FuelSHIME

Multifuel SOFC system with Maritime Energy vectors

Introduction & Achievements

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FUEL CELL & ELECTROLYSER SYSTEM WORKSHOP,

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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 CO_2 per kilometer** for each metric ton of cargo they carry.

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

Specific project Objectives

"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

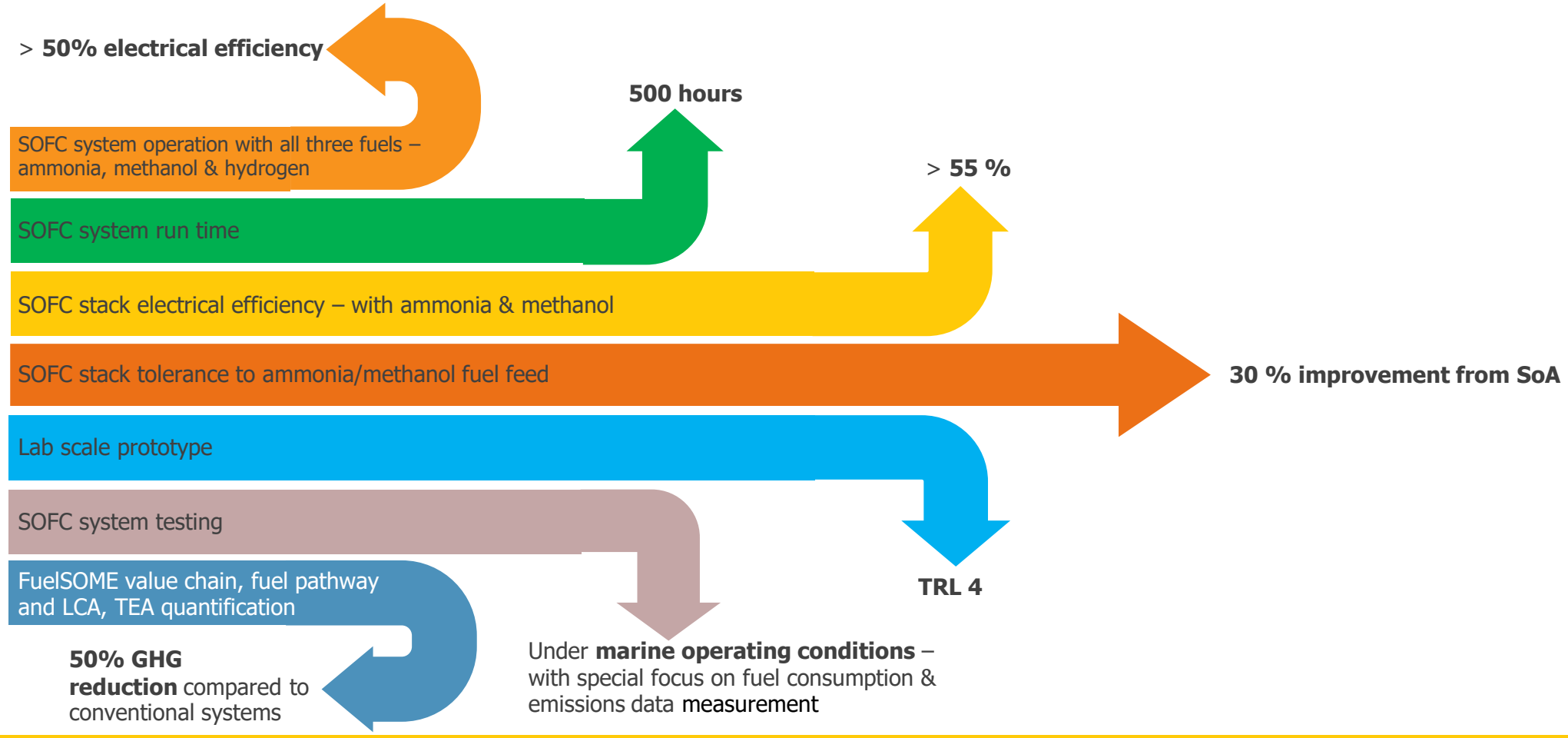
TEA & LCA studies

- 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 ultimate targets



Major Achievements

