FuelSOME

Multi**fuel** **SO**FC system with **M**aritime **E**nergy vectors

Introduction to project FuelSOME

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3RD INTERNATIONAL SUSTAINABLE ENERGY CONFERENCE,

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AVL

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Brief gist of the project

FuelSOME = Multi**fuel** **SO**FC system with **m**aritime **e**nergy vectors

4 year project, Sept 2022 to Aug 2026

Total project budget €2.5 Million

The broad call from the EU is '**Emerging technologies for a climate neutral Europe**' CL5-2021-D2-01-08.

Within this call the consortium prepared a proposal for 'Multifuel to power'

The end application is ocean going vessels

The different fuels that we are considering within the project are: Ammonia, Methanol and Hydrogen.

- Fuels processed from waste streams
- Green fuel production supply chain

The power conversion aspect is via Solid Oxide Fuel Cells

Shipping and Green House Gas

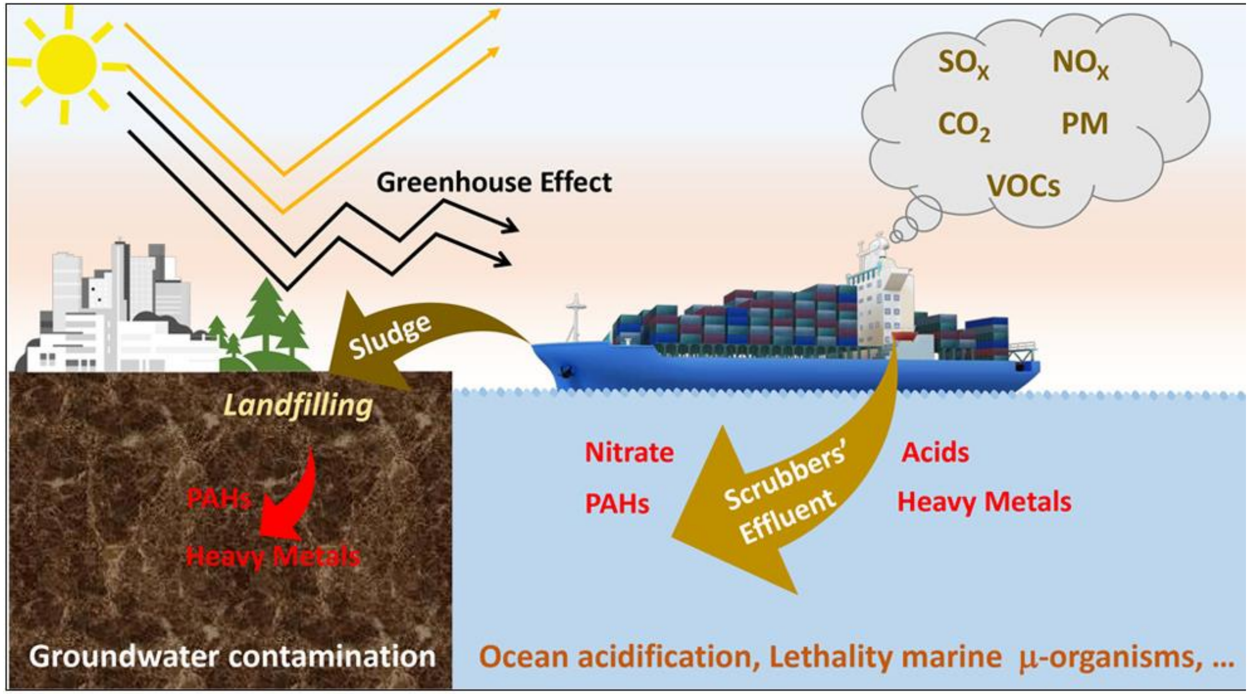
1. Shipping is responsible for around 1 billion tons of carbon dioxide emissions, making up about **2.5% of total global greenhouse gas emissions**.

2. Within the transportation sector, shipping claims the third position in terms of carbon dioxide emissions, **comprising 11% of the total**.

