D6.5 Educational material on university level

Synergetics | Synergies for Green Transformation of Inland and Coastal Shipping

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1. Introduction

The SYNERGETICS Teaching Module Series is an output of the EU Horizon Europe research project "SYNERGETICS – Synergies for Green Transformation of Inland and Coastal Shipping" (2023–2026), co-funded by the European Union, the United Kingdom, and the Swiss State Secretariat for Education, Research and Innovation. The teaching materials are freely available and designed to disseminate the project's research results to a broad academic and professional audience.

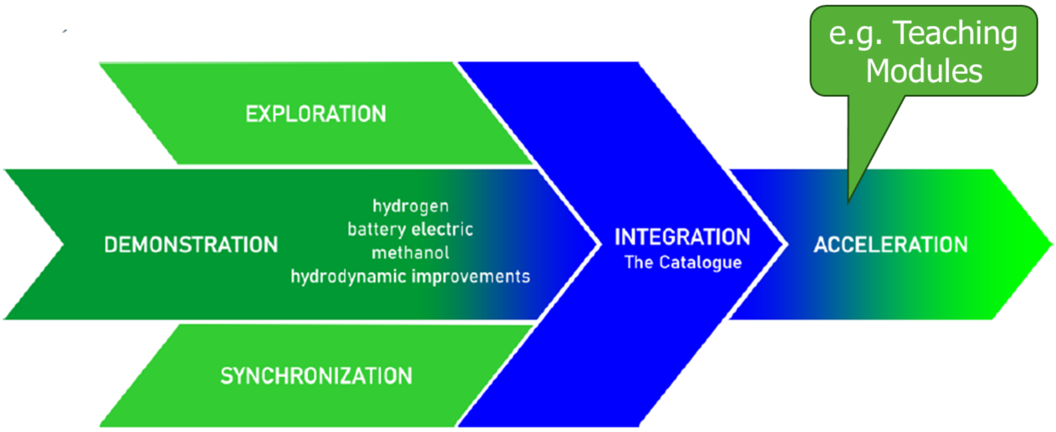

Figure 1: SYNERGETICS project concept and allocation of Teaching Material.

Deliverable 6.5 ("OTHER") is the educational material on greening retrofit solutions for inland vessels and coastal ships. It is complemented by this document, providing an explanation of the concept of the concept of the teaching material (chapter 2), a high-level description of the content (chapter 3), a summary of the pilot seminar (chapter 4) and concludes with recommendations for further use of the material (chapter 5).

The teaching material can be downloaded here (registration required):

SYNERGETICS Teaching Material

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2. Description of Concept

The core idea is to make the project's reports, deliverables, and tools accessible as structured, reusable teaching material. The concept rests on three guiding questions: Why (the Rationale), What (the Content Structure) and How (the Approach).

1. Why? – The Rationale

The material bridges cutting-edge European research on green shipping and practical academic or professional education. It is designed for lecturers at Bachelor and Master level (universities, universities of applied sciences), as well as for postgraduate seminars and continuing education programmes. Secondary target groups include ship crews and decision-makers in industry associations.

The target audience spans multiple disciplines:

- Technical programmes (e.g., naval architecture, mechanical, electrical, civil engineering)
- Economic and management programmes (e.g., industrial engineering, technically orientated courses in economics, industrial engineering & management)
- Energy and environmental technology programmes (e.g., energy and environment technology, energy systems, energy management)
- Policy-related programmes

2. What? – The Content Structure

To be attractive for a broad range of disciplines and a variety of target audience, the teaching material was set up in a module-based concept so that target group persons can pick whatever they need to extend their specific courses with relevant aspects or built new courses by combining modules of the SYNERGETICS project.

With this agile approach, the largest outreach potential should be achieved.

Furthermore, with this approach the material can be dynamically adapted/extended where needed, also after the end of the project.

Modules are comprehensive, stand-alone ppt Files, based on the content / deliverables of the SYNERGETICS project. By this, non-experts and experts can get background information to either understand or extend the content of the modules.

The material is organized as a modular matrix:

- **Rows** (Sections): Thematic topic areas, e.g. "Production and Supply of Energy Carriers" (Section 3) or "Selected Demonstrators" (Section 6).
- **Columns** (Energy Carriers): Different alternative energy carriers might be of certain interest for different target groups (e.g. electrification for electrical engineers). Therefore, the topics are divided (where applicable) in the three renewable energy carriers "electricity" (directly used), "hydrogen" and "methanol".

This leads to a matrix of modules where e.g. Section 3 describes the production and supply of renewable energy carriers (Well-to-Tank) and within Section 3 the three Modules deal with the application of renewable electricity (A.3, directly/with batteries, w/o fuel cells or other transforming units), with e-hydrogen (B.3) and e-methanol (C.3).

