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Analysis of storage and electricity price forecast for large consumers in neighbouring countries

Estonian Ministry of Climate

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Summary

Project overview

The Ministry of Climate in Estonia and Ramboll are assessing the impact of energy storage on electricity prices in Estonia and neighbouring countries. In its first phase, the study models and compares BESS and PHS systems, exploring their effects on market prices and renewable integration. In its second phase, the project forecasts component-based electricity prices—including taxes, network tariffs, and surcharges—for industrial consumers in Estonia, Latvia, Lithuania, Poland, Finland, and Sweden.

Storage

This study focuses on two key storage technologies: Battery Energy Storage Systems (BESS) and Pumped Hydro Storage (PHS). BESS offers fast response times and flexibility, ideal for short-term balancing, while PHS provides large-scale, long-duration storage suitable for managing extended periods of low renewable output. Comparing both is crucial to understand their complementary roles in supporting grid stability, integrating variable renewables, and minimizing system costs under different future electricity market conditions.

This study did not assess the technical feasibility of the planned PHS and economic rationale, nor carried out any cost-benefit analysis related to this. It is purely resembling the operation of the plant on the market and its effect on day-ahead market prices.

Modelling

In Part 1, three storage scenarios were modelled for 2030, 2035, and 2040, combining BESS and PHS in Estonia. The analysis used Ramboll's European electricity market model to simulate system dynamics across Europe. Wind and solar profiles were tailored by location, and other generation plant participation was optimized within the model. Inputs on capacity, demand, and interconnections were based on the Estonian Ministry of Climate's assumptions and external databases. Outputs include electricity prices, dispatch, cross-border flows, and storage use.

In Part 2, electricity price data and cost component breakdowns were collected from national regulatory authorities, TSOs and DSOs, European databases and suppliers. Country-specific policy frameworks were taken into account, distinguishing between high- and low-voltage consumers. Ramboll also leveraged its local expertise and in-country presence to ensure the analysis reflected accurate and context-specific conditions.

Prices

Part 1 results show that across all scenarios, both the average day-ahead electricity market price and the weighted day-ahead average electricity price decline steadily from 2030 to 2040

SC2, offering the most BESS-PHS combined storage capacity, is the most effective in reducing average electricity prices and number hours with high prices. SC1, which only incorporates a BESS system, shows the worst results in day-ahead pricing.

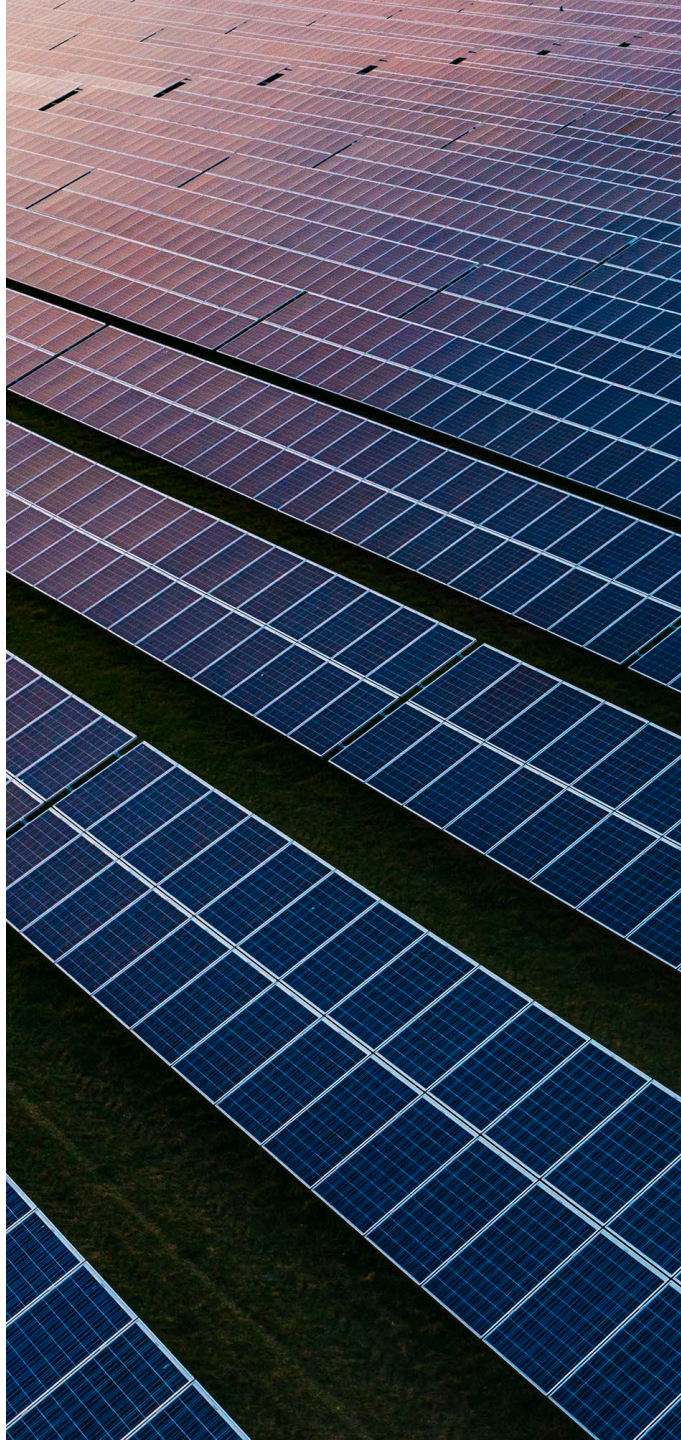
Part 2 results show that price composition is expected to shift in the future, with wholesale prices decreasing but network charges becoming more significant.

