FROM PILOTS TO SCALE - PORTS AS GREEN ENERGY HUBS

A STRATEGIC FRAMEWORK FOR ADVANCING PORT DECARBONIZATION

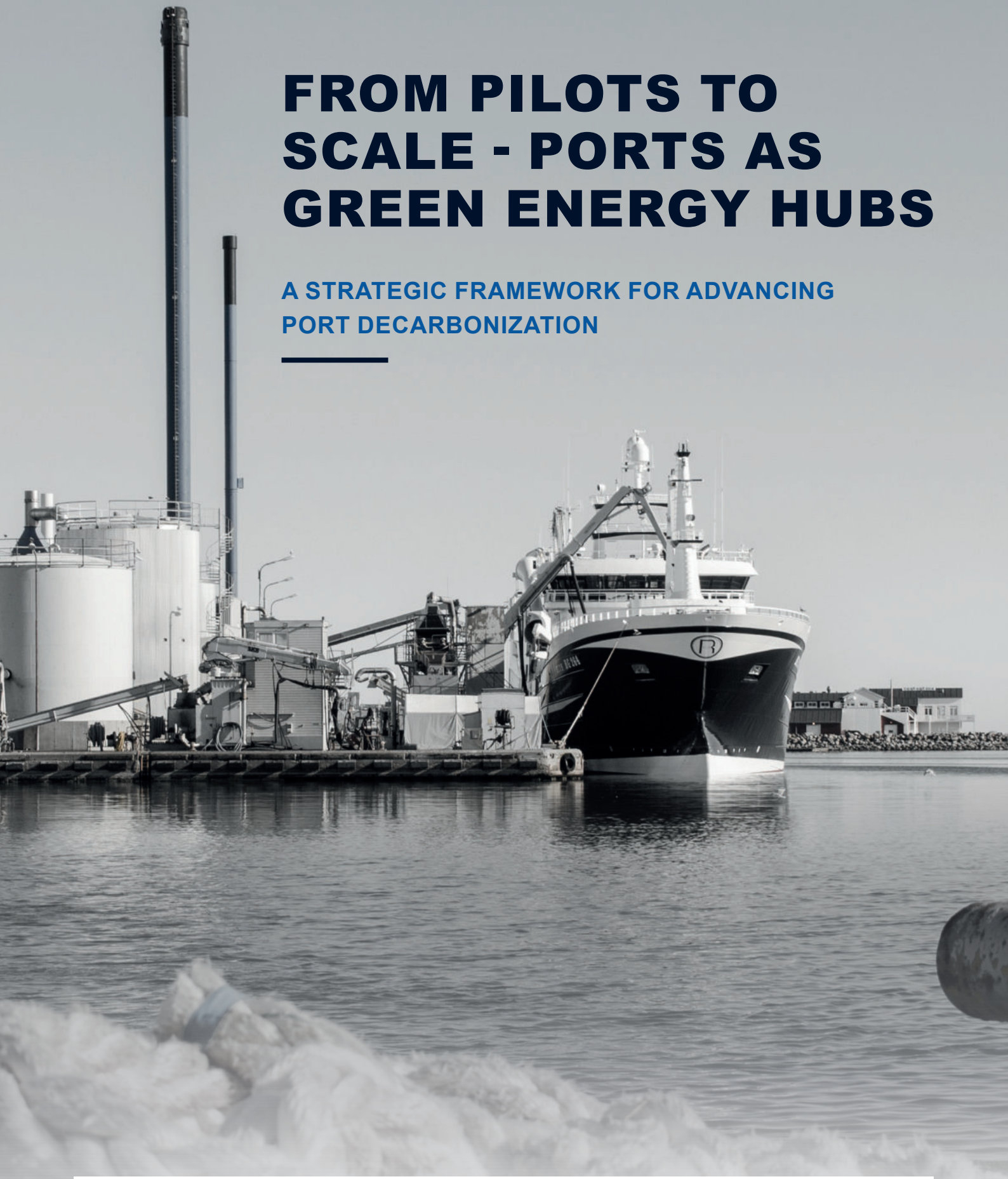

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TABLE OF CONTENT

FROM PILOTS TO SCALE: WHY PORT DECARBONISATION IS A STRATEGIC CHALLENGE

Ports across Europe are engaged in decarbonisation through projects and electrification efforts, supported by increasingly ambitious EU regulation. Yet progress from pilots to large-scale implementation remains uneven.

THE CHALLENGE IS NOT A LACK OF COMMITMENT

Drawing on experience from REDII Ports, this strategy focuses on how ports can move from experimentation to scale by aligning implementation maturity with system-level implementation readiness.