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Where a division into different energy carriers is not meaningful, only one module for the whole section is provided, called "section block" (e.g., for economics and scenarios – SB.10).

ID	Section Topic / Energy Carrier	A Modules Electricity	B Modules Hydrogen	C Modules Methanol	SB
1	Intro / How to use the Material				SB.1
2	IWT and Coastal Shipping: Greening Potential for Retrofit				SB.2
3	Production and Supply of Energy Carrier (WTT)	A.3	B.3	C.3	
4	Alternative Energy Carriers for Inland and Coastal Shipping (TTW and WTW)	A.4	B.4	C.4	
5	Propulsion and Storage Technology on Ship, Energy Carrier Handling	A.5	B.5	C.5	
6	Selected Demonstrators	A.6	B.6	C.6	
7	Hydrodynamic Improvements				SB.7
8	Regulatory Framework Technology Application	A.8	B.8	C.8	
9	Implementation of Greening Technologies for IWT, incl. ship crews				SB.9
10	Economics and Scenarios				SB.10

Figure 2: Matrix of Teaching Modules.

3. How? – The Approach

The concept is explicitly agile and flexible:

- If interested in a certain energy carrier (e.g. e-methanol) all modules C.x are relevant, but also the section blocks where no specific module for e-methanol is available
- If interested in a certain topic (e.g. Regulatory Frameworks for the Application of the Greening Retrofit Technologies), all modules from the according Section are relevant.
- The modules include references to relevant background information (literature, but specifically Deliverables and Tools of the SYNERGETICS project).
- Users/Lecturers are free to add own information or leave out slides of the modules.
- Users/Lecturers can pick individual modules or combine several into a new course compilation may combine different modules to a new compilation.
- Users may use the material as an add-on to existing lectures (e.g. only for one lesson or even parts) or to set up a whole course.

The structure allows the material to be updated and extended even after the project ends.

Additional digital tools complement the modules: SYNERGETICS developed an online catalogue of "greening options" for shipping, which forms the basis for interactive tools available at synergetics-project.eu/tools. These tools can be used alongside the teaching modules in class or for self-study.

Usage conditions: All modules are free of charge. Partial use or integration into other slide decks requires citation of the source. The authors disclaim responsibility for any consequences arising from the use of the material.

Summary

In summary, the SYNERGETICS Teaching Module Series provides a flexible, research-based, openly accessible curriculum resource for greening inland and coastal shipping — structured for maximum adaptability across disciplines and educational levels.

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3. Description of Content

In the final month of the SYNERGETICS project, the Modules marked in red are already available:

ID	Section Topic \ Energy Carrier	A Modules Electricity	B Modules Hydrogen	C Modules Methanol	SB
1	Intro / How to use the Material				SB.1
2	IWT and Coastal Shipping: Greening Potential for Retrofit				SB.2
3	Production and Supply of Energy Carrier (WTT)	A.3	B.3	C.3	
4	Alternative Energy Carriers for Inland and Coastal Shipping (TTW and WTW)	A.4	B.4	C.4	
5	Propulsion and Storage Technology on Ship, Energy Carrier Handling	A.5	B.5	C.5	
6	Selected Demonstrators	A.6	B.6	C.6	
7	Hydrodynamic Improvements				SB.7
8	Regulatory Framework Technology Application	A.8	B.8	C.8	
9	Implementation of Greening Technologies for IWT, incl. ship crews				SB.9
10	Economics and Scenarios				SB.10

Figure 3: Matrix of Teaching Modules, highlighting already existing modules.

3.1 Section 1

Module SB.1 presents the introduction for the Teaching Concept, giving an overview of all contents and how to use the material.

3.2 Section 3

The three Modules of Section 3 are bases on SYNERGETICS Work Package 1 (Task 1.1) and describe the production and supply of renewable energy carriers: electricity for direct use (A.3), e-hydrogen (B.3) and e-methanol (C.3).

All three Modules describe the context and background of the pathway modelling for the different energy carriers in a first part, e.g. the System boundaries used in the SYNERGETICS Well-to-Wake assessment as shown below (and explained in Deliverable D1.2).

