

Green Ports Systems Map

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—
Problem exploration for the transition
towards a climate-neutral port

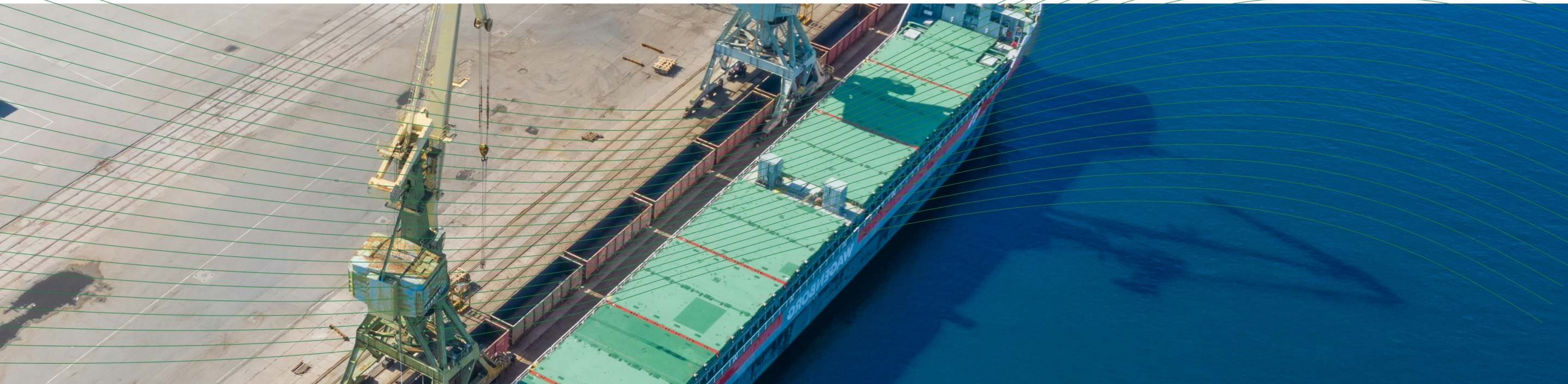
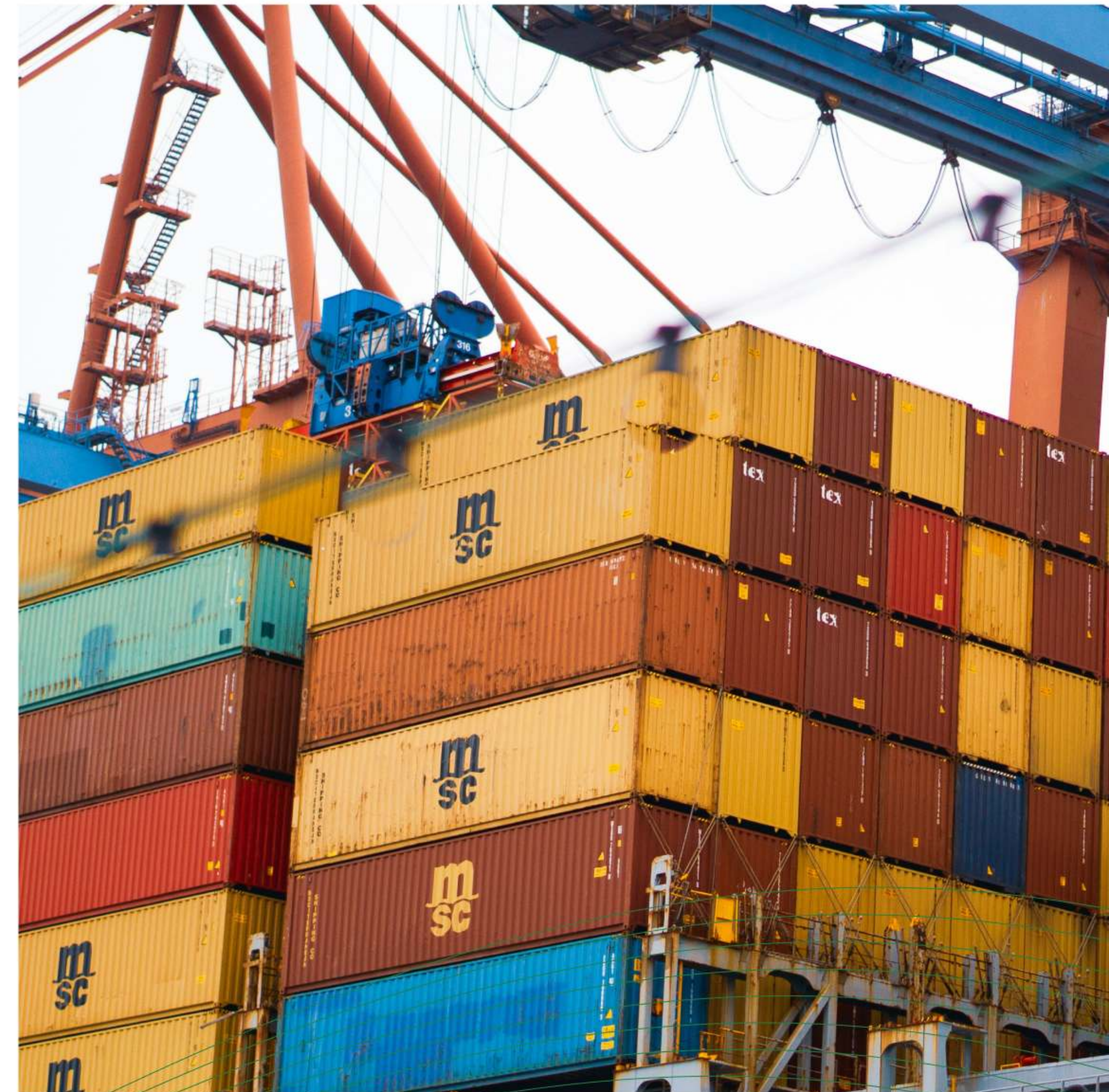


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Climate-neutral ports: a systems approach

The transition to a climate-neutral port requires a systemic perspective, viewing the port as a complex and interconnected ecosystem. Understanding this ecosystem is crucial to know what factors impact the transition to a climate-neutral port, so we can ultimately intervene where it matters most. A systems map supports this problem exploration process. It is a visual representation of all key factors and their relationships within a system, in this case the port ecosystem. This map was developed with input from internal experts, support from external specialists, and desk research.

How to read this systems map

Each of the five intervention zones in this map consists of four to six "leverage clusters". These are clusters of factors that impact the transition to a climate-neutral port. Several of these factors might be leverage points for your port.

A leverage point is a place within a complex system where a small change can lead to significant, lasting improvements. Follow the connections between factors to see how factors impact each other within the system.

A reinforcing loop is a feedback mechanism, where actions or changes in the system amplify themselves over time, leading to exponential growth or decline.

A balancing loop is a feedback loop that works to stabilize a system.

A “+” sign means that when one factor increases, the connected factor also increases, or when one decreases, the other decreases.

A “-” sign means that when one factor increases the connected factor decreases, and vice versa. If mentioned, delays in between factors range from 2 tot 10 years.

Use this systems map to identify leverage points, spot patterns, and decide where targeted actions can drive effective change toward climate-neutrality.

Five intervention zones

The systems map identifies that the transition is stalled by numerous factors and their interdependencies across five specific zones.

→ Governance & Policy

Ports need a level playing field. Without harmonised rules, early movers face "carbon leakage" where traffic shifts to cheaper, under-regulated competitors.

→ Financial & Market Dynamics

The central dynamic is the "supply–offtake commitment gap". Producers won't build fuel plants without buyers, and shipowners won't buy ships without guaranteed fuel supply. Financial interventions must bridge the "Green Premium" and de-risk these early investments.

→ Technology, Infrastructure & Operational Readiness

Solutions like hydrogen, CCUS, and OPS are often stuck at "semi-mature" levels (TRL 7-8). They are not yet "plug-and-play," requiring bespoke engineering that slows deployment and increases cost.

→ Social & Ecological Context

The transition requires public acceptance and a workforce with new skills. Neglecting this can lead to local resistance ("NIMBY") that blocks infrastructure permits,.

→ Planning, Coordination & Data

Decarbonisation requires synchronised investment cycles. This requires shared data and "Green Port Masterplans" that look 20–30 years ahead, rather than standard 5-year business cycles.

The Need for Multiple, Simultaneous Interventions

The analysis shows that linear problem-solving fails in this complex system. A blockage in one intervention zone, creates paralysis in another. Ports must experiment with multiple interventions at the same time to unlock the system.

Break the "first mover disadvantage"

You cannot solve the fuel supply shortage solely by subsidizing production. You must simultaneously create demand signals and ensure (safety) regulations are ready so the fuel can be bunkered.

Move from pilot to scale

Many initiatives currently exist as isolated pilots that fail to scale because they are not integrated into a holistic strategy. A systemic approach requires a "portfolio management" style, where a cluster of projects (e.g., a hydrogen pilot, a skills training program, and a new safety by-law) are executed together to validate a full value chain.

Manage "feedback loops"

Interventions can have unintended consequences. For example, enforcing strict environmental rules might drive companies away, if financial incentives are not provided to help them transition. A system view allows ports to anticipate these side effects.

A crucial role of the Port authority: "Community Builder"

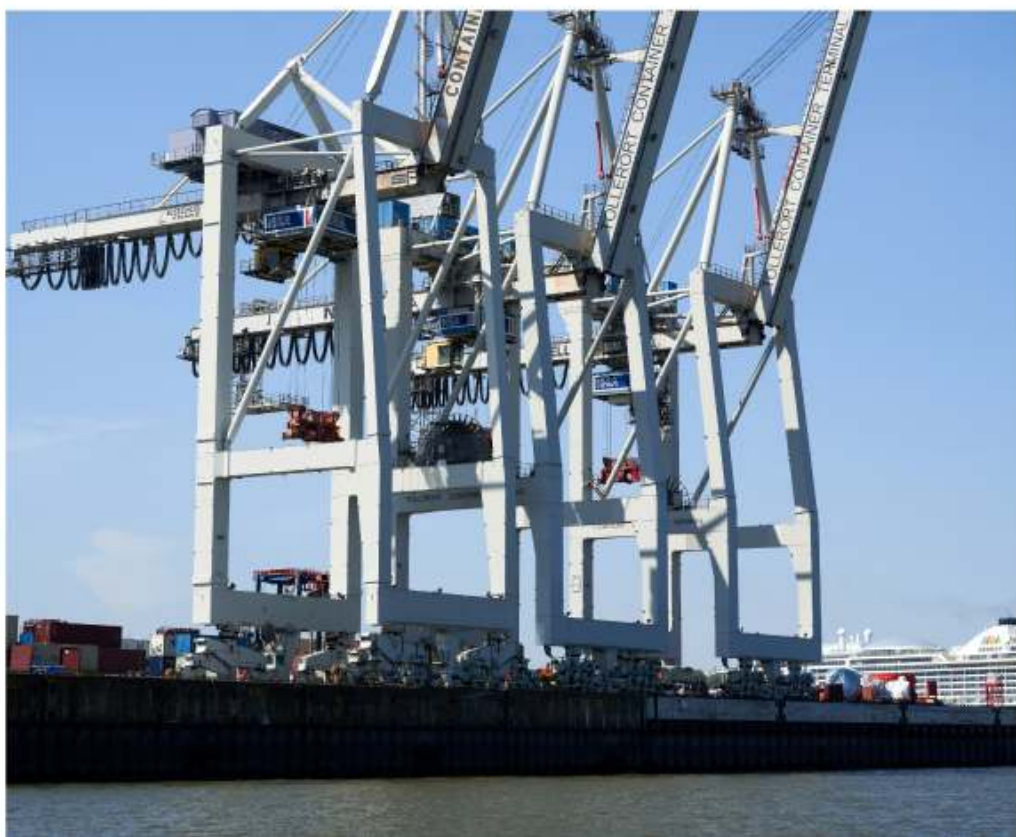
To manage these multiple interventions, the role of the port authority must evolve. It can no longer limit its role to landlord or regulator.

Because the ecosystem involves disparate actors with conflicting visions, goals and targets, the port authority is often the only neutral party capable of facilitating the necessary collaboration.

Moreover, port authorities must actively attract specific, sustainable, green flows and co-invest in shared infrastructure to strengthen the cluster.

Boundaries of the systems map

Every systems map has a boundary. What sits inside that boundary determines what the map can explain. This systems map models the dynamics experienced by actors operating within European port ecosystems as they navigate the transition to carbon-neutral port operations. Many dynamics, however, apply more broadly to port ecosystems facing similar decarbonisation pressures. The time horizon is 2050, consistent with European climate neutrality targets.



What sits outside the boundary

The following dynamics are real, interact with this system, and in some cases condition how the entire map behaves—but modelling them fully would require a separate analysis. They are named here so that readers understand what this map does not claim to explain.

Ecological feedback into port economics

This map models ecological factors primarily through their social license implications. Physical climate impacts on port infrastructure—including sea level rise, storm surge, and changing dredging requirements—fall outside the current boundary but will increasingly shape the financial viability of port assets over the 2040–2050 horizon.

Just transition in sourcing regions

The map treats green fuel supply chains as beginning at the import terminal. Socio-ecological and geopolitical dynamics in producing regions—including water stress, community displacement, and political instability—are acknowledged as emerging supply reliability risks but are not fully modelled within the current boundary.

Cyber and digital infrastructure fragility

The accelerating digitalisation and electrification of port systems introduces new systemic fragilities—including cyber vulnerability and digital infrastructure dependency—that are not captured in the current map but represent a growing operational risk as the transition matures.

Competitive geography of the transition

This map models the port ecosystem as a collective system facing shared challenges. It does not fully capture the likelihood that some ports and regions will be structurally advantaged while others face decline—and the political resistance that asymmetry will generate.

The growth imperative

This map captures the tension between decarbonisation and growth ambitions where it surfaces in specific loops. It does not fully model the deeper paradigm—embedded in the revenue models, concession structures, and masterplan assumptions of most port authorities—that throughput and industrial growth are unconditional organisational imperatives. That assumption conditions how nearly every loop in this map behaves, and challenging it falls outside the current scope.

The financial sector's internal rules.

The financial sector appears in this map as a source of capital that can be unlocked or blocked by risk perception and policy design. The internal rules of that sector—Basel capital requirements, fiduciary duty interpretations, actuarial models for novel fuel risks, and ESG rating methodologies—operate with their own logic and constraints not fully modelled here. Those rules can block investment even when all other system conditions are favourable.

The map is constructed from the perspective of actors committed to port decarbonisation.

Dynamics driven by actors with structural incentives to delay the transition are present in the map, but are not its primary focus.