3. Shipping is reported to produce **16.14 grams of CO2 per kilometer** for each metric ton of cargo they carry.

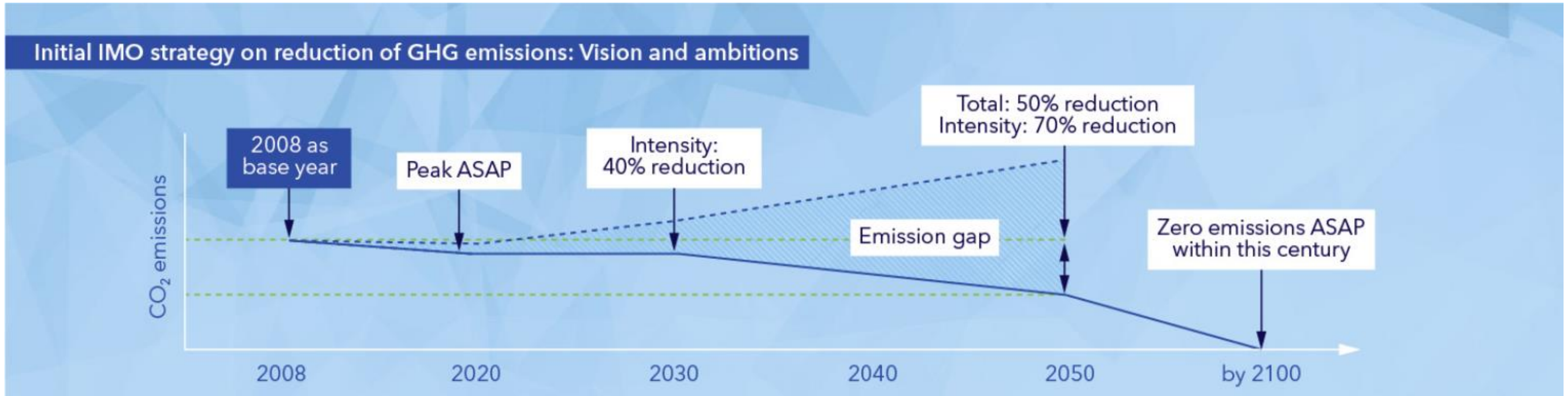
Marine Vessels and heavy diesel oil

Marine vessels have **relied on heavy diesel oil**, a fossil fuel, as the primary propulsion source for over a century. As a consequence, greenhouse gas and air pollutants like carbon dioxide, nitrogen oxides, sulfur oxides, and particulate matter have become focal points of regulation at both EU and global levels.



Ref: Industrial & Engineering Chemistry Research (IF 4.2) **Pub Date: 2023-01-23** , DOI:10.1021/acs.iecr.2c03621

International Maritime Organization (IMO) vision and ambitions



- The urgent need to significantly decrease GHG emissions from shipping - **a crucial objective within the EU Green Deal** framework.

- Internationally, in 2018, the International Maritime Organization (IMO) strongly emphasized the need to reduce CO2 emissions from shipping by at least 50% by 2050 compared to 2008 levels.

- The maritime industry - **challenging sector for decarbonization**, is actively pursuing alternative technologies that improve environmental sustainability while maintaining current performance standards.

- Uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources – **at least 5% in international shipping by 2030**

Current state-of-the-art technologies for both fuels and propulsion systems

- Existing state-of-the-art technologies for both fuels and propulsion systems do not meet the necessary emission standards established by global and EU regulations.

- Consequently, there is an urgent requirement to investigate transformative technologies**, thoroughly assessing their environmental, social, and economic implications**. This investigation is crucial for aligning with the EU's and the sector's goal of achieving climate neutrality.

Project Vision

The **vision of the project** is to find a scalable and flexible path for supply of multi-fuels, viz. **ammonia and methanol** besides hydrogen, to act as key contenders in replacing marine diesel as fuel on ocean going vessels, coupled with their use in a **multi-fuel energy generation system** using **Solid Oxide Fuel Cell** technology

Broad project objectives

1 Design an overall technology concept from source to end use and proceed with its modelling, considering fuel quality specifications as well as fuel storage and distribution aspects.

2 Undertake research at stack level to advance its performance, efficiency, degradation and tolerance limits and to proceed with development of the stack module.

3 Design, build and test a lab scale prototype of the multi-fuel energy generator based on SOFC technology.

4 Undertake a Techno-economic Assessment and perform a prospective Life Cycle Sustainability assessment

5 Maximise the project's impact a through wide dissemination, communication, exploitation, and standardisation actions.

Specific project Objective=s

"FuelSOME" will develop and validate, **up to TRL 4, a novel multifuel energy generation system based on Solid Oxide Fuel Cell Technology** – called the FuelSOME system which will be capable of operating on various fuels and fuel mixtures.

Sub- Objectives

Overall technology concept – Source to end use

- Fuel quality specification
- Fuel storage & distribution aspects
- Fuel supply value chain
- Sustainable & circular production approaches

Stack level advancements

- Multi-fuel compatible stack
- Identify operating windows
- Understand fundamental aspects related to fuel oxidation
- Investigate stack degradation mechanisms when used on multi-fuels

Lab scale prototype

- System simulation
- System design freeze
- System build up
- Testing & performance characterisation

TEA & LCA studies

- TEA & LCA for FuelSOME system
- Quantify environmental, social & economic sustainability performance
- Compare with conventional ship propulsion systems

Maximise project impact

- Dissemination
- Communication
- Exploitation
- Standardisation

FuelSOME project and the transformational technology

FuelSOME project is driving the advancement of ground-breaking technologies with a focus on two main areas

1

Prioritizing sustainable alternative fuels such as Ammonia, Methanol, and Hydrogen tailored for maritime use,

2

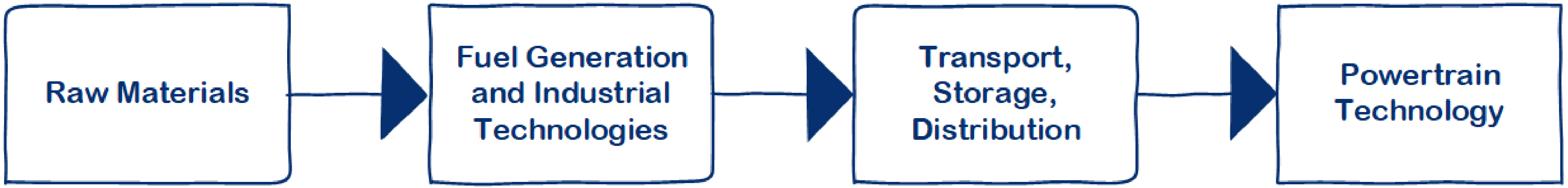
Developing highly efficient multifuel energy conversion systems.