Across all countries, low voltage consumers pay higher prices for electricity.

Scenarios

The table presents the structure of the scenario analysis, which evaluates the impact of different energy storage configurations on electricity prices. Three distinct storage scenarios are modelled: **Scenario 1, Scenario 2, and Scenario 3**. Each scenario is analyzed for three different years: **2030, 2035, and 2040**. The structure allows for two key comparative analyses: **cross-scenario analysis**, which compares different storage configurations within the same year to assess their relative impact and **cross-temporal analysis,** which examines how electricity prices evolve, and storage options play a role over time within the same scenario.

	2030	2035	2040	
Scenario 1: 1500MW BESS	SC1 -2030	SC1 -2035	SC1 -2040	Temporal comparison
Scenario 2: 1000MW BESS + 500MW PHS	SC2 -2030	SC2 -2035	SC2 -2040	Temporal comparison
Scenario 3: 233MW BESS + 500MW PHS	SC3 -2030	SC3 -2035	SC3 -2040	Temporal comparison
	Cross Scenario comparison	Cross Scenario comparison	Cross Scenario comparison	



Task 1 – System Modeling Assumptions

Scenario 1	Year		2030	2035	2040	
	Area		EE	EE	EE	
	Scenario	Units	SC1	SC1	SC1	Source
GENERATION CAPACITIES	**Fossil Fuels total Capacity**	**MW**	**1294**	**1294**	**828**	Estonian Ministry of Climate
	Oil Shale	MW	466	466	0	Estonian Ministry of Climate
	Oil Gas Shale	MW	78	78	78	Estonian Ministry of Climate
	Natural Gas	MW	750	750	750	Estonian Ministry of Climate
	Renewables total Capacity	**MW**	**4480**	**5750**	**7900**	Estonian Ministry of Climate
	Solar	MW	1480	1600	2000	Estonian Ministry of Climate
	Wind Offshore	MW	0	1000	2000	Estonian Ministry of Climate
	Wind Onshore	MW	2850	3000	3050	Estonian Ministry of Climate
	Biomass	MW	150	150	150	Estonian Ministry of Climate
	Biogas	MW	0	0	560	Estonian Ministry of Climate
	Hydrogen	MW	0	0	140	Estonian Ministry of Climate
	TOTAL GENERATION CAPACITY	**MW**	**5774**	**7044**	**8728**	Estonian Ministry of Climate
STORAGE CAPACITIES	PHS CAPACITY	MW	0	0	0	Estonian Ministry of Climate
	BESS CAPACITY	MW	1500	1500	1500	Estonian Ministry of Climate
TRANSMISSION CAPACITY	EE - LV	MW	1000	2000	2000	Estonian Ministry of Climate
	EE - FI	MW	1016	1716	1716	Estonian Ministry of Climate
DEMAND	**TOTAL ELECTRICITY DEMAND**	**TWh**	**10.4**	**12.2**	**13.8**	Estonian Ministry of Climate
FUEL PRICES AND CO2 QUOTAS	Oil Shale	EUR/MWh	15.0	15.0	15.0	Estonian Ministry of Climate
	Oil Shale Gas	EUR/MWh	16.0	16.0	16.0	Estonian Ministry of Climate
	Biomass	EUR/MWh	30.0	30.0	30.0	Estonian Ministry of Climate
	Natural Gas	EUR/MWh	19.5	18.2	16.9	IEA - Announced Pledges
	CO2	EUR/ton	128.7	152.5	166.8	IEA - Announced Pledges