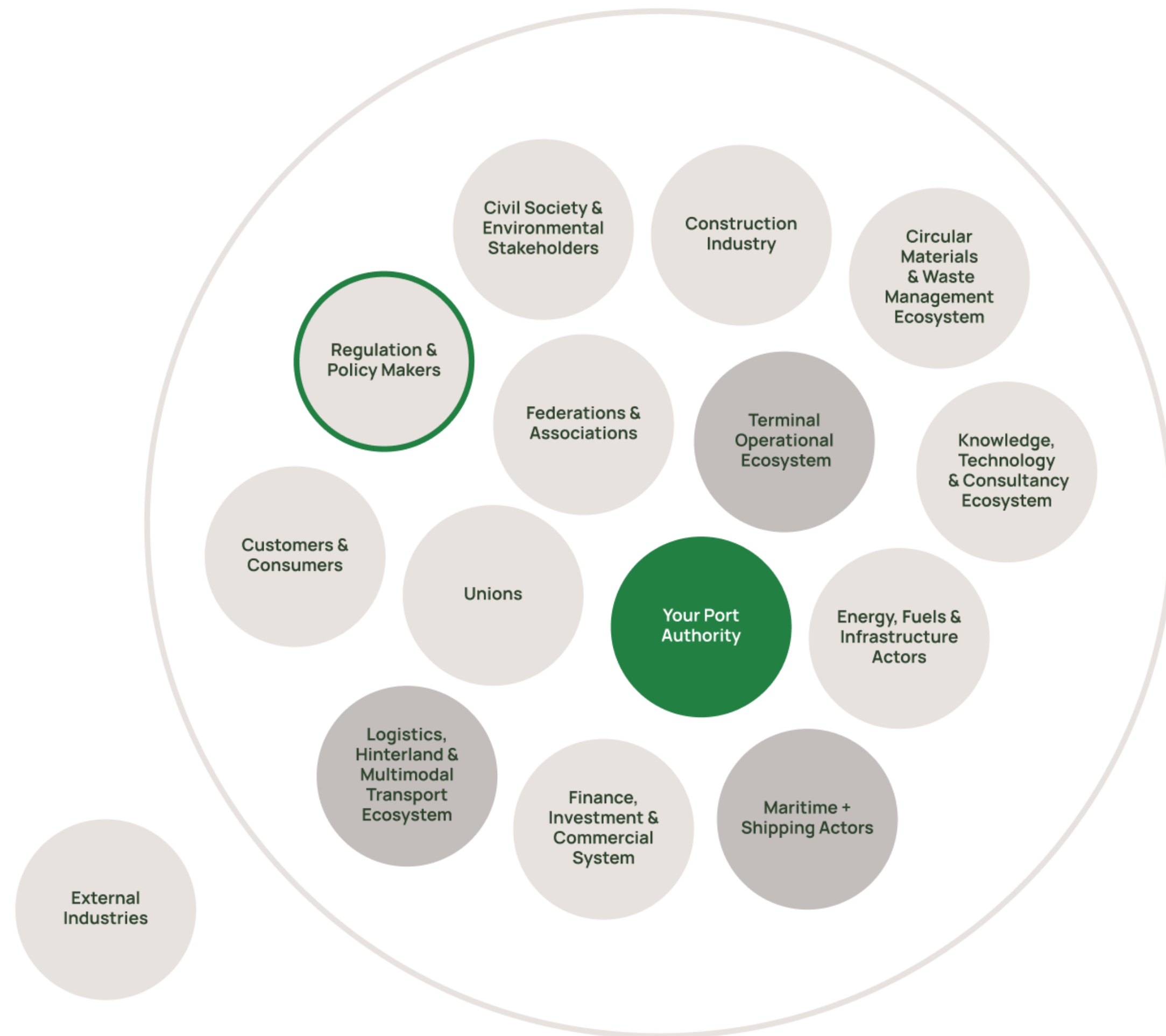
The map is designed as a strategic orientation instrument to help decision-makers identify where to focus attention and intervention in a complex system. Each dynamic represents a direction for further analysis as the transition moves from strategic orientation to implementation.

Port Ecosystem Map

The port ecosystem is a network of interdependent actors whose decisions shape whether decarbonisation accelerates or stalls. At its centre sits the port authority —not because it controls the network, but because it connects to nearly every part of it.

The strongest force driving the system is regulation and policy makers. Clear, consistent climate targets pull the network toward investment and action, while regulatory uncertainty pushes it toward hesitation. Major port authorities are not passive recipients of policy. Their economic weight and direct relationships with national and European institutions give them genuine leverage in shaping the regulatory conditions for decarbonisation — leverage that is amplified when exercised through federations, associations and unions, and informed by civil society signals about where public pressure will push policymakers next.

When climate regulation lands, its weight falls on the actors who must change how they operate: maritime, terminal and logistics stakeholders. Whether they commit to low carbon solutions, depends on whether finance and investment follow. Investors need confidence that the regulatory framework will hold and that technologies will perform at scale. That confidence is built by knowledge institutes, start-ups, scale-ups, energy and fuel partners, the construction industry and circular materials providers. Their solutions, however, require real-world proving grounds before capital will commit. This is one of the port authority's critical roles in the decarbonisation chain: convening the port ecosystem around shared pilots —creating the operational evidence that turns regulatory ambition into bankable reality.



Green Ports Systems Map



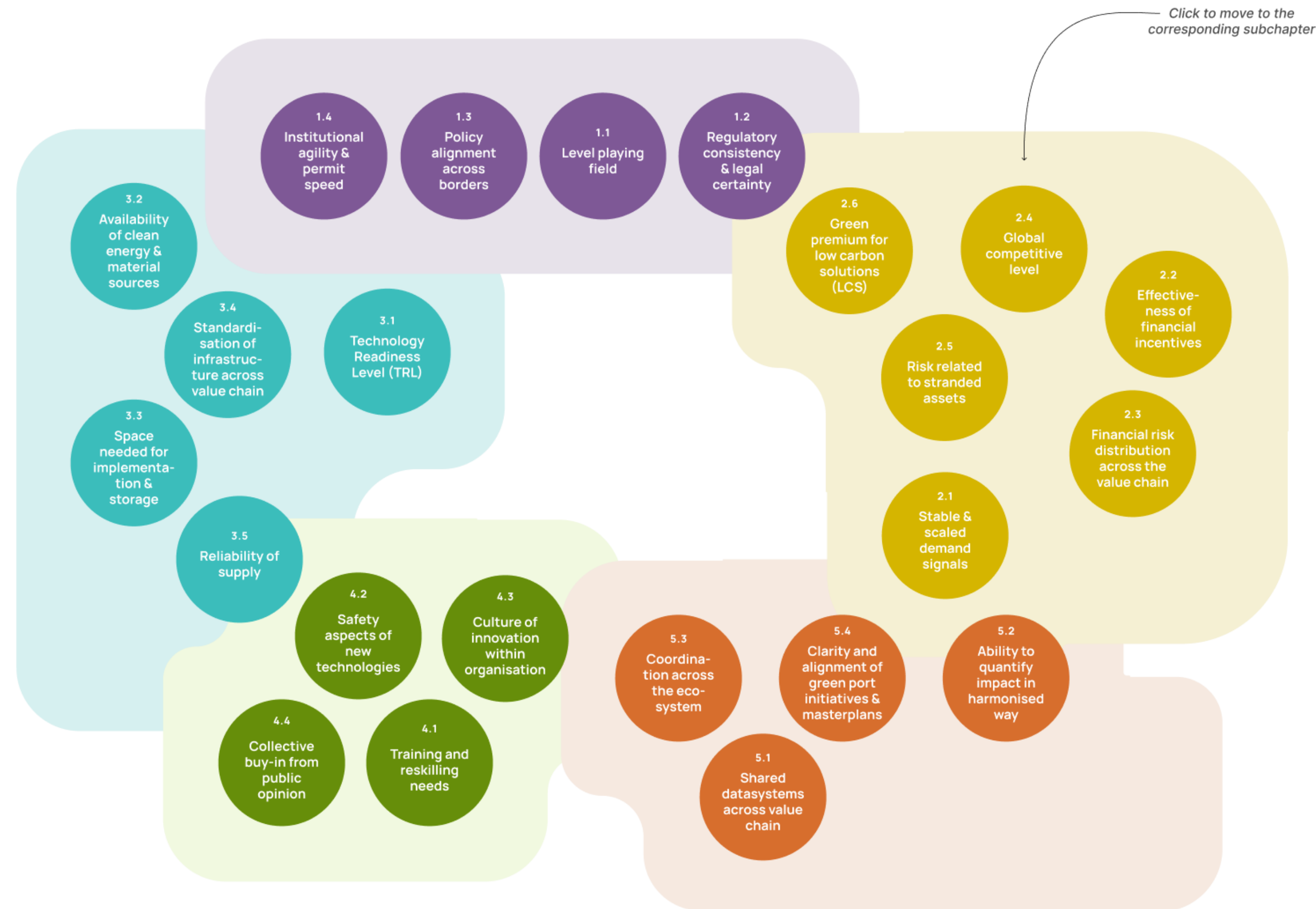
Technology, Infrastructure & Operational Readiness

Decarbonisation depends on whether technologies are ready, infrastructure is adequate, and assets can be safely integrated into port operations.



Social & Ecological Context

Innovation capabilities, community trust, workforce readiness, and ecological responsibility shape whether ports can deploy new systems without facing social or environmental backlash.



Governance & Policy

Consistent and predictable rules, aligned standards, and streamlined permitting enable ports to plan and invest confidently in long-term decarbonisation.



Financial & Market Dynamics

Making the green premium viable requires de-risking investments, stabilising demand signals, and distributing financial risk fairly across the value chain.



Planning, Coordination & Data

Synchronised roadmaps and transparent, interoperable data systems allow actors to align timelines, prevent stranded assets, and scale collectively.

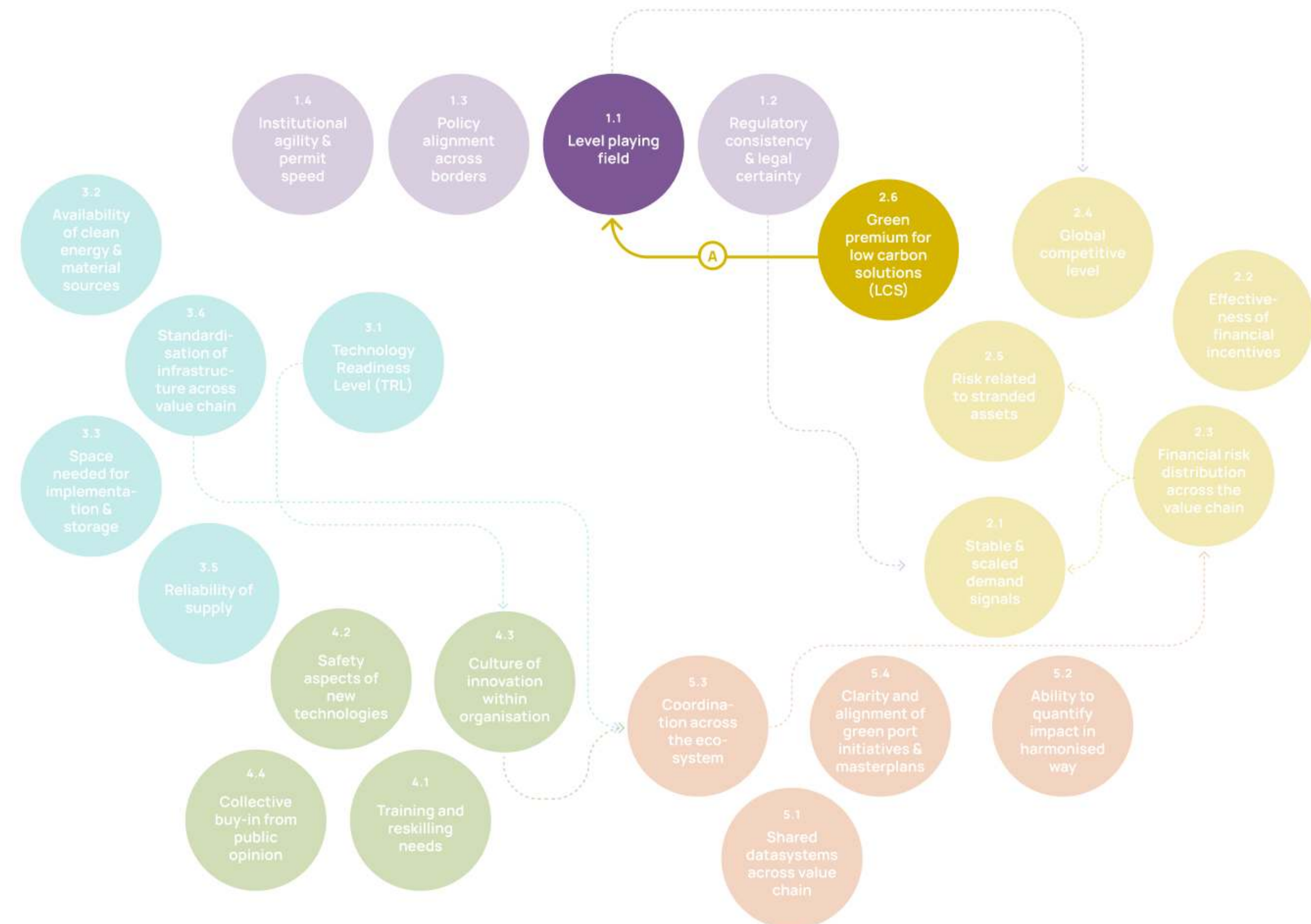
The green premium

A B C D E F G H

Green premium for low carbon solutions

Ports need to decarbonise at unprecedented speed, but nearly every low carbon solution that could enable this, arrives with a green premium: it costs more, feels riskier, and demands new infrastructure, skills, and procedures. In that early phase, the market doesn't reward the frontrunner automatically, so the premium becomes a fault line. Some actors can absorb it (or choose to), while others can't or won't. Very quickly, the transition stops being only about "what works", and becomes about who carries the cost.

That's where the level playing field tension kicks in. If one region, port, or company starts applying stricter requirements or investing in cleaner options while others keep operating under looser rules, the competitive gap created due to green shift gets distorted. The greener pathway is framed as a disadvantage, and the less ecological pathway as a short-term advantage. Instead of pulling the system forward, the premium creates pressure to avoid being the strict one.

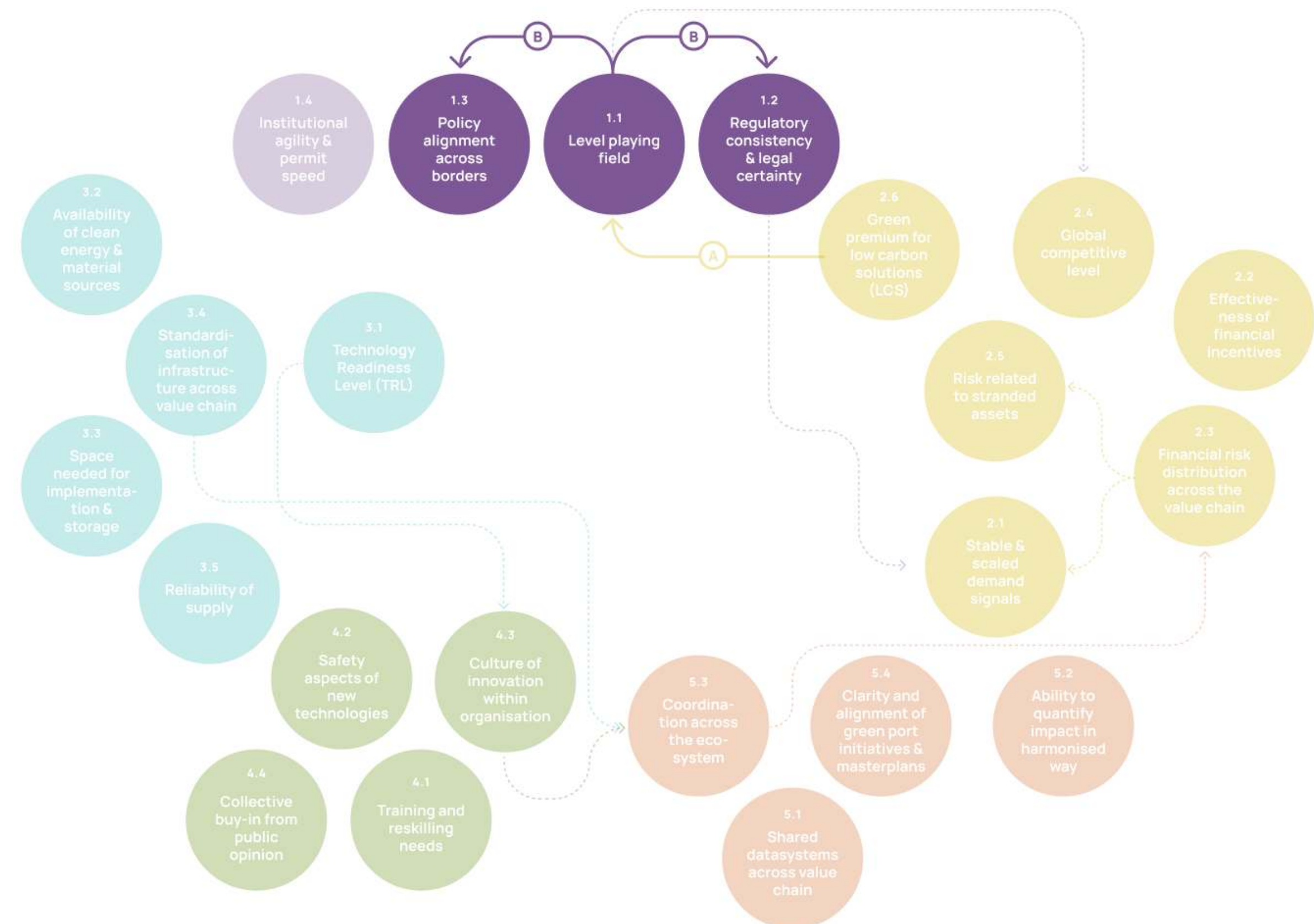


The green premium

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Regulatory Consistency & Legal Certainty

Over time, this translates into a political reflex: jurisdictions become tempted to stay less demanding because they fear losing traffic, jobs, or investment to places that move slower. The result is less policy alignment across borders and political ambitions being dialed down (less regulatory consistency and legal certainty): changing targets, different standards, different enforcement, different incentives, different “eligible” technologies. And once that happens, the ecosystem doesn’t build one coherent transition, it builds several partial ones. As ambitions are weakened, demand signals in the market become volatile.