Ammonia and methanol, known for their liquid form and exceptional energy density, are prime candidates for decarbonizing deep-sea shipping. While hydrogen has shown satisfactory performance as a fuel.

Fuel Cells, particularly Solid Oxide Fuel Cell (SOFC) systems, offer significantly high energy efficiencies compared to internal combustion engines. Among fuel cell options, SOFC systems are particularly promising for maritime applications, especially for long-distance voyages. Therefore, improving SOFC performance with above diverse fuels is essential for developing a reliable high-performance system.

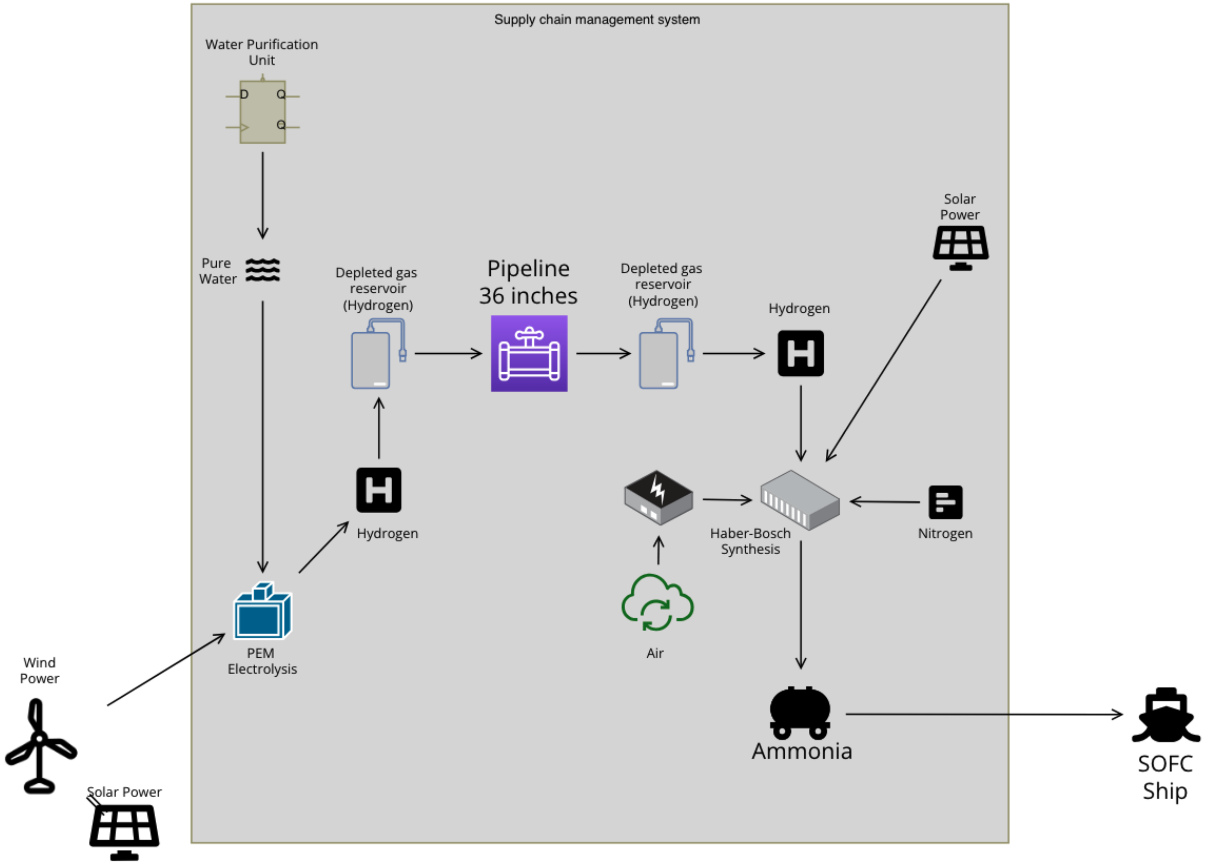
Fuel Pathway

- Includes all steps and processes involved in **transforming a raw material into the target fuel**
- The resulting fuel must fulfil:
  - Required specification
  - Quantity required for powering the propulsion system at a specific utilization efficiency
- Based on a fuel pathway, **key performance indicators** (KPIs) are calculated
- Main components of a fuel pathway:



Example: Ammonia Pathway

- Production
  - Sub-pathway: Hydrogen via PEM electrolysis
  - Haber-Bosch process producing ammonia
- Storage
- Transport
- Water purification unit for electrolysis
- Energy supply
  - primary electricity demand for electrolysis
  - auxiliary electricity demand for other pathway components (grid → country dependent CO_2 factor)



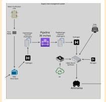
Fuel Pathway KPIs

- **Evaluate** and **compare** fuel pathways
- **Optimize** fuel pathways
  - Architecture
    - Production methods and their combinations → different sub-pathways
    - Choice in single components eg. transportation types, primary energy ressources, …
  - Parameters
    - Storage sizes
    - # of ships used in transportation
    - ...