Scenario 2	Year		2030	2035	2040	
	Area		EE	EE	EE	
	Scenario	Units	SC2	SC2	SC2	Source
GENERATION CAPACITIES	**Fossil Fuels total Capacity**	**MW**	**1294**	**1294**	**828**	Estonian Ministry of Climate
	Oil Shale	MW	466	466	0	Estonian Ministry of Climate
	Oil Gas Shale	MW	78	78	78	Estonian Ministry of Climate
	Natural Gas	MW	750	750	750	Estonian Ministry of Climate
	Renewables total Capacity	**MW**	**4480**	**5750**	**7900**	Estonian Ministry of Climate
	Solar	MW	1480	1600	2000	Estonian Ministry of Climate
	Wind Offshore	MW	0	1000	2000	Estonian Ministry of Climate
	Wind Onshore	MW	2850	3000	3050	Estonian Ministry of Climate
	Biomass	MW	150	150	150	Estonian Ministry of Climate
	Biogas	MW	0	0	560	Estonian Ministry of Climate
	Hydrogen	MW	0	0	140	Estonian Ministry of Climate
	TOTAL GENERATION CAPACITY	**MW**	**5774**	**7044**	**8728**	Estonian Ministry of Climate
STORAGE CAPACITIES	PHS CAPACITY	MW	500	500	500	Estonian Ministry of Climate
	BESS CAPACITY	MW	1000	1000	1000	Estonian Ministry of Climate
TRANSMISSION CAPACITY	EE - LV	MW	1000	2000	2000	Estonian Ministry of Climate
	EE - FI	MW	1016	1716	1716	Estonian Ministry of Climate
DEMAND	**TOTAL ELECTRICITY DEMAND**	**TWh**	**10.4**	**12.2**	**13.8**	Estonian Ministry of Climate
FUEL PRICES AND CO2 QUOTAS	Oil Shale	EUR/MWh	15.0	15.0	15.0	Estonian Ministry of Climate
	Oil Shale Gas	EUR/MWh	16.0	16.0	16.0	Estonian Ministry of Climate
	Biomass	EUR/MWh	30.0	30.0	30.0	Estonian Ministry of Climate
	Natural Gas	EUR/MWh	19.5	18.2	16.9	IEA - Announced Pledges
	CO2	EUR/ton	128.7	152.5	166.8	IEA - Announced Pledges

