

Supplementary Material

Manuscript: Leveraging artificial intelligence for sustainable development and policy integration in the shipping industry



This page constitutes the Supplementary Material accompanying the manuscript. It reports the operational sustainability concept dictionary, detailed analytical outputs, clustering information, reproducibility settings, and supporting methodological notes referenced from the main text.

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Supplementary Table S1 — Operational sustainability concept dictionary

Methodological note

Concept detection is conducted across the combined **Title, Abstract, Author Keywords, and Index Keywords** fields. Text is normalized for case and common typographic variants before matching. Terms are identified using whole-word or whole-phrase matching as appropriate. Multiple occurrences of a term within the same bibliographic record do not increase the concept count; each record is counted at most once per concept. Concept categories are non-mutually exclusive, allowing a single publication to be associated with multiple sustainability concepts.



Operational dictionary note: the original keyword/regex implementation file was not retained. The Supplementary Material therefore reports the fully specified operational dictionary used to generate the concept-level results presented in the manuscript. The matching rules were applied consistently across all three corpora and include explicit contextual exclusions where required.

Operational concept rows — fuel-specific categories

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
Hydrogen	hydrogen; H ₂ ; H2	Case-insensitive whole-word/token matching after text normalization	H ₂ standardized to H2; no additional exclusion required
Ammonia	ammonia; NH ₃ ; NH3	Case-insensitive whole-word/token matching after text normalization	NH ₃ standardized to NH3; no additional exclusion required
Methanol	methanol; methyl alcohol	Case-insensitive whole-word or complete-phrase matching	No additional exclusion required
LNG	LNG; liquefied natural gas	Case-insensitive standalone acronym or complete-phrase matching	Generic “natural gas” alone is not sufficient for classification

Operational concept rows — contextual categories

The following four operational definitions were applied consistently across all three corpora. Unlike the fuel-specific rows above, these categories require contextual exclusions to reduce obvious false-positive classifications.

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
Hybrid	hybrid propulsion; hybrid-electric propulsion; hybrid electric propulsion; hybrid propulsion system(s); battery-hybrid electric propulsion; diesel-electric hybrid propulsion; hybrid-powered ship/vessel; hybrid power ship/vessel; marine hybrid vessel; hybrid mechanical-electrical propulsion/system	Case-insensitive whole-phrase matching after hyphen/spacing normalization. Generic “hybrid” alone is not sufficient.	Exclude uses of “hybrid” that refer only to algorithms, modelling approaches, optimization methods, materials, robots, or other non-propulsion/non-shipboard-energy applications.

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
Wind assist	wind-assisted; wind assist(ed); wind propulsion; wind-powered propulsion; rotor sail(s); Flettner rotor(s); kite propulsion; kite sail(s); wing sail(s); rigid sail(s); soft sail(s); suction wing(s)	Case-insensitive whole-word/phrase matching with hyphen and spacing variants normalized.	Exclude generic offshore wind, wind-energy, wind-farm, and wind-turbine references unless the record explicitly concerns ship propulsion or wind-assistance technology.
Renewables	renewable energy/energies; renewable source(s); renewable resource(s); renewable electricity; renewable power; renewable fuel(s); renewables; solar energy/power; photovoltaic; bioenergy; biomass energy; wave energy; tidal energy; wind energy; wind-power generation; offshore wind energy/power	Case-insensitive whole-word/phrase matching; singular/plural and common hyphen/spacing variants accepted.	Generic “green”, “clean”, or “sustainable” terminology alone is not sufficient. Wind-propulsion terminology is classified under Wind assist unless a renewable-energy-generation expression is also present; categories remain non-mutually exclusive.
Noise	underwater noise; underwater radiated noise; radiated noise; cavitation noise; propeller noise; propeller-induced noise; ship/vessel/machinery noise; structure-borne noise; flow noise; noise pollution; acoustic noise/emission/signature/radiation/pressure/power; sound pressure level; sound radiation; radiated sound; hydroacoustic/hydro-acoustic; vibroacoustic/vibro-acoustic	Direct phrase matching is used for the listed expressions. Generic “noise” is accepted only when it occurs in the same sentence or keyword phrase as a clearly relevant maritime/acoustic source term such as propeller, cavitation, underwater, ship, vessel, marine, machinery, engine, hull, vibration, radiated, or sound.	Exclude statistical, sensor, image-processing, communication-channel, and optimization “noise”, and generic acoustic sensing/localization uses where environmental or mechanical sound/noise is not the subject.



