, 5 and 6, together with stakeholders feedback, have been used to define over 30 actions (grouped in 7 action sets) which aim to put in place the conditions for the deployment of the different technology mixes required in each pathway. Table 0-9 summarises this information and suggests that the *RES + Storage* pathway and the *All Technologies* pathway are the scenarios that offers the best balance across the indicators considered in both evaluations (consultant and Ministry's indicators). The *RES + Storage* pathway is weighted down by high costs, but it is also the scenario that generates the highest net economic benefits, including job, and security of supply. The *All technologies* has lower overall expected benefits, but it also appears to be easier to achieve as it has a technology-neutral approach. The other two scenarios (*Renewable gas* and *Nuclear*) are recommended in only one of the two assessment proposed.

However, the choice of the preferred pathway is a "political" choice, as all pathways presented reach the decarbonisation objectives and the other main objectives set for the Estonian electricity system. This report, and the evaluation it provides, should be used by decision makers and stakeholders to identify the path towards decarbonisation that they feel more comfortable with, rather than to be considered the final decision. We expect different stakeholders to put different weight on different indicators, and arrive at different conclusions on the preferred choice.

[3] Generation only

Table 0-9 key actions at pathway level

Pathway	Details	Key actions	Financials	Impact and risk assessment	Consultant assessment	Alternative ranking
Renewable electricity + Storage (RES + Storage)	Is the most ambitious pathway, which foresees the deployment of large amounts of offshore wind and storage, and that results in the highest total investment costs, both in generation and transmission infrastructure. However, the investment generates positive economic impacts, and environmental impacts from large offshore deployment can be managed. Key actions focus on facilitating offshore deployment (technology-specific support; offshore grid; transmission capacity), on supporting the deployment of storage solutions, and on protecting vulnerable consumers from possible increases in energy bills.	• Streamline the planning process for offshore wind installations (1A, 1B, 1C) • Technology-specific risk reduction mechanisms aimed at supporting offshore wind (3B) • Completion of the Baltic offshore grid (5E)	• Total investment: €14.6 bn • Subsidies: €105-€209 m • Elec prices: ○ 2030: €113/MWh ○ 2050: €139/MWh	• Very positive effect on GDP, prices and distributional impacts • Medium risk	Recommended	2
All technologies (AT)	This is the base case technology neutral scenario. It provides a balanced generation mix and investment profile over time. While it does not score particularly positive in any of the areas considered, it also has no major negative point.	• Technology-neutral risk reduction instruments (3B)	• Total investment: €9.2 bn • Subsidies: €36-€71 m • Elec prices: ○ 2030: €99/MWh • 2050: €97/MWh	• Positive effect on GDP and prices, negative impacts on employment • Low risk	Recommended	2
Renewable gas (RES GAS) Modified	While the modelling results for the Renewable gas scenario provide a relatively balanced power system, there are inconsistencies that suggest this may not be an ideal trajectory for Estonia, unless some of the assumptions change. In particular, deploying lower quantities of biogas would create a more cost effective system.	• Technology-specific support for biogas installations (3B)	• Total investment: €11.7 bn • Subsidies: €37-€73 m • Elec prices: ○ 2030: €113/MWh ○ 2050: €101/MWh	• Very positive effect on GDP, employments, prices and distributional impacts • Low risk	Recommended	4
AT-No net imports (AT-NIMP)	The other two technology-competition pathways have similar results in terms of technology mix, costs and dispatchable capacities. Based on the assumptions, different technologies emerge. Recommended actions also follow a technology-neutral approach, and aim to keep all options open until costs become clearer. The *AT-NIMP* is amongst the pathways expected to be most economically beneficial. It is also one of the few pathways that does not rely on biomass-fuelled oil shale plants for a significant share of generation after 2030, which points to a more sustainable impact on Estonian forests, however at the cost of greater use of natural gas	• Begin groundwork for future nuclear deployment (2A, 7B)	• Total investment: €10.6 bn • Subsidies: €94-€189 M • Elec prices: ○ 2030: €96/MWh ○ 2050: €107/MWh	• Very positive impact on GDP and employment; positive distributional and price impacts • Medium-high risk	Viable	6
1000 MW dispatchable capacity (AT+1000)		• May require dedicated instrument to reward required dispatchable capacity (5A)	• Total investment: €10.0 bn • Subsidies: €41-€82 M • Elec prices: ○ 2030: €91/MWh ○ 2050: €103/MWh	• Positive impact on GDP, negative impact on employment and prices • Low risk	Viable	5
Nuclear	The pathway is characterised by a focus on nuclear and solar PV, and it is expected to be the second most expensive pathway, although it is expected to have lower electricity prices in 2050. The main actions identified concern the development of a national nuclear programme and supporting actions to other renewables. According to stakeholders, this is the riskiest scenario, especially as it relies on a technology that has no history in Estonia and that is not expected to come online before 2035.	• Nuclear programme, with actions to already lay groundwork for future nuclear deployment (2A) • Mandatory solar PV in all buildings (4A)	• Total investment: €13.3 bn • Subsidies: €39-€78 M • Elec prices: ○ 2030: €88/MWh ○ 2050: €88/MWh	• Neutral GDP impact and positive price impact, negative employment effect • Riskiest scenario	Not recommended	1
CCU	This scenario requires the lowest investment and continues exploiting fossil fuel reserves in the long term, although modelling suggests this will still decline to around ¼ of current levels. While the actions required for its implementation are fewer and simpler than for other pathways, this is the pathway expected to be worst for the economy and employment, and would leave Estonia most dependent on power imports in future. CCU could be a good option for Estonia if further use and transport options for CO_2 are identified, so that carbon capture can be deployed to other power plants (beyond the two considered in this analysis) and industrial installations, and if costs can be made economically competitive.	• CCU programme, with the main aim to identify new options for CCU and CO_2 storage	• Total investment: €4.1 bn • Subsidies: €28-€55 M • Elec prices: ○ 2030: €103/MWh ○ 2050: €149/MWh	• Negative GDP, employment, prices and distributional impact • High risk scenario	Not recommended	7

1 Introduction

This report presents the results of Deliverable 7 of the project 'Transitioning to a climate-neutral electricity generation'. This deliverable brings together the results of the previous deliverables of the project to suggest a number of actions that would allow Estonia to reach a carbon-neutral electricity system along the pathways defined by the energy system modelling.

The actions recommended have been identified by:

- Reviewing current strategies and government initiatives that already align with the deployment objectives of the different pathways;[4]
- Understanding main barriers stakeholders face in deploying decarbonisation technologies according to the trajectories set in the pathways; [5]
- Gathering opinions from stakeholders on actions they would like to see implemented to ensure they can do their part in the implementation of the decarbonisation pathways. Stakeholders were involved via interviews and a workshop held in February 2022;
- Understanding from other countries how they are pursuing the same objectives and taking inspiration from those practices.[6]

This report presents first a general overview of key Estonian strategic documents, financing options, barriers and risks, and pathways details. Then it identifies and describes a series of actions with the objective of:

- Streamlining the energy infrastructure planning process;
- Adapting the institutional framework to the new energy technology mix;
- Defining new risk reduction and financial support mechanisms;
- Strengthening the power network by considering how new assets and new initiatives should be deployed to manage demand and integrate more renewable energy sources;
- Ensuring citizens are supportive of the strategy and that they are not excessively burdened by too high energy bills.

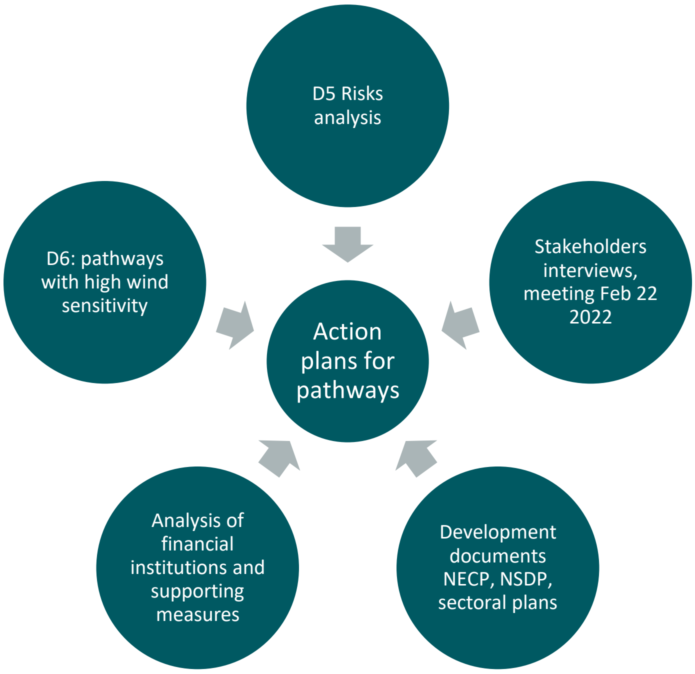
Finally, the report concludes with a series of recommendations, including identifying a number of no-regret actions that should be undertaken independently of the pathways chosen.

1.1 Methodology

The methodology followed to arrive at the action plans at pathway level is broadly presented in Figure 1-1. The action plans attempt to include inputs deriving from other deliverable plus some specific analysis carried out for the purpose of this report. Action plans aim to consider all of these at the same time, although the link with the input may not appear evidence in every instance.

[4] Estonia 2035; National Energy and Climate Action Plan 2030; Recovery and Resilience Plan for Estonia; Reverse Auctions for renewable electricity generation
[5] Based on a questionnaire sent to over 80 stakeholders (8 full responses received) and interviews with 8 stakeholders: Power Industry Association; Renewables Association; Wind Association; Nuclear Energy interested company Fermi; Biofuels Association; Chamber of environmental organisations; Sunly.
[6] All EU MS countries were considered

Figure 1-1 Inputs to action plan



To draft this report, we followed a six-step process:

1. Understanding the current landscape (Annex C)
This report presents the results of a desk-based research exercise aimed at providing an overview of key strategies, objectives and policies aiming at decarbonising the power sector, including major infrastructure work such as network reinforcement. This analysis is one of the key inputs for the development of new actions. To carry out this task, we have identified and analysed key documents (e.g., NECPs, NRRPs, National Development Plan of the Energy Sector…) that give a broad picture of the main ongoing and planned actions.

2. Overview of financial institutions (Annex C)
Chapter 3 provides a brief overview of financial institutions and opportunities to access their financial support. The analysis has focused on the main institutions and their financial products which are (in principle) accessible by investors in Estonia.

3. Bring together the results from other tasks (Chapters 0 and 3)
Chapter 0 presents a summary of the results of the risk analysis, including key insights from stakeholders interviews. Chapter 3 presents the results of the energy system and impact assessment modelling and provides additional considerations across the whole set of pathways considered: how the power generation technology mix evolves over time; CO_2 emissions trajectories and implications for decarbonisation targets; expected land-use requirement, particularly relevant for onshore wind energy deployment; investment needs; socio-economic impacts; and required investments in transmission network capacity. Further insights from the energy system modelling and impact assessment are presented at the pathway level in Chapters 5 to 9.

4. Define main scope of required actions across the pathways

The following steps were implemented to identify the actions needed to support the required technology deployment trajectories, and have driven the analysis presented in Chapters 5 to 9:

a. **Define a long list of policy options.** In order to determine a long list of actions, two main methods were used:
   - Interviews: stakeholders have been asked to identify barriers and solutions for implementing the pathways. All those invited to take part in the survey (over 70 organisations) were asked whether they would like to discuss policy options, plus some direct invitations were made. In the end, eight interviews were carried out with sectorial associations (renewables, wind, biofuels, nuclear), NGOs and environmental organisations, and investors. Other stakeholders contacted directly (Elering, Power Industry association, the Solar energy association) declined participation, although Elering was then interviewed in May 2022. All other stakeholders were interviewed in December 2021 and January 2022;
   - Documents review: identification of possible actions to decarbonise the power sector as proposed by stakeholders, government's white papers, consultant reports and other sources. Primarily, the research has focused on Estonian sources, complemented with international work where national sources were insufficient. The review of key Estonian sources on the subject is presented in Annex C.

   The long list of policy actions identified in this way was then mapped against the pathways, aiming to align the instruments to the expected technology uptake in the scenario. For example, an action to review the planning process for onshore wind energy projects was deemed of high relevance for scenarios that foresee a high deployment of wind energy, and of minor relevance for scenarios where wind energy does not play an important role.

b. **Receive feedback.** The long list has been shared with the Estonian authorities and with stakeholders. Stakeholders had the opportunity to provide feedback during a workshop held on 22 February 2022.

c. **Group policies in a coherent set of actions.** During this step, the long list of actions developed in the previous step has been grouped into seven actions sets and further details have been added. The seven areas considered are: infrastructure planning process; institutional reform; investment risk reduction; financial incentives and other support for households and SMEs; power networks; involvement of the civil society; other actions that do not fit under any of the previous headings.

The initial set of actions has then been mapped against the barriers identified by stakeholders and re-evaluated against the expected technology deployment trajectory in the various pathways. For each action, further pathway-specific elements have been introduced. Where possible, costs ranges are provided, in particular for the risk reduction instruments. These actions are additional to any action already planned by the Estonian Government or other stakeholders.

5. Adapt actions to the pathways

In order to adapt the set of actions to the pathways, the following steps were taken:

a. **Identify key insights** from energy system and macroeconomic modelling at pathway level. These quantitative insights are necessary to calibrate the actions proposed.
b. **Calibrate actions.** Based on the list of actions defined in step 4, the most relevant actions for each pathway have been identified and adapted. Short term priorities across the seven policy areas have then been determined.
c. **Provide supporting considerations associated with the main actions.** For each pathway, additional qualitative and quantitative considerations have been provided, including:
    - Costs of main actions;
    - Environmental impacts;
    - Additional impacts from proposed actions;
    - Further considerations concerning legal aspects and public perception.

6. Conclusions

The final chapter (Chapter 10) brings together the key results from the analysis presented in this report and in other tasks of the project, and provide recommendations concerning:
- No-regret actions (actions that can be implemented whichever pathway is chosen;
- Best-scoring pathway across a set of criteria.

1.1.1 Definitions

Throughout this document, we use terms which refers to analysis carried out in other deliverables of this assignment. While for the full definition it is necessary to consult the relevant reports (Final reports for Deliverable 2, 3, 4, 6), here we provide a short methodological explanation of the key terms utilised.

Forecast years: The assessment uses the three years modelled as part of the other deliverables of this assignment, namely 2030, 2040 and 2050. These years are intended as indicative, i.e., the suggested technology deployment, investment or action should take place around these years, but in practical terms it could be up to three or four years, earlier or later. Furthermore, interpolated results for 2035 have been provided within the Excel outputs of Deliverable 6.

Costs: All costs and benefits are expressed in 2020 EUR.

Average electricity prices: Average of electricity prices over the years, presented as euro per kWh or MWh. Wholesale electricity prices are estimated in the model using levelized cost of electricity (LCOE) approach. Specifically, the estimated price in each region, year, and time slice is calculated as the highest LCOE among resources providing power in the region, year, and time slice, including imports if applicable. Average annual prices are calculated by weighting time-sliced prices by time slice width (i.e., the fraction of the year covered by each time slice). To determine average prices in Estonia, prices for the NUTS 3 regions are weighted by the regions' shares of national electricity production requirements[7].

Carbon capture utilisation and storage (CCU/S): CCU is an important CO_2 emissions reduction technology, which captures carbon to avoid that it enters into the atmosphere. In this study, carbon capture utilisation (and storage) is considered in terms of retrofitting oil shale fuelled power plants

[7] See section 2.4.2 of Deliverable 3 for further information on this and other key power system modelling definitions and assumptions.

with carbon capture technology. In this scenario, oil shale fuelled power plants which are retrofitted with CCU do not need to be converted to run on biomass. The model allows carbon capture in Estonia through CCU retrofits of the TG11 and Auvere oil shale power plants. In addition, in scenarios that target climate-neutral electricity production, direct air capture of CO_2 can be deployed (although it is quite expensive, as discussed below). Total captured CO_2 in Estonia (from all sources) is limited to about 700 kt/year, an estimated potential for CO_2 utilization in Estonian industry based on the Deliverable 2 data collection.

Electricity transmission and distribution: The transmission system within the study area is simulated as a nodal network in which each modelled region is a separate node. Total high-voltage transmission capacity between any two nodes is aggregated and represented as a single notional line. Power flow is then allowed subject to capacity limits. The model includes average transmission line losses in the power flow calculations. The model does not explicitly represent the electricity distribution system or transmission lines that do not cross regional boundaries. Average electricity losses in these components of the grid are calculated separately (based on RS2020) and added to the required electricity production volumes. Additionally, by default the model allows net electricity imports into all Estonian regions. As the model was constructed, stakeholders debated whether net imports should be permitted, and the consensus was ultimately that they should be unless a scenario rules them out.

Dispatchable power generation capacity: Installed electricity production capacity which can be dispatched on demand. Solar PV, wind power plants and run-of-river hydro, for instance, are not dispatchable, whereas fossil fuels and biomass based power plants are. For the main purposes of the work both batteries and DSM are also dispatchable, but further discussion on this is provided in section 3.1.3.

Figure 1-2 List of generation technologies by dispatchability

Dispatchable	Non dispatchable
Biogas & other renewables	Offshore wind
Biomass	Onshore wind
DSM	Solar PV
Fossil gas	Hydro
Nuclear	
Oil shale (inc. CCU)	
Pumped hydro	
Waste	
Batteries	

Demand-side management (DSM): Adjusting consumer demand for electricity to take benefit of the electricity price volatility and/or to create more flexibility in the electricity system, e.g. to balance supply and demand or to avoid/reduce grid congestion. The DSM options considered in the modelling include load shifting in three categories: 0-1 hours of load, 1-2 hours of load, and 1-8 hours of load in the industrial, commercial, and residential sectors.

<u>Electricity production technologies considered</u>

- **Oil Shale:** The generation of electricity through burning of oil shale. Oil shale extraction used for electricity generation in Estonia, are mainly from the Auvere oil shale plant. In the model,

after 2030, former oil shale plants will be converted to use 100% biomass, unless they are retrofitted with carbon capture (only in the CCU pathway does this occur).
- **Fossil gas**: The generation of electricity through burning of fossil gas.
- **Offshore wind**: The generation of electricity through wind farms located off the coast of Estonia.
- **Onshore wind**: The generation of electricity through wind farms located on Estonian land.
- **Solar PV**: The generation of electricity through solar photovoltaics, which can be from solar parks or rooftop solar.
- **Other renewable energy sources**: The generation of electricity through renewable energies other than solar and wind power such as biogas.
- **Nuclear**: The generation of electricity through nuclear power plant(s).
- **Biomass**: The generation of electricity through the burning of biomass.
- **Waste**: The generation of electricity through the burning of waste.

Electricity storage technologies
- **Hydro**: The storage of electricity through natural hydropower reservoirs.
- **Batteries**: The storage of electricity through grid-connected lithium ion batteries.
- **Pumped hydro**: The storage of electricity through pumped hydropower. The model includes the proposed pumped hydro facility at Paldiski.

1.1.2 Limitations

There are a number of constraints and limitations to the results and recommendations presented here:
- Ongoing international events are affecting short-term energy prices, but may also affect long-term energy prices beyond the ranges forecasted (and used in modelling) when this project was started. All scenarios are affected by this. However, the sensitivity analysis carried out in Deliverable 6 suggest that the results are robust to a number of factors.
- The actions suggested are focussed on the electricity sector. Interactions with other sectors (such as heating and cooling, buildings, transport, industry) are not considered as part of the actions, but will have substantial impacts on electricity demand and the higher need for and utilization of flexibility resources, in particular electricity storage.
- This report considers a number of electricity network reinforcement and extension actions as they emerge from the modelling. However, the model considers only a limited set of candidate (endogenous) transmission lines – specifically, potential new lines between Lääne-Eesti and Kesk-Eesti, Lääne-Eesti and Latvia, Lõuna-Eesti, and Põhja-Eesti. Furthermore, all new lines projected by ENTSO-E, including interconnectors, are considered as exogenous parameters in all scenarios (see the Deliverable 3 report).
- Costs for the reinforcements and extensions of transmission lines are presented in Chapter 4, but costs for the interconnectors projected by ENTSO-E are not included in the model.
- As noted in the Deliverable 3 report, the model does not represent the electricity distribution system, so no reinforcement/extension needs or related costs are considered, even though deployment of RES (onshore wind, PV) and electrification of buildings' heating (HP) and transport (EVs) have a major impact on distribution.

1.2 Impacts on consumers

According to a report on the rollout of smart meters[8], there were a total of 751,000 metering points (708,000 for Electricity and 43,000 for Gas) in Estonia, in 2019. The majority (98%) of electricity metering points are equipped with smart meters.

According to Statistics Estonia[9], there were 626,500 households in Estonia in 2020, which suggests that there are about 81,500 metering points that belong to businesses or other institutions, including the public sector. Estonia's electricity consumption amounted to 8.3 TWh in 2020, while households were responsible for 24% of total electricity use (2 TWh).[10] These figures will be used across the pathways (Chapters 5 to 9) to estimate the impact on consumers' bills of the actions that are expected to be financed via a levy or a charge on the electricity bill (typically, support for renewables and charges for network assets).

1.3 Estimating the cost of renewable electricity support (auctions) schemes

The various options to support the cost of renewable electricity generation in Chapter 4 and onwards rely on flexible mechanisms that provide payments to renewable electricity generators only when the market price is insufficient to recover investment costs. These schemes are targeted at renewable electricity generation with low operational costs (wind, solar PV), rather than other renewables with higher operational costs (biomass, biogas).

The effective cost of these instruments depends on the electricity market price, which is largely an endogenous factor as it is heavily affected by international fossil energy prices. This will change during the period considered, as it is expected in the future that the marginal power plant in the merit order will not be a fossil fuel based generator any more for the vast majority of the time. However, without an estimate of how the wholesale electricity price will vary throughout the year, it is not possible to reliably evaluate the cost of a renewable support instrument.

Based on the assumption that these schemes will include a maximum pay-out limit[11], it is possible to estimate the maximum amount of support that these may require based on assumed limits built in as part of the scheme. The table below shows the pay-out limits assumed for the main renewable electricity production technologies.

Table 1-1 Assumed maximum support paid out by technology in 2030

Technology	Maximum support paid out (€/MWh)		
	Maximum	Medium	Low
Offshore Wind	40	20	0
Onshore Wind	20	10	0
Other Renewables	30	15	0
Solar PV	20	10	0

[8] https://www.vert.lt/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf
[9] https://www.stat.ee/en/find-statistics/statistics-theme/well-being/households
[10] Statistics Estonia (2021). KE062: Consumption of fuels by economic activity and type of fuel.
[11] Ongoing renewable auctions schemes have a €20/MWh maximum pay-out limit

The medium case has been assumed to be half of the maximum support payable. The medium case could be intended as if the maximum assumed support was paid half of the time (i.e. if, on average, wholesale prices are below bid price only half of the time), or as if the difference between the bid price and the wholesale price is less than the maximum payable. In the low case, wholesale price remains above the bid price throughout the period considered.

In order to estimate the per unit cost, it is assumed that the cost of the scheme would be distributed across all users proportional to their energy use. However, it will be necessary to account for the fact that the total electricity withdrawn from the network will be less than total demand, due to self-consumption (prosumers). Therefore, while demand in 2030 is expected to be 11 TWh, it is assumed that only 9 TWh would use the network and be subject to a renewable electricity levy.

1.4 Impact of technologies and infrastructure on the environment, society and economy

This section provides an overview of the general environmental, social and economic impacts of the main technologies and infrastructures required by the pathways to reach a climate-neutral electricity system in Estonia: offshore wind, onshore wind, solar PV, biomass, nuclear, transmission and distribution lines, and battery storage. Recommendations are provided to either mitigate the negative impacts or increase the positive impacts.

1.4.1 Impacts of offshore wind farms

The table below provides an overview of the positive and negative impacts of offshore wind farms on the local environment and economy and recommendation on how to minimise negative impacts and increase positive impacts. Most of the negative impact from offshore wind farms occur during the time of construction and decommissioning. Construction and decommissioning of offshore wind farms create a physical disturbance of the local marine habitat and can lead to habitat loss, however in the long-term, offshore wind farms can have a positive impact on marine habitats and biodiversity. Fishing prohibitions/restrictions in offshore wind farms allow for proliferation of marine life in the vicinity of offshore wind farms.[12] Furthermore, installations can act as artificial reefs and fish aggregation devices.[13] Proper management and design of offshore wind farms are crucial to ensure that offshore wind farms have this positive impact. Wind turbines can create a collision hazard for avian populations. However, this impact is highly dependent on the local situation (e.g. the nature and conservation status of both resident and migratory species).

Although offshore wind farms protect local marine life from fishing activities, this is also considered a negative impact for the Estonian fishing industry (particularly trawling). However, as mentioned, these fishing activities have a negative impact on the local flora and fauna, thus the positive environmental impact could outweigh the negative economic impact. It is possible also that non-trawling fishing activities could see benefits from reduced marine environment destruction. Therefore, it will be important to involve all stakeholders in offshore wind farm projects in order to

[12] Degraer, S. et al. (2019). Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Marking a Decade of Monitoring, Research and Innovation. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, 134 p. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Degraer-2019-Offshore-Wind-Impacts.pdf
[13] Inger, R. et al. (2009). Marine renewable energy : potential benefits to biodiversity? An urgent call for research. Available at: https://doi.org/10.1111/j.1365-2664.2009.01697.x

select the most appropriate location and configuration, while taking into account the required electricity transport infrastructure.

As offshore wind energy installations would be constructed in the proximity of the **Lääne-Eesti** region, this is the area where offshore wind energy projects would have the most impact.

Table 1-2 Impacts of offshore wind farms and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environmental	C & D	Reduce water quality, contamination of chemical emissions[14]	Monitor water quality during construction
	C & D	Decrease marine biodiversity[15]	Avoid construction works during specific seasons, depending on the local fish species
	C & O & D	Noise disturbance for local wildlife (such as grey seals)[16]	Avoid construction works during specific seasons, depending on the local wildlife
	C & D	Negative impact on seabed flora/fauna and seabed dwelling places[17]	Ensure that the material used for underwater parts of turbines are suitable for the marine life and use natural materials to prevent erosion. Ensure that foundations are carefully located to not significantly harm the local seabed flora/fauna
	C & O	Collision hazard for local avian and bat populations[18]	Ensure assessment of the potential impact on avian population for new projects with bird experts and implement minimisation via location selection, suitable construction time
	D	Disturbance and waste from decommissioning	Requirements on developers to set sufficient funds aside for decommissioning and maximise recycling of material
	O	Protect marine population and increase biodiversity (due to decreased fishing activity in the vicinity)[19]	Ensure proper management and design of offshore wind farms
	C & O	Creation of artificial reef to provide a habitat for local marine species[20]	Ensure the right materials are used to create a suitable artificial reef

[14] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf; Degraer et al. (2019). Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Marking a Decade of Monitoring, Research and Innovation. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, 134 p. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Degraer-2019-Offshore-Wind-Impacts.pdf

[15] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf

[16] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf; Inger, R. et al. (2009). Marine renewable energy : potential benefits to biodiversity? An urgent call for research. Available at: https://doi.org/10.1111/j.1365-2664.2009.01697.x

[17] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf

[18] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf; Inger, R. et al. (2009). Marine renewable energy : potential benefits to biodiversity? An urgent call for research. Available at: https://doi.org/10.1111/j.1365-2664.2009.01697.x; SEI (2021). Kohalike omavalitsuste tuule- ja päikeseenergia käsiraamat. Available at: https://cdn.sei.org/wp-content/uploads/2021/05/kov-te-kasiraamat.pdf

[19] Degraer et al. (2019). Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Marking a Decade of Monitoring, Research and Innovation. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, 134 p. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Degraer-2019-Offshore-Wind-Impacts.pdf

[20] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf

Type of impact	Time of impact	Impact	Recommendation
Social	O	Health benefits from reduced air pollution from fossil fuel use (e.g. reduction of respiratory diseases, heart attacks, death)[21]	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)
	O	Visual disturbance for local community[22]	Construct offshore wind farms near industrial areas, such as ports, where the landscape with already altered
Economic	C & O	Negative impact on fishing industry[23]	Ensure consultation with fishing industry stakeholders during the design and construction of wind farms.
	C & O	Negative impact on maritime activities[24]	Limit maritime traffic in the construction zone and have clear markings of wind park and maritime traffic zones
	C & O	Require public support funded from either consumers (via energy bill) or via taxation and lead to substantial variability in supply (need for back-up)	Adequate measures to ensure consumers are not significantly affected by RES charges and intermittency (see the security of supply strategy)
	C, O & D	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the wind energy industry
	O	Reduce energy import and fossil fuels dependence	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.2 *Impacts of onshore wind farms*

Table 1-3 below provides an overview of the positive and negative impacts of onshore wind farms on the local environment and economy and recommendations on how to minimise negative impacts and increase positive impacts. To minimise negative impacts, it is important to ensure that the site selected for onshore wind farms is not critical for local wildlife nor does it disturb the local human population.

Onshore wind farms are expected to be constructed by 2030 in **Laane Eesti** (850 MW), **Pohja Eesti, Kesk Esti and Kirde Eesti** (each 100 MW). The impacts are therefore expected to be in these regions, with greater impact in **Laane Eesti.**

Table 1-3 Impacts of onshore wind farms and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	C, O & D	Noise disturbance for local wildlife[25]	Avoid construction/decommissioning works during ecologically sensitive periods; Use of sound insulation materials inside windmills

[21] Buonocore, J. et al (2016). Health and climate benefits of offshore wind facilities in the Mid-Atlantic United States. Available at: https://doi.org/10.1088/1748-9326/11/7/074019.
[22] Virtanen, E.A. (2022). Balancing profitability of energy production, societal impacts and biodiversity in offshore wind farm design. Available at: https://doi.org/10.1016/j.rser.2022.112087
[23] Aunapuu, A. et al. (2017). North-West Estonia offshore wind park. Summary of Environmental Impact Assessment Report. Available at: http://media.voog.com/0000/0039/7997/files/north-west-estonia-offshore-windpark-eia_09032017.pdf
[24] idem
[25] European Commission (2020). Guidance document on wind energy developments and EU nature legislation. Available at: https://ec.europa.eu/environment/nature/natura2000/management/docs/wind_farms_en.pdf; SEI (2021). Kohalike omavalitsuste tuule- ja päikeseenergia käsiraamat. Available at: https://cdn.sei.org/wp-content/uploads/2021/05/kov-te-kasiraamat.pdf

Type of impact	Time of impact	Impact	Recommendation
	C	Impact of site preparation on local environment & impact on local wildlife habitat[26]	Ensure that the site is not critical for local wildlife and minimise the cutting of trees for land clearing
	C & O	Collision hazard and for local avian populations[27]	Ensure assessment of the potential impact on avian population for new projects with bird experts and implement mitigation measures
Social	C & O	Noise and shadow flicker disturbance as well as visual disturbance for local population	Ensure onshore wind parks are not close to houses of local population
	O	Health benefits from reduced air pollution from fossil fuel use (e.g. reduction of respiratory diseases, heart attacks, death)[28]	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)
Economic	C, O & D	Increase in economic development and direct/indirect employment Reduce energy import and fossil fuels dependence	Ensure that nationally there are enough highly skilled professionals in the wind farm industry
	O	Reduce energy import and fossil fuels dependence	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.3 Impacts of solar PV

The table below provides an overview of the positive and negative impacts of solar PV parks on the local environment and economy and recommendation on how to minimise negative impacts and increase positive impacts. Although there are a few possible negative environmental impacts from solar PV, they are not critical and can be mitigated by proper measures. These negative impacts are not applicable to rooftop solar.

Solar PV is expected to be installed in the regions **Laane Eesti, Pohja Eesti, Kesk-Eesti, Louna Eesti and Kirde Eesti**. The impacts are therefore expected to mainly be situated in these regions.

Table 1-4 Impacts of solar PV parks and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	C	Impact of site preparation on local environment[29]	Ensure that the site is not critical for local wildlife and minimise the cutting of trees for land clearing
	O	Impact on microclimate/biodiversity[30]	Ensure vegetation and soil management during operation Avoid use of fences around solar power plants to reduce landscape fragmentation

[26] European Commission (2020). Guidance document on wind energy developments and EU nature legislation. Available at: https://ec.europa.eu/environment/nature/natura2000/management/docs/wind_farms_en.pdf
[27] idem
[28] Buonocore, J. et al (2016). Health and climate benefits of offshore wind facilities in the Mid-Atlantic United States. Available at: https://doi.org/10.1088/1748-9326/11/7/074019.
[29] Wheeler. J. et al. (2011). Major Environmental Impact Assessment Popua 1MW Solar Farm. Available at: https://www.eib.org/attachments/pipeline/20100599_eia_en.pdf; Armstron, A. et al. (2016). Solar park microclimate and vegetation management effects on grassland carbon cycling. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016/pdf
[30] Wheeler. J. et al. (2011). Major Environmental Impact Assessment Popua 1MW Solar Farm. Available at: https://www.eib.org/attachments/pipeline/20100599_eia_en.pdf; Armstron, A. et al. (2016). Solar park microclimate and vegetation management effects on grassland carbon cycling. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/11/7/074016/pdf; SEI (2021). Kohalike omavalitsuste tuule- ja päikeseenergia käsiraamat. Available at: https://cdn.sei.org/wp-content/uploads/2021/05/kov-te-kasiraamat.pdf

Type of impact	Time of impact	Impact	Recommendation
Social	O	Health benefits from reduced air pollution from fossil fuel use (e.g. reduction of respiratory diseases, heart attacks, death)[31]	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)
Economic	C, O & D	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the solar energy industry
	O&C	Large amount of land use[32]	Preference for less valuable areas (i.e. non-agricultural areas)
	O	Reduce energy import and fossil fuels dependence	Ensure that RES is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.4 Impacts of nuclear power

The table below provides an overview of the positive and negative impacts of nuclear power plants on the local environment and economy and recommendations on how to minimise negative impacts and increase positive impacts. While the normal operation of nuclear power plants generally has little negative impact on the environment and human health, the severity of the negative impact in case of an accident can be significantly high. Therefore, strict requirements for maintenance and prevention/mitigation of accidents are critical.

Nuclear power plants would be installed in **Kesk Eesti and Kirde Eesti**, so these are the most impacted regions from nuclear energy.

Table 1-5 Impacts of nuclear power plants and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	O	Thermal pollution of fresh waterbodies via cooling systems (less of a problem for seawater)[33]	Strict control of the maximum discharge temperatures
	O	Water consumption[34]	Careful analysis of the impact of excessive water consumption for site selection
Environment & Social	O	Radiological and non-radiological impact on environment and human health (limited during normal operation) [35]	Strict requirements for prevention and mitigation of severe accidents
	O & D	(Long-term) storage of nuclear waste is expensive and a hazard for the local community and wildlife[36]	Strict limitations on the release of toxic and radioactive waste into the environment and ensure proper waste management
	C, O & D	Areas surrounding the power plants negatively affected, e.g. negative perceptions affecting house prices, increased traffic close to plant	Carefully consider siting and impact on local communities and infrastructure
Social	O & D	Increased security risk	Strict requirements for prevention and mitigation of severe accidents, especially in the case of a security risk

[31] Buonocore, J. et al (2016). Health and climate benefits of offshore wind facilities in the Mid-Atlantic United States. Available at: https://doi.org/10.1088/1748-9326/11/7/074019.
[32] SEI (2021). Kohalike omavalitsuste tuule- ja päikeseenergia käsiraamat. Available at: https://cdn.sei.org/wp-content/uploads/2021/05/kov-te-kasiraamat.pdf
[33] European Commission (2021). Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation'). Available at: https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf
[34] idem
[35] idem
[36] idem

Type of impact	Time of impact	Impact	Recommendation
	O	Health benefits from reduced air pollution from fossil fuel use (e.g. reduction of respiratory diseases, heart attacks, death)[37]	Ensure that nuclear energy is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)
Economic	C, O & D	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the nuclear energy industry
	C & O	Reduce energy import and fossil fuels dependence	Ensure that nuclear energy is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.5 Impacts of electricity transmission and distribution lines

The table below provides an overview of the positive and negative impacts of transmission and distribution lines on the local environment and economy and recommendations on how to minimise negative impacts and increase positive impacts. To minimise the negative impacts on the environment, it will be important to take the relevant maintenance and preventative measures.

Table 1-6 Impacts of transmission and distribution lines and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	C & O	Deforestation of areas where transmission and distribution lines are placed[38]	Proper maintenance of land with transmission and distribution lines underneath; avoid unnecessary cutting of trees
	O	Noise pollution from substations[39]	Reduce via construction and technical solutions
	O	Risk of spill of hazardous transformer oils & soil contamination[40]	Ensure proper maintenance and disposal of equipment
Environment & Social	O	Negative impact of electromagnetic fields on environment and human health[41]	Avoid impact on human life by imposing housing restrictions near high-voltage lines
Social	O	Visual impact of overhead lines	Avoid overhead lines in populated areas
Economic	C, O & D	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the T&D industry

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.6 Impacts of battery storage

The table below provides an overview of the positive and negative impacts of battery storage on the local environment and economy and recommendation on how to minimise negative impacts and increase positive impacts. To minimise the negative impacts on the environment, it will be important to take the relevant maintenance and preventative measures.

[37] Buonocore, J. et al (2016). Health and climate benefits of offshore wind facilities in the Mid-Atlantic United States. Available at: https://doi.org/10.1088/1748-9326/11/7/074019.
[38] https://www.energia.ee/c/document_library/get_file?uuid=e704c22c-c190-469b-9e3e-f2a9bf95b777&groupId=10187
[39] Eesti Energia (2009). Environmental Report. Available at: https://www.energia.ee/c/document_library/get_file?uuid=e704c22c-c190-469b-9e3e-f2a9bf95b777&groupId=10187
[40] idem
[41] idem

Notably, one of the largest environmental impacts of battery storage is the manufacturing of batteries, which requires large amounts of limitedly available raw materials.[42] However, as this is not related to the electricity sector per se, it is out of scope. Nonetheless, it is recommended that plans are drawn for the recycling of batteries reching end-of-life. Battery storage is expected to be installed in all regions, i.e. **Laane Eesti, Pohja Eesti, Kesk-Eesti, Louna Eesti and Kirde Eesti**. The impacts from disposal would be however associated with chones disposal sites.

Table 1-7 Impacts of battery storage and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	C	Significant excavation of raw materials for battery manufacturing[43]	Not applicable - out of scope as it is likely to happen outside of Estonia
	D	End-of-life battery waste[44]	Requirements for proper disposal/recycling of batteries at end of life.
Economic	C, O & D	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the energy storage industry
	O	Enable more RES generation by allowing for more flexibility in the electricity grid	Modernise the electricity grid with smart technologies to enhance the development of battery storage[45]

Legend: C = construction; O = operation, D = decommissioning; Positive impact; Negative impact

1.4.7 Impacts of use of biomass for energy purposes

The table below provides an overview of the positive and negative impacts of biomass use for energy purposes on the local environment and economy and recommendation on how to minimise negative impacts and increase positive impacts.

Table 1-8 Impacts of biomass energy and recommendations to minimise negative impacts and increase positive impacts

Type of impact	Time of impact	Impact	Recommendation
Environment	O	Deforestation - decrease of biodiversity, soil erosion, reduction of carbon sink[46]	Adequate regulation and management of the use of forest timber for energy; establish clear limits to biomass quantities that can be extracted
	O	May not be a climate-neutral or even climate positive option. Full emissions accounting over life-cycle suggestive that it has negative climate impacts.	
Social	O	Health benefits from reduced air pollution from fossil fuel use (e.g. reduction of respiratory diseases, heart attacks, death)[47]	Ensure that biomass is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)

[42] Dehghani-Sanij, A.R. (2019). Study of energy storage systems and environmental challenges of batteries. Available at: https://doi.org/10.1016/j.rser.2019.01.023
[43] Eesti Energia (2009). Environmental Report. Available at: https://www.energia.ee/c/document_library/get_file?uuid=e704c22c-c190-469b-9e3e-f2a9bf95b777&groupId=10187; https://acola.org/wp-content/uploads/2018/08/wp3-sustainability-evaluation-energy-storage-full-report.pdf
[44] Eesti Energia (2009). Environmental Report. Available at: https://www.energia.ee/c/document_library/get_file?uuid=e704c22c-c190-469b-9e3e-f2a9bf95b777&groupId=10187; https://acola.org/wp-content/uploads/2018/08/wp3-sustainability-evaluation-energy-storage-full-report.pdf
[45] Deloitte (n.d.). Challenges and opportunities of battery storage. Available at: https://www2.deloitte.com/nl/nl/pages/energy-resources-industrials/articles/challenges-and-opportunities-of-battery-storage.html
[46] Wu et al. (2018). Bioenergy production and environmental impact. Available at: https://doi.org/10.1186/s40562-018-0114-y
[47] Buonocore, J. et al (2016). Health and climate benefits of offshore wind facilities in the Mid-Atlantic United States. Available at: https://doi.org/10.1088/1748-9326/11/7/074019.

Type of impact	Time of impact	Impact	Recommendation
Economic	C & O	Increase in economic development and direct/indirect employment	Ensure that nationally there are enough highly skilled professionals in the bioenergy industry
	O	Using locally available biomass reduces fossil energy import dependency	Ensure that biomass is competitive with fossil fuel sources and viable solutions for grid balancing (e.g. batteries, hydrogen, demand side flexibility)
	O	Using biomass for energy purposes can have negative impact on its availability and price for using it for other purposes (as feedstock, for feed or food)	Adopt strict sustainability criteria to minimise negative impact on other industries

Legend: C = construction; O = operation; Positive impact; Negative impact

1.4.8 Other considerations

In addition to these specific recommendations for the different developments, in order to enhance the positive impacts of renewable energy, it is important to encourage the development of RES and ensure that RES are able to timely and substantially replace fossil fuel sources. This includes ensuring that administrative barriers to RES development are removed. Additionally, viable solutions to balance the grid (via battery storage, power-to-hydrogen, and/or demand-side flexibility) are important to ensure that the grid is able to handle high volumes of variable RES. By promoting RES, the local community will benefit from health benefits from less air pollution from fossil fuels as well as security of supply by reducing energy imports and dependence on fossil fuels. Additionally, improving energy efficiency (i.e. reducing energy demand by using electric heat pumps) in industry and the built environment would further decrease the dependence on fossil fuels.

2 Summary of key barriers for decarbonising the electricity system and related risks

2.1 Stakeholders inputs

Stakeholders have identified a number of barriers to the uptake of one or more pathways for decarbonising the Estonian electricity system– i.e., issues with the current setup that would prevent the pathway(s) from materialising. The actions and recommendations identified in Chapter 4 and onwards either directly address one or more of these barriers, or are outlined so to address the concern raised by stakeholders. Stakeholders were also asked to provide further written submission that could help us identify relevant actions, their cost and outcomes. No written submissions were received.

We offered the opportunity to speak to us to all those that were invited to the survey carried out as part of deliverable 5 (over 80 organisations). Further, some stakeholders were specifically reached out and asked for an interview. Details are provided in Table 2-1.

Table 2-1 stakeholders interviewed

Organisation	Representative	Details
Elering	Erkki Sapp	Did not respond to invitation
Power Industry Association	Tonis Vare	unavailable, suggested Kallemets instead
Renewables Association	Mihkel Annus	Interview held in January 2022
Association of Power Station and District Heating	Siim Umbleja	Did not respond to invitation
Wind Association	Terje Talv	Interview held in January 2022
Solar Association	Andres Meesak	Did not respond to invitation
Nuclear Energy interested company Fermi OÜ	Kalev Kallemets	Interview held in January 2022
Biofuels Association	Ülo Kask	Interview held in January 2022
Chamber of environmental organisations	Laura Uibopuu	Interview held in January 2022, including Johanna Maarja Tiik and Ingrid Nielsen (Estonian Nature Fund), Silver Sillak (Estonian Green Movement)
Sunly	Priit Lepasepp	Interview held in January 2022

Further discussions with Elering were held in May 2022.

2.1.1 *Government Strategy*

Several stakeholders brought up issues with the Government not yet providing a clear direction

- Unclear strategy at national level, with mixed messages concerning the trade-offs between nature conservation and renewable generation. Stakeholder told us that while the government had a sufficient strategy on paper, this has so far not been supported by appropriate actions or funding.
- While it may make sense to include in any pathway some actions to maintain nuclear energy as a potential option in the future, this may give the wrong message:
    - Stakeholders may consider that the government is not yet committed to its main strategy (e.g. whether or not CCU or nuclear energy will be part of it). This may increase the perceived political risks for renewable energy investments, as

stakeholders may fear that ambitious renewable energy policies will negatively affect the electricity market prices, as they will increasingly be determined by intermittent renewable electricity sources with low variable costs.
    - The public will also continue to receive a mixed message, which would further encourage NIMBY reactions. Other options to develop nuclear energy (e.g. close cooperation/agreements with Finland) should be considered.
- The optimal share of renewable energy to be integrated in the system should be more clearly defined by the government, as the current strategy is actually achieving the opposite result of what is desirable (the use of fossil fuel plants controlled by the SO as reserve capacity is discouraging any significant private investment in storage and flexibility).[48]

2.1.2 Electricity infrastructure planning process

The currently slow planning and approval process for renewable energy projects, in particular for wind and solar energy parks, has been identified by all stakeholders as the main barrier to the uptake of more renewable energy. Stakeholders identified the following causes:

- Lack of incentives for local administrations and communities to approve the installation of renewable energy infrastructure. They would suffer from loss of amenities (for example a less pristine landscape) but receive no benefits (see public opinion below);
- Limited capacity and skills of local administrators involved in the planning process;
- Limited capacity and skills in the supply chain. Currently there are a few bottlenecks in the process, related to the fact that in Estonia there is only a handful of experts able to carry out essential steps for an installation, such as proper environmental impact assessments or spatial planning. This has three main consequences:
    - Developers have to wait for their availability to progress with a project, and this often means months of delay as the experts are overbooked;
    - Developers face substantially high costs, as the fees of the professionals reflect the high demand for their services
    - The work carried out is often not sufficiently robust (presumably due to time and cost constraints); for example, instead of carrying out a site-specific impact assessment, an assessment made for a similar project is adapted to the new site. Consequently, opponents of the project are able to exploit the weaknesses in the application and delay or block the approval process.

2.1.3 Public opinion

Barriers related to public opinion are primarily associated with the infrastructure planning process:

- NIMBYism tends to be one of the main barriers to the development of renewable electricity infrastructure. The current planning and appeal process is often ‘abused’ by individuals or small groups, which are generally driven by the perceived negative impact on the quality of their neighbourhood. The debate about the protection of landscapes, birds and natural

[48] Currently, the TSO is in charge of procuring flexibility services to the Estonian electricity system. To this end, the TSO owns and operates backup capacity (two power plants) that is used according to criteria set by the TSO itself. This prevents the existence of proper price signals that would incentivize private investments in back-up capacity; the current approach hinders private operators to offer this service (as they would be able to sell flexibility services only after the reserve capacity has been exhausted). There are also indications that the TSO-owned backup capacity would be used too frequently, which is artificially affecting the wholesale price. Most other MSs have opted for a market mechanism to provide balancing and reserve energy and capacity to the TSO. Introducing a similar system in Estonia would allow all relevant market parties (including power producers, storage operators and demand response) to provide such services to the TSO at a price set by the market.

habitats is often exaggerated, and some individuals tend to view the issue rather 'emotionally', and do not properly take into account the positive impacts of investments in energy infrastructure, both in economic (local employment, reduced energy import dependence) and in environmental terms, e.g. by reduced GHG and other (Nox, SO_2,…) emissions. Stakeholders campaigning for environmental protection (Estonian Nature Fund, Estonian Green Movement) are aware of this issue, and believe the underlying problem is the lack of proper communication and correct information available to citizens.

- While there is evidence that a majority of the population may be in favour deploying nuclear energy[49], opponents tend to be very vocal. If the nuclear pathway is chosen, or if further actions are planned to ensure that nuclear energy remains as an option in the future, the lack of overall public acceptance may hinder the implementation of the programme.
- The costs associated with some technologies may be too high. Once consumers/taxpayers become aware of the cost implications of pursuing some pathways (e.g. the CCU pathway; pathways linked to substantial offshore development; pathways that rely on synthetic fuels; Power-to-X solutions) the public support for the government strategy may fade.

2.1.4 Financing and investment decision

The availability of funding to invest in low carbon generation technologies does not appear to be a problem – stakeholders indicated many developers are ready to invest in energy projects or are able to access institutional funding (banks) or private foreign capital.

However, lenders often require guarantees of sufficient income during the contract period – i.e. they are not willing to fund projects fully exposed to market risks (as the market price may be too low to ensure capital repayment). While the current electricity price levels may be high enough to properly cover the CAPEX and OPEX for most RES projects, the future development of electricity prices is highly uncertain. As the electricity price is mainly determined by the marginal cost, an increased penetration of intermittent renewable energy sources will in principle lead to a lower average price. Project developers have hence a relatively high certainty that the variable costs of their power generation (and storage) assets will be covered by the market prices, but the recovery of their fixed costs is uncertain. This risk can also materialise independently of the Estonian energy policy and strategy, e.g. because of a substantial increase in wind/solar power generation in nearby markets, for example because of subsidies provided by other Baltic or Nordic governments.

If developers risks are reduced, for example via a price floor, there is a high number of projects ready to take investment decision. Considering the average wholesale prices recorded in the last few years, they are not expected to require high subsidy amounts.

Financing less established technologies, such as nuclear energy or CCU, will have different challenges. Stakeholders could not provide more details concerning CCU, but for nuclear energy their view was that subsidies would not be needed, but risk reduction is essential. Given the long payback period of nuclear power plants, risk reduction instruments will also have to be long term to ensure investors are ready to commit. The key barrier is, in fact, political rather than strictly financial. Investors worry that the government:

[49] According to a survey commissioned by the Nuclear Energy Association

- may change strategy and abandon nuclear energy (meaning they would not recover their investment);
- may decide to clamp down on profits (once investment costs are recovered, nuclear energy tends to be a highly-profitable energy generation source);
- may subsidise the deployment of a too high share of renewable energy sources with low variable cost (wind and solar energy), which would erode the economic case for nuclear energy by depressing wholesale prices.

Finally, there is a clear link between the length of the infrastructure planning process and the perceived institutional risk associated with some investments. Given that even bringing a project to the point where construction can start involves substantial investments (e.g. feasibility study, permitting procedure), financing the pre-construction phase is often a key barrier for developers.

2.1.5 Other barriers

Stakeholders also provided an indication of other pathway/technology specific barriers:

- Lack of suitable commercial-scale technologies for nuclear energy and CCU;
- Lack of a nuclear regulator and nuclear expertise in Estonia;
- Delays with the Estonian Maritime Spatial Plan.

3 Summary of pathways' results

The section reports the results for the seven different pathways in 2030, 2040 and 2050. The pathways are defined in Table 3-1. The following results are shown for each pathway: electricity and storage capacity, electricity generation, average prices and CO_2 emissions.

Table 3-1 Climate-neutral pathways assessed[50]

Pathway		Description
Baseline	Reference	Business as usual scenario
Technology-focused	Renewable electricity + Storage (RES + Storage)	Evaluates a large deployment of offshore wind in Estonia (1 GW by 2030, 2 GW by 2035, 3 GW by 2040, and a total of 4 GW by 2050)
	Nuclear	Simulates climate-neutral electricity production in Estonia given an addition of 900 MW of Generation III+ small modular nuclear capacity by 2040
	CCU	Explores the impacts of adding carbon capture to two large oil shale generators in Estonia
	Renewable gas (RES GAS)	Assumes implementation of 1 GW of new biogas generation by 2030
Technology competition	All technologies (AT)	The least constrained climate-neutral pathway explored, which allows for the model to endogenously invest in any electricity generation technology based on least-cost optimisation
	AT-NIMP (AT-NIMP)	Supplements the *All technologies* pathway by requiring that Estonia's electricity imports and exports should approximately offset each other
	1000 MW dispatchable capacity (AT+1000)	Reassesses the *All technologies* pathway by applying the constraint that Estonia must have at least 1000 MW of readily dispatchable electricity production capacity at all times

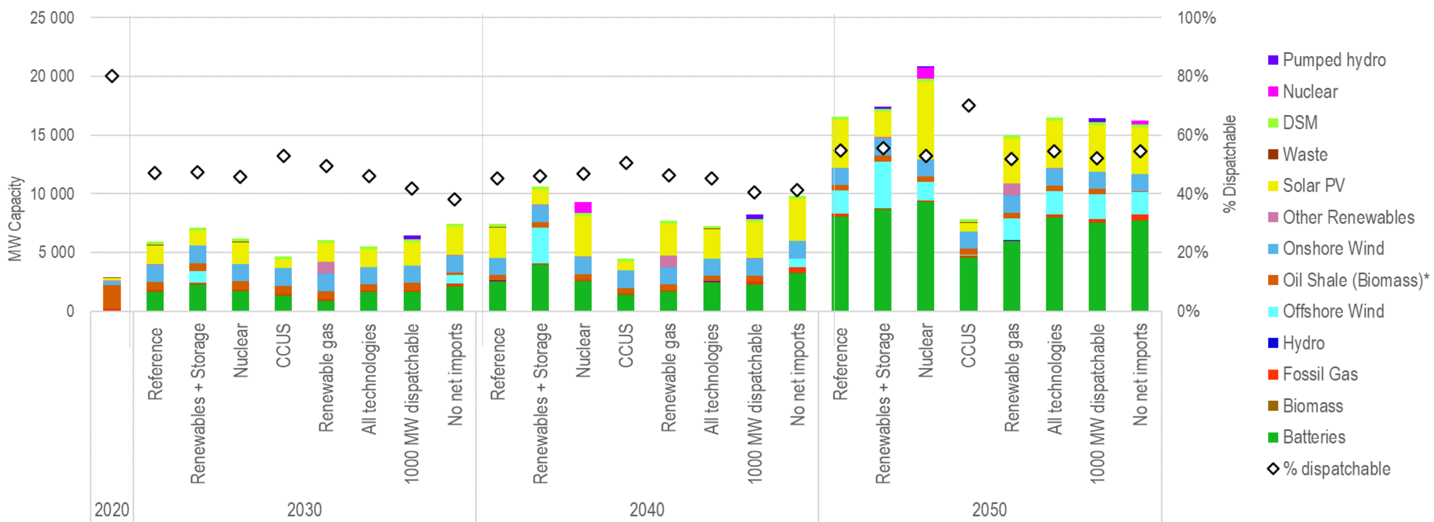
3.1 Development of technology mix

3.1.1 Summary of electricity generation and storage capacity and output per pathway

Overall, installed power generation and storage capacity increases from 2020 to 2050 for all pathways, though the installed capacity is greatest in 2050 for the *Nuclear* and *RES + Storage* pathways and the least for the *CCU* pathway (see Figure 3-1). For most of these pathways, the increase in capacity is mainly driven by an increased capacity of batteries (for storage) as well as solar PV and wind power. In 2050, the capacity of offshore wind energy increases for all pathways except the *CCU* pathway. For the *Nuclear* and *AT-NIMP* pathways, the introduction of nuclear energy capacity plays a small role. For all the pathways, over half of the electricity generation and storage capacity is dispatchable by 2050.