KPI	Unit	Calculation Method
Levelized cost of fuel	€/kWh	Component-wise
GHG emissions	t_{CO2equ}/year	Component-wise, grey GHG emissions of new infrastructure not included
Well-to-wake-efficiency	%	Efficiency component-wise + Total efficiency
Land use demand	m^2	Calculated for renewable electricity generation for electrolysis only
Weighted pathway TRL	# (1-9)	Defined component-wise, weighted with CAPEX

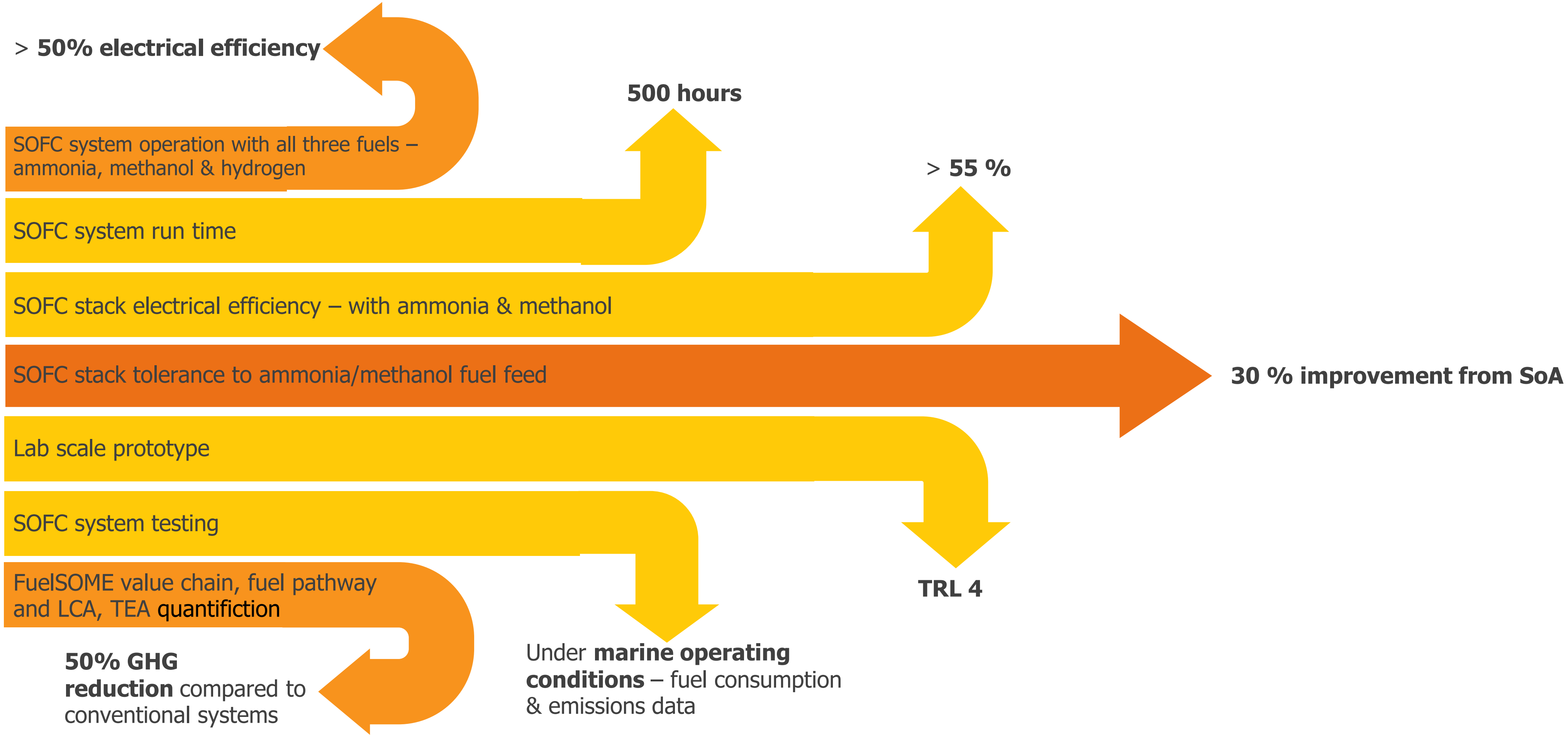
Pathway Tool

- Open-Source Python Package/Library
- Flexible Modular Design
- Easily implement new use cases



- Easily implement new components (e.g. ammonia production from waste water)
- Compare and evaluate
- Optimize fuel pathways
- Pathway represented as directed acyclic graph (networkx)
- Nodes: components (e.g. storage unit, production process)
- Edges: transported quantities (e.g. power, fuel)

FuelSOME ultimate targets



FuelSOME project consortium

4 Academic and research technology organizations

Leading European institute of applied research in renewable energy and resource efficiency.