WHAT THIS STRATEGY DOES

- Explains why pilots alone do not guarantee scale
- Identifies the conditions required for large-scale implementation
- Provides strategic pathways to move from learning to deployment

PORTS AT THE CENTRE OF THE ENERGY TRANSITION

Port are the interfaces between shipping, energy systems, regional development and ports are increasingly expected to enable electrification, support alternative fuels and facilitate low-carbon logistics solutions.

PORTS ARE RESPONDING TO THIS ROLE

Electrification projects are underway, port authorities are actively engaging with shipowners, terminal operators and energy providers. These efforts demonstrate strong commitment and a willingness to act under conditions of uncertainty.

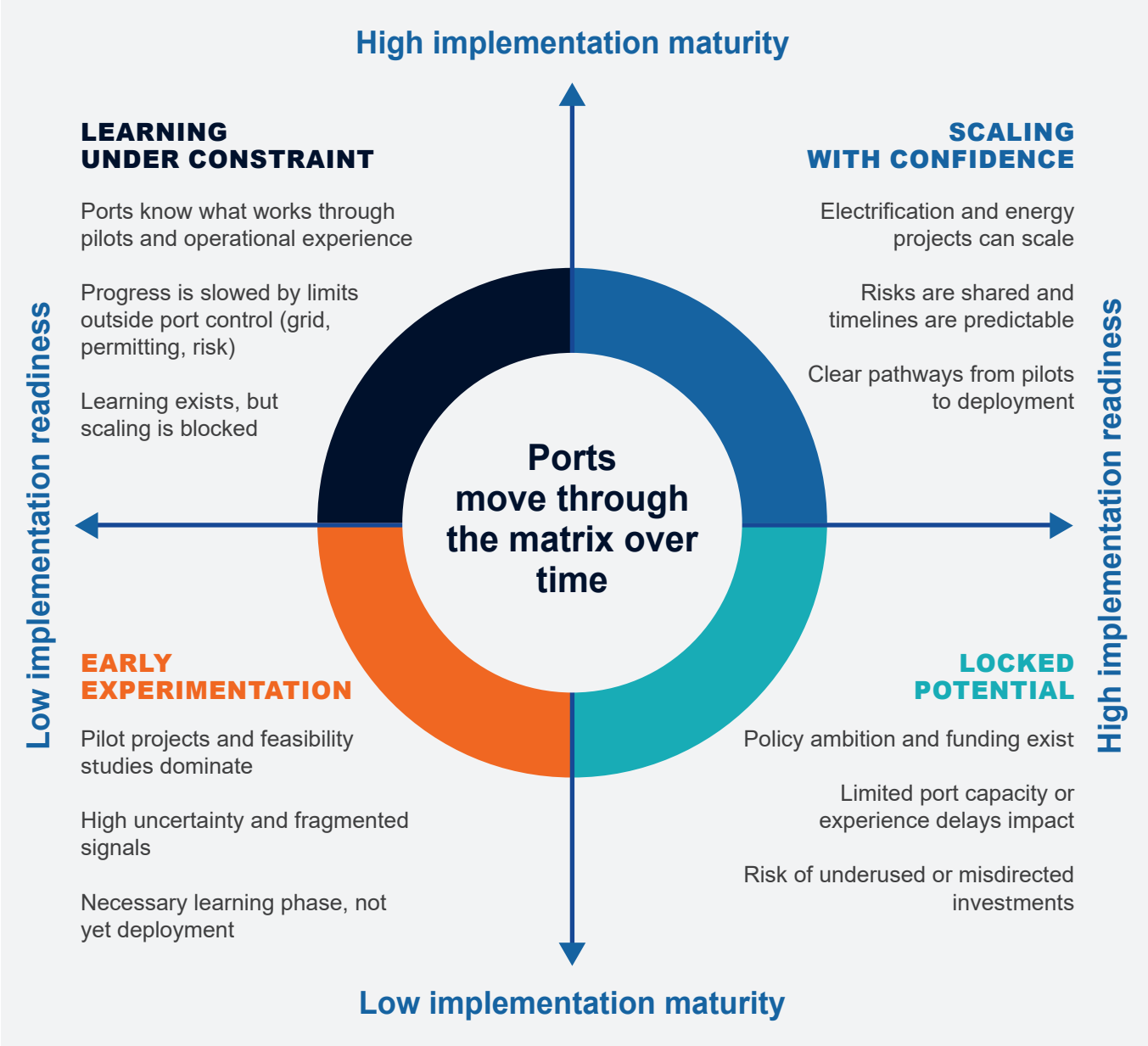
Ports operate within complex systems that extend far beyond their direct control. Grid capacity, permitting processes, investment frameworks and regulatory responsibilities are often governed by different actors and timelines.