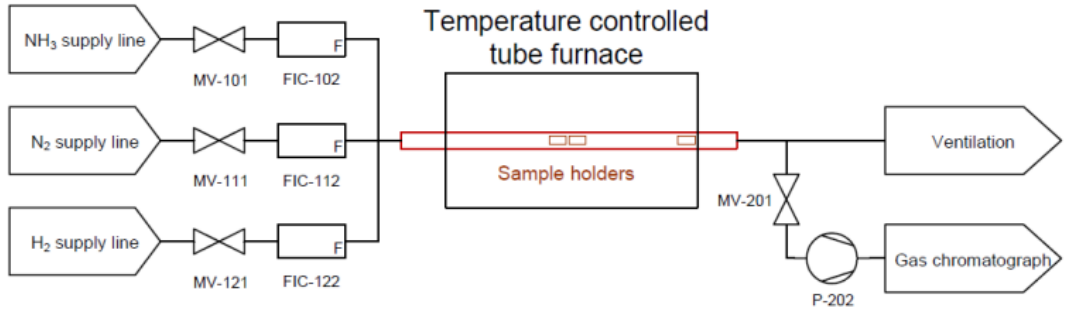
The next few slides summarize the major achievements in the project so far. This for the period of ~ 20 Months

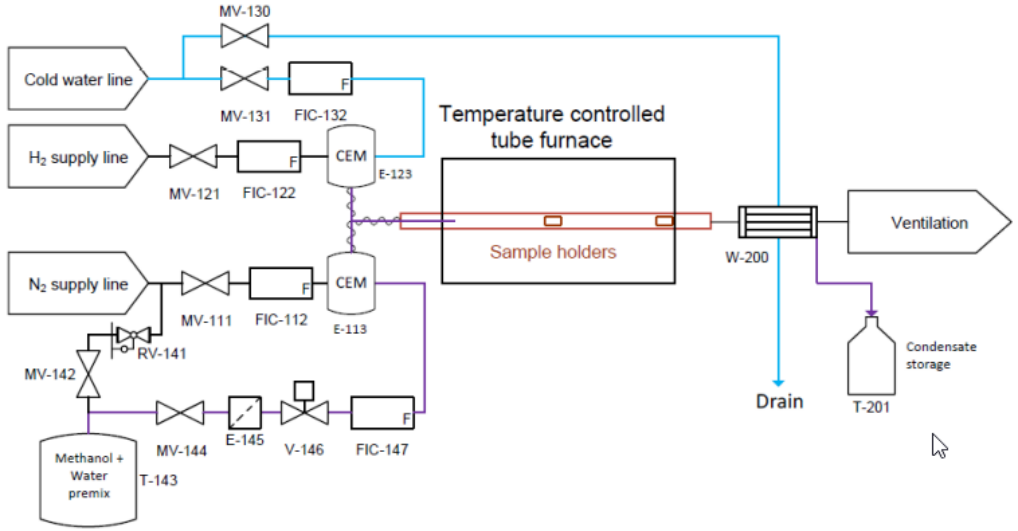
Core SOFC stack

The SOFC stack development is being carried out with Elcogen & VTT

- Two short stacks (15 cells) 350 W (Elcostack E 350 nominal power) tested with ammonia and methanol pre-processed mixtures
- Ex-situ testing & validation of components
  - Provides valuable degradation mechanisms that might occur
  - Which sealing materials & steel samples can withstand multi-fuel operation

Set-up for testing in NH_3 & CH_3OH atmosphere





3 exposure tests with ammonia:

- 0.1% NH_3 concentration
- 1 % NH_3 concentration
- 5% NH_3 concentration

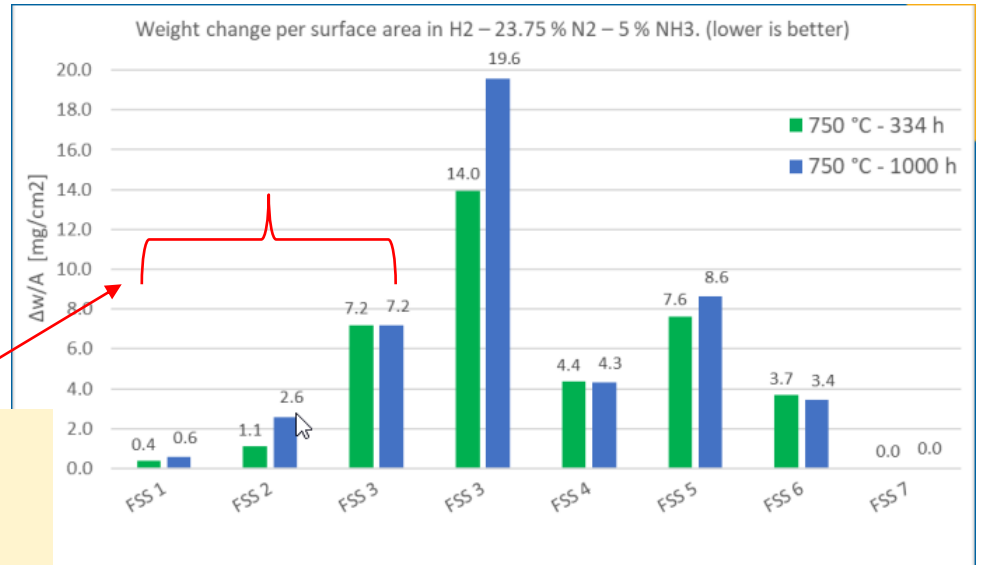
Mainly pieces of stack (metal parts) and sealing material

Exposure tests with ammonia:

- 8.6 % methanol concentration

Results – Short stack & Ex-situ testing

Operating conditions	Power	Voltage	Current
With Ammonia:	399W	13.3V	30A
With Methanol:	414W	13.8V	30A



Used commonly in SOFC stacks

Fuel feed with NH_3: 5.17 l/min of cracked ammonia resulting in 7.755 l/min of H_2 & 2.585 l/min of N_2

Fuel feed with CH_3OH: 2.5 g/min of CH_3OH & 2.1 g/min of H_2O, resulting in a reformate mixture of CO, CO_2, CH_4 & H_2

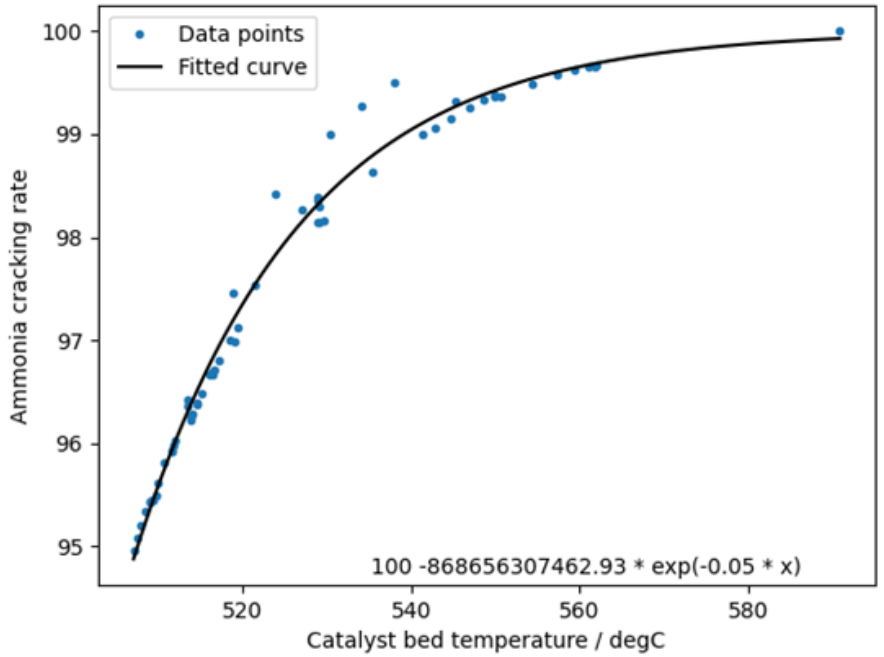
5 vol% Ammonia exposure:

- Weight gain correlates to nitrogen intake

Multi-fuel reformer

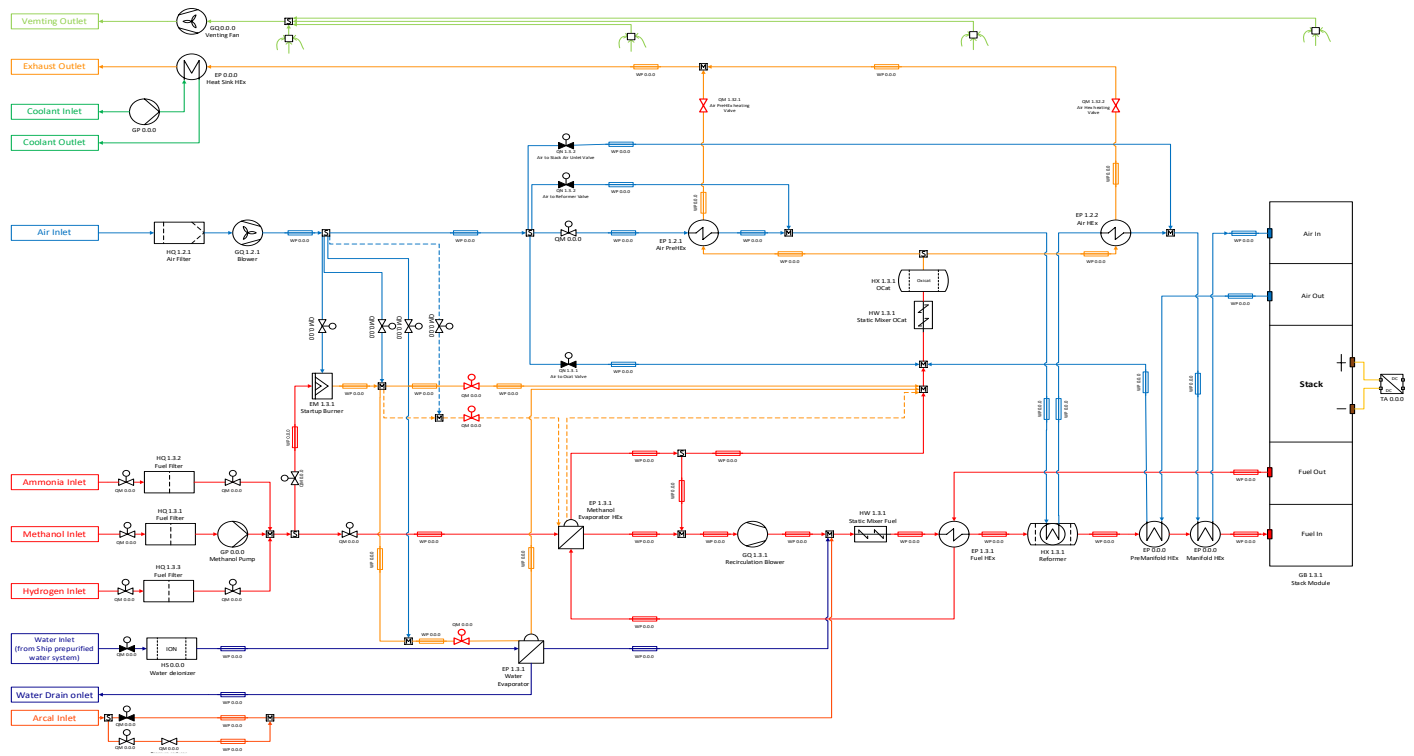
- **Single catalyst compound developed** which is able to handle both ammonia & methanol
- The reformer will be able to handle both fuels – NH_3 & CH_3OH
- Heat requirements balanced out when integrated into the system

Fundamental studies on catalyst loading, reaction modelling, 3D simulation



Design, manufacturing and testing of the component – on going

SOFC system – Architecture development



- **Harmonized system architecture** development for multi-fuel operation
  - <u>> 70% reusability</u> of different BoP components
- **Main BoP dev. focus** - multi-fuel reformer, anode gas recirculation sub-system & thermal management sub-system