[50] All pathways presented in this chapter include the alternative wind availability curves modelled in Deliverable 6 of this work, as sensitivity 1 (S1), these represent a more volatile, and expected to be, more realistic scenario of wind power generation.

Figure 3-1 Comparison of installed capacity and percent dispatchable for all pathways by technology, 2020-2050, MW[51]



Note: After 2030, oil shale plants are converted to run on biomass in all pathways except CCU. In CCU, the oil shale plants continue to use oil shale as a fuel.

Table 3-2 Main increases in deployed electricity generation and storage capacity for all pathways to 2050, GW[52]

Pathways	Years	Batteries	Offshore wind	Onshore wind	Solar PV	Other technologies
RES + Storage	2020-2030	+2.2	+1.0	+1.2	+1.0	Fossil gas: -0.1 GW
	2031-2040	+1.7	+2.0			Fossil gas: -0.05 GW
	2041-2050	+4.6	+1.0		+0.8	Biomass: +0.02 GW Pumped hydro: +0.2 GW Other RES: +0.1 GW
Nuclear	2020-2030	+1.7			+1.6	Fossil gas: (=RES+S)
	2031-2040	+0.9		(=RES+S)	+1.6	Nuclear: +0.9 GW Fossil gas: (=RES+S)
	2041-2050	+6.7	+1.6		+3.1	Pumped hydro: +0.2 GW
CCU	2020-2030	+1.3			+0.5	Fossil gas: (=RES+S)
	2031-2040	<0.1		(=RES+S)		Fossil gas: (=RES+S)
	2041-2050	+3.2	+0.1			
RES GAS	2020-2030	+0.9			+1.3	Other RES: +1 GW Fossil gas: (=RES+S)
	2031-2040	+0.8		(=RES+S)	+1.1	Fossil gas: (=RES+S)
	2041-2050	+4.2	+1.9		+1.2	
AT	2020-2030	+1.6			+1.3	Fossil gas: -0.1 GW
	2031-2040	+0.8		(=RES+S)	+1.0	Fossil gas: -0.05 GW
	2041-2050	+5.6	+2.0		+1.6	Fossil gas: +0.1 GW
AT-NIMP	2020-2030	+2.1	+0.7		+2.2	Fossil gas: -0.01 GW
	2031-2040	+1.2		(=RES+S)	+1.2	Fossil gas: +0.2 GW
	2041-2050	+4.5	+1.2		+0.4	Nuclear: +0.3 GW
AT+1000	2020-2030	+1.6			+1.7	Pumped hydro: +0.3 GW Fossil gas: -0.1 GW
	2031-2040	+0.6		(=RES+S)	+1.1	Fossil gas: +1.2 GW
	2041-2050	+5.3	+2.1		+0.9	

**Note: Other technology developments: Capacity for hydro and waste based power generation do not change; DSM: +0.26 GW in 2030 for all pathways; Oil shale development is not shown, in all but the AT-NIMP pathway (where*

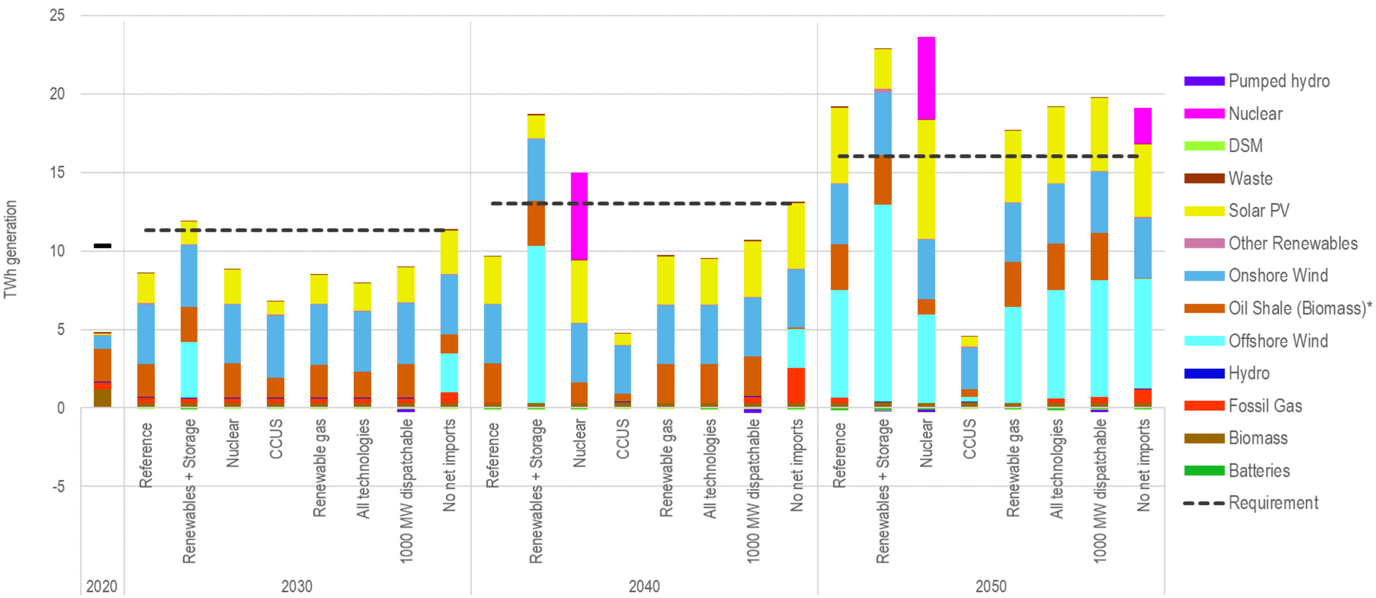
[51] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

[52] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

capacity is reduced to 10MW) a remaining 476MW of capacity is maintained in 2050, this capacity burns biomass (except in CCU where oil shale continues to be used, with carbon capture),
***Legend: ≥ 1 GW*

The *RES + Storage* and *AT-NIMP* pathways are the only pathways that have generation that meets net domestic electricity requirements in 2030, 2040 and 2050, whilst the *Nuclear* pathway meets these requirements in 2040 and 2050. The rest of the pathways, with the exception of the *CCU* pathway, eventually meet the requirements by 2050 (Figure 3-2). In all pathways, the major component of electricity generation in 2030 is the increased generation from onshore wind energy, as well as solar PV. For the *RES + Storage* and *AT-NIMP* pathways, offshore wind electricity generation also plays a key role in 2030. By 2050, the main driver for increased electricity generation is a significant increase in offshore wind power. This is the case for all pathways, except for the *CCU* pathway. For the *Nuclear* and, to a lesser extent the *AT-NIMP*, pathways, nuclear also plays an important role in increasing electricity generated from 2040 onwards.

Figure 3-2 Comparison of net electricity generated for all pathways, 2020-2050, TWh[53]



Note: After 2030 oil shale plants are converted to run on biomass in all pathways except CCU. In CCU the oil shale plants continue to use oil shale as a fuel.

Table 3-3 Main increases in electricity generation and storage for all pathways to 2050, TWh[54]

Pathways	Years	Batteries	Offshore wind	Onshore wind	Solar PV	Other technologies
RES + Storage	2020-2030	-0.05	+3.54	+3.12	+1.32	Fossil gas: -0.12 TWh Other RES: +0.03 TWh
	2031-2040	-0.04	+6.46		+0.03	Fossil gas: -0.32 TWh
	2041-2050	-0.04	+2.55	+0.05	+1.03	Biomass: +0.07 TWh Fossil gas: +0.01 TWh Other RES: +0.19 TWh Pumped hydro: -0.07 TWh
Nuclear	2020-2030	-0.04		+2.92	+2.04	Other RES: (=RES+S) Fossil gas: -0.14 TWh
	2031-2040	-0.01		-0.01	+1.80	Nuclear: +5.52 TWh Fossil gas: -0.31 TWh

[53] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[54] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Pathways	Years	Batteries	Offshore wind	Onshore wind	Solar PV	Other technologies
	2041-2050	-0.06	+5.59	+0.06	+3.59	Nuclear: -0.29 TWh Pumped hydro: -0.11 TWh Fossil gas: +0.01 TWh
CCU	2020-2030	-0.04		+3.12	+0.71	Other RES: (=RES+S) Fossil gas: -0.14 TWh
	2031-2040	0.03		-0.87	-0.15	Fossil gas: -0.29 TWh
	2041-2050	0.00	+0.32	-0.43	-0.04	Fossil gas: -0.02 TWh
RES GAS	2020-2030	-0.03		+3.01	+1.71	Other RES: (=RES+S) Fossil gas: -0.14 TWh
	2031-2040	-0.02		-0.10	+1.23	Fossil gas: -0.3 TWh
	2041-2050	-0.04	+6.08	+0.02	+1.49	
AT	2020-2030	-0.04		+3.00	+1.63	Other RES: (=RES+S) Fossil gas: -0.14 TWh
	2031-2040	-0.01		-0.09	+1.17	Fossil gas: -0.30 TWh
	2041-2050	-0.05	+6.88	+0.09	+1.89	Fossil gas: +0.30 TWh
AT-NIMP	2020-2030	-0.05	+2.45	+2.96	+2.65	Other RES: (=RES+S) Fossil gas: -0.13 TWh
	2031-2040	-0.01	0.01	-0.06	+1.41	Fossil gas: +0.09 TWh
	2041-2050	-0.04	+4.55	+0.10	+0.44	Nuclear: +2.29 TWh Fossil gas: -0.01 TWh
AT+1000	2020-2030	(=AT)		+3.02	+2.13	Other RES: (=RES+S) Pumped hydro: -0.22 TWh Fossil gas: +0.14 TWh
	2031-2040			-0.12	+1.31	Pumped hydro: -0.01 TWh
	2041-2050		+7.42	0.16	+1.12	Pumped hydro: +0.06 TWh

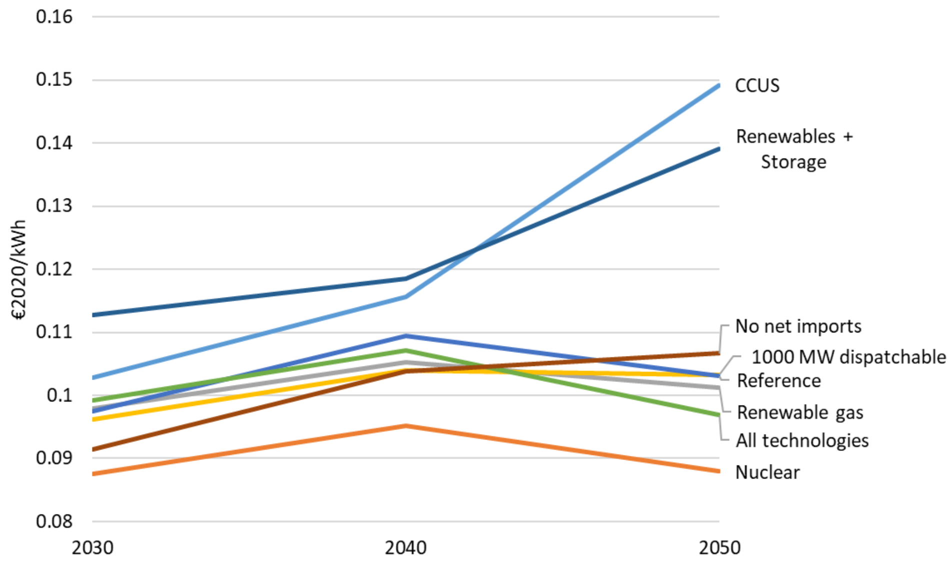
**Note: No change in generation from hydro power; Biomass: -0.9 TWh in 2030 for all pathways; Waste: +0.01 TWh in 2030 for all pathways; DSM: -0.03 TWh in 2030 for all pathways; Oil shale development is not shown, however in all but the Nuclear (1 TWh) and AT-NIMP (0.05 TWh) pathways it provides around 3 TWh of generation each year, fuelled by biomass in all pathways except CCU where oil shale continues to be used.*
***Legend: ≥ 1 TWh*

3.1.2 Summary of average electricity prices per pathway

The modelling of the pathways calculated a weighted average levelized cost of electricity for the total pathway, including investments in key transmission and distribution infrastructure. The modelling did not calculate estimated wholesale or retail prices but the prices could give an indication of wholesale market prices, and the changes compared to the reference level provide an indication of how these vary per pathway. The *CCU* and *RES + Storage* pathways have the highest average electricity prices, while the *Nuclear* pathway has lowest average electricity prices (Figure 3-3). For all pathways, the average price of electricity rises from 2030 to 2040. In 2050, the price further increases for the *CCU*, *RES + Storage* and the *AT-NIMP* pathways. For the other pathways, the price slightly decreases from 2040 to 2050. Namely, along with the *Nuclear* pathway, the average price for the *RES GAS*, *AT* and *AT+1000 MW* pathways are lower than the price for the *Reference* pathway.

The sensitivity analysis of Deliverable 6 showed that for the Nuclear pathway enforcing a high load factor for nuclear (e.g. 90%) can have a significantly detrimental effect on the price of the pathway, making it one of the most expensive. For RES-storage, the price of the pathway increased significantly with the increase in wind volatility, if this volatility is able to be reduced (through technological or other solutions) then prices could be significantly lower than estimated.

Figure 3-3 Comparison of average electricity prices for all pathways, 2030-2050, €2020/kWh[55]



3.1.3 *Summary of indicators relevant for energy security*

The volume and type of power capacity and generation can inform on the security of supply for each pathway. In the first instance analysis of the share of the power supply that is dispatchable (essentially all capacity except hydro, solar and wind power) provides insight into the volume of demand that could be met domestically and in a short timeframe. The dispatchability % are presented in Table 3-4 and Table 3-5. The first table shows that in each of the pathways dispatchable capacity as a % of total capacity in 2030 decreases from 2020 levels, to around 38-53% of total capacity. In most pathways there is a small increase to a level of around 55% of total capacity by 2050, driven mainly by increasing battery capacity matching or outpacing renewable energy capacity growth. It also shows that dispatchable capacity exceeds the peak power requirement in every period and pathway, except for CCU in 2040. However, it should be noted, that if batteries and DSM are excluded from dispatchable capacity, on the basis that this storage is only short term, then total dispatchable capacity is a much lower percentage of the total capacity, i.e. 7-31% in 2030, 5-11% in 2050. Whilst these % relative to total capacity are quite low, as a percentage of peak capacity demand the values are higher, i.e. 23-86% in 2030, 21-52% in 2050. Overall, the RES-GAS and Nuclear pathways provide the highest coverage by these measures.

The second table compares the pathways on the extent to which their total annual generation compares to the annual domestic power requirement. In 2020 there is a significant deficiency in this, leading to major imports. However, apart from CCU where generation does not keep pace with increased demand, all pathways provide a higher share of demand from domestic generation. In the case of RES-STORAGE and AT-NIMP these pathways already match (or produce more) annual domestic production and consumption by 2030, the nuclear pathway does this by 2040, and the other pathways except CCU all do so by 2050, at which time all pathways are net annual exporters. It should be noted that in these cases there can still be short term needs for imports to meet needs, however over the average year the balance can be as modelled. Indeed, integration in the broader regional power network and use of imports is one of the main strategies to deal with prolonged periods of low RES production.

[55] Source: data from Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 3-4 Dispatchable % of electricity generation capacity, MW and % of total

	2020 (Peak power requirement: 2 007 MW)		2030 (Peak power requirement: 2 197 MW)		2040 (Peak power requirement: 2 537 MW)		2050 (Peak power requirement: 3 118 MW)	
	MW	%	Dispatchable MW S1 (AltWind)	Dispatchable as % of total S1 (AltWind) %	Dispatchable MW S1 (AltWind)	Dispatchable as % of total S1 (AltWind) %	Dispatchable MW S1 (AltWind)	Dispatchable as % of total S1 (AltWind) %
Reference	2 282	80%	2 791	47%	3 364	45%	9 077	55%
RES + Storage	2 282	80%	3 382	48%	4 873	46%	9 844	56%
Nuclear	2 282	80%	2 823	46%	4 348	47%	11 255	54%
CCU	2 282	80%	2 476	53%	2 272	51%	5 486	70%
RES-gas	2 282	80%	3 006	50%	3 563	46%	7 799	52%
AT	2 282	80%	2 561	46%	3 303	45%	9 007	55%
AT+1000 MW	2 282	80%	3 053	47%	3 667	45%	8 948	54%
AT-NIMP	2 282	80%	2 848	38%	4 071	41%	8 822	54%

Table 3-5 % of domestic power requirement met by domestic electricity generation, S1 (AltWind) all pathways

	2020 (Total domestic requirement: 10.3 TWh)		2030 (Total domestic requirement: 11.3 TWh)		2040 (Total domestic requirement: 13.0 TWh)		2050 (Total domestic requirement: 16.0 TWh)	
	TWh domestic generation	% of total requirement	S1 (AltWind) TWh domestic generation	S1 (AltWind) % of total requirement	S1 (AltWind) TWh domestic generation	S1 (AltWind) % of total requirement	S1 (AltWind) TWh domestic generation	S1 (AltWind) % of total requirement
Reference	4.8	47%	8.5	76%	9.6	74%	19.1	119%
RES + Storage	4.8	47%	11.8	105%	18.6	143%	22.8	142%
Nuclear	4.8	47%	8.8	78%	14.9	114%	23.5	147%
CCU	4.8	47%	6.8	60%	4.8	37%	4.6	29%
RES-gas	4.8	47%	8.5	75%	9.7	74%	17.6	110%
AT	4.8	47%	7.9	70%	9.5	73%	19.1	119%
AT+1000 MW	4.8	47%	9.0	80%	10.7	80%	19.7	123%
AT-NIMP	4.8	47%	11.3	100%	13.0	100%	19.0	119%

3.2 Power-to-X assumptions

As part of the analysis to define electricity demand, the energy system modelling assumes that an economically feasible level of Power-to-X is deployed in Estonia. This has an increasingly significant effect on total demand in the reference scenario, as electric heating, electric transport, and hydrogen demand raise electricity production requirements in Estonia by more than 50% by 2050 (when production totals 16 TWh). The growth in electricity demand is nonlinear as adoption of Power-to-X technologies accelerates in the later years of the projection. By 2050, electric vehicles and heating add about 2 TWh to electricity demand compared to the BAU, while hydrogen production adds almost 4 TWh. The Power-to-X demands in 2050 account for 46% of the total projected electricity supply requirements in that year (Table 3-6). Similar deployment levels are foreseen in all pathways.

Table 3-6: Power-to-X and total electricity supply requirements in Estonia

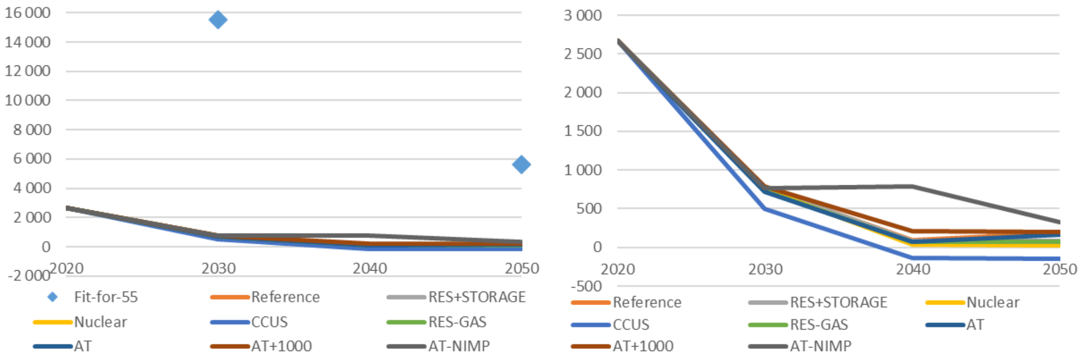
Electricity supply requirements	Unit	2020	2030	2040	2050
Total electricity supply requirements					
BAU	TWh	10.3	10.2	9.8	10
Reference scenario	TWh	10.3	11.3	13	16
Power-to-X requirements in the Reference scenario					
Total Power-to-X requirements	TWh	0.7	2.1	4.3	7.4
Hydrogen production	TWh	0	1	2.5	4.1
Electric vehicles	TWh	0.01	0.1	0.2	0.8
Electric heating	TWh	0.7	1.1	1.7	2.5
% of total Reference scenario requirements					
Power-to-X	%	7%	19%	33%	46%
Hydrogen production	%	0%	9%	19%	26%
Electric vehicles	%	0%	1%	2%	5%
Electric heating	%	7%	10%	13%	16%

3.3 CO_2-emissions trajectory mapped against Fit-for-55

Direct GHG emissions are for all of the pathways significantly below the Fit-for-55 trajectory, with the lowest emissions achieved by the CCU pathway (Figure 3-4). This is unsurprising for a few reasons, especially that (1) emissions for the power (and heat sector) in the 1990 reference year for Estonia were much higher and reduced by more than 75% already by 2019. It is also clear that the power sector is typically expected to do more than other sectors in achieving emissions reductions, as other sectors are harder to decarbonise, therefore achieving high emissions reductions is necessary.

For all pathways, emissions are significantly reduced from 2020 to 2030 and continue to decline below or almost to zero by 2050. The pathway with the highest emissions is the *AT-NIMP* pathway. By 2040, the *CCU* pathway achieves negative emissions. As noted in Deliverable 3, all pathways are effectively carbon neutral by 2050 as direct emissions capture is assumed to be used (costs are accounted in prices) to offset any remaining emissions.

Figure 3-4 Comparison of GHG emissions for all pathways, 2020-2050, ktCO₂e (left with Fit-for-55 trajectory; right without the Fit-for-55 trajectory)[56]



3.4 Expected land use related with renewable electricity installations

The expected land use is tied almost exclusively to onshore wind energy development as the land use footprint of other technologies is either negligible or offshore. In every pathway the model elects to build an additional 1,150 MW of onshore wind energy capacity by 2030. This capacity does not grow post-2030 due to land-use and other constraints, i.e. the model builds onshore wind energy to the maximum allowed as it is one of the cheapest renewable energy technologies. The model distributes the additional capacity as follows: Laane Eesti 850 MW; Pohja Eesti, Kesk Esti and Kirde Eesti each 100 MW, Louna Eesti, no additional wind capacity added. Using multiplication factors also used by IRENA[57] an estimated land use of around 230-460 km^2 (or less than 1% of the total land area in Estonia) would be required to accommodate this wind capacity, it should be noted that from this total only around 1% or less of the land would actually be used for the turbines, with the remainder of the land typically retaining its original character and use.

In addition to the onshore wind capacity, all offshore wind capacity is modelled to be added in proximity to Laane Eesti.

For solar power, it is likely that a large part of the increased capacity will be rooftop installations with minimal impact on land use. Using an estimation, based on US examples, of approximately 4 ha of land being needed for each MW of solar PV installed, and a ratio of 50:50 between rooftop and land-based installations, an additional 3.5-4 GW of solar PV by 2050 will require an estimated 450-500 hectares (or 4.5-5 km^2). The land use in the *RES + Storage* and *CCU* pathways is much lower as solar PV additions are much lower, whilst land use is almost double in the *Nuclear* pathway which installs much more solar PV than the other pathways.

In terms of biomass and land use, the model foresees an increase in overall power generation from biomass (see following section 3.5 for further details).

[56] Source: data from Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[57] See IRENA (2019) Future of Wind, which estimates 2.5-5MW of wind can be installed per square km

3.5 Biomass use

Within the model, biomass is used both in dedicated biomass plants and in oil shale plants, converted to biomass at some point in the 2030s. Dedicated biomass plants have limited total capacity in the base year, and their generation is small and declines after 2020 (1.2 TWh -> 0.3 TWh) in almost every pathway. However, post-2030, all oil shale plants will switch to biomass (except in the CCU pathway) and the generation from these plants increases by varying amount according to the scenario. The only pathways with limited biomass generation from oil shale plants are the AT–NIMP (No net imports) and the CCU pathways. Overall, in four out of seven scenarios total generation from biomass will increase (more than double), in two scenarios it will decrease compared to 2020, and in the nuclear scenario it will increase by 2040 but then by 2050 drop back to roughly the level it was in 2020 (Table 3-7).

Table 3-7 Generation from biomass across scenarios (TWh)[58]

Pathway	Dedicated biomass plants generation			Oil shale generation from biomass			Other renewables (biogas)			Total		
	2020	2040	2050	2020	2040	2050	2020	2040	2050	2020	2040	2050
Renewable electricity + Storage	1.20	0.30	0.37	0	2.83	3.15	0.03	0.06	0.25	1.23	3.19	3.76
Nuclear	1.20	0.30	0.30	0	1.30	0.99	0.03	0.06	0.06	1.23	1.66	1.35
CCU	1.20	0.37	0.37	0	0.00	0.00	0.03	0.06	0.06	1.23	0.43	0.43
Renewable gas	1.20	0.30	0.30	0	2.48	2.88	0.03	0.06	0.06	1.23	2.84	3.24
All technologies	1.20	0.30	0.30	0	2.47	2.95	0.03	0.06	0.06	1.23	2.83	3.31
1000 MW dispatchable capacity	1.20	0.30	0.30	0	2.55	2.99	0.03	0.06	0.06	1.23	2.91	3.35
AT-NIMP	1.20	0.30	0.30	0	0.08	0.05	0.03	0.06	0.06	1.23	0.44	0.41

It is important to consider that biomass conversion will have to comply with the Renewable Energy Directive (Directive (EU) 2018/2001 (recast), currently being revised)[59], which imposes strict conversion efficiency limits and requires projects to include heat recovery (Combined Heat and Power), with limited exceptions. Therefore, for an equal amount of electricity generation, fewer biomass quantities will be required in 2040 and 2050 compared to 2020. This is important, as given the conversion efficiency of the fuel to electricity, substantially more biomass (by energy content) would otherwise be needed, e.g. around 8-8.5 TWh in the highest pathways. As noted in Deliverable 3, the use of this volume would equate to around 3 million cubic meters of wood, or around 30% of the national harvest. This is a substantial volume, and would lead to increased competition for fuel for heating and/or export, and may expand pressures for woodland exploitation or require imports., Therefore improved conversion efficiency and other criteria resulting from RED revisions would mean that these increases of biomass use in electricity generation could come from the share of biomass that would otherwise be used in the heat sector alone. For this reason, whilst still important, biomass use is not considered a key criteria when comparing the environmental performance of the different pathways.

[58] Modelling data
[59] https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

3.6 Investment needs

As shown in Figure 3-5, the investment needs (in power generation and storage only, grid infrastructure is addressed below in Chapter 3.8) can vary considerably per pathway. On the overall, the highest investment needs are in both the 2021-2030 and 2041-2050 periods, with a hiatus in high investment needs in most pathways between 2031-2040.

In the 2021-2030 period, three investment needs are broadly common across all pathways, namely (1) a need to invest in batteries totalling between €170 million to €440 million across the pathways; (2) a need to invest in solar PV in all (except the *CCU*) pathways of between €170 million to €540 million; and (3) a need to invest in onshore wind of €1,264 million, consistent across all scenarios. It is notable that no additional onshore wind capacity is added after 2030, this results from the spatial limits placed in the model, but shows that in every pathway onshore wind is exploited to the fullest at the earliest opportunity. Where there are possibilities to expand onshore wind potential, these will be beneficial in all pathways.

In the same period, the main variations between pathways result from the difference in investment needs.

(i) In the *RES + Storage* and *AT-NIMP* pathways, investments of €2,040 million and €1,481 million respectively are required in offshore wind;
(ii) In the *CCU* pathway, a €978 million investment in CCS for oil shale are required;
(iii) In the *AT + 1000* pathway, a €368 million investment in pumped hydro are required;
(iv) In the *RES GAS* pathway a €2,635 million investment in biogas (other renewables) are required.

The investments in offshore wind and biogas mean the *RES + Storage*, *RES GAS* and *AT-NIMP* pathways have the highest investment needs up to 2030.

Between 2031-2040 the *RES + Storage* pathway requires €3,826 million investments to build 2 GW offshore wind, and the *Nuclear* pathway requires €2,329 million to build a 900 MW nuclear plant. Investments in solar PV continue in almost all pathways.

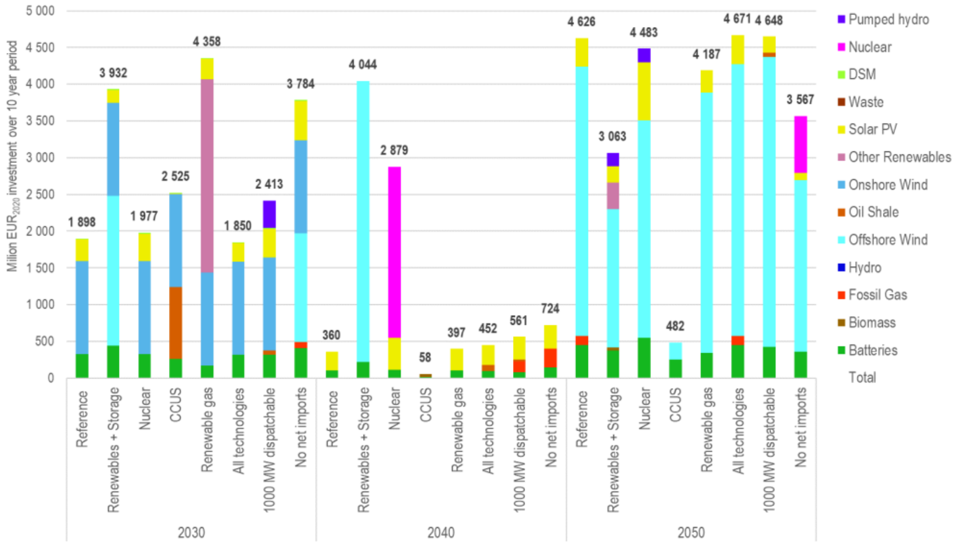
In the 2041-2050 period, investment needs increase to more than €3,000 million in all (except the *CCU*) pathways. Every pathway builds significant offshore wind capacity, requiring between €1,880 million (*RES + Storage*) to €3,947 million (AT) of investment. Other notable investment needs in the 2041-2050 period include:

(i) a €363 million investment in biogas (other renewables) in the RES + Storage pathway;
(ii) a €776 million investment in a 300 MW nuclear plant in the AT-NIMP pathway; and
(iii) a €184 million investment in pumped storage in both the RES + Storage and Nuclear pathways.

Overall, in this period the *RES + Storage* pathway requires the lowest investment (excluding CCU), partially balancing out high earlier investments. However, as shown in Table 3-8, it requires the highest total investment over time, totalling just over €11 billion or approximately €370 million annually for the next 30 years. This compares to estimates of average investments in new power generation of around €100 million per year in the period 2008-2018[60]. The other pathways (with the exception of CCU) require between €6.9 billion to €9.3 billion investments in the same period or between €230 million to €310 million annually. Therefore, investments in power generation will need to double or triple compared to recent levels.

Due to the importance of batteries in all pathways, especially RES+Storage, and the large potential uncertainties in their cost reduction trajectory, a sensitivity analysis of their costs was carried out in Deliverable 6. This found, in the context of the RES-Storage pathway, that an increase in battery capital costs of x2.5, did contribute to an increase in investment costs, in which case the total cost of the pathway increased, but also that the additional battery and solar PV capacity decreased to lead to a relatively small increase in total investments (11 billion increasing to 12 billion).

Figure 3-5 Investment needs per pathway, cumulative investment needs for 10-year intervals, million EUR_{2020}[61]



Source: Own calculations based on modelling
Note: the investment needs are for the 10-year period prior to the year, i.e. 2030 is the cumulative total for 2021-2030, 2040 for 2031-2040, 2050 for 2041-2050.

Table 3-8 Total investment needs per pathway (excluding interest payments), million EUR_{2020}[62]

	2021-2030	2031-2040	2041-2050	Total	Average annual
Reference	1,898	360	4,626	6,884	229
Renewable electricity + Storage	3,932	4,044	3,063	11,040	368
Nuclear	1,977	2,879	4,483	9,338	311
CCU	2,525	58	482	3,065	102
Renewable gas	4,358	397	4,187	8,942	298
All technologies	1,850	452	4,671	6,972	232
1000 MW dispatchable	2,413	561	4,648	7,623	254
AT-NIMP	3,784	724	3,567	8,075	269

[60] Trinomics et al (2020) Energy costs, taxes and the impact of government interventions on investments. Final report – energy investments
[61] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[62] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

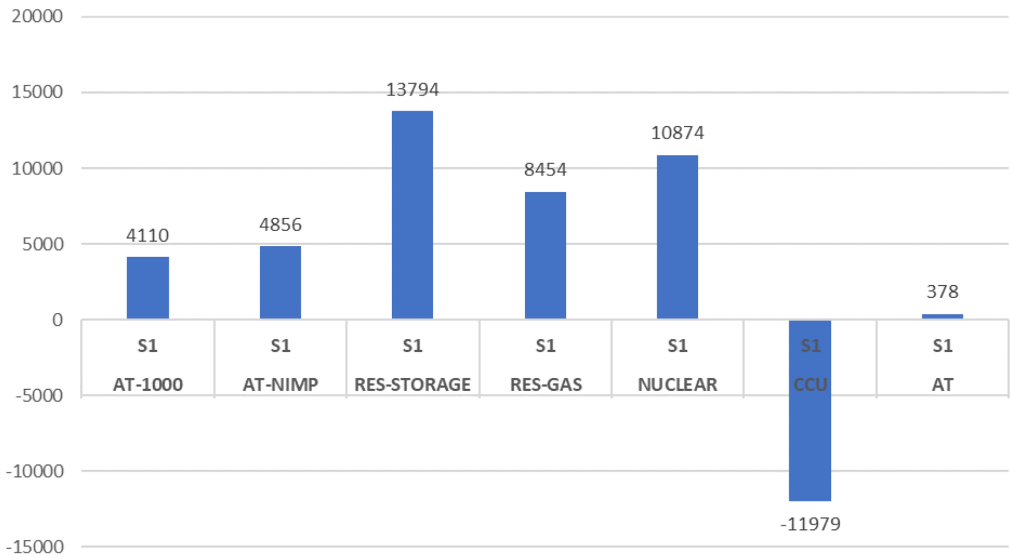
3.7 Socio-economic impacts

The socio-economic impacts of the pathways were fully analysed in Deliverables 4 and 6 of this work, these showed that by the main parameters the *AT-NIMP*, *RES GAS*, *RES + Storage* and *Nuclear* pathways offer the most positive socio-economic outcomes. A summary of the main results is presented below, pathway specific results are described in the following chapters.

Economic impact

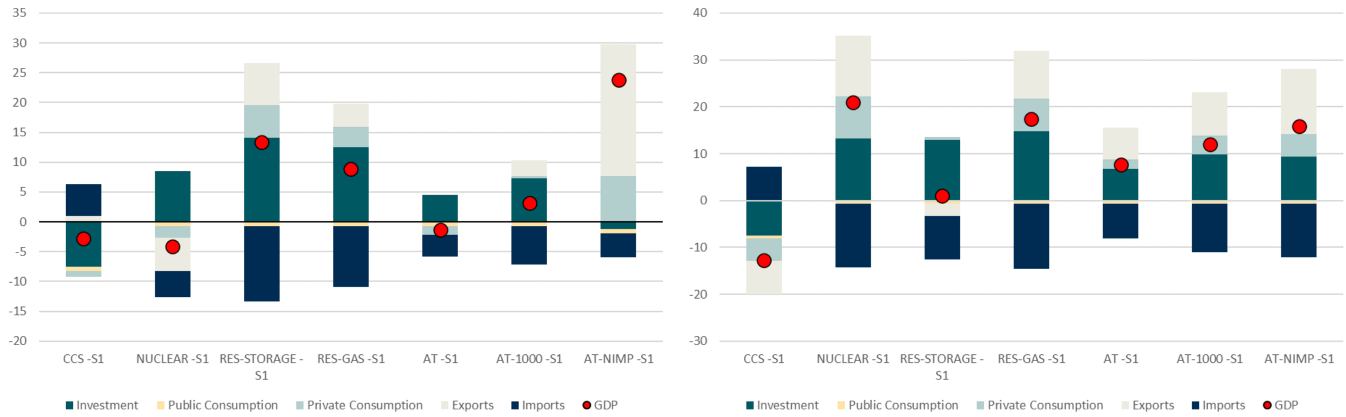
Economic impacts were modelled using both dynamic and static economic modelling approaches. Under static approaches, assuming financing of the pathways using loans (external rather than domestic debt finance) the *RES + Storage* pathway had by far the most positive impacts on economic output, followed by the Nuclear *and RES GAS* pathways (see Figure 3-6). The main results of the dynamic modelling, see Figure 3-7, showed that from the initial investments the AT-NIMP, *RES + Storage* and *RES GAS* pathways generate the largest increase in economic demand, the nuclear pathway having a negative effect. However, when also considering the price impacts on competitiveness and the economic multipliers of this, the *Nuclear*, *RES GAS* and *AT-NIMP* pathways resulted in the most positive impacts, with the *RES + Storage* pathway seeing a much reduced positive impact due to its relatively high prices. Sensitivity checks on the nuclear pathway showed that enforcing high load factors turns the positive economic impact into a negative impact, and for *RES + Storage*, higher biomass prices would lead to changes in the pathway that deliver significant positive economic impacts, equivalent to those of the *AT-NIMP* pathway.

Figure 3-6 Static modelling - pathway results for change in economic output - Cumulative (2025-2050) (Type-I [direct]+Type-II [induced]) output changes compared to the reference (in million €)[63]



[63] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Figure 3-7 Macroeconomic adjustment of the different scenarios (left - demand effects only) (right - demand & price effects) - GDP - cumulative (2025-2050)[64]



Employment impact

Employment impacts were also modelled using both dynamic and static economic modelling approaches. Under static approaches (see Figure 3-8), the impact largely mirrors the economic impacts, with the Nuclear and RES + Storage pathways having by far the most positive impacts on employment across the whole period, followed by the RES GAS and AT pathways. The dynamic modelling (see

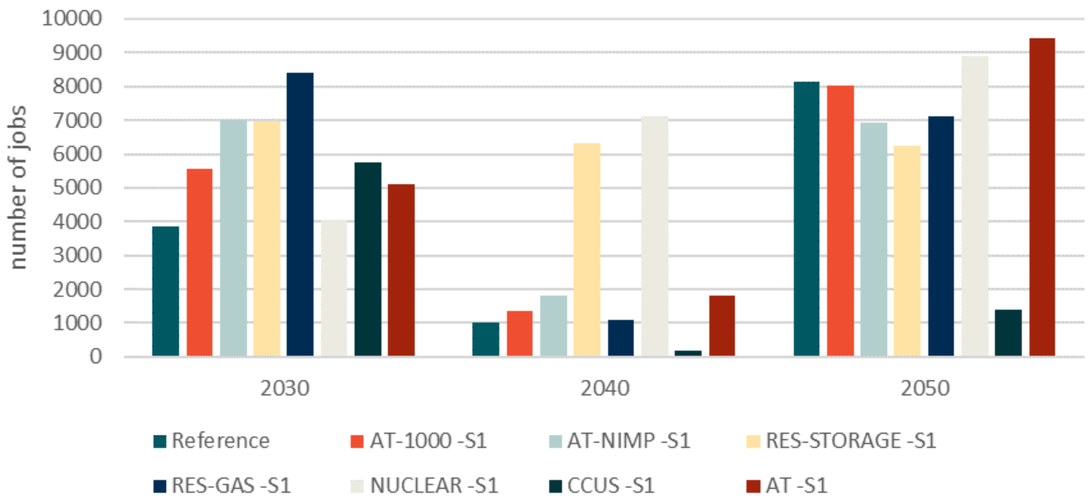


Figure 3-9) also showed employment results that largely mirror the dynamic economic results, with Nuclear, RES GAS and AT+1000 showing the largest gains. In the sensitivity cases of high nuclear load, the employment impact turned negative for the Nuclear pathway, and for RES + Storage with high biomass prices (sensitivity 3) the employment impact turned positive. Employment impacts in the pathways also show that with higher economic impact, the greater the growth in employment for unskilled workers.

[64] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Figure 3-8 Change in employment, static analysis, Total Type I + Type II employment multipliers, number of jobs

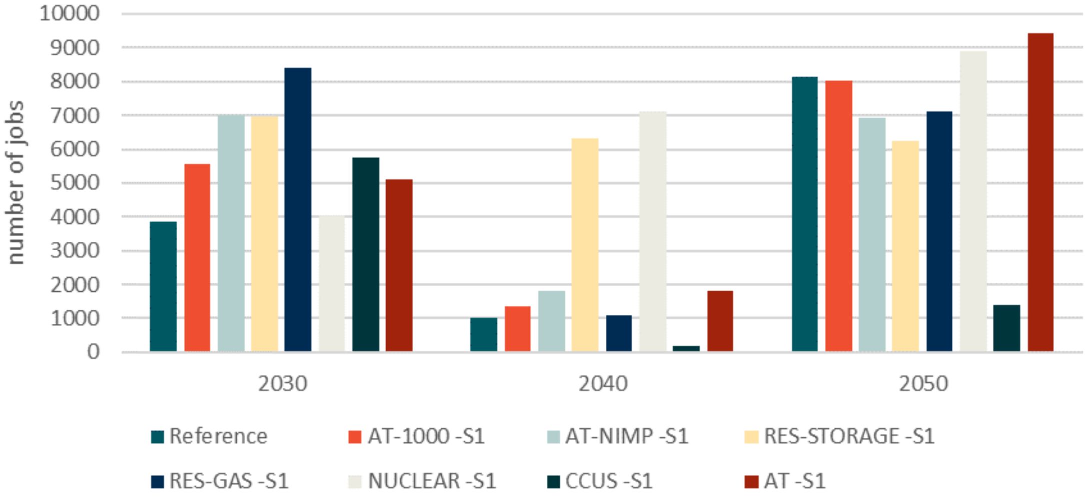
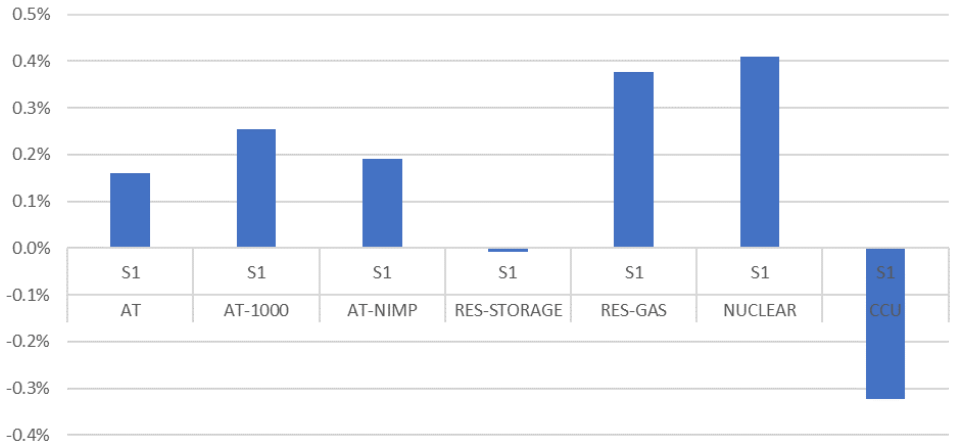


Figure 3-9 Change in employment, dynamic analysis, % cumulative change 2025-2050[65]



Impact on electricity prices

The analysis of these is presented in section 3.1.2.

Distributional impacts

Combining the economic and price effects in the model also provides outputs on the overall impact on the disposable income of consumers. These show the most positive impacts in the *RES + Storage*, *RES GAS* and *Nuclear* pathways. However, for nuclear the impact turns negative if a 90% load factor is enforced.

3.8 Main electricity network infrastructure development

As part of the energy system modelling exercise, a number of network reinforcement options were considered, while the distribution network was not included in the analysis[66]. Network reinforcement options include some key transmission lines and potential new interconnector with Latvia. While the

[65] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

[66] However, distribution network investments are likely to be needed, creating additional costs, particularly in scenarios with high Solar PV capacity.

costs for internal transmission lines are considered as part of the system optimization calculations, interconnection costs are not included because they would not influence the results.

Lääne-Eesti and Kesk-Eesti

- No reinforcement foreseen in any pathway

Lääne-Eesti and Latvia

- The following reinforcement capacities and costs are foreseen in each scenario.

Table 3-9 Reinforcement capacities and cost by pathway for the Lääne-Eesti - Latvia interconnector[67]

	New transmission (MW)			Transmission investment (million EUR_{2020})		
	2030	**2040**	**2050**	**2030**	**2040**	**2050**
Reference	45.7	73.9	564.0	10.2	16.5	125.8
Renewables + storage (offshore wind)	331.6	534.1	328.9	73.9	119.1	73.3
Nuclear	-	318.2	711.7	-	71.0	158.7
CCU	84.5	242.6	278.1	18.8	54.1	62.0
Renewable gas	39.0	84.1	508.5	8.7	18.8	113.4
All technologies	40.6	81.4	574.2	9.1	18.2	128.1
AT-NIMP	262.1	74.9	269.6	58.5	16.7	60.1
1000 MW dispatchable capacity	44.8	30.7	620.8	10.0	6.8	138.4

Lääne-Eesti and Lõuna-Eesti

- No reinforcement foreseen in any pathway.

Lääne-Eesti and Põhja-Eesti

- Reinforcements are needed only in the Renewables + storage (offshore wind) pathway.

Table 3-10 Reinforcement capacities and cost by pathway for the Lääne-Eesti - Põhja-Eesti transmission line[68]

	New transmission (MW)			Transmission investment (million EUR_{2020})		
	2030	2040	2050	2030	2040	2050
Renewables + storage (offshore wind)	--	123.2	253.4	--	29.0	59.7

CCU

Another key infrastructure deployment is the development of Carbon capture and utilisation (CCU) infrastructure. This is 'imposed' as a constraint in the CCU pathway, while for other pathways, it is allowed although whether or not it happens depends on the model. Following the revised wind energy availability included in Deliverable 6, no pathway sees the deployment of CCU.

In the CCU pathway, TG11 would upgrade to CCU during the scheduled refurbishment in 2025, while Auvere would upgrade to CCU in 2030.

[67] Author calculations based on Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[68] Author calculations based on Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

4 Description of key actions

4.1 Introduction

This section provides some preliminary considerations before new actions are presented from section 4.2 onwards. These include the expected results of renewable auctions already planned; impact of projected international energy and ETS prices; and inputs received from the stakeholder workshop held in February 2022.

4.1.1 Expected results of the auctions for renewable electricity generation projects[69]

The first three renewable electricity auctions (2019, 2020 and 2021) of 5 GWh each provide a total of 13.1 MW of capacity, and 14.4 GWh of annual generation. The winning projects are mostly small sized solar PV (about 86% of the concerned electricity production comes from solar and 14% from wind projects).[70]

The next auctions will cover a much larger volume of annual power generation, 450 GWh in the 2022 auction and 650 GWh in the 2023 auction. It is unclear which types of projects will be selected, but it would be consistent with the modelling result if a large proportion were onshore wind energy projects, as in every pathway onshore wind generation grow by around 3,000 GWh from 2020 levels by 2030 (see Table 4-1). To provide a rough estimate of the split in wind and solar projects, we have considered the previous auction results and the split of onshore wind and solar generation in the *AT* pathway. Since the *AT* pathway is the least constrained pathway, it provides the best representation of how technology investments would develop endogenously. Based on this, we expect that in the 2021 and 2023 auctions, 75% of the awarded electricity production would come from onshore wind and 25% from solar projects. This means 836 GWh of electricity generation would come from onshore wind and 279 GWh from solar PV.

Looking forward and across the pathways, as shown in Table 4-1, around 3,000 GWh to 7,000 GWh of renewable electricity generation growth is foreseen by 2030. The announced auctions only provide 1,115 GWh of this additional generation, and whilst not every GWh of additional generation should need support, there could still be a significant gap without further support. Following a two-year schedule for auctions in 2025, 2027 and 2029 and keeping a 650 GWh procurement target, a total 3,065 GWh could be supported by 2030. This may be sufficient in all but the *RES + Storage* and *AT-NIMP* pathways.

The *RES + Storage* and *AT-NIMP* pathways are the only two pathways that foresee offshore wind energy generation by 2030, and it is notable that the volume of generation contributed by this technology is high in both pathways. In each pathway, more than 2,500 GWh extra total generation is provided. Therefore, additional auction volume and/or a specific mechanism for offshore wind would also be necessary to encourage investments. As there is in general a time lag of some years between the auctions and the effective commissioning of selected plants, the timing of the power generation coming online may deviate from the pathway. Anticipating the next auctions to 2025 and 2027 would reduce this risk.

[69] https://www.mkm.ee/et/tegevused-eesmargid/energeetika/taastuvenergia
[70] https://www.mkm.ee/et/tegevused-eesmargid/energeetika/taastuvenergia

Table 4-1 Annual additional electricity generation (compared to current deployment and to the amount expected to be procured via the auctions in 2022 and 2023) foreseen by 2030 in the pathways, in GWh

	Reference	RES + Storage	Nuclear	CCU	RES GAS	AT	AT + 1000	AT-NIMP
Offshore Wind	0	3,542	0	0	0	0	0	2,447
Onshore Wind	2,144	2,284	2,088	2,284	2,173	2,159	2,187	2,121
Other Renewables	33	33	33	33	33	33	33	33
Solar PV	1,501	1,046	1,762	435	1,432	1,349	1,850	2,370
Total	3,678	6,904	3,883	2,752	3,638	3,540	4,069	6,972

Source: own calculation based on modelled results.

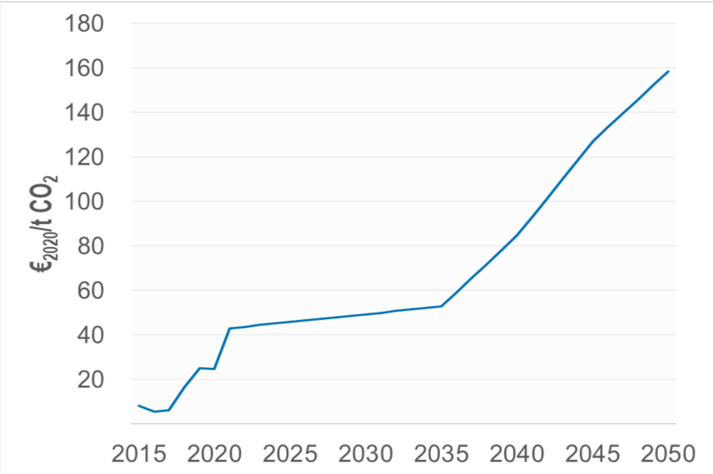
Note: Assume that 75% of the GWh from the 2019-2021, 2021 and 2023 auctions are from onshore wind (836.25 GWh) and 25% are from solar PV (278.75 GWh).

4.1.2 Impact of projected international energy and ETS prices

International fossil energy prices have a very low impact on the assessed pathways as none of the pathways faces significant exposure to fossil fuel prices. There is a low exposure of the power system to international movements in natural gas prices. Oil shale is sourced within Estonia and therefore also shielded from international markets.

The ETS prices assumed in the modelling are based on the EU reference scenario 2020[71] and evolve as shown in Figure 4-1. The impact on the pathways is relatively small, with the EUA prices largely serving to reinforce the incentives to switch to decarbonized energy sources not subject to the EU-ETS. Sensitivity analyses carried out in the Deliverable 3 report demonstrated that significant variations in the assumed EUA prices do not lead to major changes in pathway outcomes. The key finding is that even with moderate EUA prices the cost projections for renewable electricity and storage make them a compelling alternative to conventional fossil fuel based power generation.

Figure 4-1 ETS price increase assumption in the modelling



4.1.3 Inputs from the Workshop

On 22 February 2022, MKM held a workshop to gather insights from stakeholders concerning possible areas for action to be included in the pathways. Stakeholders suggested that:

- Feed-in premiums as traditional support schemes for electricity generated from renewable sources are outdated, creating unwanted market distortions and should be

[71] Specifically, a draft version of RS2020 that was shared with the project team during the Deliverable 3 modelling.

removed. PPAs or auctions offer better opportunities and sufficient financial security to raise private finance for renewable installations.

- A solution is needed to encourage investment in electricity grid assets on the level of the TSO and DSO to allow a higher share of renewable electricity in the grid
- Clarifications are needed on how renewable electricity development areas that are developed by the state are identified and how state aid rules are applied and conflicts with privately developed projects are avoided
- There are concerns regarding planning and the role of local governments, such as:
  - Additional administrative burden of tasks related to renewable energy development decreases the independence and motivation of local administrators to ensure swift procedures;
  - Time to carry out internal procedures in the local governments should be limited to a level that is still feasible for the local government while allowing the project to be developed within a reasonable timeframe. Any amendments to the regulatory framework should aim to simplify the planning process, and to ease the administrative burden on local administrators;
  - Objective of conflict solvers group should be clarified with regards to which criteria they should fulfil and what is their role. One option could be to create a position of ombudsman of strategic infrastructure;
  - There is a perceived lack of capacity and skill at the local level. A national Energy Agency-type organisation with presence at a regional/local level could ease the burden on local administration.

