Webinar #5– March 12th 2026

zhenit

E-learning program

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OVERVIEW OF ZHENIT PROJECT AND TECHNOLOGIES

ZHENIT aims to promote WHR as a key and *"ready-to-scale up" solutions* to reach the decarbonization targets by validating different systems at various temperature levels for different end-product (cooling, power, desalination) and optimizing integration/performance thanks to Thermal Energy Storage (TES).

ZHENIT valorizes WH via *different WH-to-X solutions*:

- WH-to-Trigeneration via innovative recuperated ORC integrated with an HP with ejector (T>100°C)
- WH-to-Cooling and Desalination via an adsorption system (70<T<100°C)
- WH-to-Mechanical Work (e.g. for fuel compression) via an isobaric expansion (IE) engine (T<100°C)

These solutions straight forward to making the shipping sector more sustainable, accessible and clean.

https://www.youtube.com/watch?v=nIKpNXnR7oQ

ZHENIT WHtoX TECHNOLOGIES

WH-to-Cooling and Desalination

Sorption Refrigeration and Desalination

Innovative concept of combined desalination and cooling system for medium temperature (70°C - 100°C) waste heat recovery and conversion

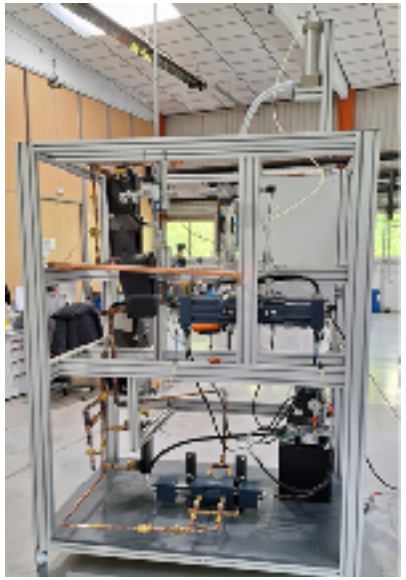
WH-to-Trigeneration (cooling, heating, power)

Organic Rankine Cycle

Marine-ready WH trigeneration system incorporating an ORC with a recuperator and a hybrid HP for producing electricity and H&C from high temperature waste Heat (> 100°C)

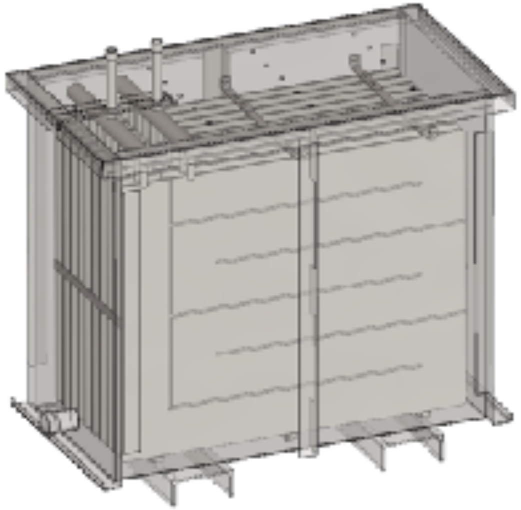
WH-to-Mechanical Work

Isobaric Expansion Engine



Waste-Heat to-mechanical-work system for the compression of diesel fuel via an Isobaric Expansion Engine powered by low-grade heat (<100°C)

Thermal Energy Storage



Thermal energy storage system (TES) for optimal controllability of the integrated ZHENIT technologies

SCOPE OF THE WEBINAR

- ➢ Discuss the approach used for the assessment of environmental and economic performances of ZHENIT solutions, along the life-cycle
- ➢ Present environmental and economic performances of Isobaric Expansion Engine and Sorption Refrigerator & Desalinator, considering identified life-cycle stages
- ➢ Present environmental and economic performances of these technologies when installed onboard vessels