The green premium

A B C D E F G H

Standardisation of infrastructure across the value chain

That policy patchwork then shows up physically as fragmented infrastructure (no standardisation of infrastructure across the value chain). Some ports invest in certain fuels, some prioritise electrification, others hedge. Requirements for connection, safety, reporting or use differ from place to place. For users of the system — shipowners, logistics operators, industrial clusters— this fragmentation reduces reliability. Without shared data systems across the value chain, actors can't even see each other's readiness, capacity, or impact. They can't plan confidently across routes and time horizons, because the rules of the game change by geography.



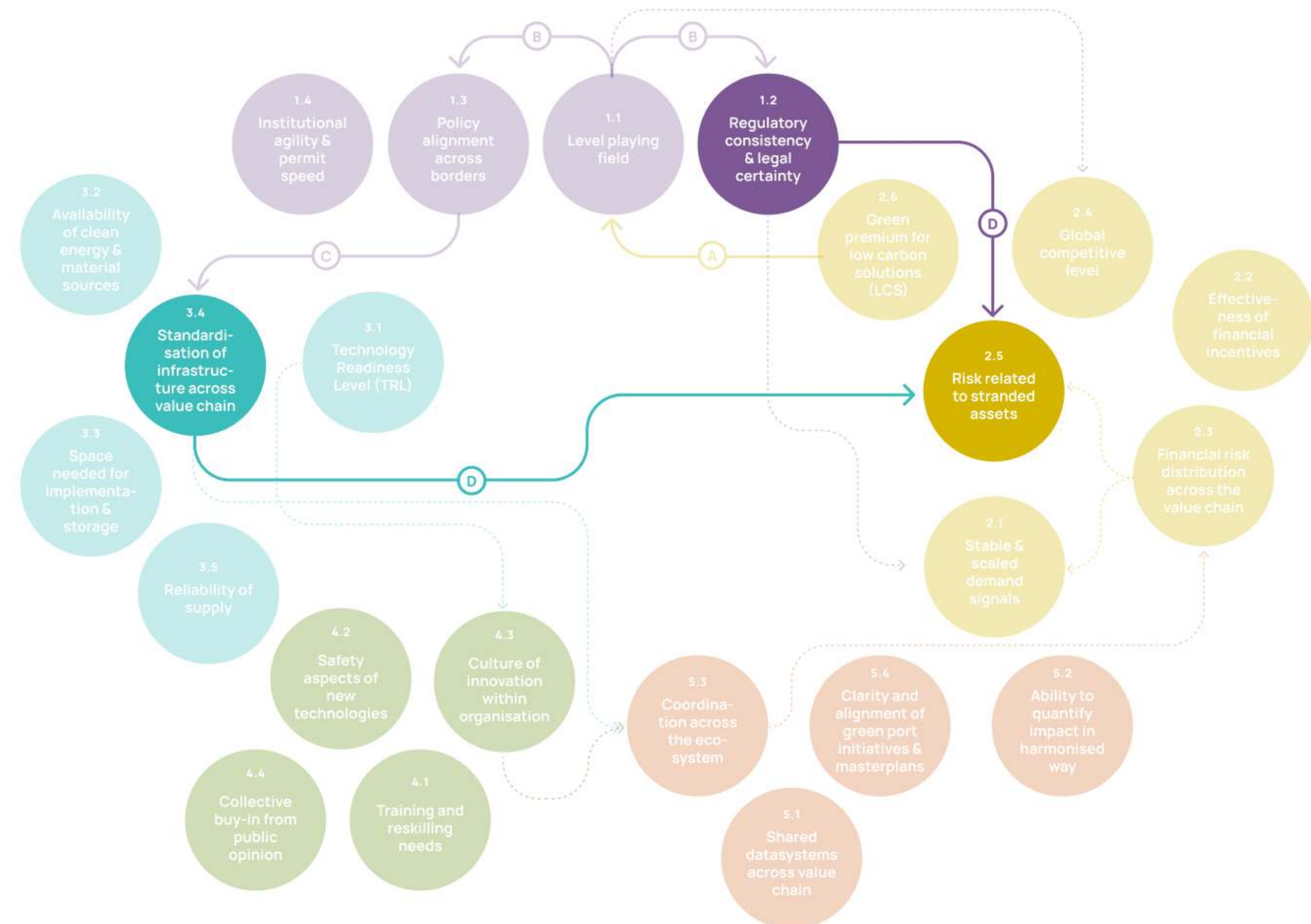
The green premium

A B C **D** E F G H

Risk related to stranded assets

Uncertainty creeps in and so does the risk for stranded assets. If you invest in one pathway and the ecosystem later tilts toward another — because regulation shifts, subsidies change, or adoption accelerates elsewhere— you risk being left with expensive infrastructure that no longer fits the dominant direction.

The ecosystem falls into “wait and see” behaviour: each actor waits for others to move first, but nobody wants to be first. Risk and cost aren’t distributed fairly when there is a lack of coordination (financial risk distribution across the value chain).

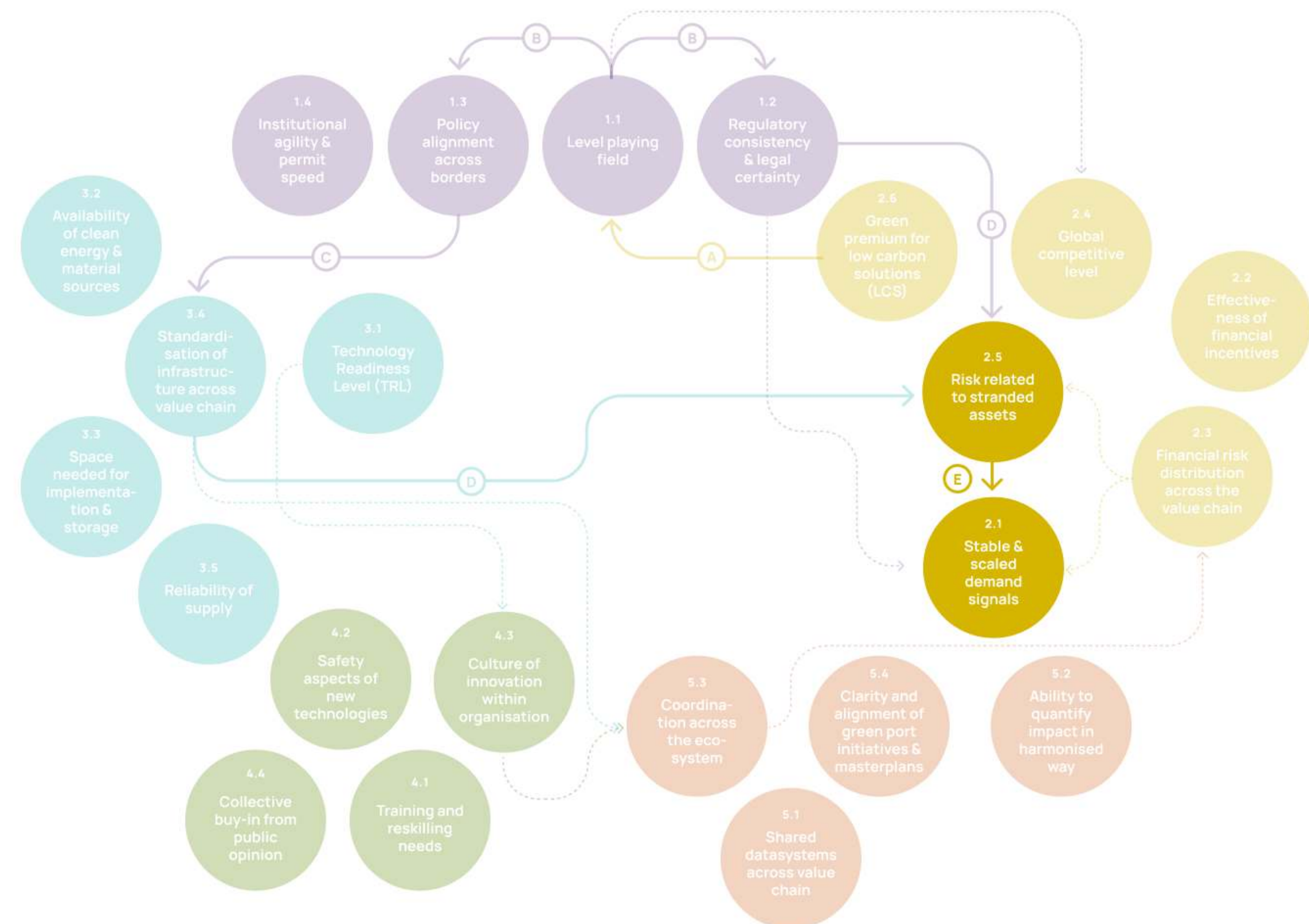


The green premium

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Stable & scaled demand signals

Volumes remain small and scattered, demand signals stay weak. At the same time, the availability of clean energy and material sources remains limited and geographically concentrated, making it nearly impossible to scale operations even when investors are ready. Buyers hesitate, offtake agreements remain limited and investment cases can't be closed. Costs don't come down, so the financial upside of scaling doesn't materialise.

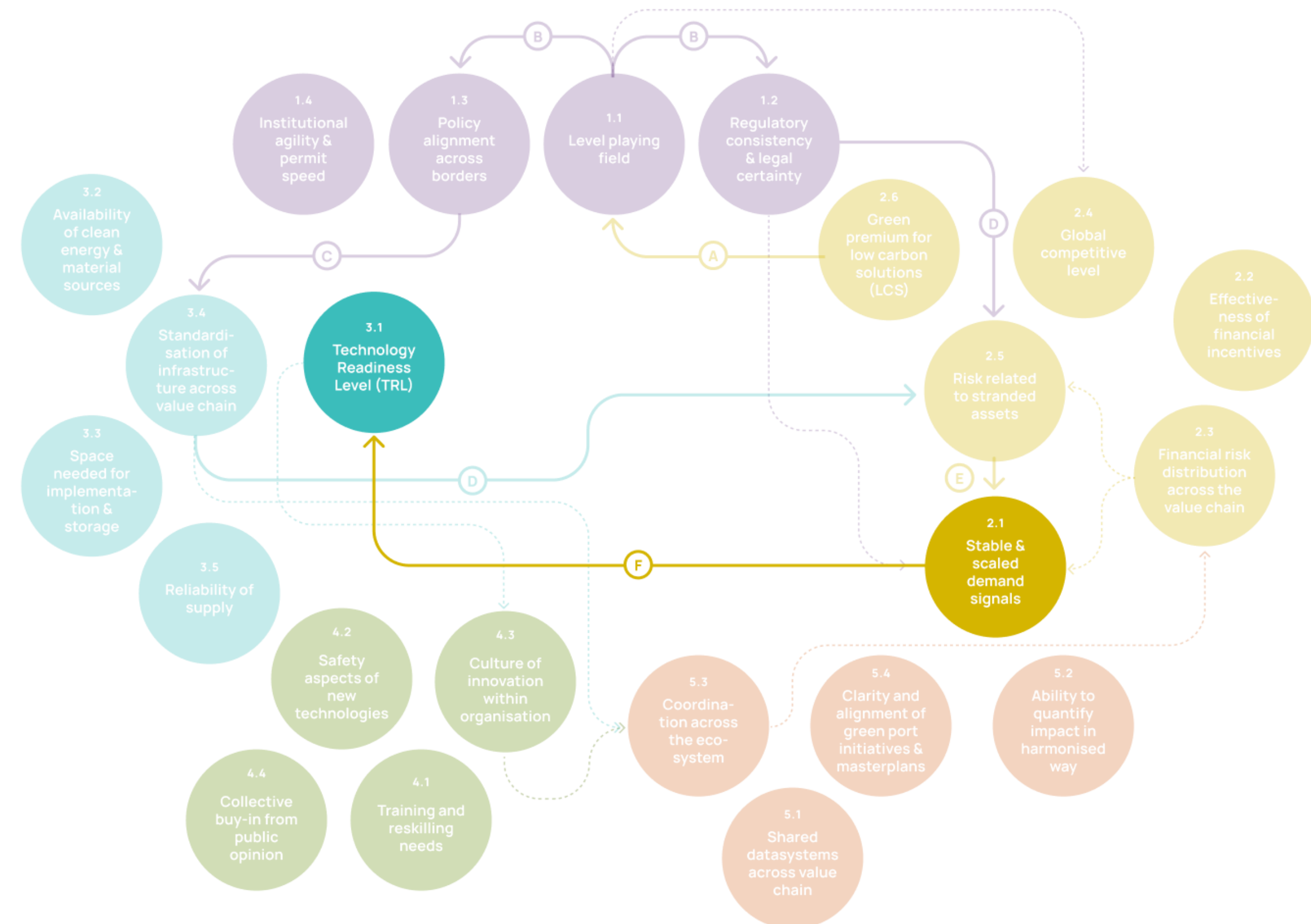


The green premium

A B C D E **F** G H

Technology Readiness Level (TRL)

The new technology struggles to find the necessary resources to invest in the technology maturity (TRL). Innovation slows because real world learning is what early-stage deployment needs. This only happens in organisations that are willing to experiment, adapt, and tolerate failure as part of the learning process. Without a culture of innovation within the organisation, promising technologies remain locked in controlled environments —tested but never truly stress-tested. At that point, the technology risks getting stuck in the innovation valley of death: proven enough to be real, but not supported enough to become competitive.