When allowing private citizens to invest in renewable energy development and take part in the Green Deal, it should be considered how households with lower income could be included in this process, e.g. special conditions. Stakeholders also suggested that:

- A principal set of studies, analysis and considerations should be agreed for off-shore parks that takes into account practices from other countries to lower the likelihood of arbitrary additional costs and ensure equal treatment between developers;
- One-stop-shops are especially important for smaller developers;
- Solutions where developers agree compensation measures with interested parties directly, for example, to compensate energy prices, may not be in local governments' interest.

4.2 Action set 1: Infrastructure planning process reform

Criteria		Notes
Costs	Low	
Financed via	General taxation	
Complexity	High	The complexity of the action is mostly related to the number of stakeholders involved and to the need to align their interests.
Stakeholders involvement	High	
Implementation	Short term	Steps have already been taken towards simplifying the planning process, but further measures should be taken.

Relevance for different pathways

RES + Storage	*Nuclear*	*CCU*	*RES GAS*	*AT*	*AT-NIMP*	*AT + 1000*
xxx	x	x	x	xxx	xxx	xxx

The slowness and unpredictability of the planning process have been identified as one of the key barriers currently hindering the development of renewable energy sources, in particularly, for solar parks and onshore/offshore wind energy projects. A planning process reform should remove the main barriers and bottlenecks by acting on different elements of the planning process. To ensure its success, it will have to be supported by complementary actions, such as information campaigns and skills development. The Energia Teekaart 2021-2031-2040[72] proposes several relevant actions, while stakeholders involved in this assessment indicated some further steps that may facilitate the process.

4.2.1 Energy generation infrastructure planning process in Estonia

The process for developing wind and large-scale solar energy projects, such as solar PV parks, is complex and can take from 3 months to several years (depending on the complexity of the project). Particularly, the detailed planning and permitting procedure can take up to three years. [73]

National and local spatial plans determine the planning process for wind and solar energy projects, while the Ministry of Finance is the authority in charge of the national spatial plans. For offshore wind parks, Ministry of Economic Affairs and Communications is responsible for assigning permits. The Ministry of Interior is responsible for coordinating spatial planning, including maritime spatial planning. Further, the Environmental Board/Ministry of Environment supervises the EIAs.

The planning process consists of four main steps:

1. Location selection;
2. Preparation of detailed plans (including environmental impact assessment) (2-3 years);
3. Application for design conditions (30-60 days); and
4. Application for building and environmental permits (30 days).

Location selection

The first step of planning a wind or a large-scale solar energy project is selecting a location, where several restrictions and conditions must be taken into account. When selecting a location for RES infrastructure, network connections options have also to be considered.

The national Maritime Spatial Plan (MSP) determines which areas are suitable for the development of offshore wind energy. These areas are determined based on:

- Suitability for wind energy production;
- Natural restrictions and importance of area for bird migration;
- Social buffer (11.1 km away from shoreline);
- Results of the impact assessment;
- Input form the Maritime Administration and Civil Aviation Administration.[74]

Further, offshore wind farms cannot obstruct view corridors, overlap cultural monuments or impact national defence interests (mainly related to disruptions of wind turbines to radar functionality).

Onshore wind and solar projects are also restricted by national and local spatial plans. For instance, these restrictions can include:

- No solar parks on valuable agricultural land;

[72] Energia Teekaart 2021-2031-2040, Rohetiiger, TalTech, 07.12.2021
[73] Source: SEI (2021). Kohalike omavalitsuste tuule- ja päikeseenergia käsiraamat. Available at: https://cdn.sei.org/wp-content/uploads/2021/05/kov-te-kasiraamat.pdf
[74] Rahandusministeerium & Hedrikson&KO (2020). Estonian Maritime Spatial Plan. Available at: http://mereala.hendrikson.ee/dokumendid/Eskiis/Estonian_MSP_main-solution_ENG.pdf

- Onshore wind is only permitted in sparsely population areas; and
- Location must be approved by the Road Administration.

According to the National Spatial Plan, former mining areas and other areas outside of human activity where the use of wind energy is viable are primarily suitable for the construction of onshore wind farms.

Preparation of detailed plans

In Estonia, the local governments prepare the detailed plans primarily for the general plan, which is the basis for construction activities in the coming years. The preparation of detailed plans is generally not required, but some are mandatory, set out in the Planning Act. When preparing the detailed plans, the local government must cooperate with government agencies and relevant stakeholders, such as:

- **Ministry of Defence**: to avoid impact on national defence from planned wind farm;
- **Environmental Board and/or Ministry of Environment**: if the plan could have a significant environmental impact (Ministry of Environment in the case where a strategic transboundary EIA is required);
- **Civil Aviation Administration**: to avoid impact on civil aviation form planned wind farm;
- **Road Administration**: if the planning area is adjacent to a state road, the traffic load in the area increases significantly or the plan may cause a visual disturbance to road users;
- **National Heritage Board**: if involving a protected zone;
- **Police and Board Guard Board**: if planning is closer than 5km from the border.

Application for design conditions and building/environmental permits

The procedures for design conditions for solar and wind energy projects are the same, which are issued within 30-60 days of the application. Examples of design conditions are:

- Compliance with land use guidelines;
- Indication of planned capacity;
- For wind farms, the planned height of the wind turbines.

In some cases, building and environmental permits are required for the construction of solar or wind energy infrastructure. For onshore wind and solar, the need for a building permit depends on several factors, including the planned capacity. The need for an environmental permit depends on the environmental impact assessment results. For offshore wind farms (i.e. construction on public water bodies), a building and environmental permit are always required.

4.2.2 Energy generation infrastructure planning process across the EU

Estonia is an active participant in the Baltic Energy Market Interconnection Plan (BEMIP) work group, which deliberates the regional cooperation options in the Baltic region for electricity, gas, renewable energy and energy efficiency.[75] Their objective is to monitor and coordinate the implementation of the harmonisation action plans, including for the infrastructure planning. Table 4-2 compares the process for infrastructure planning in the Baltic States for renewable electricity generators. Notably, all of the Baltic States suffer from inefficiencies in the administrative process, but the type of administrative barrier varies from State to State. A key difference between Estonia and the other Baltic States is that Estonia's national spatial planning authority is the Ministry of Finance, whereas

[75] European Commission (2019). Estonia's 2030 National Energy and Climate Plan. Available at: https://energy.ec.europa.eu/system/files/2020-04/ee_final_necp_main_en_0.pdf

the competent authority in the other States is the Ministry of Environment. All of the Baltic State NECPs include actions to simplify administrative procedures, particularly to set up contact points.

Table 4-2 Comparison of renewable electricity infrastructure planning procedure in the Baltic states

	Estonia	Latvia	Lithuania
National spatial planning authority	Ministry of Finance	Ministry of Environmental Protection and Regional Development	Ministry of Environment
Time required for planning process	2-3 years, process can take much longer, up to 10 years (due to lack of admin. capacity, complaint rights)	Onshore wind: 3.4-4 years[76]	1-2 years[77] (general estimate from 2010)
Main administrative barriers	Current push for widening buffer zones from the Environmental board would block a significant share of locations for wind projects[78] Conflicts with national security for offshore wind development due to radar interference[79] Admin. process is too long and complex[80] Procedures for Nature conservation areas are not transparent and non-inclusive[81] The planned MSP does not have a sufficient level of details[82] Poor quality and low requirements for EIAs[83]	Land lots are fragmented and small, need for agreement with several landowners, but data protection limits ability for developers to get the contacts of relevant owners[84] Developers cannot use agriculture or forest land[85]	Opposition of local communities against development of onshore wind Limitations of wind power due to near air surveillance radars and sanitary protection zones Complex special territorial planning Long EIA for repowering wind power turbines Conditions and spatial rulings are unclear
NECP actions to simplify administrative procedures	Setting up one or more contact points and streamlining administrative procedures.[86]	Setting up contact points and setting deadlines for issuing licenses; develop a procedure for use of public forest lands for wind parks[87]	Setting up of contact points and simple notification for small installations[88]

Simplification of the electricity infrastructure planning application process in Baltic States

In Estonia's National Recovery and Resilience Plan (NRRP), the *Boosting the green transition in the energy economy* reform includes the removal of administrative barriers to renewable energy

[76] Rapacka, P. (2022). Latvia will increase energy independence, less bureaucracy for wind projects is predicted. Available at: https://balticwind.eu/latvia-will-increase-energy-independence-less-bureaucracy-for-wind-projects-is-predicted/
[77] Lithuanian Energy Agency (2010). National Renewable Energy Action Plan. Available at: https://www.ena.lt/uploads/PDF-AEI/KITI-doc/EN/6a-national-renewable-energy-action-plan-lithuania-en.pdf
[78] European Climate Foundation (2022). Environmental restrictions by the Environmental Board can hinder wind energy development in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/285/
[79] European Climate Foundation (2022). Conflicts between national security reasons and wind energy development in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/286/
[80] European Climate Foundation (2022). The administrative processes take too long and are too complex in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/290/
[81] European Climate Foundation (2022). Intransparent and non-inclusive procedures for Nature Conservation Areas in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/308/
[82] European Climate Foundation (2022). Insufficient level of details in the planned Maritime Spatial Plan in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/309/
[83] European Climate Foundation (2022). Poor quality and low requirements for environmental impact assessments in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/1486/
[84] European Climate Foundation (2022). Limited wind power development due to spatial planning regulations and administrative issues in Latvia. Available at: https://resmonitor.eu/en/lv/barriers/1411/
[85] ibidem
[86] European Commission (2019). Estonia's 2030 National Energy and Climate Plan. Available at: https://energy.ec.europa.eu/system/files/2020-04/ee_final_necp_main_en_0.pdf
[87] European Commission (2018). National Energy and Climate Plan of Latvia 2021-2030. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lv_necp.pdf
[88] European Commission (2020). Assessment of the final national energy and climate plan of Lithuania. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_lithuania.pdf

installations. This measure entails adopting legislation and compiling guidance materials for accelerating the installation of renewable electricity production capacity and actions for alleviating the defence-related height restrictions on wind parks.

Further, the action plan for Estonia's Spatial Planning *Estonia 2030+* includes several initiatives related to facilitating spatial planning for renewable energy installations:[89]

- Updating maritime spatial planning (2021-2024);
- Carrying out the location selection of a nuclear power plant and the associated infrastructure with a special state plan if decisions have been made for the development of nuclear energy in Estonia (to be determined if needed);
- Planning of wind farms using local government or state plans (2011-2023);
- Planning of energy storage facilities (incl. renewable gas and pumped hydro) (2020+);
- Electricity interconnection between Estonia and Finland (2020+);
- Planning grid refurbishments/extensions to connect RES installations to the grid (onshore and offshore) (2030).

Other Baltic States also include relevant measures in their NRRPS. For instance, the Lithuanian NRRP includes measures to:

- Promote production and transmission of electricity from renewable sources by improving institutional and legal mechanisms;
- Carry out preparatory work for development of offshore wind power plants (environmental impact assessment, consultancy services for network connection, preparation, adoption, and implementation of spatial planning documents);
- Support construction of onshore RES plants and individual storage facilities by providing support for acquisition and installation of onshore solar and wind power plants, prioritizing self-consumption, farmers or economic needs.

The Latvian NRRP includes a measure to improve the regulatory framework for electricity transmission and distribution networks and enabling conditions to facilitate the deployment of onshore wind energy on state forest land and reduce legal uncertainty for wind power investments.

Best practices for simplifying administrative processes adopted in other EU Member States

In other EU Member States, successful actions have been taken to remove administrative burdens for RES deployment, including:

- **France:** to remove aviation-related security restrictions in France, the Civil Aviation Authority re-evaluated areas previously restricted and as a result made 9,000 m^2 available for developing wind power.[90]
- **Netherlands**: For onshore wind and ground-mounted solar PV, a sector binding Code of Conduct was developed, which has reduced resistance and number of appeal procedures against RES projects.[91]

[89] Rahandusministeerium (2020). ÜLERIIGILISE PLANEERINGU „EESTI 2030+“ TEGEVUSKAVA (UUENDATUD 2020). Available at: https://www.rahandusministeerium.ee/sites/default/files/Ruumiline_planeerimine/yrp_uuendatud_tegevuskava_130820.pdf

[90] Banasiak, J. et al. (2022). Barriers and best practises for wind and solar electricity in the EU27 and UK. Available at: https://www.eclareon.com/sites/default/files/res_policy_monitoring_database_final_report_01.pdf

[91] ibidem

- **Denmark**: For offshore wind farm development, there is a one-stop-shop for developers. The number of permits required is the same, but the procedure is more streamlined and provides more clear communication between authorities and developers.[92]
- **Belgium**: environmental and urban permits are combined, which reduces the administrative burden for developers. Depending on the type of permit required, the application can be done online.[93]

4.2.3 EC consultation: permit-granting processes & power-purchase agreements

The European Commission had launched a consultation procedure[94], which was open until 12 April 2022, to collect stakeholders' views on how to overcome key barriers to implementing renewable energy projects, including:

- Length of permit application and granting procedures;
- Complexity of administrative authorisations;
- Complexity of the processes and rules for site selection and planning of land/sea space use;
- Constraints and good practice examples related to grid connection and repowering;
- Staffing and skilling of permitting authorities;
- Main barriers to PPA deployment.

Following the consultation, the Commission has now published a working document, a synopsis and a proposal for a directive[95]. The proposal introduces a maximum duration of the permit-granting process applicable to renewable energy plants, enhanced measures to accelerate permitting procedures, obligates Member States to promote the deployment of solar installations on buildings and raises the 2030 target for energy efficiency to 13%.

Several options and best practices for faster permitting are included in the staff working document and cover aspects such as shorter administrative authorisation, internal coordination and digital procedures, human resources and skills, identification of appropriate site, and easier grid connections.

4.2.4 Actions already started

The Estonian government has already put in place a number of actions to improve the planning process:

- Lifting of the limit on wind turbines deployment due to special limitation imposed by the operation of military radar systems;
- Other minor improvements to the planning application and permitting process.

4.2.5 Recommended actions

1A. Streamline the infrastructure planning approval process

- Set a detailed national onshore and offshore spatial planning strategy, with strong political and public support, which clearly identifies designated areas, capacities that can be deployed and related transport and distribution infrastructure needs

[92] ibidem
[93] ibidem
[94] European Commission (2022). Public consultation launched on renewables permitting and Power Puchase Agreements. Available at: https://ec.europa.eu/info/news/public-consultation-launched-renewables-permitting-and-power-purchase-agreements-2022-jan-18_en
[95] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13334-Renewable-energy-projects-permit-granting-processes-power-purchase-agreements_en

- Update the legal framework surrounding the approval process for renewable energy installations, including the creation of a single approval procedure and single contact point beginning with large projects (e.g. offshore wind energy farms) but with the aim to extend to all applications. The contact point will coordinate inputs from other relevant authorities.
- Establish maximum allowable time-limits for all stages of the planning process, including the approval of the environmental impact assessment;
- Set up a group of sectoral experts, national defence and representatives from the civil society to resolve conflicts concerning proposed development sites for wind and solar energy. Options should be considered whether such a group could play a formal role in the appeal process. This role could be assigned to a newly formed energy Agency (see section Recommended actions – short term).

1B. Increase administrative resources dedicated to planning and permissions

- Dedicate additional human and financial resources at national level (e.g. experts, commission studies, prioritisation in approval processes) to support projects of national interest. The Government should define a set of criteria that identify projects of national interest, according to the overall strategic direction chosen. The overall project size (capacity) and its contribution to the energy and climate targets and security of energy supply (electricity system stability, independence from imported fossil fuels) should be major criteria; in this context wind energy farms and nuclear and conventional power plants could be considered as projects of national interest. See below (Institutional Reform) the suggested action concerning a new agency and the role it could play in respect to these projects.
- Support local administrations with additional resources to timely deal with project proposals. Solutions may include:
  - Providing additional budget;
  - Providing experts (secondments);
  - Providing tools to facilitate the process;
  - Providing training to administrators in charge of managing the process.

Other actions to support upskilling and increase in human resources with the right skills are discussed in section 4.8.

1C. Supporting actions to speed up the approval process

- Make the inclusion of new promising renewable energy production areas mandatory in local statutory, thematic and special plans, and link payments from the local government equalisation fund to this requirement. This action should have a short-term conclusion (i.e., max by end of 2023);
- If, following the previous action, the number of sites identified is not sufficient, a new spatial plan will be defined at national level. A rough amount of land required is indicated in section 3.4, but further studies should be carried out to quantify this with more precision according to the selected scenario;
- Prescribe, by law, the baseline studies that must be carried out for the encumbered marine area, the list of which will be definitive and delimited by the EIA programme. The results of the studies will be finalised by the EIA expert group and the decisions taken as a result of the studies should be binding on all parties;

- Create possibilities for municipalities to benefit from renewable energy investments in their jurisdictions. This could take the form of profit/revenue sharing with municipalities, co-financing via local authorities or energy communities, or direct purchase contracts;
- Options should be explored to increase the areas that can be used for onshore wind energy projects. These options should consider brownfield and greyfield sites (e.g. previously developed areas, underdeveloped industrial parks), combined use (e.g. in industrial areas, co-location with other infrastructure) and options to locate alternative onshore wind turbine designs, such as bladeless wind turbines.

4.3 Action set 2: Institutional reform

Criteria	Score	Notes				
Costs	Low	Major costs for these actions are associated with staff deployed at the new institutions, but it is assumed that the majority of staff can be transferred from similar functions currently carried out by different Ministries				
Financed via	General taxation					
Complexity	Medium					
Stakeholders involvement	Low to Medium					
Implementation	Medium term					
Relevance for different pathways						
RES + Storage	*Nuclear*	*CCU*	*RES GAS*	*AT*	*AT-NIMP*	*AT + 1000*
x	xxx	xxx	xx	x	x	x

Substantial institutional changes will be required only for scenarios that foresee the building of nuclear power plants, and the deployment of CCU and hydrogen. However, setting up an energy agency would be an effective and efficient way to steering and monitoring the deployment of renewable energy (similar to several other Member States) and therefore this institutional change is recommended in every scenario.

4.3.1 Energy Agencies in EU Member States

Table 4-3 provides an overview of the energy agencies across all EU-27 Member States. Out of the 27 Member States, 20 Member States have an energy agency established, with the exception of Belgium, Cyprus, Czech Republic, Estonia, Latvia, Romania and Slovenia.

Across the EU, there are wide differences in the arrangements concerning the role and responsibilities of the ministries dealing with energy related matters and supporting bodies such as energy agencies. The division of roles and responsibilities, as well as the institutional framework within which energy agencies are set, differs per Member State and often also within the same Member States according to the energy area (for example, energy agencies may have clear roles in electricity and energy efficiency but a less prominent role concerning gas).

Generally, the role of ministries takes a broader perspective for the development of the energy landscape for the country. This includes strategic decisions concerning the future energy mix, the design of the policy and legislative frameworks, and engaging in conversations with stakeholders such as industry, consumers, and with other ministries and/or government departments. National energy agencies, on the other hand, do not have policy-making powers, but play an important role in developing knowledge and supporting the clean energy transition. Some of the key responsibilities they hold include the planning and management of research, development and innovation activities, providing policy and strategic advice to government, facilitating cooperation among stakeholders and abroad, conducting training and organising promotional activities.

Among the Baltic and Nordic countries, Lithuania, Finland, Sweden and Denmark have an energy agency. Motiva Ltd is a Finnish state-owned energy agency that was first established as an Information Centre for Energy Efficiency to promote the implementation of the Energy Conservation Programme of the Finnish Government. Today, Motiva is setup almost as a private company, it provides expertise and consulting services, carries out monitoring and impact assessments, conducts training, facilitates cooperation, and provide energy advice for energy consumers. Research, development and innovation efforts are coordinated by VTT Technical Research Centre of Finland, a non-profit research institution owned by the Finnish state. Research areas cover a variety of topics including nuclear, CCU/S, hydrogen, and biomass[96].

The Lithuanian Energy Agency is a non-profit legal entity that was established as a public institution in 2018, and is affiliated with the Ministry of Energy. The objectives of the Agency are to implement state policy measures in the fields of energy, including efficient use of energy and energy resources; monitor the National Energy Strategy and state programs; organise and manage oil products and oil stocks. The Lithuanian Energy Agency also provides expertise and strategic consulting, conducts technical, economic and market studies, prepares materials as basis for policy decisions, conducts monitoring and impact assessments, and facilitates cooperation amongst stakeholders. Lithuania has a distinct research organisation which runs under the state budget, the Lithuanian Energy Institute (LEI), which was established in 1956 and has about 230 employees (as of Jan 2021). Their research area covers renewable energy, security of supply, nuclear safety, fuel cells and hydrogen.[97]

Latvia does not currently have an energy agency established, but several research institutions and organisations provide similar services by focussing on different research areas, including renewable energy, smart energy, and biomass[98].

[96] https://www.vttresearch.com/en/topics/future-energy
[97] https://www.lei.lt/about/
[98] Details on the specific research areas of these research institutions and organisations are available here: https://www.izm.gov.lv/en/media/6433/download (see chapter 8)

Table 4-3 Overview of energy agencies in EU27 Member States

Country	Name	Details	Description	Roles / Functions
Austria	Austrian Energy Agency	Non-profit scientific association; President of the AEA is the federal minister responsible for managing environmental protection issues; vice-presidents of the AEA are the federal minister responsible for energy and a provincial governor.	The Austrian Energy Agency is the Austrian energy research and policy institution in which the federal and the provincial administration and important institutions and corporations from a variety of economic sectors cooperate. The board of directors comprises the federal minister charged with environmental affairs, the federal minister charged with energy affairs and the chairman of the provincial governors.	- Expertise and strategic consulting - Preparation of materials as basis for decisions - Research and Development - Conducts technical, economic, and market studies - Conducts feasibility studies - Conducts training - Organises promotional activities - Programme coordinator / manager for Klimaaktiv, Austrian Energy Partnerships - Programme support for energy-relevant EU programmes, Concerted Action Renewables, National Energy Efficiency Monitoring Centre
Bulgaria	Sustainable Energy Development Agency	Executive agency within Ministry of Energy; State budget	SEDA is a legal entity at state budget support with headquarters in Sofia and has the status of an executive agency within the Ministry of Energy. Within SEDA, the Directorate General of coordination and management of energy efficiency and renewable energy agency executes the role of an energy regulator.	- Expertise and strategic consulting - Preparation of materials as basis for decisions - Preparation of reports and templates required for reporting - Conducts technical, economic, and market studies - Conducts training - Organises promotional activities - Collects and submits information about funding opportunities (EU, national and international sources)
Croatia	Energy Institute Hrvoje Požar (EIHP)	State-owned, non-profit scientific institution	The Institute is a wholly state-owned, non-profit scientific institution financed on a per-project basis through the execution of project development contracts won following international and national competitive biddings.	- Expertise and strategic consulting - Preparation of materials as basis for decisions - Conducts technical, economic, and market studies - Conducts training - Organises promotional activities
Denmark	Danish Energy Agency	Ministry of Climate, Energy & Utilities	The Danish Energy Agency is a part of the Ministry of Energy, Utilities and Climate. The Agency is responsible for tasks linked to energy production, supply and consumption, and for the efforts to reduce greenhouse gases emissions. It also supports the economical optimisation of utilities, including energy.	- Expertise and strategic consulting - Research and Development - Facilitates cooperation with various stakeholders, including international actors - Collects data / statistics
Finland	Motiva Ltd	State-owned, affiliated Government agency	Motiva is a Finnish state company which promotes the efficient and sustainable use of energy and materials. Motiva's mission is to advance sustainable development determinedly at all levels of the society. It offers authorities, companies, municipalities and consumers information, solutions and services helping them to make resource-efficient, effective, and sustainable choices.	- Expertise and strategic consulting - Conducts monitoring and impact assessments - Conducts training - Facilitates cooperation with public, private and third party actors - Provides energy advice for energy consumers
France	Environment and Energy Management Agency (ADEME)	State-owned	ADEME is a public agency under the joint authority of Ministry of Environment, Energy and the Sea and the Ministry of Higher Education and Research.	- Expertise and strategic consulting - Research and Development - Management of an open data portal - Participates in the development and implementation of policies

Country	Name	Details	Description	Roles / Functions
				- Facilitates cooperation with various stakeholders
Germany	German Energy Agency (dena)	Private company; Main stakeholder is the Federal Republic of Germany, followed by the reconstruction bank, Deutsche Bank AG, DZ Bank AG and Allianz SE	The voting shareholders of dena include the federal government, represented by the Federal Ministry for Economic Affairs and Energy, the Federal Ministry for Food and Agriculture, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety and the Federal Ministry for Transport and Digital Infrastructure, and the KfW banking group.	- Expertise and strategic consulting - Research and Development - Conducts technical, economic, and market studies - Facilitates cooperation with various stakeholders - Organises promotional activities
	Project Management Jülich	Affiliated with Forschungszentrum Jülich GmbH, whose partners are the Federal Republic of Germany (90%) and Federal State of North Rhine-Westphalia (10%)	Project Management Jülich is a partner for science, industry and policy-makers. It implements the energy research programmes of the German Federal Government. They work independently of economic interests and are bound to strict neutrality.	- Research & Development
Greece	Centre for Renewable Energy Sources and Saving (CRES)	Public entity supervised by the Hellenic Ministry of Environment and Energy with financial and administrative independence	CRES is the Greek organisation for Renewable Energy Sources (RES), Rational Use of Energy (RUE) and Energy Saving (ES). It is a public entity, supervised by the Ministry of Environment and Energy and has financial and administrative independence.	- Research & Development - Demonstration projects - Development of energy information systems - Conducts feasibility studies - Conducts technical, economic, and market studies - Conducts training - Organises promotional activities
Hungary (Dual function; Regulator)	Hungarian Energy and Public Utility Regulatory Authority (HEA)	Legal entity with separate and independent budget; reports annually to Parliament	HEA is the regulatory body of the energy and public utility market, supervising the national economy's sectors of strategic importance. It is an independent regulatory authority entrusted with provision making power established under Act XXII of 2013. HEA also cooperates with the Hungarian Competition Authority to ensure the sound, transparent functioning of the energy and public utility markets.[99]	- (tasks as energy agency) - Preparation of materials as basis for decisions on, for e.g. tariffs and fee etc. - Manages data reporting obligations - Collects data / statistics
Ireland	Sustainable Energy Authority of Ireland (SEAI)	Affiliated with Minister for Communications, Climate Action and Environment, with the consent of the Minister for Finance	SEAI promotes and assists the development of sustainable energy in Ireland. They engage and work with a variety of stakeholders, including householders, businesses, communities and the government to create a cleaner energy future.	- Research & Development - Facilitates cooperation with various stakeholders - Manages data reporting obligations - Management of an open data portal - Collects data / statistics
Italy	Italian national Agency for New Technologies, Energy and	Public body supervised by Ministry of Economic Development	ENEA is a public body aimed at research, technological innovation and the provision of advanced services to enterprises, public administration and citizens in the sectors of energy, the environment and sustainable economic development.	- Expertise and strategic consulting - Research & Development - Facilitates cooperation with various stakeholders - Promotes innovation amongst industry stakeholders, and partnerships with national and international projects

[99] https://www.gvh.hu/en/press_room/press_releases/press-releases-2020/the-hungarian-competition-authority-and-the-hungarian-energy-and-public-utility-regulatory-authority-have-renewed-their-cooperation-

Country	Name	Details	Description	Roles / Functions
	Sustainable Economic Development (ENEA)			- Hosts an Integrated Service for managing non-electro-nuclear radioactive waste
Lithuania	Lithuanian Energy Agency	Public Institution; non-profit legal entity	The objectives of the Agency is to implement state policy measures in the fields of energy, efficient use of energy and energy resources, monitoring of the National Energy Strategy and state programs in accordance to national and EU legal acts. They also organise and manage oil products and oil stocks.	- Expertise and strategic consulting - Conduct technical, economic, and market studies - Preparation of materials as basis for decisions - Conducts monitoring and impact assessments - Facilitates cooperation with various stakeholders
Luxembourg	Klima-Agence	Supported by the State of the Grand Duchy of Luxembourg, represented by the Ministry of Energy and Regional Planning, the Ministry of the Environment, Climate and Sustainable Development and the Ministry of Housing.	The agency targets the reduction of energy consumption, the promotion of renewable energies, sustainable housing and mobility as well as the management of natural resources and the implementation of the circular economy.	- Acts as an information centre for individuals, municipalities, experts and businesses
Malta	Energy and Water Agency	Established within the Ministry for Energy, Enterprise and Sustainable Development	The agency is tasked with formulating and implementing Government's national policies in the energy and water sectors, aimed at ensuring security, sustainability and affordability of energy and water in Malta.	- Expertise and strategic consulting - Research & Development - Facilitates cooperation with various stakeholders - Conduct feasibility studies - Conduct technical, economic, and market studies - Management of schemes and grants - Organises promotional activities
The Netherlands	Netherlands Enterprise Agency (RVO)	Executive body of the Dutch Ministry of Economic Affairs and Climate policy	RVO is part of the Ministry of Economic Affairs and Climate. The agency helps entrepreneurs and organisations to invest, develop and expand their businesses and projects, sustainably, both in the Netherlands and abroad. We are a government agency that carries out the Dutch Ministry of Economic Affairs and Climate policy.	- Management of subsidies and financing programmes - Facilitates cooperation with various stakeholders - Acts as an information centre for subsidies and financing programmes
Poland	National Energy Conservation Agency (KAPE)	Joint stock company established in 1994 by Agency on Industrial Development Co., Bank Gospodarstwa Krajowego, and the National Fund of Environment and Water Management	The agency aids companies, municipalities, public institutions, and non-governmental institutions through advice, instruction and education in the field of rational energy use. Their strategic goal is to support the growth of competitiveness of the polish economy through improving energy efficiency, while respecting the principles of sustainable development.	- Expertise and strategic consulting - Provide advice through carrying out energy audits - Conduct feasibility studies - Acts as an information centre for subsidies and financing programmes - Acts as an information centre for individuals, municipalities, experts and businesses
Portugal	ADENE	Public utility statute; State budget	ADENE helps to promote and carry out activities of public interest in the area of energy and its interfaces with other sectoral policies, facilitate	- Facilitates cooperation with various stakeholders - Conduct feasibility studies - Conducts training - Organises promotional activities

Country	Name	Details	Description	Roles / Functions
			cooperation in the areas of efficient water use and energy efficiency in mobility.	- Acts as an information centre for energy consumers - Management of an open data portal - Collects data / statistics
Slovakia	Slovak Innovation and Energy Agency (SIEA)	Contributory organisation established by the Ministry of Economy	SIEA helps to raise awareness about energy efficiency, renewable energy sources and innovations in all fields of economy and provide expert consulting in those areas.	- Expertise and strategic consulting - Organises promotional activities - Acts as an information centre for energy consumers - Conducts monitoring and evaluation activities - International cooperation
Spain	Institute for the Diversification and Saving of Energy (IDAE)	Public business entity reporting to the Spanish Ministry of Energy, Tourism and Digital Agenda (MINETAD) through the State Secretariat for Energy	IDEA promotes the conservation, saving and diversification of energy sources.	- Expertise and strategic consulting - Research & Development - Collects and publishes data / statistics - Conducts training - Organises promotional activities - International cooperation - Management of schemes and grants
Sweden	Swedish Energy Agency	Works within the Ministry of Infrastructures; budget decided by parliament and the government	The agency contributes to creating a sustainable energy system, combining ecological sustainability, competitiveness and security of supply.	- Expertise and strategic consulting - Research & Development - Management of subsidies and financing programmes - Collects and publishes data / statistics - International cooperation

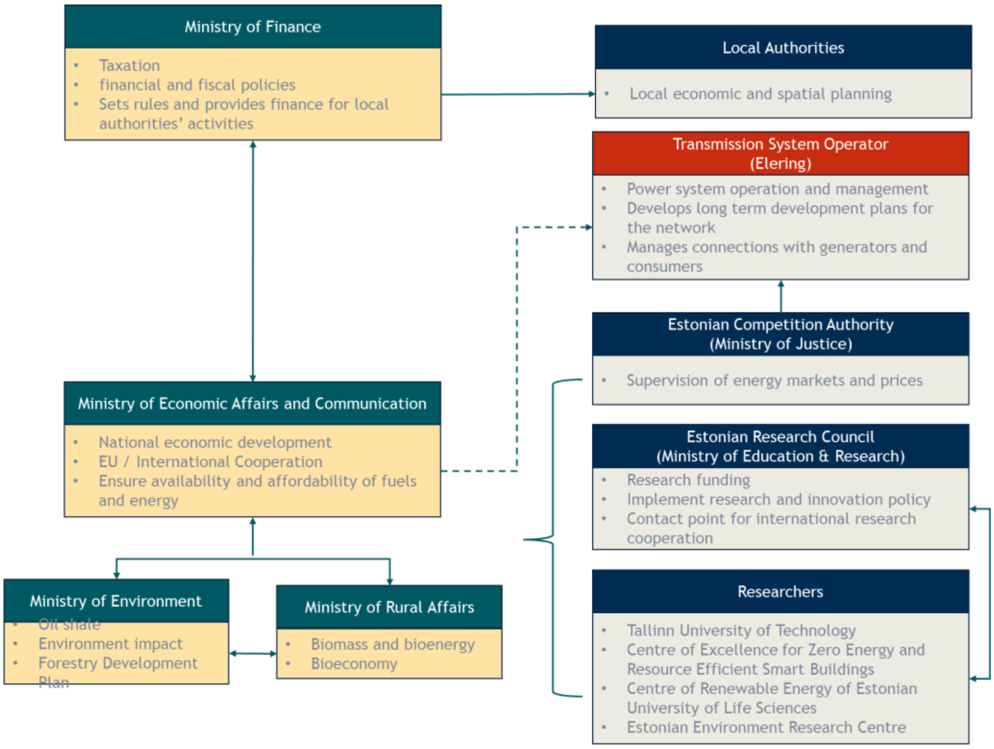
4.3.2 *Current state of play in Estonia*

The coordination and organisation of the energy sector in Estonia involves several ministries. For example, the implementation and co-ordination for the use of oil shale, biomass and bioenergy are the responsibilities of the Ministry for the Environment and the Ministry for Rural Affairs, respectively. Also, while the development of the bioeconomy falls also under Ministry for Rural Affairs, the Ministry for Economic Affairs and Communication maintains an oversight of the overall economic development, and facilitates cooperation across government.

One of the key functions of energy agencies across Europe concerns developing and coordinating the research, development and innovation activities in the field of energy. While Estonia does not have a dedicated energy agency, the Estonian Research Council (under the Ministry of Education and Research) issues research funding, coordinates the development and implementation of research and innovation policy, and is the contact point for international research cooperation. It also provides inputs to inform policy making when necessary. There are also several other research organisations and departments carrying out research on energy within Estonia. Some of the research areas that are covered by these organisations are:

- National energy strategy; taxation and pricing policy; sustainable energy and fuels; smart district heating systems – Tallin University of Technology
- Zero-energy smart buildings, including demand side management; wood structures and composites – Centre of Excellence for Zero Energy and Resource Efficient Smart Buildings;
- Bioenergy – Centre of Renewable Energy of Estonian University of Life Sciences;
- Fuel quality analyses – Estonian Environmental Research Centre.

Figure 4-2 Illustration of the different actors involved in the energy sector in Estonia



As illustrated above, some of the roles and responsibilities commonly allocated to energy agencies (see next paragraph) are divided across various ministries, government agencies and other organisations. While some division of responsibilities is inevitable, there are opportunities to streamline the knowledge-management related to energy. The main role of an energy agency would be to develop the knowledge base that the government could use to inform its new policies, but also to support the authorities in implementing energy policies and energy schemes, and to coordinate consultations with local communities. Additionally, the option to give the agency responsibilities related to climate should be considered (therefore, creating an energy and climate agency), such as developing knowledge related to mitigation and adaptation, provide data to support the development of carbon reduction policies beyond the energy sector, and support in generating public support for climate policies across all sectors.

4.3.3 *Recommended actions – short term*

- **1D. Set up a nuclear regulator**, which should be able to guide Estonia to comply with the various EU and international nuclear conventions and oversee the involvement of private investors. A nuclear regulator will be a necessity in case of implementation of a scenario that relies on nuclear energy to achieve the decarbonisation targets. However, a nuclear authority could be initiated also in scenarios that do not exclude the emergence of nuclear energy, or in scenarios that foresee intensified nuclear collaboration with neighbouring countries.
- **1E. Review the mandate of the Estonian National Regulatory Agency (NRA)**, to include more explicitly the regulation for decarbonised and renewable gases. The regulation of transport infrastructure for hydrogen and CO_2 is indeed necessary in the scenarios that rely on CCU and renewable gases, but it is an action that could be initiated also in the other scenarios. The NRAs of the Baltic states should also closely cooperate in view of harmonising regulatory practices to further facilitate cross-border electricity trade and procurement of ancillary services, and to enable the realisation of joint hybrid offshore wind energy projects.
- **1F. Set up an energy and climate agency**, in charge of supporting the deployment of the selected pathway.
  - In collaboration with the National Regulatory Authority (the National Competition Authority), the agency could support the (or take charge of) administering the infrastructure planning process, overseeing the development plans of gas and electricity (and heating) network assets, monitoring of national energy and climate targets, issuing and managing grants, initiating and coordinating energy research, and dealing with stakeholders more in general;
  - The agency may also be charged with supporting other government objectives in the energy field, for example concerning energy efficiency and GHG emissions;[100]
  - The Energy Agency could support the function of the ‘Single Point of Contact’ for relevant planning applications and have regional offices (where possible, these could be integrated with one-stop shops for citizens and small developers) so that they can also provide support to local administrations during planning processes;
  - The energy agency could be responsible for the role of coordinator for the conflict solvers group. Alternatively, the agency could be in charge of an ombudsman role, in charge of arbitering disputes between developers and local communities.

[100] See links to European agencies with a similar mandate here: https://enr-network.org/members/

1G. **Increase cross border cooperation** (or transfer this competence from the Ministry) to facilitate cooperation with the other Baltic states (on the model of NSEC countries[101] and of the cross-country working groups). The scope of the increased cooperation could be extended to cover energy technologies such as nuclear energy and CCU, with the aim of exploring opportunities for co-investing in these technologies. For example, in a scenario where the nuclear option is abandoned, an agreement can be sought with Finland to make use of their nuclear expertise and capability. Other areas for cross-border cooperation may include cybersecurity, electricity interconnection capacity extensions, sharing electricity capacity reserves and storage. For these domains, close cooperation with the NRAs and TSOs will be necessary.

4.4 Action set 3: New framework for investment risk reduction instruments

Criteria		Notes
Costs	Variable	
Financed via	Options available	Largely the energy bill, but some elements may be financed via general taxation
Complexity	Medium	
Stakeholders involvement	Low to Medium	
Implementation	Short term	

Relevance for different pathways

RES + Storage	*Nuclear*	*CCU*	*RES GAS*	*AT*	*AT-NIMP*	*AT + 1000*
xx	xxx	xxx	x	xx	xx	xx

Investing in zero carbon electricity generation carries more risks than traditional sources. These risks can be grouped into market risks related to the (usually) higher capital intensity of renewable electricity projects (compared to high OPEX for fossil fuels fired power plants) and the intermittency of most renewable electricity generation installations (exposing them to higher price risks), and technology risks, which are in general also higher for RES projects.

Reducing market risks

Reducing the risks for developers can be achieved with a number of mechanisms:

- **Feed-in Tariff premiums** (FiTs): with this type of scheme the power generator receives on top of the market price an additional payment, which can be fixed or variable depending on the market price. **Contracts for difference** (CfDs) are a particular type of variable premiums, where the generator receives an additional payment when the market price is below a certain threshold (lower limit) and pays back the difference when the market price is above the upper limit. CfDs ensure a stable income to the generator, but limit the "upside", i.e. the revenue the generator can make when the price increases. In this respect, it is fairer than a price floor for the consumer.
- **Fixed price**: the power generator has a long-term contract with a supplier, trader or end-user that ensures the sale at set conditions (as opposed to market conditions) of all or part of its output. A common form of this instrument are Power Purchase Agreements (PPAs).
- **Price floor**: the power generator receives a premium on top of the wholesale price when this is below a certain threshold. This means that the generator has a minimum income guaranteed, but can make substantially higher return when the wholesale price is high.
- **Green Certificates and Guarantees of Origin (GO) markets**: renewable electricity generators are able to sell their green certificates and/or GOs, allowing them to increase their revenues.

[101] Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden

This instrument is often related to an obligation scheme or to a supply contract for green electricity, so that there is an effective demand for green certificates and/or GOs.

Reducing other risks

State guarantees are in some cases considered an appropriate tool to protect investments against sovereign risks, i.e. risks associated with a change in government policy. For example, regulatory risks, changes in the tax treatment, termination clauses. These risks are bigger for technologies with longer payback period (e.g. nuclear, infrastructure investments). A state guarantee reduces the risks for the project developer; it facilitates access to funding, and reduces the financing cost.

There are many options to finance the different mechanisms proposed. Usually:

- Market risk reduction instruments are financed by a levy on the energy bill, usually the electricity bill. However, some Member States are considering moving the levy for renewable electricity to the natural gas bill, as this would further encourage the switch from fossil gas to electricity or to renewable gas. Some Member States finance part of the RES support via the state budget (taxpayers). In the case of green certificates, GOs and fixed price contracts (PPAs), these are financed by market actors that purchase them (including public actors);
- State guarantees are financed by the general budget (i.e., the government signs the guarantee and is responsible for the pay-out). This is because, in general, guarantees are set to mitigate political and regulatory risks. In Estonia, Estonian Business and Innovation Agency | KredEx (Kredex from now on in the document) provides this type of guarantees, but currently their credit limits are too low to support the investments required for the pathways considered.

The current spot and forward electricity prices in the Baltic market are high enough to cover the investment and operational cost of most renewable electricity technologies. In technical terms, this means that the Levelised Cost of Electricity[102] (LCOE), assuming an average return on investment, is lower than the wholesale price, which in turn means that investments in most technologies are at present likely to have a positive return for investors. Yet, investors' risk perception in Estonia is currently high, which increases their required return on investment, pushing up the LCOE and making investments less attractive. Based on these considerations, Estonia should consider a specific support scheme that reduces investment risk but that has no cost for the consumer (or state budget) if the wholesale electricity prices remain high. Consumers (or tax payers) would have to support these investments only when wholesale prices would substantially decrease, but if this is the case consumers should be able to bear this cost.

4.4.1 Overview of renewable electricity support schemes in EU

EU Member States have set up various schemes to support renewable electricity, via Feed-in tariffs (FiTs), Feed-in premiums (FiPs); Green Certificates (GCs) and Investment grants. In 2019, EU Member States supported renewable energy with €78 billion of subsidies, of which €61 billion was in the form of FiTs and FiPs.[103] Across Member States, support for renewable technologies varies substantially according to the country. For instance, countries with higher solar potential, such as Greece, Italy and Spain, spend more for solar energy, whereas colder countries with a lot of woodlands, such as

[102] The average net present value of the cost of generating electricity for a given plant over its lifetime, including returns over the initial investment.
[103] European Commission, Enerdata & Trinomics (2021). Study on energy subsidies and other government interventions in the European Union. Available at: https://op.europa.eu/en/publication-detail/-/publication/be5268ba-3609-11ec-bd8e-01aa75ed71a1/language-en#

Estonia, Finland and Latvia, provide more support for biomass. Nordic countries often subsidies mostly onshore and offshore wind.

A recent CEER report[104] provides an overview on how EU Member States are financing renewable electricity generation projects. It shows that the majority of EU Member States finance their support schemes via the electricity bills, although Denmark, Luxembourg, France and Malta use also (or exclusively) general taxation or other funds. The report also shows that most countries are moving towards FiPs awarded via auctions. The weighted average support premium (on top of the market price) amounted to €98/MWh in 2019. This average support level is substantially higher than in Estonia (€53.7/MWh). Similarly, considering the cost of RES support over total gross electricity generation in 2018, public support in Estonia amounted to €6.71/MWh, compared with an average of €19.12/MWh in the EU (Table 4-4). Estonia's support per MWh is also much lower than in the other Baltic States.

Table 4-4 RES electricity support per unit of gross electricity produced in 2018, Baltic States and EU28

Country	RES electricity support expenditure (MEUR)	Gross electricity produced (TWh)	RES support per unit of gross electricity (EUR/MWh)
Estonia	83	12	6.71
Latvia	95	7	14.19
Lithuania	84	4	24.04
EU28	60,080	3,382	19.12

Source: CEER (2021). Status Review of Renewable Support Schemes in Europe for 2018 and 2019. Available at: https://www.ceer.eu/documents/104400/-/-/ffe624d4-8fbb-ff3b-7b4b-1f637f42070a

Estonia has, as of 1 January 2019, changed its support policy for renewable energy.[105] The fixed support level per MWh for new renewable electricity producers was abolished and replaced by an auction-based support system. An exception was granted to small producers (< 50 kW); this exception was valid until the end of 2020. The new scheme is in line with the Commission's state aid guidelines and the market principles. In the new system, project developers compete in a *reverse auction*, in which the qualifying RES projects with the lowest price are selected to receive FiPs.[106] The new premium is also a *sliding* scheme, where the premium starts at €53.7/MWh, and reduces if the average electricity price increases above €39.3/MWh and reaches zero if the average market price is above €93/MWh, which reduces the risk of over subsidisation. However, some RES developers argue that the auction system favours state-owned RES companies and solar energy over wind power, despite the scheme being technology-neutral.[107] A similar scheme has been launched in Lithuania.[108] In 2019, Latvia's feed-in tariff system was suspended, because of reported cases of fraud. Most other EU Member States have also feed-in schemes, such as:

[104] CEER (2021). Status Review of Renewable Support Schemes in Europe for 2018 and 2019. Available at: https://www.ceer.eu/documents/104400/-/-/ffe624d4-8fbb-ff3b-7b4b-1f637f42070a

[105] European Commission (2020). State Aid: Commission approves amended Estonian scheme worth €450 million to support production of electricity from renewable sources. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2454

[106] IEA (2019). Estonia Amendments to the Electricity Market Act establishing reverse auctions and sliding premium. Available at: https://prod.iea.org/policies/6545-estonia-amendments-to-the-electricity-market-act-establishing-reverse-auctions-and-sliding-premium

[107] European Climate Foundation (2022). Auctions' support scheme: schedule and conditions not fully inclusive in Estonia. Available at: https://resmonitor.eu/en/ee/barriers/312/

[108] ICIS (2019). Power perspective: Lithuania announces redesigned renewable energy auctions. Available at: https://www.icis.com/explore/resources/news/2019/09/12/10416921/power-perspective-lithuania-announces-redesigned-renewable-energy-auctions/

- **Netherlands**: The Dutch FiP scheme (SDE++) is based on carbon emissions avoided instead of the renewable energy production.[109] Priority is given to the projects with the lowest cost per avoided tonne CO_2 emissions.
- **Italy**: The Italian FiP is based on the difference between the base feed-in tariff and zonal electricity prices.[110] This scheme allows to account for regional differences in electricity supply and demand.
- **Poland**: a FiP scheme which compensates generators for unused electricity (i.e. not self-consumed) from biogas or hydropower installations installed for own consumption.[111] The premium equalises the negative balance caused if the price for unused electricity is lower than the price in the approved declaration.

4.4.2 *Actions already started*

There are a number of actions already planned and started by the Esotnian government:

- 450 GWh new renewable electricity projects auction in 2022[112];
- 650 GWh auction in 2023, also opened to existing installations;
- Mandate for all central government divisions to procure only green electricity via PPAs (100 GWh per year).

4.4.3 *Recommended actions:*

3A. Power Purchase Agreements (PPAs) between RES producers and suppliers, traders or end-users can be an efficient instrument to reduce the market risks for RES developers and facilitate access to financing. The European Commission has recently concluded a consultation on how to overcome key barriers to implementing renewable energy projects (see section 4.2.3). The staff working document includes guidance on facilitating renewable energy purchase agreements.[113]

To facilitate the use of PPAs it is recommended to:

- Issue standardised contracts (template) that can be easily adapted by the concerned market parties;
- Promote actions to aggregate end-users' demand in order to reduce transaction costs and open the PPA instrument also to end-users that would not be able to participate on their own;
- In order to support the uptake of PPAs by all potential organisations, the conclusion of PPAs should be enabled also for organisations with a poor credit rating. This could be achieved by means of a guarantee system provided by Kredex. A similar guarantee could be available for aggregated users;
- Extend the obligation of procuring electricity via PPAs to all public and government-owned organisations;
- Communicate more effectively the benefits of PPAs, for example their role as a market-risk reduction mechanism: consumers that sign long-term PPAs are less exposed to the volatility of the electricity prices;

[109] RVO (2022). Stimulation of sustainable energy production and climate transition. Available at: https://english.rvo.nl/subsidies-programmes/sde
[110] DLA Piper (2018). Energy Investment in Italy. The Legal Perspective.
[111] European Commission (2019). Feed-in Premium. Available at: http://www.res-legal.eu/en/search-by-country/poland/single/s/res-e/t/promotion/aid/feed-in-premium/lastp/175/
[112] Three separate 5 GWh auctions were held.
[113] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13334-Renewable-energy-projects-permit-granting-processes-power-purchase-agreements_en

- Provide incentives for businesses that opt to make use of PPAs for their electricity procurement. This may require the setup of a strong Guarantee of origin system.
- In the long term, consider options to make use of PPAs mandatory on all business above a certain size.

PPAs may be an efficient instrument in every pathway and could contribute significantly to enabling investments in new renewable electricity generation capacity, although on their own, they will be insufficient to stimulate new projects development. Essentially, if developers have the opportunity to sell a large share of their generation via PPAs, they are exposed to lower market/price risks and may hence have access to finance at lower interest level, which would reduce the required support via other schemes.

3B. Amend the current renewable electricity auction scheme. A revised scheme could maintain the reverse auction system and still be tied to output (MWh) rather than capacity (MW), as this makes it easier to control the costs. However, an amended scheme could be based on:

- a FiP (Dutch scheme). In this case the remuneration is equal to the difference between the base rate and the correction amount. The base rate is equal to the production costs of renewable electricity while the correction rate is the market price of renewable electricity. Both the base rate and the correction rate would be technology dependent, but the auction is open for all technologies, and the most cost-efficient projects across all technologies are selected;
- A CfD scheme (UK scheme). It has the advantage of limiting the market risks for developers and investors (as it guarantees a minimum electricity price) while at the same time avoids excess profits in case of high wholesale prices (claw back clause). During periods of high electricity prices, as it is the case at the beginning of 2022, generators would pay back revenues above strike price into a fund, which will then be used to support generation during periods with low market prices. For pathways where a specific technology should be supported (e.g., offshore wind), dedicated “budgets” should be created.

A maximum remuneration limit[114] would remain in place, but this may be increased in cases where technology-specific budgets or base rates are created.

3C. Move all or part of the funding for renewable electricity to the fossil gas bill or to other funds. These funds could be replenished via general taxation or via other levies, for example environmental levies or by using revenues from the EUA auctions (ETS). This is in line with the advice from the European Commission[115]. However, according to ACER[116], the average Estonian electricity bill for households was in 2020 among the lowest in Europe (at €483 per year) of which 9% (equivalent to €40) was used to finance RES, compared to an EU average of 13.5%. This suggests that there may be still room for increased RES support via the electricity bill, although this approach may not be feasible in the short term given the current high energy prices due to the international situation.

3D. Extend the current size of state guarantees provided by Kredex and develop a broader framework for government guarantees, so that when the need arises investors know what support they can expect from the Estonian government (i.e., which risks can be shared with

[114] Difference between bid price and market price. Current maximum is €20/MWh
[115] See: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0660&from=EN.
[116] https://extranet.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Monitoring%20Report%202020%20%E2%80%93%20Energy%20Retail%20and%20Consumer%20%20Protection%20Volume.pdf

the Estonian Government, and at which conditions). State guarantees will in particular be needed for technologies with higher risks and longer payback period (e.g. nuclear, CCU).

3E. **Public co-investing and sharing risks**: the government or Estonian Central Bank could buy green bonds issued by project developers or to signify public interest and lower the risks. In some cases, joint-ventures or PPAs for energy infrastructure investments could be setup.

Supporting actions:

Ensure consumers (in particular vulnerable households) are not excessively affected by high electricity bill resulting from renewable electricity generation support schemes are discussed in Chapter 4.7.

4.5 Action set 4: Support for RES for households and SMEs

<table>
<tr><th colspan="2">Criteria</th><th colspan="2"></th><th colspan="3">Notes</th></tr>
<tr><td colspan="2">Costs</td><td colspan="2">Variable</td><td colspan="3"></td></tr>
<tr><td colspan="2">Financed via</td><td colspan="2">Options available</td><td colspan="3"></td></tr>
<tr><td colspan="2">Complexity</td><td colspan="2">Medium</td><td colspan="3"></td></tr>
<tr><td colspan="2">Stakeholders involvement</td><td colspan="2">Low to Medium</td><td colspan="3">The main challenge is related to households’ resistance to renovation and to other energy savings installations in their homes</td></tr>
<tr><td colspan="2">Implementation</td><td colspan="2">Short term</td><td colspan="3"></td></tr>
<tr><th colspan="7">Relevance for different pathways</th></tr>
<tr><td>RES + Storage</td><td>Nuclear</td><td>CCU</td><td>RES GAS</td><td>AT</td><td>AT-NIMP</td><td>AT + 1000</td></tr>
<tr><td>xxx</td><td></td><td>xx</td><td>x</td><td>xx</td><td>xx</td><td>xx</td></tr>
</table>

4.5.1 Actions already started

- Currently, homeowners can sell excess electricity produced back to the grid operator, at a price equivalent to the hourly wholesale price, minus a margin that depends on producer’s conditions.