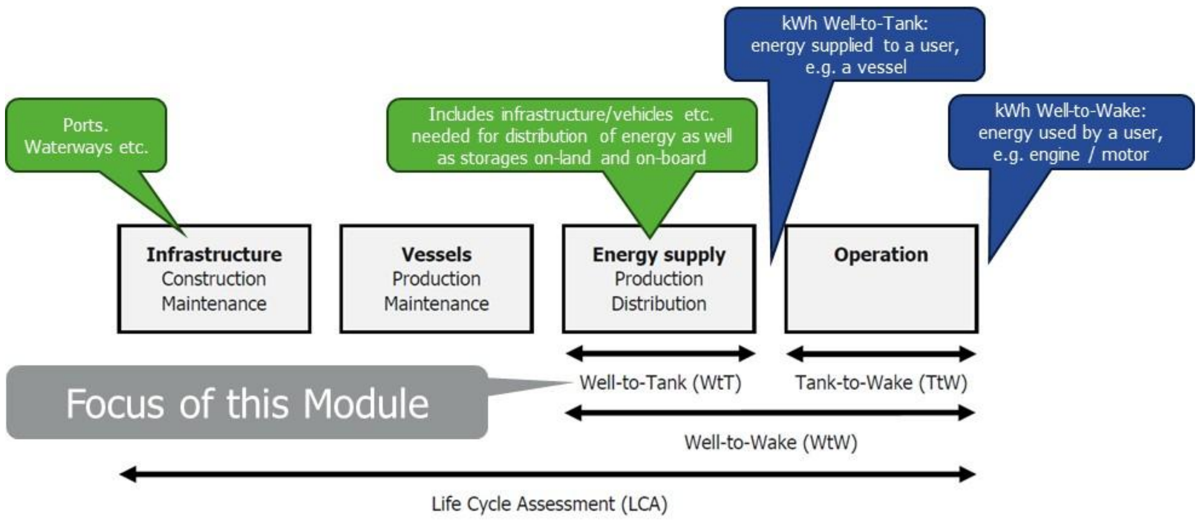

Figure 4: System Boundaries of Section 3 WTT Modelling.

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Also, the modular modelling behind the pathway description is explained. The following Figure shows all individual modules for two exemplary e-methanol supply paths with electricity from European offshore wind parks and with e-methanol transport (500km) by either lorry or vessel from the decentralised methanol synthesis plant to the centralised fuelling station in Rotterdam:

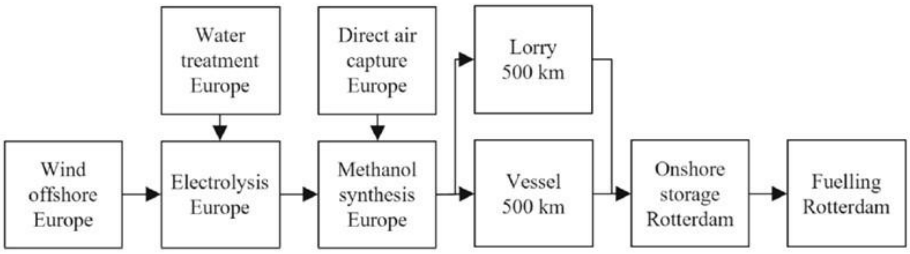

Figure 5: Illustration of Modular Modelling for different WTT pathways.

Additional details and sources of information for the modelling are explained in the general part of all three Modules as well as the transport of energy and general background on how charging and fuelling stations as well as energy storages have been modelled.

Then, divided on the three relevant energy carriers, a second part in all three modules described the pathways and results of the Well-to-Tank (WTT) modelling. The results have been illustrated for teaching purposes and comprise pathway comparisons for GHG emissions, NOx and PM emissions, costs and pathway energy efficiencies based on current status (2020) data. Finally, projections for 2050 are shown.

3.3 Section 6

This teaching module Section introduces the demonstrator work carried out within Work Package 3 of the SYNERGETICS project, focusing on the preselection of retrofit solutions for inland waterway and coastal ships. The work package investigates which ships in the inland and coastal fleet can be successfully retrofitted to minimise emissions, how to select the most suitable retrofit technology for a given situation, and what lessons can be drawn for all stakeholders.

The teaching material describes the process which follows a structured four-step approach. First, stakeholder interviews and operational data are used to define a vessel's power and energy demand and build an operational profile — broken down into tasks, missions, and a Bunkering Independent Operation (BIO) definition covering required range, endurance, and emission targets. This feeds into a Ship Power and Energy Concept (SPEC) analysis, a multi-criteria tool that evaluates combinations of energy carriers and converters against design constraints such as weight, volume, efficiency, and cost. Technologies are pre-screened using minimum readiness thresholds (Technical Readiness Level ≥ 7, Societal Readiness Level ≥ 3).

Pilot Project Review (WP2): Complementing WP3, Work Package 2 surveyed over 185 existing greening pilot projects across Europe. Key lessons learned were identified in three areas: technical developments (energy density and space remain the main challenge), business case (very high capital costs, mixed operational costs, regulatory incentives expected from 2026/27), and infrastructure (bunkering of alternative fuels is costly, infrequent, and hampered by a chicken-and-egg problem with supply availability).