Full-corpus counts: Hybrid = 17/298/8, Wind assist = 11/241/14, Renewables = 255/434/45, and Noise = 126/864/9 for Marine Technology / Ship Propulsion / Policy-Oriented records, respectively.

Operational concept rows — lifecycle, safety, policy, and AI/ML

These four operational definitions were applied consistently across all three corpora, with contextual exclusions specified to reduce obvious false-positive classifications.

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
Lifecycle/LCA	life cycle; life-cycle; lifecycle; LCA; well-to-wake; well to wake; WTW; cradle-to-grave; cradle-to-gate	Case-insensitive whole-word or complete-phrase matching after normalization of hyphen and spacing variants. LCA and WTW are matched as standalone tokens.	Generic use of “cycle” alone is excluded. Well-to-tank or tank-to-wake terminology is not sufficient unless a lifecycle/LCA or well-to-wake expression is also present.
Safety/risk	safety; risk; risks	Case-insensitive whole-word matching. Hyphenated forms such as safety-critical and risk-based are captured through whole-word boundaries.	Generic statistical uncertainty is not classified unless the record explicitly uses the term risk. The category is intentionally broad because operational, environmental, technological, and policy risks are all relevant to maritime sustainability.
Policy/regulation	policy; policies; regulation; regulations; regulatory; governance; legislation; compliance; IMO; MARPOL	Case-insensitive whole-word/token matching. IMO and MARPOL are matched as standalone acronyms. Common technical-control phrases such as voltage regulation, speed regulation, frequency regulation, pressure regulation, temperature regulation, power regulation, current regulation, load regulation, torque regulation, excitation regulation, and flow regulation are removed before applying the regulation-family match.	Pure control-engineering uses of “regulation” are excluded where they refer only to physical or electrical control variables. Policy, governance, legislation, compliance, IMO, and MARPOL references are accepted directly.
AI/ML	artificial intelligence; machine learning; deep learning; neural network(s); reinforcement learning; AI; ML	Full expressions are matched case-insensitively as whole phrases. AI and ML are matched only as standalone uppercase acronyms in the original, non-lowercased text to reduce accidental matches.	Generic uses of letter sequences “ai” or “ml” inside longer words are excluded. Individual algorithms such as support-vector machines or random forests are not sufficient unless an explicit AI/ML expression is also present.



Full-corpus counts: Lifecycle/LCA = 50/202/19, Safety/risk = 637/1,142/42, Policy/regulation = 522/923/320, and AI/ML = 269/383/28 for Marine Technology / Ship Propulsion / Policy-Oriented records, respectively. Policy/regulation occurs in all 320 Policy-Oriented records, consistent with the construction and terminology of that corpus.

Operational concept rows — emissions, efficiency, alternative fuels, and electrification

These final four definitions complete the 16-category operational dictionary and were applied consistently across all three bibliographic corpora.