Life Cycle Thinking

The **Life-Cycle Thinking** is an approach through which the product or service system is evaluated in terms of environmental, economic and social performance throughout the entire life cycle.
The main goals of LCT are to reduce a product's resource use and emissions to the environment as well as improve its socio-economic performance through its life cycle. (LCI, UNEP)

With the Life Cycle Thinking approach it is possible to estimate:

Environmental sustainability: Ability to protect the ecosystem and renew natural resources → Life Cycle Assessment: LCA

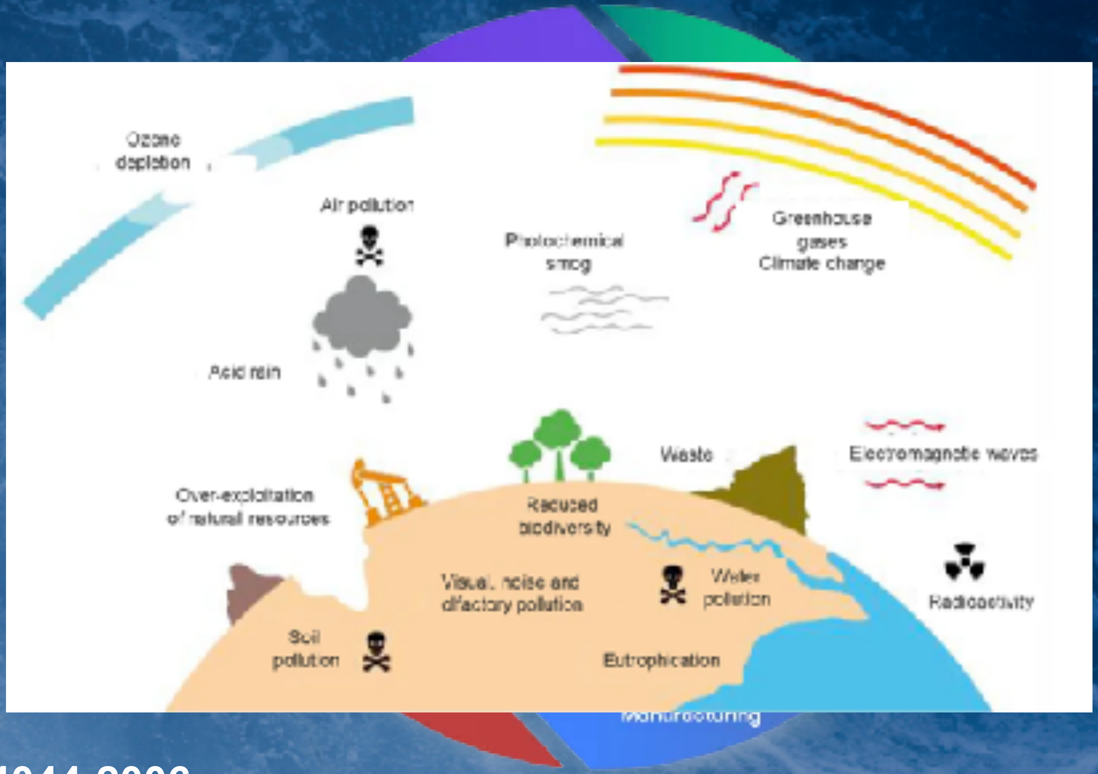
Economic sustainability: Ability of an economic system to generate sustained growth in economic indicators → Life Cycle Costing: LCC

Social sustainability: Ability to ensure that human well-being is equitably distributed → Social Life Cycle Assessment: S-LCA

LCA Methodology

LCA Definition

Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardized methodology for evaluating the environmental impacts of a process or activity, carried out by identifying the energy and materials used and the waste released into the environment, throughout its life cycle.



LCA Regulations and Guidelines

ISO 14040:2006

Environmental Management Life Cycle Assessment Principles and Framework

Provides a clear overview of the practice, applications, and limitations of LCA to a wide range of potential users and stakeholders, including those with limited knowledge of LCA

ISO 14044:2006

Requirements and Guidelines

standard that addresses the preparation, development, and critical review of life cycle inventory analysis. It also provides guidance on the impact assessment phase of the LCA and the interpretation of LCA results, as well as the nature and quality of the data collected.