Scenario 3	Year		2030	2035	2040	
	Area		EE	EE	EE	
	Scenario	Units	SC3	SC3	SC3	Source
GENERATION CAPACITIES	**Fossil Fuels total Capacity**	**MW**	**1294**	**1294**	**828**	Estonian Ministry of Climate
	Oil Shale	MW	466	466	0	Estonian Ministry of Climate
	Oil Gas Shale	MW	78	78	78	Estonian Ministry of Climate
	Natural Gas	MW	750	750	750	Estonian Ministry of Climate
	Renewables total Capacity	**MW**	**4480**	**5750**	**7900**	Estonian Ministry of Climate
	Solar	MW	1480	1600	2000	Estonian Ministry of Climate
	Wind Offshore	MW	0	1000	2000	Estonian Ministry of Climate
	Wind Onshore	MW	2850	3000	3050	Estonian Ministry of Climate
	Biomass	MW	150	150	150	Estonian Ministry of Climate
	Biogas	MW	0	0	560	Estonian Ministry of Climate
	Hydrogen	MW	0	0	140	Estonian Ministry of Climate
	TOTAL GENERATION CAPACITY	**MW**	**5774**	**7044**	**8728**	Estonian Ministry of Climate
STORAGE CAPACITIES	PHS CAPACITY	MW	500	500	500	Estonian Ministry of Climate
	BESS CAPACITY	MW	233	233	233	Estonian Ministry of Climate
TRANSMISSION CAPACITY	EE - LV	MW	1000	2000	2000	Estonian Ministry of Climate
	EE - FI	MW	1016	1716	1716	Estonian Ministry of Climate
DEMAND	**TOTAL ELECTRICITY DEMAND**	**TWh**	**10.4**	**12.2**	**13.8**	Estonian Ministry of Climate
FUEL PRICES AND CO2 QUOTAS	Oil Shale	EUR/MWh	15.0	15.0	15.0	Estonian Ministry of Climate
	Oil Shale Gas	EUR/MWh	16.0	16.0	16.0	Estonian Ministry of Climate
	Biomass	EUR/MWh	30.0	30.0	30.0	Estonian Ministry of Climate
	Natural Gas	EUR/MWh	19.5	18.2	16.9	IEA - Announced Pledges
	CO2	EUR/ton	128.7	152.5	166.8	IEA - Announced Pledges

*All other countries in the EU were modelled according to the projected generation capacities, demand and lines in the TYNDP-NT 2024 scenario: Visualisation Platform | ENTSOs TYNDP 2024 Scenarios

Task 1 - Analysis of the Role of Storage in the Electricity Market

Key Results

Scenario	Period	Average Electricity Market Price (€/MWh)	Weighted Average Electricity Price (€/MWh)
Scenario 1. 1500 MW BESS	2030	50.38	49.88
	2035	38.90	38.27
	2040	27.00	26.45
Scenario 2. 1000 MW BESS, 500 MW PHS	2030	48.87	48.85
	2035	38.06	37.69
	2040	25.99	25.66
Scenario 3. 233.1 MW BESS, 500 MW PHS	2030	49.58	49.35
	2035	38.35	37.90
	2040	26.36	25.97

Comments

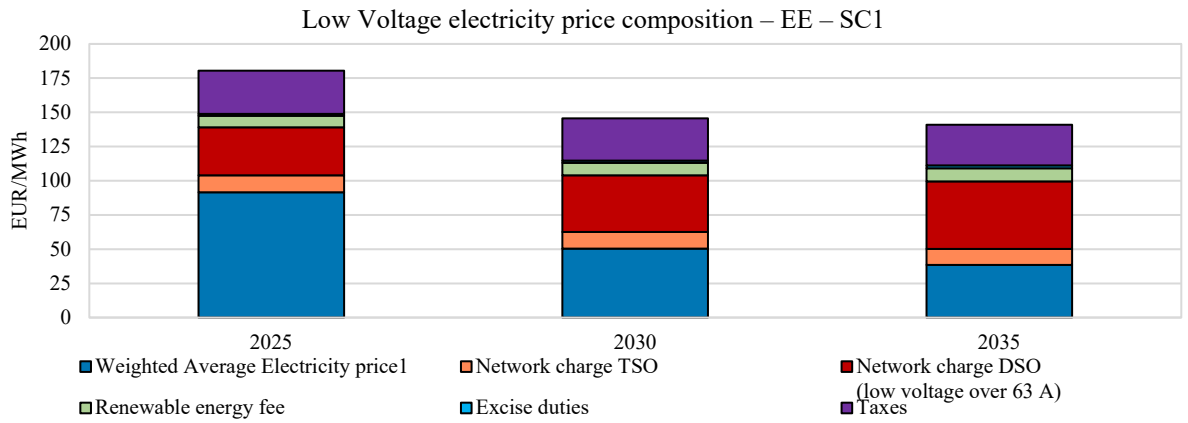
- Across all scenarios, both the **average day-ahead electricity market price and the weighted day-ahead average electricity price decline steadily from 2030 to 2040**. This reflects increased renewable integration and the role of storage in reducing price volatility.
- **Scenario 1** consistently shows the **highest prices among the three scenarios.** This indicates that battery energy storage alone (BESS), even at 1500 MW, has a limited impact on reducing average electricity prices compared to scenarios that include PHS.
- **Scenario 2** delivers the **most effective average price reduction** with its hybrid setup and its increased storage capacity, suggesting synergistic effects of combining technologies.
- **Scenario 3 suggests intermediate results,** with prices slightly higher than Scenario 2 but still lower than Scenario 1.
- The results suggest that the larger storage capacity provided by **PHS**, compared to BESS, is a **more effective means of reducing average electricity prices** in Estonia.
- Other results from the price modelling exercise (including consumption, production, storage behaviour, curtailment and lineflows) can be found in the attached excel file

