Deliverable 3.1: Green Demonstration Pilot Setup Report in SMSPs

DigiTechPort2030
Within the frame of the South Baltic Programme

Work Package: 3

WP Leader: PP4 Blekinge Institute of Technology

Task: Implementing new systems, technologies or equipment with a running port ecosystem is always a challenging approach. Often, more actors than the port itself are involved in such processes – port ecosystems. Hence, pilot implementations need to be very well prepared at port sites. This includes necessary contracting (tendering, legal compliance, etc.) and local condition analysis (Activity 3.1). Moreover, different scenarios and models will be analysed using the real conditions in the ports participating in the pilot implementation. Afterwards, the best option (based on economic, social, and environmental factors) will be chosen for the following pilot application (Activity 3.2). Form: Setup Report including scenario analysis

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Green Demonstration Pilot Setup Report in SMSPs

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	released		public in large, public distribution

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Acknowledgement

This report in hand stands for a compilation of data, its analysis, gradual update, and finalization in the frame of the DigiTechPort2030 project, part-financed by the ERDF.

Representing the project partner PP4 – Blekinge Institute of Technology, herewith we would like to express my gratitude to the project partners, associated partners and their contribution in the frame of provided information.

1. Introduction

The DigiTechPort2030 project supports small and medium-sized ports (SMSPs) across the South Baltic Sea Area (SBA) in their green transition by implementing pilot demonstrations and capacity building strategies aligned with the EU Green Deal, IMO Fit for 55, and upcoming EU maritime fuel regulations.

This report documents Deliverable 3.1 under Work Package 3 (WP3), which focuses on preparing and executing green decarbonisation pilots in SMSPs. The report provides the framework and analysis required to ensure informed, effective, and scalable pilot demonstrations.

1.1 Strategic Role of WP3

Work Package 3 (WP3) plays a pivotal role in the implementation phase of the project. It focuses on the design, deployment, and evaluation of two distinct types of green pilot initiatives within participating SMSPs. These pilots are scheduled to be executed and fully assessed by the end of June 2026.

The outcomes of WP3 are integral to two flagship outputs of the DigiTechPort2030 project:

- The Green Energy Harmonisation Toolbox for SMSPs, which provides operational models and best practices for port decarbonisation.
- The EU Regulation and Green Policy Compliance Development Roadmap, which assists SMSPs in navigating and aligning with emerging EU environmental directives and climate policies.

Drawing upon the insights and tools developed in earlier work packages—especially the structured training, technology mapping, and decision-support instruments outlined in the Green Transition Capacity Building Portfolio—WP3 transitions the project from planning to real-world validation.

1.2 Deliverable 3.1 – Green Demonstration Pilot Setup Report in SMSPs

Deliverable 3.1 sets the foundation for all WP3 pilot activities. It focuses on the preparation, feasibility assessment, and scenario modelling necessary to successfully implement green technologies and systems in the complex operational ecosystems of small ports.

Implementing new systems or equipment in a live port environment is inherently challenging due to the interconnectedness of port actors, logistics workflows, and energy infrastructure. Therefore, pilot demonstrations require thorough preparation, including:

- Contractual and Regulatory Readiness: Activities such as stakeholder engagement, procurement planning, legal compliance checks, and site-specific regulatory assessments are addressed under Activity 3.1.
- Scenario Development and Analysis: Under Activity 3.2, multiple decarbonisation and energy transition models are developed and tested against real-world data from the selected pilot sites. Each scenario is evaluated based on economic feasibility, environmental performance, and social impact, with the most suitable one selected for implementation.

This deliverable synthesizes technical, regulatory, and strategic dimensions to ensure that the forthcoming pilots are not only viable but replicable across the South Baltic region. It also builds directly on the methodologies and frameworks laid out in Deliverables 2.1, 2.2, and 2.3.

Work package description WP3 aims at implementing, testing and evaluating two types of decarbonisation pilots in SMSPs in the partnership until end of June 2026. The deliverables and activities strongly contribute to finalise the solution **"Green Energy Harmonisation Toolbox for Small and Medium-Sized Ports"** but also contribute as inputs for the solution **"EU Regulation and Green Policy Compliance Development Roadmap of Green Transition for Small and Medium-Sized Ports"**. Picking up the results from the previous work package, the following deliverables shall be achieved during WP3 implementation:
Deliverables
Deliverable 3.1: Green Demonstration Pilot Setup Report in SMSPs Implementing new systems, technologies or equipment with a running port ecosystem is always a challenging approach. Often, more actors than the port itself are involved in such processes – port ecosystems. Hence, pilot implementations need to be very well prepared at port sites. This includes necessary contracting (tendering, legal compliance, etc.) and local condition analysis (Activity 3.1). Moreover, different scenarios and models will be analysed using the real conditions in the ports participating in pilot implementation. Afterwards, the best option (based on economic, social and environmental factors) will be chosen for the following pilot application (Activity 3.2). Form: Setup Report including scenario analysis
Deliverable 3.2: Applied Demonstration Pilots for Green Transition in SMSPs The second Deliverable of this WP is covering all "hands-on" activities needed to implement the decarbonisation pilots in SMSPs of the SBA (Activities 3.3 - 3.5). Here, two types of showcase pilots to achieve significant decarbonisation in port ecosystems are planned to be developed, implemented and evaluated:
1. **Energy Twin: Digital Twins** are already well-known in port industry. Also, the core consortium has already developed, implemented and tested such tools in SMSPs in the SBA through Connect2SmallPorts project. However, the current systems miss the integration of energy related data flows. Hence, this group of actions will up-scale current digital twin layers into **Energy Twins increasing the efficiency of port capacities utilisation (AP9 Rostock Port) and integrating smart energy daemand layers that distribute green energy most efficiently depending on the demand in the port, e.g. unsteady demand of docking ships vs. unsteady green energy supply (PP7 Port of Klaipeda)**, to contribute to decarbonisation of the whole port ecosystems.
2. **Port Electrification:** This group of actions foresees to electrify current port operations using different approaches. **(1) A forklift truck shall be electrified completely (PP9 Terminal Świnoujście).** Exchanging vehicles, cranes and other equipment into electrified ones is a common approach, but narrowly implemented in SMSPs, hence, the showcase pilot will contribute to minimise hesitation in port sector. This is taken up by the second approach **(2) shifting from fuel-based vehicles to electrified ones for the ship unloading systems (PP6 Port of Elblag). (3) Renewable Energy in the Box (AP2 Port of Stralsund)**: physical modular and mobile "play and plug" renewable energy showcase – a 20-feet container equipped with different energy technologies for flexible demonstration, plug-in, installation and transportation purposes (based on adoption of the existing EBox solution by Mega Watt Solutions, Sweden)
Form: Pilot Summary Reports
Deliverable 3.3: Proof of Concept for Green Pilots in SMSPs The last deliverable is integrating the pilots into the Transition Tool (Activity 3.6) which is also finalising its methodology, which will then be put into practice to accomplish a working and interactive solution on the project website. In addition, pilot approaches shall be evaluated internally and externally (min. 5 experts) on its decarbonisation and sustainability potentials (Activity 3.7). Form: Proof of Concept Report
Activity 3.8: Subsumption of WP related communication activities

Table 1. DigiTechPort2030 Project – WP 3 Description of Deliverables and Activities

1.2.1 Relation to the Capacity Building Portfolio

The Green Transition Capacity Building Portfolio (compiled in prior deliverables and summarized in Section 7 of the main report) underpins Deliverable 3.1 by equipping SMSPs with the knowledge, tools, and institutional capacity to carry out pilot projects effectively. This includes:

- Technical readiness training in AI, blockchain, and AR
- Renewable energy integration guidelines
- Use of tools such as the Green Energy Compass
- Stakeholder engagement methodologies
- Workforce development and certification tracks

By combining this foundational training with localised scenario planning and pilot testing, Deliverable 3.1 ensures that SMSPs are fully prepared to move from conceptual green transition strategies to practical, measurable action.

2 Conditions for Green Energy Application in SMSPs.

DigiTechPort2030 project partners, by implementing project activities such as study visits, participating in the international conferences and expositions, as well as individual meeting with the main South Baltic Sea region ports ecosystems actors indicated the framework conditions for Green Energy Application in SMSPs.

2.1 Regulatory & Policy Framework

When analysing the Regulatory & Policy Framework across countries in the South Baltic Sea region (Germany, Poland, Lithuania, Sweden, and Denmark (sometimes also Latvia)) - there are both common elements due to EU membership and national differences in how green energy policies are implemented and enforced at the port level.

The main aspects that are needed to look for are alignment with EU Green Deal, Fit-for-55, TEN-T, and related directives, as well as its integration with national transport and energy policies. Also, the development of a localized roadmap for regulatory compliance and mapping of legal and environmental permitting processes.

Commonalities Across the South Baltic Region

1. EU Membership and Policy Alignment. All countries are EU members and follow overarching regulations such as: EU Green Deal, Fit-for-55 Package, Alternative Fuels Infrastructure Regulation (AFIR), TEN-T (Trans-European Transport Network), FuelEU Maritime Regulation. Mandatory decarbonization targets, emission reduction pathways, and climate neutrality goals by 2050 are shared.
2. Access to Common EU Funding Mechanisms. Access to instruments like: CEF (Connecting Europe Facility), Horizon Europe, Interreg South Baltic Sea, and Interreg Baltic Sea Region to encourage cross-border cooperation in green port development.
3. Commitment to Maritime Emission Reductions. Common focus on reducing emissions from: shipping, port operations, onshore power supply.