PILOT PROJECTS ARE ESSENTIAL

Experience from REDII Ports shows that pilots rarely translate directly into large-scale deployment. The barriers are seldom technological but relate to system-level constraints such as grid delivery, permitting predictability and investment risk. This creates a recurring gap between learning and implementation. The matrix on the following page illustrates how these two dimensions interact.

SCALING PILOTS REQUIRES MORE THAN TECHNICAL SOLUTIONS ALONE

FROM PILOTS TO SCALE: MATURITY AND READINESS BOTH MATTER



HOW TO READ THE MATRIX:

In the lower-left quadrant, ports start with pilot projects and feasibility studies dominate high uncertainty, fragmented signals and necessary learning phase. Learning is therefore not translated into scale, and progress remains confined to experimentation.

In the upper-left quadrant, ports have accumulated substantial experience through pilots and testing yet face constraints beyond their direct control. Here, high implementation maturity is not matched by sufficient readiness in energy systems, permitting frameworks, or investment conditions. Learning is therefore not translated into scale, and progress remains confined to experimentation.

In the lower-right quadrant, ports enabling conditions may be broadly in place, but ports lack the operational capacity, organisational experience, or internal resources required to act. This creates a risk of locked or underused potential, where investments are introduced too early, and fail to deliver their intended impact.

In the upper-right quadrant, ports can scale pilots with confidence. Risks are shared and timelines are predictable. Clear pathways from pilots to deployment is done and make the base for investment.

WHAT THE MATRIX REVEALS

Ports are distributed across different quadrants depending on their level of implementation maturity and the degree of readiness in the surrounding system. As a result, similar pilot initiatives can lead to very different outcomes, depending on where a port is positioned within the matrix.

Progress is neither linear nor uniform

Ports can enter the transition from different starting points and face distinct combinations of constraints. Effective strategies therefore need to be sequenced and adapted to context, rather than driven by requirements or single policy instruments.

Sustained progress requires movement along maturity and readiness

One-size-fits-all approaches are unlikely to succeed

Advancing port decarbonisation depends on simultaneously strengthening implementation maturity at port level and improving readiness across regulatory, energy, and investment systems. This understanding provides the analytical basis for identifying differentiated pathways from pilots to large-scale deployment.

STRATEGIC PATHWAYS FROM PILOT TO SCALE

This figure below translates these insights into strategic pathways that support ports in moving from pilots to large-scale implementation.

The pathways illustrate how insights from REDII Ports can be translated into sequenced strategic actions that support ports in moving from pilots to large-scale implementation.

STRATEGIC ACTIONS AND PRIORITIES

The strategic pathways illustrate that moving from pilots to scale is not a single decision, but a sequence of actions that must be aligned over time. Based on experience from REDII Ports, four strategic priorities stand out as particularly important for ports seeking to translate learning into impact.

BUILD IMPLEMENTATION MATURITY AT PORT LEVEL

Ports should continue to invest in pilots, testing and organisational capacity. This includes strengthening internal competencies, collecting and sharing operational data, and using pilots strategically to reduce uncertainty rather than as isolated demonstrations.

STRENGTHEN IMPLEMENTATION READINESS IN THE SURROUNDING SYSTEM

Progress depends on early and structured dialogue with actors beyond the port authority, including grid operators, permitting authorities and energy providers. Aligning expectations, timelines and responsibilities is a prerequisite for follow-up investment.

ALIGN AND SEQUENCE INVESTMENTS

Rather than committing to large-scale infrastructure upfront, ports should prioritise phased and modular investments that reflect both demand development and system readiness. Sequencing investments helps avoid premature lock-in and reduces the risk of stranded assets.

PREPARE FOR SCALE AND REPLICATION

Once maturity and readiness come together, focus should shift towards deployment, replication and long-term integration. This includes embedding solutions in port development plans, coordinating with shipowners and operators, and ensuring that lessons learned are transferred across ports.

Delivering these actions requires coordinated efforts across ports, market actors and policymakers.

The experience from REDII Ports points towards a next phase where the main challenge is no longer experimentation, but coordination and sequencing. The key question is not whether solutions work, but whether systems are ready to absorb them on a scale. Addressing this challenge will require closer alignment between port planning, energy infrastructure development and policy instruments.