Possible uses of LCA

Identifying opportunities

Identification of opportunities for improvement at different stages of the product and process lifecycle.

Decision support

Strategic planning, definition of environmental priorities and objectives and other sustainability policies

Marketing

Basis for improving brand reputation: environmental claims, environmental labels, or environmental product declarations

Product development

Improvement of product design, Hotspot analysis

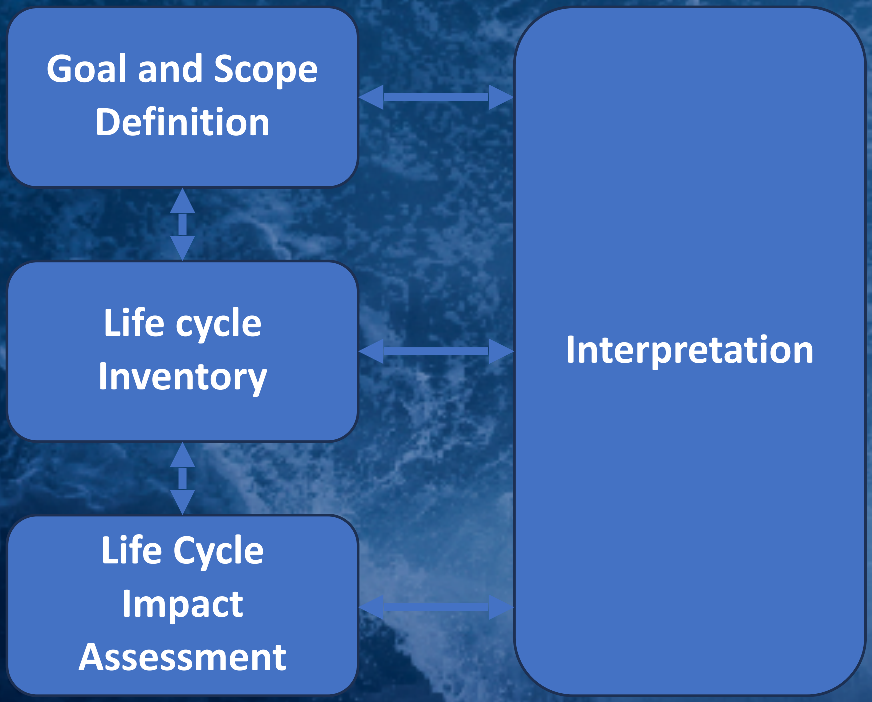
Circular economy

Implementation of circular economy actions: reduce resource consumption through more efficient use of materials and increase reuse/ recovery/recycling

Supply chain management

Supply chain analysis, supplier evaluation, Procurement Process

LCA Methodology



1. Goal and scope definition:
Describing the reasons for executing the study and its intended use are described. Functional unit and the system boundary are also specified

2. Life Cycle Inventory (LCI):
where the product system and its constituent unit processes are described, including the inputs and outputs (data). Their amounts are in reference to one functional unit and system boundary

3. Life Cycle Impact Assessment (LCIA):
where the magnitude and significance of impacts are evaluated. This is done by associating the life cycle inventory results with impact categories and category indicators

4. Interpretation of the results:
where the findings of the previous two phases are combined to reach conclusions or recommendations.

LCA – Goal and Scope Definition

Objective of the study:

Establish the intended application, the reasons for conducting the study, and the target audience to whom the study results are intended to be communicated.

Scope of application:

- ✓ System under study and its function
- ✓ Functional unit
- ✓ System boundaries and cut-offs
- ✓ Data quality requirements
- ✓ Assumptions
- ✓ Allocations procedures

LCA – Goal and Scope Definition

Functional Unit (FU)

The **Functional Unit** allows to quantify the function provided by the product, thereby enabling several systems to be compared fairly. The functional unit must be quantifiable, precise, and reflect the actual performance of the product.