Country	Key Distinctions
Germany	- Strong national push for electrification of transport, including shore power. - Extensive incentive programs for green port infrastructure. - Advanced hydrogen policy and pilot ports (e.g., Rostock).
Poland	- Rapidly evolving green energy policy, but still coal-reliant. - Investment in offshore wind via ports (e.g., Gdańsk). - Bureaucratic complexity in project permitting can delay port greenification.
Lithuania	- Progressive stance on green hydrogen and LNG terminals. - Klaipėda Port is a pilot site for multiple EU green maritime projects. - Legal reforms underway to streamline green energy investments.
Sweden	- Leader in sustainable maritime practices. - Ports already equipped with shore power. - Strong regional climate targets, often stricter than EU mandates.
Denmark	- World leader in wind energy and port electrification. - Integrated port-city energy planning. - Pioneering PtX (Power-to-X) infrastructure in ports like Esbjerg.

Table 2.. Key Differences in National Implementation of Green Energy Transition

Summarising regulatory and policy framework across countries in the South Baltic Area, we see that SMSPs have some common challenges, and some of them are first movers and could be a good example for others to move faster to green energy transition.

Aspect	Common Across Region	Different By Country
EU Climate Policy	Shared through legislation (Green Deal, Fit-for-55)	National interpretations and speed of implementation vary
Port Electrification Goals	General target to reduce maritime emissions	Extent and maturity of shore power infrastructure differs
Hydrogen Strategies	Encouraged by EU	Some (e.g., Denmark, Lithuania) are more advanced
Funding Instruments	Shared access to EU funds	Local co-funding mechanisms and bureaucracy differ

Table 3. Comparison of Regulatory and Policy Frameworks accross the South Baltic Region

2.1.1 Governance and Multi-Stakeholder Coordination

Governance and multi-stakeholder coordination in Small and Medium-Sized Ports (SMSPs) in the South Baltic Sea region are often complex due to the diversity of actors and the evolving nature of green transition goals. Despite national differences, several common governance challenges and coordination issues emerge across the region - the formation of port ecosystem working groups by including port authorities, terminal operators, municipalities, energy providers, and shipping stakeholders. Clear governance structures for coordination and engagement strategies for stakeholder cooperation are also very important in the formation of the port ecosystem. Most important and common governance, and coordination issues in SMSPs:

1. Fragmented Stakeholder Landscape. SMSPs often involve many small, local actors: municipal governments, local utility companies, small private port operators, and Fishermen's associations. Lack of a unified decision-making body can slow down implementation of green energy solutions.
2. Unclear Role Distribution. No clear definition of who is responsible for what in terms of: infrastructure upgrades, environmental compliance, funding application and project coordination. This often leads to overlaps, gaps, or delays in execution.
3. Limited Institutional Capacity. Smaller ports lack human and technical resources to handle complex projects or coordinate EU-funded initiatives. Staff may not have expertise in green energy planning, procurement, or regulatory compliance.

4. Lack of Communication Channels**.** Poor communication between: Port authorities and local governments**,** Port stakeholders and national ministries**,** Ports and regional innovation/technology providers.
5. Disconnection Between Policy and Practice. National and EU green policies are not always translated into actionable steps for small ports. Guidelines may exist, but SMSPs often need tailored, hands-on support to interpret and implement them effectively.
6. Funding Complexity and Fragmentation. Challenges in forming multi-stakeholder consortia needed for EU project applications. Lack of pre-established partnerships makes it hard to respond quickly to funding calls (e.g., Interreg, CEF).
7. Resistance to Change or Risk Aversion. Stakeholders may hesitate to invest in green technologies due to fear of disrupting ongoing operations, lack of proven ROI, perceived complexity or risk in trying something "new".

These identified challenges are well known and are going to be overcome by implementing the project "DigiTechPort 2030" activities, with the support of experts, advisors, and implemented pilots.

Challenge	Needed Response
Fragmented actors	Neutral facilitators (e.g., port coordinators or innovation hubs)
Undefined roles	Clear governance structures and stakeholder mapping
Low capacity	Training, twinning with larger ports, access to expert advisory
Poor communication	Shared digital platforms, regular stakeholder meetings
Policy-practice gap	Translation of high-level strategies into actionable local roadmaps
Funding barriers	Pre-arranged consortia, guidance in proposal writing
Resistance	Awareness-raising, small-scale pilot demos, financial incentives

Table 4. Challenges and Needed Responses compiled from DigiTechPort2030

2.1.2 Infrastructure readiness

Infrastructure readiness is determining how effectively small and medium-sized ports (SMSPs) in the South Baltic Sea region can implement green energy solutions. All ports need to have assessment of existing electrical and operational infrastructure, clear identification of retrofit potential or need for new infrastructure.

Country	Infrastructure Readiness	Port Typology Highlights	Notable Gaps/Opportunities
Germany (Mecklenburg-Vorpommern)	Moderate to high – modern ferry ports like Rostock, good shore power base	Ferry, RoRo, cargo	Smaller ports still lack cold ironing; retrofit potential is high
Poland (e.g., Gdańsk, Kołobrzeg, Elbląg)	Mixed – major ports are advanced; small ports lack grid capacity	Fishing, regional cargo, some ferry	Major bottlenecks in grid access and space
Lithuania (e.g., Klaipėda)	High – Klaipėda is investing in offshore wind support & hydrogen	Industrial, cargo, bulk	Good model for replication in smaller Lithuanian ports
Sweden (e.g., Karlskrona, Ystad)	High – shore power widely implemented	Ferry-dominant, short-sea shipping	Strong port-city energy integration; small ports well-supported
Denmark (e.g., Rønne, Nykøbing Falster)	High – progressive infrastructure investment	Ferry, mixed-use	Leading in modular infrastructure and electrification

Table 5. South Baltic Sea Region – current situation as defined from the DigiTechPort2030

Green energy technologies, such as shore-side electricity, hydrogen fueling, and solar/wind installations, rely on specific infrastructure, including electrical grid capacity, space availability, and quay and terminal configurations. If the base infrastructure is not adequately prepared, the deployment of these green technologies becomes inefficient or even impossible. The typology of a port - whether it serves ferry, cargo, fishing, or recreational traffic - directly influences its energy demand profiles, peak load expectations, and the types of green technologies that are suitable. Smaller ports serving fishing or leisure activities may benefit from solar and small-scale battery technologies, while ferry ports would require heavier-duty shore power systems. Additionally, the port's layout and infrastructure significantly impact operational disruption during upgrades. Ports with modern, modular infrastructure are easier to retrofit without causing major disruptions, while SMSPs with older, fragmented layouts typically face higher upgrade costs and greater risks of downtime. Infrastructure readiness also plays an important role in access to funding, as ports with ready-to-implement infrastructure are more likely to attract EU funding. The condition of the infrastructure is often a key criterion in the evaluation of grant applications, such as those for the Connecting Europe Facility (CEF) or Interreg funding programs.

While analising the ports it was identified regional trends:

1. Larger SMSPs are already testing shore power and hydrogen solutions (especially in Sweden, Germany, and Lithuania).
2. Fishing and leisure ports often have outdated electrical and quay systems, needing support for scalable and modular green upgrades.
3. A big opportunity lies in shared service models—where multiple small ports or terminals pool infrastructure investments or adopt mobile green units (e.g., floating solar, mobile battery banks).

2.1.3 Parameters for Green Energy transition implementation planning

The transition to green energy in Small and Medium-Sized Ports (SMSPs) in the South Baltic region requires careful consideration of several key parameters that ensure both technical feasibility and alignment with EU regulations. These parameters encompass local conditions, infrastructure readiness, and the technical and financial frameworks necessary for successful implementation.

Local Conditions Analysis important in understanding the port's unique environment, including its climate, available space, and proximity to renewable energy sources. Additionally, a robust governance model involving multiple stakeholders such as port authorities, energy providers, and shipping companies ensures effective coordination and the successful integration of green technologies.

Tendering and Contracting Mechanisms are essential for securing innovative solutions through public procurement procedures, ensuring legal compliance, and structuring joint ventures or third-party partnerships. Scenario Modelling and Decision-Support Tools are crucial to simulate the technical, economic, and environmental impacts of green energy solutions, facilitating informed decision-making and ensuring efficient resource allocation.

Financing Readiness is also a pivotal factor, requiring the identification of available funding sources such as EU grants, national green funds, and private investments. Finally, Capacity Building initiatives are necessary to ensure the long-term success of green energy adoption, equipping local stakeholders with the skills and knowledge to manage new systems and maintain sustainable practices.

Collectively, these parameters offer a holistic framework for supporting the green transition in SMSPs, guiding the development of harmonized tools and regulatory roadmaps that facilitate the integration of green energy technologies, reduce carbon footprints, and enhance the overall sustainability of port operations.

2.1.4 Tendering and contracting mechanisms

They are defined as *critical* parameters for successful implementation of green energy solutions in ports, especially in the South Baltic Sea region, where public and semi-public stakeholders dominate small and medium-sized port governance.

While meeting with Ports, green energy projects in ports require public procurement of technology (e.g., shore power units, EV chargers), Service contracts with third-party energy providers or ESCOs (Energy Service Companies), as well as Infrastructure works (grid upgrades, quay retrofitting).

Without proper tendering mechanisms, Ports risk non-compliance with EU/state rules, projects may be challenged legally, and delays or funding ineligibility can occur.

Typical tendering and contracting steps:

1. **Needs Assessment** → Technical studies define what needs to be procured
2. **Procurement Strategy** → Choice of procurement type (open, restricted, negotiated)
3. **Tender Preparation** → Specification documents (technical, financial, ESG criteria)
4. **Tender Publication** → Via national or EU-wide systems (TED)
5. **Bid Evaluation** → Based on pre-set criteria (price, energy efficiency, innovation)
6. **Contracting** → Legal agreements with suppliers/partners (installation, O&M)

Despite some local nuances, these shared elements are consistent across Germany, Poland, Sweden, Lithuania, and Denmark:

Common Element	Details
Public Procurement Rules	All must follow EU Procurement Directives
Green Public Procurement (GPP)	Encouraged (sometimes required) to include environmental criteria
Tendering Platforms	Use of TED (Tenders Electronic Daily) + national platforms (e.g., Doffin, BZP, SIMAP)
Pre-qualification procedures	Often used in technically complex tenders (e.g., hydrogen bunkering)
Multi-actor contracting	Often involve municipalities, utilities, and third-party energy service providers

Table 6. Common practice across the South Baltic Region.