Again, the three modules of Section 6 are, in the second part, divided into the three renewable energy carriers and give information about the respective demonstrators of the SYNERGETICS project. Together, these modules provide a solid evidence base for understanding the practical realities of green retrofitting in European shipping.

To give an example, Teaching Module B.6 is summarized in the following. It presents two real-world hydrogen retrofit demonstrators from Work Package 3 (WP3) of the SYNERGETICS project, illustrating different approaches to hydrogen propulsion in inland and coastal shipping.

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Demonstrator 1: Hydrocat – Crew Transfer Vessel

The Hydrocat is a Crew Transfer Vessel (CTV) operated by Windcat Workboats (a CMB.TECH subsidiary), shuttling crew between shore and offshore wind farms in the North Sea. It uses a hydrogen dual-fuel internal combustion engine: a small pilot diesel injection ignites a hydrogen/air mixture, displacing a portion of diesel consumption and achieving a 1:1 CO_2 reduction for every unit of hydrogen used. The hydrogen tanks are installed in open air behind the wheelhouse for safety. A key advantage is the full diesel back-up capability when hydrogen is unavailable. The system is designed as an add-on to existing engine hardware, meaning it cannot compromise the vessel's baseline reliability. Regulatory clarity — particularly the IMO's pending hydrogen rules (expected approval in 2026) — remains a critical factor for broader adoption.

1 | Section 6 - Demo 1 evaluation

	situation	insight
Operational	CMB.TECH has developed a dual fuel hydrogen technology that uses internal combustion engines (H_2ICE).	Less traditional fuel means less CO_2, so adding hydrogen equals a CO_2 reduction 1:1.
Technical	Hydrogen is released from the storage tanks and brought to low pressure, then injected into the air inlet of the engine at the right time and dosage.	By aspirating the hydrogen, a part of the traditional fuel is displaced to get the same amount of energy from combustion.
Future proof	A set of compressed hydrogen tanks are combined into one stillage which has its own control unit.	The stillages are interchangeable, so in case of maintenance they can be easily swapped with the spare set by which service can be guaranteed.
Extra	The system is designed to work on top of the existing hardware and electronics of the engine and machine.	It can therefore never affect the reliability or performance of the machine.

Demonstrator 2: H2Barge1 & H2Barge2 – Inland Cargo Vessels

Operated by Future Proof Shipping on the Rotterdam–Meerhout route, these two retrofitted cargo barges (built in 1993/1997, converted in 2023) represent the first diesel-to-zero-emission fuel cell retrofit in inland shipping. Propulsion relies on PEM hydrogen fuel cells (275 kW each) connected to an 800 kW electric motor, supported by a 504 kWh battery buffer. A sophisticated Power Management System (PMS) controls fuel cell output, motor input, and all electrical systems. The PMS was progressively refined across both vessels — lessons from H2B1 directly improved H2B2's configuration (six fuel cells with better peak-shaving algorithms), and these improvements were subsequently back-applied to H2B1.

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2 | Section 6 - Demo 2 evaluation

	situation	insight
Operational	First month of testing in operation, most of the control was kept to manual mode to gain experience in the system and assess what parts of control and the PMS can be safely automated.	The control software must maintain similar ship control capability for the crew while optimizing the size of the battery packs and the number of fuel cells.
Technical	The control software is completely reshaped to balance the use of the batteries onboard together with the output of the fuel cells.	Moreover, the control software needs to continuously log data to provide a solid and consistent basis to improve the control ergonomics and the PMS efficiency.
Future proof	While FPS and manufacturer are in constant communication and the PMS is continuously being updated there were two distinct versions of it.	For H2B2, the PMS was adapted to the different configuration with six fuel cells and with a better peak shaving algorithm.
Extra	Extra improvement: possibility to de-activate the systems when throttle is in the neutral position and the cooling water is <50°C. Change resulted in the consumption dropping from ~20kWe to ~10kWe.	In the new version of the PMS the batteries are being charged at 60 kW instead of maximum current. Additionally batteries are being charged depending on their State of Charge (SoC) while sailing.

Key Lessons Learned (B.6 – hydrogen)

Both demonstrators show that hydrogen can serve as a viable zero-emission energy source in maritime applications, whether via combustion or fuel cell technology. Novel battery–fuel cell combinations produce unexpected operational behaviours that require iterative software refinement. Continuous PMS improvement delivers meaningful additional energy savings, and operational experience is essential to safely progress from manual to automated control.

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3.4 Section 8

The three teaching modules A.8, B.8 & C.8 cover the regulatory frameworks governing the use of electricity, hydrogen, and methanol as alternative propulsion solutions for inland and coastal shipping. They share a common structure and many cross-cutting themes, with fuel-specific differences highlighted below.