4.5.2 Recommended actions:

4A. **Set up an on-site small scale renewable generation support scheme, in combination with other actions to incentivise building renovation** (as part of actions associated with the Renovation Wave and in the NRRP). Concerning renewable electricity generation, the scheme would incentivise mostly rooftop PV installations, possibly coupled with home batteries. Concerning the installation of a PV system + battery, the scheme could provide support in different forms:

- A grant (or a fiscal incentive, e.g., a tax discount to be redeemed in the years following installation) covering the majority of installation costs (>80%), but recipients will not be rewarded for any excess electricity that they are not able to use (this will be fed back to the grid for free);
- Provide a FiP for exported electricity as a premium on wholesale price. This option would appeal to prosumers that are able to exploit daily variability in market price (prosumers);
- A grant would be financed via general taxation, while the FiP would be financed via the energy bill.

4B. **Allow households and SMEs to invest in remote renewable electricity generation,** in cases where they do not have the physical possibility to install the system in their premises. In order for remote installations to be built at cost-competitive prices, households should be allowed to purchase a share in large PV or wind farms planned to be built in the surrounding areas. Network charges associated with self consumption in these instances should be eliminated or substantially reduced.

Other actions aimed at households and SMEs are presented in Chapters 4.7 (involvement of the civil society) and 4.8 (other actions).

4.6 Action set 5: Power networks and infrastructure

Criteria		Notes
Costs	High	
Financed via	Bills and general taxation	Investments in network assets are financed via the network cost component in the energy bill in Estonia. This approach is recommended while it ensures cost reflectivity, but it affects disproportionately vulnerable users as the costs are reflected on electricity bills and the share of electricity costs in regular expenses is high for this consumer group y. Therefore, one of the recommended actions is to consider funding grid costs via alternative methods (i.e., either raising private finance or financing directly via general taxation).
Complexity	Medium	Actions proposed
Stakeholders involvement	Medium/High	
Implementation	Short/Medium term	The timing of implementation depends on the action and on the pathway.

Relevance for different pathways						
RES + Storage	*Nuclear*	*CCU*	*RES GAS*	*AT*	*AT-NIMP*	*AT + 1000*
xxx	xxx	x	xx	xx	xxx	xxx

Battery storage

Across Member States, the uptake of battery storage is supported mainly via financial measures (grants) and fiscal measures (tax rebates) in two different ways:

- Behind-the-meter batteries are generally supported for domestic and small renewable installations (generally PVs). These allow PV owners to better use the electricity they generate, reduce injection into the grid at peak generation times (to avoid negative or very low wholesale prices), help reducing peak load on the distribution network (avoiding grid reinforcements), and to actively participate – via aggregators - in the electricity spot market and market for ancillary services. The grants are generally awarded on per KW basis, and are often included in a scheme aimed at supporting on-site energy generation;
- Front-of-the meter batteries are aimed at providing flexibility and ancillary services. Battery operators are using this flexibility to balance their portfolio or offer it to other market parties via organised platforms to take benefit of the price volatility (intraday and balancing market). Ancillary services are procured by the SOs, increasingly via technology-neutral tenders.

Considering the different scenarios, battery deployment and associated costs are expected to be substantial:

Table 4-5 Capacity and associated investment cost for batteries in Estonia in 2030 and 2050

Pathway	Battery capacity (MW) by 2030	Battery capacity (MW) by 2050	Cost of capacity additions to 2030 (MEUR)	Cost of capacity additions to 2031-2050 (MEUR)
Reference	1645	8040	324	554
RES + Storage	2235	8617	441	593
Nuclear	1677	9288	331	654
CCU	1330	4571	262	263
RES GAS	860	5907	170	444
AT	1607	7970	317	550
AT + 1000	1616	7533	319	507
AT-NIMP	2075	7705	409	507

The estimates are based on an assumed investment cost of €0.2 million per MW in 2030 and €0.09 million per MW between 2030 and 2050.

Incentivising Demand Side Response (DSR)

A recent study prepared for DG ENERGY[117] concludes that the main barriers to the uptake of DSR are:

- absence of a clearly defined congestion management market at the electricity distribution level;
- lack of provisions to ensure demand side has non-discriminatory access to all existing electricity markets, including for ancillary services;
- lack of specific products reflecting emerging needs and the geographical delineation of such markets;
- lack of an institution responsible for operating the market platform,
- absence of adequate coordination between TSO and DSO, and
- the need to enhance integration of the demand-side markets with existing wholesale (day-ahead, intraday and balancing) markets.

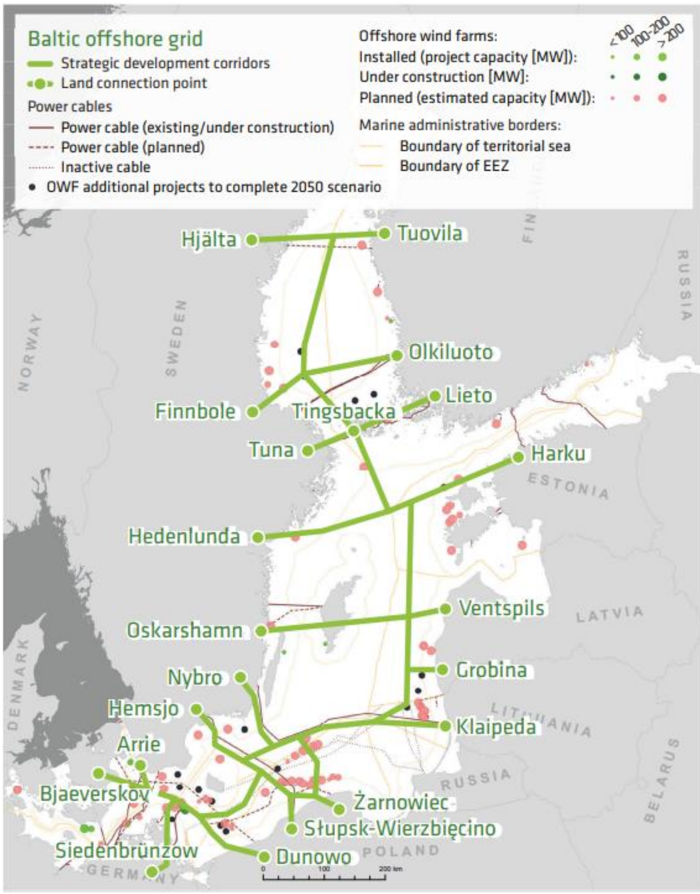
4.6.1 Actions already started

- Transition to synchronous operation with the frequency area of Continental Europe will be finished by the end of 2025.INTERRFACE, a demonstration project in Latvia, Estonia and Finland. It aims to facilitate competition between energy markets by linking wholesale, retail, balancing and new congestion management markets;[118]
- Since 2018, the Baltic countries are balanced as a single area.
- The Estonia NRRP includes an investment measure aimed at supporting 4 MW of battery storage by 2026;[119]
- Estfeed platform for flexibility, a platform for exchanging private energy metering data between Data Providers and Data Users;
- Elering launched an initiative to develop an offshore network connected to Latvia (Elwind), so that a 1 GW offshore wind farm can be deployed by private investors in the pre-developed

[117] https://asset-ec.eu/wp-content/uploads/2020/12/ASSET-EC-Regulatory-priorities-for-enabling-Demand-Side-Flexibility.Final_-1.pdf
[118] https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/SOC%20Reports/210957_entso-e_report_neutral_design_flexibility_platforms_04.pdf
[119] https://ec.europa.eu/info/sites/default/files/com-2021-625_annex_en.pdf

marina areas. There are plans to further expand the offshore network to open up new areas favourable to other cooperation programmes.[120]

Figure 4-3 The Baltic Offshore Grid concept 2050[121]



4.6.2 *Recommended actions*

4.6.2.1 Security of electricity supply

Batteries are expected to contribute significantly to the required flexibility and capacity in 2050 for the majority of scenarios (between 4.5 GW and 9.3 GW, or between 40% and 60% of installed capacity), based on an expected investment cost of €0.09 million per MW. Other flexibility instruments (Demand Side Management (DSM), pumped hydro) are expected to amount to only up to 0.6 GW in 2050.[122] Stakeholders indicate a major risk with the assumptions concerning batteries and their costs, namely that the increased world demand for the rare materials used to produce batteries will drive up the cost. Therefore, while setting up an ambitious strategy for the deployment of batteries, alternatives may have to be considered if resources' prices are not declining according to expectations.

5A. Develop a long term national flexibility strategy to timely provide the assets required to meet the electricity system's flexibility and stability needs. The strategy should address main policy barriers and identify where appropriate support mechanisms

[120] https://www.elering.ee/en/elering-will-start-surveying-potential-routes-connecting-estonian-latvian-offshore-network-onshore
[121] https://elering.ee/sites/default/files/public/elering_vka_2020_ENG_WEB.pdf
[122] Note that, as this report is being drafted, plans for a 500-600 MW pumped hydro to be opened in 2030 are progressing.

adapted to the different technological maturities.[123] It should also set indicative targets for a deployment of storage proportional to the amount of new renewables added to the power system. The strategy should be revised at regular intervals (e.g. 5 years) to validate to what extent cost and deployment trajectories are evolving according to expectations.

5B. Further improve the transparency of the Baltic balancing market. The Baltic TSOs collectively ensure the operability of the network with balancing, flexibility and ancillary services procured from the market. The three TSO take turns in managing the balancing responsibilities. There is however perceived lack of offers and competition on the Baltic market and a lack of transparency on the merit order of service providers and their actual costs of providing the service (i.e., how much different providers receive for the services they provide). An inefficient market raises the costs of entering to the market for potential new market participants and increases uncertainty and distrust between TSOs and other market participants. For example, a recent IEA report states that: *The role of the state-owned TSO in Estonia's balancing and reserve market is unclear. It appears to deploy its own gas-fired emergency reserve generating capacity (250 MW) on a regular basis (once or twice a month). However, there is a lack of transparency over the operation of this reserve, as it sometimes seems to be deployed to keep prices in check, and it is unclear if it is restricting the opportunity for other, potentially more cost effective, solutions. Moreover, the deployment of these plants for balancing may restrict the possibilities to integrate into the European balancing markets*[124]

It is recommended that the current Baltic balancing roadmap[125] is reviewed as soon as possible and actions leading to increased transparency and enhanced level of competition are streamlined. The importance of coupled and efficient balancing market is even more prominent due to the fact that recent results of the LFC study where preliminarily at least 30% of interconnector capacity needs to be reserved for balancing market.

5C. Improve the economic viability and access to finance for batteries deployment through various targeted instruments, given the importance of batteries to ensure the electricity system's flexibility and stability in Estonia in all scenarios:

- Setup dedicated loans and state guarantees specific for storage projects;
- Consider including storage as part of renewable electricity support schemes, both for residential and commercial-scale installations.
- Direct financial or fiscal support for battery projects should be provided for specific situations: new technologies, new applications, innovative solutions.

These actions should be coordinated by the ministry of economic affairs and communications.

5D. Create a DSM framework to increase uptake and increase participation in the Baltic market for flexibility. Elements to consider include the definition of the role of aggregators, the implementation of time-of-use grid tariffs and supply contracts with

[123] https://op.europa.eu/en/publication-detail/-/publication/a6eba083-932e-11ea-aac4-01aa75ed71a1
[124] https://iea.blob.core.windows.net/assets/21965e0d-c9a9-4617-b1ad-5b4539d91ad7/Estonia_2019_Review.pdf
[125] https://elering.ee/en/regional-balancing-cooperation#tab1

variable commodity pricing linked to spot prices. A recent report published by the European Commission[126] proposes a long list of recommendations to address the main barriers concerning the customer perspective, market access, product design and market processes and other technical aspects. In particular, the process to define the appropriate framework should involve the Central government, the TSO, energy suppliers and other stakeholders participating in the electricity market.

5E. **Other actions to support storage know-how and reduce barriers** to the uptake of new storage and flexibility technologies:
   - MKM and the TSO should seek active participation in research programs to improve performance of batteries (energy conversion efficiency, life-time, environmental impacts, use of primary resources, recycling), in particular support the piloting market readiness for some programmes;
   - MKM and the TSO should seek active participation in standardization initiatives of CEN/CENELEC/etc. for EV batteries (charging infrastructure, communication protocols) including for vehicle-to-grid applications. This is so the TSO can coordinate the rollout of roadside charging and the planning for charging points along the main routes.

4.6.2.2 Electricity network Infrastructure

5F. **Consider alternative approval models and funding mechanisms for key offshore infrastructure**. For the moment all grid connection costs are borne by the generation/consumption asset owner, which may be a barrier for projects coming online. There would however be wider benefits for consumers in relevant electricity markets if generation projects would be built (I.e. via more competitive markets and better prices). Thus socialising part of the connection costs would be reasonable. For example, transmission assets such as cables and substations could be extended towards development sites for wind parks in order to reduce connection costs for new developments, socializing part of the cost. Baltic and Northern area TSOs are currently advancing an initiative to develop an offshore grid in the Baltic sea[127], which would simplify the development of offshore wind farms and interconnection among the interested countries and could be eligible for co-funding on EU level as well. A similar approach was adopted in Denmark, where developers of offshore wind farm built following a tender procedure can connect to an offshore connection point, for with the TSO is responsible. In Germany a similar approach resulted in a zero-subsidy tender result. It is as yet unclear how the connection cost to an offshore gird would be allocated in Estonia, but allocating these entirely to the TSO will allow offshore wind to participate in the market at more competitive prices. Further, as the possible development sites will be dictated by the layout of the offshore grid, the TSO should carry out the relevant studies and support potential developers by making these plans available.

5G. **Transmission and interconnection infrastructure will have to be reinforced and built** in order to accommodate the increasing decentralised power generation capacities. According to the power network asset management model of Estonia (Regulated Asset

[126] https://ec.europa.eu/energy/sites/ener/files/documents/eg3_final_report_demand_side_flexiblity_2019.04.15.pdf
[127] https://www.elering.ee/en/tsos-agreed-strengthen-cooperation-future-offshore-grid-baltic-sea

Base), network reinforcement and extension costs are passed through to grid users via network charges proportional to their energy use. Table 4-6 estimates the increase in the electricity bill per dwelling (household) that will be necessary to cover the network reinforcement and extension costs. In reality, the effective increase on the energy bill may be slightly higher, as investments in assets are spread over a longer amortisation period, which means returns on invested capital has also to be paid. Also, the figures provided are based on total energy demand, while network charges are in general proportional to energy withdrawn from the network. It is also important to note that:

- Interconnectors may be built as commercial assets (merchant model). In this case their costs will be recovered via arbitration (price differences) on transmitted electricity, which ultimately will be charged to consumers but via an increased wholesale price (rather than via network charges).
- Interconnectors are usually recognised as Projects of Common Interest (PCIs), and therefore eligible to receive EU funding via CEF. The Harku to Riga interconnector was partly financed with €112 million of EU funds, equivalent to 65% of the total project costs. Obtaining such funding would reduce substantially costs for final users.

Table 4-6 Estimated impact on bills of transmission network reinforcement and extension actions

Pathways	Transmission investment (EUR)			Network cost (EUR/MWh demand[128])			Cost per dwelling (EUR/year)[129]		
	2030	2040	2050	2030	2040	2050	2030	2040	2050
Reference	10.2	16.5	125.8	0.09	0.13	0.79	0.32	0.44	2.75
RES + Storage	73.9	148.1	133.0	0.72	1.31	1.02	2.51	4.59	3.58
Nuclear	-	71.0	158.7	-	0.63	1.22	-	2.20	4.27
CCU	18.8	54.1	62.0	0.18	0.48	0.48	0.64	1.68	1.67
RES GAS	8.7	18.8	113.4	0.08	0.17	0.87	0.30	0.58	3.05
AT	9.1	18.2	128.1	0.09	0.16	0.99	0.31	0.56	3.45
AT-NIMP	58.5	16.7	60.1	0.57	0.15	0.46	1.99	0.52	1.62
AT + 1000	10.0	6.8	138.4	0.10	0.06	1.06	0.34	0.21	3.73

4.7 Action set 6: Involvement of the civil society (to enhance public acceptance of energy infrastructure projects)

Criteria			Notes			
Costs		Low				
Financed via		General taxation				
Complexity		Medium				
Stakeholders involvement		High				
Implementation		Medium term				
Relevance for different pathways						
RES + Storage	*Nuclear*	*CCU*	*RES GAS*	*AT*	*AT-NIMP*	*AT + 1000*
xxx	xxx	x	x	xxx	xxx	xxx

[128] Based on assumed total annual demand of: 11.3 TWh in 2030, 13 TWh in 2040, 16 TWh in 2050. As investment costs refer to a 10 year investment period, the consumption figures used to calculate the cost per MWh also relate to a 10-year period.

[129] Assuming 3500 kWh/year electricity consumption per household. According to Odysee-Mure, electricity consumption per dwelling in Estonia amounted to 3,000 kWh per year in 2019. Based on previous trends and current projections, electricity use per dwelling is expected to increase towards the EU average.

4.7.1 *Recommended actions:*

The active involvement of the civil society is essential in pathways that require large investment (e.g., renewable + storage), pathways that impose changes that would affect citizens directly (scenarios with large amount of solar PV), and pathways which focus on technologies that may raise public opposition (nuclear). Considering that citizen opposition to onshore wind already emerged for some ongoing projects, and that all scenarios foresee further deployment of onshore wind, sensitisation and citizen involvement become necessary in all pathways. To promote citizens involvement, it will be necessary to:

- **6A.** Plan an **information campaign to be launched together with a new renewable energy strategy**, explaining clearly the government priorities, actions and expected benefits for the local/national economy;
- **6B.** **Setup One-stop shops**, to provide information and guidance to local communities;
- **6C.** Promote and support the **local action groups**, to be involved since the early stages of renewable electricity sites selection;
- **6D.** implement actions to **facilitate the uptake of Citizens and Renewable Energy communities**,[130] for example showcasing success stories and lessons learned, and provide facilitation via local action groups.

4.8 Action set 7: other actions

This section covers actions that do not fall under any of the categories of Chapter 4.

4.8.1 *Recommended actions:*

7A. Support for vulnerable households

In all scenarios, it is likely that a substantial amount of the support for renewable electricity generation will be funded by levies on the energy bill, while actions to reinforce the power networks and ensure system adequacy/security of electricity supply are by default passed through to the consumers via the wholesale price or network charges. Across all scenarios, specific measures to support vulnerable households should be considered, but these should be provided via more sophisticated approaches than a hand out to help cover part of the bill. One-stop shops could be an appropriate channel to provide this support. A holistic set of measures to support vulnerable households should include:

- Providing training and guidance on how to access relevant government support (often, energy poverty is a consequence of poverty, rather than an independent issue);
- Providing support to facilitate energy consumption reduction, both via behavioural change and via access to grants to stimulate the installation of insulation and energy efficient equipment;
- Providing access to dedicated finance instruments to support investments in energy efficiency measures. One of the possible ways is to provide public guarantees to banks that finance households with low credit scores. The State

[130] https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en#:~:text=Citizens%20and%20renewable%20energy%20communities,-Through%20the%20Clean&text=The%20directive%20aims%20to%20improve,electricity%20system%2C%20as%20active%20participants

guarantee allows banks to offer loans at reduced interest rate and make investments more accessible.

- Energy suppliers should provide contracts with strong DSM incentives – i.e. substantially different rates according to time of the day and wholesale prices. If joined with smart-meters and in-home display, convenient tariffs would allow vulnerable households to reduce their costs.
- Identify overlaps with other actions included in this plan, so that any financial support to pay for the electricity bill is channelled to support renewable installations. For example:
  - vulnerable households could be given access to preferential contracts tied, via PPAs, to renewable installations, with government covering part of the cost if necessary.
  - Require that new onshore wind and PV installations provide a certain amount of low cost PPAs to local vulnerable households.

7B. Skills and knowledge development programme

- Setup training and certification schemes for professionals involved in the electricity infrastructure planning process (new environmental assessors, planners, project managers, revisors…), including both the commercial and the public sector side of it.
- Continuing studies of systems and technologies that could contribute to implementation of CCS and CCU, linked to the oil shale plants. These studies should involve local skills to the largest extent
- Fund additional R&D on renewable technologies and on options for bringing to market of promising energy storage solutions.
- Reducing fossil fuel subsidies is in general an important policy measure to facilitate the decarbonisation of the energy system and is typically an area for attention in reform plans. However, review of the latest energy subsidy inventory prepared for the EC, shows that subsidies to fossil fuel sources in Estonia are negligible.

Action plans by pathway

The chapters 7 to 11 of this document present a pathway-level view of the actions proposed in Chapter 6. Where possible, actions have been “calibrated” to the requirements of the pathways. For example, if a certain amount of a technology is required by 2030, and support should come via a risk reduction mechanism, the size of the measure per pathway and its costs would be estimated.

However, some actions should be implemented to the largest extent possible independently of the pathways chosen. These are:

- Actions to support the uptake of PPAs;
- Actions to facilitate the update of DSM;
- Actions to support vulnerable households. While the financial transfer to vulnerable households via current may vary per scenario (higher in scenarios with higher electricity prices), the majority of support for vulnerable families would come from other activities (guidance, access to new products, support with energy reduction measures) which should be implemented in any scenario.

The pathway-specific action plans will assume that these actions are implemented, and we will not provide further details unless there is some additional requirement related to that pathway. For example, consumer support in the renewable + storage pathway may need to be strengthened – as this is the scenario that requires higher investment costs (and likely higher consumer support).

Other actions are recommended across all pathways, although there are differences in how they are applied and in their costs, are:

- Streamline the planning process and dedicate additional administrative resources at local level;
- Creation of an energy agency, with local offices to support planning process;
- Put in place mechanisms to reduce the market risk of renewable installations (feed-in premiums);
- Include support for rooftop PVs in public schemes for building renovations;
- Develop a national flexibility strategy and Review the approach for balancing the electricity system;
- Support citizens’ investments in local renewables installations.

5 *RES + Storage* pathway

Key findings
• Major investments in offshore wind energy will make available a significant amount of intermittent electricity supply in Estonia at low variable cost. • Integrating offshore wind energy into the electricity system requires several complementary changes, including about 1.6 GW of new transmission capacity from Lääne-Eesti, including at least 1.2 GW interconnector to Latvia. • The offshore wind energy build-out enables Estonia to return to its historical position as a net electricity exporter by 2030, providing power mainly to Latvia and Lithuania. • Electricity prices are likely to increase after 2040 to be amongst the most expensive of the pathways. • Positive socio-economic impacts are expected, among the top-performing pathways due to high investments.

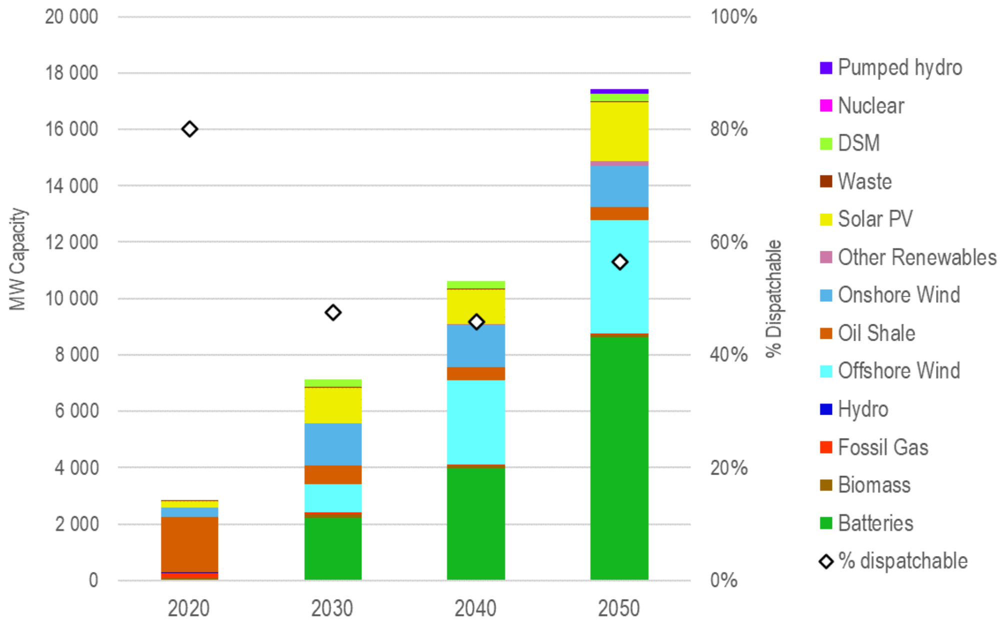
5.1 Pathway overview

The *RES + Storage* pathway evaluates a large deployment of offshore wind energy in Estonia: a total of 4 GW by 2050, or about 60% of the country's potential according to the most recent National Energy and Climate Plan (Government of Estonia 2019). The new capacity would be constructed in Lääne-Eesti and according to the modelling additional transmission capacity would be needed to transport the production to the users. Endogenous investments in storage and other renewables in Estonia are also estimated in the modelling.

5.1.1 Impact of the Renewables and Storage pathway on installed capacity and electricity generation

The *Renewables + Storage* pathway involves a significant increase in installed capacity of batteries, solar PV, onshore wind and offshore wind (Figure 5-1). In 2030, most of the capacity increase comes from batteries (+2.2 GW), onshore wind energy (+1.15 GW), solar PV (+1 GW) and offshore wind energy (+1 GW). In the same year, there is also an increase in capacity of DSM (reduction in peak demand of+261 MW). In 2040 there is an increase in offshore wind energy (+2 GW) and batteries (+1.75 GW). In 2050, there is an increase in capacity of batteries (+4.6 GW), offshore wind energy (+1 GW), solar PV (+0.85 GW), pumped hydro (+174 MW), other renewables (+138 MW) and biomass based electricity (+22 MW). These results point to seasonal complementarity between solar and wind – solar production is high in summer and low in winter, whereas wind energy production tends to be greater in winter. When these resources are not added together, the required storage capacity is higher.

Figure 5-1 Installed capacity by technology and percent dispatchable according to the *RES + Storage* pathway, 2020-2050, MW[131]



For this pathway, offshore and onshore wind energy are the most crucial sources for electricity generation, as well as solar PV (Figure 5-2). In 2030, there is a significant increase in electricity generation from offshore wind energy (+3.54 TWh), onshore wind energy (+3.12 TWh) and solar PV (+1.32 TWh). Table 5-1 provides an indication of how much additional electricity generation is needed in 2030 beyond the generation resulting from the auctions from 2019 to 2030. An additional 2.3 GWh of onshore wind energy 1 GWh of solar PV are needed. In 2040, there is a drastic increase in offshore wind electricity generated (+6.46 TWh) as well as an increase in electricity generated from oil shale (biomass fuelled) (+0.62 TWh). In 2050, most of the increased generation is from offshore wind energy (+2.55 TWh) and solar PV (1.03 TWh). In 2050, there is also an increase in electricity generated from other renewables (+0.19 TWh) and biomass (+0.07 TWh). From 2030 to 2050, the electricity generated from this pathway meets the domestic electricity demand (electricity produced within the country is greater than total electricity used).

131 Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Figure 5-2 Electricity generation by technology according to the *RES + Storage* pathway, 2020-2050, TWh[132]

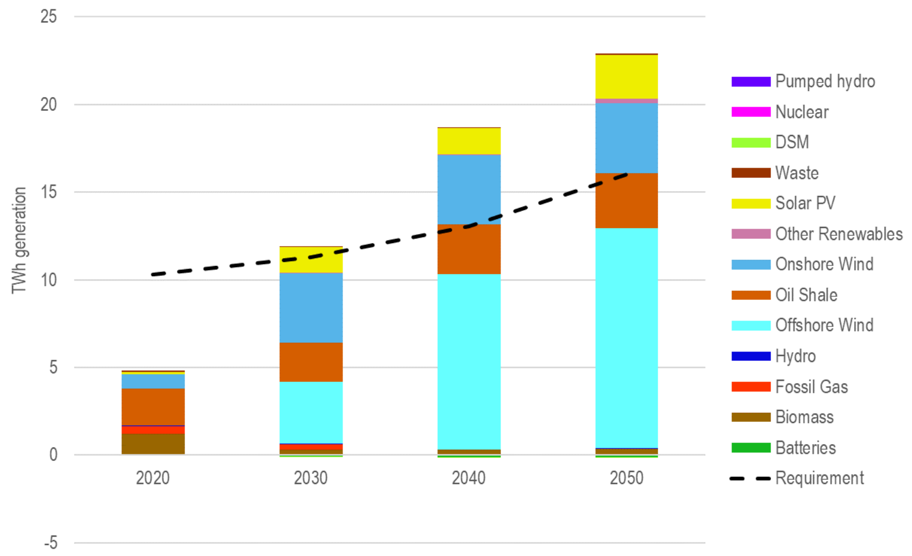


Table 5-1 Additional generation needed in 2030 beyond the generation from planned auctions in 2019-2023 according to the *RES + Storage* pathway, GWh

	Solar PV	Onshore wind
Total additional generation	1,325	3,120
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation needed	1,046	2,284

5.1.2 *Investment and infrastructure requirements according to the Renewables and Storage pathway*

The *Renewables + Storage* pathway requires a total of €11 billion in investments in generation and storage from 2020 to 2050 (Table 5-2). By 2050, the investment in Estonian offshore wind energy is about €7.75 billion, with €2 billion in investment by 2030, €3.8 billion in 2040 and €1.9 billion in 2050.

Table 5-2 Required investments by technology according to the *RES + Storage* pathway, 2030-2050, million EUR_{2020}[133]

Technology	2030	2040	2050	Total
Batteries	441	218	375	1,034
Biomass	0	0	46	46
Fossil Gas	0	0	0	0
Hydro	0	0	0	0
Offshore Wind	2,040	3,826	1,881	7,748
Oil Shale	0	0	0	0
Onshore Wind	1,264	0	0	1,264
Other Renewables	0	0	363	363
Solar PV	174	0	214	388
Waste	0	0	0	0
DSM	13	0	0	13
Nuclear	0	0	0	0
Pumped hydro	0	0	184	184
Total generation	3,932	4,044	3,063	11,040
Lääne-Eesti - Latvia	74	119	73	266
Lääne-Eesti - Põhja-Eesti		29	60	89
Total	4,006	4,192	3,196	11,395

[132] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[133] Source: Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

The need to transport onshore and offshore wind generation drives the need for two transmission reinforcements (Lääne-Eesti – Latvia and Lääne-Eesti - Põhja-Eesti) for a total 1,570 MW and an estimated cost of €355 million. This is the scenario with the highest network reinforcement needs[134].

5.1.3 Risk analysis of the RES + Storage pathway

According to the risk analysis carried out as part of this assignment[135], the *RES + Storage* pathway benefits of the highest support from stakeholders and is deemed moderately risky (average score 2.92 out of 5 for likelihood and 3.23 of 5 for severity for all risks considered. The highest risk perceived is associated with the access to the electricity system (such as inadequate funding for necessary grid infrastructure, stalling of electricity system development plans in neighbouring countries and with local opposition to new infrastructure). According to interviewed stakeholders, this pathway is considered less risky because the technology is available today at a competitive cost, the actions required to mitigate risks are relatively straightforward, and the pathway is in line with the course taken by other Nordic countries that are showing strong progress towards their decarbonisation targets (Germany, Denmark, Sweden, Finland, Norway). Finally, the pathway offers a clear strategy which is easy to communicate and has a positive track record in other EU countries.

5.1.4 Impact of higher biomass prices on the RES + Storage pathway results

Compared to the baseline pathway, higher biomass prices would reduce capacity additions electricity generation and net electricity exports, as higher biomass prices would push up average generation costs and make exports less competitive. The reduction in capacity additions would particularly affect batteries, solar PV and onshore wind energy. This is because biomass would primarily be used in converted oil shale plants and as costs of power from biomass fuelled oil shale increased it would be used less, reducing the flexibility of the system and the intermittent capacity that could be economically added would be reduced. The overall impact of these changes would also lead to lower electricity prices.

5.2 Actions

Given the predominant focus on offshore wind energy, short-term actions to facilitate the implementation of the pathway are focussed on facilitating and accelerating the permitting of offshore wind projects in the three main marine sites already identified, and ensure sufficient energy storage capacity becomes available. It is important to consider that this scenario requires the largest investments to 2050 (€11 billion compared to €3 billion in the *CCU* pathway, for example) for an average of €368 million per year. This means that a robust set of measures will have to be taken to support the necessary funding by Estonian or foreign investors. To attract this level of investment it will be necessary to:

- Show clear long-term government commitment to the technology;
- Provide risk reduction/price guarantee mechanisms at least until 2040s. The effective cost of these instruments for the consumer will vary depending on the wholesale electricity price;
- Streamline the infrastructure planning process, by simplifying some administrative steps and clearing some of the planning hurdles, in particular for large offshore wind energy sites.

[134] Distribution is not included in this analysis
[135] Deliverable 5, Risk analysis

Priority actions will be:

Offshore wind energy

- Streamlining of the planning approval process for offshore wind energy parks, via a simplified procedure and a dedicated task force at government level (to be moved to a dedicated energy agency when it becomes operational). The governmental task force will also coordinate with the TSO to ensure appropriate transmission capacities and connections are timely available.
- The planning approval process will to the largest extent possible facilitate the participation of international actors in the tenders, in order to ensure maximum competition. Elements to be considered include submission language, requirements for studies (e.g. EIA), accreditation of experts and eligibility criteria.
- Setup of technology-specific reverse auctions for offshore wind energy, to be held in 2024, 2026 and 2028 aiming to procure a total of 3.5 TWh of offshore wind energy (per year). Awarded capacities are expected to be operational by 2028, 2030 and 2032 respectively and to reach 1 GW by the early 2030s.
- Depending on market developments, including investment costs and energy and CO_2 emission prices, further offshore wind energy auctions may have to be set up between 2030 and 2040
- The TSO should further pursue its plans for an hybrid offshore grid in the Baltic sea, that optimally connects the offshore wind parks with the consumption centres and also contributes to markets' integration.

Onshore wind energy and solar PV

- Streamlining of the planning approval process for onshore wind energy and utility scale solar PV (and also utility scale batteries and storage), by simplifying the permit application and approval process and by providing additional resources and incentives for local administrations and local communities.
- Extension of the current technology-neutral auction scheme, to stimulate additionally 3.1 TWh of onshore wind energy by 2030 and 1.3 TWh of solar PV by 2030. Auctions should be held in 2025, 2027 and 2029.

Security of Supply and flexibility

It is considered appropriate to elaborate and publish a security of supply and flexibility strategy, which should be tailored to the expected deployment trajectory of wind energy and other renewables according to the auctioned capacities. The strategy would cover:

- Required transmission and interconnection infrastructure;
- Extended agreements with other Baltic states for increased cooperation on flexibility matters, in view of facilitating cross-border trade of (balancing) energy by market operators and cross-border procurement of ancillary services (including balancing capacity and energy) by TSOs, in order to enhance competition and markets' liquidity and transparency;
- Roadmap for deployment of storage solutions, which should include steps that market platform operators and the TSO and DSOs should take to facilitate the participation of storage in the spot markets and in the procurement of ancillary services (e.g. by enabling aggregation) .
- Government-funded pilot scheme for the award of grants to the deployment of innovative large-scale storage solutions and to flexibility providers. The Renewables + storage pathway foresees the most ambitious battery deployment by 2030 (2.2 GW, requiring €440 million of investment), which is unlikely to happen only relying on market forces. Options to support flexibility and storage solutions may include:

- Direct grant (set via administrative procedure) for the deployment of innovative technologies;
- Auction-based grants, awarded via reverse auctions to the most competitive bidder to support those technologies close to market-readiness;
- Inclusion of batteries support as part of other instruments (e.g. within a capacity instrument; or as part of the technology specific auctions, where each auction would have two pots: one for generation only, one for supporting generation + storage installations).

Consumer support

- This scenario focusses on a relatively expensive technology mix, which can cause higher electricity prices than in other scenarios. Therefore, actions detailed in Chapter 4.8.1 could be started by 2024.

The full list of actions recommended for implementation in the short and long term is presented below.

Table 5-3 Recommended actions

Ch 4 ref	Actions	Timing and responsibility	Further details
A-C	1. Infrastructure planning process • Streamline process, with particular focus on large projects • Setup of single contact point for the permitting process • Mandate the designation of suitable renewable energy areas in local spatial plans • Additional administrative resources at national level, dedicated to offshore wind energy deployment	Short term (by 2025) The review process will include national and local administrations and other interested bodies	Largely one-off administrative costs + some additional human resources dedicated to the process
B, C, D	2. Institutional reform • Setup of an Energy Agency, with a clear remit to facilitate and accelerate offshore wind energy deployment	Short term (by 2025) Setup by Central government as an independent body	Financed via the general budget
A-E	3. Investment risk • Technology specific reverse auction for Offshore wind energy. Procure at least 3.5 TWh by 2030 (including the 1.1 already planned) • Various actions to facilitate the uptake of PPAs • Increased funding and limits for Kredex guarantees • CfDs with separate budget by technology	Short term (by 2025) Action led by central government, should involve also institutional investors and Kredex	Loan guarantees financed via general budget and EU funds CfDs funded via the energy bill (€105-€209 million)
A	4. Financial incentives for RES investments by households and SMEs • On-site small scale renewable energy generation support scheme, linked to a buildings energy efficiency scheme	The action starts in the short term but likely to continue beyond	Financed via the energy bill (either directly as environmental levy or indirectly via supplier obligation) In the short term, financing via Recovery and Resilience fund also available
A - G	5. Power networks and infrastructure • Development of plans to reinforce transmission capacity from Lääne-Eesti (up to 3000 MW to Kesk-Eesti, up to 3000 MW to Latvia, up to 3000 MW to Lõuna-Eesti, up to 3000 MW to Põhja-Eesti) • Review the approach for balancing the electricity system and open the markets for flexibility	Ongoing process, expected to continue throughout the period interested Led by the TSO in cooperation with other Baltic TSOs	Financed largely via the current RAB model Merchant-model assets should be considered

Ch 4 ref	Actions	Timing and responsibility	Further details
A - D	6. Involvement of the civil society • Start-up support for Energy communities • Setup of one-stop shops to support vulnerable customers with energy efficiency advice and access to specific support schemes (for example, schemes to incentivise home insulation)	Short term (2025) Involves Central government, local government, and other relevant agencies (for example, an Energy and Climate Agency)	Relatively low cost, depending on implementation options
A - B	7. Other actions	•	•

5.3 Expected costs and revenues of short term actions

This section discusses the costs and (when relevant) revenues associated with the actions indicated in the previous sections for this pathway.

The *RES + Storage* pathway foresees large investments in offshore wind energy, batteries and transmission assets. These are all to be financed by private or public investors, while the government is expected to provide support either via direct grants or fiscal measures. The support can be financed by issuing a levy on the energy bill or by tax payers.

5.3.1 Estimating the cost of reverse auctions for renewable incentives

The total annual cost of a scheme to support offshore wind via a reverse auction depends on the type of support instrument chosen and on the wholesale electricity prices during the contracted years. Table 5-4 estimates the total amount of support required by different renewable technologies in 2030, in the case of unfavourable conditions (high cost) and the central case.[136] Assuming that any support scheme is designed to cut incentive payments to generators in case of high energy prices (as investors will be able to recover investment and operational costs based on market income), under the most favourable conditions the support required will tend towards zero. Assuming support up to the ceiling established by the schemes will be needed 50% of the time, the costs per unit may increase up to €0.012, which for the average household means around €41 per year. For organisations the total cost will depend on the amount of energy used.

Table 5-4 Subsidy paid out in 2030 and average cost to household consumers[137]

Technology	Subsidy paid out (€ million)[138]	
	High case	Central case
Offshore Wind energy	142	71
Onshore Wind energy	46	23
Other Renewables	1	0
Solar PV	21	10
Total	209	105
Cost increase € per kW[139] (assumed demand: 9 TWh)	0.023	0.012
Cost increase (€ per household per year) (assumed energy import from network: 3500 kWh)	81.37	40.69

[136] Estimated according to the methodology presented in section 1.3
[137] Source: author calculation based on Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis.
[138] See section 1.3 for the rates used to estimate the high and low case.
[139] Assumed unit cost increase if the cost of the renewable support scheme is spread across all users according to electricity imported from the network (i.e., excluding self-consumption). It is assumed subsidy costs will be spread over 9 TWh of demand as around 2 TWh are expected to be on-site generation and consumption (e.g., rooftop PV) that would not be metered and on which no levies will be placed).

It is important to note that this analysis does not include the effect of wholesale prices' levels, which are likely to be low under the *high* case and average under the *central* case. For the consumer, this means that the net effect will be lower than what is presented in Table 5-4.

The cost of network reinforcement are included in Chapter 6, while cost of other actions are largely administrative, or already part of other government policy (e.g., financial support to citizens).

5.4 Recommendations to reduce the negative and increasing the positive environmental, social and economic - including regional - impacts

The *RES + Storage* pathway is expected to have both positive and negative impacts on the environment, as well as a positive and negative impacts on the economy. All Estonian regions would be affected. Section 1.4 provides a detailed overview of the expected environmental and economic impacts and provides specific recommendations on how to mitigate negative impacts and enhance positive impacts.

5.4.1 Environmental Impacts of the RES + Storage pathway

The main negative environmental impacts are associated with the exploitation of marine areas, with some 60% of suitable marine areas to be dedicated to offshore wind energy. The construction of offshore wind energy farms can reduce water quality, decrease marine biodiversity, disturb seabed flora/fauna and create a noise disturbance for local wildlife. Also, wind energy turbines can represent a collision hazard for local bird populations. However, in the medium to long term, offshore wind energy farms have a positive impact on marine life by restricting fishing activities and creating artificial reefs.

Other relevant impacts from the substantial deployment of onshore wind energy, biomass and solar PV are:

- **Onshore wind** energy has similar negative impacts as offshore wind, such as noise disturbance, impact on local habitats and a collision hazard for birds;
- **Ground-mounted solar PV** may negatively impact local habitats and land use;
- **Biomass** is associated with deforestation, which could decrease biodiversity, cause soil erosion and reduce Estonia's carbon sink; biomass plants are also responsible for air pollution. Whilst power production from dedicated biomass falls to around ¼ of its 2020 level, the switching of oil shale plants to biomass in the 2030's sees total biomass use increase significantly, from 1.2 TWh in 2020 to 3.51 TWh in 2050. In order to limit negative impacts on forest coverage, it will be necessary to put in place adequate regulation and management of the use of forest timber for energy, including establishing clear limits to biomass quantities that can be extracted. For Estonia this may include either restricting exports or increasing the import of biomass, bearing in mind the requirements of the Renewable Energy Directive (Directive (EU) 2018/2001 (recast), currently being revised)[140].

The installation of battery storage may also have a negative impact on the local environment, particularly if battery waste is mishandled and disposed into the local environment. New transmission

[140] https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

lines between Lääne-Eesti and Latvia and between Lääne-Eesti and Põhja-Eesti will also have an environmental impact.

Overall the environmental impact of this pathway is rather small and manageable, and the pathway will significantly reduce GHG emissions compared to 2020 levels, consistent with the climate-neutral goal and other climate and energy targets.

5.4.2 Socioeconomic impact of the RES + Storage pathway

In the absence of financial and production capacity constraints, i.e. static economic modelling, the RES + Storage pathway is the best performing scenario from an investment point of view, with a total increase in economic output (production) of €13.8 billion between 2025 and 2050 (€5.8 billion direct and indirect and €8 billion induced). However, when taking demand and price effects into account, i.e. dynamic modelling, the Renewables and Storage pathway has only a marginally positive impact on GDP, with the strong positive impact on demand from high investments offset by higher electricity prices having negative impacts on the competitiveness of the wider economy. Average electricity prices are in this scenario higher than in the *Reference* pathway and increase over time from 2030 to 2050. In 2030, the average electricity price is €113/MWh (16% more than in the reference pathway). In 2050, the price increases to €139/MWh (35% higher than in the reference pathway). In sensitivity scenarios with higher biomass prices, or battery costs then prices are reduced as less capacity is installed (and lower investment and loan interest needs to repaid).

The estimated employment impacts are consistent with the economic modelling approach used, amongst the most positive in a static case, marginal in a dynamic case. Throughout the modelled time period, the *RES + Storage* pathway has a greater positive impact on disposable income, compared to the *Reference* pathway. Sensitivity analysis shows that the socio-economic impacts of this pathway improve in a case of higher biomass prices, as the systematic changes result in lower electricity prices and improved economic impacts.

Additionally, the transition to renewable energy sources will improve Estonia’s overall security of energy supply by largely eliminating the need for fossil fuel imports for power production in this pathway which is 100% renewable. This is strategically important and reduces exposure to global energy price swings. However, this requires additional investment in storage and flexibility technologies to ensure system reliability, and as noted above these require additional investments and can impact on affordability. It is also the case that there will remain some exposure to fossil fuel prices if others in regional markets (which contribute to price formation across the whole region including in Estonia) still use fossil fuels. This is evident currently where price increases for natural gas, which is the marginal power generation technology in many countries/markets, has driven electricity price spikes across Europe, and even in Estonia where natural gas usage for power is very low.

In terms of social impacts, onshore and (to a much lesser extent) offshore wind energy farms can be a discomfort for local communities due to the visual impact/noise disturbance. Mitigating measures should be explored and implemented. These investments should have positive social outcomes for local communities for example by: creating local jobs either directly or indirectly; or providing renewable energy generation based financial payments to the local municipality budget or community organisations; or providing improvements in local infrastructure and so on. The different measures and their impacts have been researched separately.[141] Additionally, the deployment of RES will reduce fossil fuel use and therefore reduce associated health risks from air pollution in the medium- to long-term. This not only reduces air pollution-related fatalities but also reduces the burden on the local health system.

5.4.3 *Main impacts by region*

Table 5-5 provides an overview of how the *RES + Storage* pathway would affect the different regions. Offshore wind energy farms are expected to be developed in the proximity of Lääne-Eesti, which would affect the local marine environment (mainly positive outcomes), and positively affect the local economy with the exception of the fishing industry. Onshore wind energy and solar PV farms would be developed in Lääne-Eesti, Põhja Eesti, Kesk Eesti,Kirde Eesti and Louna-Eesti region (in the latter region mostly solar PV). These would require land-use which would impact the local environment, however the land footprint is small, and the investments would have a positive impact on the economy.

Table 5-5 Overview of impacts of the *RES + Storage* pathway by region.

Region	Environmental impact	Socio-economic impact
Lääne-Eesti	moderately positive	moderately positive
Põhja Eesti	neutral	positive
Kesk Eesti	neutral	positive
Kirde Eesti	neutral	positive
Louna Eesti	neutral	positive

5.4.4 *Additional actions to reduce negative impacts and increase positive impacts*

The table below provides an overview of the recommendations on how to minimise negative impacts and increase positive impacts. More detailed recommendations for these types of impacts are provided in Chapter 1.4.

Table 5-6 Overview of recommendations for increasing positive impacts and minimising negative impacts by type of development and type of impact

Impact from	Type of impact	Recommendations
Offshore wind	Environmental	• Ensure careful design, monitoring and management of construction works to reduce disturbances to marine wildlife and maintain water quality; • Use proper materials to create a suitable artificial reef and prevent erosion; • Enforce fishing restrictions near wind farms; • Define a strategy to ensure the health of marine areas is maintained
	Social	• Construct offshore wind farms near industrial areas where the landscape is already altered to reduce additional visual disturbances for the local community
	Economic	• Ensure relevant stakeholders are involved in early consultations, such as fishing industry and maritime sector; • Adequate measures to ensure consumers are not significantly impacted by RES charges; • Ensure supply of highly skilled professionals in the wind energy industry
Onshore wind	Environmental	• Ensure careful design, monitoring and management of wind parks to avoid disturbing wildlife and their habitat
	Social	• Ensure onshore wind parks are not close to houses of local population

[141] ("Kohaliku kasu instrumentide analüüs", https://www.fin.ee/media/2723/download)

Impact from	Type of impact	Recommendations
	Economic	• Ensure supply of highly skilled professionals in the wind energy industry
Solar PV	Environmental	• Ensure careful design, monitoring and management of solar parks to avoid disturbing wildlife and their habitat
	Economic	• Ensure supply of highly skilled professionals in the solar energy industry
Biomass & Biogas	Environmental	• Adequate regulation and management of the use of forest timber for energy
	Economic	• Ensure that nationally there are enough highly skilled professionals in the bioenergy industry; • Adopt strict sustainability criteria to minimise negative impact on other industries
Battery storage	Environmental	• Requirements for proper disposal/recycling of batteries at end of life.
	Economic	• Modernise the electricity grid with smart technologies to enhance the development of battery storage; • Ensure supply of highly skilled professionals in the energy storage industry
Transmission & distribution	Environmental	• Plan construction of new transmission and distribution lines underground or underwater where technically possible; • Avoid unnecessary cutting of trees; • Reduce noise pollution via construction and technical solutions; • Strict requirements for maintenance and disposal of equipment (e.g. SF6)
	Social	• Impose restrictions on high-voltage lines near housing to reduce health impact; • Avoid overhead lines in populated areas to reduce visual impact
	Economic	• Ensure availability of highly skilled professionals in the T&D industry

5.4.5 *Further impacts from proposed actions and mitigating actions*

Among the proposed actions, the most consequential one for the Estonian consumer will be the support required by offshore energy wind farms and, to a lesser extent, by onshore wind energy and solar PV farms. The most likely outcome is that the interventions required to support these technologies will be quite low (in terms of direct financial transfers), because long term energy prices, driven by several factors such as technology costs and ETS price, are expected to remain high.

However, the amount consumers may have to pay via a levy on the electricity bill can be substantial under specific conditions, which means some vulnerable households may be severely affected, depending on how the schemes are set up. The pathway itself already includes several actions that will reduce the likelihood of this occurrence (increase in generation capacity and various flexibility options, including ambitious storage deployment).

To further reduce the risk of high consumer prices (this scenario already foresees prices 35% higher than the reference scenario by 2050), there are several options that can be considered:

- Financing some of the actions via general taxation or international funds, such as CEF (see Chapter 0 for financing options). For example, support of innovative storage technology;
- Enforcing a limit on the amount of support to renewable generation that can be charged to the electricity bill. Amounts in excess of this would be covered via general taxation;
- Raise all or part of the environmental levies on the natural gas bill. This would have the further benefit of incentivizing fossil fuel switch to electric heating, reducing emissions in the heating sector. This action should be considered once significant progress has been made in decarbonizing the power supply;

- Increase support to households and businesses for reducing their energy use. This includes soft measures such as one-stop shops, information campaigns, involvement in energy communities.

If a substantial part of the transition is still to be financed via the energy bills, a number of safeguards should be introduced:

- Energy efficiency actions should include financial support to most vulnerable consumers, for example via a supplier obligation scheme, by providing a direct rebate, or an exemption from environmental levies;
- Increase citizens' and businesses' participation in local energy generation. This will ensure that in case of high prices, they also benefit from higher revenues which will partly offset the bill.

5.5 Compatibility with the Estonian legal system and public perception

A strategy that focusses on offshore wind and that may increase energy costs will have to be clearly communicated to Estonian businesses and citizens, including its pros and cons. Given the substantial influx of private investments required, efforts should be made to show a clear government commitment to the main technology mix envisaged by the pathway (wind energy and storage).

Regarding the legality of **technology-specific subsidies**, the issue of EU competition rules on **state aid** needs to be considered. The issue of state aid is addressed in the Treaty on the Functioning of the European Union (TFEU), specifically in Art. 107. According to Art. 107(1) *'any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall (…) be incompatible with the internal market'*. However, the same article[142] also states that in some cases state aid can be compatible with the internal market. These are then subject to a review by the European Commission body on competition (DG COMP). Any new state support scheme should also be in line with the newly revised 2022 Guidelines on State aid for climate, environmental protection and energy (CEEAG).[143] These provide guidance on how the Commission will assess the compatibility of environmental protection, including climate protection, and energy aid measures which are subject to the notification requirement under Article 107(3), point (c), of the Treaty. The CEEAG thus broadens the scope of categories for investments and technologies that Member States can support in order to support the delivery of the Green Deal targets while not be in breach of the TFEU rules on the state aid and thus remain compatible with the internal market. Paragraph 16 on scope and aid measures to be covered by the guidelines mention '*aid for the reduction and removal of greenhouse gas emissions, including through support for renewable energy and energy efficiency'*[144] and specifically '*aid for energy infrastructure'*[145] as according to the definitions provision of the guidelines includes both onshore and offshore wind. Both of these types of can be considered to cover the actions listed under the pathway at hand. As such, no negative implications for this pathway are anticipated.

[142] TFEU, 107(3)
[143] COMMUNICATION FROM THE COMMISSION on the Guidelines on State aid for climate, environmental protection and energy 2022 (CEEAG) (2022/C 80/01)
[144] CEEAG, para 16(a)
[145] CEEAG, para 16(j)

6 *Nuclear* pathway

Key findings
• Deploys 900 MW of nuclear power in Estonia • A RES share of 78% in 2050 is the lowest of all pathways, however it remains a low carbon pathway • If nuclear capacity is used flexibly (modelled load of 65-70% over a year), then average electricity prices are the lowest of all pathways. However, imposing higher load requirements (e.g. 90%) displaces cheaper generation and increases prices considerably above most pathways.

6.1 Pathway overview

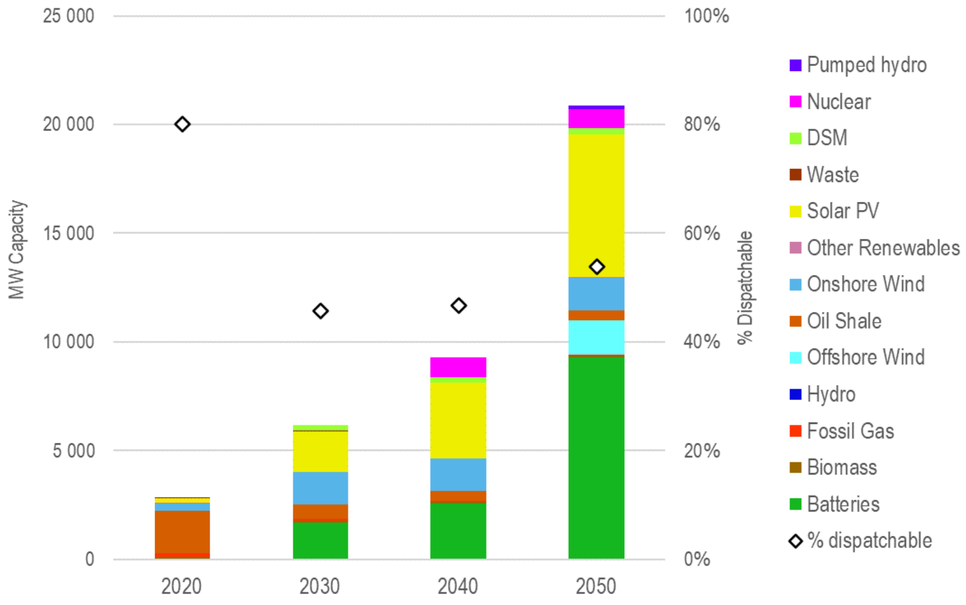
The *Nuclear* pathway simulates climate-neutral electricity production in Estonia given an addition of 900 MW of Generation III+ small modular nuclear energy capacity by 2040. Generation III+ nuclear technology is modelled to have high flexibility, allowing it to contribute to grid stability when paired with wind and solar.[146] Once constructed, the nuclear facilities are used flexibly throughout the year to facilitate solar and wind integration (rather than to maximise nuclear power output). Beyond the 900 MW of Generation III+ nuclear, the model is allowed to construct additional Generation III+ and Generation IV nuclear, storage, and renewable generation if it contributes to minimizing costs. The modelled pathway does not independently select further nuclear power, beyond the 900MW that is included to model the pathway.