Institution of higher education. One of Poland's top centers for chemical engineering education and research.

One of Europe's leading research institutions and a visionary research and innovation partner for companies and society.

One of the leading universities of applied sciences in Switzerland, focusing on important societal challenges.

3 Small to medium enterprises

World's most advanced manufacturer of ceramic anode-supported solid oxide cells and stacks.

Research and Technology Hub comprising Italian universities, research institutes, and private companies collaborating on projects.

A leading research and development institution, is an innovative and client-focused SME providing technologically-advanced e-business software solutions.

1 Large industry

An experienced Project Coordinator with a proven track record of excellence, has led numerous successful collaborative projects throughout Europe. They bring their extensive expertise to the development, integration, and testing of Solid Oxide Fuel Cell systems.

FuelSOME

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Thank you!

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Innovation Action **SYNERGETICS**

SYNERGETICS | Synergies for Green Transformation of Inland and Coastal Shipping

ISEC 3rd International Sustainable Energy Conference | 10/11 April 2024, Graz (Austria)

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Innovation Action SYNERGETICS

General information

Project number	101096809
Project title	Synergies for Green Transformation of Inland and Coastal Shipping
Project acronym	SYNERGETICS
Call	HORIZON-CL5-2022-D5-01
Topic	HORIZON-CL5-2022-D5-01-04
Type of action	HORIZON-IA
Project starting date	January 1st, 2023
Project duration	42 months
Total eligible costs	EUR 5 321 955.05
Maximum grant amount	EUR 4 184 312.03
Total eligible costs of APs	EUR 1 840 965.63

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Structure

- The SYNERGETICS consortium gathers 16 partners and two associated partners from eight countries which were selected with a purpose to take full advantage of concepts of Synergies.
- The project Coordinator is DST – Development Centre for Ship Technology and Transport Systems from Germany.

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Synergies

- Synergy between the ongoing pilot and research projects and SYNERGETICS;
- Synergy between the innovation centres and research institutes;
- Synergy between the shipping industry, and the regulatory bodies and policy-makers;
- Synergy between the shipping industry and other (transport) industrial sectors;
- Synergy between the shipping industry and energy providers;
- Synergy between the shipping industries of Rhine/Seine and the Danube/Elbe regions.

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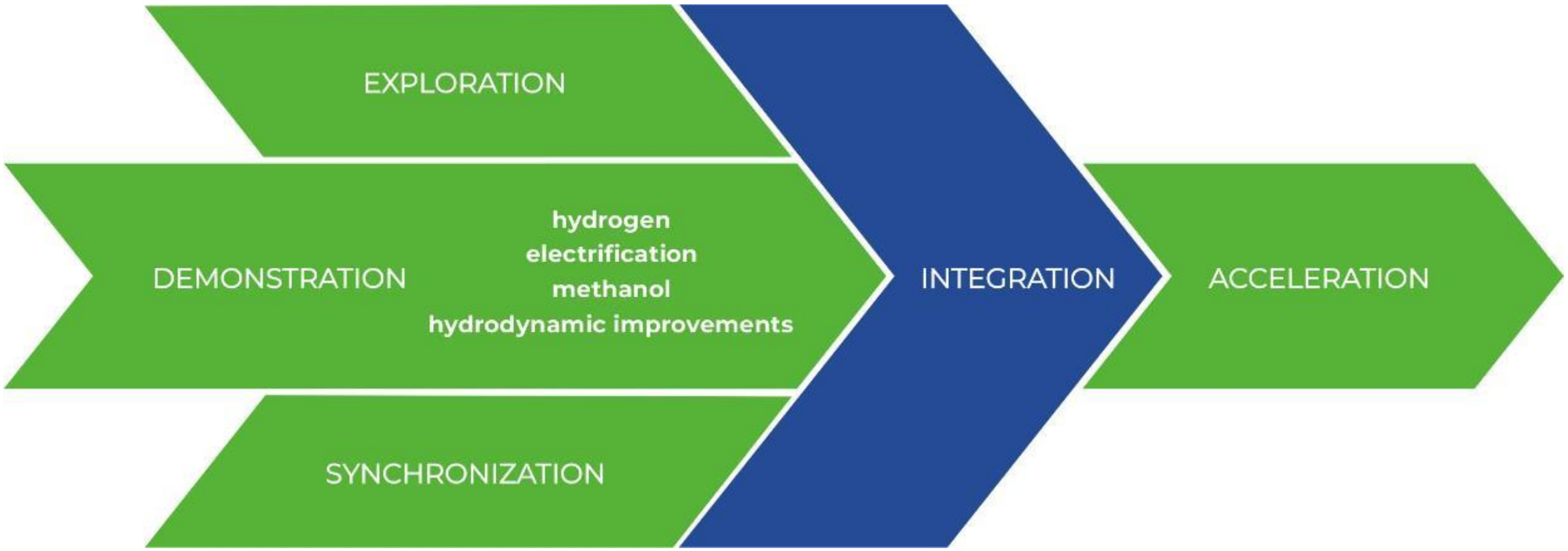
Synergies



