

# CESI

*Inspired with innovation*

## Latvia-Sweden interconnection initial implementation studies



January 2025

**AST**

<b>Introduction .....</b>	<b>4</b>
<b>Context and objectives of the study .....</b>	<b>4</b>
<b>Adopted methodologies.....</b>	<b>6</b>
<b>Scenarios and main assumptions for network, economic and cost-benefit analysis .....</b>	<b>8</b>
<b>Main Results .....</b>	<b>10</b>
<b>Conclusions .....</b>	<b>17</b>
<b>Recommendations .....</b>	<b>20</b>

**GLOSSARY**

AC	Alternative Current
BtB	Back-to-Back
CAPEX	Capital Expenditures
CBA	Cost-Benefit Analysis
DC	Direct Current
EE	Estonia
ENPV	Economic Net Present Value
ENTSO-E	European Network of Transmission System Operators for Electricity
ETS	Emission Trading Scheme
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
LaSGo	Latvia Sweden Gotland Island
LCC	Line-Commutated Converter
LT	Lithuania
LV	Latvia
NTC	Net Transfer Capacity
OPEX	Operational Expenditures
PECD	Pan European Climate Database
PEMMDB	Pan European Market Modelling DataBase
PV	Photovoltaic
RES	Renewable Energy Sources
SCR	Short Circuit Ratio
SE	Sweden
SMP	System Marginal Price
SPS	Special Protection Scheme
SvK	Svenska Kraftnät
TSO	Transmission System Operator
TYNDP	Ten Years National Development Plan
VRES	Variable Renewable Energy Source
VSC	Voltage Source Converter

## DISCLAIMER

This executive summary has been drafted upon request of the Client exclusively with the aim of presenting the key outcomes of *“Latvia-Sweden interconnection initial implementation studies”*.

This executive summary does summarize the activities conducted by CESI and the relevant results, based on current regulatory, technical and factual situation. In particular, due to the nature of the study itself, the latter does represent a future scenario based on assumptions and conditions that may/may not exist or events that may/may not occur in the future or events that may not be within our control or the control of any other person in the future.

The activity carried out by CESI has been based on selected documents and information disclosed by the Client, at its discretion, until the date of the study (“Input Data”). Findings in this study refer to the Input Data selected and provided by the Client and to the best available technologies applicable to this interconnection project.

Findings of this study are not meant to replace a more detailed analysis of any specific issues arising from the above-described activities.

This study shall neither be intended as certifying or not certifying any specific product or result nor shall it be used to demonstrate the compliance or non-compliance with specific laws or regulations. CESI shall neither guarantee the suitability of its activities and of this executive summary to any specific purpose nor shall be liable for the use that the Client and/or any third party shall make of this executive summary and the relevant findings.

No person or entity is entitled to rely on this executive summary or on any matter referred to in this executive summary. The extension or the application by analogy of such findings to any data or information is expressly excluded.

CESI shall not be liable for: (i) any use of this executive summary by the Client; (ii) any use of this executive summary by any third party; (iii) any decision based on the contents of this executive summary. In relation to the above, the Client shall indemnify and hold harmless CESI from and against any claims. This executive summary must be used and/or reproduced in its entirety only; any partial use is prohibited.

## Introduction

The interconnected power system plays a vital role in ensuring the secure, reliable, and stable operation of the electricity grid, as well as supporting the functioning of competitive electricity markets. The Latvian power system is currently interconnected with Estonia and Lithuania but lacks direct connections to other European countries.

Due to its geographical location, Latvia has the potential to establish a connection with Sweden, enabling the integration of the Latvian and Swedish power systems. Considering the synchronization of the Baltic power systems with continental Europe, the significant growth of renewable energy sources (RES) in both Latvia and Sweden, and the ongoing challenges related to system security, stability, and market dynamics, these issues remain critical for both the Baltic and Nordic regions.

To explore these challenges in greater depth and assess the feasibility of an interconnection between Latvia and Sweden, the Latvian Transmission System Operator (TSO) initiated a study for the LaSGo (Latvia-Sweden-Gotland Island) project. The study aimed to evaluate the technological solution of the LaSGo project, the impact on the grids of both countries, the possible routing and connecting substations, the estimation of energy exchanges and benefits as well as the key economic KPI. The study was started in early 2024 and was carried out by the energy consultant CESI from Italy.

## Context and objectives of the study

The Latvia -Sweden – Gotland Island (LaSGo) HVDC project is a planned interconnection between Latvia and Sweden by means of a submarine direct current cable. The project foresees two sections: the first is the internal line from Gotland to Sweden, which adds 700 MW of capacity and strengthens the link between the Swedish mainland and the island of Gotland while the second section is between the island of Gotland and Latvia which adds 700 MW of capacity. A conceptual scheme of LaSGo link is shown in Figure 1.