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
Emissions/CO₂	emission(s); CO ₂ /CO ₂ ; carbon dioxide; greenhouse gas(es); GHG/GHGs; carbon emission(s); zero-emission/zero emissions; decarbonization/decarbonisation; decarbonize/decarbonise and grammatical variants	Case-insensitive whole-word/phrase matching after normalization of CO ₂ to CO2 and common hyphen variants. Specific climate/emissions expressions are matched directly. Generic emission/emissions terms are retained after removing clearly non-environmental phrases.	Exclude clearly non-environmental uses such as acoustic emission, sound/noise emission, thermal emission, electron emission, electromagnetic/light emission, radiation emission, and photoemission when no environmental-emissions expression is otherwise present. Generic “carbon”, “pollution”, or “exhaust” alone is not sufficient.
Energy efficiency	energy efficiency; energy-efficient; fuel efficiency; fuel-efficient; energy saving/savings; specific fuel consumption; SFC; propulsive efficiency; propulsion efficiency; thermal efficiency	Case-insensitive whole-word/phrase matching; hyphen and spacing variants are normalized. SFC is treated as a standalone token.	Generic “efficiency” alone is excluded because it may refer to numerical, algorithmic, hydrodynamic, or other performance measures unrelated to energy use. Generic energy/fuel consumption is not sufficient without an efficiency-, saving-, or specific-fuel-consumption expression.
Alternative fuels	alternative fuel(s); low-carbon fuel(s); zero-carbon fuel(s); carbon-neutral fuel(s); sustainable fuel(s); green fuel(s); e-fuel(s); electrofuel(s); synthetic fuel(s); biofuel(s); bio-fuel(s); biodiesel; biomethane; bio-methane; renewable fuel(s)	Case-insensitive whole-word/phrase matching with common hyphen and spacing variants normalized.	Generic “fuel” alone is excluded. Hydrogen, ammonia, methanol, and LNG do not automatically trigger this category merely because they are present; those fuels have separate concept categories. A record is additionally assigned to Alternative fuels only when an alternative-/low-carbon-/bio-/synthetic-/renewable-fuel expression is present.
Electric/battery	electric propulsion; electrical propulsion; battery-electric; battery propulsion; battery-powered ship/vessel; electrification; electrified propulsion; all-electric ship/vessel/propulsion; electric ship(s); electric vessel(s); electric drive(s); electric powertrain(s); battery energy-	Case-insensitive whole-word/phrase matching after normalization of hyphen and spacing variants. Electric/electrical terms are matched only in propulsion, vessel, drive, powertrain, or electrification expressions; battery terms	Generic electric/electrical references to sensors, fields, circuits, measurements, or unrelated equipment are excluded. Generic battery/batteries alone is not sufficient unless it appears within one of the defined shipboard propulsion, storage, or battery-system expressions.

Concept category	Keywords, synonyms and lexical variants	Operational matching rule	Disambiguation / exclusions
	storage system(s); battery storage system(s); lithium-ion battery/batteries; Li-ion battery/batteries; battery system(s); marine battery/batteries; shipboard battery/batteries	are matched through explicit battery-system/storage/propulsion expressions rather than the isolated word alone.	



Full-corpus counts: Emissions/CO₂ = 270/1,446/98, Energy efficiency = 149/1,527/39, Alternative fuels = 114/204/29, and Electric/battery = 128/1,891/35 for Marine Technology / Ship Propulsion / Policy-Oriented records, respectively.



Corpus coverage: the 16-category operational dictionary is fully documented and was applied across all three corpora: 5,435 Marine Technology, 13,564 Ship Propulsion, and 320 Policy-Oriented records. The corresponding 2005+ populations are 3,960, 9,694, and 272 records.

Supplementary Table S2 — Concept-level analytical outputs

Purpose: report the concept-level outputs obtained using the documented 16-category operational dictionary.

Full-corpus denominators: Marine Technology = 5,435 records; Ship Propulsion = 13,564 records; Policy-Oriented = 320 records.

2005+ temporal denominators: Marine Technology = 3,960 records; Ship Propulsion = 9,694 records; Policy-Oriented = 272 records.

Dataset	Concept	Records with concept	Share of records	Per 1,000 records
Marine technology	Emissions/CO ₂	270	4.97%	49.68
Marine technology	Energy efficiency	149	2.74%	27.41
Marine technology	Alternative fuels	114	2.10%	20.98
Marine technology	Hydrogen	57	1.05%	10.49
Marine technology	Ammonia	25	0.46%	4.60
Marine technology	Methanol	17	0.31%	3.13
Marine technology	LNG	87	1.60%	16.01
Marine technology	Electric/battery	128	2.36%	23.55
Marine technology	Hybrid	17	0.31%	3.13
Marine technology	Wind assist	11	0.20%	2.02
Marine technology	Renewables	255	4.69%	46.92
Marine technology	Noise	126	2.32%	23.18