Regulations and documents to follow

EU-Wide Regulations:

- Directive 2014/24/EU on public procurement
- Directive 2014/25/EU (utilities sector, including ports)
- EU Green Public Procurement Guidelines
- Regulation (EU) 2021/1153 (CEF) - for projects co-financed by EU
- State Aid Rules - especially for funding support in port infrastructure

Key tender documents typically required

- Terms of Reference (ToR)
- Technical Specifications
- Evaluation Criteria (weighted score matrix)
- Environmental Impact Criteria
- Draft Contract Agreement
- Compliance Declarations (EU origin, no conflict of interest, etc.)

Challenge	Example
Lack of internal procurement expertise	Especially in smaller Lithuanian or Polish ports
Overly technical specifications	May restrict competition or innovation
Legal bottlenecks in cross-border tenders	Particularly when joint infrastructure is planned

Challenge	Example
Short timelines for funding-tied tenders	Matching EU calls with national tender procedures is tricky

Table 7. Practical challenges observed in the region

Accelerating the green energy transition in Small and Medium-Sized Ports (SMSPs) requires a strategic blend of digital modelling, financial preparedness, and human capital development. These three interlinked pillars - Scenario Modelling & Decision-Support Tools, Financing & Funding Readiness, and Capacity Building & Skills Development - form the backbone of a resilient, scalable transition framework.

Scenario modelling and decision-support tools in the project DigiTechPort2030 will be implemented as one of the Pilot of Digital Energy Twin enable evidence-based planning by simulating energy flows, emission reductions, and cost-benefit scenarios. In addition, analyzing charging of equipment by studying where to place charging stations, when to charge so as to not disrupt operations strategies for enhancing overall port or terminal management. This digital tool (Pilot) provides ports with actionable insights by evaluating different technological pathways, supported by pilot-based simulations and assessments of Technology Readiness Levels (TRL). This ensures that investments would be technically viable and aligned with long-term sustainability targets.

Funding Readiness is equally critical, focusing on the identification of diverse funding streams such as EU programs (CEF, Horizon Europe, Interreg), national green energy funds, and Public-Private Partnerships (PPPs). Complementing this source is the development of innovative business models and risk-sharing mechanisms, which improve bankability and investor confidence in port decarbonization projects.

Finally, capacity building and skills development address the human and institutional capabilities necessary for a successful green transition. DigiTechPort2030 includes tailored training programs, study visits for ports and its staff, the transfer of knowledge from established "lighthouse" ports, and toolkits to support green energy transition.

Together, these components provide a comprehensive support structure that empowers SMSPs to implement green technologies effectively, optimize investments, and foster long-term resilience within the port ecosystem.

2.2 Technical feasibility and technological options

While discussing technical feasibility and technological options for the green transition in ports, we recommend evaluating solutions such as shore-side electricity (cold ironing), on-site renewables (solar and wind), hydrogen refueling infrastructure, electrified cargo handling equipment, and compatibility with existing port operations.

Several data, variables and parameters were collected during the site visit to the port. In addition, the interviews with the port management highlighted the need for IT solutions that could help with improved decision making under various scenarios and time horizons.

2.2.1 Digital Challenges in Introducing Decarbonisation Technologies in SMSPs

As part of the preparatory activities under Work Package 3 (WP3) of the DigiTechPort2030 project, a comprehensive review of technical conditions, capacity-building outcomes, and stakeholder consultations revealed a set of persistent digital challenges that hinder the successful deployment and scaling of decarbonisation technologies in Small and Medium-Sized Ports (SMSPs). These findings are based on the synthesis of prior deliverables, including the *Green Transition Capacity Building Portfolio* and pilot preparation assessments conducted across the South Baltic region.

This section outlines the primary digital barriers SMSPs face in aligning their operational environments with the EU Green Deal, IMO Fit for 55, and forthcoming maritime fuel regulations. Addressing these barriers is essential to ensure the effective implementation of pilot activities, including those planned under Deliverable 3.2 and beyond.

1. **Fragmented Digital Infrastructure.** Most SMSPs operate with legacy information systems and siloed data environments, where Terminal Operating Systems (TOS), energy management systems (EMS), and equipment telemetry platforms lack integration. This fragmentation leads to:
   - Limited real-time visibility into energy consumption or emissions.
   - Inability to model “what-if” decarbonisation scenarios accurately.
   - Challenges in conducting baseline measurements necessary for pilot benchmarking.

2. **Low Maturity in Data Governance and Standardizatio.** Ports often lack standardized data protocols for critical operational and environmental parameters such as fuel consumption, equipment cycles, and energy source mix. Consequences include:
   - Difficulty in harmonizing datasets for cross-border comparison and EU reporting.
   - Incompatibility with digital twin simulation software (e.g., CHESSCON).
   - Inadequate documentation of carbon accounting or performance metrics.

3. **Insufficient IoT and Connectivity Readiness.** Many pilot sites reported limited or unreliable connectivity across terminal areas, impeding the deployment of IoT sensors and smart equipment. Specific issues identified include:
   - Inadequate Wi-Fi or 5G coverage across yard and quay zones.
   - Poor integration of crane, forklift, or battery data into central EMS platforms.
   - Lack of infrastructure for real-time performance tracking and anomaly detection.

4. **Underdeveloped Digital Twin Capabilities.** While digital twin technologies such as CHESSCON were introduced as part of the pilot design phase, several implementation barriers were discovered:
   - SMSPs do not have access to high-resolution geospatial data (e.g., LiDAR-based terrain models).
   - Technical staff are often unfamiliar with simulation tools, limiting in-house use.
   - Telemetry datasets are often incomplete or not exportable in structured formats.

5. **Cybersecurity and Data Privacy Concerns.** Introducing new digital technologies into port ecosystems raises legitimate concerns about:
   - Data breaches related to operational telemetry, energy use, or cargo handling.
   - GDPR compliance when sharing personnel or tracking data across EU member states.
   - Trust issues between ports and solution providers regarding intellectual property and performance transparency.

6. **High Dependency on External Technology Vendors.** Many SMSPs lack internal IT departments or digital innovation teams, resulting in:
   - Overreliance on external vendors for critical functions such as software integration and analytics.
   - Difficulty in assessing the credibility, interoperability, and cost-effectiveness of vendor solutions.
   - Limited capacity to troubleshoot or adapt technologies post-deployment.

7. **Financial Constraints for Digitalisation.** Even when digital technologies demonstrate long-term energy and cost savings, many SMSPs:

- Struggle to fund upfront capital investments in smart infrastructure.
- Face gaps in knowledge regarding eligibility and application for EU funding schemes (e.g., CEF, Horizon Europe).
- Encounter misalignment between funding cycles and port infrastructure project timelines.

8. **Knowledge Gaps in Emerging Technologies**
   - Despite rising interest, digital literacy across the port ecosystem—particularly in smaller facilities—remains low. Key insights from capacity-building sessions showed:
   - Artificial Intelligence (AI) is viewed as too complex or not directly applicable.
   - Blockchain applications are poorly understood, particularly in energy certification and traceability.
   - Digital twins are often perceived as research tools rather than operational assets.

9. **Strategic Implications for WP3 Pilot Deployment**
   - The above challenges underscore the need for deep digital readiness assessments as part of pilot planning (Activity 3.1) and targeted technical support during pilot execution (Activity 3.2). Specifically:
   - Scenario modelling and electrification simulation tools (e.g., CHESSCON) must be coupled with training for local teams to foster digital literacy.
   - Energy monitoring infrastructure (e.g., sensors, EMS, cloud dashboards) should be prioritized alongside physical upgrades.
   - Cross-border knowledge exchange platforms can help SMSPs learn from more digitally mature peers, accelerating replication.
   - These insights also reinforce the value of the *Green Transition Capacity Building Portfolio*, which includes digital enablement tracks and decision-support tools tailored to SMSP needs.
   - Ultimately, without addressing these digital barriers, decarbonisation technologies may be underutilized or fail to achieve measurable results, limiting the impact and scalability of the pilots.

2.3 Statement

To effectively implement green energy transition in SMSPs of the South Baltic, ports must create enabling conditions rooted in regulatory clarity, ecosystem coordination, local context adaptation, and strategic investment. Pilot implementations must be systematically prepared, ensuring they not only demonstrate feasibility but also generate replicable insights that feed into both a harmonisation toolbox and a regulatory compliance roadmap for wider adoption.

3 Overview of Pilot Projects and Processes under Activity 3.1

As part of Activity 3.1 of Work Package 3 (WP3)**, the** DigiTechPort2030 project has launched several pilot initiatives designed to test and evaluate decarbonisation strategies through digital innovation in Small and Medium-Sized Ports (SMSPs) across the South Baltic Sea Region. Each pilot aims to address specific challenges related to operational efficiency, energy consumption, and environmental performance.

The following pilot projects are currently under implementation. Though still in progress, they are advancing through structured methodologies involving stakeholder engagement, data acquisition, modelling, and simulation using the CHESSCON platform and other digital/energy twin tools.

3.1.1 Euroterminal (Świnoujście, Poland) – possible extendion of Energy Twin for Operational Efficiency

Objective: Implement a fast-track ENERGY Twin pilot within a 2–3 week timeframe, focusing on the tracking of forklift activity, crane operations, and cargo-handling efficiency through the CHESSCON simulation platform. The initiative will include collaboration with Liebherr to digitally integrate mobile harbor crane operations into the simulation environment. Additionally, a fully operational electric forklift (E-Forklift) will be deployed, with its performance data imported into the Energy Twin model of the Euroterminal yard. This model will enable detailed battery performance and energy consumption analysis, with the goal of evaluating and comparing energy efficiency between diesel and electric driven equipment in terminal operations.