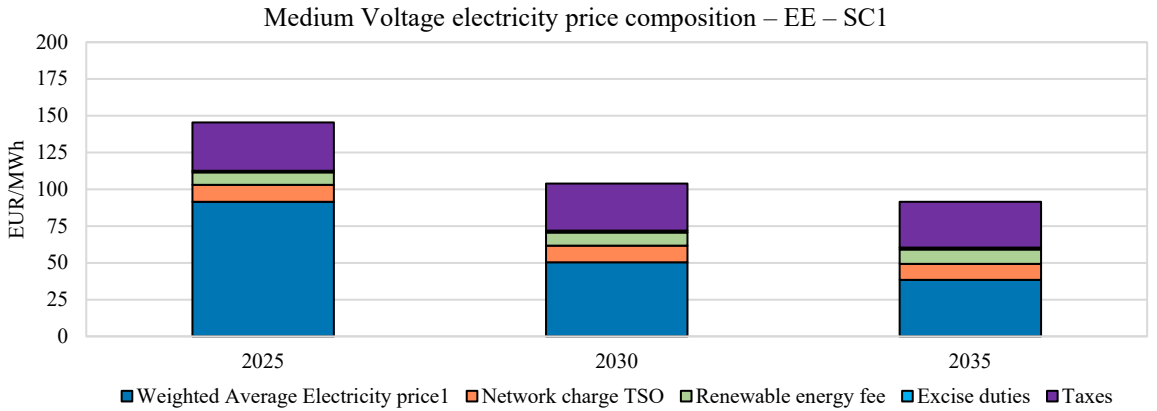
Task 2 - Electricity Price Analysis for Large Consumers and Industry