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Full-scale Demonstrators

Image: CMB.TECH

H2-ICE

Image: Mercurius Shipping

CH3OH-ICE

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Full-scale Demonstrators

Image: CFT

Electrification of the main propulsion plant

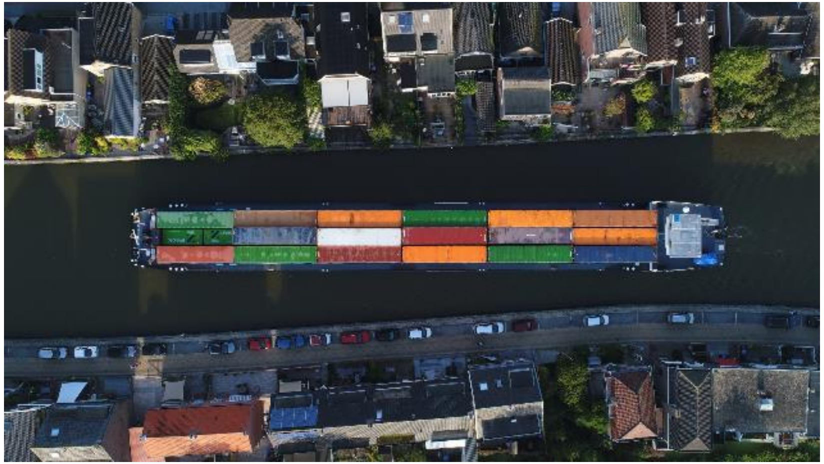
Image: Zero Emission Services

Battery-electric

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Model-scale Demonstrators

Image: DST / Benjamin Friedhoff

Aft-ship replacement

Image: via donau / Johannes Zinner

Use of digital tools and virtual assets in finding the optimal greening solution

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System Demonstrators

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Image: ScandiNAOS

Image: Future Proof Shipping

Comparison of a dual fuel methanol engine with a compression ignited methanol engine

Development of power and energy management system for fuel cells and hydrogen powered ships

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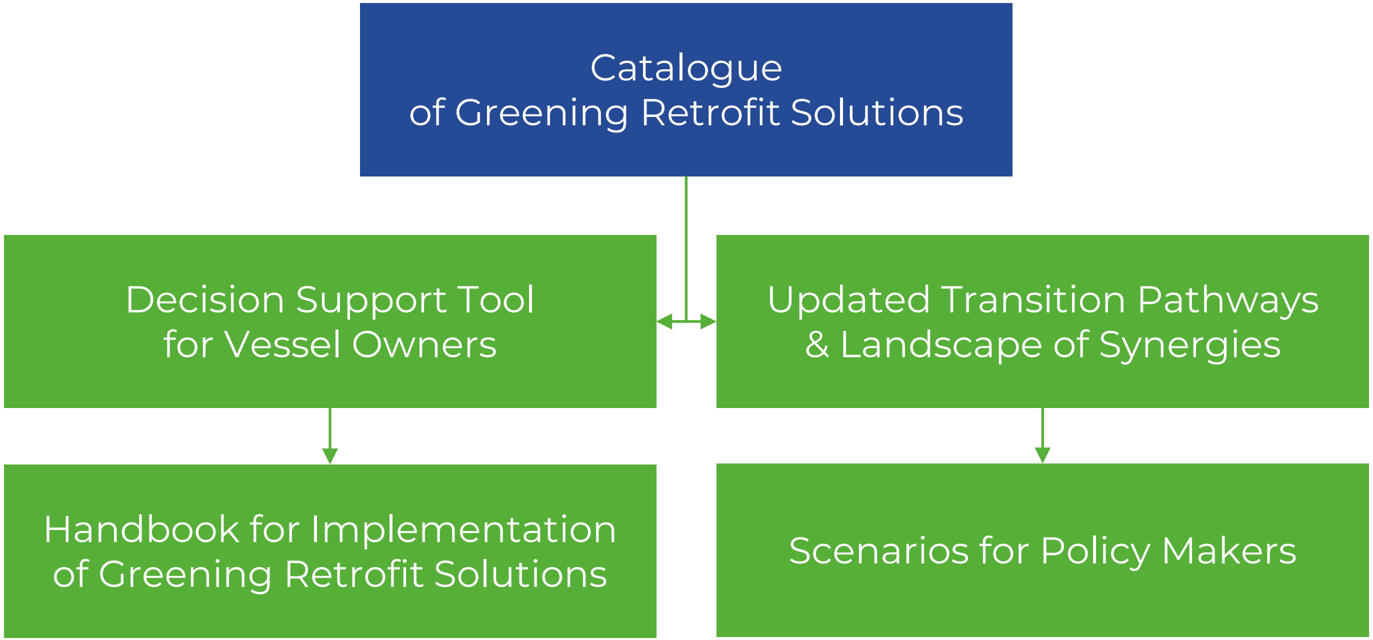
SYNERGETICS Tools