Key Processes:

- Deployment and testing of E-Forklift.
- Elaborating data requirements and flight planning protocol for RGB vision and lidar sensors data collection procedures to cover a 1000 x 100 m terminal area as show in Figure 1.
- Execute terminal layout scan(s) with Lidar mapping sensor by RTK Drone.
- Import Mapping data into Web-based data processing software to process the data, generate visual 3D model of terminal and identify cargo objects.
- Execute sample tracking in real-world, with forklifts and mobile harbour cranes during cargo movement to collect performance indicators from telematic data.
- Use of CHESSCON to simulate and optimize CHE energy efficiency.

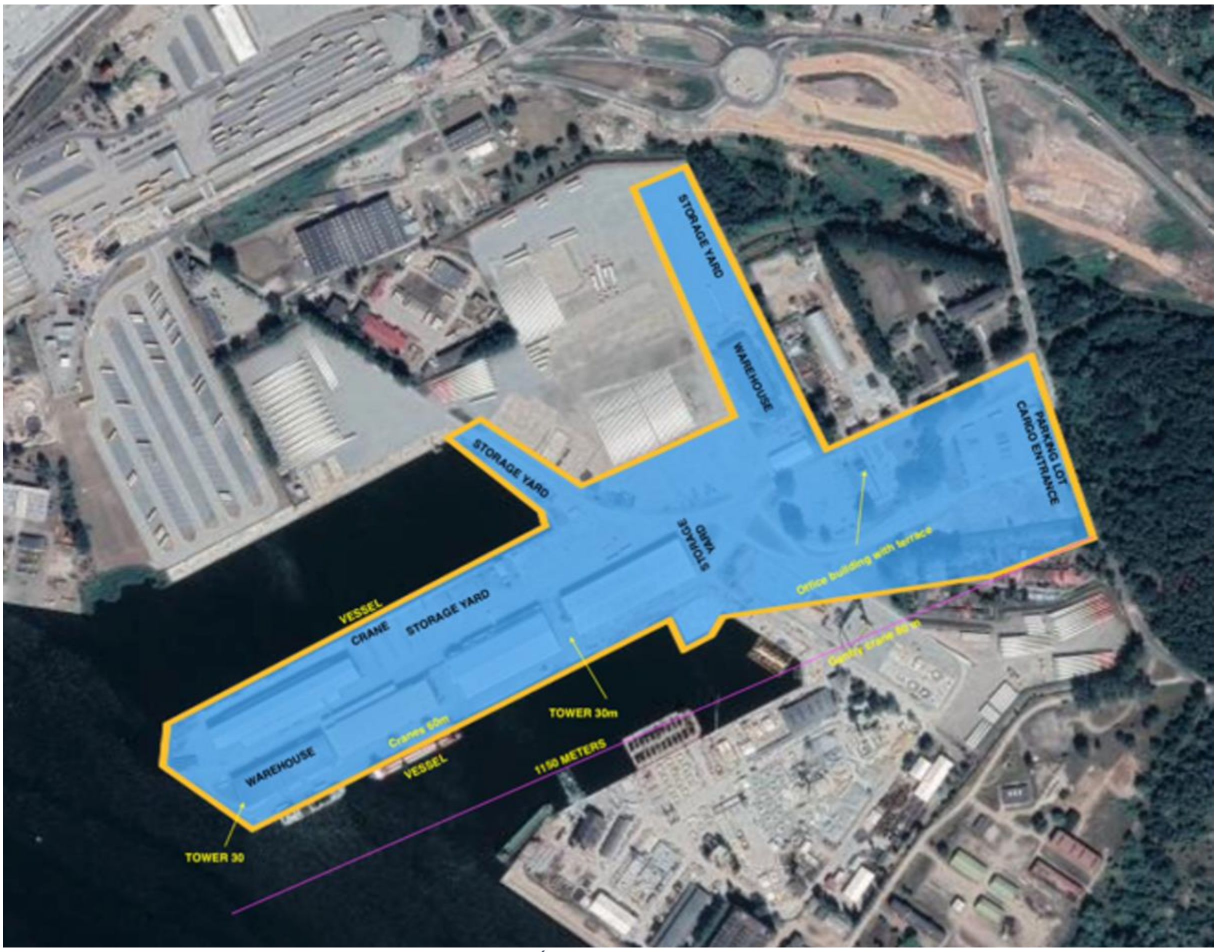

Figure 1. Euroterminal area layout with facilities map (Świnoujście, Poland).

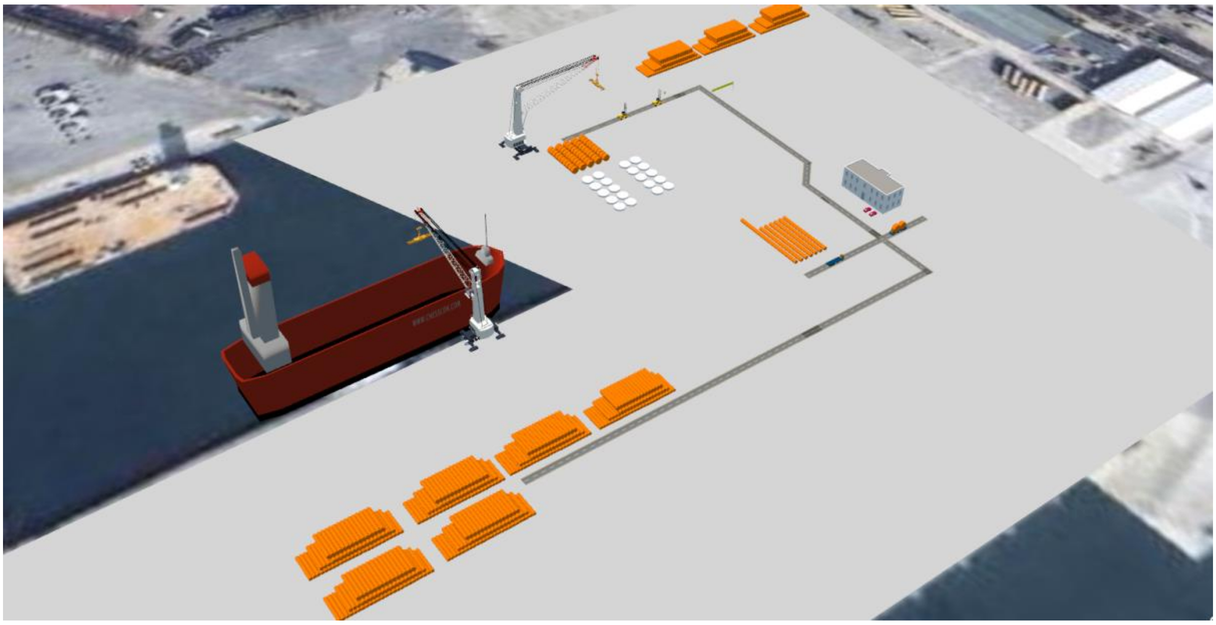

Figure 2. CHESSCON software screenshot, 3D Viewer output for Euroterminal terminal layout.

Expected Outcome: First phase will be the testing results of the E-Forklift to be input for phase 2, which is a 3D simulation-based performance assessment leading to recommendations for operational improvements and energy reduction for electric equipment, including battery driven.

PP8 'EuroTerminal, Świnoujście, PL		2025												2026		
2. Port Electrification:	**Location**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**UPDATE June 28 2025**
Project Management																Forklift delivery delayed by manufacturer. Several onsite/offsite meetings to prepare project proposal. Requirments and specifications generated. Upon delivery of E-Forklift. Can proceed with modeling and running software
Tender of Electric Forklift		*	*	*												
Deployment of single E-Forklift								*								
Electricification Simulation of Fleet of E-Forklifts										*	*					
Extension with Live-Data for EnergyTwin												*				
Final Reoort													***			

Figure 3 4. Pilot Project on Electric Forklift and EnergyTwin

3.1.2 Liebherr Multi-Site Pilot – Energy Twin for CHE Decarbonisation

Locations: Świnoujście, Karlshamn, Rostock
Objective: To compare diesel and electric cargo-handling equipment performance using telemetry data and simulation models.

Key Processes:

- Collection of telemetry data from mobile harbor cranes and electric CHE.
- Use of CHESSCON's command-line interface for batch simulation and emissions analysis.
- Benchmarking against carbon reduction KPIs.
- Scenario analysis using CHESSCON automation tools.
- Evaluation of electrification benefits.

Expected Outcome: Evidence-based evaluation of energy savings and emission reductions from equipment electrification.

AP9 Rostock, DE		2025												2026		
1. Energy Twin	**Location**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**UPDATE June 28 2025**
Project Management																Several discussion and onsite/online meetings. Work in progress with LIEBHERR to start in August as soon as new hire begins work on Energy Twin of cranes and equipment. Meantime, projet proposal has been generated
Data Gathering		*	*	*	*	*	*	*								
Model Definition and Tuning								*	*	*	*					
Testing and modeling with Energy Twin software programme											*					
Analysis of electrification / Energy Twin Final Report												***				

Figure 5. Pilot Project on EnergyTwin - Rostock/LIEBHERR

3.1.3 Port of Karlshamn (Sweden) – Energy Twin Implementation

Objective: To implement a high-fidelity Energy Twin to assess CHE operations and simulate the impact of transitioning to electric systems.