6.1.1 *Impact of the Nuclear pathway on installed capacity and electricity generation*

The development of electricity capacity in the *Nuclear* pathway is mainly focused on development of batteries, onshore wind energy, solar PV, offshore wind energy and nuclear power (Figure 6-1). In 2030, there is an increase in capacity of batteries (+1.7 GW), solar PV (+1.6 GW), onshore wind energy (+1.15 GW) and DSM (+ 261 MW). In 2040, the model foresees a further increase in battery capacity (+ 0.88 GW) and solar PV (+1.6 GW), in addition to the installation of 900 MW of nuclear capacity which allows for a substantial expansion of low-cost solar power. In 2050, the capacity of batteries (+6.7 GW) and solar PV (+3.1 GW) increases, and new technologies are deployed: offshore wind energy (1.58 GW) and pumped hydropower (174 MW). By 2050, the percentage of dispatchable installed electricity capacity is 53%.

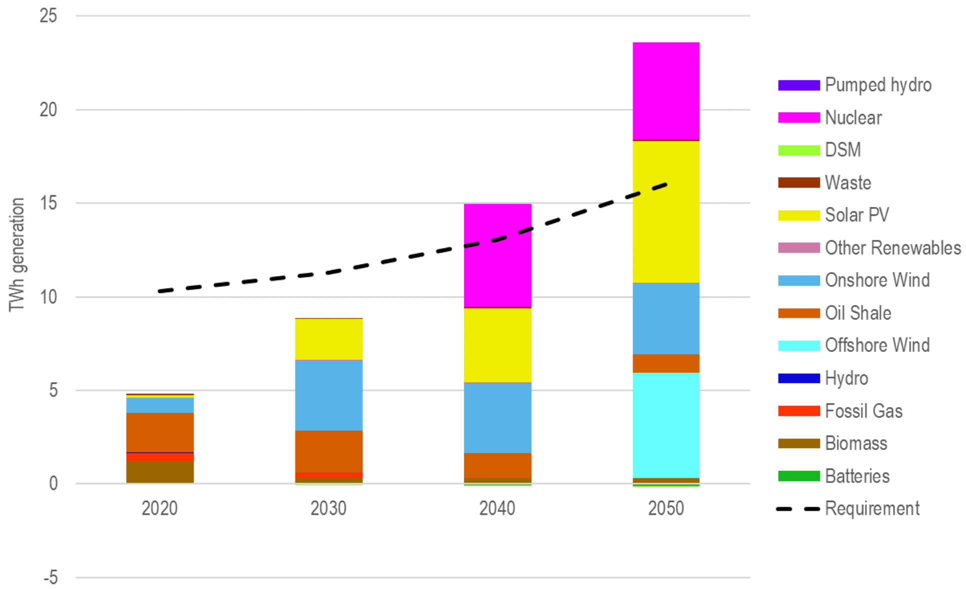
[146] Wald, M. (2021). The BWRX-300 Keeps It Simple—and Small—to Pair Well With Wind and Solar. https://www.nei.org/news/2021/bwrx-300-small-simple-wind-solar.

Figure 6-1 Installed capacity by technology and percent dispatchable for the *Nuclear* pathway, 2020-2050, MW[147]



While in 2030 Estonia is still dependent on electricity imports, by 2040, the *Nuclear* pathway is able to satisfy Estonia's electricity demand (see Figure 6-2), mainly by generation from nuclear and offshore wind energy. Compared to 2020, more electricity is generated in 2030 from onshore wind energy farms (+2.92 TWh) and solar PV (+2.04 TWh), as well as from other renewables (+0.03 TWh), oil shale (+0.1 TWh) and waste (+0.01 TWh). In 2040, there is a significant increase in electricity generated from nuclear power (+5.52 TWh) as well as solar power (+1.8 TWh), In 2050, power generation from nuclear decreases while generation from offshore wind energy (+5.6 TWh) and from solar PV (+3.59 TWh) increases significantly.

Figure 6-2 Electricity generation by technology in the *Nuclear* pathway, 2020-2050, TWh[148]



[147] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[148] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 6-1 provides an estimate of how much additional electricity generation would be needed in 2030, beyond the generation already supported by the five reverse auctions (see section 4.1.1). To align with the pathway, it will be necessary to generate additionally 2.1 GWh from onshore wind energy and 1.8 GWh from solar PV.

Table 6-1 Additional electricity generation needed in 2030 beyond the generation from planned auctions in 2019-2023 according to the *Nuclear* pathway, GWh

	Solar PV	Onshore wind
Total required electricity generation	2,041	2,924
Generation from completed and planned auctions (2019-2023)	279	836
Remaining additional generation	1,762	2,088

6.1.2 *Investments in infrastructure requirements for the Nuclear pathway*

The nuclear capacity added requires a total investment cost in generation of €9.3 billion by 2040 (Table 6-2).[149] In total, €9.34 billion of investments are required in generation and storage from 2020 to 2050. Most of the investment is needed after 2030, with the installation of nuclear, offshore wind and additional solar PV capacity.

Table 6-2 Required investments by technology according to the *Nuclear* pathway, 2030-2050, million EUR$_{2020}$

Technology	2030	2040	2050	Total
Batteries	331	110	544	985
Offshore Wind	0	0	2,966	2,966
Onshore Wind	1,264	0	0	1,264
Solar PV	369	440	789	1,597
DSM	13	0	0	13
Nuclear	0	2,329	0	2,329
Pumped hydro	0	0	184	184
Total	1,977	2,879	4,483	9,338
Lääne-Eesti - Latvia		71	158.7	229.7
Total	1,977	2,950	4,642	9,568

The *Nuclear* pathway requires an increase in transmission capacity of over 1 GW by 2050, for an estimated cost of €230 million.

6.1.3 *Risk analysis of the Nuclear pathway*

According to stakeholders surveyed in the risk analysis[150], the *Nuclear* pathway is one of the least preferred pathways and has the worst average score for all risks (3.52 out of 5 for likelihood and 3.83 out of 5 for severity of risks). Perceived risks in most of the categories of risks surveyed (technological, economic, societal and regulatory) are relatively high, and stakeholders are particularly concerned about delayed technology development, local opposition to new infrastructure, and local and national policies presenting barriers to implementation. Investors and proponents of renewable energy sources consider the main risk for committing to nuclear energy is

[149] New reactor designs (like the BWRX-300 considered in the model) will be deployed and tested in Canada in upcoming years, which will lead to further clarity on costs and operational profiles associated with the reactor type.
[150] Deliverable 5, Risk analysis

related to the fact that the chosen nuclear technology (SMR) is currently not available and is expected not to be commercially mature in the next decade. Furthermore, they believe that Estonia lacks the administrative capacity and skills to successfully run a nuclear programme. Nuclear technology also risks creating a monopoly, given the small size of the energy sector in Estonia and the average size of a nuclear power plant. According to representatives from the nuclear industry, the main risks for the nuclear pathway are subsidies to renewable energy (which may jeopardise the business case for nuclear) and the risk of the government deciding to retroactively tax windfall profits made by investors in nuclear energy.

6.1.4 Impact of operating nuclear power plants with a load factor of 90% on the Nuclear pathway results

Enforcing a 90% nuclear dispatch when modelling the *Nuclear* pathway reduces the total capacity of power technologies deployed (solar PV and battery capacities significantly reduced) but increases total electricity generated by 2050 due to additional nuclear power output. 90% dispatchable nuclear would lead to a significant increase in average electricity prices, ranging from 40-52% above the reference scenario. GHG emissions would also be higher than in the base *Nuclear* pathway. Enforcing high loads for nuclear is not recommended.

6.2 Actions

The deployment of nuclear energy will pose significant regulatory and organizational challenges to Estonia. The main assumption is that both the technology and at least part of the capital required (assuming electricity generation will be financed largely by private investors) will come from abroad. Generally, the reactor vendor assumes the technical and commercial risks associated with the construction phase; operation of the plant may also be contracted with international companies. However, the Estonian public administration will have to significantly develop its expertise in nuclear energy, covering areas such as nuclear safety, risk management, and nuclear policies.

The IAEA recently published a comprehensive report outlining the *Responsibilities and Capabilities of Owners and Operators*.[151] *Building a national position for a new nuclear power programme*, also from the IAEA, provides guidance to countries considering to establish a nuclear power programme for decision makers, energy experts, and other stakeholders.

A number of actions have already been started by the Estonian government and stakeholders:

- The first requirements concerning the development of nuclear energy in Estonia were set around 2010.
- Eesti Energia was put in charge of starting a nuclear programme that aimed at building a power plant of up to 1000 MWe, including permission to explore a suitable site. Explorations at Suur-Pakri Island confirmed the island was suitable for the development of a nuclear power plant.
- Since then, the technology choice has shifted towards SMRs, with several designs being taken into consideration. FERMI Energia is leading the work to identify concrete options for Estonia.
- In April 2021, the Government appointed a nuclear energy working group to analyse technologies and projects under development in other countries and identify the best option for Estonia. Also in 2021, a cooperation programme with the US was established.

[151] https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1867_web.pdf

Priority actions to continue the nuclear energy deployment are:

- Development of an Estonian Nuclear Energy Strategy;
- Setup of a Nuclear Authority, with a clear mandate and adequate power and resources to take important decisions concerning nuclear energy deployment;
- Development of a framework for adequate risk assessment and transfer were deemed appropriate, state support and the provision of state guarantees.
- Establishment of further cooperation channels with potential commercial and technical partners across the EU. For example, the Agency France Nuclear International (AFNI) helps interested countries to set up structures and systems to enable the establishment of civil nuclear programmes;
- Build the necessary skills in the public and private sectors, for example via setting appropriate training facilities and national training programmes. Exchange programmes with other countries that use nuclear energy (e.g. Finland) should also be established;
- Prepare early involvement of stakeholders and citizens, with the aim of creating public acceptance of the technology and confidence in the government's capability to manage the programme successfully. Dedicated campaigns should be targeted to communities more directly affected (those neighbouring the selected sites). This process was already started for the site initially selected (Suur-Pakri island).

Renewable electricity generation

Nuclear energy is not expected to contribute to electricity generation in Estonia before the mid-2030s, which means that investments in other technologies will have to be continued in the short term. The *Nuclear* pathway relies heavily on solar PV, onshore wind energy, and storage (batteries); actions should be undertaken to ensure these are deployed in sufficient capacities in the short term. Particular care should be put into the design and timing of supporting instruments chosen for wind and solar energy, as over subsidisation may affect the energy bill significantly and reduce the economic case for nuclear energy and other technologies. It is also important to consider the timing of the support to renewable energy technologies, ensuring support contracts end when nuclear capacity is expected to come online. If this is not the case, financial support may also have to be provided for nuclear energy, for example via a feed-in premium/Contract for difference mechanism. The latter option is chosen by the UK government to support the construction of Hinkley Point C. On the other hand, Olkiluoto-3 in Finland is built without government support, but TVO (the owner) states that the plant's profitability is being harmed by subsidized renewables.[152] However, Olkiluoto-3, similar to all other recent European nuclear construction also came in significantly over-budget and delayed, e.g. 11 billion euros v 3 billion original estimate, commissioning in 2022 v planned 2009.

Concerning the deployment of main renewable energy technologies (onshore wind, solar PV, offshore wind energy), priority actions should include:

- Streamline and speed up the planning process, focussing on onshore wind energy and solar PV (rooftop and ground-based).
- Award market-based support to new onshore wind energy, solar PV and other renewable technologies via new technology-neutral reverse auctions, so that by the late 2030s support contracts would expire (assuming 12-15 year contracts). In addition to the five completed and

[152] https://www.nucnet.org/news/renewable-subsidies-undermining-profitability-of-nuclear-in-finland-says-tvo

planned auctions (for a total of 1.1 GWh), a further 3.8 GWh of renewable electricity generation could be supported by 2030 according to this scenario.
- Given the expected high deployment of solar PV (1.9 GW by 2030, 6.6 GW by 2050):
  - identify additional suitable sites for rooftop and ground installations. These could include facades, parking spaces, transport routes and so on. Public buildings and publicly-owned facilities (including local administrations) should lead by example and consider these solutions together with any new refurbishment or new building work.
  - Introduce a regulation to mandate that all new buildings and buildings undergoing major renovation are equipped with solar panels.

Security of Supply and flexibility

The nuclear scenario is the scenario with the highest battery deployment in 2050 (9.3 GW). It is considered appropriate to elaborate and publish a security of supply and flexibility strategy, which should be tailored to the expected deployment trajectory of wind energy and other renewables according to the auctioned capacities. The strategy would cover:
- Required transmission and interconnection infrastructure;
- Extended agreements with other Baltic states for increased cooperation on flexibility matters, in view of facilitating cross-border trade of (balancing) energy by market operators and cross-border procurement of ancillary services (including balancing capacity and energy) by TSOs, in order to enhance competition and markets' liquidity and transparency;
- Roadmap for deployment of storage solutions, which should include steps that market platform operators and the TSO and DSOs should take to facilitate the participation of storage in the spot markets and in the procurement of ancillary services (e.g. by enabling aggregation) .
- State-funded pilot scheme for the award of grants to the deployment of innovative large-scale storage solutions and to flexibility providers. The *Nuclear* pathway foresees the most ambitious battery deployment by 2030 (1.7 GW, requiring €330 million of investment), which is unlikely to happen only relying on market forces. Options to support flexibility and storage solutions may include:
  - Direct grants (set via administrative procedure) for the deployment of innovative technologies;
  - Auction-based grants, awarded via reverse auctions to the most competitive bidder to support the technologies close to market-readiness;
  - Inclusion of batteries support as part of other instruments (e.g. within a capacity instrument; or as part of the technology specific auctions, where each auction would have two pots: one for electricity generation only, one for supporting generation + storage installations).

Additional considerations

The choice of a pathway that relies heavily on a technology that may be commercially unavailable for several years, and that has historically presented several challenges (cost, delays) for countries that are implementing it, requires Estonia to have a robust contingency plan in place. A Estonian Nuclear Strategy would have to establish clear milestones, that will trigger remedial actions where needed. The need to undertake short-term remedial actions is likely to be more expensive for the Estonian consumers or tax payers than opting for these actions in the first place, so it will be necessary to clearly assign responsibilities and liabilities to the stakeholders involved in the development of the nuclear programme.

Similarly, the reliance on vast battery capacity in 2050 (the nuclear pathway has the highest battery capacity of all pathways) exposes the scenario to specific risks associated with this technology, in particular the risk that battery prices will not decline in line with expectations, mainly due to the limited availability of raw materials.

Table 6-3 Recommended actions

Ch 5 reference	Actions	Timing and responsibility	Further details
A-C	1. Infrastructure planning process • Streamline process, with particular focus on developing a planning process for nuclear power installations; • Setup of single contact point approval process; • Mandate the inclusion of renewable energy in local spatial plans; • Additional administrative resources at national level, dedicated to offshore wind deployment	Short term (by 2025) The review process will include national and local administrations and other interested bodies	Largely one-off administrative costs + some additional human resources dedicated to the process
A	2.Institutional reform • Setup of a nuclear regulator, which is able to guide Estonia to comply with the various EU and international nuclear conventions and oversee the involvement of private investors; • Nuclear regulator to be in charge of expanding cooperation with nuclear countries.	Medium term (by 2030) The regulator will be an independent body setup by Central government	The body will be initially financed by the general budget, but it can be foreseen that regulated entity have to fund all or part of the Regulator's budget once they are operational
A-E	3.Investment risk • Various actions to facilitate the uptake of PPAs; • Increased funding and limits guarantees provided by Enterprise Estonia and KredEx • Technology-neutral CfDs	Short term (by 2025) Action led by central government, should involve also institutional investors and Kredex	Loan guarantees financed via general budget and EU funds CfDs funded via the energy bill (€39-78 million)
A	4.Financial incentives for RES investments by households and SMEs • On-site small scale renewable generation support scheme, linked to a buildings energy efficiency scheme, with focus on rooftop PVs in commercial and residential buildings	The action starts in the short term but likely to continue beyond 2030	Financed via the energy bill (either directly as environmental levy or indirectly via supplier obligation) In the short term, financing via Recovery and Resilience fund also available
A - E	5.Power networks and infrastructure • Development of plans to strengthen transmission capacity from Lääne-Eesti; • Review the approach for balancing the electricity system and open the markets for flexibility services	Ongoing process, expected to continue throughout the period interested) Led by the TSO in cooperation with other Baltic TSOs	Financed largely via the current RAB model Merchant-model assets should be considered
A - C	6.Involvement of the civil society • Start-up support for Energy Communities; • Setup of one-stop shops to support vulnerable customers with energy efficiency advice and access to specific support schemes (for example, schemes to incentivise home insulation); • Enhance public acceptance for new energy infrastructure	Short term (2025) Involves Central government, local government, and other agencies (for example, an Energy and Climate Agency)	Relatively low cost, depending on implementation options
A - C	7.Other actions • Setup of a nuclear development programme that covers: o Skills development; o Development of the nuclear supply chain;	Central government	Variable cost

Ch 5 reference	Actions	Timing and responsibility	Further details
	○ Defining government's role in the nuclear programme; • Building regulations to include mandatory rooftop PVs in new built and building renovations; • Research programme into alternative solar technologies and applications		

6.3 Expected costs and revenues

This section discusses the costs and (when relevant) revenues associated with the actions indicated in the previous sections for this pathway.

The *Nuclear* pathway also foresees large investments in solar, onshore wind and batteries, besides nuclear. These are to be financed all or in part by private investors, but the government will in this scenario provide support either via direct grants or by other instruments such as state guarantees. The state support will in this scenario be financed via a levy on the energy bill. Renewable energy deployment is less ambitious up to 2040 (compared with other pathways).

6.3.1 Estimating the cost of a nuclear programme

The estimated cost of investment in nuclear is €2,329 million in the mid- to late 2030s to build 900MWe of capacity. According to the financing option chosen, this cost could affect the public budget, and the government could also be partially responsible for cost overruns and for which there are significant risks, based on current European nuclear projects, in both probabilities of overrun (high) and size of overrun (x2-3 times or more). The assumed cost per MW of building nuclear generators used in the model are also significantly lower than assumptions used by the IEA[153].

Additional costs associated with the nuclear energy programme are:

- Administrative costs related to the setup of appropriate management and oversight bodies
- Costs to support the development of the whole nuclear supply chain (skills, processes, dedicated business and services).

6.3.2 Estimating the cost for renewable energy incentives

The total annual cost of a scheme to support solar PV, onshore and offshore wind energy, and other renewables via a reverse auction scheme depends on the type of support instrument chosen and on the wholesale price during the contracted years. Table 6-4 estimates the total amount of support required by different renewable energy technologies in 2030, in the case of unfavourable conditions (high cost) and the central case.[154] Assuming that any support scheme is designed to cut incentive payments to generators in case of high energy prices (as investors will then be able to recover investment and operational costs based on market income), under the most favourable conditions the support required will tend towards zero. Assuming support up to the ceiling established by the schemes will be needed for 50% of the electricity produced, the costs for an average household would be of around €15 per year. For businesses, the total cost will depend on the amount of energy used.

[153] IEA techno-economic cost assumptions for nuclear in the European Union list costs of between 4 500 – 5 100 USD/kW, translating to around EUR4.3 billion (assuming the midpoint value 4 800, a 1.1 exchange rate, and the 900MW installation). https://www.iea.org/reports/world-energy-model/techno-economic-inputs

[154] estimated according to the methodology presented in section 1.3

Table 6-4 Subsidy paid out in 2030 and average cost to consumers

Technology	Subsidy paid out (€ million)[155] High	Subsidy paid out (€ million)[155] Central
Offshore Wind	-	-
Onshore Wind	42	21
Other Renewables	1	0
Solar PV	35	18
Total	78	39
Cost increase € per kW[156] (assumed demand: 9 TWh)	0.009	0.004
Cost increase (€ per household per year) (assumed energy import from network: 3500 kWh)	30.33	15.16

It is important to note that this analysis does not include the effect of wholesale prices, which are likely to be low under the *high* case and average under the *central* case. For the consumer, this means that the net effect will be a net increase of less than what is presented in Table 6-4.

6.4 Recommendations to reduce the negative and increasing the positive environmental, social and economic - including regional - impacts

The *Nuclear* pathway is expected to have a potential negative environmental and social effects, but can have some positive economic impacts. This section provides an overview of the expected environmental and economic impacts associated with the deployed technologies, and specific recommendations on how to mitigate negative impacts and enhance positive impacts.

6.4.1 *Environmental impact of the Nuclear pathway*

The main risk of negative environmental impact for this pathway will be associated with the installation and operation of nuclear energy capacity. In the medium to long term, Estonia will have to ensure appropriate capacities and processes to deal with spent nuclear fuels and nuclear waste.

Although the potential impact of nuclear energy is very severe in case of a major accident, i.e. a Chernobyl or Fukushima type event could potentially render large parts of Estonia (and neighbouring countries) unsafe for habitation, the probability of such an accident is very low and in regular operation and storage conditions nuclear energy does not have significant negative impacts on the environment. To avoid that a severe accident would occur, strict regulation and management of nuclear power plants and the disposal of nuclear waste is critical. In 2021, the JRC published an extensive review[157] to assess nuclear energy generation under the “do no significant harm” (DNSH) criteria, considering the effects of the whole nuclear energy life-cycle. The assessment concludes that, while there are several risks associated with the normal operations of nuclear power plants, if these risks are appropriately managed, the environmental impacts are comparable to those of renewable energy sources. However, according to recent research[158], Small Modular Reactors (SMRs), e.g. the type envisioned for Estonia,will actually generate more (x2-30 times) radioactive waste than conventional nuclear power plants. According to the authors, “intrinsically higher neutron leakage associated with SMRs suggests that most designs are inferior to LWRs with respect to the generation,

[155]See section 1.3 for the rates used to estimate the high and low case.
[156]Assumed unit cost increase if the cost of the renewable support scheme is spread across all users according to electricity imported from the network (i.e., excluding self-consumption). It is assumed subsidy costs will be spread over 9 TWh of demand as around 2 TWh are expected to be on-site generation and consumption (e.g., rooftop PV) that would not be metered and on which no levies will be placed).
[157]https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210329-jrc-report-nuclear-energy-assessment_en.pdf
[158] https://www.pnas.org/doi/full/10.1073/pnas.2111833119

management, and final disposal of key radionuclides in nuclear waste". The nuclear technology assumed to be deployed in this pathway is SMR, which means likely increased costs of managing waste treatment and higher environmental negative impacts.

In addition to nuclear energy, offshore and onshore wind energy and solar PV will in this pathways also have an impact on the local environment:

- **Onshore wind** energy has similar negative impacts as offshore wind, such as impact on local habitat and a collision hazard for birds. However, onshore wind energy affects more directly nearby communities.
- **Solar PV** can also negatively impact the local habitat and, to a lesser extent, nearby communities (in terms of land use).
- The construction and decommissioning of **offshore wind farms** can reduce water quality, decrease marine biodiversity and disturb seabed flora/fauna. Also, windmills can be a collision hazard for local bird populations. However, offshore wind farms can also have a positive impact on marine life by restricting fishing activities and creating artificial reefs.
- The construction of **offshore wind farms** can reduce water quality, decrease marine biodiversity, disturb seabed flora/fauna and create a noise disturbance for local wildlife. Also, windmills can be a collision hazard for local bird populations. However, offshore wind farms can also have a positive impact on marine life by restricting fishing activities and creating artificial reefs.
- **Biomass** is associated with deforestation, which could decrease biodiversity, cause soil erosion and reduce Estonia's carbon sink; biomass plants are also responsible for air pollution. This pathway sees power production from dedicated biomass plants fall to around ¼ of its 2020 level, the switching of oil shale plants to biomass in the 2030's offsets this improvement, but this pathway makes notably less use of biomass than most of the other pathways, reducing risks to Estonian forests relative to them. Overall, generation from biomass stays roughly at the same level, going from 1.2 TWh in 2020 to 1.29 TWh in 2050.

The installation of significant battery storage capacity may also have a negative impact on the local environment, particularly if used batteries are not recycled and disposed into the local environment. New transmission lines between Lääne-Eesti and Latvia could have an environmental impact on the marine environment during construction.

6.4.2 *Socioeconomic impact of the Nuclear pathway*

The *Nuclear* pathway has relatively high capital costs, totalling €12.1 billion (€9.3 billion for capital and €2.8 billion of interest payments), making it the 2nd most expensive pathway. These investments, would, in the static modelling case lead to the 2nd highest increase in economic output. In the dynamic modelling, relying heavily on imports of nuclear technology would be a drag on economic demand compared to the reference case. However, the resulting average power price decrease would make this pathway the one with the lowest average prices, and would generate a significant economic multiplier thanks to the competitiveness benefits. The combined effects would generate the highest positive economic impact of all pathways over the 2025-2050 period. Alongside this, the employment impact would also be most positive.

As noted above, average electricity prices are lower from 2030 to 2050 compared to the Reference pathway and the price is fairly stable throughout the modelled time period. In 2030, the average price is 0.088 EUR/kWh, increases to 0.095 EUR/kWh in 2040 and drops back down to 0.088 EUR/kWh by 2050. As a consequence, the *Nuclear* pathway also has the highest positive impact on disposable income of all pathways including the *Reference* pathway, particularly in 2040.

However, as a note of caution, the sensitivity analysis showed that these positive impacts are all significantly reduced in the case that nuclear power plants are used for base load generation, i.e. run at high load factors of e.g. 90%. This operational mode would push the electricity average prices significantly higher than in most other pathways and would reduce the positive economic impacts. Positive economic performance is linked to the nuclear technology being able to deliver flexible (dispatchable) generation based on market price signals. The impact on investors' business case of lower load factors should be taken into account.

The social impacts noted for the *RES + storage* pathway in chapter 7 are also relevant for this pathway as there would also be significant wind energy and solar power production in the mix. Additionally nuclear energy poses specific social acceptance challenges, not only in the local community but also nationally and internationally. Nuclear power would in addition to avoiding GHG emissions, also avoid toxic emissions to air that result from fossil fuel use and therefore reduce associated health risks from air pollution, although a small increased risk of occupational exposure to nuclear materials would add in this pathway and waste is additional.

6.4.3 *Main impacts by region*

Table 6-5 provides a summary of impacts of the *Nuclear* pathway by region. The development of nuclear power plants would mainly impact the Kesk-Eesti and Kirde-Eesti regions (where nuclear capacity is expected to be built), affecting the local aquatic and terrestrial environment as well as create risks to the local community. Offshore wind energy would have a negative impact on the fishing industry in Lääne-Eesti as well as on maritime traffic in the area, however this is a relatively minor sector economically, and there would be significant economic opportunities in construction and operation of the wind energy farms, although efforts would need to be made to ensure local jobs are created. Solar PV would also impact the same regions as onshore wind energy, with the addition of the Louna-Eesti region. All capacity additions would have a land-use footprint, however these would be relatively small.

Table 6-5 Overview of impacts of the *Nuclear* pathway by region.

Region	Environmental impact	Socio-economic impact
Lääne-Eesti	moderately positive	moderately positive
Põhja Eesti	neutral	positive
Kesk Eesti	negative	mixed
Kirde Eesti	negative	mixed
Louna Eesti	neutral	positive

6.4.4 *Additional actions to reduce negative impacts and increase positive impacts*

Table 6-6 provides an overview of the recommendations on how to minimise negative impacts and increase positive impacts. More detailed recommendations for these types of impacts are provided in Chapter 1.4.

Table 6-6 Overview of recommendations for increasing positive impacts and minimising negative impacts by type of development and type of impact

Impact from	Type of impact	Recommendations
Nuclear	Environmental	• Strict control of water use and disposal (due to thermal pollution); • Strict limitations on the release of toxic and radioactive waste into the environment and ensure proper waste management
	Social	• Strict requirements for prevention and mitigation of severe accidents
	Economic	• Ensure that nationally there are enough highly skilled professionals in the nuclear energy industry
Offshore wind	Environmental	• Ensure careful design, monitoring and management of construction works to avoid disturbing marine wildlife and maintain water quality; • Use proper materials to create a suitable artificial reef and prevent erosion; • Enforce fishing restrictions near wind farms; • Define a strategy to ensure the health of marine areas is maintained
	Social	• Construct offshore wind farms near industrial areas where the landscape is already altered to reduce additional visual disturbances for the local community
	Economic	• Ensure relevant stakeholders are in consultation of wind farm projects, i.e. fishing industry and maritime. • Adequate measures to ensure consumers are not significantly impacted by RES charges and intermittency; • Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Onshore wind	Environmental	• Ensure careful design, monitoring and management of wind parks to avoid disturbing wildlife and their habitat
	Social	• Ensure onshore wind parks are not close to houses of local population
	Economic	• Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Solar PV	Environmental	• Ensure careful design, monitoring and management of solar parks to avoid disturbing wildlife and their habitat
	Economic	• Ensure that nationally there are enough highly skilled professionals in the solar energy industry
Battery storage	Environmental	• Ensure proper disposal/recycling of batteries at end of life.
	Economic	• Modernise the electricity grid with smart technologies to enhance the development of battery storage • Ensure that nationally there are enough highly skilled professionals in the energy storage industry
Transmission & distribution	Environmental	• Proper maintenance of land with transmission and distribution lines underneath; • Avoid unnecessary cutting of trees; • Reduce noise pollution via construction and technical solutions; • Strict requirements for maintenance and disposal of equipment
	Social	• Impose restrictions on siting of high-voltage lines near housing to reduce health impact; • Avoided overhead lines in populated areas to reduce visual impact
	Economic	• Ensure that nationally there are enough highly skilled professionals in the T&D industry

6.4.5 Further impacts from proposed actions and mitigating actions

Among the proposed actions, the most consequential ones for the Estonian consumer and taxpayer will be the measures to support the nuclear sector. From a financial point of view, support to onshore wind energy and solar PV farms may also be significant, especially in the short term, but using the appropriate support mechanisms (see section 4.4) reduces the cost for the consumer.

Actions to support the nuclear sector are of two kinds:

- Direct interventions to support nuclear developers, which are likely to take the form of state guarantees or risk-sharing agreements. For example, nuclear developers will not be able to insure their installation against all risks, such as long-term risks related to radiation leakage or dramatical accidents, and investors cannot protect themselves from the risk that changes in the regulatory environment would negatively affect their business case. Taken into account the uncertain price developments, investors may expect long-term wholesale prices not to be sufficiently high to ensure a fair return on their investment, and will hence possibly not commit unless some form of state protection against market risks is provided, e.g. via Contracts for Differences. This is important to note in the context of the socio-economic benefits highlighted above, e.g. that if nuclear power plants are operated at high load factors, as investors would prefer, then socio-economic benefits are likely to be much lower.
- Indirect interventions to support the nuclear sector, for example to ensure that the right skills are available (both in the public and private sector), and that a long term disposal solution is found for radioactive material.

The main effect of the various direct actions would be a transfer of some of the risks from project developers to the Estonian state or consumers. To mitigate the risk of negative consequences for the Estonian taxpayers or consumers, the priority actions that the Estonian Government should undertake are:

- Clearly define the risks the state is willing to take over from nuclear developers and operators, and the risks that will lie with private investors and developers.
- Ensure that nuclear investors, developers and operators set aside sufficient financial reserves to cover radioactive waste treatment and storage, as well as power plant decommissioning and clean-up costs;
- Ensure that nuclear developers and operators are incentivized to deliver on time on their commitment. Delays are one of the most common issues affecting nuclear programmes, and may have financial consequences for Estonia if decarbonization targets are missed because of these delays.

In terms of the potential negative impacts from indirect actions, the most significant will be those associated with long-term storage of nuclear waste such as spent fuel. Unless a foreign country is willing to take care of the nuclear waste on a permanent basis, the liability will stay with the Estonian state, which will have to ensure a secure location for nuclear waste until a solution for final disposal/storage is found.

6.5 Compatibility with the Estonian legal system

In April 2021, the European Commission published the new EU taxonomy[159], which sets out which economic activities can be considered sustainable. A Complementary Climate Delegated Act[160] discusses under which conditions, nuclear and gas energy activities can be included in the list of economic activities covered by the EU taxonomy. However, as of 14 June 2026, two European Parliament committees (economic affairs and environmental committee) have rejected the European

[159] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
[160] https://ec.europa.eu/info/publications/220202-sustainable-finance-taxonomy-complementary-climate-delegated-act_en

Commission's proposal to include fossil gas and nuclear energy under the EU taxonomy. In the next steps, the plan will pass under the scrutiny of the European Parliament for a final vote.

In the scenario of the potential construction of nuclear power plants in Estonia, the issue of **nuclear non-proliferation** should be considered. Actions to be taken need to comply with the UN Treaty on the Non-Proliferation of Nuclear Weapons (NPT), ratified by Estonia in 1992. The NPT is a landmark international treaty whose objective is to prevent the spread of nuclear weapons and weapons technology, to promote cooperation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament. In accordance with Article IV of the NPT, the purpose of the Treaty is by no means to affect 'the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination'.[161]

The aim of the Vienna Convention on Civil Liability for Nuclear Damage is to harmonise national law of the Contracting Parties (Estonia being one of them), by establishing some **minimum standards to provide financial protection against damage resulting from certain peaceful uses of nuclear energy**. According to Art. II f the Convention, *'the operator of a nuclear installation shall be liable for nuclear damage upon proof that such damage has been caused by a nuclear incident - (a) in his nuclear installation; or (b) involving nuclear material coming from or originating in his nuclear installation'*.[162] As Estonia currently has no nuclear installations[163], the international and EU legal framework for nuclear safety has been brought to the national legal system in a general level, relying upon the Radiation Act. Within the Radiation Act, responsibilities of license holders are addressed. The 2011 amendment of the Radiation Act gives the regulatory body the right to demand **financial guarantee** from the applicant to ensure that the funds necessary for safe disposal of the radioactive source or waste are immediately available. With regards to financial guarantees for accidents, at present, interest of Estonia in nuclear safety is primarily related to the safety of nuclear installations in the neighbouring countries. Following an example of other EU Member States,[164] Estonia could introduce a legal requirement for nuclear operators to be financially liable in case a nuclear accident was to occur. In situations where the insurance market is not in the position to cover certain categories of nuclear damage, the state of Estonia could step in to cover such risks. However, in such cases the EU Treaties on competition law must be considered. Under the Treaties, Member States are free to determine their energy mix and have the choice to invest in nuclear technology. The Commission's role is to ensure that when public funds are used to support companies, this is done in line with EU state aid rules, which aim to preserve competition in the Single Market. Case-to-case decisions are then issued by the European Commission (DG Competition) as to whether such state guarantee is in conformity with EU competition law.

With regards to the establishment of a designated **national regulatory authority** in relation to the nuclear sector, the Nuclear Safety Directive[165] reinforces that the national responsibility of Member States for the nuclear safety of nuclear installations is the fundamental principle on which nuclear safety regulation has been developed at the international level, as endorsed by the Convention on Nuclear Safety. The principle of national responsibility shall be under the supervision of its national

[161] Treaty on the Non-Proliferation of Nuclear Weapons, Article IV.
[162] Vienna Convention on Civil Liability for Nuclear Damage, Art. II
[163] As per the definition of the Convention on Nuclear Safety
[164] For example Belgium
[165] Directive 2009/71/EURATOM

competent regulatory authority.[166] Furthermore, in accordance with Art. 5 of the Nuclear Safety Directive, 'Member States shall establish and maintain a competent regulatory authority in the field of nuclear safety of nuclear installations'.[167] In addition, the European Nuclear Safety Regulators Group (ENSREG) provides an overview of existing designated authorities in other EU Member States.[168] In 2011 the requirements of the Nuclear Safety Directive were brought into Estonian legislation by amending the Radiation Act.[169] As such, the legal basis (and requirement) for the establishment of such domestic regulatory authority should exist under the Estonian domestic legal system.

166 Directive 2009/71/EURATOM, Preamble (8)
167 Directive 2009/71/EURATOM, Art. 5
168 See https://www.ensreg.eu/members-glance/national-regulators
169 See https://www-ns.iaea.org/downloads/ni/safety_convention/7th-review-meeting/estonia_nr-7th-rm.pdf

7 *CCU* pathway

Key findings

- The estimated potential for captured CO_2 utilization in the Estonian industry is considered as a binding constraint on the use of power plants with carbon capture.
- Restrictions to CO_2 capture lead to decreased output from Auvere and TG11 (compared to the Reference scenario) if these plants are retrofitted with carbon capture technology.
- The lower effective availability of the dispatchable capacity at Auvere and TG11 inhibits the uptake of wind and solar energy in Estonia, increasing the need for electricity imports and raising long-run electricity prices to the most expensive of all pathways.
- High energy prices lead the most negative socio-economic impacts of all pathways.
- The modelling suggests that total power generation does not increase from 2020 levels by 2040 or 2050 and covers less than half of the domestic power demand, leaving the country heavily reliant on imports

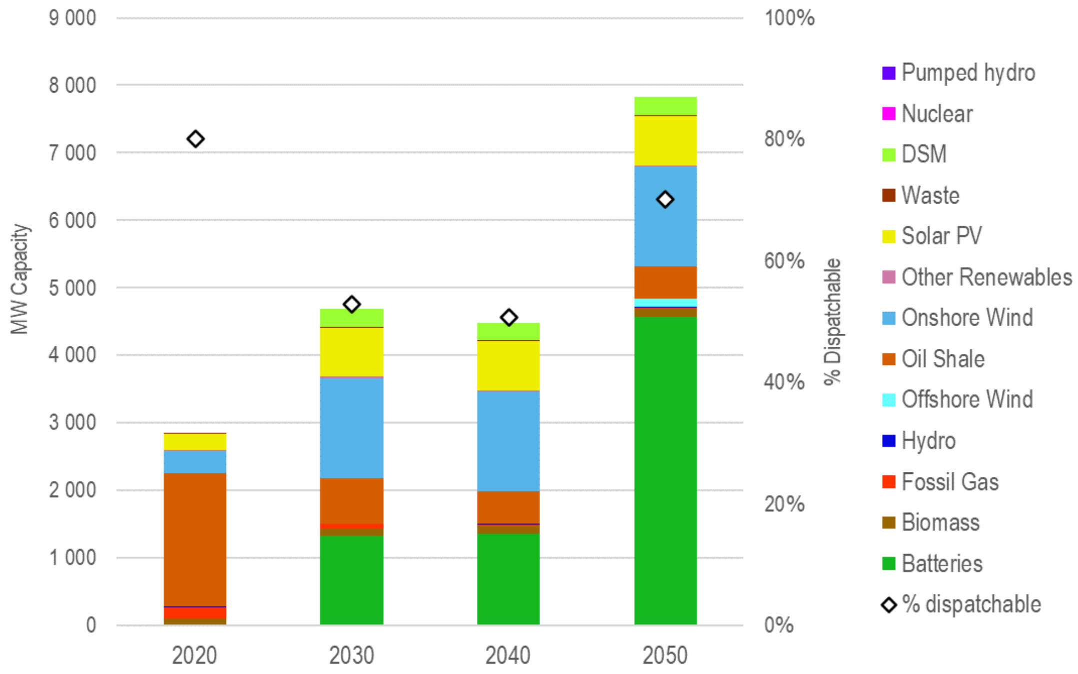
7.1 Pathway overview

The *CCU* pathway explores the impacts of adding carbon capture to two large oil shale fired power generators, TG11 and Auvere. The TG11 facility is in the modelling outfitted with carbon capture at its scheduled refurbishment in 2025, while the Auvere facility is upgraded in 2030. Similar to the other technology-focused pathways, there is a requirement of climate-neutral electricity production by 2050, and in the modelling there is no limit on building supplemental storage, renewable or nuclear electricity generation in Estonia.

7.1.1 *Impact of the CCU pathway on installed capacity and electricity generation*

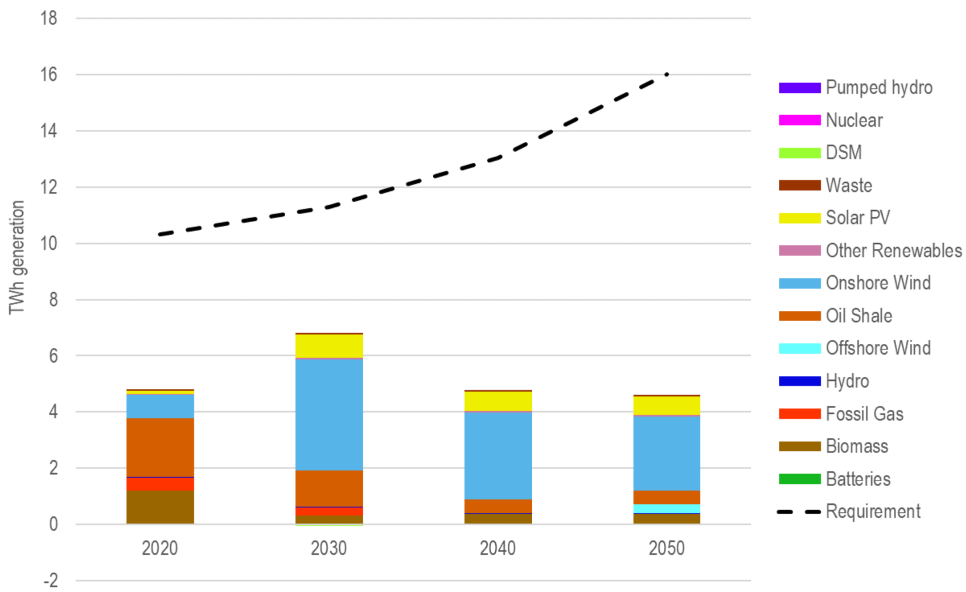
The *CCU* pathway has the smallest increase in capacity from 2020 to 2050 compared to the other pathways, with most of its capacity coming from batteries and onshore wind energy (Figure 7-1). In 2030, the capacity of batteries (+1.3 GW), onshore wind energy (+1.15 GW), solar PV (+495 MW) and DSM (+261 MW) increases while the capacity of power production using fossil gas (-100 MW) and oil shale (-1.3 GW) decreases. In 2040, the capacity of batteries (+28 MW) and biomass further increases (+22 MW) while the capacity of fossil gas and oil shale continues to decrease. In 2050, battery capacity continues to increase (+3.2 GW) and new offshore wind capacity is installed (+123 MW). The capacity of the other technologies remains the same. By 2050, the percentage of dispatchable capacity is 70%.

Figure 7-1 Installed capacity by technology and percent dispatchable for the *CCU* pathway, 2020-2050, MW[170]



Until 2050 the electricity generated in Estonia in the *CCU* pathway fails to meet Estonia's electricity demand (Figure 7-2). This pathway relies heavily on onshore wind electricity generation, which would increase by 3.12 TWh in 2030. Electricity generated from solar PV increases from 0.12 TWh in 2020 to 0.83 TWh in 2030, then decreases to 0.68 TWh in 2040 and 0.65 TWh in 2050. Table 7-1 provides an indication of how much additional generation is needed in 2030 beyond the generation ensured by the currently installed capacities and the generation expected from the planned auctions in 2022 and 2023. It is estimated that additionally 2.3 GWh of onshore wind energy and 0.4 GWh of solar PV energy will be needed by 2030 to respect the trajectory indicated by this pathway.

Figure 7-2 Electricity generation by technology according to the *CCU* pathway, 2020-2050, TWh[171]



170 Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
171 Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 7-1 Additional remaining generation needed in 2030 beyond the generation from planned auctions in 2019-2023 for the *CCU* pathway, GWh

	Solar PV	Onshore wind
Total additional generation	714	3,120
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation	435	2,284

7.1.2 Infrastructure investment requirements according to the CCU pathway

Required investment in generation and storage amount to around €3.07 billion by 2050, with most of it required by 2030 (€2.53 billion). The investment required by 2030 is mainly in onshore wind energy and oil shale, to cover the installation costs of CCU at Auvere and TG11 .

Table 7-2 Required investments by technology for the CCU pathway, 2030-2050, million EUR_{2020}

Technology	2030	2040	2050	Total
Batteries	262	12	252	526
Biomass	0	46	0	46
Offshore Wind	0	0	231	231
Oil Shale	978	0	0	978
Onshore Wind	1,264	0	0	1,264
Solar PV	8	0	0	8
DSM	13	0	0	13
Total generation	2,525	58	482	3,065
Lääne-Eesti - Latvia	18.8	54.1	62	134.9
Total	2,544	112	544	3,200

The *CCU* pathway is the one with the lowest overall costs, including the lowest network reinforcement costs (only 605 MW of transmission capacity to Latvia is added).

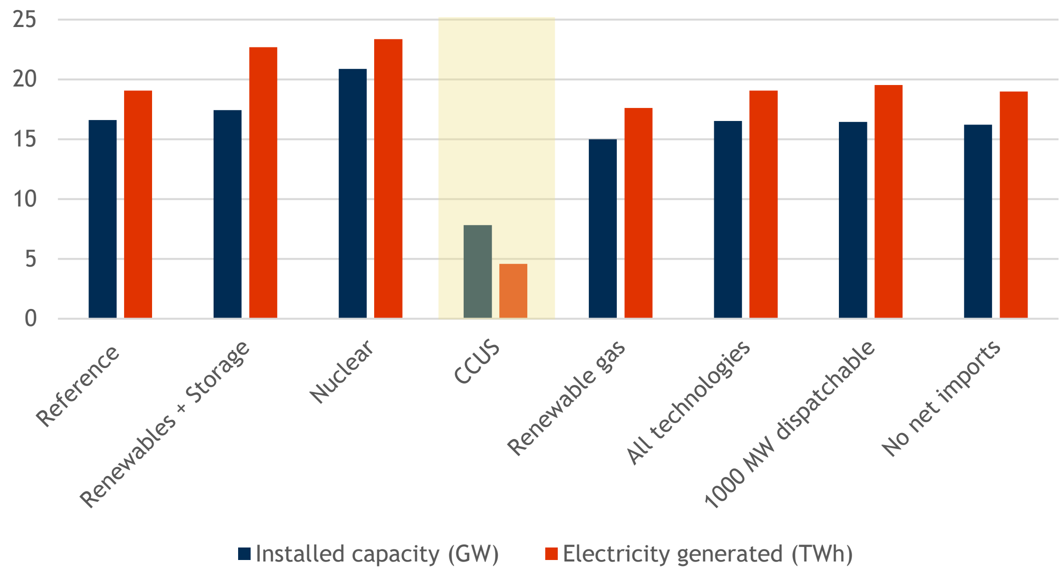
7.1.3 Risk analysis of the CCU pathway

Stakeholders surveyed in the risk analysis task (deliverable 5) rated the *CCU* pathway as the least preferred, even though the average risk score for all risks evaluated is moderate (averaging 2.94 out of 5 for likelihood and 3.16 out of 5 for severity of these risks). Most of the concerns about CCU are technological: the risk of delayed development of the carbon capture equipment and of the related infrastructure, and the risk of CCU technologies not reaching economies of scale. Most interviewed stakeholders are sceptical of the *CCU* pathway because of the costs and unproven technology. However, stakeholders consider that CCU is a strategy worth considering, especially because it appears to require relatively low investments. Other advantages are the opportunity to continue using local fossil fuel resources and that fossil fuel plants will, with CCU, be able to support renewables during peak times and at low generation/high demand events.

7.2 Actions

The conversion of Auvere and TG11 to CCU in 2025 and 2030, respectively, allows Estonia to cope with its electricity needs by deploying lower capacities compared to other scenarios, although a substantial amount of storage (batteries) is still necessary in the short term. This is because the reduced output from Auvere and TG11 is expected to be compensated by solar and onshore wind in the short term, while in the long term retaining the use of oil shale and Retort gas means Estonia would have lower total capacity and total output compared to other scenarios. From the point of view of investments, this is the scenario with the lowest requirement (€3 billion compared to €11 billion of the *RES + Storage* pathway).

Figure 7-3 Installed capacity and generation in 2050 across scenarios[172]



CCU is a technology that has reached commercialisation stage in many countries, but the required investment costs are still a key challenge, because the large upfront investment required, and because of the risks. In order to be bankable, CCU projects needs the right market conditions, such as high ETS prices and a reliable channel able to absorb the CO_2 captured. According to the Global CCS Institute[173], key barriers for private investments in CCS are related to revenues (risk that CO_2 price is too low to generate sufficient revenues), cross-chain risks (risk that a failure along the chain de facto jeopardise operations across all stages), and long-term storage liability risk. Given the limited storage potential in Estonia, the latter is not as relevant, but support to mitigate the other two risks is essential. Also, to mitigate these risks, will be important to pursue options to connect the CO_2 flows to other countries, for example via facilities near the coast.

Therefore, when developing actions for this pathways, it is necessary to consider:

- **Specific actions to support the deployment of CCU to be given high priority**. Given the expected deployment timeline, these actions have to start as soon as possible and have to be completed in the short term:
  - Pass a supporting legislative package, which includes reviewing the mandate of the Competition Authority to be responsible for CO_2. In case that an Energy Agency is

[172] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[173] https://www.globalccsinstitute.com/news-media/insights/carbon-capture-and-storage-challenges-enablers-and-opportunities-for-deployment/

established to deal with the broader issues related to the energy transition, its powers in respect to CO_2 should also be clarified. The legislative package should include the national regulatory framework for CCUS, which removes the prohibition of storing CO_2 and clarifies risk sharing among market parties and compensation mechanisms.

- Development of a national strategy for CCUS. The conversion of Auvere and TG11 with limited output is based on the assumed maximum amount of CO_2 that can be utilised by the chemical industry in Estonia. However, a national strategy could explore options for: further uses of CO_2; storage options; development of a CO_2 transport network (pipelines) to allow the connection of industrial complexes and potential links with nearby countries that may be able to store the CO_2. The sharing of infrastructure is one of the key enabler for CCUS, as it benefits from economies of scale and reduce commercial risks, with new business models focused on transport and storage services.[174] The current proposal for the revised ETS[175] also includes CO_2 transport modes other than pipelines, which means options to ship or transport CO_2 via trucks and ships should be considered. There are good storage options in Latvia, the Baltic sea, and also in other Baltic states – although in some cases national regulations are still a barrier to the import and injections of CO_2.[176] Similar to what is happening with the Baltic offshore grid, cooperation for CO_2 storage options at regional level should be explored.
- The pathway foresees a total investment of almost €1 billion in CCU among the two plants, which is unlikely to happen without substantial financial support to project investors. The EU offers support to CCUS via several instruments, such as the Innovation Fund (which already supports several CCUS projects), the modernisation fund and the Connecting Europe Facility (linked to Projects of Common Interests). Options to obtain support from these funds should be explored as a priority, but the projects will have to show a strong business case to compete against similar proposals from around Europe
- Any support to developers and investors should be granted via an instrument that provides payments only when market conditions are unfavourable, and does not over reward investors. The possibility to run a competitive process for the award of support should be explored, but in the case the insufficient perspective bidders are available, support could:
  - be awarded via a negotiated procedure;
  - be awarded via a CO_2-based scheme, where carbon capture can compete with other technologies because the scheme will be based on CO_2 savings, rather than on MWh of clean electricity. An example of this scheme is the SD++ in the Netherlands, where all technologies compete in the same auction scheme, and where CCS is mainly applied to industrial processes.
  - Be awarded via a capacity-based instrument (i.e., supporting security of supply).

[174] https://www.ccusnetwork.eu/sites/default/files/HLR2021_CCUS-in-Europe-at-the-verge-of-a-real-break-trough.pdf
[175] https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf
[176] https://bcforum.net/presentations2020/02.01%20-%20Alla%20Shogenova,%20Carbon%20Neutral%20Baltic%20States%20-%20Do%20We%20Have%20CCUS%20Among%20Accepted%20Options.pdf

- When awarding financial support, the government would essentially tackle market risk (i.e. the risk of insufficient revenues generated from CO_2 savings, or from producing low carbon electricity), while, as discussed above, cross-chain risks should be mitigated by an appropriate risk sharing framework.

Essentially, a combination of instruments would allow to deploy the technology in the short term, while opening up opportunities to extend its use in the long term:

- High capital investment: identify right development grant from EU;
- Uncertain revenue: provide operational support via a subsidy scheme;
- Cross-chain risk: tailored risk management framework, with some risks absorbed by government.

Similar to other pathways, it will be necessary to:

- Streamline and speed up the planning process, dedicating additional resources to onshore applications (the scenario foresees large deployment of onshore wind a solar PV);
- Launch further reverse auction rounds;
- Review the approach for balancing the electricity system. The high dispatchable capacity for this scenario (70%) requires the lowest battery deployment across scenarios (1.3 GW by 2030 and 4.5 GW by 2050 compared with 8 GW of the reference scenario and 9.2 GW of the nuclear scenario).