Figure 1: A conceptual scheme of LaSGo project

The LaSGo project can potentially yield substantial technical, environmental and economic benefits, such as:

- Increase the competitiveness of the electricity market in the Baltic and Nordic countries
- Foster in Latvia and Sweden, especially in Gotland Island, the integration of Variable Renewable Energy Sources (V-RES), especially off-shore and on-shore wind, and electrolysers for green hydrogen production
- Help to handle the eventual RES surplus in all involved countries and especially in Gotland Island
- Contribute to the reduction of the greenhouse gas emissions in Baltics, Gotland Island and rest of Sweden and support energy transition from fossil fuels to RES
- Improve the security of supply for all involved power systems and guarantee a secure and stable system operation.

In order to evaluate the technical and economic feasibility of this HVDC project, the following tasks were performed in the study:

1. **Technological analysis** to investigate the HVDC state-of-the-art and to define the most suitable HVDC architecture and the cost of the LaSGo project
2. **Network analyses** to assess the impact of the HVDC project on the involved transmission networks and to identify the eventual network reinforcements or redispatching actions

3. **Market analysis** to evaluate the impact of the HVDC project on the electric market of the involved power systems and to execute a **cost-benefit analysis** to proof the economic profitability of the project.

## Adopted methodologies

### *Technological analysis*

The main purpose of technological analysis is to investigate the most suitable HVDC architecture for the LaSGo HVDC link. More in detail, the main outcomes for this task are:

- the definition of the HVDC technology, configuration and DC voltage
- the cost estimation of the project based on a preliminary line routing of DC cables and the selected HVDC architecture.

### *Network analyses*

Network analyses are a crucial task to evaluate the impact of the HVDC on the involved transmission networks: in fact, the additional power flows of from/to the HVDC link could cause overloads on network elements, voltage violations or undermine the system robustness. For these reasons the network analyses task was structured in three sub-tasks:

1. **Load flow analyses in N and N-1 conditions**<sup>1</sup> are the first sub-task and its objective is to assess if the transmission network can carry the additional HVDC power flows in a secure way without overloads or voltage violations. The main outcomes of these analyses are the definition of a possible new set of transmission network reinforcements or curative redispatching actions to cope with overloads.
2. **Short Circuit Ratio (SCR) evaluation** is the second sub-task, and its aim is to have a preliminary measure of the network's robustness at the HVDC connection substations: to have a proper HVDC power/frequency control, as the SCR must be higher than a specific threshold. The main outcome of this sub-task is the calculation of SCR and the identification of new equipment to increase the network robustness, if necessary.
3. The **dynamic analyses** are the last sub-task, and its goal is to investigate the dynamic behavior of the transmission network after severe contingency such as short circuits or

---

<sup>1</sup> N condition means that load flow analysis is performed considering all lines and transformers in service. Instead N-1 condition is when the load flow analysis is performed considering one element (line or transformer) out of service. The N-1 analysis is applied to all network elements, one at the time.

loss of active power sources. The identification of possible new equipment to improve the system inertia or defining dispatching limitations are the main outcomes of this sub-task.

The network analyses were performed by considering fully detailed network models for Baltic countries (provided by AST) while a simplified model was adopted for Sweden (provided by Svenska Kraftnät, the Swedish TSO). The network model of Gotland Island was built based on public information. More precise analyses on the Swedish and Gotland Island systems can be carried out in a later stage adopting a detailed network model.

The previous sub-tasks were carried out for two horizon years (2035 and 2040), two seasons and load conditions (Summer PV: low load with max PV production and Winter peak: low load without PV production), two levels of PV and wind production (high and low) and three HVDC operating conditions (HVDC out of operation, max import from Sweden/Gotland Island and max export to Sweden/Gotland Island) as summarized in Figure 2 for year 2035. The same was performed for year 2040.

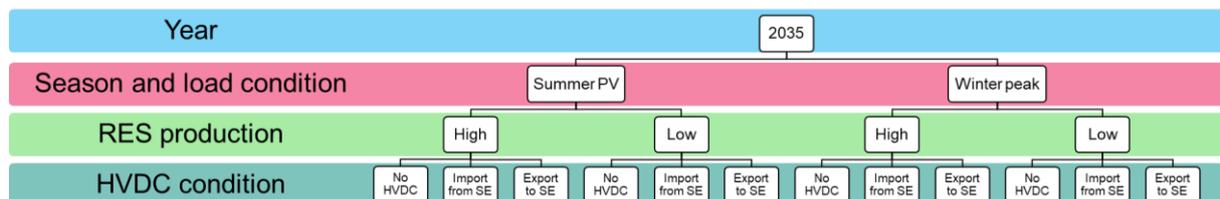


Figure 2: Set of analysis performed for every analyzed year

### Market and cost-benefit analyses

The third task of this work is divided into two main sub-tasks: the first one is dedicated to market analyses while the second one is focused on cost-benefit analyses. More in detail:

- The **market analyses** have the goal to assess some key aspects as the expected optimal energy exchanged by means of LaSGo project, the variation of system marginal prices, the reduction of CO<sub>2</sub> emissions, the increase of RES integration, the production of hydrogen and the evaluation of the Socio-Economic Welfare (SEW).
- The **cost-benefit analyses** have the purpose to evaluate the profitability of LaSGo project. These analyses are based on the fourth guideline of ENTSO-E for grid

development projects<sup>2</sup> in which the capital expenditures (CAPEX) and operational costs (OPEX) of LaSGo project are compared with the monetized benefits (above all the Socio-Economic Welfare) in order to quantitatively assess the project economic profitability.

The horizon years for market and cost-benefit analyses were 2035, 2040 and 2050. The economic profitability was evaluated by comparing the results with and without the LaSGo project.

## Scenarios and main assumptions for network, economic and cost-benefit analysis

As explained in the methodology section, the technical analyses were performed for three horizon years: 2035, 2040 and 2050 to consider the evolving situation of the demand, generation fleet and grid development over the lifetime of the interconnection project. Table 1 presents the expected installed power capacity in Baltic countries and Sweden. It is worth noting substantial investments in terms of renewables (in all Baltic countries) and electrolysers (only in Latvia, Lithuania and Sweden).

Table 1: Expected generation fleet in Baltic countries and Sweden for years 2035, 2040 and 2050, [MW]

[MW]	LATVIA			LITHUANIA			ESTONIA			SWEDEN		
TYPE	2035	2040	2050	2035	2040	2050	2035	2040	2050	2035	2040	2050
NUCLEAR	-	-	-	-	-	-	-	-	-	6881	5763	3560
THERMAL	1000	850	850	495	495	50	359	269	269	170	170	170
HYDRO	1608	1608	1608	1136	1136	1136	4	4	4	16502	16502	16502
BIOMASS	173	168	168	212	212	212	119	-	-	4755	4755	4755
PV	2296	2628	3227	5800	5900	7307	1720	1820	2210	4157	4745	8002
WIND	1780	2602	3086	7420	8230	9186	3942	6542	7034	24761	27594	33378
BESS STORAGE	120	200	200	749	700	700	27	27	27	800	800	1050
ELECTROLYSER	1000	2000	2000	2000	2000	2000	0	0	0	4120	5882	7895

The following figures (*Figure 3* and *Figure 4*) show the detail of the expected evolution of Latvian power system for years 2035 and 2040. More in detail:

- The yellow pointers represent solar (PV) power plants

<sup>2</sup> [https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/news/2024/entso-e\\_4th\\_CBA\\_Guideline\\_240409.pdf](https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/news/2024/entso-e_4th_CBA_Guideline_240409.pdf)

- The light green pointers correspond to onshore wind farms while the dark green pointers are for offshore wind farm
- The blue pointers refer to electrolyzers in industrial plants
- The orange dashed line represents the new 330 kV line Ventspils – Broceni – Varduva already planned by AST
- The red dashed line is for the planned 4<sup>th</sup> interconnection between Latvia and Estonia.

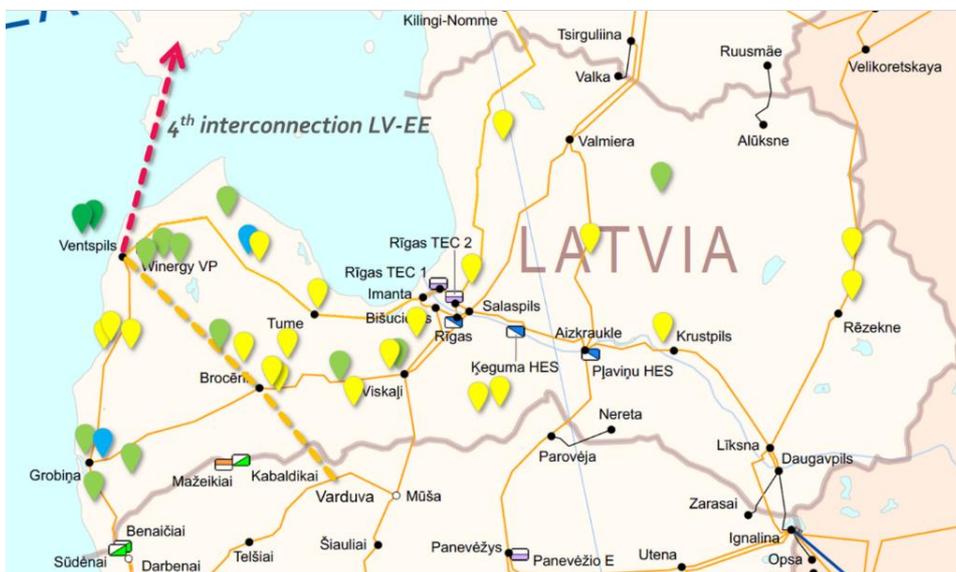


Figure 3: Development of Latvian transmission network in 2035

A massive RES development is foreseen to be deployed in the Western part of Latvia over the period 2035-2040, as evident from the maps.