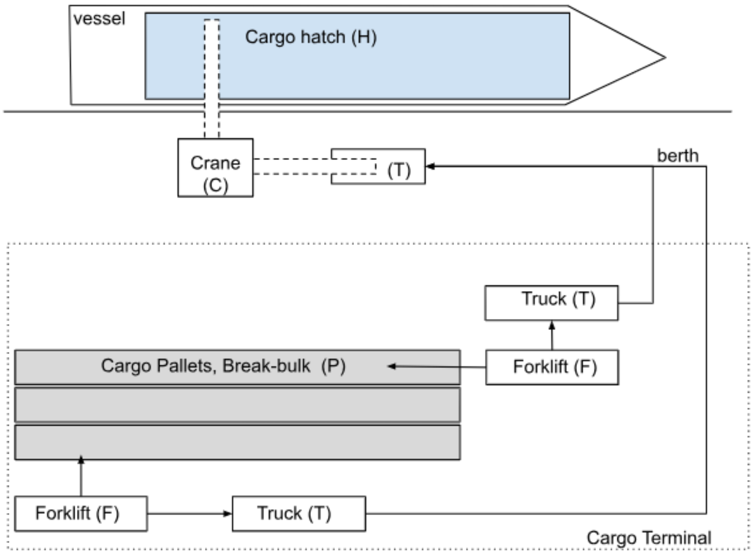

Figure 6. Pilot scenario model for cargo operations.

Key Processes:

- Asset and equipment modeling (trucks, tractors, reach stackers, cranes) for sample scenario model presented in Figure 6.
- Integration of real-time electric equipment telemetry (telematic data) and terminal mapping.
- Scenario analysis for diesel vs. electric operation using similations

Expected Outcome: Operational decision support tools for port planners targeting reduced energy use and increased equipment efficiency

Karlshamnhamn,SE		2025												2026		
1. Energy Twin	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	UPDATE June 28 2025
Project Management																Simulation Prototype running with electrification parameters. Input with real data and generate improved model is in progress
Data Gathering				*	*	*	*	*	*							
Simple Model Defined and Prototye running						*	*	*	*	*	*					
Additional effort with real data										*	*	**	**			
Running CHESSCON Energy Twin /Simulation														**		
Final Report														***		

Figure 7. Pilot Project on EnergyTwin at Port of Karlshamn

3.1.4 Seaport of Klaipėda (Lithuania) – Vessel Arrival Digital Twin for Berth Optimization

Objective: To reduce vessel idle time and energy consumption through the development of a digital twin focused on vessel traffic and berth coordination.

Key Processes:

- Integration of AIS (Automatic Identification System) data into the Klaipėda Vessel Management System (VMS).
- Development of a Digital Twin for real-time monitoring and simulation of ship arrivals.
- Coordination between pilots, port control, terminal operators, and tugboat services to optimize berth allocation and reduce waiting times.

Strategic FocusThis pilot directly addresses decarbonisation goals by:

- Minimizing engine idle time at anchor and in port approaches.
- Improving berth scheduling and enhancing port call predictability.
- Reducing overall fuel consumption and emissions from both vessels and port support services.

Expected Outcome: A replicable model for integrating digital twins into port-wide traffic management systems, contributing to the overarching DigiTechPort2030 goal of optimising energy and resource use in maritime operations.

PP7 Klaipeda, LT		2025												2026		
1. Energy Twin	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	UPDATE June 28 2025
Project Management																Digital/Energy Twin Completed by Klaipeda SeaPorts. Fine Tuning of software and system is ongoing with additional features being added.
Data Gathering		*	*	*												
Model Definition and Tuning				*	*	*	*									
Fine tuning							*									
Final Report										***						

Figure 8. Pilot Project on Digital Twin of Vessels for Intelligent Vessel Management System

3.1.5 Port of Elbląg (Poland) – Renewable Energy Integration through Solar Power

Objective: To reduce dependency on grid electricity through the implementation of solar panel systems tailored for port infrastructure.

Key Challenges:

- Procurement Barriers: Difficulty identifying port-ready solar technology suppliers with suitable equipment for coastal environmental conditions.
- Installation Expertise Gaps: Lack of local specialists experienced in designing and installing solar PV systems in port environments, which include structural integration with warehouses, cranes, and administrative buildings.

Collaborative Impact: A critical success factor was the exchange of technical knowledge and experience with Euroterminal Świnoujście, which had previously implemented its own solar panel installation. Through this collaboration:

- Euroterminal achieved 14% of its energy supply from solar within the first operational year.
- Euroterminal has set a target of 50% solar energy use by 2026.
- Elbląg port was able to fast-track its feasibility studies and vendor engagement, benefitting from templates and insights shared by Euroterminal.

Status and Outlook: While the solar implementation in Elbląg is still underway, the pilot represents a significant step in enabling smaller Polish ports to participate meaningfully in national and EU-wide decarbonisation efforts. The port aims to position itself as a lighthouse example of renewable energy adaptation in inland SMSPs, aligned with Fit for 55 targets.

PP6 Port of Elblag		2025												2026		
2. Port Electrification:	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	UPDATE June 28 2025
Project Management																No update - discussions with vendors and integrators at port.
Data Gathering		*	*	*												
Tuning and configuration of Solar Panel System								*	*	*	*					
Installation & Integration																
Analysis																
Final Report												***				

Figure 9. Pilot Project with Port of Elblag on Solar Panel system

3.1.6 Port of Vordingborg (Denmark) – Energy Simulation for Strategic Decarbonisation Planning

Status: In Progress

Objective: To perform a comprehensive energy simulation study of Vordingborg Port to identify operational and infrastructural areas for decarbonisation, based on electrification potential and digital twin modelling.

Background & Context: Preliminary discussions have taken place between the DigiTechPort2030 project team and Vordingborg Port representatives. The port has expressed interest in enhancing its energy and environmental performance, but requires data-driven insights to inform investment and policy decisions.

Approach:

- Previous simulation models developed for the port offer a valuable foundation and will be refined and expanded using the CHESSCON Electrification Module.
- Port-specific data (infrastructure and facilities layout, power consumption, equipment inventory) will be integrated into the updated simulation environment.
- The study will model energy flows, identify high-consumption assets, and explore potential for charging infrastructure, battery storage, and on-site renewable integration.

Next Steps:

- Formal data collection and model validation in collaboration with port stakeholders.
- Scenario analysis under different electrification and operational strategies.
- Identification of concrete pilot actions and investment pathways for decarbonisation.

Significance: This pilot reinforces the cross-border nature of the DigiTechPort2030 initiative by bringing a Danish port into the South Baltic decarbonisation effort. It also highlights the value of reusing and enhancing existing simulation work, providing cost-effective pathways to accelerate energy transition planning.

Vordingborg, DK		2025												2026		
Pilot 3.- Sim & Autom - Measuring Decarbonisation and Energy Co	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	UPDATE June 28 2025
Project Management																Internal discussion on renewing license from Connect2SmallPortss -€9001
model review for SIM										*						
E-Simulation model testing										**	**					
E-Simulation results											**	**	**			
Final Report														***		

Figure 10. Pilot Project with Port of Vordingborg on Eletrfication Simulation

3.1.7 Cross-Pilot Insights and Preliminary Observations

One of the most prominent cross-cutting insights from the DigiTechPort2030 pilot activities is the critical role of data-driven modeling in supporting decarbonisation and energy efficiency across small and medium-sized ports (SMSPs). In some of the pilots, Energy twin technology, enabled through tools such as CHESSCON, has been used to simulate port equipment performance, cargo flows, vessel movements, and energy consumption. These virtual environments allow port operators to test decarbonisation scenarios without disrupting ongoing operations, offering a safe and cost-effective pathway to transition planning.

Another important observation is the value of collaborative innovation among diverse stakeholders. Each pilot has benefited from the coordinated input of port authorities, terminal operators, equipment manufacturers like Liebherr, software providers such as Akquinet, and academic research teams. This multi-actor approach enables the sharing of domain expertise, operational knowledge, and technical tools, resulting in scalable, replicable strategies that can be adapted to different port contexts. The collaboration also accelerates learning cycles and lowers barriers for ports with limited internal capacity to undertake digital transformation.

Initial results from the pilots have already revealed tangible benefits, including measurable improvements in energy efficiency, increased operational transparency through telemetry and real-time tracking, and stronger digital readiness across participating sites. Ports that had previously operated without systematic energy performance data are now able to visualize and assess their energy footprint, identify inefficiencies, and prepare for future electrification investments with a clear evidence base.

Collectively, these pilot projects serve a dual purpose: they are both proof-of-concept experiments and living laboratories. They not only validate the feasibility of decarbonisation technologies in real port environments but also generate valuable data, methodologies, and templates that feed directly into the development of the Green Energy Harmonisation Toolbox. Moreover, the lessons learned from these early-stage implementations contribute directly to the formulation of compliance strategies for upcoming EU regulatory frameworks, particularly those tied to the EU Green Deal and Fit for 55 initiatives.

In summary, these pilot studies offer a critical foundation for scaling green transition strategies across the South Baltic Region and beyond, reinforcing the importance of digitalisation as a key enabler of maritime decarbonisation.

4 Conclusions for DigiTechPort2030 and pointers for Future Work

In the DigiTechPort2030 project has made substantial progress in advancing the digital and decarbonisation readiness of small and medium-sized ports (SMSPs) across the South Baltic Sea Region. Through collaborative pilot implementations, simulation modelling, and capacity-building efforts, the project has demonstrated how digital innovation and energy transition strategies can be tailored to the operational realities of SMSPs.

One of the most significant outcomes of WP3 has been the validation of simulation and digital twin technologies as effective tools for enabling data-driven decisions in port environments. The use of CHESSCON software across multiple pilot sites has demonstrated its capability in modeling energy use, operational performance, and cargo-handling processes. By creating virtual representations of real-world port ecosystems, these digital twins allow ports to test scenarios, optimize resource deployment, and evaluate the effects of transitioning to electric or hybrid equipment configurations. This capacity is especially valuable for SMSPs, where direct experimentation can be prohibitively expensive or operationally disruptive.