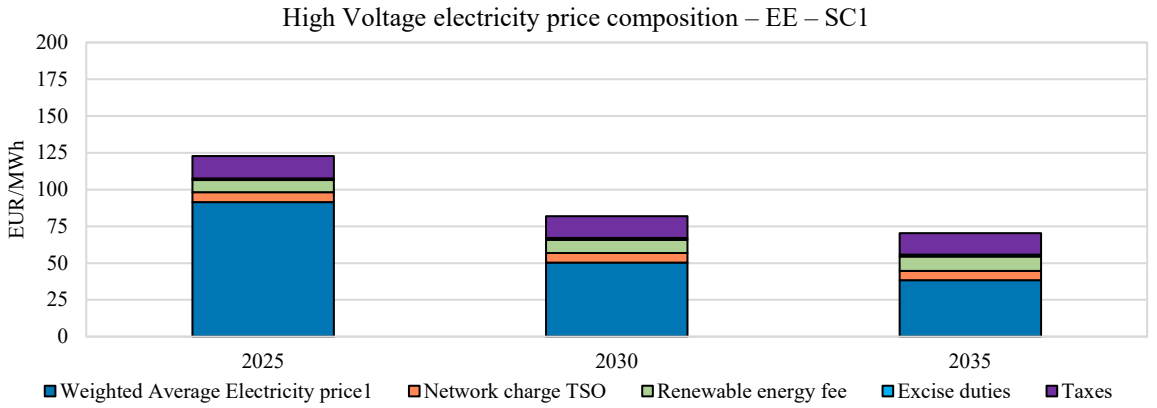
Comments

- The **second part** of the analysis presents **projected electricity price compositions** in Estonia and neighbouring countries for the years 2025, 2030, and 2035 across different voltage levels.
- The forecasts for charges, fees, taxes and duties are developed using historical data and projecting trends adjusting for inflation. Electricity prices are obtained from the simulation for Task 1.
- The 'Results Dashboard' offers a comprehensive description of the different price components as well as the sources and reasoning behind their forecasts. The figures on the right display a sample of result price composition for Estonia if Scenario 1 was to become reality.[1]
- Results show that for most of the countries in the study, day-ahead prices are projected to decline across all voltage levels between 2025 and 2035. The **price composition**, however, **is shifting**: while **wholesale prices decrease, network charges**—especially at low voltage—**are becoming more significant**. Low voltage consumers are also the ones paying higher prices for electricity in most scenarios.
- It is important to note that while there are some trends for network charges, fees and taxes, **regulatory and political decisions,** harder to forecast**, will be key to shape electricity prices in the future.**

[1] The prices used for the average electricity price are developed as part of Task 1 in this study.
The graphs show results for Scenario 1. The attached dashboard allows to extract the same figures for the other analysed scenarios.







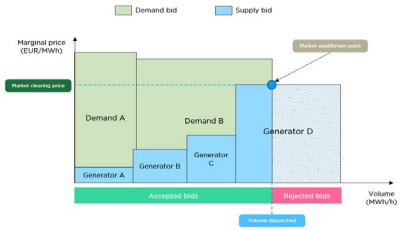
Appendices

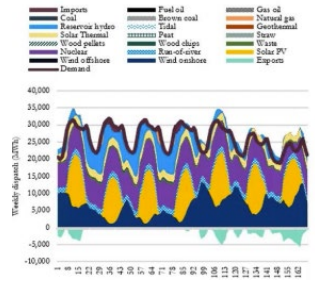
1. Model description
2. Excel Spreadsheet

Model Description

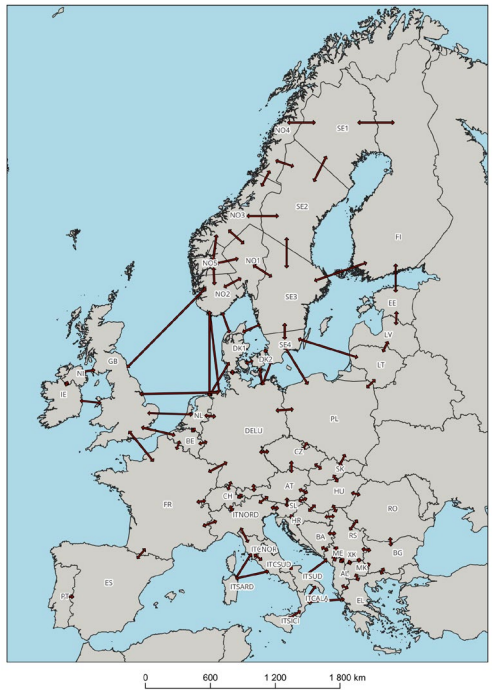
Our approach to delivering electricity market analyses and forecasts

	1. INPUT	2. MODEL	3. OUTPUT
DESCRIPTION	European market data • Power plants • Power demand • National development plans • Energy commodity prices • Cross-border interconnection capacity available per hour and line.	Optimization energy market model • Python simulation of EU electricity market • Model solves the cost-minimization of EU power system for every hour for the coupled European electricity system (similar to SDAC – single day-ahead coupling algorithm).	Electricity market result • Energy production • Energy consumption • Electricity prices Results are prepared in databases for the delivery.
FORMAT	ENTSO-E Eurostat National market data	Python software	Excel dashboards