Common Foundation (all three modules)

All modules open with an energy density comparison to diesel as the benchmark. Batteries have dramatically lower energy density (factor ~110×), methanol roughly half of diesel, and hydrogen a very high gravimetric energy content but extremely low volumetric density in gaseous form — making storage in compressed (700 bar) or cryogenic form necessary. Common challenges across all alternatives include reduced autonomy, the need for denser bunkering infrastructure, more complex fuel handling, and higher crew qualification requirements.

The regulatory structure is examined across six dimensions: engines, fuel quality, onboard storage, energy converters, supply infrastructure, crew qualification, and derogation pathways.

Module A.8 – Electric Propulsion

Electric motors are governed by ES-TRIN 2025 Article 11.03, which sets requirements for load changes, electromagnetic harmonics, and insulation. Additional EU directives apply (Low Voltage, EMC, Ecodesign, RoHS, REACH). There are no specific inland navigation regulations for electricity as a fuel. Battery storage is regulated under ES-TRIN Article 10.11, with specific fire protection and ventilation requirements for Li-Ion systems above 20 kWh. Shore-side power supply is covered by EN 15869 and EN 16840 standards. The Alternative Fuel Infrastructure Regulation (EU) 2023/1804 mandates shore-side electricity at TEN-T ports, but leaves hydrogen and methanol infrastructure to national policy. Crew qualification guidelines (non-mandatory) are available from CESNI.

Module B.8 – Hydrogen

Internal combustion engines using hydrogen must be type-approved under the NRMM Regulation (EU) 2016/1628 — but hydrogen is not yet an official reference fuel. Progress was made in October 2025 at the UNECE GEME working group, with adoption into the NRMM reference fuel list appearing likely in the next amendment. Onboard storage requires a formal HAZID risk assessment and safety plan (ES-TRIN Articles 30.04–30.05). Specific ES-TRIN provisions for pressurised hydrogen storage are planned for 2027; cryogenic storage rules are still under development. A key safety consideration is that hydrogen burns with an invisible flame, requiring dedicated flame detectors. Fuel cells must comply with IEC 62282 and ES-TRIN Annex 8. Large hydrogen storage facilities (>5 t and >50 t thresholds) fall under the Seveso III Directive.

Module C.8 – Methanol

Methanol is also not yet an official NRMM reference fuel. A key technical obstacle is the absence of established emission limits for formaldehyde, a combustion by-product, which complicates regulatory approval. A Belgian research project involving a dual-fuel methanol engine, supported by the EU's Joint Research Centre, is expected to provide further data. For fuel cell use, methanol purity of at least 99.85% is required; industrial-grade methanol is generally unsuitable. Onboard storage regulations mirror those for hydrogen (ES-TRIN Articles 30.04–30.05 plus Annex 8), with specific provisions for tank materials, secondary barriers, venting, piping, and bunkering couplings (EN 14420-6:2013). CESNI has published non-mandatory crew qualification guidelines specifically for methanol vessels.

Shared Derogation Pathways

All three modules address how operators can obtain derogations when a fuel's flash point is below 55°C or when the engine has not received type-approval for a new fuel. Two routes exist: a permanent derogation requiring proof of equivalent safety, and a time-limited derogation (up to 48 months) for research and development purposes — both requiring action by the European Commission or CCNR.

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3.5 Section 10

The module SB.10 examines the economic and policy dimensions of greening inland waterway transport (IWT) and coastal shipping, structured around four thematic sections.

Global and EU Policy Landscapes

The overarching driver is the European Green Deal, which mandates a 55% economy-wide GHG reduction by 2030 and a 90% reduction in transport emissions by 2050. The Fit for 55 package translates these ambitions into binding instruments: the Renewable Energy Directive (RED-III) requires fuel suppliers to meet a 29% renewable energy share by 2030; the EU Emissions Trading System (ETS) now covers maritime vessels above 5,000 GT; and ETS2 offers Member States an opt-in for IWT fuel suppliers. The Alternative Fuel Infrastructure Regulation (AFIR) mandates shore power and hydrogen bunkering along TEN-T corridors. The EU Taxonomy steers green investment by requiring either zero Tank-to-Wake emissions or a declining Well-to-Wake GHG threshold.

Sector-Specific Strategies: IWT vs. Coastal Shipping

IWT benefits from relatively developed governance through the EC's NAIADES III programme and the CCNR Mannheim Declaration (targeting 35% GHG reduction by 2035, 90%+ by 2050). Coastal shipping faces a significant regulatory gap: most vessels fall below the 5,000 GT threshold that triggers FuelEU Maritime and the maritime ETS, leaving them in a legislative limbo with no dedicated EU strategy and no effective financial incentives to green the fleet. Fragmented national implementation of RED-III and ETS2 further risks "bunker tourism" and an uneven playing field.