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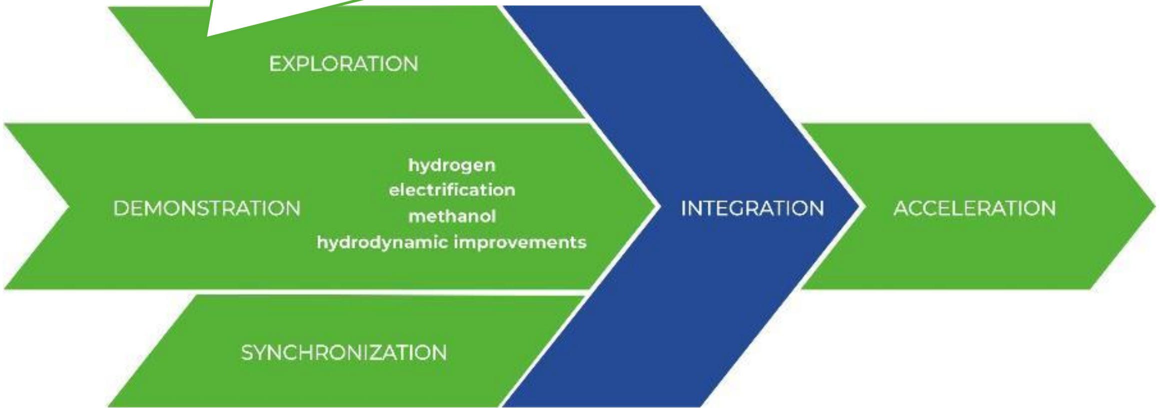
WP1 Exploration

Example:
- Focus on Well-to-Tank scenarios
- Supply of 6.2 TWh renewable hydrogen to Rotterdam
- Assessment of emissions and costs



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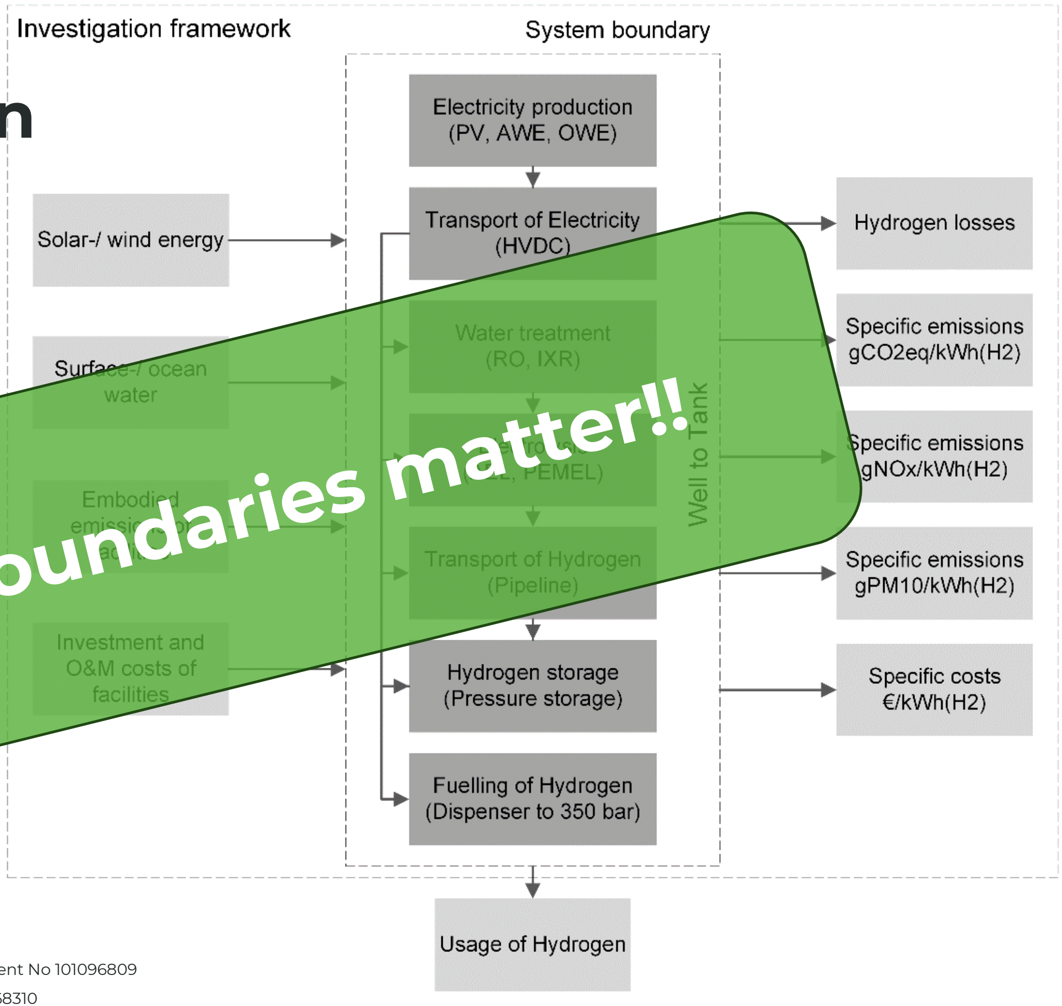
Renewable Hydrogen Scenarios

- Cradle-to-Grave
- Emissions:
  - GWP ($CO_{2,eq}$)
  - NOx
  - PM
- Costs:
  - CAPEX and OPEX for key modules
  - Transport: Service costs
  - No taxes, subsidies etc.