The collaborative implementation of pilot projects in five South Baltic countries—Poland, Sweden, Lithuania, Denmark, and Germany—has proven the effectiveness of regional knowledge-sharing and joint development. Each port brought its own context, constraints, and innovation potential, but it was through structured exchanges, shared simulation frameworks, and peer-to-peer mentoring that real progress was made. For example, the successful transfer of knowledge from Euroterminal to Elbląg on solar energy implementation illustrates how such cooperation can accelerate decarbonisation planning and empower smaller ports to act with greater confidence and clarity.

Despite the progress made, the pilots revealed persistent gaps in internal expertise and digital readiness across several SMSPs. Many ports lack dedicated energy managers or IT specialists capable of operating simulation tools, interpreting telemetry data, or designing electrification strategies. Without this internal capacity, SMSPs remain heavily reliant on external consultants or project-based interventions, making long-term sustainability and independent innovation difficult to achieve. Building in-house competence must be a strategic priority for any future support initiative.

The integration of renewable energy sources, particularly solar power, emerged as both a promising and challenging path for decarbonisation. The pilot cases in Elbląg and Euroterminal showed that solar energy can realistically contribute to port energy supply—Euroterminal already sources 14% of its energy from solar panels and targets 50% within two years. However, these successes also highlighted several structural and market-related barriers, including limited local expertise in installing port-scale PV systems, regulatory uncertainty in procurement processes, and the need for robust business case modeling. These are not insurmountable challenges, but they do require tailored strategies that take the unique physical and institutional characteristics of SMSPs into account.

Another key insight from WP3 stems from data-driven berth and vessel traffic management, particularly the pilot conducted in Klaipėda. By integrating Automatic Identification System (AIS) data into the port's Vessel Management System, Klaipėda was able to simulate and improve vessel arrival scheduling. This approach reduced idle time, enhanced berth allocation efficiency, and minimized fuel consumption while ships were at anchor or awaiting service. As ships represent one of the largest sources of emissions in port areas, improvements in arrival coordination and service readiness can have an outsized impact on the overall decarbonisation strategy of any SMSP.

References:

- **https://www.chesscon.com/home.html (last checked on June 27, 2025)**
- https://smallports.eu/ **last checked on June. 28, 2025)**

Glossary:

CHEESCON – Software program for Windows computer. Allows to design, model, visualize and simulate container, cargo, and multipurpose port terminals.

Energy Twin – Real-time virtual representation of physical port assets, processes, and energy systems, which allows for continuous simulation, monitoring, and optimization. By integrating energy-related data flows, Energy/Digital Twins serve as decision-support systems for terminal operators, policymakers, and energy providers.

Forklift – transport specially designed to lift heavy weight cargo, transport it within a terminal and release on the ground or on top of another cargo. Maybe equipped with a timber grabber or spreader to lift containers. Forklift that is specially designed to lift containers called reach stacker.

Mobile Harbor Crane (MHC) – special type of crane used in small port terminals, usually on wheels. Uses timber grabber to lift timber logs, spreader to lift containers or multipurpose cargo such as pallets.

Trailer – cargo transportation mechanism on the wheels that does have it own engine. Usually carried by a truck.

Truck – general cargo or container transportation transport with 4 or 6 wheels, that usually used to deliver container on mainland.

5 APPENDIX

CHESSCON software for Electrification Simulation of Terminals. CHESSCON Energy Twin modules.

5.1 Key Benefits of Energy/Digital Twin Technology for Port Electrification

1. Smart Energy Demand Management
    - Energy/Digital Twins predict and balance energy demand and supply by integrating data from renewable sources, electric vehicle (EV) charging stations, and port operations.
    - This ensures efficient energy distribution, reducing peak loads and optimizing battery storage systems for onshore power supply (OPS).
2. Optimized Electrification of Equipment and Infrastructure
    - By simulating different electrification scenarios, Energy/Digital Twins help in the gradual replacement of diesel-powered machinery (e.g., cranes, trucks, and forklifts) with electric alternatives.
    - Ports can evaluate cost-benefit analyses for electrification investments based on actual usage data.
3. Renewable Energy Integration
    - Through Energy Twins, ports can integrate solar, wind, and other renewable sources by predicting energy fluctuations and adjusting grid usage dynamically.
    - This is particularly relevant for shore-to-ship power, where vessels docked at ports can use clean electricity instead of burning fossil fuels.
4. Emission Reduction & Compliance with Green Regulations
    - The DigiTechPort2030 project aligns with the EU Green Deal and Fit for 55 strategy, targeting 55% greenhouse gas (GHG) emissions reduction by 2030.
    - Digital Twins provide data-driven insights to help SMSPs comply with IMO regulations, EU Emission Trading Systems (ETS), and decarbonization targets.
5. Simulation for Strategic Decision-Making
    - Scenario-based testing enables ports to assess the impact of different electrification pathways before making costly infrastructure changes.
    - This includes electrified rail operations, automated EV fleets, and port-wide microgrids.
6. Intermodal and Rail Electrification Support
    - Energy/Digital Twins optimize rail and intermodal terminal energy flows, ensuring that electrified cargo handling equipment operates at maximum efficiency.
    - This contributes to sustainable multimodal transport solutions, aligning with the EU's shift toward rail freight electrification.

5.2 Pilot Actions in DigiTechPort2030

Under Work Package 3 (Testing Decarbonization Pilots in SMSPs), the project is implementing Energy Twins to:

- Enhance smart port electrification strategies.
- Improve the efficiency of renewable energy adoption.
- Develop real-world electrification pilots, such as:
    - Electrification of forklifts and cranes.
    - Shifting ship unloading systems from fuel-based to electric power.
    - Deploying mobile renewable energy units.

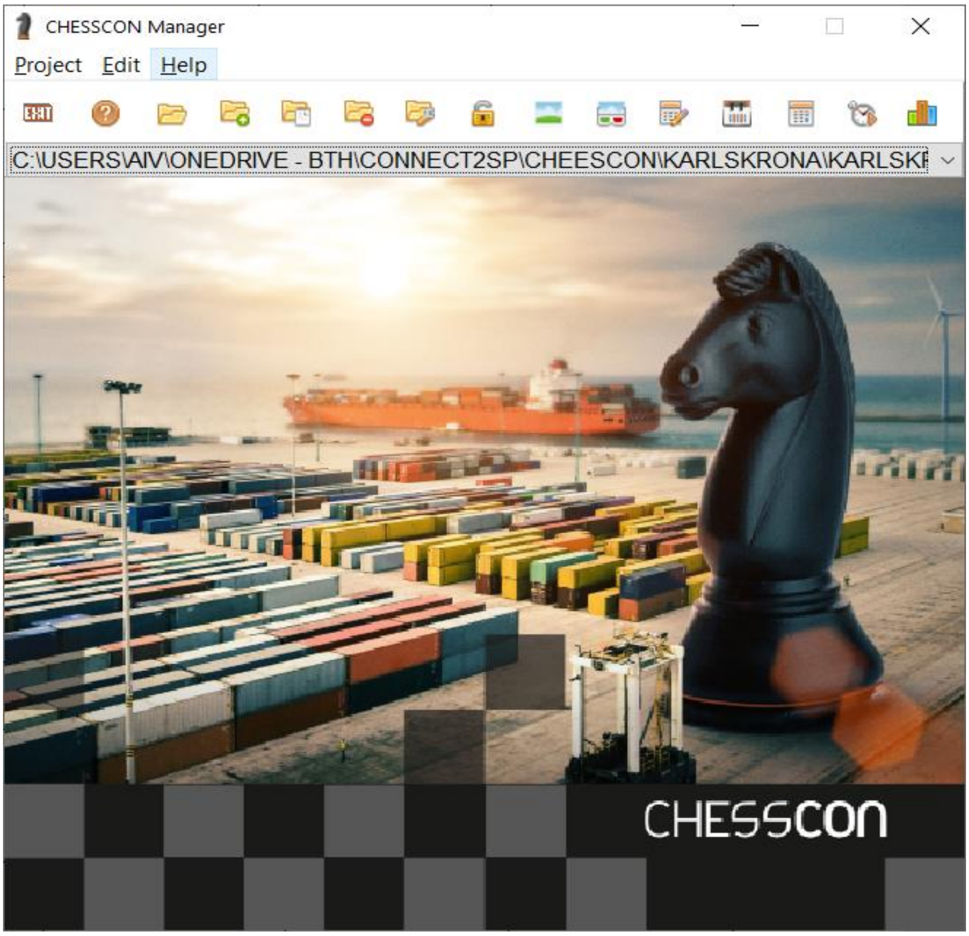

Figure 11: CHESSCON® software main screen (Source; [www.Chesscon®.com](http://www.Chesscon.com))