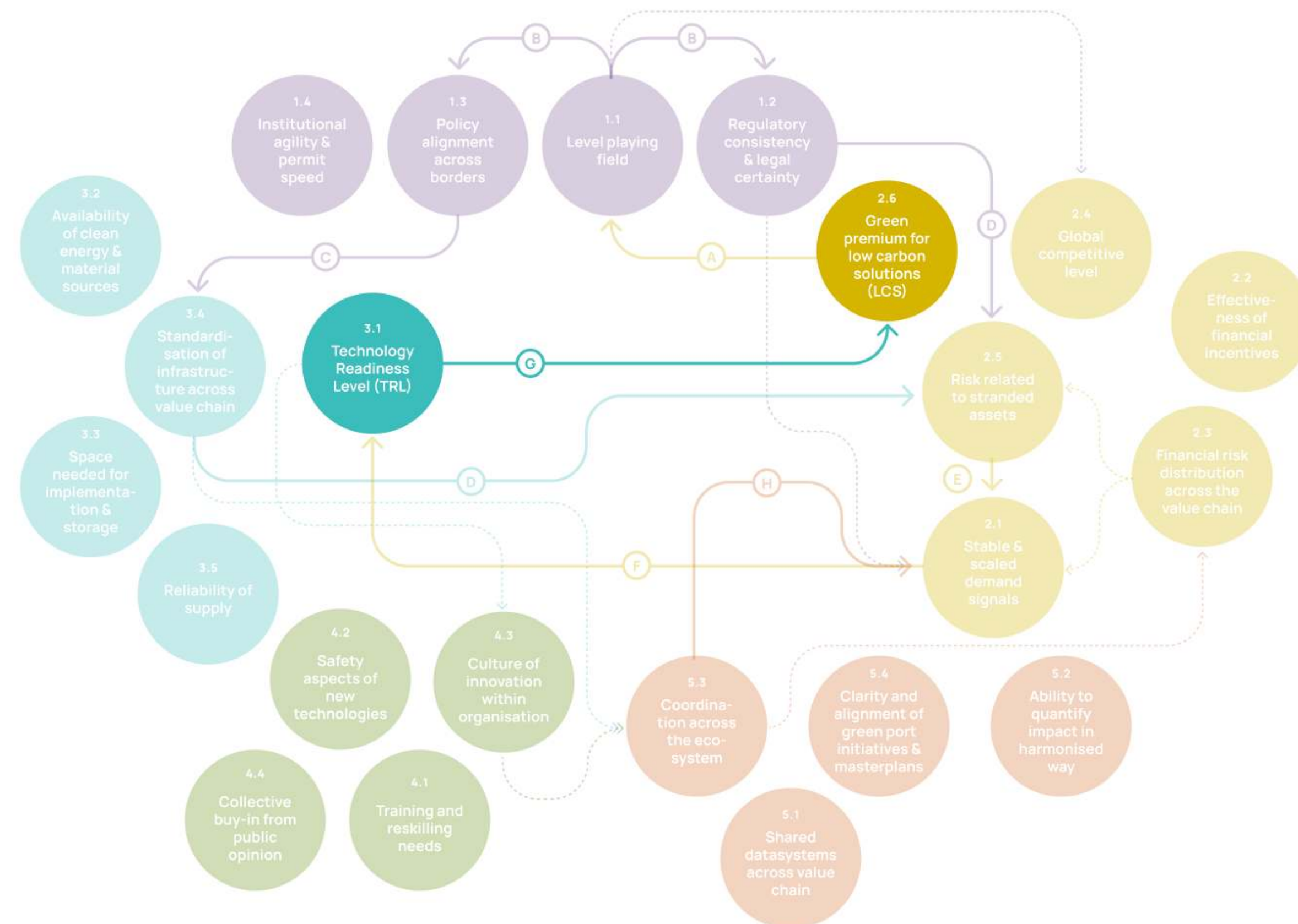


The green premium

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Green premium for low carbon solutions

The technology survives in niche pockets, never reaches mass adoption, and therefore never earns the learning curves and economies of scale that would reduce the premium. The premium stays high, and the whole cycle reinforces itself. In other words, the green premium persists because the system never gives it the conditions to scale. And because the premium persists, the competitive distortion between greener and less ambitious actors widens further, restarting the cycle.

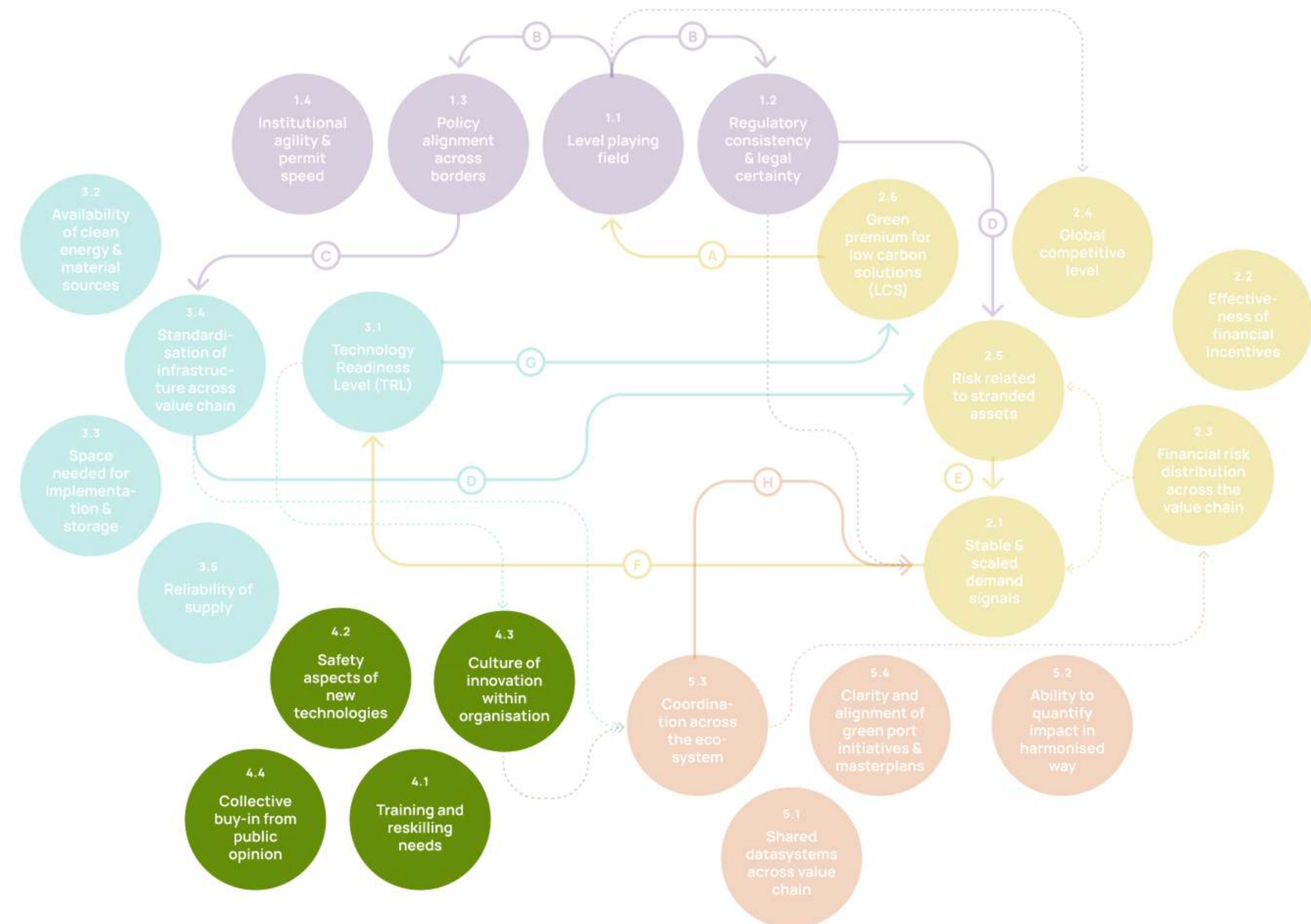


The green premium

A B C D E F G H

Training and reskilling needs

But even when coordination, funding, and regulation align, the transition can still stall if the human system isn't ready. New technologies demand skills that the current workforce doesn't have, and retraining takes years — not months. If local communities experience the transition as imposed rather than fair, resistance mounts: project delays, permit appeals, and political backlash slow everything down. And within organisations, if the culture doesn't tolerate experimentation and failure, promising technologies stay stuck in controlled environments, never reaching the operational learning they need. Workforce readiness, community trust, and innovation culture are not side conditions — they determine whether everything else in this map actually moves



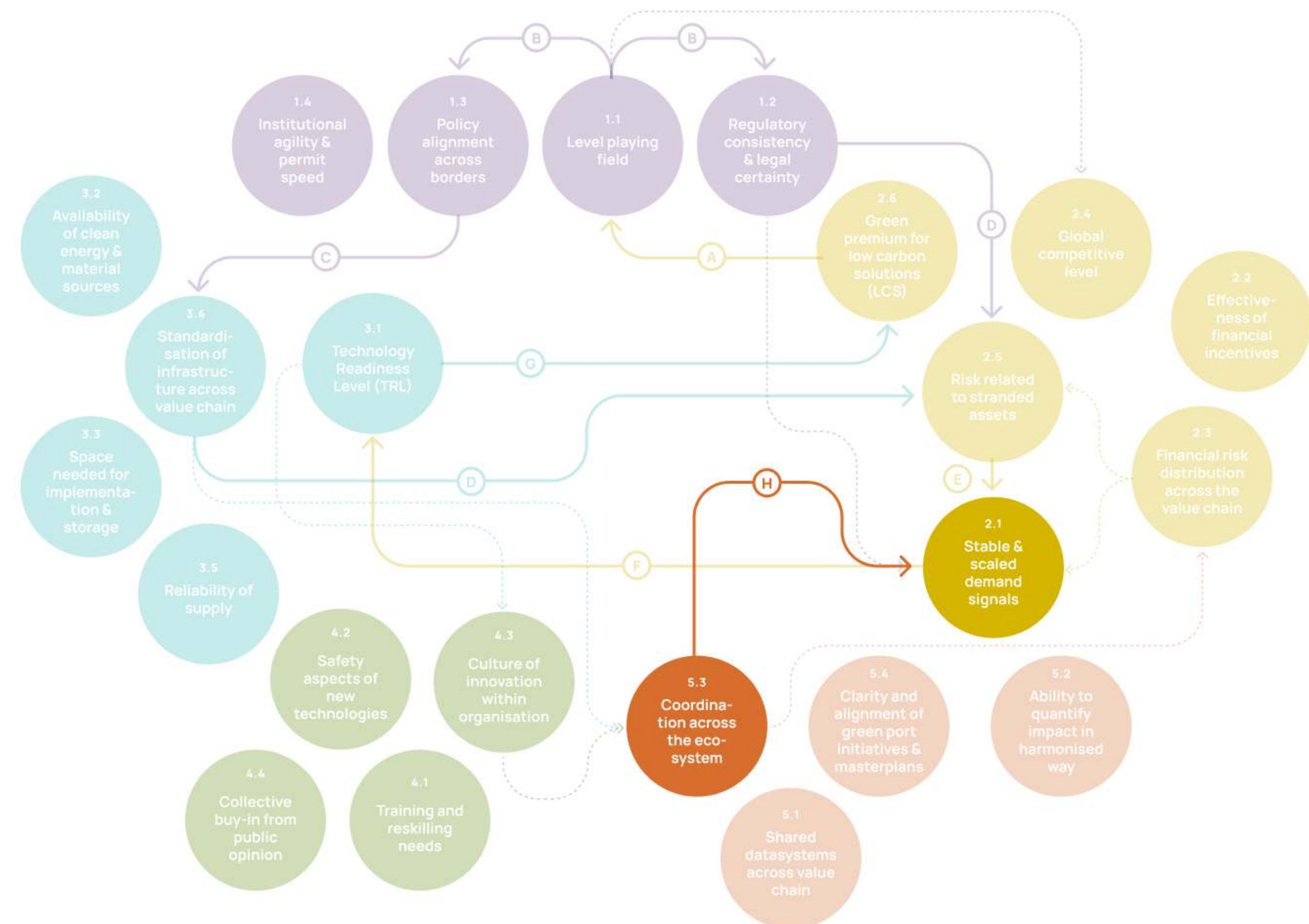
The green premium

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Coordination across the ecosystem

The green premium isn't just a price issue, it's a system dynamic. If there is no active coordination across the ecosystem on a few connected leverage clusters, the system naturally drifts toward fragmentation, hesitation, and slow adoption, locking the premium in place instead of breaking it. Why commit to shared standards if you're not sure the market will follow? Why lock into a corridor agreement if it might disadvantage you later? Coordination becomes harder precisely when it's most needed, slowing down the technology development overall (Technology Readiness Level).

On the upside, the same dynamics can work in reverse. When a credible, coordinated commitment is made —harmonised standards, shared infrastructure, stable demand signals— the cycle begins to turn. Standardisation lowers compliance costs and enables insurance. Lower risk attracts investment. Investment enables deployment at scale. Deployment generates learning curves that bring costs down. As the green premium narrows, the level playing field tension eases: being ambitious is no longer a competitive disadvantage but an early-mover advantage. The system that currently locks the premium in place is the same system that, once tipped, accelerates its decline.

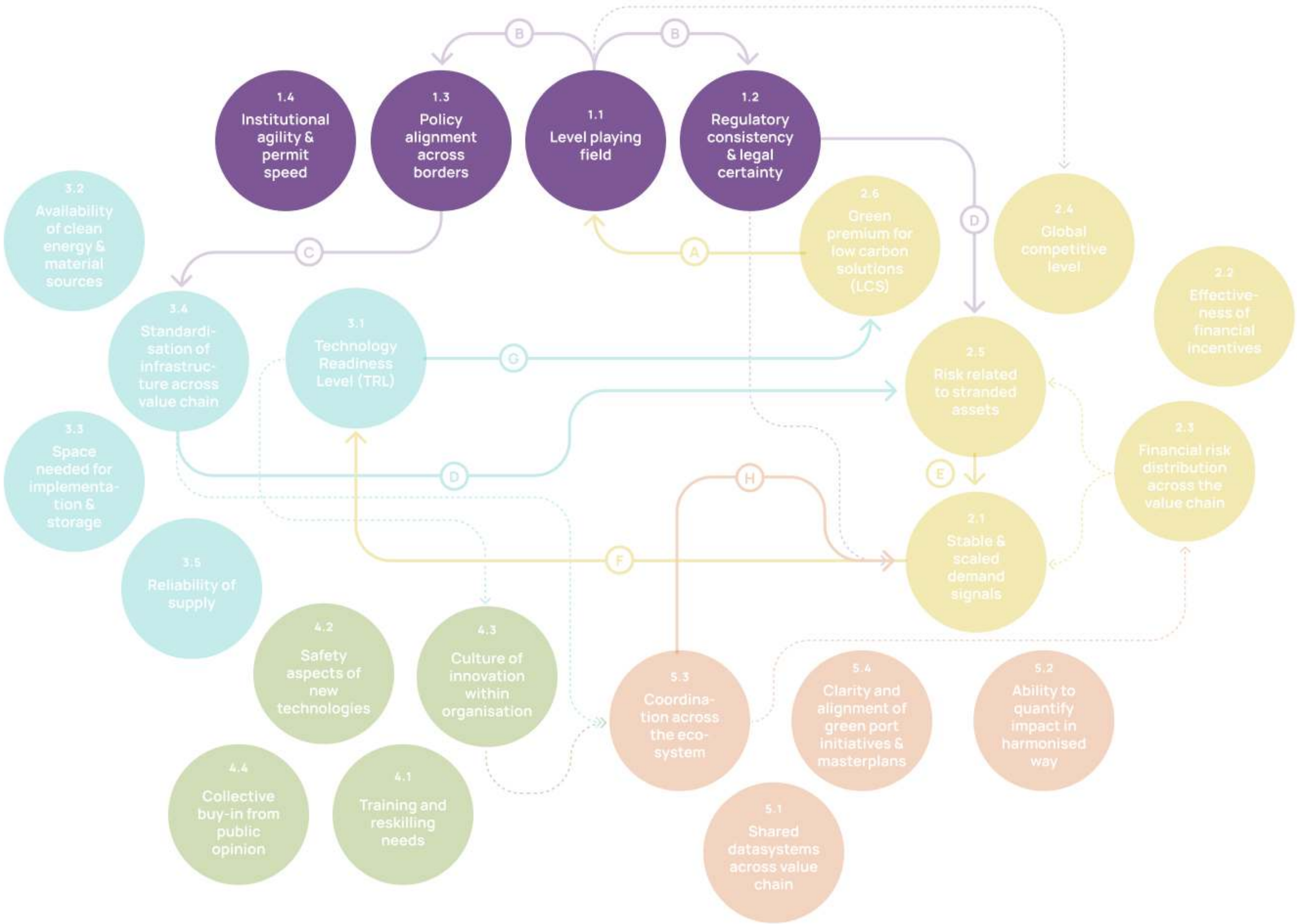




01 / Governance & policy

Consistent and predictable rules, aligned standards, and streamlined permitting enable ports to plan and invest confidently in long-term decarbonisation.