Greening Technologies & Energy Carriers

The module reviews the main technology options and their constraints. Methanol and hydrogen ICE both face a regulatory showstopper: neither is recognised as a reference fuel under the NRMM Regulation for engine certification. Fuel cell variants are more legally developed but significantly more expensive. Battery solutions come in two forms — swappable containers (suited to fixed container routes, "Energy as a Service" model) and fixed on-board batteries (suited to vessels with predictable idle time for recharging) — but both suffer from high weight-to-energy ratios reducing payload. HVO is the most immediately practical option as a drop-in fuel requiring no engine modification, though feedstock competition and long-term price uncertainty are concerns. A cross-cutting constraint is that lower energy density of all alternatives reduces cargo capacity and increases bunkering time, directly impacting vessel productivity and operating costs.

Practical Assessment & Operational Impacts

The SYNERGETICS project developed a Decision Support Tool (DST) — available at synergetics-project.eu/dstool — enabling vessel owners to model the Total Cost of Ownership (TCO) across eight technology pathways. The tool accounts for emission reduction targets, payload losses, bunkering time, and potential subsidies, presenting results as a ranked top-3 shortlist with detailed economic and emissions data. Key implementation risks identified include: fragmented ETS2 opt-in creating competitive distortions; limited shipyard capacity for large-scale retrofitting; the need for full life-cycle emissions accounting (including battery manufacturing); and the fundamental priority of energy efficiency first — since zero-emission fuels are costly and resource-intensive, minimising energy demand through hydrodynamic improvements should be the primary strategic objective.

Core finding

Today, virtually no retrofit solution has a positive business case. The main barrier is the absence of binding regulation that internalises external emission costs, combined with tax-free fossil diesel remaining the cheapest and most operationally straightforward option.

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4. Summary of Pilot Seminar

4.1 Application of the Teaching Material

A pilot use has been carried out during a Webinar in the BlueFriday Maritime Tech Talk Series on May 22nd 2026, organised by University of Rostock together with University of Duisburg-Essen, Technical University of Hamburg and Technical University of Berlin.

Figure 6: Invitation to Pilot Seminar for the SYNERGETICS Teaching Material.

For this course, 32 participants registered of which 7 were from SYNERGETICS partners. The 25 "external participants" were lecturers, PhD students and other interested persons from various European countries. 15 out of 25 "external participants" provided their Email-Adress to receive the teaching material. The 90 minutes programme was meant to introduce the teaching concept and the teaching material with the purpose to motivate and broaden its usage. It was structured as follows:

- Elimar Frank:
  Introduction and Teaching Module Concept
- Benjamin Friedhoff:
  Background – IWT&Coastal, retrofit, GHG emission reduction goals
- Niels Kreukniet:
  Pilot database and application of alternative technologies
- Elimar Frank:
  Production and Supply of Alternative Energy Carriers (WTT)
- Friederike Dahlke:
  Energy Conversion on ships (TTW)
- Daan Siebenheller:
  Demo of the Decision Support Tool
- All: Q&A

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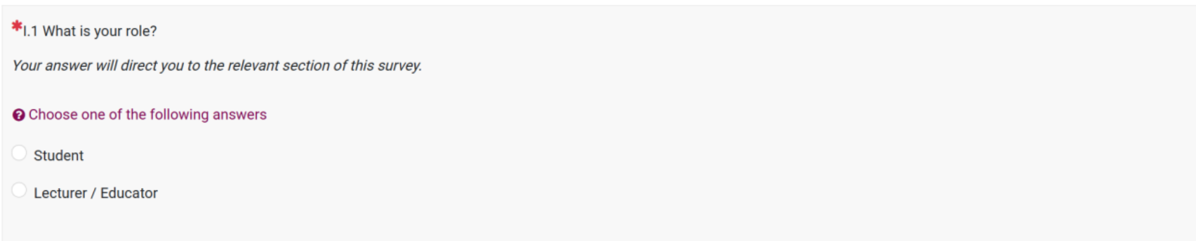
Numerous questions were discussed. The overall feedback was very positive. Some participants spread the material even after the course, e.g. a participant from VSM, the German Shipbuilding and Ocean Industries Association who forwarded the access information to the material to relevant stakeholders within the organisation.

4.2 Evaluation of the use of the teaching material

Four weeks after the pilot seminar, a questionnaire to evaluate the usability of the material was sent out to all people registered for the use of the material. The questionnaire is provided below. The evaluation will be part of the activities after official termination of the SYNERGETICS project, as well as the completion and updates of the teaching modules ("living material"), see also chapter "Recommendations for further roll-out".

4.2.1 Introduction to the questionnaire

Part 1: Introduction



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The teaching materials are structured in various modules and section (see module overview for reference in the table below).