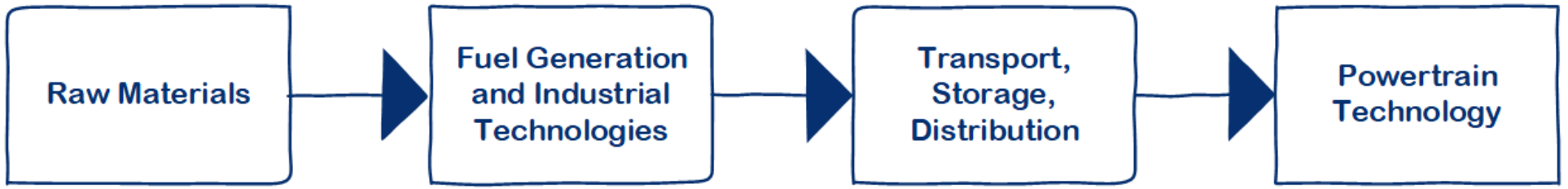
What criteria were taken into account?

- Target **system efficiency of > 50%** for all three fuels
- Reduce electrical power consumption of the system
- Execute different operation states: *heat-up, cool-down*, *hot standby*
- Usage of **start-up burner for all three fuels**
- Methanol evaporator – heated by off-gas streams
- Recirculation blower – operation with all 3 fuels & withstand T up to 350 °C
- Reformer/Cracker unit

A multi-fuel SOFC system brings several challenges – *optimised operating conditions*, *material compatibility*, *cost optimisation*, controllability

Fuel pathways

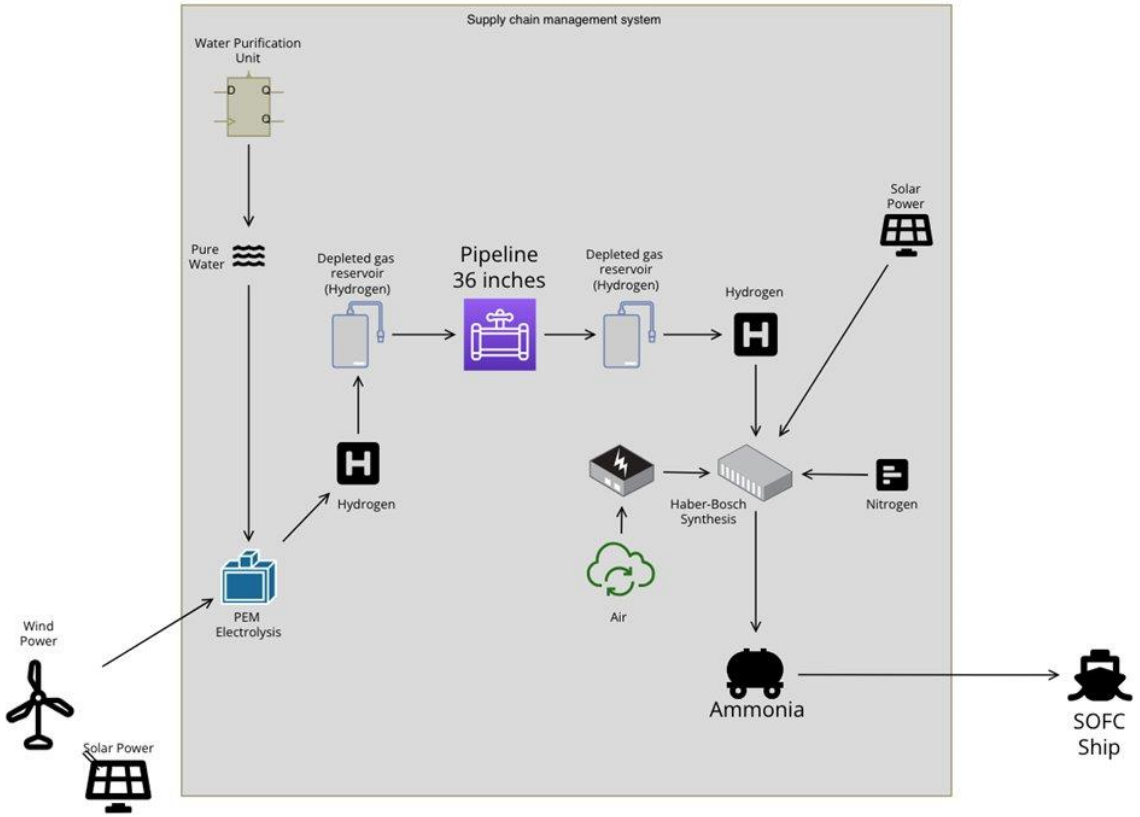
Definition **"fuel pathway"** includes **all steps and processes involved from transforming a raw material** (any type) by any technology to a state where the resulting product (i.e., fuel) fulfils the required specification and the quantity which is required **for powering the propulsion system within the propulsion systems limit** at a specific utilization efficiency.