Figure 4: Development of Latvian transmission network in 2040

## Main Results

### Technological analysis

After having examined the state of the art of the HVDC sector and its perspective evolution, for the LaSGo HVDC project the adoption of the following solution is suggested:

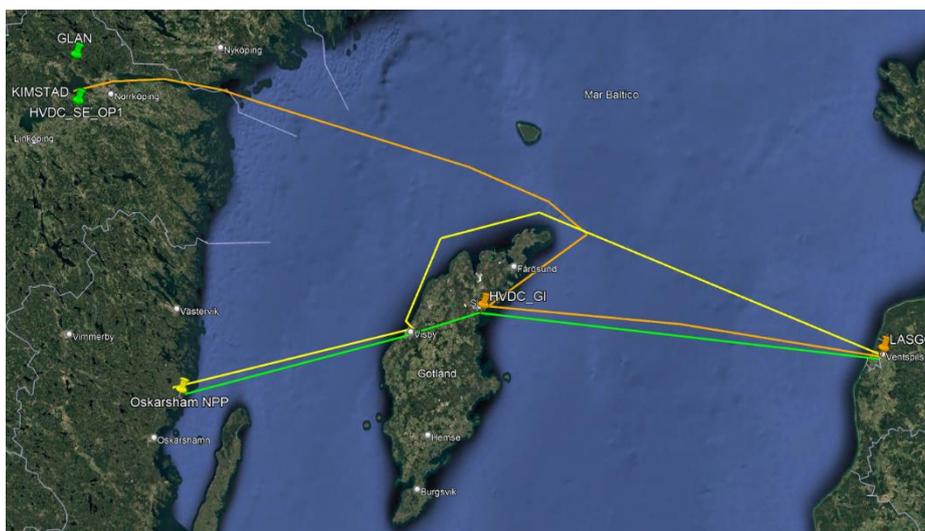
- Voltage Source Converter (VSC) technology since it provides more system services (above all: continuous voltage regulation, black start and less sensitivity to short circuits) compared to the Line-Commutated Converters (LCC) technology.
- Monopolar symmetric configuration: this HVDC architecture is commonly used in the HVDC today in operation in the North Sea.
- In terms of DC voltage, it is possible to adopt either 320 kV or 500 kV solutions. The main difference is about the return of experience: today there are many of examples in operation at 320 kV with at least 14 years of operation while there are several examples at 500 kV in construction or planned but not yet in operation. Nevertheless, 500 kV seems more suitable, considering the expected future projects of DC network among Baltic and Nordic countries and offshore wind farms. Furthermore, this solution is characterized by lower losses.

## HVDC cost estimation

The estimation of upfront investment costs is closely related to the link routing, which impacts on the cost of DC cables. The identification of the line routing is a quite complex task from the environmental point of view, so, to be conservative, three preliminary line routings were defined from a desktop study, as shown in *Figure 5*. More in detail:

- the green line refers to a routing between Ventspils (Latvia), Slite (Gotland Island) and Oskarsham (Sweden). The total length is 300 km
- the yellow line identifies a routing between Ventspils (Latvia), Visby (Gotland Island) and Oskarsham (Sweden). The total length is 350 km
- the orange line identifies a routing between Ventspils (Latvia), Slite (Gotland Island) and Kimstad or Glan (Sweden). The total length is 450 km

As it is possible to note, the starting point of the HVDC link is the Ventspils bus since it is the most robust bus (four 330 kV lines: Ventspils – Grobina, Ventspils – Stelo Orienta/Tume, Ventspils – Saarema and Ventspils – Broceni) and the distance from Gotland Island is the shortest: this introduces not negligible savings in HVDC capital expenditures.



*Figure 5: Possible routings of the LaSGo project*

Considering the wind potential for offshore installations, the bathymetry of the Baltic Sea, the HVDC state-of-the-art and the expected trends of this technology in terms of integration of offshore wind farms, four possible connection schemes were identified:

- **Tri-terminals HVDC:** This is the basic solution and foresees three terminals: one in Latvia, one in Gotland Island and one in Sweden. The converter stations in Latvia and Sweden have a size of 700 MW whereas in Gotland Island the size could be at maximum 200 MW. The length and the width of the 700 MW converter station including AC switchyards are respectively 100 m and 190 m and therefore the total surface is about 19000m<sup>2</sup>. The LaSGO project is not integrated with offshore wind farms.
- **Hybrid HVDC with offshore wind farm integration from DC side:** This solution foresees the addition of one or two offshore converter stations in the sea between Latvia and Gotland Island and Gotland Island and Sweden. This solution has two main critical issues: the first one is that the offshore floating substation requires dynamic cables and, according to the Consultant visibility, this is a new technology and currently dynamically floating cables are not present in the market for voltage higher than 250 kV. In any case, since the depth of the Baltic Sea is not too high, some technical solutions based on standard cables could be found, but the costs of such solutions are considerable. The second weak point is the distance from the offshore converter station and the coast: if this distance is lower than 50 -60 km, an AC connection will be cheaper.
- **Hybrid HVDC with offshore wind farm integration from AC side:** This second scheme for hybrid HVDC has the goal to reduce the costs by connecting the offshore wind farms from the AC side of the onshore converter station: this way can avoid the costs related to the floating offshore substations. In this case the cost of the HVDC is practically the same of tri-terminal solution: the cost difference is due to the fact that the AC side of converter station requires more bays to integrate the offshore wind farms, but this is almost negligible compared to the total cost of HVDC.
- **HVAC without offshore wind farm integration with Back to Back:** This last scheme is based on the experience of Krieger's Flak offshore wind project: a group of offshore wind farms connected to Denmark and Germany by AC submarine cables. Considering the HVAC solutions, the reactive power plays an important role in the cable operation and therefore, considering the distances of LaSGo context only 220 kV cable solution can be used. Unfortunately, these cables have limited capacity in terms of MW transmitted and therefore more than one submarine cable should be laid in parallel. Another important aspect is that Baltic and Nordic countries belong to different synchronous areas and a direct AC connection would entail a synchronization between the Nordic power system with the system composed by Baltics countries and Continental Europe. Of course, this is an interesting possibility, but it should be explored more deeply and in detail with the involved countries, from Poland to Norway. To avoid the effect of synchronization on

the neighboring countries, a Back-to-Back converter station should be installed in Gotland Island or Latvia.

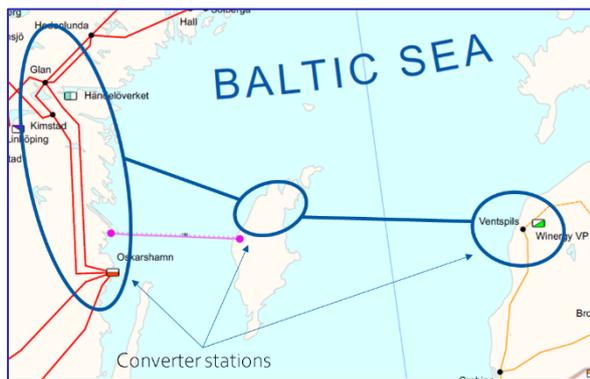


Figure 6: Tri-terminals HVDC



Figure 7: Hybrid HVDC with offshore wind farm integration from DC side



Figure 8: Hybrid HVDC with offshore wind farm integration from AC side



Figure 9: HVAC without offshore wind farm integration with Back to Back solution

## Network analyses

The network analyses don't highlight particular criticalities and this means that AST has already planned the transmission grid with sufficient power transfer capacity to host also the power flows from/to the LaSGo project. More in detail:

- The static analyses at year 2035 with and without HVDC don't highlight significant issues
- In 2040 the Ventspils area will be particularly affected by power flows from:
  - Latvia's offshore wind farms
  - 4<sup>th</sup> interconnection with Estonia

- Electrolysers (above all, the electrolyzer foreseen in Stelo Orienta, a new station on the 330 kV line between Ventspils and Stelo Orienta)
- LaSGo interconnector.

Consequently, in the year 2040, the network analyses detected some possible overloads on the 330 kV line Ventspils – Stelo Orienta: however, it is important to note that, in the worst case scenario, the overload in N-1 mode would be at 119% after the tripping of the 330 kV line Ventspils - Brocēni. This overload can be easily managed with redispatching actions and it is not necessary to evaluate a new network reinforcement.