Table 7-3 Recommended actions

Ch 5 reference	Additional details	Timing and responsibility	Further details
A-C	Infrastructure planning process • Streamline process, with particular focus large projects; • Setup of single contact point approval process; • Mandate the inclusion of renewable in local spatial plans; • Additional administrative resources at national level, dedicated to offshore wind deployment	Short term (by 2025) The review process will include national and local administrations and other interested bodies	Largely one-off administrative costs + some additional human resources dedicated to the process
B, C, D	Institutional reform • Setup of an Energy Agency, whose mandate has a clear remit to support offshore wind deployment	Short term (by 2025) Setup by Central government as an independent body	Financed via the general budget
A-E	Investment risk • Support developers at Auvere and TG11 with accessing EU funds for CCU implementation; • Various actions to facilitate the uptake of PPAs; • Increased funding and limits for Kredex guarantees • CfDs	Short term (by 2025) Action led by central government, should involve also institutional investors and Kredex	Loan guarantees financed via general budget and EU funds CfDs funded via the energy bill (€28-€55 million)
A	Financial incentives for RES investments by households and SMEs • on-site small scale renewable generation support scheme, linked to a buildings energy efficiency scheme	The action starts in the short term but likely to continue beyond 2030	Financed via the energy bill (either directly as environmental levy or indirectly via supplier obligation) In the short term, financing via Recovery and Resilience fund also available
A - H	Power networks and infrastructure	Ongoing process, expected to continue	Financed largely via the current RAB model

Ch 5 reference	Additional details	Timing and responsibility	Further details
	• Development of plans to strengthen transmission capacity from Lääne-Eesti to Latvia; • Review the approach for balancing the electricity system and open the markets for flexibility and	throughout the period interested Led by the TSO in cooperation with other Baltic TSOs	Merchant-model assets should be considered
A - C	Involvement of the civil society • Start-up support for Energy Communities; • Setup of one-stop shops to support vulnerable customers with energy efficiency advice and access to specific support schemes (for example, schemes to incentivise home insulation); • Enhance public acceptance for new energy infrastructure	Short term (2025) Involves Central government, local government, and other agencies (for example, an Energy and Climate Agency)	Relatively low cost, depending on implementation options
A - C	Other actions		

In the medium to long term, actions should focus on exploiting the carbon capture capacity, for example by exploiting the options to link industrial clusters and to develop a transport pipeline to storage in nearby countries.

7.3 Expected costs and revenues

This section discusses the costs and (when relevant) revenues associated with the actions indicated in the previous sections for this pathway.

The limited investments required in this pathway is mainly related to the CCU infrastructure (around €1 billion), although in absolute terms investments in onshore wind are going to be higher up to 2050 and significant investments in batteries are envisaged. Because of the rather conservative estimates associated with this pathways, it will not be necessary to develop overly ambitious packages to promote renewables and storage, but direct support will be needed for the CCU conversion and infrastructure.

7.3.1 Estimating the cost for renewable incentives

The total annual cost of a scheme to support offshore wind via a reverse auction depends on the type of support instrument chosen and on the wholesale price during the contracted years. Table 7-4 estimates the total amount of support required by different renewable technologies in 2030, in the case of unfavourable conditions (high cost) and the central case.[177] Assuming that any support scheme is designed to cut incentive payments to generators in case of high energy prices (as investors will be able to recover investment costs based on market income), under the most favourable conditions the support required will tend towards zero. Assuming support up to the ceiling established by the schemes will be needed for 50% of the electricity produced, the costs for the average household would be of around €11 per year.

[177] estimated according to the methodology presented in section 1.3

Table 7-4 Subsidy paid out in 2030 and average cost to consumer

Technology	Subsidy paid out (€ million)[178]	
	High	Central
Offshore Wind	-	-
Onshore Wind	46	23
Other Renewables	1	0
Solar PV	9	4
Total	55	28
Cost increase € per kW[179] (assumed demand: 9 TWh)	0.006	0.003
Cost increase (€ per household per year) (assumed energy import from network: 3500 kWh)	21.53	10.77

It is important to note that this analysis does not include the effect of wholesale prices, which are likely to be low under the *high* case and average under the *central* case. For the consumer, this means that the net effect will be a net increase of less than what is presented in Table 7-4.

7.4 Recommendations to reduce the negative and increasing the positive environmental, social and economic - including regional - impacts

The *CCU* pathway has the least positive impact on the Estonian economy and similar environmental impacts as the other pathways. Section 1.4 provides a detailed overview of the expected environmental and economic impacts from these developments at technology level and provides specific recommendations on how to mitigate negative impacts and enhance positive impacts.

7.4.1 *Environmental impact of the CCU pathway*

The *CCU* pathway is expected to impact the local environment mainly via the development of onshore wind and battery storage as well as solar PV:

- **Onshore wind** creates similar negative impacts as offshore wind, such as noise disturbance, impact on local habitat and a collision hazard for birds.
- The significant installation of **battery storage** may also have a negative impact on the local environment, particularly if battery waste is mishandled and disposed into the local environment.
- **Solar PV** can also negatively impact the local habitat.
- **Biomass** is one of the few positives of the CCU pathway, as without a transition to biomass use at the oil shale plants, as in all the other pathways, biomass use declines compared to 2020 levels (from 1.2 TWh in 2020 to 0.85 TWh in 2050), reducing pressure on Estonian forests.

There are also the environmental impacts from offshore wind, but offshore wind plays a very minor role in this pathway, i.e. 123 MW installed between 2040-2050. CCU infrastructure could cause environmental disruptions depending on the need for additional pipelines and other infrastructure to support transport and/or storage of CO_2.

7.4.2 *Socioeconomic impact of the CCU pathway*

[178]See section 1.3 for the rates used to estimate the high and low case.
[179]Assumed unit cost increase if the cost of the renewable support scheme is spread across all users according to electricity imported from the network (i.e., excluding self-consumption). It is assumed subsidy costs will be spread over 9 TWh of demand as around 2 TWh are expected to be on-site generation and consumption (e.g., rooftop PV) that would not be metered and on which no levies will be placed).

The CCU pathway has relatively low capital costs, totalling to €4.0 billion (€3.1 billion for capital and €0.9 billion of interest payments[180]). After 2050, there would be €0.3 billion of payments remaining. Compared to the other pathways, the *CCU* pathway is the only pathway to have cumulative 2025-2050 negative GDP and employment impacts compared to the reference case (in both the static and dynamic modelling results), with the negative impact increasing over time (with prices). Additionally, average electricity prices in the CCU pathway are higher than the *Reference* pathway for all years and increases over the modelled time period. The cost increases from 0.103 EUR/kWh in 2030 to 0.149 EUR/kWh in 2050, by far the highest of all pathways. Throughout the modelled time period, the *CCU* pathway has a negative impact on disposable income, compared to the reference case, from 2040 onwards.

In terms of social impact, onshore wind farms can be a nuisance for local communities due to the visual/noise disturbance, which is why relief measures must be explored and implemented. These in turn should have positive outcomes for local communities whether creating direct or indirect local jobs, improvements in local infrastructure, or generating payments to the local municipality or community organisations for renewable energy generation based on agreements with developers. The different measures and their impacts have been researched in a recent paper by the Ministry of Finance.[181] Additionally, the deployment of RES will reduce fossil fuel use and therefore reduce associated health risks from air pollution in the long-term. This not only reduces air pollution-related fatalities but also reduces the burden on the local health system.

Social impacts of this pathway can have a small positive for communities and firms reliant on oil shale extraction, as this is the only pathway in which these activities continue in some form. However, the rest of society would bear the social costs of the economic damage done in this pathway.

7.4.3 Main impacts by region

Table 7-5 provides a summary of impacts of the *CCU* pathway by region. Based on where the technology developments are expected, the pathway is expected to impact the economies in all regions. Solar PV would also impact the same regions as onshore wind, with the addition of the Louna-Eesti region. Based on where the technology developments are expected, the pathway is expected to impact the economies in all regions. Further, offshore wind could have a negative impact of the fishing industry in Lääne-Eesti as well as maritime traffic. However as offshore wind is not a significant technology in this pathway, the impact would be very limited.

Table 7-5 Overview of impacts of the CCU pathway by region.Table 7-6 Overview of impacts of the CCU pathway by region

Region	Environmental impact (marine/freshwater)	Socio-economic impact
Lääne-Eesti	(minimal impact)	negative
Põhja Eesti	neutral	negative
Kesk Eesti	neutral	negative
Kirde Eesti	neutral	negative
Louna Eesti	neutral	negative

[180] Costs and interests do not include investment in transmission infrastructure
[181] ("Kohaliku kasu instrumentide analüüs", https://www.fin.ee/media/2723/download)

7.4.4 Additional actions to reduce negative impacts and increase positive impacts

Table 7-7 provides an overview of the recommendations of how to minimise negative impacts and increase positive impacts. More detailed recommendations for these types of impacts are provided in section 1.4.

Table 7-7 Overview of recommendations for increasing positive impacts and minimising negative impacts by type of development and type of impact

Impact from	Type of impact	Recommendations
Onshore wind	Environmental	• Ensure careful design, monitoring and management of wind parks to avoid disturbing wildlife and their habitat
	Social	• Ensure onshore wind parks are not close to houses of local population
	Economic	• Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Solar PV	Environmental	• Ensure careful design, monitoring and management of solar parks to avoid disturbing wildlife and their habitat
	Economic	• Ensure that nationally there are enough highly skilled professionals in the solar energy industry
Battery storage	Environmental	• Ensure proper disposal/recycling of batteries at end of life.
	Economic	• Modernise the electricity grid with smart technologies to enhance the development of battery storage; • Ensure that nationally there are enough highly skilled professionals in the energy storage industry
Transmission & distribution	Environmental	• Proper maintenance of land with transmission and distribution lines underneath; • Avoid unnecessary cutting of trees; • Reduce noise pollution via construction and technical solutions; • Strict requirements for maintenance and disposal of equipment
	Social	• Impose housing restrictions near high-voltage lines • Avoided overhead lines in populated areas to reduce visual impact
	Economic	• Ensure that nationally there are enough highly skilled professionals in the T&D industry

7.4.5 Further impacts from proposed actions and mitigating actions

Compared to other scenarios, the changes required to the energy system are limited, and so is the scope of the actions necessary to drive the changes. However, the actions proposed to promote the deployment of CCS could negatively affect the Estonian taxpayer and consumer:

- The promotion of CCS will require public support, either via energy bills/taxation (grant or tax rebate) and/or via a guarantees system. Sufficient private investments are also required, and from stakeholders involved at various stages of the supply chain. If any of the investors (or any of the assets) fail to deliver, all other investors will be affected. According to how public support is provided, taxpayers or billpayers may also have to compensate investors along the supply chain. For example, if the industrial plant that agrees to absorb the CO_2 is unable to continue operations, those who have invested in the capture and in the transport infrastructure will be unable to operate until they find an alternative CO_2 utilisation or storage solution. These issues will have to be dealt with by a tailored regulatory framework, and the solution would lie between the two possible extreme:
  a) All stranded asset risks are borne by the developers/investors. In this case, the expected return for investors may be too high and render the investment prohibitively expensive. Accessing finance from public lenders will also be challenging;

b) All stranded asset risks are guaranteed. In this case, the cost of CCU will be lower, but the guarantor will have to bear a large amount of risk that it will be unable to influence.[182, 183]

- While the scenario foresees the lowest total investments, the majority of these will have to happen in the short term (€2.5 billion invested by 2030). Furthermore, 40% of this investment will go to upgrading the two oil shale plants, rather than investing in renewables. This creates three risks:
  a) Public opposition at the government choosing to provide support to fossil fuel technologies rather than cleaner renewables;
  b) Estonian supply will be still highly dependent on international energy prices, because of the high level of dependency that is expected in this pathway (over 70% of electricity is expected to be imported in 2050);
  c) Any failure across the CO_2 supply chain means that Estonia will be unable to produce low carbon electricity, which would affect either its inland emissions or its energy dependence.

On the other hand, the deployment of CCU technology in Estonia opens several opportunities:

- The knowledge and infrastructure developed will be useful in other sectors, such as opening opportunities for the deployment of carbon capture technology in industrial clusters;
- Combined with biomass, carbon capture can generate negative emissions via processes that are cheaper and more efficient that air capture;. Although there are many that challenge the actual carbon neutrality of biomass and note the adverse effects on forests.
- While at the moment opportunities for CO_2 use in Estonia are limited, its availability may be seen as an opportunity for industries that use it as an input (e.g. chemical processes).

7.5 Compatibility with the Estonian legal system and public perception

As discussed in the previous paragraph, devolving large investments to upgrade fossil fuel plants rather than supporting clean generation may raise issues concerning public perception.

Providing dedicated support to specific power plants will raise State aid issues. Therefore, while the modelling has identified Auvere and TG11 as the best candidates for the installation of CCU, any support scheme will have to be designed to comply with State aid compliance. This means that other plants may end up providing a better business case, or that third-party investment should be allowed for financing all or part of the CCU infrastructure.

As discussed under Pathway 7, the TFEU provides specific **rules on state aid** and its compatibility with the internal market, which are further elaborated upon in the new 2022 Guidelines (CEEAG). The CEEAG touches upon CCU specifically, as well stating that in principle *'all technologies that contribute to the reduction of greenhouse gas emissions are in principle eligible'*[184], including

[182] https://www.globalccsinstitute.com/wp-content/uploads/2022/01/Unlocking-Private-Finance-For-CCS-Thought-Leadership-Report-1-1.pdf
[183] https://www.sciencedirect.com/science/article/pii/S1876610213006280/pdf?md5=101c1f5d4da6baf2bb05f9a301bbb249&pid=1-s2.0-S1876610213006280-main.pdf
[184] CEEAG, Para 83

CCS/CCU. However, it is further specified that primary objective of the technology must be reduction or removal of greenhouse gas emissions. Where a measure contributes to both the reduction of greenhouse gas emissions and the prevention or reduction on pollution other than from greenhouse gas emissions, the compatibility of the measure with the internal market will be assessed separately by the Commission.

As storage of the captured CO_2 is not presumed under this Pathway, which is the main issue addressed under existing legislation (e.g. the London Dumping Convention and its Protocol or the CCS Directive), no striking legal implications have been identified at EU-level in relation to **CCU-related liability**. The current legal system relevant for CCU on EU-level is fragmented and spans over approx. 15 pieces of legal instruments. Nevertheless, two of these instruments should be mentioned when (environmental and financial) liability is being considered, namely the Seveso III Directive and the Environmental Liability Directive (ELD) as they impose requirements for industry-related stakeholders. Jointly, these instruments apply to industries involving dangerous substances, requiring control of major-accident hazards, applying the precautionary principle. Furthermore, with regard to financial liability the ELD establishes the ‘polluter-pays-principle’.

8 *RES GAS* pathway

Key findings
• The high expected cost of biogas as generation input prevents meaningful utilization of biogas generators. Meaning the €2.5 billion cost of this capacity would be largely wasted. • Adding 1 GW of biogas generation capacity in Estonia alters the mix of capacity used as system reserves, but it does not have an appreciable impact on electricity generation, imports and exports, or electricity prices.

8.1 Pathway overview

The *RES GAS* pathway models a scenario to climate-neutral electricity production in Estonia assuming the deployment of 1 GW of new biogas generation by 2030. This capacity is evenly distributed among Estonia's NUTS 3 regions, and the biogas required to operate it is assumed to be freely available at the cost reported in Eesti Arengufond (2015).[185] Like in the other technology-focused pathways, the model may endogenously add other renewable generation capacity and storage in Estonia.

The new biogas capacity is essentially incorporated into the electricity system as reserve. Due to the high cost of biogas – about €80/MWh, which is 2.5 times the projected cost of natural gas and more than four times the projected cost of biomass – it is not cost-effective to dispatch the biogas generators. As a result, the *RES GAS* pathway ends up resembling the *Reference* scenario. From 2020 to 2050, this pathway requires €8.9 billion in investments in generation and storage.

8.1.1 Impact of the RES GAS pathway on installed capacity and electricity generation

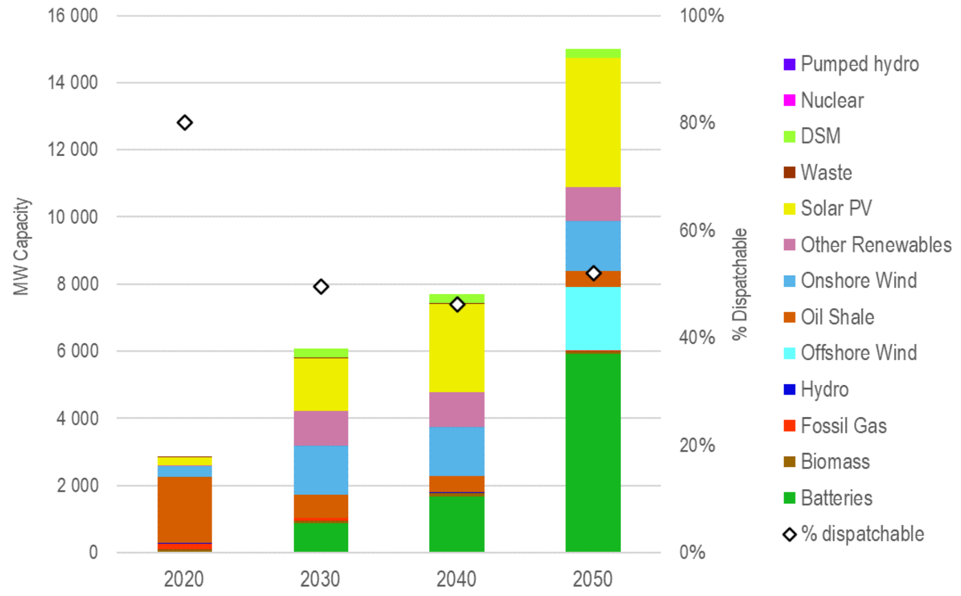
In the *RES GAS* pathway, electricity capacity increases from 2020 to 2050, mainly due to an increase in capacity of batteries, solar PV, onshore and offshore wind and other renewables (Figure 8-1). In 2030, the increase in capacity is mainly due to increases in:

- onshore wind (from 329 MW to 1479 MW);
- solar PV (from 230 MW to 1572 MW);
- other renewables capacity (from 20 MW to 1020 MW);
- DSM capacity from 0 to 261 MW.

Furthermore, in 2030, oil shale capacity decreases from 1972 MW in 2020 to 675.5 MW and further to 476 MW in 2040. In 2030, batteries capacity increases from 0 to 860 MW, and to 1670 MW in 2040 and 5907 MW in 2050. In 2040, there is a significant increase in solar PV capacity (+1076 MW) as well as in 2050 (+1188 MW). Additionally, in 2050, there is an increase in offshore wind capacity from 0 to 1883 MW.

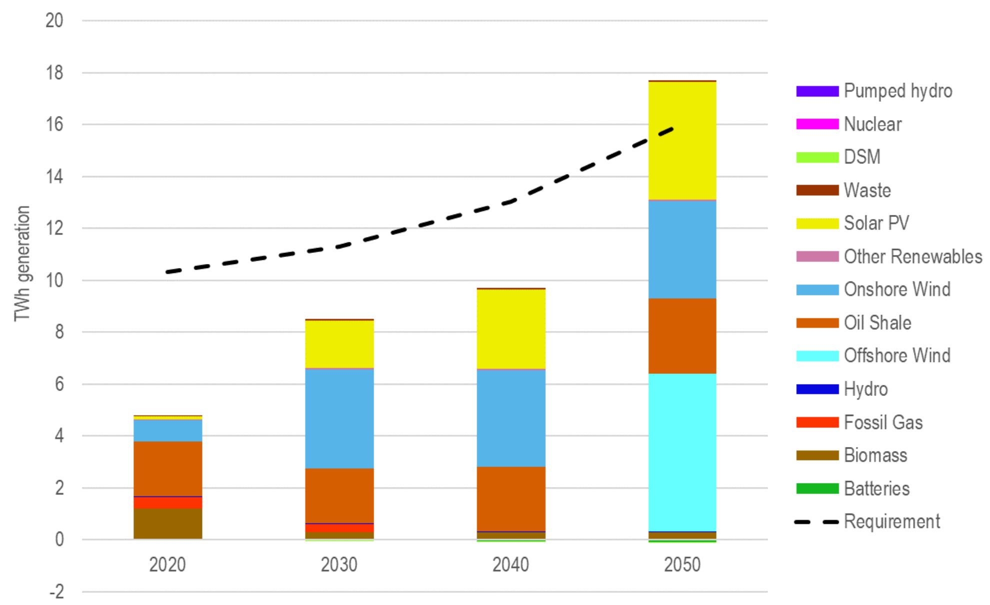
[185] Eesti Arengufond (2015). BIOMETAANI TOOTMINE JA KASUTAMINE TRANSPORDIKÜTUSENA –VÄÄRTUSAHEL JARAKENDUSETTEPANEKUD. http://www.arengufond.ee/wp-content/uploads/2015/10/Eesti_Arengufond_Biometaani_tootmine_ja_kasutamine_transpordik%C3%BCtusena_-_v%C3%A4%C3%A4rtusahel_ja_rakendusettepanekud._2015.pdf.

Figure 8-1 Installed capacity by technology and percent dispatchable for the *RES GAS* pathway, 2020-2050, MW[186]



The *RES GAS* pathway only meets the electricity generation requirements[187] in 2050, mainly due to offshore wind power (Figure 8-2). This pathway relies on oil shale, onshore wind and solar PV for increased electricity generation from 2030 to 2050. In 2030, solar PV power generation increases from 0.12 TWh in 2020 to 1.83 TWh, followed by 3.06 TWh in 2040 and 4.55 TWh in 2050. Onshore wind power generated also increases from 0.82 TWh in 2020 to 3.83 TWh in 2030. Table 8-1 provides an indication of how much additional generation is needed in 2030 beyond the already generation from auctions from 2019 to 2030. For onshore wind, an additional 2.2 GWh is needed and for solar PV, an additional 1.4 GWh is needed. From 2040 to 2050, there is a drastic increase in offshore wind generation (+6.08 TWh).

Figure 8-2 Electricity generation by technology for the *RES GAS* pathway, 2020-2050, TWh[188]



[186] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis
[187] Ability to produce sufficient electricity to cover internal demand
[188] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 8-1 presents the additional generation required in 2030 beyond what can be reasonably expected could be delivered by the next rounds of renewable auctions.

Table 8-1 Additional remaining generation needed in 2030 beyond the generation from planned auctions in 2019-2023 for the *RES GAS* pathway, GWh

	Solar PV	Onshore wind
Total additional generation	1,711	3,009
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation	1,432	2,173

8.1.2 *Investment and infrastructure requirements for the RES GAS pathway*

€9.1 billion of investment in technologies is required for the *RES GAS* pathway (Table 8-2). Most of this investment is needed in 2030 and 2050. In 2030, significant investment of €2 635 million is needed for the construction of 1GW of biogas capacity (Other renewables) and large investments are also made in onshore wind; in 2050, most investment is directed to offshore wind.

Table 8-2 Required investments by technology for the *RES GAS* pathway, 2030-2050, million EUR_{2020}

Technology	2030	2040	2050	Total
Batteries	170	101	343	613
Offshore Wind	0	0	3,543	3,543
Onshore Wind	1,264	0	0	1,264
Other Renewables (Biogas)	2,635	0	0	2,635
Solar PV	277	296	301	874
DSM	13	0	0	13
Total	4,358	397	4,187	8,942
Lääne-Eesti - Latvia	8.7	18.8	113.4	140.9
Total	4,367	416	4,300	9,083

The *RES GAS* pathway has relatively high overall costs compared to other scenarios, but has among the lowest network reinforcement costs (only 632 MW of transmission capacity to Latvia is added).

8.1.3 *Risk analysis of the RES GAS pathway*

Stakeholders consider *RES GAS* as the least risky of all the pathways, in terms of average risk score across all risks (2.61 out of 5 for likelihood and 2.67 out of 5 for severity), though there is only moderate support for the pathway from stakeholders surveyed in the risk analysis. For this pathway, the greatest risk is that an EU or global economic crisis would result in market volatility and limit spending potential. The *RES GAS* pathway is considered less risky because of the limited change to the current system compared to the other pathways. However, interviewed stakeholders are still concerned about whether the pathway can actually reach carbon neutrality, the excessive exploitation of forests biomass that may be required, and about the feasibility of deploying hydrogen in district heating. A clear risk from the modelling results is that the market conditions to use biogas rarely present themselves (generation from 1 GW of biogas capacity was modelled to be effectively zero) as the fuel is so expensive it rarely becomes competitive against other sources or imports.

8.2 Actions

The main focus of the scenario is the installation of 1 GW of biogas generation by 2030, for an estimated cost of €2.6 billion. Given the relatively balanced mix across technologies, and the fact that biogas capacity is utilised as reserve (due to its high price) a number of actions to promote onshore wind, solar PV and other technologies are required. However, actions related to the deployment of flexibility and storage would be more light touch (860 MW of batteries are needed by 2030, compared to twice as much in the reference scenario and almost 2.2 GW in the offshore wind scenario).Between 2040 and 2050, offshore wind also comes to the fore, and it is expected to be the single largest source in 2050, followed by solar PV and onshore wind.

For this reason, priority actions should include:

- **Actions to support the uptake of solar and onshore wind** in similar amount to their deployment in the other scenarios:
    - Streamline and speed up the planning process;
    - Award substantial incentives/support to new solar PV and onshore wind installations. Technology neutral auctions would still be an efficient way to ensuring the cheapest technologies comes to the front. Options should be explored to finance the conversion of oil shale plants to biomass via this or other dedicated mechanisms.
- **Dedicated risk reduction mechanisms for the support of new biogas plants**. This could take the form of a dedicated support instrument or via a capacity-remuneration instrument.

Although some biogas installation may come forward within the current reverse auction schemes, the deployment of biogas required in this pathway is unlikely to be achieved with the current technology-neutral approach. This is because the current reverse auction scheme rewards generation, rather than capacity, and expected generation from biogas in 2030 and beyond is considerably low (below 1% load factor). For this reason, support for new biogas installations could either come from a dedicated scheme or (preferably) be included into a market instrument to support flexibility and reserve capacity providers in general (so they would be eligible alongside batteries and reserve capacity services). The scheme would aim to provide an estimated 1.9 GW of capacity and 85 GWh of electricity by 2030 both via biogas peaking plants and batteries. Further details over the scheme are provided in Chapter 4.6.2.

Security of Supply and flexibility

While the renewable gas scenario is the scenario with the second lowest battery deployment in 2050 (5.9 GW of capacity), it is still considered appropriate to elaborate and publish a security of supply and flexibility strategy, which should be tailored to the expected deployment trajectory of wind energy and other renewables according to the auctioned capacities. The strategy would cover:

- Required transmission and interconnection infrastructure;
- Extended agreements with other Baltic states for increased cooperation on flexibility matters, in view of facilitating cross-border trade of (balancing) energy by market operators and cross-border procurement of ancillary services (including balancing capacity and energy) by TSOs, in order to enhance competition and markets’ liquidity and transparency;
- Roadmap for deployment of storage solutions, which should include steps that market platform operators and the TSO and DSOs should take to facilitate the participation of storage in the spot markets and in the procurement of ancillary services (e.g. by enabling aggregation) .

- Government-funded pilot scheme for the award of grants to the deployment of innovative large-scale storage solutions and to flexibility providers. Options to support flexibility and storage solutions may include:
  - Direct grant (set via administrative procedure) for the deployment of innovative technologies;
  - Auction-based grants, awarded via reverse auctions to the most competitive bidder to support those technologies close to market-readiness. A technology-specific budget should be set for biogas projects, tailored to their costs and to the additional revenues generators could earn from running as dispatchable technology;
  - Inclusion of batteries support as part of other instruments (e.g. within a capacity instrument; or as part of the technology specific auctions, where each auction would have two pots: one for generation only, one for supporting generation + storage installations).

Table 8-3 Recommended actions

Ch 5 reference	Additional details	Timing and responsibility	Further details
A-C	1. Infrastructure planning process • Streamline process, with particular focus large projects; • Setup of single contact point approval process; • Mandate the inclusion of renewable in local spatial plans; • Additional administrative resources at national level, dedicated to offshore wind deployment	Short term (by 2025) The review process will include national and local administrations and other interested bodies	Largely one-off administrative costs + some additional human resources dedicated to the process
B, C, D	2. Institutional reform • Setup of an Energy Agency, whose mandate has a clear remit to support offshore wind deployment	Short term (by 2025) Setup by Central government as an independent body	Financed via the general budget
A-E	3. Investment risk • Various actions to facilitate the uptake of PPAs; • Increased funding and limits for Kredex guarantees • Technology-neutral CfDs	Short term (by 2025) Action led by central government, should involve also institutional investors and Kredex	Loan guarantees financed via general budget and EU funds CfDs funded via the energy bill (€37-€73 million)
A	4. Financial incentives for RES investments by households and SMEs • on-site small scale renewable generation support scheme, linked to a buildings energy efficiency scheme	The action starts in the short term but likely to continue beyond 2030	Financed via the energy bill (either directly as environmental levy or indirectly via supplier obligation) In the short term, financing via Recovery and Resilience fund also available
A - H	5. Power networks and infrastructure • Development of plans to strengthen transmission capacity from Lääne-Eesti to Latvia; • Review the approach for balancing the electricity system and open the markets for flexibility and	Ongoing process, expected to continue throughout the period interested Led by the TSO in cooperation with other Baltic TSOs	Financed largely via the current RAB model Merchant-model assets should be considered
A - C	6. Involvement of the civil society • Start-up support for Energy Communities; • Setup of one-stop shops to support vulnerable customers with energy efficiency advice and access to specific support schemes (for example, schemes to incentivise home insulation);	Short term (2025) Involves Central government, local government, and other agencies (for example, an Energy and Climate Agency)	Relatively low cost, depending on implementation options

	• Enhance public acceptance for new energy infrastructure		
A - C	7.Other actions		

8.3 Expected costs and revenues

This section discusses the costs and (when relevant) revenues associated with the actions indicated in the previous sections for this pathway.

8.3.1 Estimating the cost for renewable incentives

The total annual cost of a scheme to support offshore wind via a reverse auction depends on the type of support instrument chosen and on the wholesale price during the contracted years. Table 8-4 estimates the total amount of support required by different renewable technologies in 2030, in the case of unfavourable conditions (high cost) and the central case.[189] Assuming that any support scheme is designed to cut incentive payments to generators in case of high energy prices (as investors will be able to recover investment costs based on market income), under the most favourable conditions the support required will tend towards zero. Assuming support up to the ceiling established by the schemes will be needed for 50% of the electricity produced, the costs for the average household would be of around €14 per year. For other organisations the total cost will depend on the amount of energy used.

Table 8-4 Subsidy paid out in 2030 and average cost to consumer

Technology	Subsidy paid out (€ million)[190]	
	High	Central
Offshore Wind	-	-
Onshore Wind	43	22
Other Renewables	1	0
Solar PV	29	14
Total	73	37
Cost increase € per kW[191] (assumed demand: 9 TWh)	0.008	0.004
Cost increase (€ per household per year) (assumed energy import from network: 3500 kWh)	28.42	14.21

It is important to note that this analysis does not include the effect of wholesale prices, which are likely to be low under the *high* case and average under the *central* case. For the consumer, this means that the net effect will be an increase of less than what is presented in Table 8-4.

8.4 Recommendations to reduce the negative and increasing the positive environmental, social and economic - including regional - impacts

The *RES GAS* pathway has a high positive impact on the Estonian economy, but it also entails negative environmental impacts similar to the *RES + Storage* pathway. This section provides a detailed overview of the expected environmental and economic impacts from these developments and

[189] estimated according to the methodology presented in section 1.3
[190] See section 1.3 for the rates used to estimate the high and low case.
[191] Assumed unit cost increase if the cost of the renewable support scheme is spread across all users according to electricity imported from the network (i.e., excluding self-consumption). It is assumed subsidy costs will be spread over 9 TWh of demand as around 2 TWh are expected to be on-site generation and consumption (e.g., rooftop PV) that would not be metered and on which no levies will be placed).

provides specific recommendations on how to mitigate negative impacts and enhance positive impacts.

8.4.1 Environmental impact of the RES GAS pathway

The environmental impacts expected from the *RES GAS* pathway are similar to those of the Renewables and Storage pathway, where most of the impacts are related to the deployment of offshore and onshore wind farms, biomass plants and solar PV capacity. The main impacts on the local environment in this pathway are:

- The construction of offshore wind farms can reduce water quality, decrease marine biodiversity, disturb seabed flora/fauna and create a noise disturbance for local wildlife. Also, windmills can be a collision hazard for local bird populations. However, offshore wind farms can also have a positive impact on marine life by restricting fishing activities and creating an artificial reef;
- Onshore wind creates similar negative impacts as offshore wind, such as noise disturbance, impact on local habitat and a collision hazard for birds;
- Ground-mounted solar PV can also negatively impact the local habitat and land use; and
- **Biomass** is associated with deforestation, which could decrease biodiversity, cause soil erosion and reduce Estonia's carbon sink; biomass plants are also responsible for air pollution. Whilst power production from dedicated biomass falls to around ¼ of its 2020 level, the switching of oil shale plants to biomass in the 2030's sees total biomass use increase significantly, from 1.2 TWh in 2020 to 3.18 TWh in 2050. In order to limit negative impacts on forest coverage, it will be necessary to put in place adequate regulation and management of the use of forest timber for energy, including establishing clear limits to biomass quantities that can be extracted. For Estonia, this may include either restricting exports or increasing the import of biomass, bearing in mind the requirement of the Renewable Energy Directive (Directive (EU) 2018/2001 (recast), currently being revised)[192].

The installation of battery storage may also have a negative impact on the local environment, particularly if battery waste is mishandled and disposed into the local environment. New transmission lines between Lääne-Eesti and Latvia will also have an environmental impact.

Overall the environmental impact of this pathway is rather small and manageable, and the pathway will significantly reduce GHG emissions compared to 2020 levels, consistent with the climate-neutral goal and other climate and energy targets.

8.4.2 Socioeconomic impact of the RES GAS pathway

Compared to the other pathways, the Renewable Gas pathway has relatively high capital costs, totalling to €11.6 billion (€9.0 billion for capital and €2.6 billion of interest payments[193]). After 2050, there would be €3.2 billion of payments remaining. These investments would, in the static modelling case lead to the 3rd highest increase in economic output of €8.5 billion. In the dynamic modelling, the Renewable Gas pathway has relatively higher positive impacts on GDP, when taking demand and price effects into account, as the relatively high capital investments in technology produced locally helping

[192] https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

[193] Costs and interests do not include investment in transmission infrastructure

to stimulate demand effects, matched with relatively low prices which boost competitiveness. This also has beneficial impacts on employment. Additionally, average electricity prices in the *RES GAS* pathway are relatively similar to the Reference pathway and increase over the modelled time period. The price starts at 0.098 EUR/kWh in 2030 and increases to 0.101 EUR/kWh by 2050.

In terms of social impacts, onshore and (to a much lesser extent) offshore wind energy farms can be a discomfort for local communities due to the visual impact/noise disturbance. Mitigating measures should be explored and implemented. These investments should have positive social outcomes for local communities for example by: creating direct or indirect local jobs either directly or indirectly; or providing renewable energy generation based financial payments to the local municipality budget or community organisations for renewable energy generation based on agreements with developer.; or providing improvements in local infrastructure and so on. The different measures and their impacts have been researched separately.[194] Additionally, the deployment of RES will reduce fossil fuel use and therefore reduce associated health risks from air pollution in the medium- to long-term. This not only reduces air pollution-related fatalities but also reduces the burden on the local health system.

8.4.3 Main impacts by region

Table 8-5 provides a summary of impacts of the *RES GAS* pathway by region. Based on where the technology developments are expected, the pathway is expected to impact the economies in all regions. Further, offshore wind would have a negative impact of the fishing industry in Lääne-Eesti as well as maritime traffic, however the balance of the environmental impact is positive for the marine environment as the wind farm provides for an effective protected area. Solar PV would also impact the same regions as onshore wind, with the addition of the Louna-Eesti region. These capacity additions would require land which would impact the local environment, however the land footprint is small, and the investments would have a positive impact on the economy.

Table 8-5 Overview of impacts of the Renewable Gas pathway by region

Region	Environmental impact	Socio-economic impact
Lääne-Eesti	moderately positive	moderately positive
Põhja Eesti	neutral	positive
Kesk Eesti	neutral	positive
Kirde Eesti	neutral	positive
Louna Eesti	neutral	positive

8.4.4 Additional actions to reduce negative impacts and increase positive impacts

Table 8-6 provides an overview of the recommendations of how to minimise negative impacts and increase positive impacts. More detailed recommendations for these types of impacts are provided in section 1.4.

[194] ("Kohaliku kasu instrumentide analüüs", https://www.fin.ee/media/2723/download)

Table 8-6 Overview of recommendations for increasing positive impacts and minimising negative impacts by type of development and type of impact

Impact from	Type of impact	Recommendations
Offshore wind	Environmental	• Ensure careful design, monitoring and management of construction works to avoid disturbing marine wildlife and maintain water quality; • Use proper materials to create a suitable artificial reef and prevent erosion; • Enforce fishing restrictions near wind farms; • Define a strategy to ensure the health of marine areas is maintained
	Social	• Construct offshore wind farms near industrial areas where the landscape is already altered to reduce additional visual disturbances for the local community
	Economic	• Ensure relevant stakeholders are in consultation of wind farm projects, i.e. fishing industry and maritime; • Adequate measures to ensure consumers are not significantly impacted by RES charges and intermittency; • Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Onshore wind	Environmental	• Ensure careful design, monitoring and management of wind parks to avoid disturbing wildlife and their habitat
	Social	• Ensure onshore wind parks are not close to houses of local population
	Economic	• Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Solar PV	Environmental	• Ensure careful design, monitoring and management of solar parks to avoid disturbing wildlife and their habitat
	Economic	• Ensure that nationally there are enough highly skilled professionals in the solar energy industry
Biomass & Biogas	Environmental	• Adequate regulation and management of the use of forest timber for energy
	Economic	• Ensure that nationally there are enough highly skilled professionals in the bioenergy industry; • Adopt strict sustainability criteria to minimise negative impact on other industries
Battery storage	Environmental	• Ensure proper disposal/recycling of batteries at end of life
	Economic	• Ensure that nationally there are enough highly skilled professionals in the energy storage industry; • Modernise the electricity grid with smart technologies to enhance the development of battery storage
Transmission & distribution	Environmental	• Proper maintenance of land with transmission and distribution lines underneath; • Avoid unnecessary cutting of trees; • Reduce noise pollution via construction and technical solutions; • Strict requirements for maintenance and disposal of equipment
	Social	• Impose housing restrictions near high-voltage lines; • Avoided overhead lines in populated areas to reduce visual impact
	Economic	• Ensure that nationally there are enough highly skilled professionals in the T&D industry

8.4.5 *Further impacts from proposed actions and mitigation actions*

The focus on biogas and traditional renewables of this scenario requires relatively little change to the energy system and therefore few remedial actions. Expected impact on the energy bill is also limited.

However, investment in biogas capacity opens up the opportunity to utilise these capacities more than the modelling results suggest, via acting on their price. Essentially, by putting in place a series of actions to increase the availability and quantity of biogas, the load factor of the biogas capacity could be increased and diminish investment needs in other technologies.

According to a recent report published by Engie,[195] the main potential sources of biogas feedstock in Estonia are forest wood and residues (5.88 TWh/year), intermediate crops (crops which are cultivated between two main crops as a soil management solution[196], 1.57TWh/year) and green waste (roadside vegetation residues such as grasses or leaves, 1.11 TWh/year). The study concludes that the cost of biomethane is still high, but could decrease to below €70/MWh, on average, in 2050 if sufficient efforts to scale up capacity and unlock economies of scale are made. This is still above the expected average market price.

Actions to support better exploitation of these biogenic sources could include[197]:

- Long-term policy stability concerning biomass and biogas would allow the supply chain to invest and increase production while reducing costs;
- Exploit the interactions with other sectors (transport, heat), as biogas is an important decarbonisation option for both. For example, CHP installations would allow biogas plants to increase load factor throughout the year while retaining the capability to act as reserve capacity when necessary (the current reverse auction scheme already foresee the support only for CHP plants).
- However, if biogas deployment is the main target, electricity-only installations should be allowed, even if overall less efficient. While they do not offer the same benefits of CHPs, the expectation is that these plants would operate only for a limited number of hours every year.

In the short term, increasing the production of biomethane could have important implications for reducing gas dependency from third countries, and the capacity developed could, in the long term, be converted to electricity reserve. On the other hand, increasing biogas production risk having negative effect on forests, if it leads to the exploitation of wood resources that could be used higher up in the value chain (e.g. timber industry). Therefore, robust measures should be put in place to ensure that the main feedstocks are waste and not materials with higher potential. It is unclear if these waste feedstocks would be sufficient to support the modelled 1 GW of capacity, if this had a high load factor. What is clear is that if high loads were sustained then the average cost of power generation (and then prices) would increase.

8.5 Compatibility with the Estonian legal system and public perception

According to Article 2 of the revised Renewable Energy Directive (RED II), biogas falls within the scope of the Directive.[198] RED II lays down a binding EU-wide target for overall share of energy from renewable sources by 2030 as well as laying down **rules on financial support** for electricity from renewable sources, thus also including biogas.[199] Article 6 of the Directive lays down specific rules on financial support provided by Member States. Member States shall 'publish a long-term schedule anticipating the expected allocation of support, covering, as a reference, at least the following five years', with annual updates. At the same time, the effectiveness of the financial support schemes has to be regularly assessed. However, as discussed under Pathway 7, the TFEU provides specific **rules on state aid** and its compatibility with the internal market, which are further elaborated upon in the

[195] https://www.engie.com/sites/default/files/assets/documents/2021-07/ENGIE_20210618_Biogas_potential_and_costs_in_2050_report_1.pdf
[196] The study scope excludes energy crops, in line with RED II sustainability criteria.
[197] https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf
[198] RED II, Art. 2(1)
[199] RED II, Art. 1

new 2022 Guidelines (CEEAG). According to the Guidelines '*support for biofuels, bioliquids, biogas (including biomethane) and biomass fuels can only be approved to the extent that the aided fuels are compliant with the sustainability and greenhouse gases emissions saving criteria in Directive (EU) 2018/2001 and its implementing or delegated acts*'. These criteria apply to biofuels, bioliquids and biomass fuels are outlined in Art. 29 of RED II and intend to help guarantee real carbon savings and protect biodiversity. Therefore, the main requirement for biogas installations is that projects financially supported by Estonian government must be compliant with the sustainability and greenhouse gases emissions saving criteria of RED II.

9 *All Technologies* pathways

Key findings	
All technologies (AT)	• Given free choice in technologies – this pathway shows little variation from the reference pathway in the mix of power generation and capacity. • This pathway applies partial (25%) carbon capture and use to the oil shale plants post 2030. • Socio-economic results and prices are also very similar to the Reference case, with small positive impacts.
All technologies + no net electricity imports (*AT*-NIMP)	• Increased investment in the national power system and domestic electricity production, notably from offshore wind and solar PV. • This is the only pathway, in addition to the RES+storage pathway, which installs offshore wind by 2030. It also installs the most solar PV of any pathway by 2030. • This is the only pathway that essentially phases out oil shale by 2040, however it is partially replaced by natural gas, with 400MW of capacity installed by 2040 (the highest of all pathways) and this capacity is used heavily in the 2030-2040 period, declining after 2040 as a small nuclear unit (300MW) is built. • In addition to RES+storage this is the only pathway that produces at least the domestic requirement each year (no net imports) • Estonia becomes a net exporter after 2040. • This pathway has amongst the most positive socio-economic impacts as investments are relatively high and prices are around the mid-value of all pathways
All technologies + 1000 MW (AT + 1000)	• Two phases of the Paldiski pumped hydro facility (348MW), and 160 MW of new open cycle gas are used to satisfy a requirement of 1000 MW of dispatchable capacity in Estonia. • Pathway otherwise shows little variation from the reference pathway in the mix of power generation and capacity. • Socio-economic results and prices are also very similar to the Reference case, with small-medium positive impacts.

9.1 Pathway overview

The *All Technologies* pathways are the least constrained climate-neutral pathway explored in this study. The modelling results highlight a dynamic raised in the technology-focused pathways as well: the role of dispatchable generation in facilitating the grid integration of solar and wind power. In each of the technology-focused pathways, Estonia's major oil shale plants – Auvere and TG11, which are among the largest dispatchable generators in the country – are pivotal to enabling the exploitation of solar and wind resources.

9.1.1 *Impact of the All Technologies pathways on installed capacity and electricity generation*

In the *All Technologies pathways (AT, AT + 1000* and *AT-NIMP*), electricity capacity increases over the time period considered mainly due to increased battery, onshore wind, solar PV, and offshore wind capacity. The three AT scenarios differ in terms of the total capacity deployed in 2030 (the AT pathway sees total capacity at 5.5 GW in 2030, the AT 1000 MW has 6.5 GW, while the No net imports has 7.4 GW), but by 2050, all three scenarios reach around 16.5 GW of capacity. The three *All Technologies* scenarios differ in terms of the total capacity deployed in 2030 (the *AT* pathway sees total capacity at 5.5 GW in 2030, the *AT + 1000* has 6.5 GW, while the *AT-NIMP* has 7.4 GW), but by 2050, all three scenarios reach around 16.5 GW of capacity.

However there are some differences in the technology mix:

- New technologies emerging in the 1000 MW scenario: 348 MW of pumped hydro by 2030;
- Substantially different capacities in other technologies:
  - Oil shale capacity varies from 210 MW in the *AT-NIMP* to 619 MW in the AT 1000 MW, in 2030. Oil shale capacity disappears in the *AT-NIMP* by 2050, while it remains at 476 MW in the other scenarios.
  - To compensate for lower Oil shale, the *AT-NIMP* foresees higher gas generation capacity (up to 406 MW in 2050)
- For other technologies, deployment is broadly similar across the three pathways:
  - Batteries: between 1.6 GW and 2 GW by 2030, between 7.5 GW and 8 GW by 2050
  - Offshore wind: 2 GW by 2050, with 726 MW coming already in 2030 in the *AT-NIMP* scenario
  - Onshore wind 1.5 GW by 2050
  - Solar PV: 4GW by 2050, with the No net import scenario showing an earlier deployment compared to the others.

The *All Technologies* pathway only meets the electricity generation requirements in 2050 and mainly relies on increased electricity generation from onshore wind and solar PV as well as oil shale in 2030 and 2040 (Figure 9-1). Onshore wind electricity increases by 3 TWh in 2030 while more than 1 TWh solar PV is added each decade. In 2050, offshore wind electricity generated increases to 6.88 TWh.

The 1000 MW dispatchable pathway only meets the requirements for electricity generation in 2050. In 2030, there is a significant increase in electricity generated by onshore wind (+3.02 TWh) and solar PV (+2.25 TWh). In 2040 and 2050, solar PV continues to increase more than 1 TWh for each decade. In 2050, there is a significant increase in electricity generated by offshore wind (+7.42 TWh).

The *AT-NIMP* pathway meets the electricity generation requirements for each decade, 2030-2050. In 2030, there is a significant increase in electricity generated from onshore wind (+2.96 TWh), solar PV (+2.65 TWh) and offshore wind (+2.45 TWh). In 2050, there is a drastic increase in electricity generated from offshore wind (+4.55 TWh) and nuclear (+2.29 TWh). This pathway also shows two other important variations compared to most pathways, it is the only pathway to reduce oil shale electricity to almost zero, already by 2040, most other pathways see an increase to around 2.5 TWh in 2040 and to 3 TWh by 2050. AT-NIMP achieves this by 2040 by using natural gas as a transition fuel to replace the (biomass fuelled) oil shale after 2030, and then after 2040 by the deployment of a small nuclear unit, both delivering around 2.3 TWh, although the natural gas generation declines to 0.9 TWh by 2050 as the nuclear plant comes into the mix.

Figure 9-1 Electricity generation by technology for All Technologies pathways, 2020-2050, TWh[200]

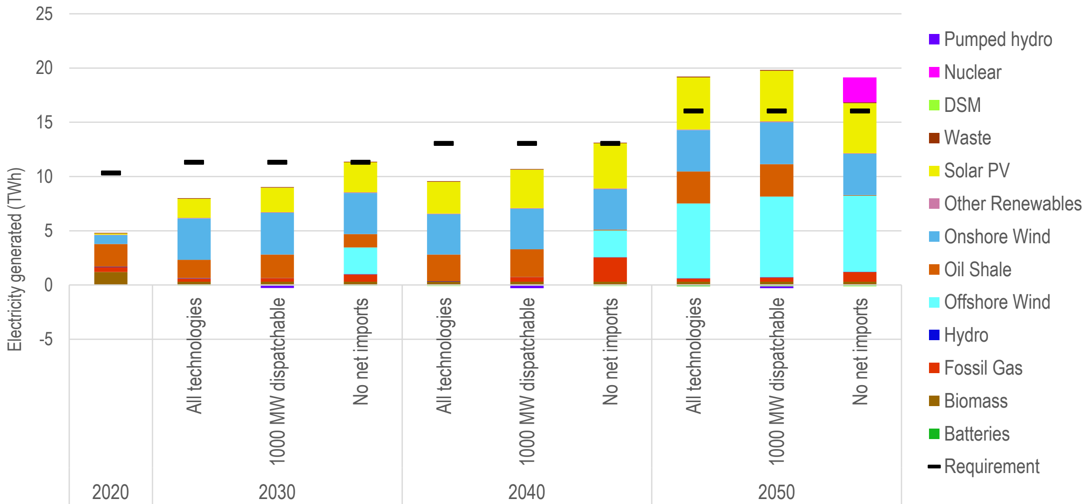


Table 9-1 provides an indication of how much additional generation is needed in 2030 beyond the already generation from auctions from 2019 to 2030.

Table 9-1 Additional remaining generation needed in 2030 beyond the generation from planned auctions in 2019-2023 for the *All Technologies* pathways, GWh

	Solar PV	Onshore wind
AT pathway		
Total additional generation	1,627	2,995
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation	1,349	2,159
AT-NIMP pathway		
Total additional generation	2,649	2,957
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation	2,370	2,121
AT + 1000 pathway		
Total additional generation	2,128	3,023
Generation from planned auctions (2019-2023)	279	836
Remaining additional generation	1,850	2,187

9.1.2 *Investment and infrastructure requirements for the All Technologies pathways*

In the *AT* pathway, the model balances access to dispatchable oil shale capacity with the 2050 climate neutrality requirement. Over the modelled period, there is €6.97 billion in investment in generation, storage, and transmission required in Estonia (Table 9-2). Most of the investment is needed by 2050, mostly for offshore wind.

[200] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

Table 9-2 Required investments by technology for the *AT* pathway, 2030-2050, million EUR_{2020}

Technology	2030	2040	2050	Total
Batteries	317	100	450	867
Fossil Gas	0	0	121	121
Offshore Wind	0	0	3,703	3,703
Oil Shale	0	80	0	80
Onshore Wind	1,264	0	0	1,264
Solar PV	256	271	396	924
DSM	13	0	0	13
Total	1,850	452	4,671	6,972
Lääne-Eesti - Latvia	9	18	128	155
Total	1,859	470	4,799	7,127

The 1000 MW dispatchable pathway reassesses the All technologies pathway with a constraint that Estonia must have at least 1000 MW of readily dispatchable electricity production capacity at all times. Technologies qualifying toward the 1000 MW requirement include non-CHP fossil fuel, biomass, and biogas; nuclear; landfill gas; and the Paldiski pumped hydro facility. Batteries are excluded. The model satisfies the new constraint by adding open cycle gas turbines (190 MW by 2040) and two phases of the Paldiski plant (348 MW). These changes in dispatchable capacity allow the model to forgo 500 MW of batteries by 2050 (compared to reference), and to build an additional 425 MW of solar PV by that year. This pathway requires €7.62 billion in investments in generation and storage from 2020 to 2050. The investment is mainly needed between 2041 and 2050 (€4.6 billion, mostly for offshore wind).

Table 9-3 Required investments by technology for the 1000 MW dispatchable pathway, 2030-2050, million EUR_{2020}[201]

Technology	2030	2040	2050	Total
Batteries	319	79	427	825
Biomass	0	0	0	0
Fossil Gas	0	150	0	150
Hydro	0	0	0	0
Offshore Wind	0	0	3,947	3,947
Oil Shale	56	24	56	136
Onshore Wind	1,264	0	0	1,264
Other Renewables	0	0	0	0
Solar PV	393	308	218	919
Waste	0	0	0	0
DSM	13	0	0	13
Nuclear	0	0	0	0
Pumped hydro	368	0	0	368
Total	2,413	561	4,648	7,623
Lääne-Eesti - Latvia	10	7	138	155
Total	**2,423**	**568**	**4,786**	**7,778**

[201] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

The *AT-NIMP* pathway adds to the *AT* pathway a requirement that Estonia's electricity imports and exports should approximately offset each other. This rule applies in all years of simulation. This pathway requires €8.08 billion in investments in generation and storage from 2020 to 2050 (Table 9-4). This includes a €1.5 billion investment in offshore wind prior to 2030 and a €0.78 billion investment in nuclear by 2050.

Table 9-4 Required investments by technology for the *AT-NIMP* pathway, 2030-2050, million EUR_{2020}[202]

Technology	2030	2040	2050	Total
Batteries	409	147	360	916
Fossil Gas	82	256	0	338
Offshore Wind	1,481	0	2,335	3,816
Onshore Wind	1,264	0	0	1,264
Solar PV	536	321	95	952
DSM	13	0	0	13
Nuclear	0	0	776	776
Total	3,784	724	3,567	8,075
Lääne-Eesti - Latvia	59	17	60	135
Total	**3,843**	**741**	**3,627**	**8,210**

9.1.3 Risk analysis of the All Technologies pathways

Stakeholders consider the *AT* pathway as being low risk, while the AT + 1000 pathway and the *AT-NIMP* pathway are higher risk (based on average risk score for all risks). Furthermore, the *AT* pathway is preferred by surveyed stakeholders that participated in the risk analysis, while there is more opposition to the *AT-NIMP* pathway. For *AT*, the greatest perceived risk is the possibility of local opposition to new infrastructure and barriers to implementation from local policies. For the AT + 1000 pathway, stakeholders perceive the greatest risk to be not achieving widespread acceptance of new infrastructure. For the *AT-NIMP* pathway, the greatest risk is not achieving widespread acceptance of new infrastructure and regulatory risks.