The two following questions are related to this strukture.

Section / Topic	A Electricity	B Hydrogen	C Methanol	SB Section Block
Intro / How to use the Material	—	—	—	SB.1
IWT and Coastal Shipping: Greening Potential for Retrofit	—	—	—	SB.2
Production and Supply of Energy Carrier (WTT)	A.3	B.3	C.3	—
Alternative Energy Carriers for IWT and Coastal Shipping (TTW)	A.4	B.4	C.4	—
Propulsion and Storage Technology, Energy Carrier Handling	A.5	B.5	C.5	—
Selected Demonstrators	A.6	B.6	C.6	—
Hydrodynamic Improvements	—	—	—	SB.7
Regulatory Framework & Technology Application	A.8	B.8	C.8	—
Implementation of Greening Technologies incl. Ship Crews	—	—	—	SB.9
Economics and Scenarios	—	—	—	SB.10

I.2 Which **module(s)** have you reviewed or used?

Select all that apply

- [ ] Module A - Electricity
- [ ] Module B - Hydrogen
- [ ] Modul C - Methanol
- [ ] SB - Section Block
- [ ] I reviewed materials across multiple carriers

I.3 Which specific **sections** were you interested in?

Select all that apply

- [ ] SB.1 / Intro - How to use the Material
- [ ] SB.2 - IWT and Coastal Shipping: Greening Potential for Retrofit
- [ ] A.3 / B.3 / C.3 - Production and Supply of Energy Carrier (WTT)
- [ ] A.4 / B.4 / C.4 / S4 - Alternative Energy Carriers for IWT (TTW)
- [ ] A.5 / B.5 / C.5 - Propulsion and Storage Technology
- [ ] A.6 / B.6 / C.6 - Selected Demonstrators
- [ ] SB. 7 - Hydrodynamic Improvements
- [ ] A.8 / B.8 / C.8 - Regulatory Framework & Technology Application
- [ ] SB.9 - Implementation of Greening Technologies incl. Ship Crews
- [ ] SB.10 - Economics and Scenarios
- [ ] all of them
- [ ] none of them

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4.2.2 Questionnaire Part 2A (only for Students)

Part 2A - for Students: About your background

A.1 What is your academic background or field of study?

e.g. Maritime Engineering, Environmental Science, Transport Management, Energy System, ...

A.2 Have you previously encountered the topic of greenng potential for IWT retrofit solutions?

Choose one of the following answers

- Yes, extensively
- Yes, briefly / in passing
- No, this was new to me

Part 2A - for Students: Content and presentation of materials

A.3 The teaching materials are organised into three carrier-specific module tracks (A – Electricity, B – Hydrogen, C – Methanol) alongside section blocks (SB). How clearly did you understand this overall structure before or while working with the materials?

Choose one of the following answers

- Very clear - I understood the structure immediately
- Clear - I understood it after a short familiarisation
- Partly clear - I had some difficulty navigating the structure
- Unclear - the structure was confusing throughout
- I was not aware of this structure

A.4 How would you rate the overall clarity and logical structure of the materials you reviewed?

1 = Very unclear / confusing - 5 = Very clear / well.structured

1 2 3 4 5 No answer

A.5 How would your rate the overall level of difficulty of the covered material?

1 = very easy - 5 = very difficult

1 2 3 4 5 No answer

A.6 In your opinion, was the level of difficulty consistent across the various modules, or did it vary considerably?

1 = consistent - 5 = very variable

1 2 3 4 5 No answer

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A.7 Would complementary formats have helped you engage with or understand the material better?

Select all that apply

- [ ] Short explainer videos (< 5 min. per topic)
- [ ] Interactive quizzes or self-assessments
- [ ] Case study worksheets / guided exercises
- [ ] Glossary or key term reference sheet
- [ ] Summary handouts (1-pager per module)
- [ ] Podcast or audio format
- [ ] No, the slide sets were sufficient
- [ ] Other:

A.8 Where there topics you felt were missing or insufficiently covered?

Part 2A - for Students: Overall assessment & roll-out

A.9 How well did the materials overall support your understanding of the current technological challenges and opportunities?

1 = Not at all - 5 = Very effectively

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ● No answer

A.10 How likely are you to recommend these materials to fellow students?

1 = Very unlikely - 5 = Very likely

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ● No answer

A.11 In your view, what would most contribute to a successful broader roll-out of these materials to more students?

Please share your thoughts freely.

A.12 Any other comments or suggestions?

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4.2.3 Questionnaire Part 2B (only for lecturers)

Part 2B - for Lecturers / Educators: About your background

B. 1 What is your academic or professional background?

e.g. Naval Architecture, Energy Economics, Maritime Law, Environmental Engineering, ...