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Renewable Hydrogen Scenarios

- Single path scenarios
- 6.2 TWh renewable H_2 in Rotterdam
- Transport of electricity or H_2
- Always incl. water treatment
- Hydrogen Storage included
- Hydrogen Fuelling included
- …

Size, locations and time matter!!

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Renewable Hyd Scenarios

- For both emissions and costs: Calculation of losses (efficiencies, leakages, …)
- Energy Flows and Mass Flows
- …

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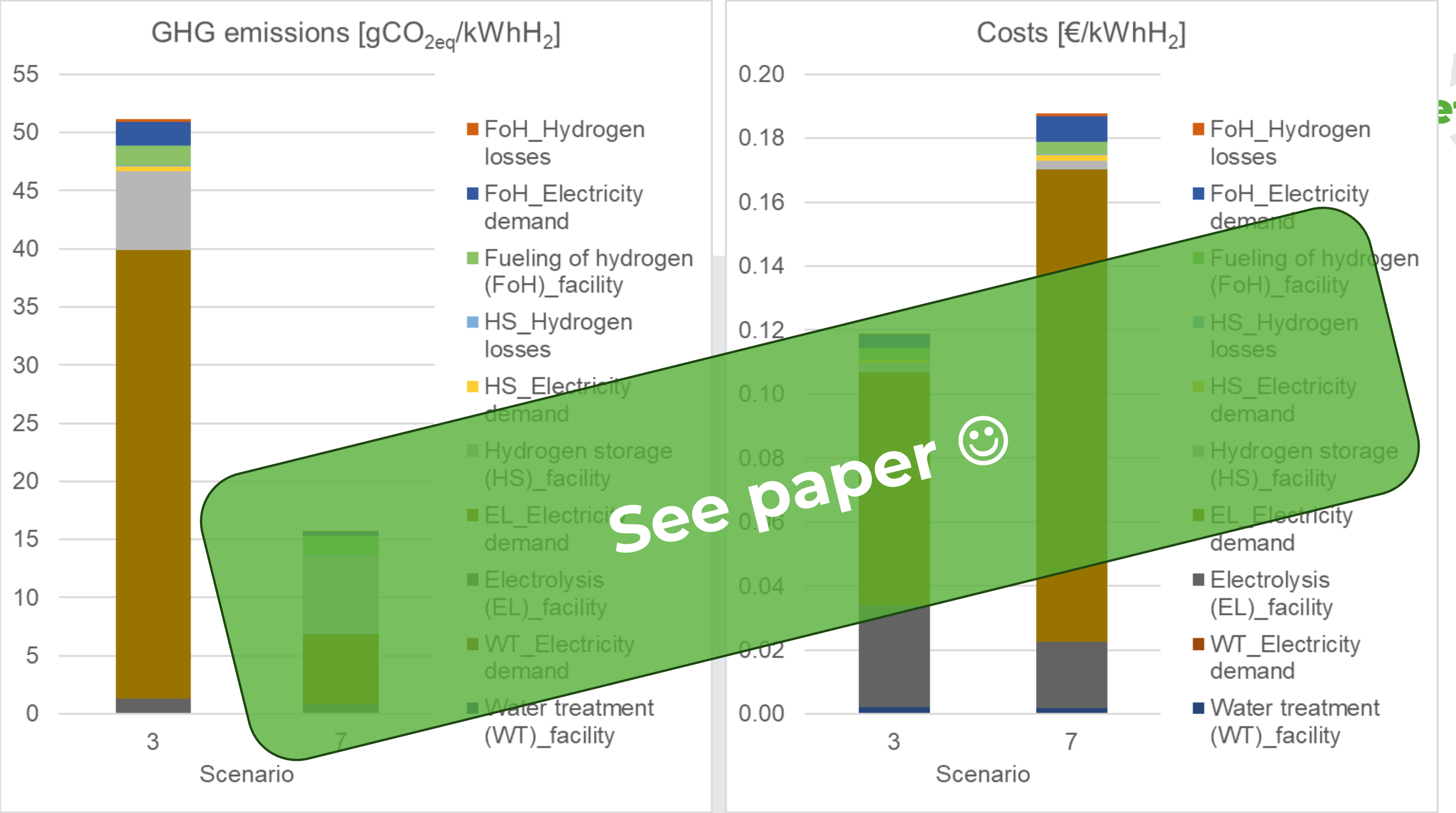

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Discussion on KPIs from (prospective) LCA and cost calculations (or parts thereof)

- When interpreting results, keep in mind
  - system boundaries (what is included, …)
  - order of magnitude (e.g. capacity-dependent cost and emission functions)
  - sources of data (completeness, comparability, reliability, accuracy, timeliness, …)
  - for which year the calculations have been made (learning curves, scaling effects, …)
  - TRL assessments
  - …
- Possibly, quantified KPIs have to be combined with qualitative aspects (e.g. by utility analysis)
- Combination of costs and emissions?

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WP "Exploration"

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