Ports need predictable rules, aligned standards, and strong governance to plan major transitions. Legislation must create a level playing field, ensuring that all ports operate under harmonised requirements across regions rather than navigating a fragmented regulatory landscape. Equally important is reducing the complexity of permits and legislative implementation, so regulatory processes enable innovation instead of delaying or blocking the pilots and projects needed for the transition.



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1.1 / Level playing field

Establishing a level playing field is fundamental to ensuring that the transition to carbon neutrality does not become a competitive disadvantage. In a globalised maritime sector uneven conditions create economic penalties for "first movers". This leverage cluster focuses on harmonising standards, fiscal rules, and compliance timelines across regions and supply chains. Without this alignment, local climate ambitions unintentionally drive traffic toward lower-cost, higher-emission alternatives.

KEY CHALLENGE

Carbon leakage & traffic diversion risk

If climate rules (ETS costs, FuelEU constraints, OPS obligations, fuel standards) are much stricter or implemented earlier in some ports than others, traffic may shift to laxer regions. This creates pressure to slow ambition locally and undermines first movers.

KEY CHALLENGE

Early adopters face higher costs and competitive risks

When ports move ahead of others with sustainability requirements (e.g., fuels, OPS, emissions standards, or circular practices), they often take on higher investment, longer permit procedures and higher operational complexity. Without shared standards or coordinated regulation, early movers may face competitive disadvantages and political pushback, discouraging leadership and slowing system-wide progress.

KEY CHALLENGE

Unequal access to subsidies and support schemes

Large or well-resourced ports are better positioned to navigate EU/ national funding, while smaller ports may struggle to access financing and technical support. This can widen the gap between frontrunners and followers instead of lifting the whole system.

KEY CHALLENGE

Inconsistent treatment of transitional fuels and CCUS across countries

Where LNG, partial CCUS or other "in-between" solutions are treated differently across countries, some ports gain a temporary economic advantage by staying more fossil-leaning, while others move ahead on stricter trajectories and bear higher short-term costs.

1.2 / Regulatory consistency & legal certainty

Maritime assets last decades, yet policy cycles are short. This mismatch creates uncertainty. To unlock capital for infrastructure, investors need long-term predictability regarding carbon pricing and fuel definitions. Without stable rules, the fear of stranded assets causes "investment paralysis," stalling the transition.

KEY CHALLENGE

Short political cycles versus long asset lives makes investors hesitate

Port and industrial assets last 20–40 years. Climate and energy policy can shift every 4–5 years. Fear of rule changes makes investors hesitate on large low-carbon projects.

KEY CHALLENGE

Unclear long-term trajectories for carbon pricing and moving targets on fuel and technology eligibility

Future carbon prices, GHG-intensity thresholds, and performance standards are unclear. Definitions of "renewable", "low-carbon", or "sustainable" (for hydrogen, ammonia, methanol, biofuels) change. This creates uncertainty about which pathways will remain compliant over time, blocking investments and port infrastructure decisions.

KEY CHALLENGE

Layered and sometimes conflicting obligations

Ports and operators must interpret overlapping rules and climate targets (IMO, EU, national law, regional plans) that don't always align in timing or scope. This legal complexity raises compliance risk and encourages "minimum compliance" behaviour instead of strategic decarbonisation.

1.3 / Policy alignment across borders

International shipping faces a "regulatory patchwork" where divergent national rules on carbon pricing, safety, and fuels create administrative barriers. This leverage cluster harmonises these legal frameworks between jurisdictions. Without such regulatory synchronisation, zero-emission vessels may be technically ready but operationally blocked by conflicting compliance regimes along their trade routes.

KEY CHALLENGE

Regulatory patchwork along shipping corridors

When ports on the same route face different implementation of ETS, FuelEU, safety rules, or OPS standards, shipping lines cannot plan a coherent fuel and compliance strategy. This undermines green corridor concepts and slows fleet transitions.

KEY CHALLENGE

Divergent safety and bunkering standards

Different interpretations of safety distances, zoning, and bunkering procedures for hydrogen, ammonia, and methanol across countries increase investment risk, uncertainty, design complexity and cost. Ports and shipowners hesitate to commit to one fuel if it won't be usable everywhere.

KEY CHALLENGE

Limited institutional structures for cross-port coordination

Many green corridor or multi-port alliances are still project-based and temporary. Without permanent governance structures, alignment on standards, timelines, and investments remains fragile and person-dependent.

KEY CHALLENGE

Uneven enforcement across jurisdictions

If some authorities enforce climate and safety rules strictly while others look away, compliant ports and operators are at a competitive disadvantage, and the overall decarbonisation effort loses credibility.

1.4 / Permit complexity & speed

Administrative rigidity throttles decarbonisation. This leverage cluster addresses the friction between climate urgency and slow permitting by shifting to standardised, fast-track frameworks. Crucially, it resolves the regulatory paradox where strict environmental protections regarding waste classification and soil contamination unintentionally block the circular economy and land redevelopment needed for the transition.

KEY CHALLENGE

High complexity and resource intensity of permits

Permits for OPS, new fuels, CCUS, large grid upgrades, and circular facilities require extensive studies, multi-agency coordination, and long review times. Regulatory staff are often overloaded, so climate-critical projects face years of delay.

KEY CHALLENGE

Case-by-case, “first-of-a-kind” treatment for every project

Because standards and templates are still emerging, each new hydrogen terminal, CO₂ hub, or OPS system is treated as unique. This multiplies workload on both regulators and project teams, slowing learning and scaling.

KEY CHALLENGE

Weak feedback loops from pilots into regulation

Lessons from pilots are not always systematically captured and translated into updated guidelines or fast-track procedures. As a result, each new pilot encounters similar hurdles (for example in permitting), instead of benefiting from accumulated institutional learning.

KEY CHALLENGE

Regulatory gridlock on circularity and legacy contamination

The reuse of materials (e.g., dredged sediment, construction debris) and the redevelopment of port land are frequently stalled by rigid legal classifications of “waste” versus “product” and strict liability regarding legacy pollution (e.g., PFAS). The high costs and legal uncertainty of remediation, combined with complex “End-of-Waste” procedures, make circular construction and brownfield redevelopment financially and administratively prohibitive, freezing essential land assets.

KEY CHALLENGE

Risk-averse culture in authorities

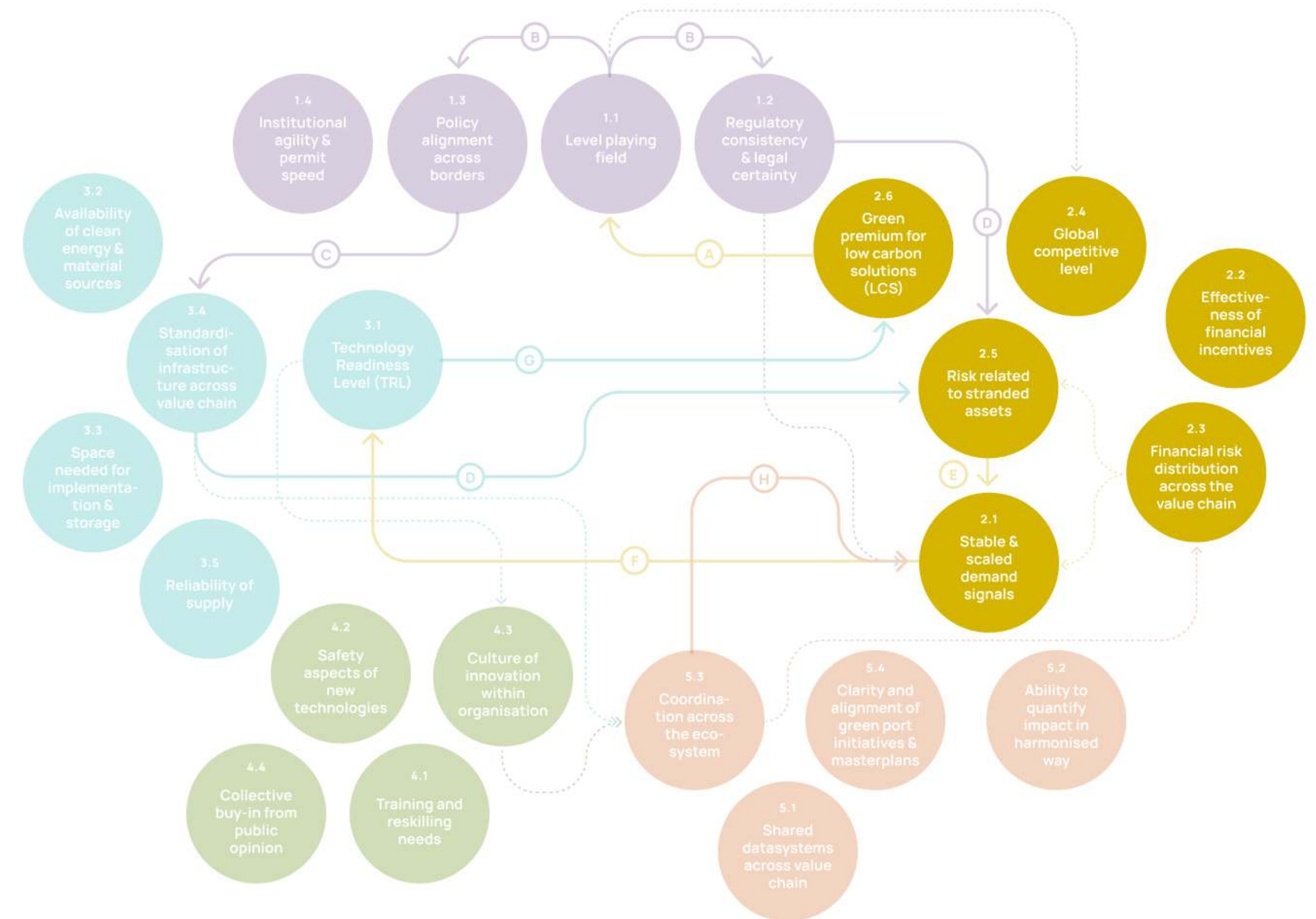
Fear of accidents, legal appeals, or political backlash incentivises regulators to default to caution and procedural thoroughness. This protects safety but can turn permitting into a structural brake on innovation and pilots.



02 / Financial & Market Dynamics

Making the green premium viable requires de-risking investments, stabilising demand signals, and distributing financial risk fairly across the value chain.

Decarbonisation requires large upfront investments with uncertain returns. Ports must manage market volatility, shifting fuel prices, evolving customer demand, and investment risks. Ensuring viable business models, access to funding, and risk-sharing mechanisms is essential for accelerating adoption of low-carbon infrastructure and technologies.



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2.1 / Stable and scaled demand signals

The transition to low carbon solutions (LCS) is stalled by a "wait-and-see" dynamic where supply awaits demand and vice versa. This leverage cluster focuses on aggregating demand across the ecosystem—spanning green fuels, shore power, and circular materials—to create the stable market conditions and long-term certainty necessary to unlock gigawatt-scale infrastructure investment.

KEY CHALLENGE

Chicken-and-egg between fuel supply and ship demand

Fuel producers won't invest in large-scale green fuel plants without long-term offtake contracts, and shipowners won't commit to zero-emission vessels or fuels without confidence in long-term, affordable supply. This "supply-offtake commitment gap" keeps both sides at pilot scale and prevents single pathways from reaching minimum economic scale.

KEY CHALLENGE

Fuel pathway fragmentation keeps demand thinly spread

Parallel bets on many different fuels (H₂, ammonia, methanol, advanced biofuels, LNG, etc.) fragment demand, so no option reaches sufficient volume for learning curves and price drops.

KEY CHALLENGE

Uncertain long-term rules weaken willingness to commit

Frequent policy updates, unclear future carbon prices, and changing sustainability definitions create "policy uncertainty", which directly reduces the willingness of cargo owners and ship operators to sign 10–15 year green fuel contracts or corridor commitments.

KEY CHALLENGE

Footloose industry undermines local long-term demand

Energy-intensive industries in European ports can relocate to lower-cost regions (energy + labour), which makes ports hesitant to bank on local industrial demand for green fuels or CO₂ infrastructure over 20–30 years. This mobility of "footloose" industry increases the perceived risk of stranded demand.

2.5 / Risk related to stranded assets

Ports face a growing risk of locking capital into assets that will not survive the 2040–2050 regulatory landscape. As climate rules tighten, today's "transition technologies" such as LNG bunkering or fossil-based heat systems, risk rapidly shifting from enablers to non-compliant liabilities. This uncertainty paralyzes long-term investment and threatens to fill ports with infrastructure that becomes obsolete before it is amortised.

KEY CHALLENGE

Transition technologies risk becoming incompatible with future climate rules

Investments in LNG bunkering, CHP/WKK installations, fossil-based heat systems, or first-generation CCUS solutions may no longer be compliant, or economically viable, under stricter 2040–2050 climate frameworks. As standards evolve, these assets can rapidly shift from "transition enablers" to "non-compliant liabilities," creating serious stranded-asset exposure across the port-industrial cluster.

KEY CHALLENGE

Policy uncertainty causes investment paralysis

Long and unpredictable political processes (e.g., RED III revisions, ETS trajectory changes, IMO rulemaking lags, national implementation choices) make it extremely difficult to commit to 20–30-year assets. When investors fear that climate rules may tighten mid-lifecycle, the rational response is to delay or minimise investment, which slows down the decarbonisation build-out.

KEY CHALLENGE

Intermediate solutions create lock-in dilemmas

Ports feel pressure to deliver short-term emissions reductions through LNG, partial electrification, limited CCUS, waste-heat projects,... yet these same solutions may lock out superior zero-carbon options later. Decisions taken for "fast wins" can hard-wire infrastructures (pipelines, terminals, storage, grid layouts) around technologies that become obsolete, creating structural lock-in.

KEY CHALLENGE

The narrowing window for future-proof investment accelerates transition risk

As 2050 targets approach, the acceptable risk tolerance for long-lived infrastructure tightens. Every year of delay compresses the viable amortisation period for new assets. This dynamic amplifies the financial pressure: when assets must pay back over shorter periods while facing higher regulatory uncertainty, stranded-asset risk rises sharply and undermines business cases across the port ecosystem.

2.6 / Green premium for low carbon solutions

The Green Premium represents the substantial cost difference between adopting zero-emission technologies and continuing with cheaper, conventional fossil fuel operations. This leverage cluster focuses on bridging the price gap that currently creates a negative business case for sustainability. Without mechanisms to cover this premium, the market naturally incentivises the lowest-cost (highest-emission) options, stalling the transition.

KEY CHALLENGE

Waste heat, waste CO₂ and “waste molecules” often have weak business cases

Industrial heat networks, CCUS chains and advanced recycling all require large CAPEX, complex coordination and long payback periods. Without strong price signals (ETS, CBAM), subsidies and stable contracts, they remain marginal.

KEY CHALLENGE

Hyper-efficient fossil systems set a tough benchmark

Fossil fuels and existing gas/WKK systems are extremely optimised and cheap. Green fuels, CCUS or reuse options start from a cost disadvantage, and many companies don't see enough return for the extra complexity and risk.

KEY CHALLENGE

Permitting and quality-proofing add invisible costs

Qualifying secondary materials, connecting heat networks and certifying CO₂ or biogenic streams all come with heavy procedural and reporting burdens, making the “waste resource as asset” narrative hard to realise in practice.