Example: Ammonia

- **Use Case Example:** Ammonia (NH_3)
- Many criteria need to be met!
  - Preconditions (7 criteria)
  - Main Flow (9 criteria)
  - Post Conditions (1 condition)
  - Acceptance Criteria (9 criteria)

- Level of detail and system boundaries are of importance!
- Use cases for emerging technologies will be investigated in project phase 2 (currently in progress)



KPIs for pathway evaluation

- For **evaluation** and **comparison** of fuel pathways

- To **optimize** fuel pathways
  - Production methods
  - Transportation types
  - Primary energy ressources
  - others

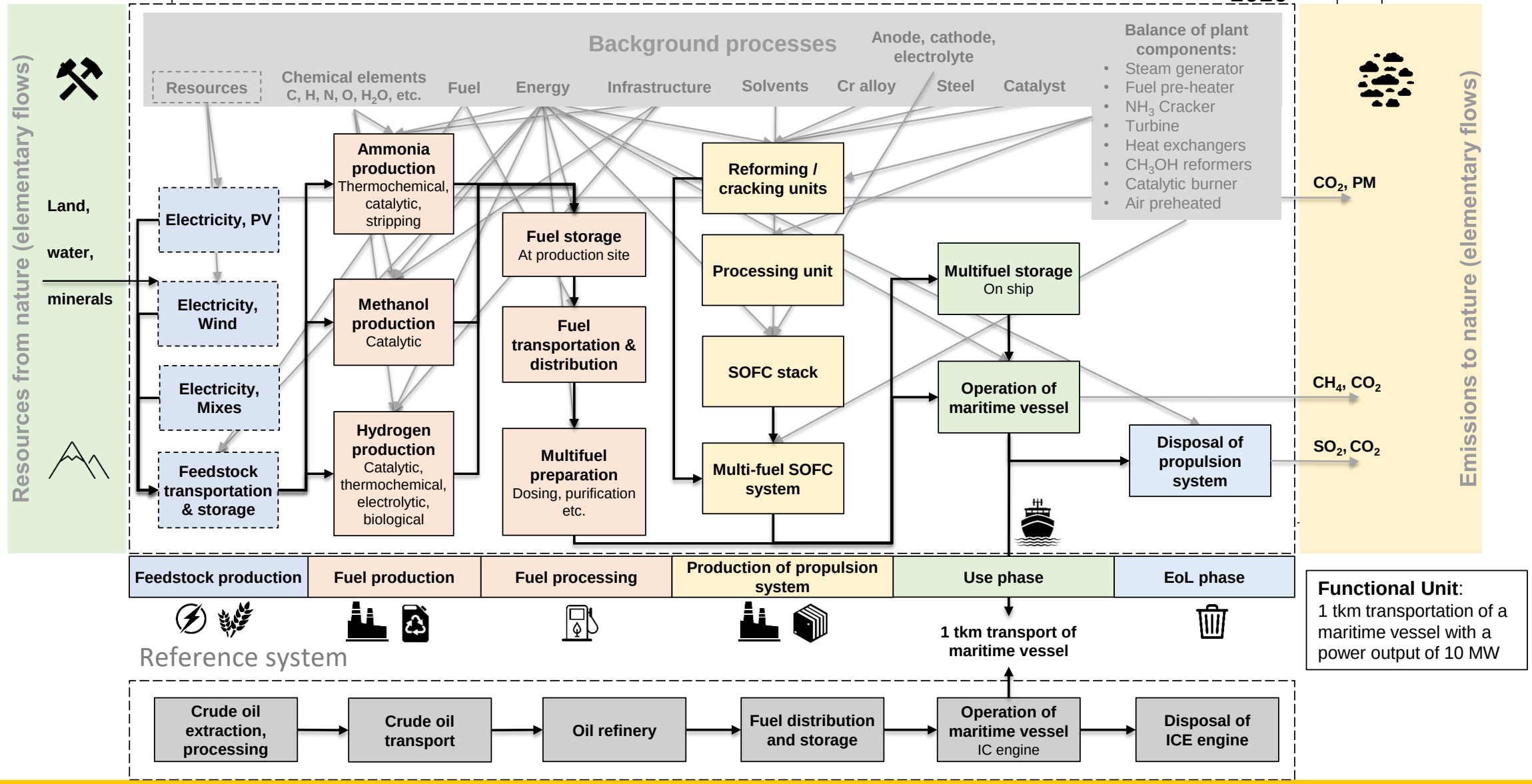
KPI	Unit	Calculation Method
Levelized cost of fuel	€/kWh	Component-wise
GHG emissions	t_{CO2equ}/year	Component-wise, grey GHG emissions of new infrastructure not included
Well-to-wake-efficiency	%	Efficiency component-wise + Total efficiency
Land use demand	m^2	Calculated for renewable electricity generation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