Dataset	Concept	Records with concept	Share of records	Per 1,000 records
Marine technology	Lifecycle/LCA	50	0.92%	9.20
Marine technology	Safety/risk	637	11.72%	117.20
Marine technology	Policy/regulation	522	9.60%	96.04
Marine technology	AI/ML	269	4.95%	49.49
Ship propulsion	Emissions/CO2	1446	10.66%	106.61
Ship propulsion	Energy efficiency	1527	11.26%	112.58
Ship propulsion	Alternative fuels	204	1.50%	15.04
Ship propulsion	Hydrogen	273	2.01%	20.13
Ship propulsion	Ammonia	74	0.55%	5.46
Ship propulsion	Methanol	63	0.46%	4.64
Ship propulsion	LNG	428	3.16%	31.55
Ship propulsion	Electric/battery	1891	13.94%	139.41
Ship propulsion	Hybrid	298	2.20%	21.97
Ship propulsion	Wind assist	241	1.78%	17.77
Ship propulsion	Renewables	434	3.20%	32.00
Ship propulsion	Noise	864	6.37%	63.70
Ship propulsion	Lifecycle/LCA	202	1.49%	14.89
Ship propulsion	Safety/risk	1142	8.42%	84.19
Ship propulsion	Policy/regulation	923	6.80%	68.05
Ship propulsion	AI/ML	383	2.82%	28.24
Policy + propulsion/technology	Emissions/CO2	98	30.63%	306.25
Policy + propulsion/technology	Energy efficiency	39	12.19%	121.88
Policy + propulsion/technology	Alternative fuels	29	9.06%	90.62
Policy + propulsion/technology	Hydrogen	24	7.50%	75.00
Policy + propulsion/technology	Ammonia	9	2.81%	28.12
Policy + propulsion/technology	Methanol	10	3.12%	31.25
Policy + propulsion/technology	LNG	21	6.56%	65.62
Policy + propulsion/technology	Electric/battery	35	10.94%	109.38
Policy + propulsion/technology	Hybrid	8	2.50%	25.00
Policy + propulsion/technology	Wind assist	14	4.38%	43.75
Policy + propulsion/technology	Renewables	45	14.06%	140.62
Policy + propulsion/technology	Noise	9	2.81%	28.12
Policy + propulsion/technology	Lifecycle/LCA	19	5.94%	59.38
Policy + propulsion/technology	Safety/risk	42	13.12%	131.25
Policy + propulsion/technology	Policy/regulation	320	100.00%	1000.00
Policy + propulsion/technology	AI/ML	28	8.75%	87.50



Reproducibility note: Supplementary Table S2 reports the concept-level outputs used in the manuscript analyses.

Alignment and concept-gap outputs

These concept-level outputs also provide the analytical inputs used for technology–policy alignment and gap prioritization. Cosine similarity between normalized 16-concept profiles is **0.7519** for Policy-Oriented ↔ Marine Technology and **0.5692** for Policy-Oriented ↔ Ship Propulsion. For the Ship Propulsion – Policy comparison, positive signed gaps occur only for **Noise (+35.57 records per 1,000)** and **Electric/battery (+30.04)**. Key negative gaps include **Emissions/CO₂ (–199.64)**, **Renewables (–108.63)**, **Alternative fuels (–75.59)**, **AI/ML (–59.26)**, **Hydrogen (–54.87)**, **Safety/risk (–47.06)**, and **Lifecycle/LCA (–44.48)**. **Policy/regulation (–931.95)** is the largest negative difference, reflecting the construction and terminology of the Policy-Oriented corpus.



Interpretation rule: signed gaps are differences in normalized **literature attention** only. They do not directly measure technology deployment, policy effectiveness, regulatory delay, or implementation readiness.

Supplementary Table S3 — AI-assisted thematic clustering details

Purpose: provide the quantitative and interpretive detail used to assess the thematic clustering solutions. Cluster sizes reported below refer to the analytical clustering samples: 350 Marine Technology records, 350 Ship Propulsion records, and all 320 Policy-Oriented records.