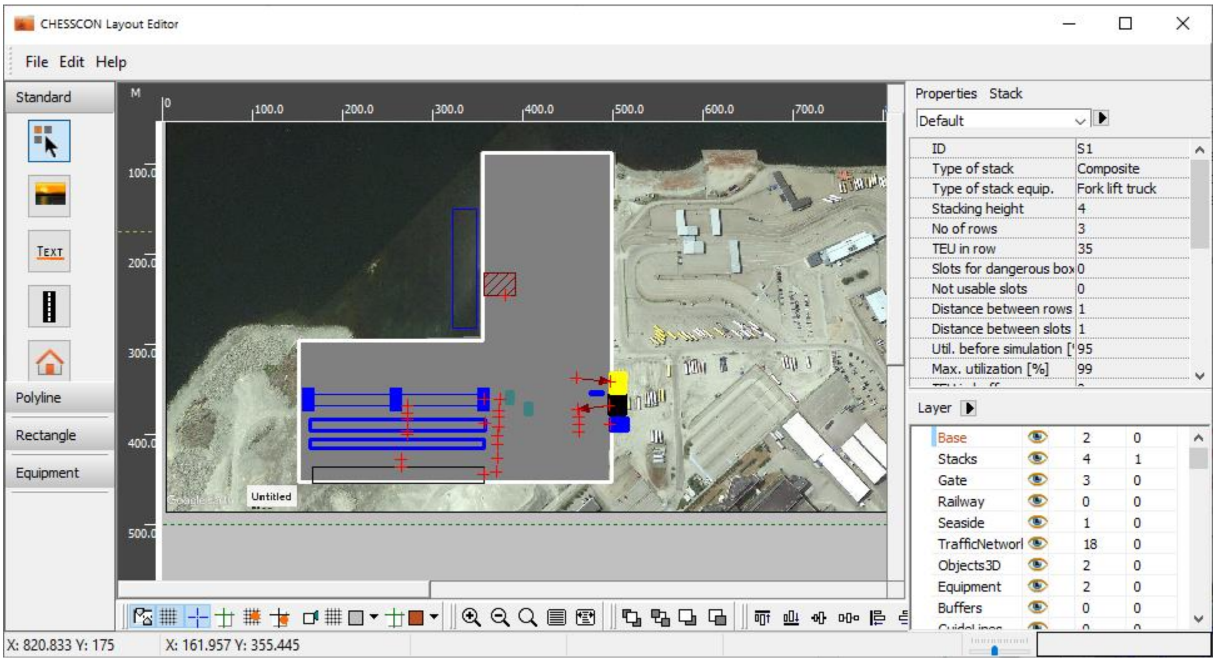

Figure 12: CHESSCON® software Layout Editor (Source; [www.Chesscon®.com](http://www.Chesscon.com))

5.3 Main scenario and Requirements

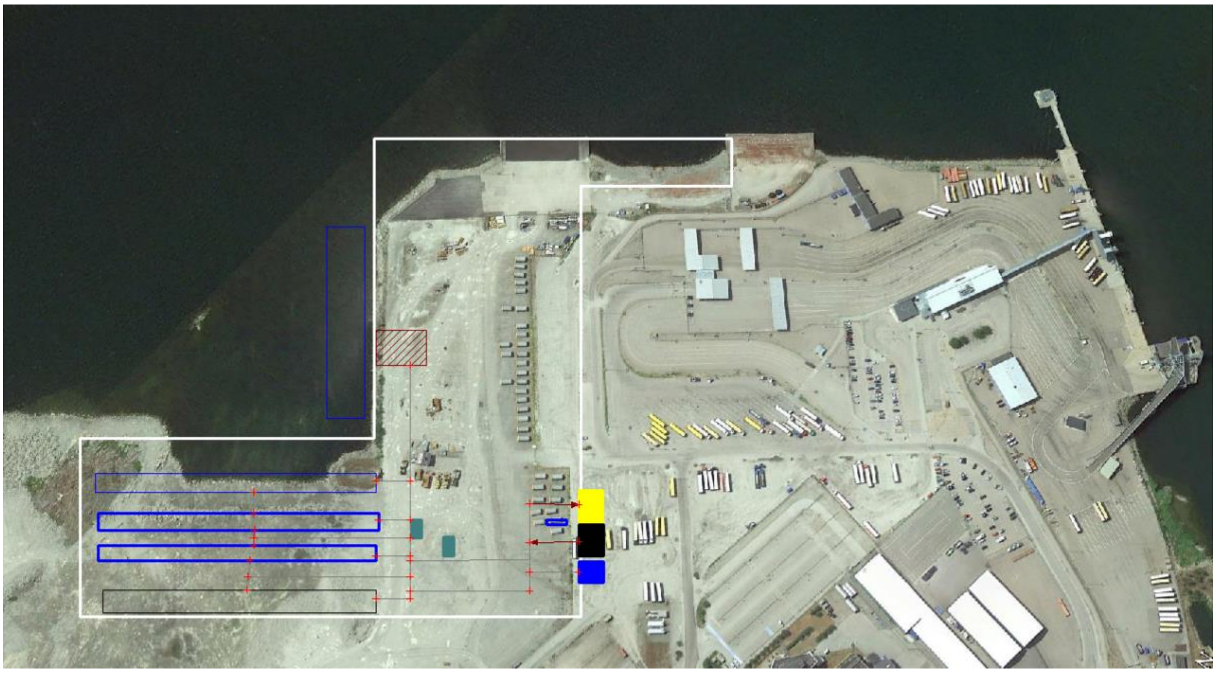

Figure 13: Cargo terminal layout in Port of Karlskrona relative to Stena terminal (Source; Results – Port of Karlskrona, 2021)

Figure 9 represents a more detailed cargo terminal geometry including quay, location of entry gates (in yellow and black color) and position of mobile harbor crane. We exported the schema of the area by using Google Maps software and then added arrows on top of it to confirm our assumptions regards the size of cargo and container stack in the terminal with the Port of Karlskrona representatives.

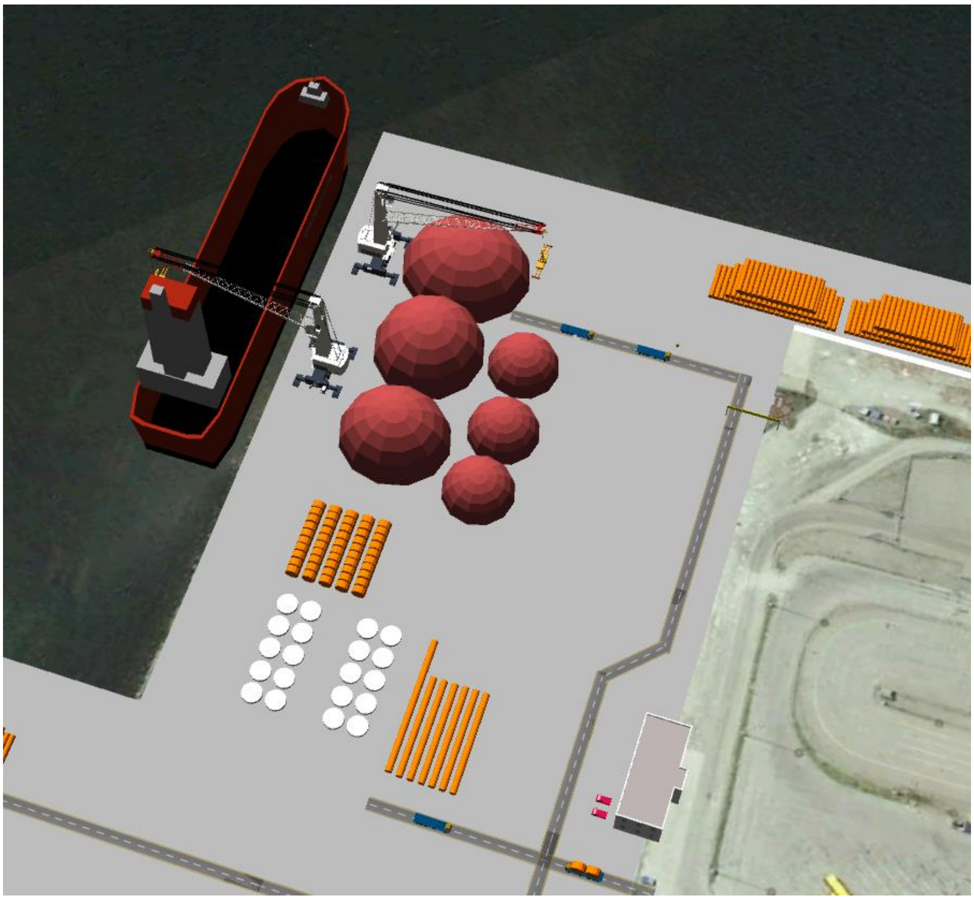

Figure 14: Cargo handling visualization in Port of Karlskrona (Source; Results – Port of Karlskrona, 2021)

Figure 15: Cargo handling visualization in Port of Karlskrona (Source; Results – Port of Karlskrona, 2021)

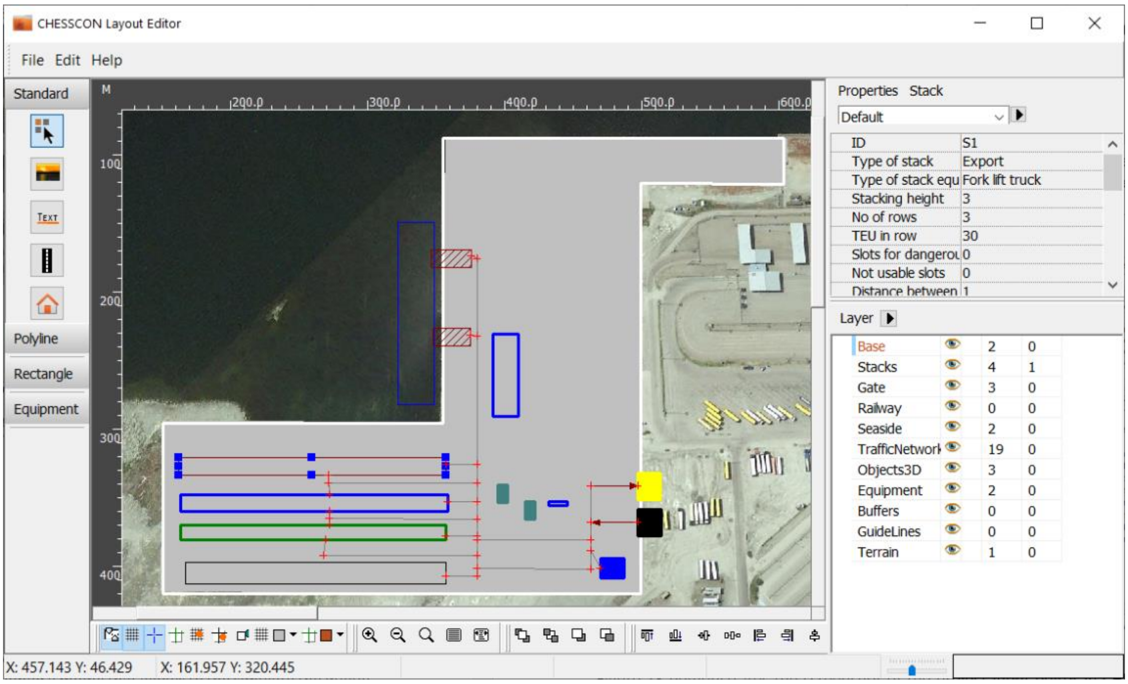

Figure 16: Container terminal layout in CHESSCON® Layout Editor (Source; computer screenshot)