9.2 Actions

The AT and AT-1000MW pathways see a similar share of generation across technologies, but with a difference in total capacity available in the short term and the emergence of some specific technologies in some pathways. Therefore, the general approach for these two pathways should be similar, but some targeted actions must also be included. The AT-NIMP pathway is more unique in the way that oil shale is phased out in preference for, at first, natural gas and, later on, nuclear. However, in general, as the main objective of all three pathways is technology neutrality, actions should be directed towards:

- Setting up appropriate technology-neutral market instruments, although these may have different strengths according to the additional objectives (no net imports and 1000 MW margin);
- Ensure a level playing-field across technologies to foster competition. In some cases, this may mean providing more support to some technologies to help them reach maturity stage, or compensate them for some disadvantage they are exposed to;

[202] Trinomics 2022, Transitioning to a climate-neutral electricity generation in Estonia, D6 sensitivity analysis

- For the *AT + 1000* and the *AT-NIMP* pathways, provisions should be made to reward capacity (rather than generation).

These are the recommended priority actions:

Support to renewables

- Technology neutral auctions should continue, aiming at procuring around 3 GWh of onshore wind and between 1.6 GWh and 2.6 GWh of Solar PV, by 2030.
- If the aim is to achieve no net imports, a technology specific auction for offshore wind, aimed at procuring 2,500 TWh (about 730 MW), should be implemented by 2025. However, if the Baltic offshore grid is deployed as expected, and if connection costs are kept reasonably low, there are chances that bids from offshore wind may come close to be competitive with onshore applications. By the late 2020s, the Estonian government should assess if this is the case, and decide whether a technology-specific auction is necessary.
- A substantial amount of new fossil gas capacity (between 160 MW and 400 MW by 2050) is required in the all technologies scenarios, but utilisation is rather low (20%-25% load factor) in the AT+1000MW pathway, and higher, but not very high (around 63%) at the 2040 peak in the AT-NIMP pathway. The expectation is that fossil gas plants will be able to earn revenues by producing during periods with low renewable generation and low battery availability, but it is unlikely new investment in fossil gas would come forward in the AT+1000MW pathway without a capacity-based support mechanism. This may also be an issue in the No net electricity import scenario particularly up to 2030 and after 2040.
- Across the three scenarios, a substantial amount of solar PV is expected to start generating in 2030, with in particular the *AT-NIMP* deploying 2.4 GW of solar by 2030 (the highest of any pathway). Therefore it will be appropriate to:
    - Identify alternatives to rooftop and ground installations. These could include facades, parking spaces, transport routes and so on. Government buildings and government-owned facilities should lead by example and consider these solutions together with any new refurbishment or new building work;
    - Introduce a new regulation to ensure all new buildings and all buildings undergoing major renovation include solar panels.

Other technologies

Modelling results for the *All Technologies* scenarios shows new technologies emerging, such as pumped hydro or nuclear, which never emerge in technology specific pathways. This is a reasonable result, as these technologies are less established and their costs less certain, but when particular constraints are imposed, they become relevant.

Therefore, in a technology-neutral approach, it makes sense to keep all potential options open, and reassess at different points in time to what extent it makes sense to commit resources to ensure these new technologies are effectively deployed. Under this scenario, it could be appropriate to provide support for:

- Research and development of new technologies and applications. This should include both generation and flexibility technologies;
- A “slow burning” nuclear programme; the programme would aim to slowly build the necessary know how but will not commit until Small Modular Reactors reach commercial

maturity and their costs become known. At that point it would also make sense to reconsider full scale nuclear reactors, with the knowledge that the supply chain and the investment will be spread across multiple facilities to reduce risks;

- A programme aimed at enhancing the case for CCU, including carbon capture, the use of CO_2 in industrial applications and CO_2 transport infrastructure. CCU could be an attractive decarbonisation option when economies of scales are reached, as at that point it becomes economically feasible for different applications beyond the power sector, such as industry and hydrogen. Such a programme would wait until there is a clear option to capture more substantial amount of CO_2 than what was envisaged in the CCU pathway, and only at that point commit to the technology. However, CCU is only really picked up as an option by the All Technologies pathway where it is partially deployed on the oil shale plants.

A limitation to the last recommendation concerns that lifetime of the plants involved, and the opportunity cost. In the modelling assumption, the installation of the carbon capture equipment at Auvere and TG11 was set to match current refurbishment schedules, to lower installation costs. If the installation of the carbon capture equipment does not happen during the scheduled refurbishments, its costs may be higher.

Security of Supply and flexibility

The three *All Technologies* scenarios have a similar amount of total generation deployed by 2050, and appear to require a similar amount of flexibility[203] even though there are some significant differences in the technology mix. Therefore, the approach to deal with flexibility can be identical, and similar to what recommended in other pathways, should include the publication of a security of supply and flexibility strategy, which should be tailored to the expected deployment trajectory of wind energy and other renewables according to the auctioned capacities. The strategy would cover:

- Required transmission and interconnection infrastructure;
- Extended agreements with other Baltic states for increased cooperation on flexibility matters, in view of facilitating cross-border trade of (balancing) energy by market operators and cross-border procurement of ancillary services (including balancing capacity and energy) by TSOs, in order to enhance competition and markets' liquidity and transparency;
- Roadmap for deployment of storage solutions, which should include steps that market platform operators and the TSO and DSOs should take to facilitate the participation of storage in the spot markets and in the procurement of ancillary services (e.g. by enabling aggregation);
- Government-funded pilot scheme for the award of grants to the deployment of innovative large-scale storage solutions and to flexibility providers. The all technologies pathways foresee ambitious battery deployment by 2030 (between 1.6 GW and 2.1 GW), which is unlikely to happen only relying on market forces. Options to support flexibility and storage solutions may include:
    - Direct grants (set via administrative procedure) for the deployment of innovative technologies;
    - Auction-based support, awarded via reverse auctions to the most competitive bidder to support those technologies close to market-readiness;
    - Inclusion of batteries support as part of other instruments (e.g. within a capacity instrument; or as part of the technology specific auctions, where each auction would

[203] In all three scenarios dispatchable capacity is between 52% and 55% in 2050.

have two pots: one for generation only, one for supporting generation + storage installations).

Table 9-5 Recommended actions

Ch 5 ref	Additional details	Timing and responsibility	Further details
A-C	Planning process • Streamline process, with particular focus large projects; • Setup of single contact point approval process; • Mandate the inclusion of renewable in local spatial plans; • Additional administrative resources at national level, dedicated to offshore wind deployment	Short term (by 2025) The review process will include national and local administrations and other interested bodies	Largely one-off administrative costs + some additional human resources dedicated to the process
B, C, D	Institutional reform • Setup of an Energy Agency, whose mandate has a clear remit to support offshore wind deployment	Short term (by 2025) Setup by Central government as an independent body	Financed via the general budget
A-E	Investment risk • Various actions to facilitate the uptake of PPAs; • Increased funding and limits for Kredex guarantees • Technology-neutral CfDs	Short term (by 2025) Action led by central government, should involve also institutional investors and Kredex	Loan guarantees financed via general budget and EU funds CfDs funded via the energy bill (€36-€189 million)
A	Financial incentives for RES for households and SMEs • on-site small scale renewable generation support scheme, linked to a buildings energy efficiency scheme	The action starts in the short term but likely to continue beyond 2030	Financed via the energy bill (either directly as environmental levy or indirectly via supplier obligation) In the short term, financing via Recovery and Resilience fund also available
A - E	Power networks and infrastructure • Development of plans to strengthen transmission capacity from Lääne-Eesti to Latvia; • Review the approach for balancing the electricity system and open the markets for flexibility and	Ongoing process, expected to continue throughout the period interested Led by the TSO in cooperation with other Baltic TSOs	Financed largely via the current RAB model Merchant-model assets should be considered
A - C	Involvement of the civil society • Start-up support for Energy Communities; • Setup of one-stop shops to support vulnerable customers with energy efficiency advice and access to specific support schemes (for example, schemes to incentivise home insulation); • Enhance public acceptance for new energy infrastructure	Short term (2025) Involves Central government, local government, and other agencies (for example, an Energy and Climate Agency)	Relatively low cost, depending on implementation options
A - C	Other actions		

9.3 Expected costs and revenues

This section discusses the costs and (when relevant) revenues associated with the actions indicated in the previous sections for this pathway.

9.3.1 *Estimating the cost for renewables support schemes*

The total annual cost of a scheme to support offshore wind via a reverse auction depends on the type of support instrument chosen and on the wholesale price during the contracted years. Table 9-6 estimates the total amount of support required by different renewable technologies in 2030, in the case of unfavourable conditions (high cost) and the central case.[204] Assuming that any support scheme is designed to cut incentive payments to generators in case of high energy prices (as investors will be able to recover investment costs based on market income), under the most favourable conditions the support required will tend towards zero. Assuming support up to the ceiling established by the schemes will be needed for 50% of the electricity produced, the costs for the average household would be between €14 and €73 per year. For organisations the total cost will depend on the amount of energy used.

Table 9-6 Subsidy paid out in 2030 and average cost to consumer

Technology	Subsidy paid out (€ million)[205]					
	AT		*AT +1000*		*AT - NIMP*	
	High	Central	High	Central	High	Central
Offshore Wind	-	-	-	-	98	49
Onshore Wind	43	22	44	22	42	21
Other Renewables	1	0	1	0	1	0
Solar PV	27	13	37	18	47	24
Total	71	36	82	41	189	94
Cost increase € per kW[206] (assumed demand: 9 TWh)	0.008	0.004	0.009	0.005	0.021	0.010
Cost increase (€ per household per year) (assumed energy import from network: 3500 kWh)	27.66	13.83	31.78	15.89	73.39	36.69

It is important to note that this analysis does not include the effect of wholesale prices, which are likely to be low under the *high* case and average under the *central* case. For the consumer, this means that the net effect will be an increase of less than what is presented in Table 9-6.

9.4 Recommendations to reduce the negative and increasing the positive environmental, social and economic - including regional - impacts

The impact of the *All Technologies* pathways are similar to the other pathways, in the sense of the impacts from offshore wind, solar PV and battery storage. For the *AT-NIMP* pathway, natural gas and nuclear impacts are also important. Chapter 1.4 provides a detailed overview of the expected environmental and economic impacts from these developments and provides specific recommendations on how to mitigate negative impacts and enhance positive impacts.

9.4.1 Environmental impact of the All technologies pathways

The main environmental impacts of the All technologies pathways are:

- The construction of **offshore wind farms** can reduce water quality, decrease marine biodiversity, disturb seabed flora/fauna and create a noise disturbance for local wildlife. Also, windmills can be a collision hazard for local bird populations. However, offshore wind farms can also have a positive impact on marine life by restricting fishing activities

[204] estimated according to the methodology presented in section 1.3
[205] See section 1.3 for the rates used to estimate the high and low case.
[206] Assumed unit cost increase if the cost of the renewable support scheme is spread across all users according to electricity imported from the network (i.e., excluding self-consumption). It is assumed subsidy costs will be spread over 9 TWh of demand as around 2 TWh are expected to be on-site generation and consumption (e.g., rooftop PV) that would not be metered and on which no levies will be placed).

and creating an artificial reef. Other relevant impacts are from onshore wind, biomass and solar PV; the balance of environmental impacts is overall positive.

- **Onshore wind** creates similar negative impacts as offshore wind, such as noise disturbance, impact on local habitat and a collision hazard for birds;
- **Solar PV** can also negatively impact the local habitat;
- **Biomass** is associated with deforestation, which could decrease biodiversity, cause soil erosion and reduce Estonia's carbon sink; biomass plants are also responsible for air pollution. Whilst power production from dedicated biomass falls to around ¼ of its 2020 level, the switching of oil shale plants to biomass in the 2030's sees total biomass use increase significantly, from 1.2 TWh in 2020 to 3.25 TWh and 3.29 in 2050 for the AT and for the AT-1000MW, respectively. Generation from biomass instead decreases substantially in the AT-NIMP scenario, from 1.2 TWh in 2020 to 0.35 TWH in 2050. In order to limit negative impacts on forest coverage, it will be necessary to put in place adequate regulation and management of the use of forest timber for energy, including establishing clear limits to biomass quantities that can be extracted. For Estonia, this may include either restricting exports or increasing the import of biomass, bearing in mind the requirement of the Renewable Energy Directive (Directive (EU) 2018/2001 (recast), currently being revised)[207].
- **Nuclear** - for the *AT-NIMP* pathway: the potential environmental impact of nuclear energy is very severe in case of an accident, however in regular operation, nuclear energy does not have significant negative impact on the environment. See also section 8.4.1 for further discussion on nuclear power and environmental risks.

Furthermore, the significant installation of battery storage could also have a negative impact on the local environment, particularly if battery waste is mishandled and disposed incorrectly.

Overall the environmental impact of these pathways is rather small and manageable, with attention points especially on sustainable biomass use and nuclear safety and waste management (AT-NIMP only). The pathways will significantly reduce GHG emissions compared to 2020 levels, consistent with the climate-neutral goal and other climate and energy targets.

9.4.2 *Socioeconomic impact of the All Technologies pathways*

All of the *All technologies* pathways have a higher GDP than the *Reference* pathway, with the *AT-NIMP* pathway having the highest positive impact, followed by the *AT + 1000* and *AT* pathways. Production would increase in all sectors for all of the *All Technologies* pathways. Production increase is greatest in the electrical equipment, machinery and equipment and other equipment goods industries. Compared to the Reference pathway, all of the *All technologies* pathways have higher employment, with the *AT + 1000* pathway having the highest level of employment.

In 2030 and 2040, the average electricity prices for the *AT + 1000* and *AT-NIMP* pathways are relatively low compared to the *AT* and *Reference* pathway (Table 9-7). However, by 2050, the average electricity prices for these two pathways are a little higher than the *AT* and *Reference* pathways.

[207] https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

Table 9-7 Average electricity prices for the *All Technologies* pathways, EUR2020/kWh, 2030-2050

Year	Reference	AT	AT + 1000	*AT-NIMP*
2030	0.106	0.099	0.096	0.091
2040	0.103	0.107	0.104	0.104
2050	0.098	0.097	0.103	0.107

The table below presents the capital costs and interest payments for the *All technologies* pathways. The *AT-NIMP* pathway has the greatest capital costs, but the lowest payments remaining after 2050.

Table 9-8 Capital costs and interest payments for all technologies pathways[208], million EUR

Pathway	Capital	Interest	Total	Post 2050 payments remaining
All technologies	6,959	2,053	9,013	3,327
1000 MW dispatchable	7,610	2,245	9,855	3,311
AT-NIMP	8,062	2,379	10,441	2,540

The all technologies pathways also result in renewable energy shares of close to 100% by 2040, except in the case of AT-NIMP where a value of 83% is lower due to the use of natural gas. The transition to renewables will improve Estonia's security of energy supply by reducing fossil energy imports for power production.

In terms of social impacts, onshore and (to a much lesser extent) offshore wind energy farms can be a discomfort for local communities due to the visual impact/noise disturbance. Mitigating measures should be explored and implemented. These investments should have positive social outcomes for local communities for example by: creating local jobs either directly or indirectly; or providing renewable energy generation based financial payments to the local municipality budget or community organisations; or providing improvements in local infrastructure and so on. The different measures and their impacts have been researched separately.[209] Additionally, the deployment of RES will reduce fossil fuel use and therefore reduce associated health risks from air pollution in the medium-to long-term. This not only reduces air pollution-related fatalities but also reduces the burden on the local health system.

9.4.3 *Main impacts by region*

Table 9-9 provides a summary of impacts of the *All Technologies* pathways by region. Based on where the technology developments are expected, the pathways are expected to impact the economies in all regions. Furthermore, offshore wind would have a negative impact of the fishing industry in Lääne-Eesti as well as maritime traffic, although a positive impact on environmental quality. Solar PV would also impact the same regions as onshore wind, with the addition of the Louna-Eesti region. In the *AT-NIMP* pathway, the development of nuclear power plants would impact the Kesk-Eesti and Kirde-Eesti regions, which would negatively impact the local aquatic and terrestrial environment as well as introduce risks to the local community.

[208] Costs and interests do not include investments in transmission infrastructure
[209] ("Kohaliku kasu instrumentide analüüs", https://www.fin.ee/media/2723/download)

Table 9-9 Overview of impacts of the *All Technologies* pathways by region.

Region	Environmental impact	Socio-economic impact
Lääne-Eesti	moderately positive	moderately positive
Põhja Eesti	neutral	positive
Kesk Eesti	negative*	Positive / neutral*
Kirde Eesti	negative*	Positive / neutral*
Louna Eesti	neutral	positive

*No net import pathway only, this reflects the additional environmental risk of the installed nuclear power in this pathway

9.4.4 *Additional actions to reduce negative impacts and increase positive impacts*

Table 9-10 provides an overview of the recommendations of how to minimise negative impacts and increase positive impacts. More detailed recommendations for these types of impacts are provided in Chapter 1.4.

Table 9-10 Overview of recommendations for increasing positive impacts and minimising negative impacts by type of development and type of impact

Impact from	Type of impact	Recommendations
Offshore wind	Environmental	• Ensure careful design, monitoring and management of construction works to avoid disturbing marine wildlife and maintain water quality; • Use proper materials to create a suitable artificial reef and prevent erosion; • Enforce fishing restrictions near wind farms; • Define a strategy to ensure the health of marine areas is maintained
	Economic	• Ensure relevant stakeholders are in consultation of wind farm projects, i.e. fishing industry and maritime; • Adequate measures to ensure consumers are not significantly impacted by RES charges and intermittency; • Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Onshore wind	Environmental	• Ensure careful design, monitoring and management of wind parks to avoid disturbing wildlife and their habitat
	Social	• Ensure onshore wind parks are not close to houses of local population
	Economic	• Ensure that nationally there are enough highly skilled professionals in the wind energy industry
Solar PV	Environmental	• Ensure careful design, monitoring and management of solar parks to avoid disturbing wildlife and their habitat
	Economic	• Ensure that nationally there are enough highly skilled professionals in the solar energy industry
Biomass & Biogas	Environmental	• Adequate regulation and management of the use of forest timber for energy
	Economic	• Ensure that nationally there are enough highly skilled professionals in the bioenergy industry; • Adopt strict sustainability criteria to minimise negative impact on other industries
Battery storage	Environmental	• Ensure proper disposal/recycling of batteries at end of life.
	Economic	• Ensure that nationally there are enough highly skilled professionals in the energy storage industry • Modernise the electricity grid with smart technologies to enhance the development of battery storage
Transmission & distribution	Environmental	• Proper maintenance of land with transmission and distribution lines underneath; • Avoid unnecessary cutting of trees; • Reduce noise pollution via construction and technical solutions; • Strict requirements for maintenance and disposal of equipment

Impact from	Type of impact	Recommendations
	Social	• Impose housing restrictions near high-voltage lines; • Avoided overhead lines in populated areas to reduce visual impact
	Economic	• Ensure that nationally there are enough highly skilled professionals in the T&D industry
Nuclear*	Environmental	• Strict control of water use and disposal (due to thermal pollution); • Strict limitations on the release of toxic and radioactive waste into the environment and ensure proper waste management
	Social	• Strict requirements for prevention and mitigation of severe accidents
	Economic	• Ensure that nationally there are enough highly skilled professionals in the nuclear energy industry

*No net import pathway only

9.4.5 Further impacts from proposed actions and mitigation actions

The three pathways require a medium-to-high level of investments but end up with a relatively balanced mix across technologies, which means that there is limited risks associated with one particular technology and limited risk that the chosen technology would be too expensive or underperforming.

9.5 Compatibility with the Estonian legal system and public perception

The *All Technologies* scenarios are those with the highest compatibility with the Estonian legal system and the current approach, given that they avoid preferential treatment of one technology.

The public perception is also unlikely to be a problem, given technology neutrality is the current approach.

With regards to **investments in natural gas**, with the introduction of the new EU Taxonomy Regulation[210] the European Commission has decided that power plants burning natural gas can be considered generators of green energy. This means they can count as sustainable. The Taxonomy Regulation lays out three types of activities: low-carbon (Article 10(1)), transitional (Article 10(2)) and enabling (Article 16). In this Complementary Climate Delegated Act, the Commission includes certain nuclear and gas activities in the second category of activities, i.e. transitional, those covered by Article 10(2) of the Taxonomy Regulation. These are activities that cannot yet be replaced by technologically and economically feasible low-carbon alternatives, but do contribute to climate change mitigation and with the potential to play a major role in the transition to a climate-neutral economy, in line with EU climate goals and commitments, and subject to strict conditions, without crowding out investment in renewables. Furthermore, this Delegated Act also provides for specific disclosure requirement associated with natural gas and nuclear energy activities included in the act, by amending the Delegated Act on disclosures under Article 8 of the Taxonomy Regulation. This amendment will introduce requirements for large listed non-financial and financial companies to disclose the proportion of their activities linked to natural gas and nuclear energy. This should help investors to distinguish between the different activities they are investing in.

For the AT-NIMP pathway, the issue of nuclear raises legal issues as outlined in section 8.5.

[210] REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment

10 Conclusions and general recommendations

10.1 Outcomes of the project deliverables

Figure 10-1 provides an overview each pathway, including the results from the energy system modelling, the socio-economic impact assessment, the risk analysis, the sensitivity analysis and the action plans. The results are color-coded, based on whether the results are favourable or unfavourable:

- Green (++): very favourable;
- Yellow (+/0): moderately favourable/neutral;
- Light red (-): moderately unfavourable; and
- Dark red (--): very unfavourable.

Figure 10-2 provides an assessment of each pathway against key indicators: security of supply, limit to fossil fuels use, cost, socio-economic impact, CO_2 emissions, environmental impact, perceived risk, and main implementation challenge. The results are color-coded in the following manner:

- Green (++): very favourable;
- Light green (+): moderately favourable;
- Yellow (0): little or no impact;
- Light red (-): moderately unfavourable; and
- Dark red (--): very unfavourable.

The rating for security of supply is based on the total electricity generated (TWh) in 2030, 2040 and 2050 compared to the generation requirement. The indicator assesses whether the total electricity generated is greater than the amount of electricity demand in the three modelled years (on an annual basis). The *RES + Storage*, *Nuclear* and *AT-NIMP* pathways have the highest rating, whereas the *CCU* pathway has the lowest rating for this category.

The rating for limit of fossil use is based on the fossil gas generated (TWh) in 2050. The lower the electricity generated from fossil gas, the more favourable the impact is. However, there is an exception for the *CCU* pathway, which has a *very unfavourable* rating due to the continued use of oil shale in this pathway. The *AT-NIMP* pathway achieve the lowest mark for limiting fossil use, while the *RES + Storage*, *Nuclear* and *RES GAS* pathways achieve the highest mark. This rating is based on the assumption that biomass is carbon neutral, an assumption which is questionable, and noting that almost all pathways except *AT-NIMP, CCU* and *Nuclear* rely on growing biomass fuelled oil shale generation through to 2050.

The rating for cost is based on both the average electricity price (EUR/kWh) in 2050 and the total investment costs (MEUR) from 2021 to 2050. Both values are rated relative to the other pathways, where a lower price/investment cost achieves a higher rating. The *RES + Storage* pathway is considered very unfavourable due to the relatively high electricity price and high investment costs.

The socio-economic impact rating is based on the results of Deliverable 4 (See Figure 10-1 for description for each pathway). The *RES + Storage*, *RES GAS* and *AT-NIMP* have the most favourable socio-economic impact, whereas the *CCU* pathway has the least favourable.

The rating for CO_2 emissions is based on the total emissions from 2020 to 2050 and the emissions level by 2050 ($ktCO_2$). The ratings are based on these values relative to the Fit-for-55 target. All of the pathways have a *moderately* or *very favourable* rating for carbon emissions.

The environmental impact rating is based on the perceived risk of the pathway implementation resulting in adverse environmental impacts on air, soil, water or biodiversity (based on the results of the stakeholder risk survey in DLV 5). The rating is based on the average score of severity and likelihood of an adverse environmental impact. The score is from 1 to 5, where 1 is low severity/likelihood and 5 is high severity/likelihood. The *Nuclear* pathway is considered to be *very unfavourable*.

The main implementation challenge rating is based on the severity of specific challenges for each pathway in terms of the implementation of the pathway and the required actions. The *Nuclear* pathway is considered to have the greatest implementation challenges due to the technology requirements and the resulting costs.

Figure 10-1 Overview of pathway results from each deliverable

Pathway	DLV 3 Pathway analysis (updated to S1 results from DLV 6)	DLV 4 Socio-economic impact analysis	DLV 5 Risk analysis	DLV 6 Sensitivity analysis	DLV 7
Reference	• Builds new capacity with a focus on Batteries, Solar PV and Onshore Wind. • Offshore wind follows only after 2040. • Growing use of (biomass fueled) oil shale plants, providing almost 3 TWh of power by 2050. • Only meets domestic power requirement fully by 2050.	Assessments of socio-economic impact were made relative to the reference pathway.	--		
Renewables + storage (offshore wind) [RES + Storage]	• Adds 1000 MW of offshore wind by 2030, expanding to 4000 MW by 2050. This delivers more than half of all generation. • Also expands batteries, onshore wind and solar PV similar to reference. Achieves RES shares of 100% from 2040. • Growing use of (biomass fueled) oil shale plants, providing more than 3 TWh of power by 2050. • Estonia becomes net power exporter already from 2030.	++ GDP impact, especially with open financing 0 employment impact, positive with open finance, negative under self-finance + Price impact, small reduction ++ Distributional impact, especially with open finance	Perceived as risky by stakeholders, although it is the most supported. Exposed to high energy market risk	++ GDP impact, especially in case of higher biomass prices (S3) + employment impact, small positive but only in case of higher biomass prices (S3) -- Price impact, highest prices by 2050 +++ Distributional impact	Highest investments required, but in known technologies. The success may depend on few key offshore projects being successful. Challenging actions to deploy sufficient battery capacity
Nuclear	• Builds a 900MW nuclear facility (3x 300MW small modular reactors) by 2040. This provides approx.5.5 TWh of power, or around 1/3 of total supply in 2040. • Nuclear complements major battery and solar PV additions - highest of each across all pathways. • Declining use of (biomass fueled) oil shale plants after 2030, these provide around 1 TWh of power by 2050. • Offshore wind only added after 2040. • Estonia becomes net power exporter from 2040.	0 GDP impact, slight positive with open, slight negative with closed financing - Employment small negative impact -- Prices large negative impact + Distributional impact, small positive	Riskiest scenarios, stakeholders moderately negative about it. Main risks are related to citizens opposition, regulation, and technological delay.	++ GDP impact, positive, except in case of enforced 90% dispatch (S2), then small negative + employment impact, positive, except in case of enforced 90% dispatch (S2), then negative + Price impact, lowest prices by 2050, except in case of enforced 90% dispatch (S2), then negative + Distributional impact, positive, except in case of enforced 90% dispatch (S2), then negative	Relies on unproven technologies, for which Estonia has no history. This may force Estonia to take expensive remedial actions in the mid 2030s Challenging amount of battery deployment. Positive socio-economic results occur in sensitivity analysis only at relatively low load factors (65-70%) for nuclear, enforcing higher loads leads to negative impacts.
CCU	• Continues to operate oil shale plants fueled by oil shale after 2030 with adoption of CCS technology, however at significantly lower scale, only 0.5 TWh annually by 2040. • Batteries and onshore wind are other major additions. However, relatively little solar PV capacity added, and almost no offshore wind. • Satisfies less and less of domestic power requirement, resulting in major import dependency.	-- GDP negative impact -- Employment negative impact --- Prices large negative impact - Distributional negative impact	Medium risk scenario, but disliked by stakeholders. Main risk is technological	-- GDP negative impact - Employment negative impact -- Prices negative impact - Distributional negative impact	Lowest investment required, but it could be one of the more challenging to implement in the short term. Cost savings come with high socio-economic costs and energy security risks.
Renewable gas [RES GAS]	• Adds 1000MW of biogas capacity by 2030, however this is too expensive to run and makes virtually no actual contribution to generation. • Otherwise is similar to reference, adding battery, solar PV and onshore wind capacity. Although battery additions are lowest of all pathways until after 2040.	++ GDP impact, especially with open financing ++ employment impact, especially with open finance, neutral under self-finance	Less risky scenario, overall liked by stakeholders. Very exposed to international energy prices but less exposed to the risk of	++ GDP impact, positive +++ employment impact, positive + Price impact, small positive	Biggest challenge is the financing of biogas capacity in the short term. While this reduces the risks of relying only on batteries for

Pathway	DLV 3 Pathway analysis (updated to S1 results from DLV 6)	DLV 4 Socio-economic impact analysis	DLV 5 Risk analysis	DLV 6 Sensitivity analysis	DLV 7
	• Growing use of (biomass fueled) oil shale plants, providing almost 3 TWh of power by 2050. • Offshore wind only added after 2040. • Estonia becomes net power exporter only by 2050.	- Price impact, small increase ++ Distributional impact, especially with open finance	competition for rare materials needed for batteries.	++ Distributional impact, positive	flexibility, for flexibility purposes is cheaper investing in batteries.
All technologies [AT]	• Builds new capacity with a focus on Batteries, Solar PV and Onshore Wind. Also adds small fossil gas plant after 2040. • 2000MW offshore wind follows only after 2040. • Growing use of (biomass fueled) oil shale plants, providing almost 3 TWh of power by 2050. • Only meets domestic power requirement fully by 2050.	+ GDP impact, small positive with open financing - employment impact, small negative + Price impact, small reduction 0 Distributional impact, negligible	Low risk scenario with good stakeholder support.	+ GDP impact, small positive + employment impact, small positive + Price impact, small reduction 0 Distributional impact, minimal impact	Relatively low total investment needs (€ 7 billion by 2050), most of which is expected to be required after 2040 and in proven technology means actions do not need to be too complex or expensive
1000 MW dispatchable capacity [AT + 1000]	• Adds a 348MW pumped hydro facility by 2030. This helps to always provide 1000MW of dispatchable capacity. • Builds new capacity with a focus on Batteries, Solar PV and Onshore Wind. Also adds small fossil gas plant after 2030. • 2100MW offshore wind follows only after 2040. • Growing use of (biomass fueled) oil shale plants, providing almost 3 TWh of power by 2050. • Only meets domestic power requirement fully by 2050.	+ GDP impact, small positive with open financing - employment impact, small negative - Price impact, small increase 0 Distributional impact, negligible	Second best scenario, liked by stakeholders.	+ GDP impact, small positive ++ employment impact, positive 0 Price impact, minimal impact + Distributional impact, small positive impact	The 1000 MW capacity requirement increases investment needs and strength of associated actions, in particular subsidies
No net imports *[AT-NIMP]*	• Builds new capacity with a focus on Batteries, Solar PV and Onshore Wind. Also adds medium fossil gas capacity (400MW) after 2030. This acts as a transition power source prior to the nuclear power unit coming online by 2050. • 725MW offshore wind already by 2030, expands to 2000MW after 2040. • Builds one 300MW nuclear unit after 2040. • Declining use of (biomass fueled) oil shale plants, providing almost no power by 2040. • As per defined characteristics of pathway, it meets domestic power requirement already by 2030, though only by 2050 is there significant export potential.	++ GDP impact, especially with open financing ++ employment impact, especially with open financing - Price impact, small increase + Distributional impact, positive	Second highest risk, overall disliked by stakeholders. High regulatory risks	++ GDP impact, positive ++ employment impact, positive 0 Price impact, minimal impact 0 Distributional impact, minimal impact	Main challenge is associated with high capacity required by 2030, with associated high investment

Figure 10-2 Pathway assessment against key criteria

Criteria	Unit		Reference	RES+Storage	CCU	Nuclear	*RES GAS*	AT	AT-NIMP	*AT + 1000*	Thresholds
			Pathways								
Security of supply	**Rating**		+	++	- -	++	+	+	++	+	Generation Requirement (TWh)
	Generation (TWh)	2030	8.5	11.8	6.8	8.8	8.5	7.9	11.3	8.8	11.3
		2040	9.6	18.6	4.8	14.9	9.6	9.5	13	10.4	13
		2050	19.1	22.7	4.6	23.4	17.6	19.1	19.5	19	16
Limit of fossil use	**Rating**		-	++	- -	++	++	-	- -	-	
	Fossil gas generation in 2050 (TWh)		0.34	0.01	0.48	0.01	0.01	0.3	0.89	0.39	
Cost (LCOE/CAPEX)	**Rating**		+ / +	- - / - -	- - / + +	+ + / -	+ / -	+ / +	+ / -	+ / -	
	Avg. electricity prices in 2050 EUR/KWh		0.103	0.139	0.149	0.088	0.101	0.097	0.107	0.103	
	Total investment costs (2021-2050) Million EUR		8 899	14 280	3 953	12 077	11 564	9 013	10 441	9 855	
Socio-economic impact	**Rating**		0	+ +	- -	-	+ +	0	+ +	0	
CO_2 emissions	Rating		+	+	++	++	+	+	-	++	
	Total emissions 2020-2050 ($ktCO_2$)		24306	23761	17430	22780	23092	23572	31950	25764	Fit for 55 emissions by 2050 (ktCO2)
	Emissions by 2050 (ktCO2)		187	79	-147	30	68	167	324	199	5643
Environment	**Rating**		0	0	0	- -	-	0	0	-	
	Risk of pathway implementation resulting in adverse environmental impacts on air, soil, water or biodiversity	Severity	2.7	2	2.7	4	2	3	3	3	
		Likelihood	2.3	2.5	2.3	2.5	2	2.5	2.5	3	
Perceived risk	**Rating**		+	-	-	- -	++	++	- -	+	
	Average risk score for all risks	Severity	2.98	3.23	2.94	3.83	2.67	2.82	3.27	3	
		Likelihood	2.88	2.92	3.16	3.52	2.61	2.88	3.24	2.93	
Main implementation challenge			-	Total investment need (costs)	Technology	Technology and costs	Short term investments (financing biogas capacity)	Lack of focus may discourage investments	Short term investment need	Pumped hydro by 2029	

++ = very favourable, + = moderately favourable, 0 = little or no impact, - = moderately unfavourable, -- = very unfavourable

A summary view of Figure 10-1 and of Figure 10-2 is provided in Table 0-2 (Executive Summary).

10.2 Conclusions

The main objective of this document is to present a series of actions plans to allow the Estonian electricity system to become carbon neutral by 2050, according to the seven pathways analysed as part of this assignment. This report presents first an overview of current policies and strategies in Estonia, then identifies financing options for interventions in the electricity market, and summarisers the results of other deliverables completed as part of this project. In particular, Chapter 4 summarises key barriers to the deployment of low carbon technologies, while Chapter 5 presents the aggregated results of the energy system modelling and impact assessment analysis.

The remaining chapters consider actions to support the deployment of the technologies required to decarbonise the Estonian electricity system:

- Chapter 4 presents a long list of actions, organised around seven areas identified based on stakeholders feedback, literature review and technology deployment trajectories needed according to the pathways' analysis. The seven areas are:
  - Planning process
  - Institutional reform
  - Instrument to reduce investment risk
  - Instruments to support households and SMEs
  - Power network
  - Involvement of the civil society
  - Other actions

  The measures are aimed at overcoming different barriers, but broadly they should be implemented whichever pathways is chosen for Estonia.

Chapter 5 to Chapter 9 analyse the results at pathway level, tailoring the actions identified in Chapter 4 to the specific technology deployment needs and identifying pathway-specific actions:

- Chapter 5 - *RES + Storage* (offshore wind): is the most ambitious pathways, which foresees the deployment of large amount of offshore wind and storage, and that results in the highest total investment costs, both in generation and transmission infrastructure. However, the investment generates positive economic impacts, and environmental impacts from large offshore deployment can be managed. Key actions focus on facilitating offshore deployment (technology-specific support; offshore grid; transmission capacity), on supporting to the deployment of storage solutions, and on protecting vulnerable consumers from possible increases in energy bills.

- Chapter 6 - *Nuclear*: the pathway is characterised by a focus on nuclear and solar PV, and it is expected to be the second most expensive pathway. The main actions identified concern the development of a national nuclear programme and supporting actions to other renewables. According to stakeholders, this is the riskiest scenario, especially as it relies on a technology that has no history in Estonia, is highly prone to cost overruns and timing delays, and that is not expected to come online before 2035.

- Chapter 0 – *CCU*: this is the scenario which requires the lowest investment and that will allow Estonia to continue exploiting its fossil fuel reserves in the long term. While the actions required for its implementation are fewer and simpler than for other pathways, this is a scenario that is expected to generate limited benefits for the economy. CCU could be a good option for Estonia if further use and transport options for CO_2 are identified, so that carbon capture can be deployed to other power plants (beyond the two considered in this analysis) and industrial installations.

- Chapter 0 – *RES GAS*: similar to the CCU pathway, while the modelling results provide a relatively balanced power system, there are inconsistencies that suggest this may not be an ideal trajectory for Estonia, unless some of the assumptions changes. In this case, the cost of biogas is too high to make it competitive as a dispatchable resource, and deploying large capacities of biogas plants (1 GW) to be used only as flexibility instrument is a rather inefficient choice and complex to implement from a policy point of view. Nonetheless, actions to incentivise the deployment of biogas as part of a technology neutral approach should be considered.

- Chapter 9 – *All Technologies*: the three technology-competition pathways have many similar results in terms of technology mix, costs and dispatchable capacities, however the AT-No net imports (NIMP) pathway has some unique characteristics in terms of energy mix evolution. Based on the assumptions, different technologies emerge, but overall all three scenarios appear more balanced than other technology-specific options. The actions discussed in chapter 11 also follows a technology-neutral approach. Among the three scenarios, the AT 1000 MW is estimated to be most expensive for the consumer, while adding the no net import objective (*AT-NIMP)* does not increase costs substantially and can deliver positive socio-economic outcomes.

10.3 Recommendations

Based on the outcomes of the five project deliverables and of the analysis presented in this report, we propose a number of recommendations:

There are several no-regret actions that should be implemented in the short term

Across all or the majority of scenarios, there are a number of actions that are needed to support the deployment of the required technologies, and that therefore should be included, in any decarbonisation strategy:

- **Actions to streamline the planning process.** These should be tailored to the preferred strategy, for example focussing either on small vs large projects, national vs local administrations, local communities vs national campaigns, skills quantity vs quality and so on.
- **Actions to reduce risks on renewable or low carbon investments.** For the majority of renewables, market risks are the more relevant – i.e. the risk that future deployment may reduce market prices at the time when they are able to generate. The recommended mechanism is a contract for difference, with different budgets according to the targeted deployment capacities and targeted technology mx. Other technologies

such as renewable gases, nuclear energy and CCU will instead need more tailored risk reduction instruments that address technology-specific risks.

- **Setup a market for reserve capacity, flexibility and ancillary services, open to different technologies, to nearby countries and to prosumers.** This will be the main instrument that will drive the deployment of batteries or other storage solutions.
- **Actions to support the uptake of DSM.** In all scenarios, all available Demand Side Management (DSM) capacity (261 MW) is available, with broadly similar utilisation level in 2030 (between 25 and 29 GWh) and 2050 (between 21 and 27 GWH) in all scenarios excluding CCU in 2050.
- **Actions to facilitate the diffusion of PPA**
- **Increased funding and limits for Kredex guarantees**
- **Actions to support vulnerable households.** These should include different type of support, including economic, technical, informational.

Because of the methodology followed, if a pathway does not foresee the emergence of a certain technology, no actions are recommended regarding that specific technology. For example, the model results show that no CCU technology would emerge unless this is imposed (as in the CCU pathway) and that nuclear energy my only emerge endogenously in the no net import scenario, so no recommendations concerning CCU and nuclear are provided in other pathways. However, if there is the political will to keep these options open, the actions recommended in the technology-specific pathways should be considered whichever pathway is chosen.

Government needs to show clarity on its decarbonisation strategy and commitment to it

Based on the scenarios and actions presented**, the Estonian government should publish a clear and unambiguous strategy for the decarbonisation of the power sector**. The strategy does not need to exactly mirror one of the scenarios presented, but it must include a coherent set of objectives, actions and financial commitments, including they sources (general taxation, energy bills, private finance, institutional investors). There must be a clear commitment coming from the Ministry of Finance and from the Prime Minister, and to the extent possible receive the support of all major political parties. The strategy will have to be clearly communicated to citizens and public administrators at all levels.

Scenario selection

Across the seven potential scenarios examined, the *All technologies* and the *Renewable + Storage (offshore wind)* scenario are the pathways that appear to offer the best combination of benefits, costs, risks and feasibility. The *RES + Storage* scenario scores positively concerning security of supply, limit to fossil fuel use, socio-economic impacts and CO_2 emissions, but its high costs are the key challenge. This strategy also aligns well with deployment in neighbouring countries, is based on proven technologies and the actions required are relatively straightforward. For a more balanced pathway, the *All Technologies* scenario does not have very positive score across any of the aspects considered, but at the same time it also does not have any strong negative point, and the costs are lower than other pathways.

Another option that appears to offer a balanced outcome is the *RES GAS* scenario (positive rating across the range of indicators considered), but the construction of the capacity of biogas generation envisioned in the model should be carefully revisited i.e. significantly reduced (as the model shows that biogas generates little electricity due to high operational costs).

However, the government may consider a number of actions to keep "alive" also the *Nuclear* and the *CCU* scenarios, and focus more on these technologies if the situation changes: deploying CCU without the possibility to exploit economies of scale does not make economic sense, while relying too heavily on unproven nuclear technologies is too risky. An added risk of the *Nuclear* pathway is that it may create a "false sense of security", and be used as a justification to postpone important decisions.

Across the seven potential scenarios examined, the *All technologies* and the *RES GAS* scenario are the pathways that appear to offer the best combination of benefits, costs, risks and feasibility, albeit the construction of so large capacity of biogas generation in the biogas scenario should be carefully revisited (the model shows that biogas generates little energy due to high operational costs). The *RES + Storage (offshore wind)* scenario offers the highest economic benefits and scores well across several criteria, although it requires the highest investment of all scenarios. Further, actions to keep "alive" also the *Nuclear* and the *CCU* scenarios should also be considered, so that the strategy could tilt towards these technologies if the situation changes. Currently, deploying CCU without the possibility to exploit economies of scale does not make economic sense, while relying too heavily on unproven nuclear technologies is too risky.

If instead the smaller set of indicators suggested by the client is used, the recommended scenario is the Nuclear pathway. This is because the scenario obtains excellent results when it comes to energy price, GDP and total generation in 2050. However, it should be noted that this requires the nuclear capacity to run at relatively low load factors, if high loads are enforced it is likely that prices significantly increase and socio-economic benefits decrease.

Table 10-1 Key indicators, absolute values in 2050

Criteria	Nuclear	RES + Storage	All technologies (AT)	Renewable Gas	1000 MW dispatchable capacity	No net imports	CCU
Investment cost (€bn)	12.3	14.6	9.2	11.7	10	10.6	4.1
Electricity price in 2050 (€/kwh)	0.088	0.139	0.097	0.101	0.103	0.107	0.149
GDP (output changes compared to reference, €bn)[211]	10.9	13.8	0.4	8.5	4.1	4.9	-12.0
Jobs created (2030 to 2050)	20,074	19,511	16,321	16,629	14,964	15,699	7,332
Share of domestic generation in 2050	146%	142%	119%	110%	122%	119%	29%

[211] GDP output includes tax revenues

Table 10-2 Key indicators, ranking

Criteria	Nuclear	RES + Storage	All technologies (AT)	Renewable Gas	1000 MW dispatchable capacity	No net imports	CCU
Investment cost	6	7	2	5	3	4	1
Electricity price in 2050	1	6	2	3	4	5	7
GDP (output changes compared to reference, €bn)[1]	2	1	6	3	5	4	7
Jobs created (2030 to 2050)	1	2	4	3	6	5	7
Share of domestic generation in 2050	1	2	4	6	3	5	7
Total score	**11**	**18**	**18**	**20**	**21**	**23**	**29**
Aggregate ranking	**1**	**2**	**2**	**4**	**5**	**6**	**7**

Across the two assessments, the following overlaps emerge:

Table 10-3 Recommended, viable and not recommended pathways according to the two assessments performed

Pathway	Consultant assessment	Alternative ranking according to 5 criteria
Renewable electricity + Storage (RES + Storage)	Recommended	2
Renewable gas (RES GAS) Modified	Recommended	4
All technologies (AT)	Recommended	2
Nuclear	Not recommended	1
1000 MW dispatchable capacity (AT+1000)	Viable	5
AT-No net imports (AT-NIMP)	Viable	6
CCU	Not recommended	7

Finally, it is worth stating that the choice of the preferred pathway is a "political" choice, as all pathways presented reach the decarbonisation objectives and the other objectives set for the Estonian electricity system. This report, and the evaluation it provides, should be used by decision makers and stakeholders to identify the path towards decarbonisation that they feel more comfortable with, rather than to be considered the final decision. We expect different stakeholders to put different weight on different indicators, and arrive at different conclusions on the preferred choice.

To achieve decarbonisation targets at country level, the analysis here presented should be complemented with further analysis that focusses on other sectors (heating, transport, agriculture & forestry, buildings, industry) and that considers system integration aspects.

Once a scenario has been chosen, and before the decarbonisation strategy has been defined, the government should perform an analysis of the chosen scenario under a system integration perspective. This analysis should examine the implications for other sectors of the trajectories and actions associated with the preferred scenario, and the implications for other power sector of other sectors' decarbonisation strategies. Key sectors to consider are the heating and cooling sector; buildings (energy efficiency); and the transport sector. The present analysis should also be repeated regularly to ensure that the preferred technology mix is still the best way to achieve the decarbonisation targets.

Annex A Capacity and generation tables

Table 10-4 summarises the core assumptions behind each modelled scenario and results on capacity build-up for 2030 and 2050. Table 10-5 delineates the main results for electricity generation in the same years.

Table 10-4: Pathway comparison – assumptions and capacity results for 2030 and 2050 (S1 sensitivity)

Pathway		Core assumptions[212]	Capacity in Estonia (MW by 2030)														
			Batteries	Biogas & other renewables	Biomass	DSM	Fossil gas	Hydro	Nuclear	Offshore wind	Onshore wind	Oil shale	Pumped hydro	Solar PV	Waste	Total	% Dispatchable[213]
Baseline	Business as usual	- EU Reference Scenario 2020 projections of electricity demand, generation and storage capacity, and ETS price - No climate neutrality requirement	391	20	101	261	70	8	0	0	429	676 (biomass, retort gas)	0	725	19	2,699	48%
Baseline	Reference	- BAU unconstrained by EU Reference Scenario 2020 capacity projections - Includes demand for economically feasible levels of Power-to-X	1,645	20	101	261	70	8	0	0	1,479	676 (biomass, retort gas)	0	1,635	19	5,914	47%
Technology-focused	Renewables + storage (offshore wind)	- 1 GW offshore wind installed in Estonia by 2030, 2 by 2035, 3 by 2040, 4 by 2050	2,235	20	101	261	70	8	0	1,000	1,479	676 (biomass, retort gas)	0	1,249	19	7,118	48%
Technology-focused	Nuclear	- 900 MW Gen III+ small modular reactor capacity built in Estonia by 2040	1,677	20	101	261	70	8	0	0	1,479	676 (biomass, retort gas)	0	1,864	19	6,174	46%
Technology-focused	CCU	- Carbon capture added to TG11 in 2025 and Auvere in 2030	1,330	20	101	261	70	8	0	0	1,479	676 (biomass, oil shale, retort gas)	0	725	19	4,688	53%
Technology-focused	Renewable gas	- 1 GW of renewable gas capacity built in Estonia by 2030	860	1020	101	261	70	8	0	0	1,479	676 (biomass, retort gas)	0	1,572	19	6,066	50%
Technology competition	All technologies	- Investments in all low-carbon technologies allowed - No additional constraints on imports or capacity	1,607	20	101	261	70	8	0	0	1,479	484 (biomass, oil shale, retort gas)	0	1,507	19	5,556	46%
Technology competition	1000 MW dispatchable capacity	- Investments in all low-carbon technologies allowed - At least 1000 MW of dispatchable capacity installed in Estonia at all times	1,616	20	101	261	70	8	0	0	1,479	619 (biomass, oil shale, retort gas)	348	1,940	19	6,480	42%
Technology competition	*AT-NIMP*	- Investments in all low-carbon technologies allowed - Balanced electricity imports/exports into/out of Estonia each year	2,075	20	101	261	163	8	0	726	1,479	210 (biomass, oil shale, retort gas)	0	2,390	19	7,452	38%

[212] In the technology-focused and technology competition pathways, no net non-biogenic CO_2 emissions are allowed from electricity production in Estonia in 2050, and direct air capture of CO_2 is available. Each technology-focused pathway requires an investment in a core low-carbon technology, with additional investments in all storage and renewable generation technologies (e.g., onshore wind, solar PV, Paldiski hydro plant, batteries) permitted.
[213] Dispatchable capacity in this table includes non-CHP fossil fuel, biomass, and biogas; nuclear; landfill gas; pumped hydro; batteries; and DSM.

	Pathway	Core assumptions[214]	Capacity in Estonia (MW by 2050)														
			Batteries	Biogas & other renewables	Biomass	DSM	Fossil gas	Hydro	Nuclear	Offshore wind	Onshore wind	Oil shale (inc. CCU)[215]	Pumped hydro	Solar PV	Waste	Total	% Dispatchable[216]
Baseline	Business as usual	- EU Reference Scenario 2020 projections of electricity demand, generation and storage capacity, and ETS price - No climate neutrality requirement	818	20	101	261	16	8	0	0	429	476 (biomass)	0	725	19	2,873	54%
Baseline	Reference	- BAU unconstrained by EU Reference Scenario 2020 capacity projections - Includes demand for economically feasible levels of Power-to-X	8,040	20	101	261	160	8	0	1,951	1,479	476 (biomass)	0	4,079	19	16,595	55%
Technology-focused	Renewables + storage (offshore wind)	- 1 GW offshore wind installed in Estonia by 2030, 2 by 2035, 3 by 2040, 4 by 2050	8,617	158	123	261	16	8	0	4,000	1,479	476 (biomass)	174	2,094	19	17,425	55%
Technology-focused	Nuclear	- 900 MW Gen III+ small modular reactor capacity built in Estonia by 2040	9,288	20	101	261	16	8	900	1,576	1,479	476 (biomass)	174	6,573	19	20,891	53%
Technology-focused	CCU	- Carbon capture added to TG11 in 2025 and Auvere in 2030	4,571	20	123	261	16	8	0	123	1,479	476 (biomass, oil shale, retort gas)	0	725	19	7,821	70%
Technology-focused	Renewable gas	- 1 GW of renewable gas capacity built in Estonia by 2030	5,907	1,020	101	261	16	8	0	1,883	1,479	476 (biomass)	0	3,837	19	15,007	52%
Technology competition	All technologies	- Investments in all low-carbon technologies allowed - No additional constraints on imports or capacity	7,970	20	101	261	159	8	0	1,968	1,479	476 (biomass, oil shale, retort gas)	0	4,057	19	16,518	55%
Technology competition	1000 MW dispatchable capacity	- Investments in all low-carbon technologies allowed - At least 1000 MW of dispatchable capacity installed in Estonia at all times	7,533	20	101	261	190	8	0	2,098	1,479	476 (biomass, oil shale, retort gas)	348	3,920	19	16,453	52%
Technology competition	*AT-NIMP*	- Investments in all low-carbon technologies allowed - Balanced electricity imports/exports into/out of Estonia each year	7,705	20	101	261	406	8	300	1,967	1,479	10 (biomass, oil shale, retort gas)	0	3,933	19	16,209	54%

[214] In the technology-focused and technology competition pathways, no net non-biogenic CO_2 emissions are allowed from electricity production in Estonia in 2050, and direct air capture of CO_2 is available. Each technology-focused pathway requires an investment in a core low-carbon technology, with additional investments in all storage and renewable generation technologies (e.g., onshore wind, solar PV, Paldiski hydro plant, batteries) permitted. Full definitions of all scenarios are provided in section **Tõrge! Ei leia viiteallikat.**.

[215] The oil shale category in this table refers to Estonian plants that were originally constructed to burn oil shale. In all of the modelled scenarios, large oil shale plants are converted to use 100% biomass by the early 2030s unless they are retrofitted with carbon capture (see section 2.4.2). Carbon capture retrofits are only allowed in certain cases, however: in the CCU + renewables + storage pathway and the All technologies pathways (see section 2.5). In other scenarios, capacity in the oil shale category essentially represents biomass after 2035. Fuels used by the capacity are shown in parentheses.

[216] Dispatchable capacity in this table includes non-CHP fossil fuel, biomass, and biogas; nuclear; landfill gas; pumped hydro; batteries; and DSM.

Table 10-5: Pathway comparison – net generation[217] results for 2030 and 2050 (S1 sensitivity)

	Pathway	Net generation in Estonia (GWh in 2030)																
		Batteries	Biogas & other renewables	Biomass	DSM	Fossil gas	Hydro	Nuclear	Offshore wind	Onshore wind	Oil shale (inc. CCU)[9]	Pumped hydro	Solar PV	Waste	Total	Share of domestic electricity production[8]	Net exports (TWh)	Top sources
Baseline	Business as usual	-4	60	300	-17	323	29	-	-	1,317	97	-	835	63	3,003	39%	-6.2	1. Onshore wind 2. Oil shale 3. Solar PV
	Reference	-43	60	300	-29	375	29	-	-	3,804	2,087	-	1,898	63	8,544	76%	-4	1. Onshore wind 2. Oil shale 3. Solar PV
Technology-focused	Renewables + storage (offshore wind)	-55	60	300	-29	323	29	-	3,542	3,944	2,219	-	1,444	63	8,544	105%	-2.4	1. Offshore wind 2. Onshore wind 3. Oil shale 4. Solar PV
	Nuclear	-40	60	300	-28	307	29	-	-	3,748	2,205	-	2,160	63	8,804	78%	-3.8	1. Onshore wind 2. Solar PV 3. Oil shale
	CCU	-38	60	300	-28	313	29	-	-	3,944	1,284	-	833	63	6,760	60%	-4.2	1. Onshore wind 2. Oil shale 3. Solar PV
	Renewable gas	-26	60	300	-29	307	29	-	-	3,833	2,101	-	1,830	63	8,468	75%	-3.7	1. Onshore wind 2. Oil shale 3. Solar PV
Technology competition	All technologies	-42	60	300	-28	307	29	-	-	3,819	1,680	-	1,746	63	7,934	70%	-4.4	1. Onshore wind 2. Solar PV 3. Oil shale
	1000 MW dispatchable capacity	-38	60	300	-25	316	29	-	-	3,847	2,167	-218	2,247	63	8,748	77%	-4	1. Onshore wind 2. Solar PV 3. Oil shale
	AT-NIMP	-48	60	300	-26	676	29	-	2,447	3,781	1,247	-	2,768	63	11,297	100%	-0.8	1. Onshore wind 2. Solar PV 3. Offshore wind

[217] Net generation in this table refers to generation net of storage charging.