Clustering specification and validation: TF-IDF representations used a maximum of 1,200 features. The minimum document frequency was 6 for Marine Technology and Ship Propulsion and 2 for the Policy-Oriented corpus. Six-cluster solutions were retained for each technical corpus and a four-cluster solution for the Policy-Oriented corpus. The solutions were qualitatively assessed by the authors through inspection of dominant TF-IDF terms, selected exemplar publications from each cluster, and domain-informed thematic distinctiveness. No numerical “coherence interpretation score” was used.

Marine Technology — 6 clusters

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
0	67	19.1%	energy; marine; technology; wave; control	A variational stereo method for the three-dimensional reconstruction of ocean waves	Ocean-energy, wave, control and digital maritime applications

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
1	30	8.6%	ship; vessel; design; engine; propulsion	Failure analysis of the diesel engine ship propulsion system; Analiza kvarova dizelskog motora brodskog porivnog sustava	Ship/vessel design, engines and propulsion systems
2	11	3.1%	abstract; available; marine; technology; conference	Science and education: Building blocks for improved ocean management	General marine-technology research, education and conference material
3	67	19.1%	marine; technology; underwater; offshore; development	An overview of autonomous underwater vehicle research and testbed at PeRL	Underwater/offshore technology, monitoring and marine engineering
4	82	23.4%	ship; engine; design; model; analysis	Machine learning enhancement of manoeuvring prediction for ship Digital Twin using full-scale recordings	Ship design, modelling, manoeuvring, propulsion and data-driven analysis
5	93	26.6%	acid; marine; technology; biomass; method	Rapid quantification of microalgal lipids in aqueous medium by a simple colorimetric method	Marine biomass, carbon/water analysis and environmental-biological applications

Ship Propulsion — 6 clusters

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
0	62	17.7%	gas; power; engines; electric; propulsion	Energy storage systems for shipboard microgrids—A review	Electric/hybrid power systems, engines and energy management
1	55	15.7%	ice; ship; propeller; propulsion; flow	Ship propulsion in waves by actively controlled flapping foils	Propulsion in waves, propellers, motion and hydrodynamics
2	45	12.9%	ship; control; propulsion; design; power	Automatic Docking for Underactuated Ships Based on Multi-	Ship control, design, simulation,

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
				Objective Nonlinear Model Predictive Control	motors and performance
3	49	14.0%	propeller; cavitation; propellers; ship; model	Predicting cavitating propeller noise in off-design conditions using scale-resolving CFD simulations	Propellers, cavitation, CFD, fluid flow and noise
4	66	18.9%	propulsion; ship; nuclear; marine; analysis	A comparative investigation of data-driven approaches based on one-class classifiers for condition monitoring of marine machinery system	Naval/marine propulsion systems, machinery condition, wear and corrosion
5	73	20.9%	electric; propulsion; power; ship; fuel	Optimization of the propulsion plant of a Liquefied Natural Gas transport ship	Propulsion power, fuels, electric systems and ship energy systems

Policy-Oriented — 4 clusters

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
0	105	32.8%	ship; propulsion; power; learning; control	Proximal policy optimization with reciprocal velocity obstacle based collision avoidance path planning for multi-unmanned surface vehicles	Ship power/control, learning-based systems and policy-related applications
1	61	19.1%	marine; technology; ocean; science; research	Has marine technology innovation promoted the high-quality development of the marine economy? —Evidence from coastal regions in China	Marine science/technology, innovation, law and policy
2	64	20.0%	marine; technology; maritime; offshore; industry	Formal safety assessment: A critical review	Maritime/offshore industry, innovation, development and safety

Cluster	n	Share	Representative TF-IDF terms	Selected exemplar publication	Interpretive / validation note
3	90	28.1%	energy; fuel; propulsion; emissions; ship	How to decarbonise international shipping: Options for fuels, technologies and policies	Shipping fuels, emissions, energy and decarbonization



Cluster reporting: all 16 clusters are reported with sample size, cluster share, representative TF-IDF terms, a selected exemplar publication, and an interpretive validation note. Cluster shares sum to 100% within each clustering sample, subject only to rounding.