B.2 How familiar are you with the topic of Retrofit solutions for greening the IWT and coastal shipping in Europe?

Choose one of the following answers

- Expert - I teach or actively research this topic
- Familiar - I have solid working knowledge
- Basic - I am aware of the topic but not a specialist
- New - this topic is largely new to me

Part 2B - for Lecturers / Educators: Didactic quality of the materials

B. 3 - The teaching materials are organised into three carrier-specific module tracks (A – Electricity, B – Hydrogen, C – Methanol) and a set of standalone modules (SB). How clearly does this overarching learning structure communicate itselfe to users?

Choose one of the following answers

- Very cleary - the structure is self-explanatory
- Cleary - minor orientation needed
- Partly cleary - students are likely to need guidance
- Uncleary - the structure needs to be explained explicitly before use
- I did not notice this sturcture when reviewing the materials

B.4 How would you rate the overall clarity and logical structure of the materials?

1 = Very unclear / poorly structured- 5 = Very clear / well.structured

1 2 3 4 5 No answer

B.5 How would your rate the overall level of difficulty of the covered material?

1 = very easy - 5 = very difficult

1 2 3 4 5 No answer

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B.6 In your opinion, was the level of difficulty consistent across the various modules, or did it vary considerably?

1 = consistent - 5 = very variable

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ● No answer

B.7 How would you rate the balance between theory and practical application?

1 = Too theoretical - 3 = Well balanced - 5 = Too practice orientend

○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ● No answer

Part 2B for Lecturers / Educators: Content & gaps

B.8 Which sections do you consider most valuable from a teaching perspective?

select up to 3

Please fill in the reason for your preference.

Comment only when you choose an answer.

- ☐ SB.1 / Intro - How to use the Material
- ☐ SB.2 - Greening Potential for Retrofit
- ☐ A.3 / B.3 / C.3 - Production and Supply of Energy Carrier (WTT)
- ☐ A.4 / B.4 / C.4 / S4 - Alternative Energy Carriers for IWT (TTW)
- ☐ A.5 / B.5 / C.5 - Propulsion and Storage Technology
- ☐ A.6 / B.6 / C.6 - Selected Demonstrators
- ☐ SB. 7 - Hydrodynamic Improvements
- ☐ A.8 / B.8 / C.8 - Regulatory Framework & Technology Application
- ☐ SB.9 - Implementation of Greening Technologies incl. Ship Crews
- ☐ SB.10 - Economics and Scenarios

B.9 Are there topics you feel are missing or should be expanded?

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Part 2B for Lecturers / Educators: Intended use & roll-out

B.10 How would you consider using these materials?

Select all that apply.

Select all that apply

- [ ] Directly in my own courses (as-is)
- [ ] Adapted / partially integrated into my courses
- [ ] As supplementary reading or references for students
- [ ] Shared via a teaching plattform (please specify in B.13)
- [ ] As a basis for further curriculum development
- [ ] I would not use them - please explain in B.13

B.11 If you selected "share via a teaching platform", please specify:

B.12 In your view, what are the most important success factors for a broader roll-out of these materials in higher education?

Please share your thoughts freely.

B.13 Any other comments, sugestions, or recommendations for improvement?

4.2.4 Closing of the questionnaire

Thank your for your valuable feedback!

synergetics

Synergies for Green Transformation of Inland and Coastal Shipping

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5. Recommendations for further roll-out

The concept of the teaching material was broadly accepted and welcomed by lecturers, students and project partners from industry, research and others (regulators, consultants, …). More than half of the Modules in the Matrix have been finalized, which already provides a very good basis for the main aim of the project task (to make students as potential future users and developers familiar with the new technologies).

The material developed was made freely available to interested educational organisations through the project website and dissemination activities (personal contacts to lecturers, the dedicated Webinar and contacts to the CLEVER project). The efforts have been in line with the development of the retrofit Catalogue of SYNERGETICS and all Tools derived from that.

For further roll-out, several steps are planned:

- Completion of the teaching modules in the matrix
- Evaluation of the feedback (questionnaire)
- Further outreach associations / organisations such as the VSM (the German Shipbuilding and Ocean Industries Association) and others
- Adaptation to specific needs of associations / organisations
- Strengthening of the contacts to university lecturers which might act as ambassadors for the material in their institutions
- Regular updates of the modules
- Tracking of the usage with periodical surveys
- Cooperation with the CLEVER project and team to align the teaching material with ongoing activities in the field of emission factor consolidation

The material and the concept provide a good basis for project collaboration and cooperation with organisations. This could help to ensure that (also from a financial point of view) the material stays "alive" and is further being used and developed.

As of now, the material is available on a sharepoint of OST – Eastern Switzerland University of Applied Sciences. A shift to the SYNERGETICS homepage is under development.

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