KEY CHALLENGE

ETS/EPR price often below the “real” abatement threshold

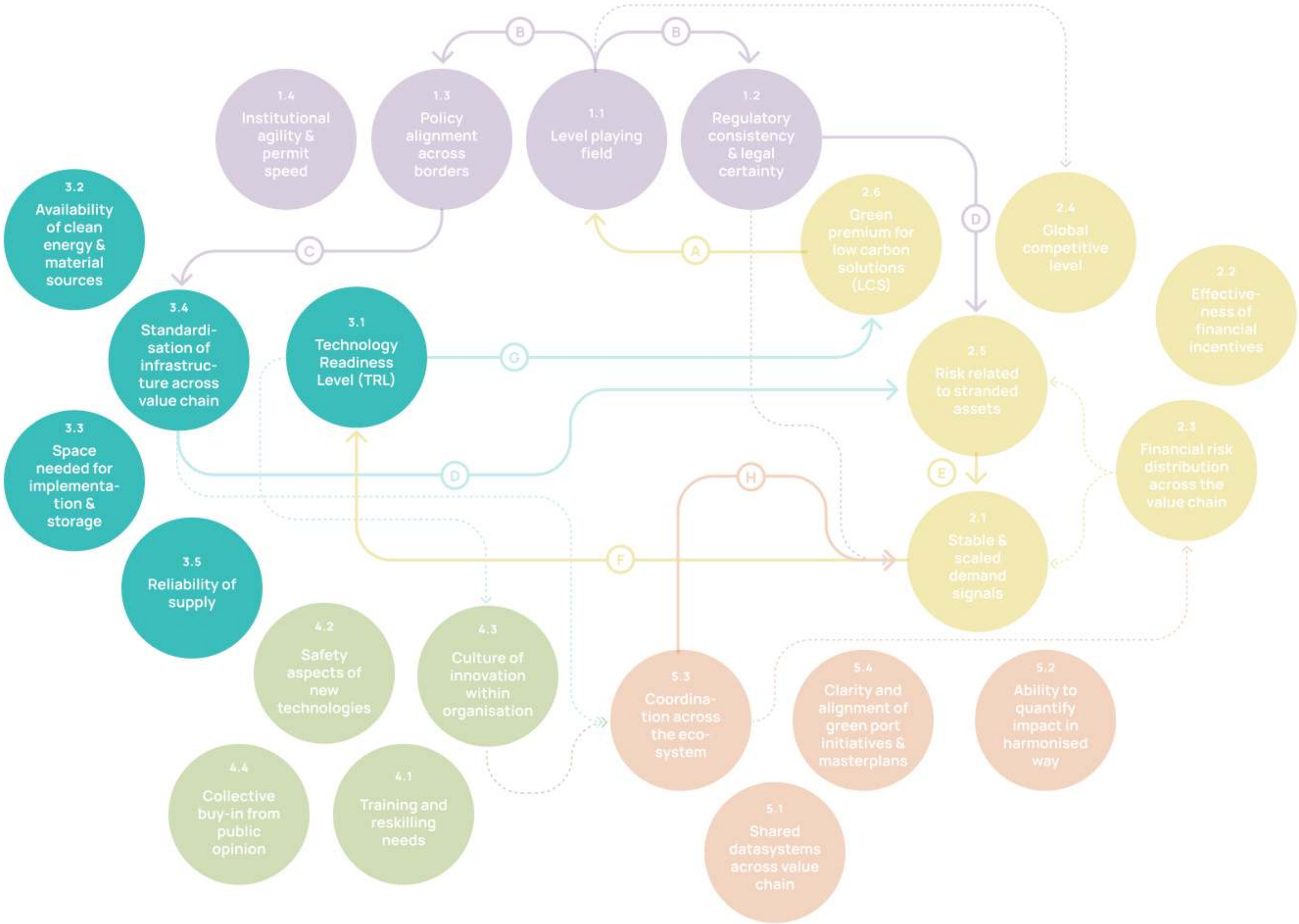
If the Emissions Trading System (ETS)/Extended producer responsibility (EPR) price stays well below the cost of abatement technologies, the effective price signal is weak. This means companies can rationally keep paying for emissions instead of investing in more expensive low-carbon technologies.



03 / Technology, Infrastructure & Operational Readiness

Decarbonisation depends on whether technologies are ready, infrastructure is adequate, and assets can be safely integrated into port operations.

Decarbonisation relies on whether technologies are ready (TRL), compatible with existing port operations, and supported by adequate infrastructure and (upgraded or retrofitted) assets.



3.1 / Technology Readiness Level (TRL)	28
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3.1 / Technology Readiness Level (TRL)

Decarbonisation depends on deploying technologies that are not just theoretically possible but operationally proven at a commercial scale. This leverage cluster addresses the "maturity gap" where critical solutions like hydrogen supply chains, flexible shore power and circular carbon hubs, are stuck in pilot phases. Bridging this gap is essential to move from experimental demonstration to the reliable infrastructure required for a climate-neutral port ecosystem.

KEY CHALLENGE

Many core solutions are still at "semi-mature" stage

Large-scale green hydrogen imports, cracking, multi-fuel bunkering, CCUS chains and large battery systems are all being developed, but are not yet "plug-and-play" at full port scale. Ports are asked to plan around technologies that will only reach semi-maturity ~2030 and beyond.

KEY CHALLENGE

Risk aversion

Businesses are reluctant to swap proven, highly optimized fossil processes for partially tested electrification, hydrogen, or circular solutions unless reliability is guaranteed and costs are competitive. The fear of disrupting continuous high-throughput operations slows the adoption of disruptive green technologies.

KEY CHALLENGE

High complexity for first-of-a-kind projects

Pioneering projects, like early CCUS, multi-fuel terminals or large OPS for container/cruise all require bespoke engineering, bespoke permitting, and complex stakeholder alignment. That slows learning and deployment.

KEY CHALLENGE

Investors favor highly-mature technologies

Technology Readiness Level (TRL) is becoming a decisive factor for financiers. Investors increasingly avoid technologies below TRL 7–8 due to safety, integration, and scale-up risks, preferring solutions with demonstrated operability. This capital flight from semi-mature pathways reinforces a "valley of death," where the promising fuel and energy options that most need investment struggle to access it.

3.2 / Availability of imported clean energy & material sources

Europe lacks sufficient renewable capacity to meet its ecosystem demands. A climate-neutral port cluster therefore depends heavily on large-scale imports of green hydrogen, derivatives (ammonia, methanol), and raw materials. This leverage cluster addresses the strategic risks of relying on immature global supply chains, high-cost emerging markets, and politically volatile sourcing regions to replace fossil fuels.

KEY CHALLENGE

Structural import dependency replacing fossil reliance

Europe does not have enough cheap renewable energy to cover its own electricity + molecule needs. A climate-neutral port cluster will depend on large-scale imports of green hydrogen and derivatives (ammonia, methanol, e-fuels), from regions with abundant sun/wind.

KEY CHALLENGE

Emerging, high-cost global hydrogen market with low realization rates

While the project pipeline for green fuels is large, the actual rate of investment is extremely low (approx. 4% for hydrogen derivatives). Developers face high capital costs and uncertain demand, causing a "standstill" in the scaling of production. Ports are forced to plan infrastructure around a global supply chain that is not yet fully formed or financially closed, keeping green hydrogen costly and scarce.

KEY CHALLENGE

Geopolitical and socio-ecological risks in sourcing regions

Large-scale renewable projects in the Global South or remote coastal regions can create "green colonialism" risks. Issues such as water stress (needed for electrolysis), competition for resources with local domestic needs, and political instability can disrupt supply or create reputational damage for European importers. Ensuring a "just transition" in sourcing regions is critical to prevent future trade barriers or social backlash.

KEY CHALLENGE

The "Midstream Gap" between import carriers and end-use

Importing energy requires complex conversion steps (e.g., cracking ammonia back to hydrogen). There is a disconnect between the carriers easiest to ship (ammonia) and the energy form often needed by industry (hydrogen gas). The lack of mature "midstream" infrastructure—such as crackers, specific import terminals, and connecting pipelines (e.g., Delta Rhine Corridor delays)—creates a bottleneck where imported molecules cannot easily reach the hinterland or end-user.

3.3 / Space needed for implementation & (energy) storage

Ports face severe spatial constraints where every hectare has a high opportunity cost. The transition demands massive footprints for hydrogen storage, battery parks, and circular hubs, competing with core terminal operations. This leverage cluster addresses the strategic trade-offs required to fit a voluminous new energy system into a crowded, contested industrial landscape.

KEY CHALLENGE

Severe space pressure and competing land claims

Every hectare in a dense port is contested. Decision-makers face strategic trade-offs between using land for conventional economic throughput (terminals, logistics) or for essential but space-hungry energy and circular projects (electrolysers, recycling plants, H₂ storage). As renewable energy carriers generally have lower energy density than fossil fuels, the transition requires significantly more physical storage space, creating friction with urban expansion and nature conservation.

KEY CHALLENGE

Operational conflicts and safety zoning

Integrating large-scale energy assets such as wind turbines and ammonia tanks into a crowded landscape creates acute land-use conflicts. Stringent safety zones (e.g., for hazardous fuels like hydrogen or ammonia) and environmental restrictions often render theoretically available land unusable, while opposition from neighbouring communities regarding visual impact or safety risks further restricts site selection.

KEY CHALLENGE

The volumetric density challenge of batteries

While effective for short-sea shipping, ferries, and port equipment, current battery technology remains too voluminous for deep-sea vessels. The low volumetric energy density compared to liquid fuels means that for long-haul voyages, the battery banks required would consume excessive cargo space, rendering the vessel commercially unviable. Ports face uncertainty on how much space to allocate for battery swapping or charging infrastructure versus storage for liquid e-fuels, pending future improvements in cell density.

KEY CHALLENGE

Retrofitting rigid legacy infrastructure

Inserting new energy grids (OPS, heat networks, H₂ pipelines) into existing, fully developed port areas requires complex "brownfield" engineering. Unlike greenfield sites, ports must navigate a maze of existing underground pipes and cables. The lack of standardised layouts means every retrofit is a bespoke, resource-intensive project, often requiring downtime that operators cannot afford, further complicating spatial planning.

3.4 / Standardisation of infrastructure across the value chain

Decarbonisation is stifled by a lack of common technical and operational standards, not just within a single port, but critically across the global trade routes that vessels traverse. From voltage frequencies for shore power to safety protocols for new fuels, the current landscape is fragmented. This leverage cluster focuses on harmonising infrastructure, data, and contractual templates to ensure "plug-and-play" interoperability. Without this alignment, a ship equipped for zero-emission operations in one region may be technically incompatible with the next port of call, effectively breaking the Green Corridor.

KEY CHALLENGE

Interoperability gaps along Green Corridors

Shipping is inherently global, yet infrastructure standards often remain local. For example, Onshore Power Supply (OPS) systems may vary in voltage and frequency (e.g., 50Hz versus 60Hz) between regions, forcing vessels to carry expensive, space-consuming transformers to connect at different ports. If infrastructure along a designated "Green Corridor" is not technically aligned, ships cannot operate seamlessly, turning potential green routes into a series of disconnected islands.

KEY CHALLENGE

Case-by-case engineering for OPS and grids

Each quay often possesses a unique layout, crane set-up, and load profile. Without standardised connection designs (e.g., plug types, cable management), OPS and grid upgrades become expensive "one-off" projects rather than replicable modules. This lack of uniformity significantly increases capital costs and engineering time for every new installation and complicates the retrofit process for vessels.

KEY CHALLENGE

Lack of standardisation slows scale-up

Divergent safety distances for hydrogen or ammonia bunkering, differing operational protocols, and non-aligned data reporting systems (IoT, MRV, GHG protocols) create systemic friction. This fragmentation prevents "plug-and-play" adoption, meaning equipment or fuels certified in one jurisdiction may face regulatory or technical barriers in the next, delaying the rollout of alternative fuels.

KEY CHALLENGE

Ports forced into custom engineering and custom contracts

For multi-fuel bunkering, CO₂ handling, or industrial heat networks, few off-the-shelf commercial or technical "templates" exist. Ports, DSOs, and terminal operators are forced to negotiate technical specifications and liability contracts from scratch for every project. This consumes scarce administrative capacity and delays investment for critical infrastructure.

3.5 / Reliability of supply

Decarbonisation hinges on the consistent availability of green electrons and molecules. This leverage cluster addresses the fragility of new energy supply chains, where grid congestion, intermittent renewables and uncertain fuel production volumes threaten business continuity. Without guaranteed reliability, ports and industries cannot retire fossil-based systems that currently ensure 24/7 operational stability.

KEY CHALLENGE

Grid capacity, timing and flexibility are major bottlenecks

Electrification of terminals, industry and ships requires huge additional grid capacity. Long lead times for studies, cables, transformers and interconnectors, plus complex TSO/DSO coordination make it hard to promise firm power to new users.

KEY CHALLENGE

Intermittency of renewables and lack of flexible contracts

Ports need stable, affordable power; markets increasingly offer volatile prices and complex arrangements. Regulatory frameworks are not yet fully adapted to flexible or partial capacity connections (e.g., OPS that doesn't always use its maximum rating).

KEY CHALLENGE

Uncertain long-term availability of green fuels

For hydrogen, ammonia, methanol, etc., both supply and offtake are still fragile. Midstream infrastructure (terminals, pipelines) won't be built without confidence in both ends of the chain. That keeps the whole system in a "wait and see" mode.

KEY CHALLENGE

Lack of flexible "Chain of custody" models

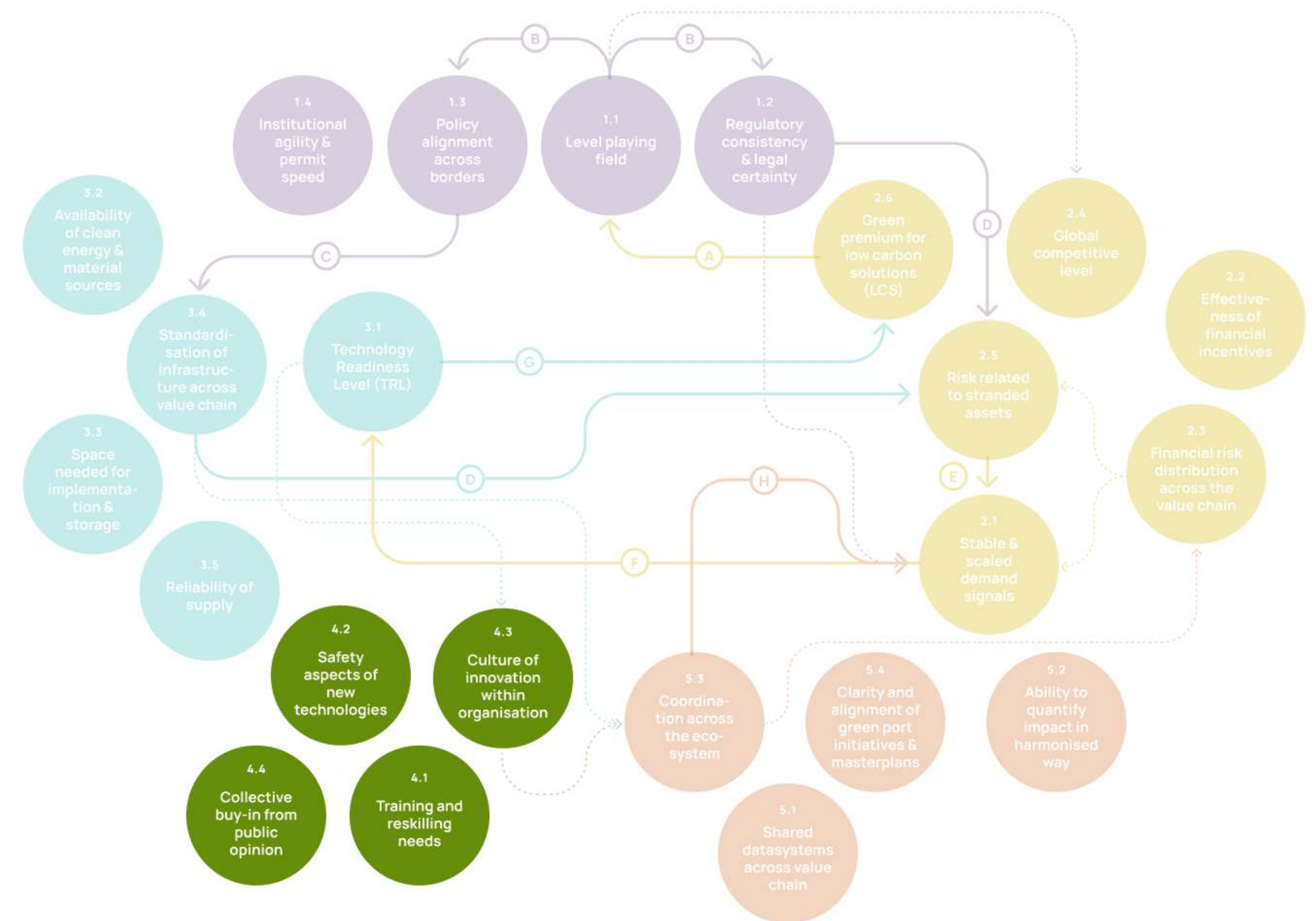
The reliability of delivering low-carbon fuels is hampered by rigid tracking requirements. Without flexible "Chain of custody" models (like mass balancing or book-and-claim), new fuels like hydrogen derivatives often require dedicated transport and storage infrastructure. This inability to co-mingle green molecules significantly increases the cost and complexity of ensuring a reliable supply to the end-user.