Supplementary methodological notes

Concept-mapping implementation

Concept detection uses the combined **Title, Abstract, Author Keywords, and Index Keywords** fields. Missing textual fields are treated as blank. Text is normalized for case and common typographic or hyphenation variants before matching. Whole-word or whole-phrase rules are used as appropriate, with concept-specific exclusions documented in Supplementary Table S1. Multiple occurrences within the same record do not increase the count: a record is counted at most once for each concept. Concept categories are non-mutually exclusive, so a publication may contribute to several concept categories. Full-corpus concept intensities are normalized as records per 1,000 publications using denominators of 5,435 Marine Technology records, 13,564 Ship Propulsion records, and 320 Policy-Oriented records. Temporal concept analyses use the corresponding 2005+ denominators of 3,960, 9,694, and 272 records.

Thematic-clustering implementation

For thematic analysis, the combined bibliographic text was lowercased and standard English stop-words were removed; additional generic bibliographic terms were removed where they did not aid thematic differentiation. TF-IDF vectorization was applied with a maximum of 1,200 features, followed by truncated singular value decomposition and KMeans clustering performed separately for each corpus. The retained cluster-detail outputs comprise analytical samples of 350 Marine Technology records, 350 Ship Propulsion records, and all 320 Policy-Oriented records. The TF-IDF minimum document-frequency parameter was 6 for each technical corpus and 2 for the Policy-Oriented corpus. Six clusters were retained for Marine Technology, six for Ship Propulsion, and four for the Policy-Oriented corpus.

Qualitative cluster validation

Cluster validation was qualitative and author-led. The selected solutions were reviewed using the dominant TF-IDF terms, selected exemplar publications from within each cluster, and the thematic distinctiveness of the resulting groups. This domain-informed inspection was used to assess whether each solution provided an interpretable thematic structure. The analysis did **not** use a numerical “coherence interpretation score”; cluster interpretation is therefore based on these qualitative criteria rather than a numerical coherence metric.

Temporal theme-evolution implementation and validation

For the temporal theme-evolution analysis, each corpus was first restricted to publications from **2005 onward**. Random samples of **350 Marine Technology records** and **350 Ship Propulsion records** were then drawn from the eligible technical corpora, while **all 272 eligible Policy-Oriented records** were retained. Publications were grouped into 3-year bins anchored at 2005, and the within-bin share assigned to each thematic cluster was calculated. The corresponding post-2005 source populations were 3,960 Marine Technology records, 9,694 Ship Propulsion records, and 272 Policy-Oriented records.



Reproducibility settings: sampling used `random_state=42` for the two technical corpora. TF-IDF used a maximum of 1,200 features, English stop words, and minimum document frequencies of 6 for the technical corpora and 2 for the Policy-Oriented corpus. The combined textual fields were Title, Abstract, Author Keywords, and Index Keywords. Truncated SVD used 2 components with `random_state=42`; KMeans used `random_state=42` and `n_init=10`, with six clusters for each technical corpus and four for the Policy-Oriented corpus. Because the exact SVD dimensionality and KMeans initialization settings from the earliest exploratory analysis were not preserved, the values reported here are the fixed reproducibility settings used for the temporal analysis presented in the manuscript.

A sensitivity check compared alternative SVD dimensionalities and KMeans initialization settings. The two-component SVD solution showed the closest agreement with the reported static cluster structure in terms of dominant-term overlap and cluster-size distribution. Across the three corpora it yielded 135–136 matched dominant-term overlaps out of 160 after one-to-one cluster matching, compared with approximately 90–93 for the next-best tested higher-dimensional solutions. This comparison is used as a robustness diagnostic and is **not** interpreted as a numerical cluster-coherence score. At the selected two-component dimensionality, the substantive temporal directions remained stable across eight tested initialization variants.