FuelSOME

Renewable product system with FuelSOME

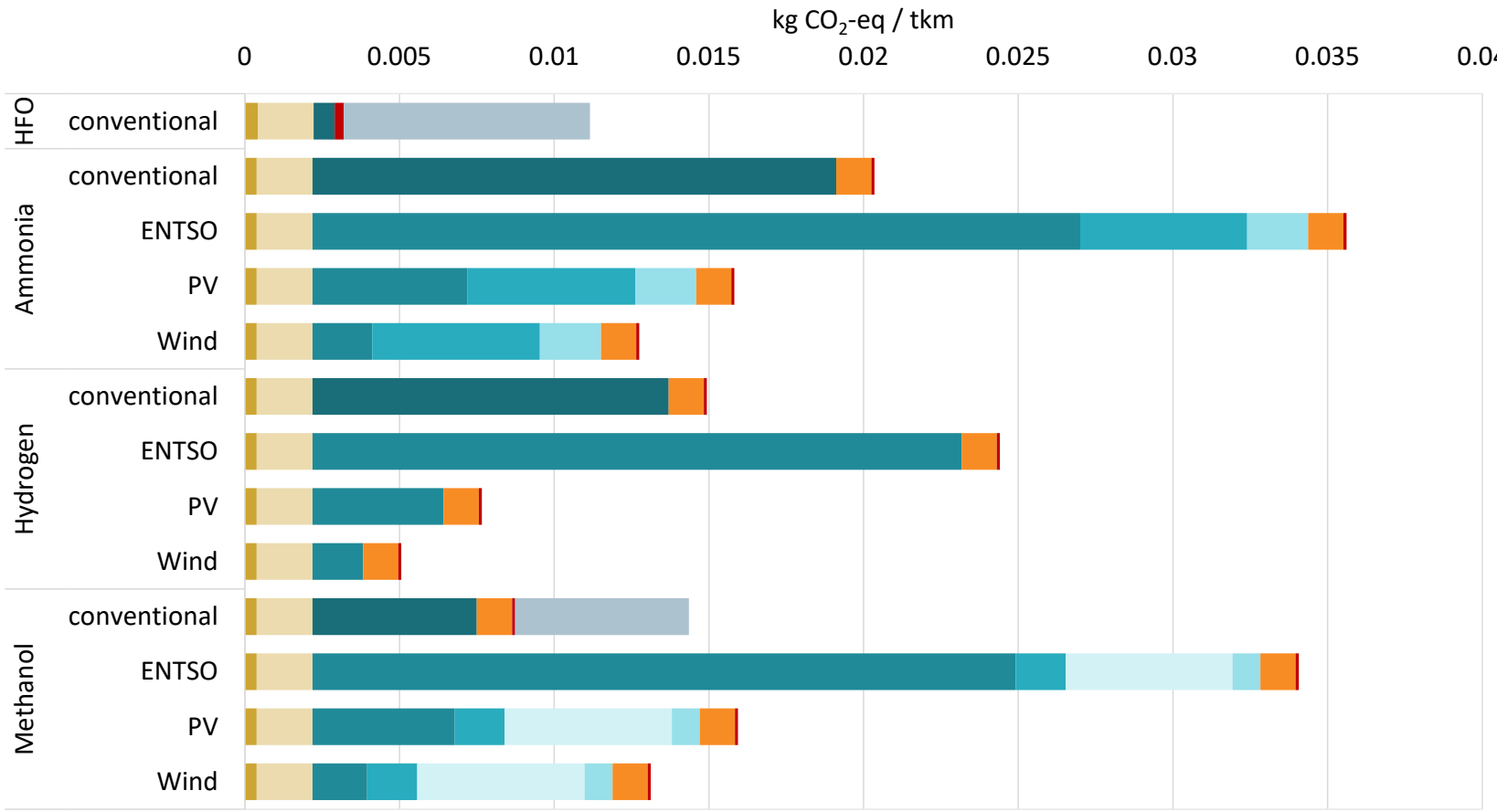
System boundary

2050
2030
2020



Functional Unit:
1 tkm transportation of a maritime vessel with a power output of 10 MW

Impact Assessment – GHG emissions



- E-fuels produced with grid mix show the highest GWP, while wind energy scenarios show the lowest
- Among e-fuels, e-hydrogen shows lowest GWP for all energy sources analysed
- Majority of scenarios are dominated by the fuel production

Next steps

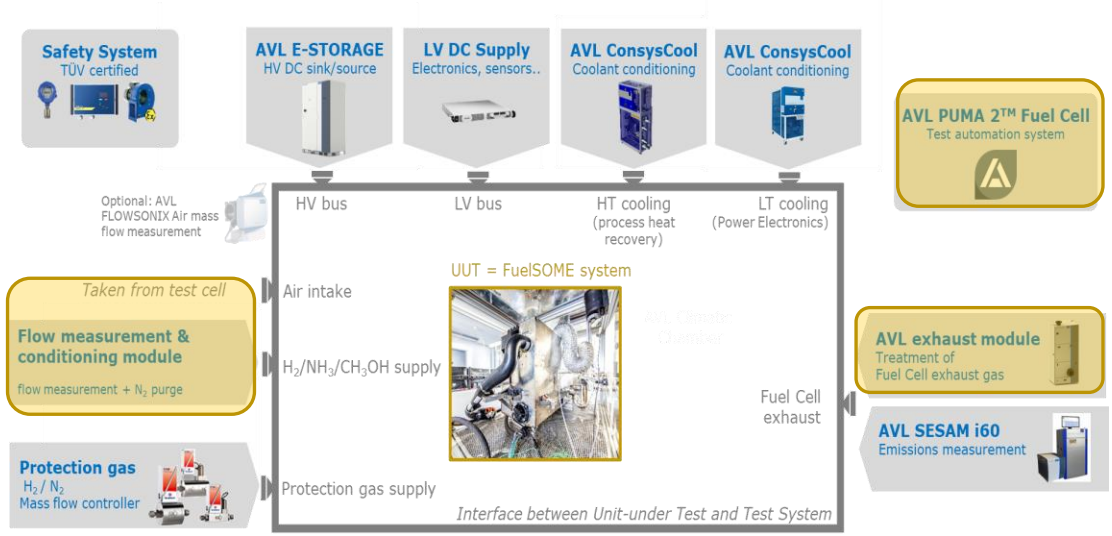
What is planned for the next 18 months (phase 2)?

(The project runs in 3 phases)

Activities in the pipeline – until M36

- Development & testing of **6 kW_e stack module**
- **TRL 4 lab scale prototype construction**
- Preparation & development of the **system test bed**
- Initial report on LCSA & TEA analysis of the FuelSOME system
- Scale-up study for 10 MW system

Here a simplified system will be built – consisting of the fuel path alone & decoupled air path



New hardware modules – for NH_3 flow measurement & Exhaust module will be developed

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.

Question for afterthought

On a broader perspective, for the climate, how much of an effect will it be if 2.5% of the emissions from shipping be reduced to zero?

Or will it suffice to bring down the contribution to 1% of global emissions?

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Thank you!

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