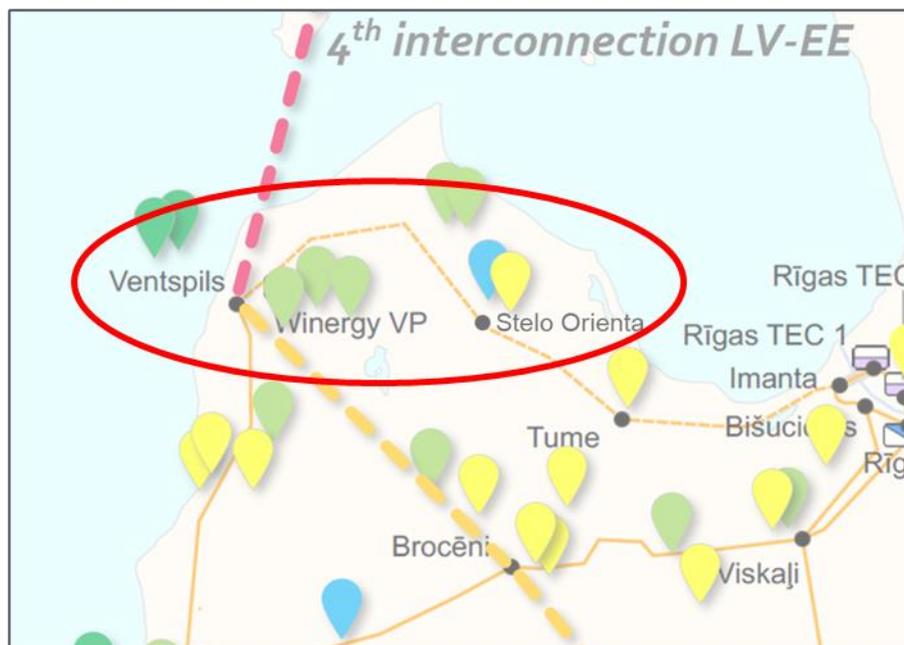


Figure 10: Development of Latvian transmission network in 2040 between Ventspils and Stelo Orienta

- The network analyses confirm the need to implement new 330kV line Ventspils – Brocēni – Varduva and the fourth interconnection with Estonia projects to ensure the Latvian power system performances compliant with the security standards.
- The Short Circuit Ratio (SCR) calculation in Ventspils identifies sufficiently high values and therefore this bus is more than adequate for the HVDC connection.
- The dynamic analyses do not show criticalities: in all simulated contingencies, the Latvian power system was able to dampen the oscillations of frequency or voltage and to reach a new steady state.

## Market analyses

The market analyses confirms the initial expectations for LaSGo project in terms of RES integration, CO<sub>2</sub> reduction and highlight additional benefits. More in detail:

- Energy flows: annual simulations reveal significant energy flows on the LaSGo interconnection: 5.4 TWh in 2035 and in 2040 and 5.3 TWh in 2050 with an average load factor of almost 90%. It is important to note that these power flows are bi-directional: during the day LaSGo exports the PV surplus from Baltic countries to Sweden/Gotland Island while during the night LaSGo imports hydro and nuclear production from Sweden to Latvia/Gotland Island.
- Directionality of energy flows: In 2035 and 2040, the energy exported from Latvia to Sweden is almost equal to the energy imported from Latvia to Sweden. Only in 2050 the energy exported from Latvia to Sweden is bigger than the energy imported.
- Impact on fossil and RES generation: LaSGo HVDC permits in Latvia a sharp decrease in fossil thermal generation (and a reduction of 35% of CO<sub>2</sub> emissions) and a slight increase in the electricity production from renewable sources.
- RES integration in the Baltic republics: LaSGo nominates Latvia as a regional hub for renewable energy: its presence reduces the RES generation curtailment also in Estonia (on average 380 GWh) and Lithuania (on average 900 GWh) and optimizes the hourly dispatching in all Baltic countries.
- Nuclear generation in Sweden: Swedish nuclear generation remains constant across scenarios but is foreseen to decrease in the late years in the timeline horizon. Although nuclear plants are generally dispatched at low capacity factors, the availability of renewable energy from the Baltic regions allows the LaSGo interconnection to support an earlier phase-out of Sweden's aging nuclear power plants (constructed between 1980 and 1985).
- Market prices: Market analyses for horizon 2050 shows a generalized price increase driven by two key factors: increased electricity demand against a less ambitious generation expansion and introduction of very expensive thermal capacity in Germany (hydrogen fired generators), which significantly unbalances the marginal prices outputs in the Nordic and Baltic area. This effect increases the net exports of power from Latvia to Sweden/Gotland Island and helps Sweden/Gotland Island to reduce the increase of marginal price.

- Socio-economic welfare: At System level, socio-economic welfare is positive for the entire time horizon for Sweden and Baltics (€ 0.19 billion in 2035, € 0.12 billion in 2040 and € 0.36 billion in 2050).
- Hydrogen: The hydrogen sector's benefit follows the trends of the consumer surplus because it decreases its energy supply costs for hydrogen production against a final selling price of the fuel that remains unchanged.