04 / Social & Ecological Context

Innovation capabilities, community trust, workforce readiness, and ecological responsibility shape whether ports can deploy new systems without facing social or environmental backlash.

Ports operate within sensitive ecological and social environments. Decarbonisation must address community expectations, environmental pressures, and the need for skilled workers, both the technical knowledge as the ability to deal with change management. Training, reskilling, community engagement, and managing ecological impacts all influence how smoothly ports can adopt new systems and technologies.



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4.1 / Training and reskilling needs

This leverage cluster addresses the widening gap between the current workforce's capabilities and the specialised demands of new technologies. As ports pivot to hydrogen, electrification, and circularity, they face a dual challenge: rapidly upskilling existing employees to handle new technologies while simultaneously attracting a new generation of technical talent in a fiercely competitive labor market. Without a strategic overhaul of education and recruitment, human capital risks becoming the primary bottleneck in deploying green infrastructure.

KEY CHALLENGE

Structural skills gap for new green roles

Handling hydrogen, ammonia, high-voltage systems, and complex battery logistics requires specialised competencies that the current workforce only partially possesses. The need for retraining is growing faster than training capacity, creating a persistent skills gap. Furthermore, high financial costs for mandatory reskilling programs can strain budgets, potentially undermining training quality and leaving organisations paying more without fully closing the competence deficit.

KEY CHALLENGE

Scarcity of specialised industrial know-how

There is a critical shortage of specialised expertise in the wider market, particularly for engineering grid upgrades and fuel systems. This scarcity often leads to failed or delayed tenders because there are insufficient capable suppliers to execute complex projects. This supply-side bottleneck discourages new entrants and perpetuates the shortage of necessary industrial skills, slowing down project implementation.

KEY CHALLENGE

Competition for STEM talent with the digital sector

Ports compete for the same limited pool of STEM talent as the digitalization, AI, and software sectors, which are often perceived as more modern, flexible, and lucrative. This "war for talent" creates a structural shortage, slowing the uptake of new energy systems and forcing early movers to pay a premium to attract the scarce expertise needed for the green transition.

KEY CHALLENGE

Weak long-term talent pipeline and educational alignment

Initiatives to reposition ports as attractive, high-tech workplaces for children and adolescents — such as school visits and STEM workshops— are often fragmented, underfunded, or dependent on individual leaders. This lack of scale and consistency makes it difficult to build a sustained long-term pipeline of certified electricians, safety specialists, and alternative-fuel operators, leaving ports vulnerable to chronic future shortages.

4.2 / Safety aspects of new technologies

The transition to electrification and new fuels is constrained by high perceived operational risk. Hydrogen, ammonia, and high-energy batteries introduce new risks—ranging from toxicity to thermal runaway. This leverage cluster addresses the need to mature safety protocols and build workforce confidence to prevent risk aversion from stalling adoption.

KEY CHALLENGE

Fragmented safety standards create operational friction

Current safety rules for hazardous fuels are often evolving or vary by jurisdiction. Different interpretations of safety distances, zoning, and bunkering protocols across ports create uncertainty. Without harmonised standards—such as defined safety envelopes for ammonia bunkering—organisations remain reluctant to scale beyond small pilots, fearing that vessels compliant in one port, may be deemed unsafe in another.

KEY CHALLENGE

The "competence gap" for handling invisible and toxic hazards

Unlike oil, new fuels present invisible or acute threats: methanol burns with a nearly invisible flame, ammonia is highly toxic even at low concentrations, and lithium-ion batteries carry risks of thermal runaway. The maritime workforce currently lacks the specialised skills to manage these specific risks, and the availability of standardized training packages (e.g., under STCW) lags behind technology deployment, keeping qualification rates critically low.

KEY CHALLENGE

"Bad image" myths and public resistance block infrastructure

Public and organisational perception is often driven by historical myths (e.g., the "Hindenburg effect" for hydrogen) or fear of toxic leaks near populated areas. This skepticism leads to reluctance to work with these new technologies and to "NIMBY" (Not In My Backyard) dynamics, where local communities and regulators oppose necessary infrastructure like storage tanks or bunkering stations due to perceived rather than actual technical risk.

KEY CHALLENGE

Reactive learning loops versus proactive risk benchmarking

The industry currently risks relying on "learning through failure," where significant investment in safety procedures often follows incidents rather than anticipation. A lack of independent, credible risk benchmarking—comparing new fuels against the accepted historical safety record of conventional oil—sustains a bias against new technologies, forcing operators to prove safety from scratch for every project rather than relying on established safety cases.

4.3 / Culture/ knowledge of innovation within the organisation

Organisational inertia and risk aversion often stifle the transition. This leverage cluster addresses the internal barriers such as heavy compliance burdens and siloed thinking that prevent the adoption of disruptive technologies. Without a shift toward systems thinking and iterative learning, innovation remains trapped in isolated pilots rather than driving core business transformation

KEY CHALLENGE

The Compliance Drag

High administrative and reporting burdens pull specialised engineers and experts away from R&D and system innovation. This resource drain leaves less time for experimentation, leading to fewer breakthroughs that could simplify operations. This creates a vicious cycle where compliance stifles the very innovation needed to solve long-term operational complexity.

KEY CHALLENGE

Lack of structured innovation processes and system thinking

Many organisations lack structured innovation processes and "system thinking" capabilities. This reduces cross-cluster cooperation and sector coupling, reinforcing the perception that integrated solutions (e.g., shared energy or material flows) are "too complicated." Consequently, firms retreat to siloed approaches rather than realizing the benefits of shared infrastructure.

KEY CHALLENGE

Risk aversion and resistance to innovation

Risk aversion reduces the appetite for radical innovation, favoring incremental adjustments over necessary transformation,.

KEY CHALLENGE

The "Pilot Trap"

The pilot trap erodes innovation confidence. "One-off" pilots that never scale or connect to corporate strategy erode confidence in innovation efforts. When experiments fail to feed into systematic learning or portfolio steering, the prevailing narrative becomes "innovation is expensive and doesn't create value."

4.4 / Collective buy-in from public opinion

Public opinion acts as a powerful gatekeeper for the transition. Without visible local benefits, a clear sense of urgency, robust risk communication, and genuine co-creation, technically sound but controversial infrastructure —such as nuclear power— risks being delayed or blocked by community resistance and entrenched scepticism.

KEY CHALLENGE

Entrenched scepticism toward high-risk technologies

Some technologies, especially new nuclear options or high-risk fuels, face entrenched public scepticism. Low public acceptance for nuclear, for example, undermines political consensus on its role in the energy mix, reinforcing a stalemate where neither nuclear nor 100% renewable alternatives are scaled fast enough.

KEY CHALLENGE

Local resistance to energy infrastructure

If the sense of urgency for the green transition isn't clear, local communities can also oppose new energy or bunkering infrastructure (tanks, pipelines, terminals), often due to safety, visual and environmental concerns. Community resistance slows projects via appeals, political pressure, and reputational risk, generating measurable revenue losses for ports and concessions

KEY CHALLENGE

Tension between legacy remediation and new disruption

There is a tension between addressing legacy pollution and enabling new infrastructure. High external health/environmental costs from current operations drive new regulations and mandated clean-up, yet some clean-up/remediation approaches can generate additional GHG emissions or disrupt local ecosystems if not designed carefully (External Cost and Action Cycle). This can undermine public trust in the “green transition” if people see more disruption than benefit.

KEY CHALLENGE

Perception of “all cost, no benefit” for locals

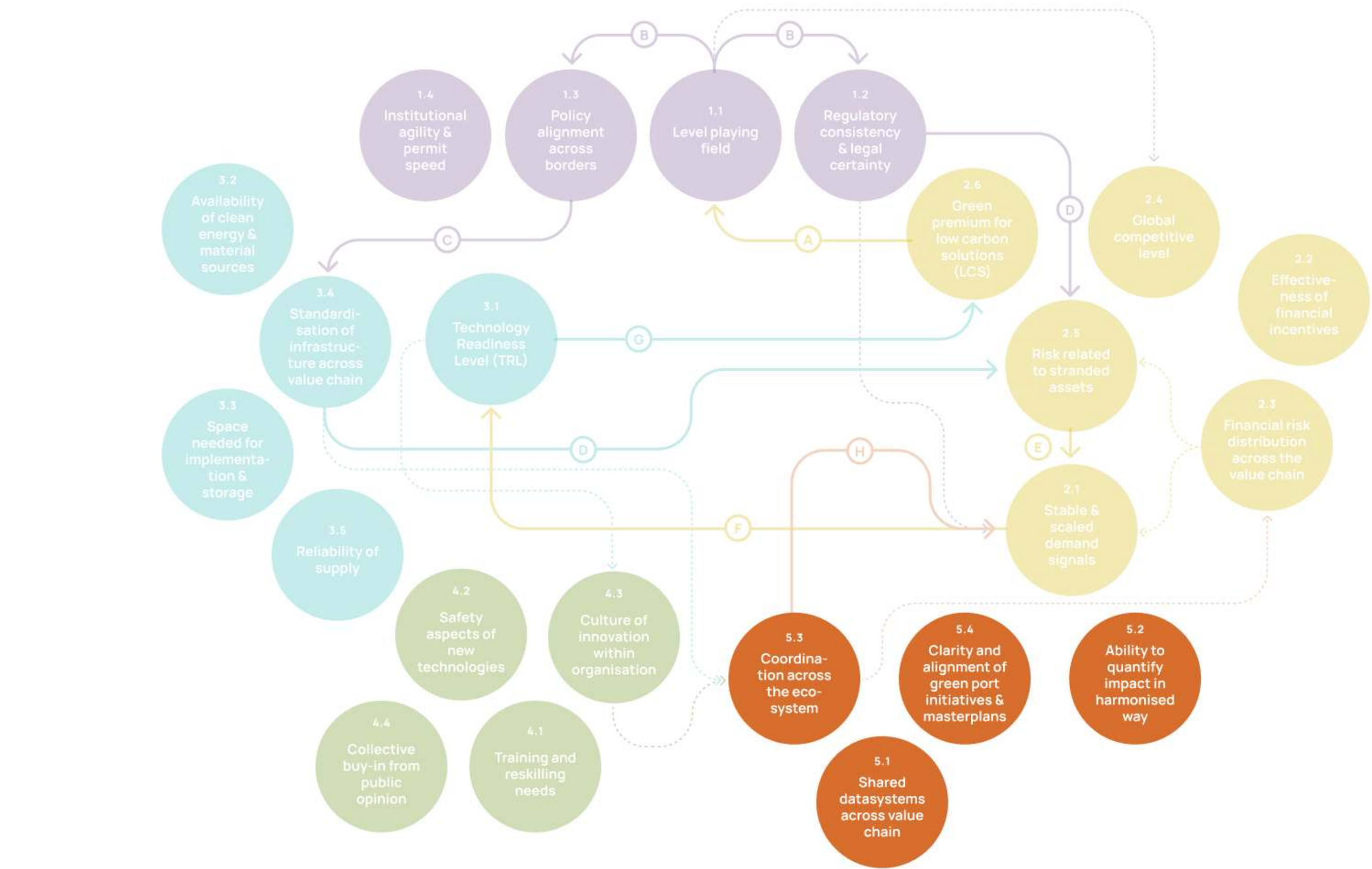
Without visible local co-benefits —such as improved air quality, new jobs, or nature restoration— citizens often experience only the downsides of decarbonisation (construction noise, disruption, perceived safety risks). When the benefits are not tangible or well-communicated, the public narrative shifts toward resistance, blocking essential projects even when they are technically sound.



05 / Planning, Coordination & Data

Synchronised roadmaps and transparent, interoperable data systems allow actors to align timelines, prevent stranded assets, and scale collectively.

Ports sit at the centre of complex, interdependent value chains, where decarbonisation depends on synchronised planning between shipowners, fuel suppliers, grid operators, terminal operators, and regulators. Achieving this requires shared long-term roadmaps, aligned investment timelines, and coordinated decisions on fuels, infrastructure, and energy demand. Equally important is the ability to share reliable, interoperable data across actors: without transparent emissions data, real-time operational insights, standardised metrics, or digital tools like digital twins and joint dashboards, ports cannot accurately forecast needs, measure progress, or prevent stranded assets. Effective decarbonisation therefore relies on both cross-actor coordination and a trusted data ecosystem that supports collective planning and continuous optimisation.



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5.1 / Shared data systems across value chain

Effective decarbonisation relies on a trusted data ecosystem that supports collective planning and continuous optimisation. This leverage cluster addresses the fragmentation of proprietary platforms and the lack of interoperability that currently prevents real-time visibility into energy demand, emissions, and cargo flows. Without a unified digital architecture, the ecosystem remains blind to system-wide inefficiencies.

KEY CHALLENGE

Fragmented, proprietary platforms

Terminal operators, shipping lines, hinterland logistics and energy suppliers often use incompatible, closed systems. This fragmentation makes it hard to build shared situational awareness on flows, congestion, energy demand and emissions, and pushes everyone back into bilateral Excel/email coordination.

KEY CHALLENGE

Low incentives to share commercially sensitive data

Many actors fear loss of competitive advantage or antitrust issues if they open up operational or cost data. Without strong governance and clear value propositions, the default is data hoarding rather than sharing.

KEY CHALLENGE

Lack of common data standards and APIs

Different formats, semantics and update frequencies mean that even when data is technically shared, it's not always clean or carefully curated, nor is it interoperable. This limits the usefulness of digital twins, corridor optimisation tools and cross-port platforms.

KEY CHALLENGE

Digital maturity gaps between ports and actors

Some major ports have advanced digital twins and data teams, while smaller ports and SMEs lack basic digitalisation. This asymmetry makes it hard to create shared tools that work across the ecosystem.

5.2 / Ability to quantify impact in harmonised and reliable way

Ports lack a common language for success. This leverage cluster focuses on establishing harmonised metrics and reliable data verification to move from fragmented estimates to trusted, actionable insights. Without a unified "ruler" for emissions and impact, the ecosystem cannot validate investments, prove compliance, or steer the transition effectively.

KEY CHALLENGE

Non-harmonised GHG accounting and boundaries

Different actors and ports use different scopes, methodologies and baselines, making results hard to compare. This weakens trust in reported impacts and complicates joint target-setting or corridor-wide KPIs.