WHO NEEDS TO ACT – AND HOW

Moving from pilots to large-scale implementation requires coordinated action across multiple actors. While ports play a central role, progress depends on how responsibilities, risks and timelines are shared across the wider system.

PORTS

- Use pilots strategically to build maturity and reduce uncertainty
- Engage early with grid operators, authorities and market actors
- Plan phased investments aligned with demand and system readiness

MARKET ACTORS AND STAKEHOLDERS

- Provide clear signals on future demand and operational needs
- Engage in joint planning, pilots and risk-sharing arrangements
- Support standardisation and replication across ports

POLICYMAKERS AND AUTHORITIES

- Align regulatory requirements with system readiness and delivery timelines
- Streamline permitting and clarify responsibilities
- Link pilot funding to pathways for follow-up investment and deployment

Pilot programmes and cooperation frameworks play a key role in enabling this coordination.

FROM LESSONS LEARNED TO TARGETED POLICY ACTION

Experience from REDII Ports shows that moving from pilots to scale depends not only on port-level action, but on how policy instruments interact over time. The table below summarises key lessons from the project and highlights where targeted policy adjustments can help remove bottlenecks and support implementation at scale.

Strategic insight from REDII Ports	What this reveal	Policy implication
Electricity and grid capacity must be treated as core port infrastructure	Electrification is the most mature pathway, but ports depend on grid delivery they do not control	Align AFIR* obligations with grid planning; combine regulatory requirements with grid investment support
Transition pathways must be phased and sequenced	Ports that sequence actions manage risk better than those pursuing multiple solutions simultaneously	Demand-driven policies (ETS**, FuelEU) should allow flexibility for phased implementation
Premature large-scale investment in alternative fuels carries high risk	Fuel supply, demand and infrastructure co-evolve slowly, creating chicken-and-egg dynamics	Prioritise supply-side support and risk-sharing over early deployment mandates
Regulatory clarity matters as much as ambition	Fragmented permitting and safety rules delay projects without improving outcomes	Strengthen enabling frameworks for permitting, safety and state aid to improve predictability
Pilots are learning instruments, not deployment solutions	Learning often stops without follow-up investment or scale	Link experimental funding (e.g. Interreg) to follow-up deployment and investment instruments

* Alternative Fuels Infrastructure Regulation
** EU Emissions Trading System

THE ROLE OF INTERREG AND PILOT PROGRAMMES

Programmes such as Interreg play an important role in supporting ports during the transition from experimentation to large-scale implementation. This phase is characterised by high uncertainty, fragmented responsibilities and investment risks that are difficult for individual actors to carry alone.

DE-RISKING EARLY ACTION

Pilots like those in REDII Ports reduce financial and institutional risk by enabling ports and partners to test solutions, explore business models and build confidence before committing to large-scale investments.

CREATING LEARNING AND SHARED UNDERSTANDING

By bringing together ports, authorities, market actors and knowledge partners, pilots generate experience and evidence. This shared learning helps align expectations, clarify constraints and inform robust decision-making.

BRIDGING PILOTS AND DEPLOYMENT

Most importantly, Interreg projects such as REDII Ports can bridge experimentation and scale. When linked to follow-up instruments and investment frameworks, they help translate learning into implementation pathways rather than isolated demonstrations.

KEY TAKEAWAYS FROM REDII PORTS

Pilots enable learning, not scale: Pilot projects are essential for reducing uncertainty and building experience, but they do not lead to large-scale deployment without clear pathways for follow-up investment and implementation.

Maturity and readiness must progress together: Scaling becomes possible only when port-level capacity and experience are matched by supportive conditions in energy systems, permitting, investment frameworks and governance.

Ports follow different transition pathways: Ports enter the transition from different starting points and face distinct combinations of constraints. One-size-fits-all approaches are therefore ineffective; strategies must be sequenced and adapted to context.

Coordination is a decisive enabler: Grid access, permitting processes, regulatory requirements and investment decisions must be aligned in practice. Ambition alone is insufficient without coordination across actors and systems.

Pilot programmes bridge experimentation and deployment: When designed with scale in mind, programmes such as REDII Ports reduce risk, build shared understanding and help translate learning from pilots into large-scale implementation.

While TEN-T ports are aligned with major EU funding instruments non-TEN-T ports also play key roles and complement the larger hubs. Despite this, ports outside the TEN-T network face difficulties in securing financial support for green transition investments. Access to support mechanisms for non-TEN-T ports is important to ensure the green transition.

ACKNOWLEDGEMENTS

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