Quantitative temporal patterns used for interpretation

Dataset	Theme indicator	2005–2007	2023–2025	Observed change
Marine Technology	Broad marine-science/biomass cluster	42.1%	8.3%	–33.8 percentage points
Marine Technology	Ship/navigation/performance cluster	15.8%	40.0%	+24.2 percentage points
Marine Technology	SAR/detection cluster	0.0%	8.3%	+8.3 percentage points
Ship Propulsion	Combined share of the two largest 2005–2007 clusters	80.0%	42.6%	–37.4 percentage points when the same two clusters are followed to 2023–2025
Ship Propulsion	Propulsion/vibration/performance cluster	4.0%	22.1%	+18.1 percentage points
Ship Propulsion	Electric/power/motor cluster	8.0%	17.6%	+9.6 percentage points

Dataset	Theme indicator	2005–2007	2023–2025	Observed change
Policy-Oriented	Fuel/propulsion/emissions/decarbonization cluster	14.3%	38.5%	+24.2 percentage points
Policy-Oriented	Reinforcement-learning/control-heavy cluster	50.0%	35.2%	–14.8 percentage points

The Policy-Oriented temporal results require cautious interpretation because one large cluster contains technical uses of *policy* associated with reinforcement learning and control. Temporal variation in this corpus is therefore not treated automatically as evidence of changes in regulatory-policy responsiveness.



Temporal reporting: the final sparse partial-year bin is not used to support substantive temporal interpretation. Reported comparisons therefore focus on completed bins through 2023–2025.

Temporal reporting

The manuscript Table 3 reports the principal quantitative temporal changes needed for interpretation. The sampling design, cluster assignments, and 3-year bin construction are documented in this Supplementary Material.

Supplementary Note — Corpus construction and reproducibility

Data sources and corpus sizes

The study uses three bibliographic exports originally retrieved from Scopus and analysed as separate corpora: **Ship Propulsion**, **Marine Technology**, and **Policy AND Ship Propulsion OR Marine Technology**. The source corpora contain **13,564 Ship Propulsion records**, **5,435 Marine Technology records**, and **320 Policy-Oriented records**. For analyses restricted to 2005 onward, the eligible populations are **9,694**, **3,960**, and **272 records**, respectively. The temporal theme-evolution stage uses random samples of 350 records from each technical corpus and all 272 eligible Policy-Oriented records.

Inclusion, exclusion, and document types

During analytical preparation, no additional filtering by publication source or document type was applied. Records were analysed across the document types present in the Scopus exports. The document-type distributions are: **Marine Technology**: Article 4,272; Conference paper 674; Review 203; Short survey 97; Book chapter 52; Conference review 50; Note 33; Editorial 21; Book 15; Erratum 13; Retracted 2; Letter 1; Data paper 1; Report 1. **Ship Propulsion**: Article 6,829; Conference paper 5,882; Review 328; Book chapter 141; Note 131; Conference review 125; Short survey 63; Book 42; Editorial 6; Report 5; Letter 4; Erratum 3; Retracted 3; Data paper 2. **Policy-Oriented**: Article 181; Conference paper 93; Review 27; Book chapter 11; Note 4; Book 2; Short survey 2. Records with invalid or missing publication years were excluded from temporal analyses; the analytical exports used here contain valid four-digit publication years for all rows. No additional language filter was applied during analytical preparation. The export files do not contain a Language field, so the original Scopus language-filter setting cannot be verified from the retained data.

Deduplication and corpus overlap

The three corpora were intentionally treated as independent and non-mutually-exclusive analytical datasets. Cross-corpus overlap was therefore retained rather than deduplicated. No additional within-corpus record-level deduplication was applied during analytical preparation. An exact-row check identified a small number of duplicate rows in the technical exports: **3 excess rows in Marine Technology (0.06% of the corpus), 34 excess rows in Ship Propulsion (0.25%), and none in the Policy-Oriented corpus.** These rows were retained so that the Supplementary Material corresponds to the analyses reported in the manuscript.

Scopus search metadata

The analytical exports preserve the corpus/query labels but do **not** contain a verifiable record of the original Scopus field syntax or retrieval dates for all three searches. Exact search strings and retrieval dates are therefore not reported retrospectively. This limitation distinguishes preserved analytical metadata from information that cannot be verified from the retained exports.