Pathway		Net generation in Estonia (GWh in 2050)														Share of domestic electricity production[10]	Net exports (TWh)	Top sources
		Batteries	Biogas & other renewables	Biomass	DSM	Fossil gas	Hydro	Nuclear	Offshore wind	Onshore wind	Oil shale (inc. CCU)[11]	Pumped hydro	Solar PV	Waste	Total			
Baseline	Business as usual	-1	60	300	-7	47	29	0	0	911	-	0	764	63	2,166	0	-8	1. Onshore wind 2. Solar PV 3. Biomass
	Reference	-102	60	300	-26	340	29	0	6,821	3,812	2,942	0	4,835	63	19,074	1	-1	1. Offshore wind 2. Solar PV 3. Onshore wind
Technology-focused	Renewables + storage (offshore wind)	-127	248	365	-22	9	29	0	12,550	3,994	3,149	-67	2,504	63	22,695	1	10	1. Offshore wind 2. Onshore wind 3. Solar PV
	Nuclear	-114	60	300	-25	6	29	5,230	5,594	3,795	993	-111	7,549	63	23,369	1	1	1. Solar PV 2. Offshore wind 3. Nuclear
	CCU	-13	60	365	-9	0	29	0	321	2,640	481	0	647	63	4,584	0	-8	1. Onshore wind 2. Solar PV 3. Oil shale
	Renewable gas	-88	62	300	-27	8	29	0	6,079	3,750	2,882	0	4,555	63	17,613	1	-1	1. Offshore wind 2. Solar PV 3. Onshore wind
Technology competition	All technologies	-102	60	300	-26	299	29	0	6,881	3,812	2,951	0	4,811	63	19,078	1	-2	1. Offshore wind 2. Solar PV 3. Onshore wind
	1000 MW dispatchable capacity	-97	60	300	-26	395	28	0	7,417	3,885	2,990	-165	4,681	63	19,531	1	-2	1. Offshore wind 2. Solar PV 3. Onshore wind
	AT-NIMP	-97	60	300	-27	890	29	2,285	7,008	3,821	49	0	4,615	63	18,996	1	1	1. Offshore wind 2. Solar PV 3. Onshore wind

Annex B Further details on actions

Table 0-1 priority and other recommended actions by pathway

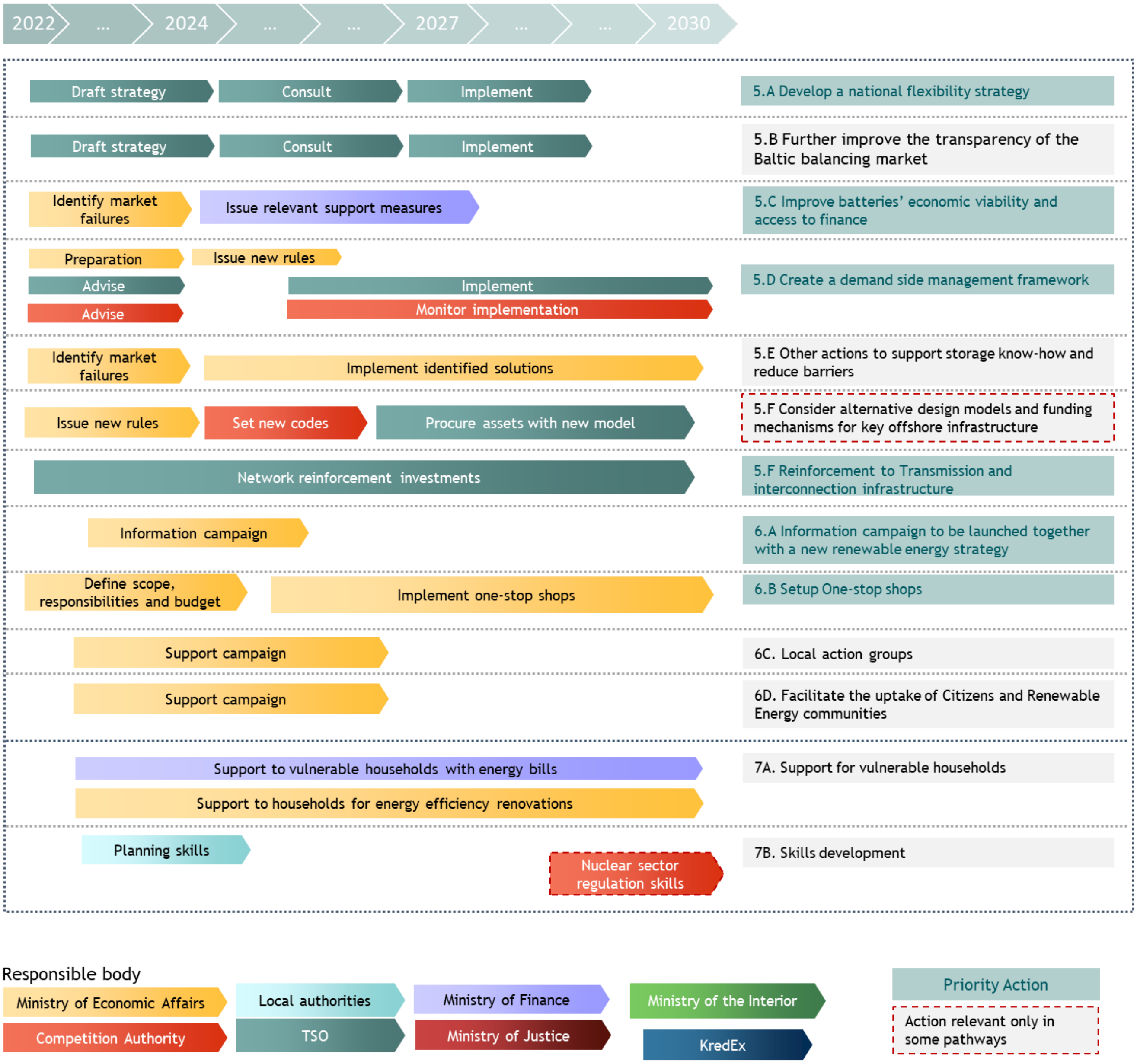
Action set	Actions	Renewables + storage	Nuclear	CCU	Renewable gas	All technologies	No net imports	AT 1000W
Planning	1A. Streamline the infrastructure planning approval process	P	P	P	P	P	P	P
	1B. Increase administrative resources dedicated to planning and permissions	P	✓	✓	✓	P	P	P
	1C. Supporting actions to speed-up the approval process	P	✓	✓	✓	P	P	P
Institutional reform	2A. Set up a nuclear regulator		P					✓
	2B. Review the mandate of the Estonian National Regulatory Agency		P	P				
	2C. Set up an Energy and Climate Agency	✓	✓	✓	✓	✓	✓	✓
	2D. Increase cross border cooperation	P		P			✓	✓
Risk reduction instruments	3.A actions to stimulate the uptake of Power Purchase Agreements (PPAs)	P	✓	✓	✓	P	P	P
	3B. Amendment to the current renewable electricity auction scheme	P	P		P	P	P	P
	3C. Move all or part of the funding for renewable electricity to the fossil gas bill or to other funds	✓	✓	✓	✓	✓	✓	✓
	3D. Extend the current size of state guarantees provided by Kredex and develop a broader framework for government guarantees	P	P	P	P	P	P	P
	3E. Public co-investing and sharing risks		P	P				
RES for households and SMEs	4A. Set up an on-site small scale renewable generation support scheme, in combination with other actions to incentivise building renovation	✓	✓		✓	✓	✓	✓
	4B. Allow Households and SMEs to invest in remote renewable electricity generation	✓	✓		✓	✓	✓	✓
Power networks	5A. Develop a national flexibility strategy	✓	✓		P	✓	✓	✓
	5B. Further improve the transparency of the Baltic balancing market	P	P	P	P	P	P	P
	5C. Improve batteries' economic viability and access to finance	P	P			✓	✓	✓
	5D. Create a demand side management framework	P	P	P	P	P	P	P
	5E. Other actions to support storage know-how and reduce barriers	✓	✓			✓	✓	✓
	5F. Consider alternative design models and funding mechanisms for key offshore infrastructure	✓		✓		✓	✓	✓
	5G. Reinforcement to Transmission and interconnection infrastructure	P	✓	✓	✓	✓	✓	✓

Involvement of the civil society	6A. Information campaign to be launched together with a new renewable energy strategy	P	P	P	✓	✓	✓	✓
	6B. Setup One-stop shops	✓	✓	✓	✓	✓	✓	✓
	6C. Local action groups	✓	✓	✓	✓	✓	✓	✓
	6D. Facilitate the uptake of Citizens and Renewable Energy communities	✓	✓	✓	✓	✓	✓	✓
Other actions	7A. Support for vulnerable households	P	P	P	P	P	P	P
	7B. Skills development	✓	P	✓	✓	✓	✓	✓

P = priority action ✓ = supporting actions

Figure 0-1 Indicative timeline and roles of the proposed actions (1/2)

Figure 0-2 Indicative timeline and roles of the proposed actions (2/2)



Annex C Current energy and climate objectives, strategies and policies

This chapter presents an overview of the energy and climate strategies and policies currently implemented in Estonia, proposed future strategies and legislative acts/packages, including proposals from key national institutions and stakeholders.

International strategies and targets

Fit for 55

On 14 July 2021, the European Commission presented the 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality package. The overall aim of the package is to deliver on the target agreed at EU level last year to reduce greenhouse gas emissions by at least 55% across the EU by 2030 compared to 1990. To this end, the European Commission has proposed changes to all major climate and energy framework legislation.[218]

The key objectives of the Fit for 55 package are perceived to have the following impact for Estonia:

- Raise the EU renewable energy target to 40% share in final energy consumption, with Member States having to set a more ambitious national commitment than the present ones.
    - In Estonia, the goal for renewable energy in the final consumption mix, which was already higher than the EU average goal, has been increased from 42% to 46% by 2030, followed by >55% in 2035 and cross-sectoral climate neutrality by 2050, with unspecified sectoral targets for renewable energy consumption.[219]
- The Commission recommends increasing cooperation between Member States through joint cooperation projects and joint offshore wind energy development.
    - Estonia and Latvia have initiated a joint project for offshore wind energy production in the Baltic Sea, near Pärnu bay. The project is in pre-development phase. Currently, new legislation setting the general framework for permitting has been set up. The planned capacity for the joint wind park is between 700 and 1000 MW and is expected to be completed by 2030. It is estimated that the wind park will produce 3.5 TWh electricity annually, which would cover approximately 40% of the annual electricity consumption in Estonia.
- Fit for 55 aims to enable the conclusion of long-term direct purchase contracts for renewable energy between producers and consumers, as a means of facilitating the integration of renewable electricity into the energy system. Estonia considers that long-term direct purchase contracts would indeed help industrial enterprises achieve the sector's renewable energy goals.[220]
- A new indicative EU target of 49% of renewable energy in the buildings sector by 2030 is foreseen to be set, with a trajectory to be set by each Member State. Estonia is not in favour

[218] European Commission (2021). European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
[219] https://www.riigikogu.ee/tegevus/dokumendiregister/dokument/8d96e946-64bb-4c22-bf6a-f8b318344884/Eesti%20seisukohad%20taastuvenergia%20direktiivi%20kohta%20-%20COM(2021)%20557
[220] https://www.riigikogu.ee/tegevus/dokumendiregister/dokument/8d96e946-64bb-4c22-bf6a-f8b318344884/Eesti%20seisukohad%20taastuvenergia%20direktiivi%20kohta%20-%20COM(2021)%20557

of this specific target, due to the already large number of initiatives regulating energy consumption in buildings (Energy Efficiency Directive, Energy Performance of Buildings Directive and Renovation Wave Strategy). Additionally, Estonia finds that this goal of 49% is not achievable within the envisaged deadlines, since Member States are at very different levels regarding what policy instruments are available in the buildings sector.

- Sustainability criteria for bioenergy should be strengthened: From 31 December 2026, Member States would not be able to grant support to plants producing only electricity from biomass, unless the production takes place in a 'fair transition area'. Even though the Eastern part of Estonia is considered a 'just transition area', Estonia is in favour of this provision.
- When granting state aid for bioenergy, ensure that the waste hierarchy and the principle of cascading use of wood are respected. Currently, biomass makes up 80% of the renewable heat produced in Estonia, about half of total renewable energy, and mainly consists of low-quality by-products from the forest industry and waste.
- The rated thermal input threshold for heat producers who need to comply with the sustainability criteria is to be lowered by 20% for heat producers using biomass. In addition, all existing and new plants with a capacity of 5 MW or more must reduce their greenhouse gas emissions by 70%, and by 80% from 2026 onwards. There are some concerns in Estonia about the potential administrative workload this could bring to small-scale producers and any modifications should be better defined to achieve the purpose of the cascading use of wood and regulating the type of land used for sourcing biomass.
- Bioenergy would no longer be allowed to be produced from primary forests or biodiverse forests, wetlands or peatlands.

Estonian energy and climate strategies and targets

Strategy "Estonia 2035"

The latest development strategy "Estonia 2035" adopted by the Estonian government sets out strategic goals for Estonia for the next fifteen years, and determines the changes necessary for achieving them. "Estonia 2035" is a strategic management tool which enables the coordination of long-term strategic planning and financial management of the country, taking into account the possibilities of public finance.

The main objectives of the document related to the energy market are:

- Transitioning to climate-neutral energy production;
- Launching of a package of services in Ida-Viru County to support the exit from oil shale energy use;
- Considering energy supply alternatives and making choices;
- Achieving a balance between energy security, environmental protection, and the interests of the population on land and at sea, supporting the growth of the share of renewable energy (e.g., a favourable regulatory environment);
- Synchronization of the electricity network with the continental Europe frequency band;
- Establishing a climate-proof infrastructure to support the transition to climate-neutral energy production/consumption and creating the necessary conditions for the transition to climate-neutral energy production/consumption, both onshore and offshore (e.g.

radars, network connections, refuelling infrastructure, smart heating and electricity networks, short and long term energy storage).[221]

Progress on some of the objectives can be followed through the indicators in Statistics Estonia application "Tõetamm"[222]. For example, the percentage of renewable energy in final consumption is compared to the goal in the "Estonia 2035" strategy (30.1% by 2020; >55% by 2035). According to this evaluation, Estonia is currently not on track to achieve this goal. The package of services in Ida-Viru County is almost complete, but it still has to be confirmed by the national government and by the European Commission[223]. Considering the current geopolitical situation, the synchronization of the electricity network with the continental Europe frequency band and desynchronisation from the Russian and Belarussian grid is of even greater importance. In January 2022, the EU granted €170 million for the final phase of the Baltic synchronisation project, which will be spent on grid reinforcements, frequency regulation equipment, and upgrading of IT control systems[224].

National Energy and Climate Action Plan 2030

Under the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, each EU Member State was obliged to submit by the end of 2019 a National Energy and Climate Action Plan 2030 (NECP), which summarises national targets by sectors and the process to achieve them. The level of ambition of the national plans must be sufficient to ensure that, when aggregated, they meet the EU-wide targets. The Estonian NECP 2030 has been prepared in a joint effort of different ministries based on development documents and various studies and analyses. The NECP 2030 brings together Estonia's energy and climate policy objectives and the 71 measures developed to achieve them. The broader objective of the NECP is to provide Estonian people, businesses and other Member States with the most accurate information possible on the measures Estonia intends to take to achieve the energy and climate policy goals agreed in the European Union.

The NECP 2030 sets the following national energy and climate objectives for Estonia:

- the share of renewable energy in total final consumption must be at least 42% by 2030;
- 40% of total final consumption of electricity should come from renewable energy sources in 2030;
- reduction of greenhouse gas emissions by 13% by 2030 as compared to 2005 levels in the non-ETS sectors (covered by the Shared Effort Regulation);
- final energy consumption must remain at 32-33 TWh until 2030;
- reduction of primary energy consumption to 14% by 2030 (compared to the peak of recent years);
- ensure energy supply security by keeping the rate of dependency on imported energy as low as possible;
- meeting the minimum criteria for interconnectivity of electricity grids.

In the context of the European Green Deal, several targets outlined in the NECP would need to be revised and set in line with the updated targets and the ambition to achieve climate neutrality.

The key actions mentioned in the Estonian National Energy and Climate Action Plan are:

221 https://www.valitsus.ee/en/estonia-2035-development-stategy/strategy/strategic-goals
222 https://tamm.stat.ee/kategooriad/eesti-areng
223 https://www.rahandusministeerium.ee/sites/default/files/Regionaalareng_poliitika/2021-12-15_jtf_ee.pdf
224 https://elering.ee/en/eu-grants-eur-170-million-final-phase-baltic-synchronisation-project

- Additional development of heating and electrical efficiency;
- Additional reconstructions of boiler houses and heating networks and additional support for customers to transition to district and local heating systems;
- Efficient public procurements, energy audits and additional reconstruction of public and commercial buildings and apartment buildings;
- Reverse tenders of renewable energy – **volume and schedule of the auctions is correlated with the trajectories of meeting the renewable energy targets (technology neutral and technology specific).** For 2019 and 2020, this was 5 GWh, but in 2021, the volume of the auction was increased significantly (450 + 5 GWh). For 2023, auctions for 650 GWh are planned.
- **Development of wind parks (including offshore).** Since the obstacles to the development of wind parks are mainly associated with national defence, environmental constraints, the opposition of local citizens and the resulting development risks, cooperation of different ministries and authorities is needed. Currently, there are more than 4 GW of wind farms on- and offshore in the development stage in Estonia, but the potential for the marine area after mitigating the restrictions around national defence is around 7 GW.
- The acquisition of air surveillance radars for the development of wind farms: Altitude constraints arising from national defence considerations are in force in large parts of onshore and offshore areas in Estonia. One possible solution could be to invest in additional pre-warning systems and through these, exempt the areas suitable for building wind farms from the altitude constraints imposed by national defence considerations;
- Possible solutions for the many risks and expenditures that go hand-in-hand with the offshore wind developments, like identifying area has to be preserved for nature protection, include national government activities for the pre-development of offshore wind farms (e.g. carrying out the necessary planning proceedings, establishing a connection to the power grid). Since the high risks increase the price of renewable energy for the society and deter potential developers, it would primarily be feasible for the national government to consider such pre-development in joint projects with other countries;
- Development of heating infrastructure;
- Reducing heat losses from district heating networks and converting inefficient district heating networks (less than 1.2 MWh of heat sold per one metre of heating pipe) into local and district heating systems;
- **Grid development, including the synchronisation with Central Europe.** This helps to achieve lasting security of energy supply and is one of the most important energy policy targets in Estonia. The Estonian electricity system must also prepare for strengthening the connections between West Estonia and its islands in connection with added capacity from the development of the offshore and onshore wind farms.
- Improving the quality of network services (compliance with EVSEN 50160, EVS-IEC 61000 standards) and definition of the responsibility of those responsible for disturbances, and implementation of measures to eliminate disturbances;
- **Synchronisation of the Baltic electricity system with the continental European synchronous area.** This helps to eliminate the bottlenecks in all Baltic States and increases the resilience of the electrical systems to fast changes in production and

consumption. As the target level of the electrical interconnectivity of the EU Member States was at least 10% for 2020 and at least 15% for 2030, investments made in connection with synchronisation not only strengthen the cross-border connections, but the domestic electricity transmission system as well.

- I**ncreasing the share of the weatherproof grid.** This helps achieving energy efficiency, energy security and to have a better interconnectivity.
- More efficient use of primary energy;
- Reduction of primary energy consumption by up to 14% (compared to the peak in recent years) in the period of 2020-2030. This includes measures such as reconstruction of different buildings, improving the fuel efficiency in the transport sector and also the development of heating sector and more efficient cogeneration of heat and electricity;
- **Energy sector research and development programme,** which will be funded from different sources during this EU financing period. These are projects that, for example, deal with Estonian bioeconomy and the innovative and sustainable technological aspects of oil shale production.
- Re**search and development activities programme under the energy development plan - Projects and activities that contribute to the implementation of the energy sector development plan, and thereby also to the promotion of renewable energy.** The research and development program activities are aggregated into the following seven areas: electricity supply; biomass and biofuel in the energy sector and transport; use of oil shale and other domestic non-renewable fuels; transport and mobility links with the energy sector; energy efficiency of buildings; heat supply; energy saving in consumption and electricity supply (generation, transmission and distribution of electricity). Measures like “Developing electricity production” and “Efficient transmission meeting the needs of the electricity sector” are considered under the electricity supply research area. To find the best solution for ensuring security of Estonia’s electricity supply, an analysis was carried out in 2020-2021 to identify roadmaps towards climate neutral electricity generation in Estonia and the socio-economic impacts of different roadmaps[225].

The Estonian Recovery and Resilience Plan

The Estonian Recovery and Resilience Plan (the Recovery Plan) is one of the annexes to the newly completed national strategy "Estonia 2035", focusing on the objectives, reforms and investments funded by the Recovery and Resilience Facility (RRF). All the reforms and investments envisaged in the Recovery Plan are based on the Estonia 2035 Strategy and its accompanying Action Plan, under which the Government has agreed on the reforms and changes needed to achieve the strategic objectives and address the European Commission's country-specific recommendations.[226] It is a temporary recovery instrument which allows the Member States to implement reforms and investments towards climate neutrality. The Recovery Plan for Estonia was approved by the Council of the European Union in October 2021 for a total of €969.3 million in grants and the pre-financing totalling €126 million was distributed in December 2021. The most important investments of the recovery and resilience plan are related to the green and digital transitions, where a total of more than €600 million is planned to be directed largely to businesses. The key measures for green transition in the Estonian plan are:

- Investments into hydrogen technologies (€50 million investment);

[225] https://ec.europa.eu/energy/sites/ener/files/documents/ee_final_necp_main_en.pdf
[226] https://rrf.ee/wp-content/uploads/2021/06/RRP-Taastekava-170621-VIISi.pdf

- Strengthening the electricity grid and energy storage to increase renewable energy production capacity (€38 million investment);
- Construction of the Rail Baltic terminal in Tallinn (€31.05 million investment);
- Setting up a Green Fund to support enterprises with green transition and development of innovative green technologies (€100 million investment).

Measures to boost the uptake of renewable energy proposed in the Recovery Plan[227] include:

- Streamlining (reform) of the procedures for the installation of renewable energy generation installations;
- Electricity grid reinforcement programme to increase renewable energy generation capacity and adapt to climate change (e.g. storms) (€30 million investment);
- Programme to boost energy production in industrial areas (€7 million investment);
- Pilot programme for energy storage (€8 million investment).

Reverse Auctions for renewable electricity generation projects

Under the Electricity Market Act[228], the Minister of Economic Affairs and Infrastructure organises public reverse auctions for generation of electricity from renewable energy sources[229] in the period of 2019-2023. Elering is responsible for conducting the reverse auctions. The auctions aim is to increase the share of renewable energy in Estonian electricity production. The volume and schedule of auctions correlate with the trajectories for meeting renewable energy targets.

The first three reverse auctions were carried out on the basis of subsection § 596 of the Electricity Market Act and were intended for installations with a capacity between 50 kW and 1 MW. The objective for the first two auctions was to provide the market with an additional 5 GWh of electricity generated from renewable energy sources per year and for the third auction, 4.52 GWh. The support rate for these reverse auctions was €53.7/MWh.[230] [231] This rate consists of the arithmetic mean of the next day's market price for the current calendar month in the Estonian price area and the subsidy defined in the § 59^6 of the Electricity Market Act.

The fourth auction, for which the bids must be submitted by 1 June 2022, aims to support 450 GWh of electricity produced from renewable energy sources per calendar year. The next reverse auction for 650 GWh of renewable electricity generation will take place in 2023.[232]

For the ongoing auction, the maximum amount of production for which support is payable is 450 GWh per calendar year. The maximum subsidy for the winner of the auction will be €20/MWh for the produced electricity. The subsidy will be calculated on an hourly basis and the amount of the subsidy will be determined on the basis of the maximum subsidy amount and day-ahead exchange prices on

[227] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698886/EPRS_BRI(2022)698886_EN.pdf
[228] https://www.riigiteataja.ee/en/eli/531122021008/consolide
[229] Electricity Market Act: § 57. Renewable energy sources - For the purposes of this Act, 'renewable energy source' means water, wind, solar, wave, tidal and geothermal energy sources, landfill gas, sewage treatment plant gas, biogases and biomass.
230 First auction decision by the Minister of Economics and Infrastructure: https://www.elering.ee/sites/default/files/2019-11/Taastuvast%20energiaallikast%20elektrienergia%20tootmise%20v%C3%A4hempakkumise%20teade_0.pdf
231 Second auction decision by the Minister of Economics and Infrastructure: https://www.elering.ee/sites/default/files/2020-05/Taastuvast%20energiaallikast%20energia%20tootmiseks%20korraldatava%20v%C3%A4hempakkumise%20korraldamise%20otsustamine%20ning%20teate%20kinnitamine%20_0.pdf
232 https://www.mkm.ee/et/tegevused-eesmargid/energeetika/taastuvenergia

the electricity market in the Estonian price area. This amount is capped at €45/MWh, which means that producer cannot submit an offer at a price that exceeds this cap. No subsidy is paid for electricity produced during periods with negative spot prices. The support is paid for the amount of electricity injected into the network or direct line of the authorised network operator. No aid is paid for the energy delivered to a closed distribution system.[233]

Participants in the auction bid by providing a price and a quantity of electricity they are able to provide at that price. The bid price is capped at €45/MWh for the running auction while the support (the amount that each winner will be awarded) is capped at €20/MWh. This means that the generator will receive a payment for the difference between its bid and the wholesale price (up to €20/MWh). Generators will sell electricity generated beyond the bid quota at market prices.

The first three and the currently open auctions were reserved for generating installations that were not commissioned before the reverse auction. But following the changes made to the Electricity Market Act in 2021, existing electricity producers will also be allowed to participate in future reverse auctions in order to incentivise them to use renewable energy sources instead of fossil fuels as primary energy input for their electricity generation installations. This is particularly aimed at incentivising the use of biomass in existing thermal power plants.

Energy and climate strategies and policy proposals from stakeholders

Energy Roadmap 2021-2031-2040

In 2021, Rohetiiger[234] and Tallinn University of Technology (TalTech) published the "*Energy Roadmap 2021-2031-2040*[235]" which provides an extensive list of actions for reaching climate-neutrality in Estonia's energy economy. The Roadmap aims to achieve climate neutrality in Estonia's energy economy in a way that preserves—and possibly even improves—the welfare of Estonia's citizens. This has to be achieved by preserving and improving the natural environment and using energy and natural resources more sustainably. The Roadmap also looks at the impact of emissions trading, risk mitigation for financing renewable energy projects, incentives for landowners to sequester natural carbon and conserve biodiversity, and improving the energy efficiency of buildings.

The recommended measures and steps to support the development of renewable electricity projects, improve planning processes and the functioning of the electricity market are:

- Establish and introduce transparent national rules based on a common basis to ensure that communities and local authorities are motivated to support renewable electricity production and to compensate for the impacts of construction/production (the introduction of a feed-in tariff for wind farms has been proposed as a draft law);
- Link the building fee for offshore wind farms to the average value of the land corresponding to the intended use of the building, calculated on the basis of the decoupled price in the Water Act;
- Increase the sometimes limited capacity of the grid, simplify and speed up connection procedures, including by setting time limits for the duration of connection procedures;

[233] https://elering.ee/vahempakkumise-kkk
[234] Rohetiiger is a cross-sectoral cooperation platform that aims to create a balanced economic model for Estonia and the world. It is a platform for cooperation between businesses, individuals, the public sector and the voluntary sector.
[235] https://rohetiiger.ee/wp-content/uploads/2021/12/Energia-teekaart-17122021.pdf

- Introduce time and technical limits for the reservation of connections and implement them retroactively for the cancellation of unused reservations;
- Ensure efficient and rapid cooperation between authorities in the granting of authorisations and consents, in the approval of planning and in the environmental impact assessment (EIA);
- Replace the successive authorisation procedures for planning offshore wind farms with a single authorisation procedure—a single permit— which also confers the right to build;
- Prescribe by law the baseline studies that must be carried out for the encumbered marine area, the list of which will be definitive and delimited by the EIA programme;
- In cooperation with the state and local communities, find ways to include new promising renewable energy production areas in statutory plans by making the inclusion of such renewable energy production areas in statutory plans mandatory and by providing funding for the necessary analyses and impact assessments during the statutory planning process;
- Balance the conflicting needs of environmental, national defence and renewable energy development. Set up teams of sectoral experts selected jointly by the public sector, the community and businesses to manage planning procedures for development projects of national importance;
- Linking payments from the local government equalisation fund to the inclusion of renewable energy development areas in statutory plans and thematic and special plans;
- Streamline and simplify the planning processes related to renewable energy development (including EIA) in a way that would accelerate the development of high potential, cost-effective projects that take into account the community interest and thereby achieve carbon neutrality;
- Launch a market for system services in the Baltic States, similar to the Nordic countries;
- Phase out subsidies for renewable electricity, backing investments with guarantees where appropriate;
- Promote public-private instruments to reduce the investment risks of renewable energy projects (e.g. EU renewable energy financing and cooperation mechanisms, PPAs, guarantees);
- Time the renewable energy auctioning scheme in such a way that it leads to more competition, ensures the lowest price and thus the lowest cost to society;
- Similar to the support measures for solar parks, implement support measures for small-scale producers and consumers to build storage capacity based on battery banks;
- Establish a legislative framework for the creation and maintenance of a strategic reserve (generation capacity).

Energy vision of environmental associations until 2035

The energy vision of the environmental associations elaborated at the initiative of the Estonian Green Movement (ERL) formulates goals and solutions based on the latest scientific assessments and the experience of other countries, which Estonia must strive for over the next 15 years and beyond. The Associations exclude from the list of future energy solutions, shale energy and mass combustion of wood, but also carbon capture technologies and nuclear energy, as the time-critical nature of the climate crisis makes it sensible to focus on feasible solutions that are already in place.

The spatial siting of wind and solar power plants must be based on thorough environmental impact studies, including field studies. Plants must not be located in the immediate vicinity of protected natural habitats and species. When siting plants, preference should be given to mixed-use land uses or to locations where there is no competition with other land uses, such as building roofs and closed quarries. The problem of uncontrolled wind and solar power generation can be offset by storage technologies and smarter management of consumption. Pumped hydro, thermal storage and hydrogen technologies will have to be relied on to store energy. Hydrogen storage and fuels can be used as an alternative to today's carbon-intensive solutions in heavy industry and transport. Alongside energy storage, attention needs to be paid to managing short-term consumption in virtual power plants, which will help to better integrate renewable energy sources into the grid and meet energy demand during peak consumption periods.

In the transition to renewables, dispersed generation is inevitable. In order to allow for large-scale distributed generation, the existing electricity network will need to be substantially upgraded and the capacity of parts of it increased. Centralised district heating should be preferred in densely populated areas and heat pumps in sparsely populated areas. The low cost and availability of renewable energy and the possibility of thermal generation will open the way for new players to enter the electricity market. These include energy cooperatives, which are springing up in growing numbers across Europe.

In a context where climate crisis mitigation will have to be tackled decisively in the coming decade, it is important to invest in existing solutions. Carbon capture and storage or use is only permissible if the chosen technology is economically viable and climate-neutral throughout its life cycle, which current technologies are not.[236]

Delph study on the energy future for Estonia (2021)

This Delph's study is a report by the Deep Transition Research Group of the University of Tartu. The Delph's survey is a method for mapping experts' vision of the future. Respondents expressed the need for wind and solar power to become the main form of electricity generation as soon as possible. The further use of oil shale for energy production in combination with carbon capture storage/utilisation (CCSU) technologies, the gradual substitution of oil shale by waste or wood, and the construction of a nuclear power plant with a modular reactor are considered unsuitable for Estonia.

According to the experts that answered the survey, the necessary actions that should be taken urgently are the installation of a pumped hydrothermal energy storage facility; improving the efficiency of cogeneration plants and making better use of industrial waste heat (thermal power stations, use of industrial waste heat for district heating); introduction of biofuels that do not compete with agricultural land; deployment of peer-to-peer energy trading technologies. Experts also expect the government to focus on "soft" measures to help and support businesses and citizens. Citizens would be expected to behave constructively, whether in setting up cooperatives or in transforming their own consumption (which does not, however, entail major lifestyle changes or significant reductions in consumption). Businesses are expected to innovate business models, to lead by example through good practice, and to provide a flexible market for trading distributed energy. Anything that involves either more forceful measures by the state (taxes or standards stating that

[236] Keskkonnaühenduste energeetikavisioon aastani 2035, Estonian Green Movement-FoE 04.02.2021https://roheline.ee/wp-content/uploads/Energeetikavisioon_veeb_2021.pdf

energy is not unlimited and always available), citizen activism, protests or voluntary restrictions on consumption is not considered realistically feasible.

The coming years will involve defining needs and redirecting investment towards a new energy system. The experts felt that both the needs and conditions for energy production and the energy efficiency requirements for products and services could be defined. In addition, the state should develop, within the next 10 years, the conditions for a systematic assessment of the health and environmental impact of the energy system.[237]

Elering (2021) Security of electricity Supply Report

The Elering annual report[238] on security of electricity supply in Estonia sets four pillars on which the security of supply is based on: capacity of management; capacity of the grid, capacity of the system and the capacity of digital processes.

1. Capacity to manage – Currently, the Baltic States all fall under the network frequency area of Russia and the focus in the upcoming years will be to disconnect from the Russian system and synchronize with the frequency area in continental Europe. Connecting to the network system in Central Europe is planned for 2026.
2. Capacity of the grid – Elering will be focusing on investments which will increase the capacity of the existing grid to cope with peak demand. Elering foresees, that the investments to be made in 2021-2030 will significantly reinforce the Estonian 110-330 kV transmission networks. New connections are needed with Finland (EstLink 3) and Latvia which will create the necessary reserve and lower the price differences between Estonian and the neighbouring countries price range.

   Investments are also planned for the upgrade of the electricity grids which will relate to large offshore wind energy parks in the upcoming years. For this, the Estonian 330 kV network needs to be enhanced and the 110 kV network in the West Estonian region and on the nearby islands needs to be upgraded.
3. Capacity of the system – This is achieved by an assessment made by the system administrators all over Europe and if this turns out to be insufficient a proposal can be made for a power mechanism. Currently, the existing system is deemed as good until 2030, as there is approximately 1000 MW of secure electricity production methods, and 240 MW of reserves. In 2021 the government set the norm of the security of supply for the electrical system at 9 hours per year[239].
4. Capacity of digital processes – Elering sets a goal to gather and analyse data as close as possible to real time. As new renewable capacities are added into the network, it is necessary to increase the number of consumers that have their electricity consumption modified based on total demand in a particular time. This kind of management is usually offered to large scale consumers, such as commercial units or production units, which can alter their use of electricity for a short period of time without jeopardizing their economic activities, and thus offer a certain relief to peak demand.

[237] https://suursiire.ut.ee/wp-content/uploads/2021/11/Eesti_energiatuleviku_Delphi_uuring_2021.pdf
[238] Elering. (2021). Eesti Tarbijate Elektrivarustuskindluse Aruanne Aastani 2030.
Available at: https://elering.ee/sites/default/files/2021-12/Varustuskindlus%202021%20lk.pdf
[239] https://elering.ee/varustuskindluse-konverents

Elering Security of Supply Conference

Elering has held a Conference on Security of Supply annually since 2010. At the latest conference, in December 2021, the Director of Green Transition and Energy System Integration from the European Commission Catharina Sikow-Magny made a presentation[240] about the role of offshore renewables in secure, sustainable and integrated EU energy systems. The DG emphasised that it is not possible to talk about security of energy supply without co-operation, in which the Baltics states are a prime example. The three pillars in the Energy System Integration Strategy, energy efficiency, accelerated electrification based on RES and promotion of renewable hydrogen, are key elements in the decarbonisation of the EU economy, which cannot be achieved without offshore wind energy. The goal for 2030 is to reach at least 300 GW of offshore wind power and 40 GW of ocean renewables. To achieve these ambitious targets, the member states must share their long-term coordinated vision of offshore RES goals per sea area, which are then followed by integrated offshore plans that give clarity of what kind of grids are necessary until 2050.

This was followed by a presentation from the Danish Senior Vice President & CEO of Energinet Søren Dupont Kristensen, who talked about the Security of Supply in a RES based Energy System. Firstly, an overview was given on the Danish situation regarding Green Transition. Denmark already produces 60% of the electricity it consumes from renewables like solar and wind. However electricity needs to be transported long distances and the grid needs to be developed according to the needs of the people. Since Denmark is far ahead in terms of RES, there is plenty to learn from the challenges the Danish have faced regarding 'Not In My Backyard' (NIMBY), grid development and planning, cost effectiveness, time expenditure of different processes of development etc. The key takeaway from this presentation was that security of supply is achieved by generation and grid adequacy, grid robustness, and IT security. The future key challenges will be the inverter-dominated power system, decreasing inertia and frequency quality. At the same time, fast-response, digital control centres with real-time data, synchronous condensers and high-voltage, direct current (HVDC) technology will create new possibilities. One solution to the energy storage problem is to use sector coupling to store large amounts of energy in gas reserves. As a comparison, while in Denmark electric vehicles are able to provide 30 GWh of flexibility, methane gas storage infrastructure can store up to 11 TWh of energy.

Taavi Veskimägi, the CEO of Elering, gave an overview of the latest "Security of electricity Supply" report (2021). The keywords Veskimägi used to describe Elering's vision were climate neutrality, security of supply and competitiveness. The electrical system has been under significant pressure regarding the political situation in Europe, with very high electricity consumption in Central and Northern Europe due to unusually cold weather in the beginning of December, low generation from RES, low amounts of water in the reservoirs of the Nordic hydropower plants, low gas reserves, high energy prices and out-of-line electricity generation stations in all of the Baltic states. However, according to Elering, the security of supply can be guaranteed in the future even when more unexpected factors come into play and the peak demand achieves new record highs.[58]

Elering Strategy 2022-2026

The Elering Strategy 2022–2026[241] states the mission to "keep the lights on and the rooms warm in Estonia". The vision for the upcoming years is to make the Estonian energy network and its market an

[240] https://www.youtube.com/watch?v=l561TvsfQ0A
[241] https://elering.ee/sites/default/files/2021-11/Strategy%202022-%202026_est_%20avalik.pdf

integral part of the European energy system. The most important step is to synchronize Estonia to the continental European energy system by 2026. Simultaneously, it is important to maintain a high level of security of supply for consumers, and support competitiveness of Estonian economy and meet climate objectives.

In its strategy, Elering enlists the key trends which will have long term impact and to which it needs to adapt to. These include:

- Energy sector decarbonisation. The electrification of the economy is increasing the importance and responsibility of electricity. There will be a high share of energy from renewables and the production mix determined by national energy and climate plans. A much larger focus needs to be on the flexibility of the system, to develop a framework for demand side response and consumer data access.
- Development towards Energy TSO. The offshore wind potential in the Baltic Sea is 325.9 TWh. A major requirement for the assumed installed offshore wind capacity in 2050 is providing storage options to allow for flexibility.
- Impact of third countries. Russia still controls the frequency of the Baltic network system.
- Rapid development of technologies and smart grid. This includes consumption management, complex system operations, new market participants and cyber security.
- Competition for talent. There is a significant decrease in the number of energetics specialists entering labour market, and a tight competition for information technology specialists. The expectation for flexible work time is growing. There is a general labour shortage and high pressure on payroll.

Based on the aforementioned trends, Elering sets strategic objectives for 2025:

1. Security of supply of electricity and gas at all times;
2. Electricity and gas prices which support competitiveness of the Estonian economy;
3. Creation of economic added value;
4. Committed employees;
5. Satisfied consumers.

Annex D Short overview of international financing options

This chapter provides an overview of the main international financing options available to support investments in renewable electricity generation (and supporting measures to ensure flexibility, security of supply) in Estonia. This overview does not aim to provide an in-depth analysis, but to map main potential opportunities and identify what type of support these may offer.

Financial institutions

Table 0-2 Overview of financial institutions offering financing options to support renewable electricity generation in Estonia

Level	Name of Institution	Acronym	Available for		Type of product(s) offered					Description
			Countries	Private sector	Loans	Equity	Guarantees	Grants	Bonds	
Private	The Nordic Green Bank	NEFCO		✓	✓	✓				Nefco was established by the Nordic countries in 1990 as an International Financial Institution dedicated to green projects. In particular, they aim to support Nordic green SMEs to internationalise and scale up their businesses worldwide. Nefco finances projects initiated by companies and actors originating in one of the Nordic countries (Denmark, Finland, Iceland, Norway and/or Sweden), and which aim to establish operations in a target country outside the Nordic countries. Financial institutions in Estonia can also apply for loans financing from Nefco for environmentally beneficial projects. There are several sectors which are of particular interest to Nefco. This includes, for example, the energy sector, including a variety of modern technologies. They offer to provide risk capital to develop new solutions for the production, storage and transportation of renewable energy. Transportation is also one of their focus areas, and see the need to reduce mobility needs and transport of goods, incorporate electrification, biogas and biofuels, and other environmentally-friendly solutions for public transport.
	Nordic Investment Bank	NIB	✓	✓	✓		✓		✓	NIB is an International Financial Institution established by five Nordic countries in 1975. It is located in Helsinki, Finland. NIB's mission is to finance projects that improve productivity and benefit the environment of the Nordic and Baltic countries. One of the business areas they provide finance to is 'Public Sector & Utilities' where they focus on projects that contribute to renewable energy production, carbon-neutral technology and increased energy efficiency.

Level	Name of Institution	Acronym	Available for		Type of product(s) offered					Description
			Countries	Private sector	Loans	Equity	Guarantees	Grants	Bonds	
	ESFC Investment Group[242]	ESFC	✓	✓			✓			ESFC Investment Group, an investment consulting company headquartered in the Spanish city of Girona, successfully serves large public and private customers in many countries around the world. They provide financing for projects in areas including energy from renewable sources.
	J.P. Morgan SE	JPMSE	✓	✓	✓	✓				J.P. Morgan is a global leader in financial services, offering solutions to the world's most important corporations, governments and institutions in more than 100 countries. On January 24, 2022, it has restructured its existing EU credit institutions into one legal entity known as J.P. Morgan SE (JPMSE). A recent renewable energy project they are financing is the Turkey's solar powerplant.
EU	European Bank for Reconstruction and Development	EBRD	✓	✓	✓	✓	✓			The EBRD focuses on private sector investment and support for policy reform. Policy reforms are at the core of the EBRD's work to help the countries where we work make the transition to a competitive, well-governed, green, inclusive, resilient and integrated market economies. EBRD financing for private sector projects generally ranges from $5 million to $250 million, in the form of loans or equity. The average EBRD investment is $25 million. Smaller projects may be financed through financial intermediaries or through special programmes for smaller direct investments in the less advanced countries. EBRD has laid out a targeted strategy for Estonia.
	European Investment Bank	EIB	✓[243]	✓[244]	✓	✓	✓			Loans starting at €25 million to public sector entities to finance a single large investment project or investment programme, aligned with one or more priorities of the EIB, i.e. climate and environmental sustainability; Innovation and skills; Infrastructure; SMEs; Cohesion; Development.245 Loans to private sector entities to finance projects or investment programmes aligned with one or more priorities of the EIB. These products include debt and hybrid debt financing to project finance. The EIB typically covers up to 50% of a project's total cost. These loans typically start at €25 million and in certain cases the EIB will consider lower amounts.246 Intermediated loans are also provided to SMEs and mid-caps.247

242 https://esfccompany.com/en/company/index.php
243 https://www.eib.org/en/products/loans/public-sector.htm
244 https://www.eib.org/en/products/loans/private-sector.htm
245 https://www.eib.org/en/products/loans/public-sector.htm
246 https://www.eib.org/en/products/loans/private-sector.htm
247 https://www.eib.org/en/products/loans/sme-mid-caps.htm

Level	Name of Institution	Acronym	Available for: Countries	Available for: Private sector	Type of product(s) offered: Loans	Equity	Guarantees	Grants	Bonds	Description
	Connecting Europe Facility	CEF	✓	✓			✓	✓	✓	The Connecting Europe Facility (CEF) is a key EU funding instrument to promote growth, jobs and competitiveness through infrastructure investment at European level. There are three programme sectors: CEF Energy, CEF Transport and CEF Digital. The key energy sectors that are supported by CEF Energy are carbon dioxide, electricity, gas and smart grid. Examples of CEF Energy projects includes, among others, enhancing grid flexibility, building new gas connectors and transmission lines, hydro-pumped electricity storage, and underground gas storage. A new category of eligible projects has been introduced under CEF Energy for the 2021-2027 funding period-cross border projects on renewable energy. The first call for preparatory studies for cross-border renewable projects, which closed on 1 February 2022, received three proposals covering wind farms, district heating and green hydrogen.
	European Regional Development Fund	ERDF	✓	✓				✓		The European Regional Development Fund (ERDF) provides funding to public and private bodies in all EU regions to reduce economic, social and territorial disparities. The Fund supports investments through dedicated national or regional programmes. The total budget for 2021-2027 is €226.05 billion (current prices). In order to be eligible, the project must meet the selection criteria and investment priorities of Estonia's regional programme.[248] Application procedures of the managing authority(s)[249] in Estonia should also be followed.
	Cohesion Fund	CF	✓					✓		The Cohesion Fund provides support to Member States with a gross national income (GNI) per capita below 90% EU-27 average to strengthen the economic, social and territorial cohesion of the EU. It supports investments in the field of environment and trans-European networks in the area of transport infrastructure (TEN-T). This includes Estonia for the 2021-2027 period.

[248] https://ec.europa.eu/regional_policy/en/atlas/programmes/2014-2020/estonia/2014ee16m3op001
[249] https://ec.europa.eu/regional_policy/en/atlas/managing-authorities//

Financing mechanisms

Table 0-3 Overview of financial mechanisms offering financing options to support renewable electricity generation in Estonia

Level	Name of financing mechanism	Acronym	Available for		Type of product(s) offered				Description
			Countries	Private developers	Loans	Equity	Guarantees	Grants	
International	IBRD Flexible Loan[250]	IFL	✓		✓				The IBRD Flexible Loan (IFL) is the leading loan product of the World Bank for public sector borrowers of middle-income countries. IBRD's purpose is to work with its borrowing members so that they can achieve equitable and sustainable economic growth in their national economies and find effective solutions to pressing regional and global problems in economic development and environmental sustainability, all with a view to overcoming poverty and improving standards of living.
EU	EU Renewable Energy Financing Mechanism[251]	RENEWFM	✓	✓				✓	This mechanism is a new initiative of the European Commission to support renewable energy projects starting from January 2021. For project developers: a system of EU-wide tenders will identify suitable renewable energy installation projects to receive support from the mechanism; For private investors: they can invest in this mechanism to broader their sustainable energy portfolio and benefit from the Union-wide green label; For Member States: they can either host a project without needing to provide finance themselves, or contribute financially to a project located in a different Member State. The allocation of the renewable statistics towards the climate targets for the host and contributing country will be defined based on a standard formula.
	European Innovation Council Fund[252]	EIC Fund		✓					The EIC Fund provides equity from €0.5m to €15m to breakthrough innovation companies selected for EIC Accelerator blended finance support (grant and equity). The EIC Fund is a unique entity owned by the European Commission and established to make direct equity investments in companies. For innovation projects.
	European Investment Fund[253]	EIF		✓	✓	✓			The EIF supports Europe's SMEs by improving their access to finance through a wide range of selected financial intermediaries. To this end, we design, promote and implement equity and debt financial instruments which specifically target SMEs. In this role, we foster EU objectives in support of entrepreneurship, growth, innovation, research and development, and employment.

250 https://treasury.worldbank.org/en/about/unit/treasury/ibrd-financial-products/ibrd-flexible-loan
251 https://energy.ec.europa.eu/topics/renewable-energy/eu-renewable-energy-financing-mechanism_en
252 https://eic.ec.europa.eu/investment-opportunities_en
253 https://www.eif.org/

Level	Name of financing mechanism	Acronym	Available for: Countries	Available for: Private developers	Type of product(s) offered: Loans	Type of product(s) offered: Equity	Type of product(s) offered: Guarantees	Type of product(s) offered: Grants	Description
	Recovery and Resilience Facility	RRF	✓		✓			✓	The Facility is a temporary recovery instrument that allows the Commission to raise funds to help Member States implement reforms and investments that are in line with the EU's priorities and that address the challenges identified in country-specific recommendations under the European Semester framework of economic and social policy coordination. It makes available €723.8 billion (in current prices) in loans (€385.8 billion) and grants (€338 billion) for that purpose.
Private	VARDAR AS	Vardar		✓					Vardar is an energy and investment company owned by 19 municipalities in the former Buskerud county municipality in Norway. They directly and indirectly own a significant portfolio of companies within the renewable energy value chain, which includes hydropower, wind power, district heating and bioenergy.

Other services

Table 0-4 Overview of other types of non-financial services that may provide further support to renewable electricity generation in Estonia

Level	Name of service	Acronym	Available for Countries	Available for Private developers	Type of service(s) provided	Description
International	IRENA Project Navigator		✓	✓	Practical information Tools Guidance	The IRENA Project Navigator is an online platform providing comprehensive, easily accessible, and practical information, tools and guidance to assist in the development of bankable renewable energy projects. It helps: - project developers improve project proposals with guidance on project timelines and development approaches; - Investors and financiers facilitate the efficient use of renewable energy funds and lower transaction costs; Government and policy makers to strengthen national project development capacity to prepare project proposals. This platform is available worldwide at no cost, the platform has a large, globally diverse and growing community of project developers and stakeholders.
	Institutional Investors Group of Climate Change[254]	IIGCC	✓	✓	Policy programme Corporate programme Investor practices programme Paris Aligned Investment Initiative Initiatives and collaborations with other investor networks	The IIGCC is the European membership body for investor collaboration on climate change and the voice of investors taking action for a prosperous, low-carbon future. IIGCC has more than 275 members, mainly pension funds and asset managers, across 16 countries, with over €35 trillion in assets under management. IIGCC works to support and help define the public policies, investment practices and corporate behaviours that address the long-term risks and opportunities associated with climate change.
EU	InvestEU Portal[255]			✓	EU-wide portal Advisory support	The InvestEU Portal brings together investors and project promoters on a single EU-wide platform, by providing an easily-accessible and user-friendly database of investment opportunities available within the EU. The InvestEU Portal provides a list of pre-checked quality projects, qualified investors have the opportunity to easily screen various projects before deciding on which ones to invest in.

[254] https://www.iigcc.org/our-work/
[255] https://ec.europa.eu/investeuportal/desktop/en/index.html

Textbox 1 The European Bank for Reconstruction and Development (EBRD)

The European Bank for Reconstruction and Development (EBRD) was created in April 1991 to 'foster the transition towards open market-oriented economies and to promote private and entrepreneurial initiative'. The EBRD is not a retail bank, and does not offer commercial products such as mortgages and bank accounts. The direct financing products it offers include loans and equity for private sector projects, ranging generally from $5 million to $250 million. In addition, it also offers guarantees to facilitate foreign trade to, from, and within the EBRD regions, which includes Estonia.[256] The EBRD also facilitates policy reforms to help countries in making the transition to a competitive, well-governed, green, inclusive, resilient and integrated market economies. In order to help economies where EBRD operates build green, low carbon and resilient economies, it has developed, among others, the Green Economy Transition approach to provide its clients with green investment and concessional financing, policy engagement, and a range of technical support services.[257] It also maintains a Green Economy Transition knowledge hub to showcase related publications.[258]

The EBRD has laid out a specific strategy for Estonia, with the following priority areas:
Support Estonia's Green Economy Transition with the key objectives of improving energy and resource efficiency and greenhouse gases emission and increased renewable energy;
Foster Estonia's Knowledge Economy through More Diversified Sources of Finance with the key objectives of post-COVID-19 recovery (2021-2023), improved access to finance or innovation and digitalization; and to deepen and diversify debt and equity capital markets.

The EBRD can provide Estonia with loans and equity investments. Details of the financing products available to Estonia are listed in the table below.

What financing can we provide?

European Bank for Reconstruction and Development

Debt

- Loans are tailored to meet the particular requirements of a project. The credit risk may be taken entirely by the EBRD or partly syndicated to the market, or in parallel with commercial banks
- Can be senior, junior or convertible or venture debt
- Long term or short term, with floating or fixed rates
- Can be through participation in capital market transactions (bond issues), including short term commercial paper (in the Baltic countries)

Equity investments

Equity investments
- These may be undertaken in a variety of forms.
- Straight equity, mezzanine, convertible and at various stages (VC onwards)
- Can be at the pre-privatization/ IPO stage, or during the IPO process (e.g. Enefit in Estonia)
- EBRD is an active investor in equity funds investing in innovative companies, green infrastructure (e.g. Eften Baltics Sustainable Property Fund) or renewable energy
- When the EBRD takes an equity stake, it expects an appropriate return on its investment and will only take a minority position.

Between 1991 to 2021, the EBRD has financed 217 projects in 32 countries, 10.1GW of new renewable energy capacity, and has invested €6.5 billion in these projects. This includes 193MW of wind energy and 20 MW of biomass energy projects in Estonia.

[256] https://www.ebrd.com/work-with-us/trade-facilitation-programme.html
[257] https://www.ebrd.com/what-we-do/get/business-model.html
[258] https://www.ebrd.com/what-we-do/get/knowledge-hub.html

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