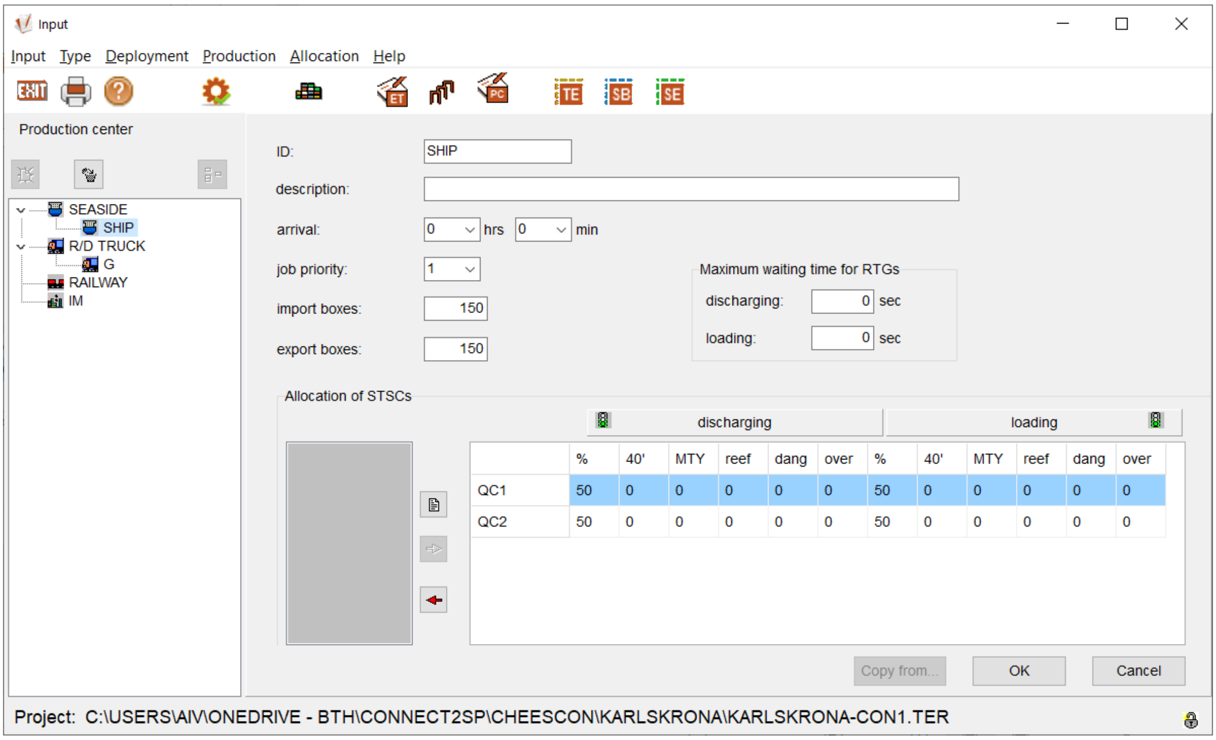

Figure 17: Simulation parameters represented in CHESSCON® Input module (Source; computer screenshot)

Figure 13 contains the screenshot of the terminal gate parameters in which we define 10 incoming containers and 50 outgoing containers carried out by external trailers during vessel discharge. This represents the real-life cargo outflow scenario from container yard to landside. According to Chesscon® model traffic to/from landside being served in special “R/D area” where external trucks and internal forklifts exchange with the cargo. These operations also require time and increase utilization of terminal traffic lines and forklifts thus in turn may increase the vessel handling time.

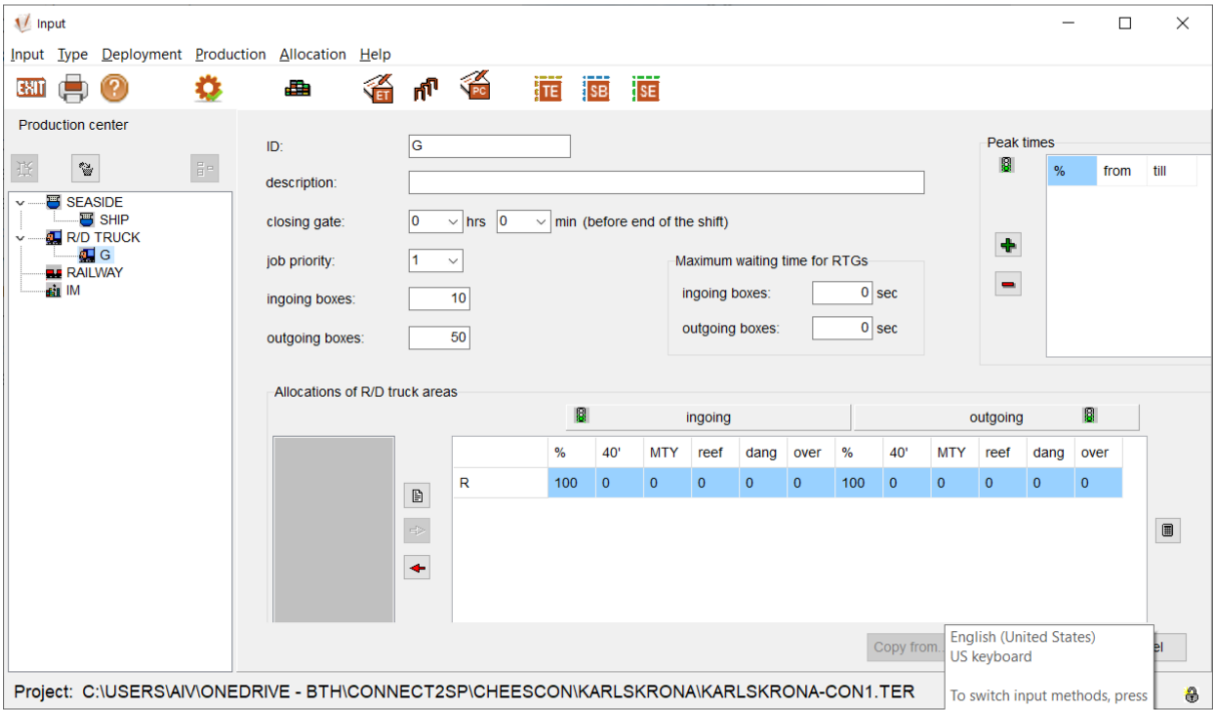

Figure 18: Simulation parameters for Gates operations represented in CHESSCON® Input module (Source; computer screenshot)

Figure 14 represent the parameters of forklifts such as length, various type of speed, container pickup and drop-off time. When forklift prepare to dispatch container for external truck some time loss may occur to shuffle (re-stack) containers in over utilized stack.

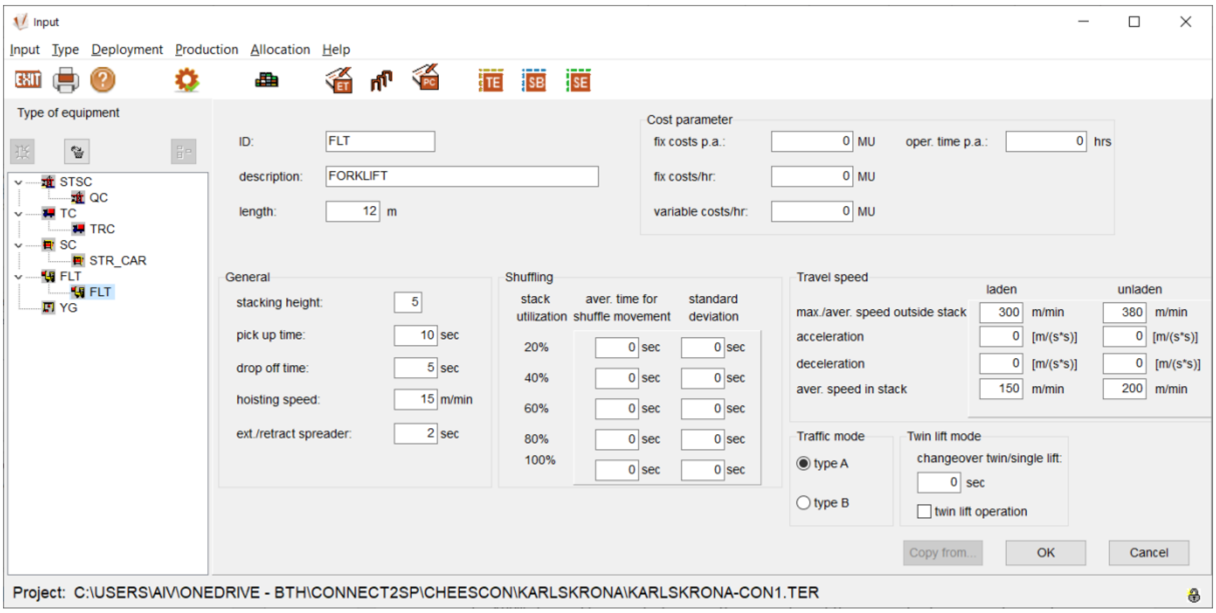

Figure 19: Simulation parameters represented in CHESSCON® Input module (Source; computer screenshot)