### Cost-benefit analyses

The cost-benefit analysis was performed after the evaluation of the benefits and the HVDC cost definition, based on the budgetary estimation of some projects that CESI is currently following. The results are shown in the following table for all investigated HVDC schemes and voltages. More in detail:

- ✓ HP means High Profitability with ENPV values higher than € 100 million,
- ✓ LP indicates Low Profitability with ENPV values between € 0 and € 100 million,
- ✓ SU means Slight Unprofitability with ENPV values between € 0 and € -100 million,
- ✓ HU indicates High Unprofitability with ENPV values below € -100 million

Table 2: Summary of Economic profitability

HVDC configuration	Voltage [kV]	Orange routing	Yellow routing	Green routing
Tri-terminals HVDC or Hybrid HVDC with offshore wind farm integration from AC side	320	HP	HP	HP
	500	HP	HP	HP
Hybrid HVDC with one offshore wind farm integration from DC side	320	SU	LP	LP
	500	HU	SU	SU
Hybrid HVDC with two offshore wind farms integration from DC side	320	HU	HU	HU
	500	HU	HU	HU
HVAC without offshore wind farm integration and BtB	220 AC	HU	HU	HU

As it is possible to note, the Three-terminals HVDC or Hybrid HVDC with offshore wind farm integration from AC side are profitable for all routings and voltage levels. In contrast, hybrid HVDC systems with two offshore wind farms integrated on the DC side, as well as HVAC systems without offshore wind farm integration, are never profitable. As for the hybrid HVDC system with one offshore wind farm integrated on the DC side, profitability is achieved only at 320 kV and for the yellow or green routing options.

## Conclusions

For Latvian perspectives, the performed technical analyses highlight that:

- **Best Connection Point:** The Ventspils substation is identified as the most suitable connection point for the HVDC due to its proximity to Gotland Island, its strong transmission network (four 330 kV lines: two existing and two planned), and appropriate short-circuit ratio (SCR) values.
- **Network Reinforcements:** It is crucial to proceed with the planned reinforcements, including the new 330 kV line Ventspils–Broceni–Varduva and the fourth interconnection with Estonia.
- **2035 Analysis:** No significant issues (e.g., voltage violations or overloads) are observed in 2035, if the mentioned the 330 kV Ventspils–Broceni–Varduva line is implemented.
- **2040 Analysis:** By 2040, some high loadings in normal (N) conditions and overloads in N - 1 conditions are observed, particularly on the 330 kV line Ventspils–Stelo Orienta (new substation). In the worst-case scenario, the maximum overload reaches 119%. However, this can be mitigated using advanced techniques discussed in the recommendations section, making additional reinforcements unnecessary.
- **The LaSGo interconnection permits to:**
  - Improve the Socio-Economic Welfare (average value of 63 M€ per year)
  - optimize the hourly dispatching
  - limit the RES curtailed energy (thanks to LaSGo, it is possible to reduce the RES curtailment of an average value equal to 22 GWh)
  - reduce the CO<sub>2</sub> emissions are expected in Latvia (about -35% equal to 68 kton)

- To foster the role of Latvia as hub of renewable power produced in Baltics since LaSGO improve the RES integration in Lithuania (an average value of about 900 GWh) and Estonia (an average value of about 380 GWh).
- After 2040 the expected massive hydrogen fired power plants in Germany increases the price in Sweden: this is beneficial for Latvia since it determines an increase of the energy exported to Sweden (3.7 TWh in 2050 while in 2035 and 2040 is 2.7 TWh)
- The operation of the cable is for most of the time horizon bi-directional, allowing a distribution of the benefits of different generation expansion plans in both the interconnected countries.

Concerning the Sweden and Gotland Island point of view, the performed technical analyses highlight that:

- Slite is the best connection point for LaSGO HVDC in Gotland (an alternative could be a new substation in the north of Visby) while Kimstad, Glan or Oskarsham could be the connection points in Sweden.
- Gotland Island has a limited transmission network and therefore LaSGO project represents a unique possibility to develop new RES or electrolyzers project in the north side of the Gotland by avoiding or limiting the investments in new terrestrial transmission networks on the island.
- With LaSGO project there is also the possibility to replace the production of the thermal Cementa power plant of 20 MW by green production in order to have a complete green supply of energy.
- Regarding the generation adequacy, the expected 220 kV AC cables from Sweden improve in a significant way the Security of Supply (SoS) of Gotland Island. In this context, LaSGO HVDC is the key element to ensure a total security of supply. In other words, in all hours of the year, the available capacity (import and internal renewable generation) is higher than the load demand of Gotland.
- Concerning the transmission adequacy, the transmission network of Gotland Island is limited and therefore in N-1 conditions some overloads could be handled by redispatching actions made possible by LaSGO HVDC. A similar approach can be adopted also in Sweden.
- The LaSGO interconnection permits to:

- optimize in Sweden the hourly dispatching (above all the hydro power plants production)
- limit the RES curtailed energy (thanks to LaSGo, it is possible to reduce the RES curtailment of an average value equal to 60 GWh)
- After 2040, the massive introduction of hydrogen fired power plants in Germany increases the price in Germany and in Southern market areas of Sweden (SE03 and SE04) and Gotland Island: LaSGo helps Sweden to limit this price increase importing low-cost energy from Latvia (3.7 TWh in 2050 while in 2035 and 2040 is 2.7 TWh)
- Thanks to the renewable availability of the Baltic regions and the LaSGo interconnection, it is possible to support Sweden to schedule an early phase-out of the old Swedish nuclear park.
- For instance, on 12 December 2024, when Germany has low wind production and at the same time a high load demand, the prices in the market zones around Germany are significantly increasing (even 10 times). In Sweden, the two southernmost market zones SE03 and SE04 are affected by this phenomenon due to the market coupling. In contrast, the price in the market zones SE01 and SE02 is not affected by this general price increase, so the LaSGo interconnection could be seen as an avoided grid reinforcement within Sweden to import lower-cost energy to market zones SE03 and SE04 with a beneficial effect for the Swedish consumer in these market zones. These situations will be more frequent in the following years due to the deployment of additional wind farms in Germany.

## Recommendations

### *HVDC recommendations*

- *HVDC Technology Choice*: Based on the state-of-the-art advancements in HVDC technology, the consultant emphasizes that the slight price difference between Voltage Source Converter (VSC) and Line Commutated Converter (LCC) technologies does not justify choosing LCC. Instead, VSC technology is recommended, as it offers significantly more services at a marginally higher cost.
- *Configuration Recommendation*: For this project, the minimum recommended configuration is the 320 kV symmetrical monopolar HVDC technology, which has already been successfully implemented in similar projects in the North Sea.
- *Evaluation of 500 kV Technology*: An alternative to consider is increasing the voltage to 500 kV. While this would raise the costs of the converter station—due to the need for larger buildings and higher insulation levels for components—it could reduce the cost of the cable. Higher voltage reduces the nominal current, allowing for a smaller cable cross-section, thereby reducing the required quantity of aluminium or copper. This trade-off could result in overall cost savings.
- *Hybrid HVDC Flexibility*: The consultant suggests that the decision to build a hybrid HVDC system could be deferred. Initially, a standard three-terminal HVDC system could be constructed, with the option to add an offshore converter station later if needed.
- *Landing Points on Gotland*: For Gotland, the recommended landing points are either Slite or a location north of Visby. These options provide greater resilience, allowing the island to be counter-powered in case of a failure on one of the two AC cables between Gotland and Sweden.
- *Marine Study Importance*: An accurate marine study is essential to determine the precise route for cable laying, particularly in the more rugged section between Sweden and Gotland, as opposed to the relatively smoother section between Gotland and Latvia.
- *Cable Burial Risk Assessment*: A detailed Cable Burial Risk Assessment is necessary to ensure proper cable protection. As outlined in CIGRE Technical Brochure 815, a well-protected cable minimizes future failures caused by human activities.

- **Cable Repairs and Spare Parts**: Repairs for damaged cables are both expensive and time-consuming, especially if spare parts are not readily available. Therefore, it is strongly recommended to purchase extra cable lengths and joints during the initial procurement phase. These spare parts should be stored in a suitable warehouse, ready for immediate use, to prevent prolonged outages in the event of a cable failure.
- **Reactive power capability**: concerning the choice of the HVDC reactive power capability, it is useful to mention that in the last HVDC VSC projects, TSOs have opted for important reactive power capability equal to  $\pm 45\%$  of the maximum power in the connection point<sup>3</sup>.

### **Transmission network recommendations**

- **Overloads from High Wind Production**: Based on the static analyses, some overloads may occur due to high wind production. To address these issues, potential solutions include implementing dynamic line rating or enhancing the system that integrates weather forecasts with wind production data. This would allow for more accurate predictions of potential overloads on a weekly, daily, and hourly basis.
- **Special Protection Scheme (SPS)**: Based on the results of the dynamic analyses, it is recommended to equip the HVDC system with a Special Protection Scheme (SPS). This SPS would monitor the power exchange between Latvia and Lithuania (or potentially between Lithuania and Poland) and enable appropriate load or production curtailment in the event of HVDC tripping, ensuring system stability.

### **Market recommendations**

- In the context of LaSGo, for Latvia, the fostering of V-RES capacity is crucial, at the same time demand-side flexibility should be promoted by implementing time-of-use tariffs, dynamic pricing, and demand response programs to maximize benefits from the interconnection. Deploying smart metering systems will help align domestic electricity demand with periods of low-cost imports or high renewable energy output and export, minimizing curtailment and optimizing system efficiency.

---

<sup>3</sup> <https://download.terna.it/terna/0000/1119/44.PDF>, page 38 and 39

- Capacity markets to reward flexible resources such as batteries and variable resource like renewables could be an opportunity. Additionally, creating revenue streams for ancillary services like frequency regulation and grid balancing will ensure reliability and encourage renewable integration.
- To support renewable investment, regulatory frameworks should prioritize grid access for renewable projects, streamline permitting processes, and offer long-term contracts, such as Feed-in Tariffs (FiTs) or Contracts for Difference (CfDs) to de-risk investments.