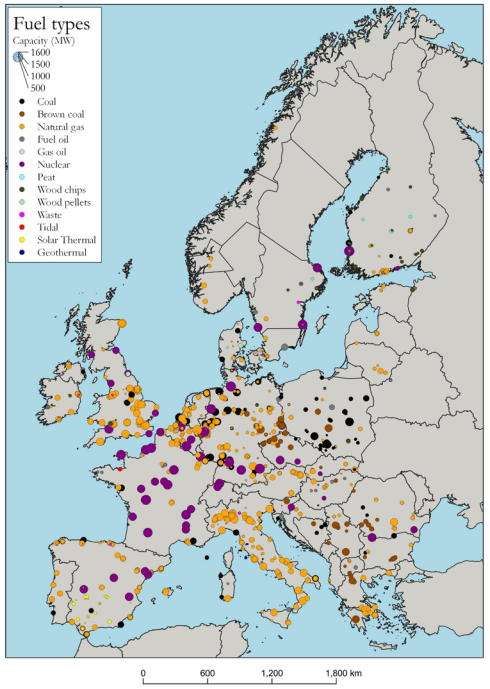




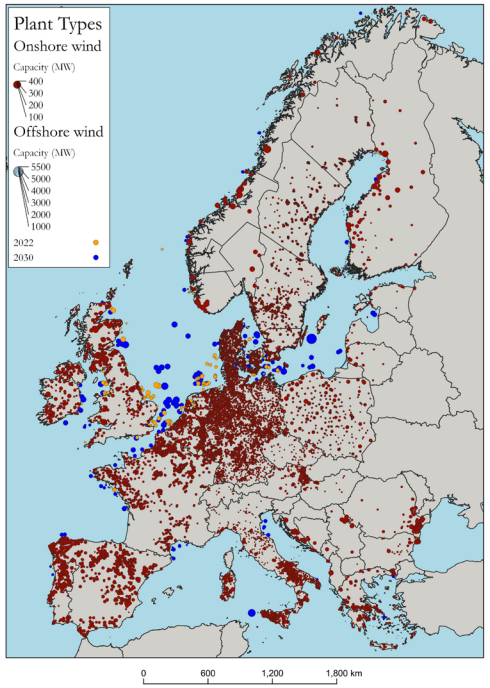
The model is based upon datasets of the European electricity system and market structure



Interconnectors



Thermal power plants



Wind power plants

The specific data for the Estonian energy system will be updated based on the data given by the Ministry.

- **Variable renewable energy hourly timeseries (2015-2023)**: Wind, solar PV, run-of-river hydro. Considering the installed capacity as well as projected development plans and associated production profiles.
- **All conventional power plants** in Europe including commissioning/decommissioning of power plants.
- **Electricity demand** per electricity market zone and its projected development per demand types.
- **Cross-zonal interconnection capacity** and projected development.
- **Hydro reservoir database** with power plants historical water inflow, water reservoir levels, etc.
- **Fuel and CO2 prices**: statistics and projections from relevant institutions.

The output of the model can cover three focus areas

Focus area		Description	
1 Forecasting and Price Analysis	a	Electricity price forecast	Hourly electricity price forecasts for bidding zones.
	b	Scenarios comparison	Generation of different price projections based on different sets of assumptions.
2 Future energy mix	a	Annual energy balances	Assessing future energy mix and technology deployment.
3 System analysis	a	Generation dispatch	Analysis of generators dispatch.
	b	Demand dispatch	Analysis of demand components dispatch.
	c	Zones interconnectors	Analysis of congestion on lines and bottlenecks.

Report details

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Sources and methodology

Techno-economic analysis

- Ramboll's Electricity Market model has been utilised to conduct the analysis and facilitate scenario comparisons, enabling the evaluation of the different storage technologies and price forecasting.
- The electricity market model is a Python-based computational tool**,** specifically developed by Ramboll and customized for this project. It is designed to handle electricity market operations, integrating various technical and economic parameters to support informed decision-making.
- The industry price forecasts were developed using historical data to extract trends.

Project sources

- Technical specification provided by the ministry and documents exchanged along the project.

External sources

Please refer to the Spreadsheet attachment for a detailed list of sources**.**

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