KEY CHALLENGE

Data quality and verification gaps

Incomplete, inconsistent, or unverified data (fuel use, load factors, hinterland modes, etc.) reduces confidence in models and dashboards. Without credible MRV (Monitoring, Reporting, and Verification of GHG emissions), it's hard to justify large investments or prove compliance.

KEY CHALLENGE

High cost for complex measurement schemes

Complex MRV (Monitoring, Reporting, and Verification of GHG emissions) schemes and certification requirements can make high-quality measurement costly, especially for smaller players. This pushes some actors to default to crude estimates or minimum compliance instead of granular, decision-useful data.

KEY CHALLENGE

Weak feedback loops from monitoring to decision-making

Even where indicators exist, they're not always embedded in governance (e.g., portfolio steering, masterplan updates). Measurement becomes a reporting exercise rather than an active steering tool.

5.3 / Coordination across the ecosystem

Decarbonisation requires synchronized action across a complex web of independent actors. This leverage cluster addresses the structural fragmentation where port stakeholders currently operate in silos. Without a shift from temporary, ad-hoc projects to permanent, structural governance, the ecosystem cannot align the investment timelines or share the risks necessary to build shared infrastructure like heat networks, hydrogen hubs, or green corridors.

KEY CHALLENGE

Project-based collaboration instead of structural governance

Many initiatives (corridors, pilots, consortia) are temporary and personality-driven. When projects end or people move, coordination evaporates; there's no permanent structure to carry joint planning forward.

KEY CHALLENGE

Misaligned planning horizons and investment cycles

Shipowners, ports, fuel suppliers, grid operators and cargo owners all plan on different timescales and risk profiles. Without deliberate alignment, infrastructure can arrive too early, too late or in the wrong configuration, creating stranded or underused assets.

KEY CHALLENGE

Siloed optimisation within organisations

Each actor optimises for its own KPIs (throughput, cost, reliability) rather than system-level emissions or energy efficiency. This erodes the business case for shared infrastructure (CCUS hubs, heat networks, multimodal shift) that requires coordinated commitment.

KEY CHALLENGE

Limited neutral facilitation capacity

Ports are expected to act as neutral conveners, but may lack mandate, staffing or tools to meaningfully orchestrate multi-actor planning across the whole ecosystem, especially across borders.

5.4 / Clarity and alignment of green port initiatives and masterplans

Port masterplans need to provide the long-term certainty that investors and stakeholders require. While energy and infrastructure transitions play out over decades, port planning often remains trapped in short-term cycles. This leverage cluster focuses on bridging the gap between static, high-level visions and the dynamic, long-term steering required to synchronize investments across the ecosystem.

KEY CHALLENGE

Short business plans versus long asset lifetimes

Many ports still work with 3–5 year business plans, while energy and infrastructure transitions play out over 20–30 years. This misalignment leads to reactive rather than anticipatory planning.

KEY CHALLENGE

Inconsistent ambition and scenarios between ports

Different ports adopt different decarbonisation targets, fuel bets and growth assumptions. Without shared vision and future scenario frameworks, it's hard to coordinate corridor investments or avoid duplicative/contradictory infrastructure choices.

KEY CHALLENGE

Weak links between masterplans and implementation portfolios

Even where green masterplans exist, they're not always backed by structured portfolio management, KPI tracking and regular revision. Plans can become static documents rather than living instruments for steering investments.

KEY CHALLENGE

Limited transparency between ports

Ports don't consistently share their masterplan assumptions, capacity trajectories, or key decisions with other (competitor) ports. This opacity hampers cross-port alignment, especially along shared trade routes or hinterland corridors.

What can you do as a port authority?

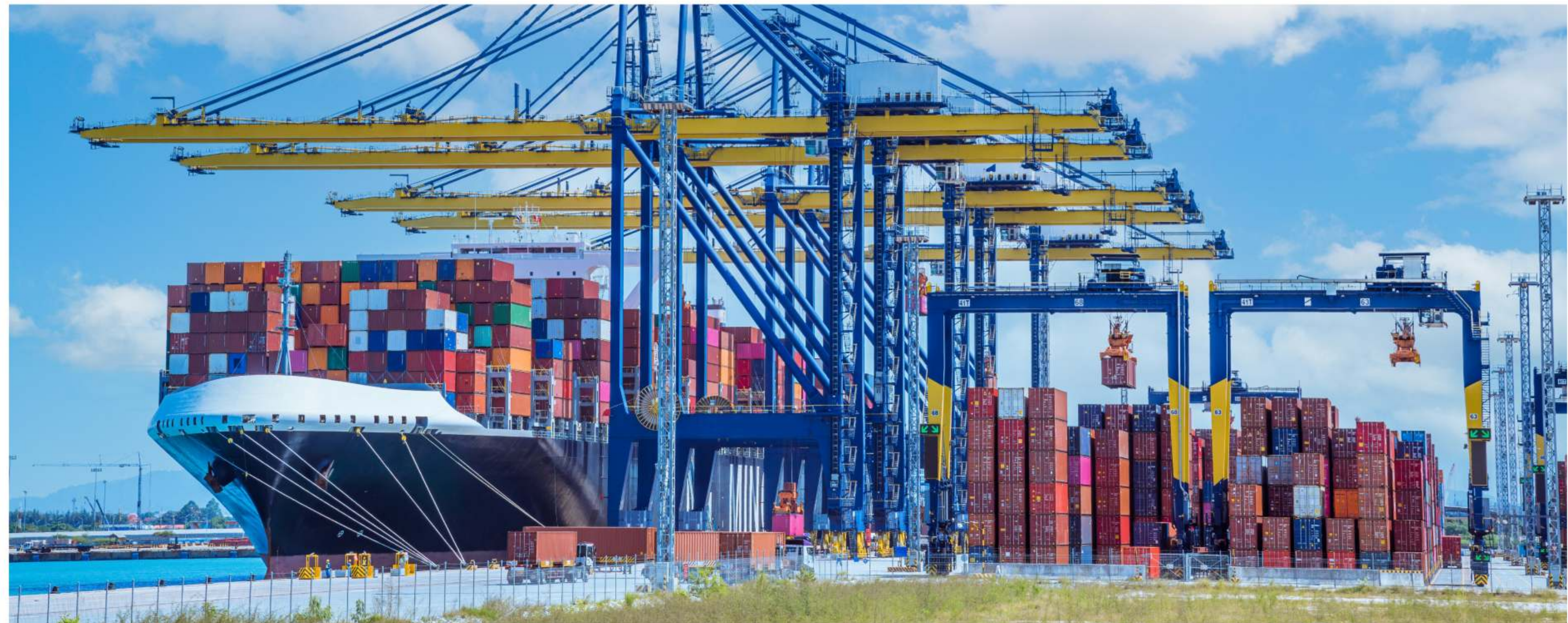
The path to a climate-neutral port does not follow a straight line from ambition to implementation. Between the two lies a system of interconnected forces and self-sustaining dynamics that together determine whether decarbonisation accelerates or stalls. The Green Ports Systems Map makes these forces visible.

Understanding these forces and dynamics is a precondition for effective action. Without it, interventions risk addressing symptoms while leaving the underlying structure intact.

The systems map also reveals where action matters most. Not every variable in the system carries equal weight, and not every actor has the same leverage.

A port authority sits at a unique intersection in this system. It cannot set carbon prices, dictate global shipping standards, or control geopolitical energy markets. But it can shape the local conditions that determine whether the broader system tips toward transition or remains locked in hesitation.

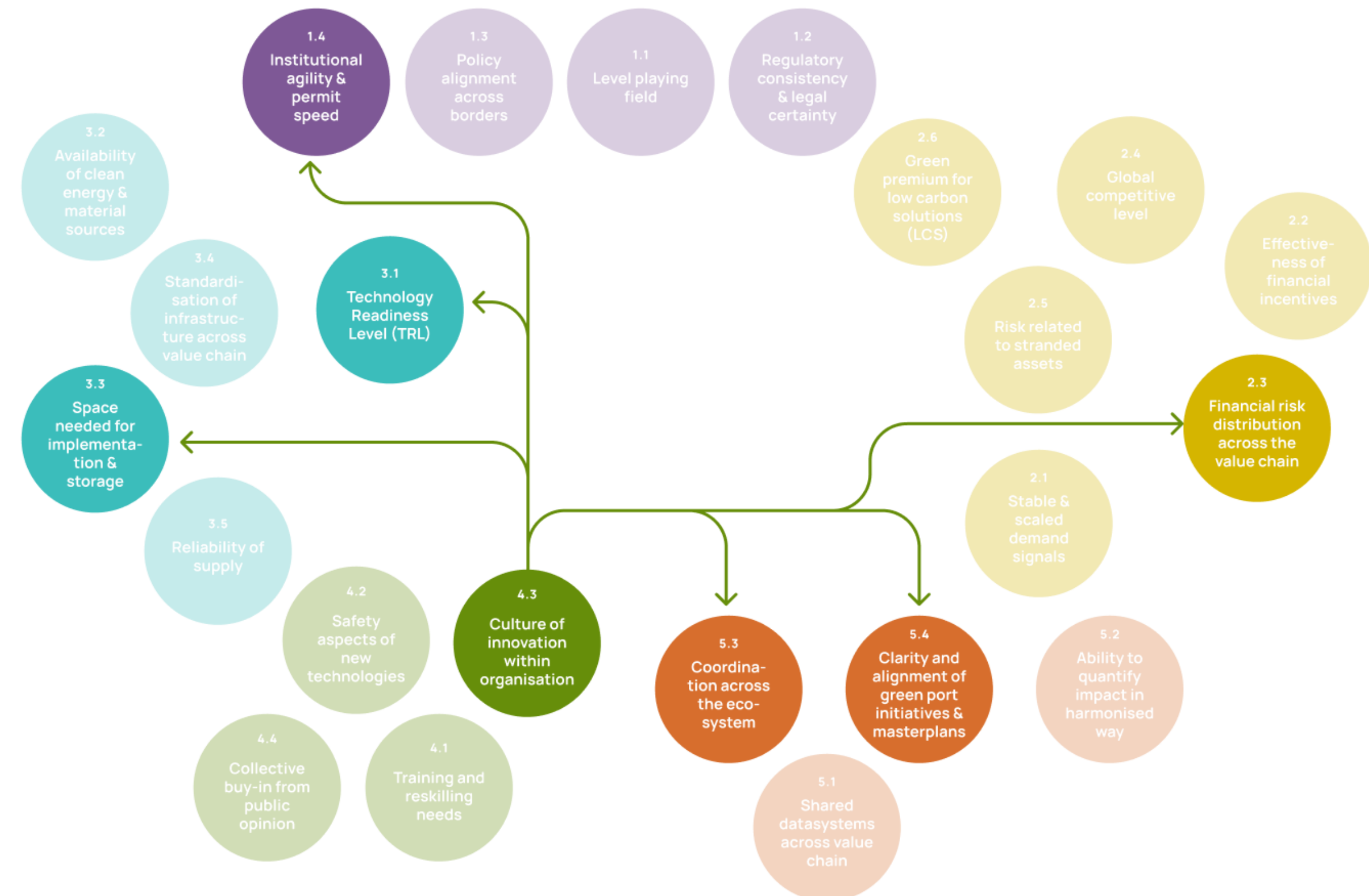
The interventions that follow are grounded in the causal architecture of the map: they target the specific points where port authority action has the highest probability of shifting feedback loops from vicious to virtuous.



Create the conditions

What if we used our landlord and regulatory authority to accelerate innovation?

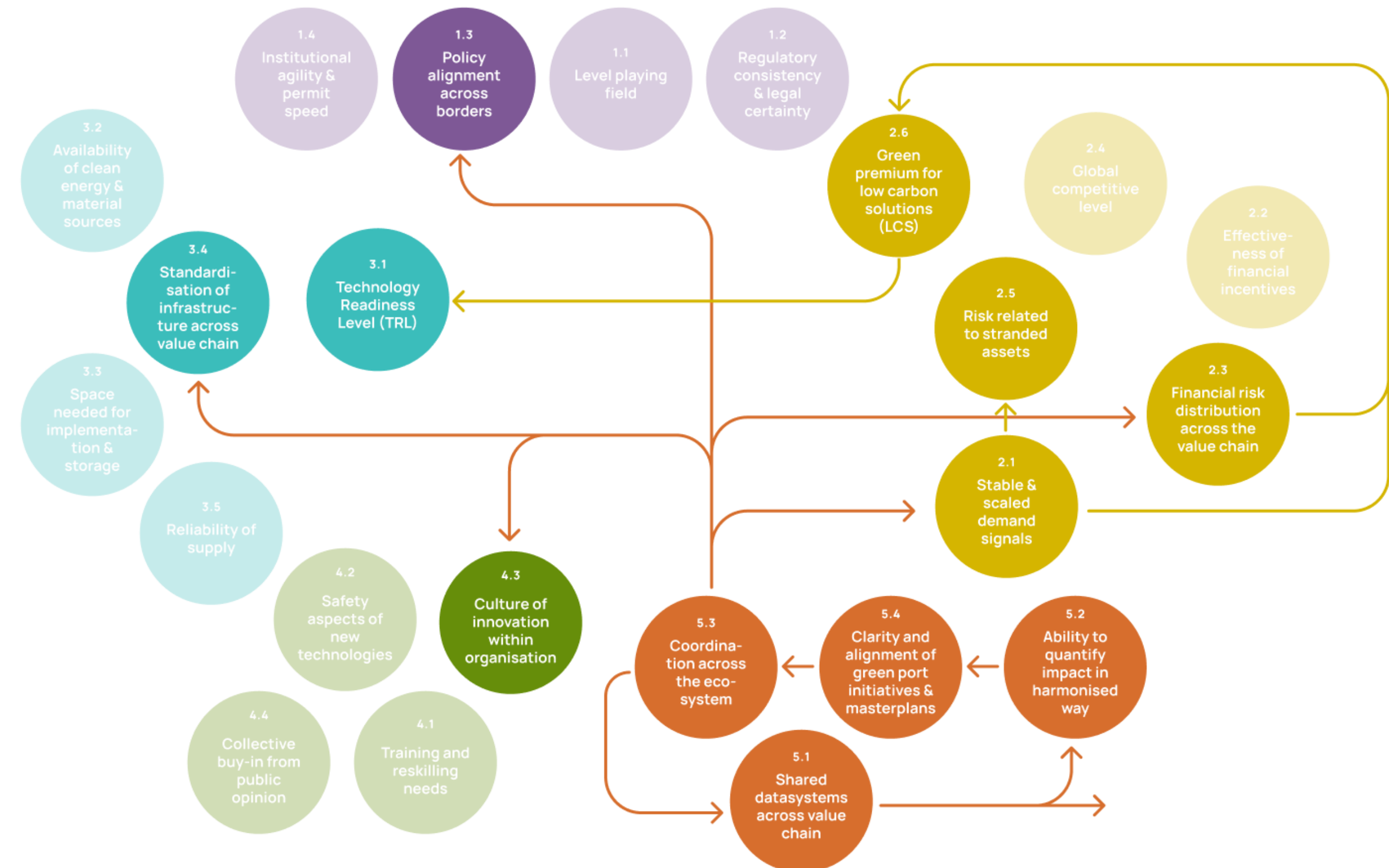
Make it easy, fast, and predictable for companies to deploy green solutions in your port. Provide the physical space, help remove administrative friction and serve as an open innovation platform or testbed.



Build the coalition

What if we used our convening power to orchestrate collective action across the value chain?

No single actor can decarbonize alone. Bring fuel suppliers, terminals, logistics operators, shipping lines, grid operators, and other important stakeholders and ports to the table. Make coordination across the ecosystem happen.



Shape the playing field

What if we used our credibility as a (semi-)public entity to advocate for policy conditions that enable the transition?

Use your voice, your data, and your legitimacy to push for systemic change at EU and national level.