Having chosen the functional unit, the **reference flow** shall be defined. Reference flow quantifies the system's specific resources needed to achieve that functional unit.

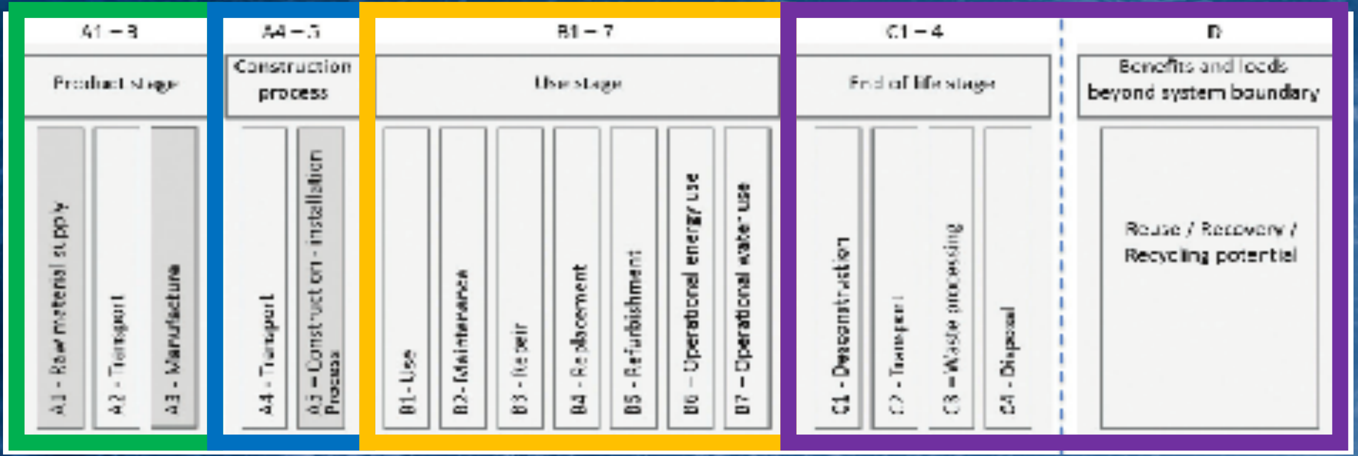
Ex: FU = the complete coverage of 1m^2 of external wall for 10 years with 99.9% opacity

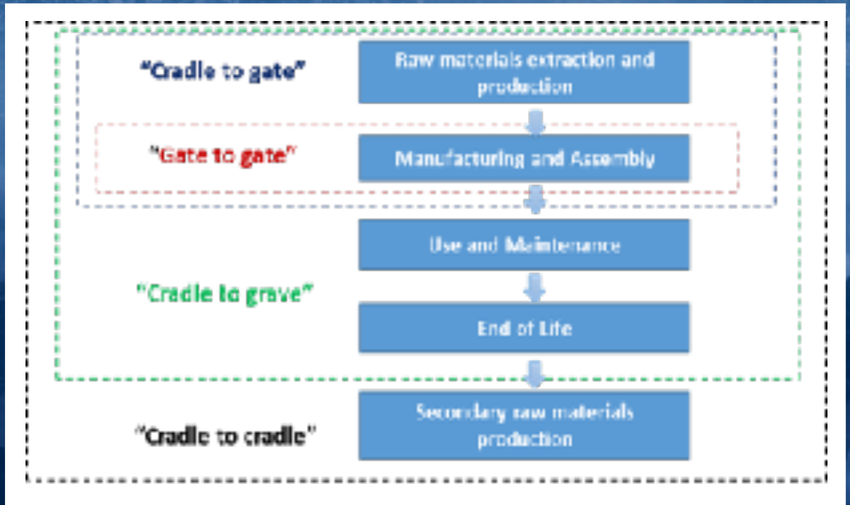
Reference flow = «the complete coverage of 1m^2 of external wall for 10 years with 99.9% opacity with paint X», or «0,67 liters of paint X»

LCA – Goal and Scope Definition

System Boundary

As per EN 15804





LCA – Life Cycle Inventory

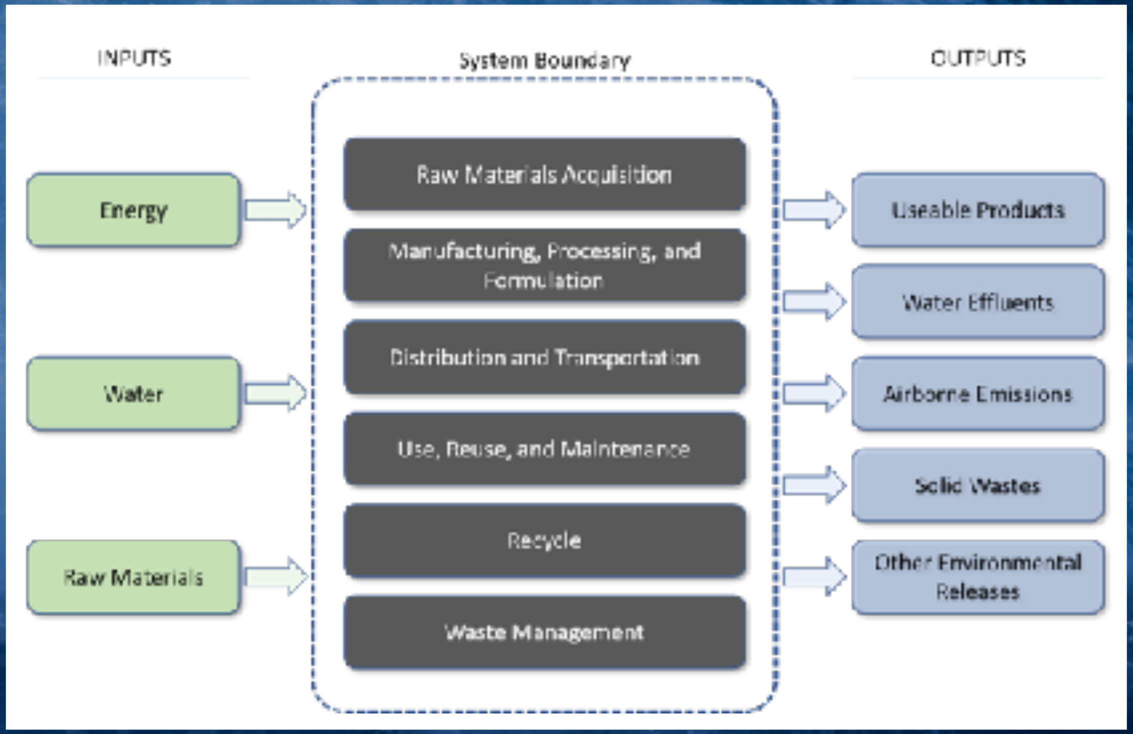
Inventory analysis involves data collection to quantify system inputs and outputs and modeling the system (using LCA-specific software)

Data Collection

For each unit process, qualitative and quantitative inventory data are identified and collected:

- ✓ Material and energy Input
- ✓ Products, co-products, waste
- ✓ Emissions to air (e.g. CO_2, SO_2, PM, VOC), water (e.g. PO_4, NO_3) and soil (e.g. pesticides, metals)

Block Flow Diagram



LCA – Life Cycle Inventory

The inventory analysis is the phase with longer and more variable timelines. It also requires several iterations

- **Primary data**: System specific data

Directly measured in the manufacturing plant

Derived from supplier-specific data sheets/EPDs

- **Secondary data**: Generic data from third parties (processes that the client do not directly influence)

Inventory databases

Literature

Estimated

Calculated based on formulas obtained from literature

LCA – Life Cycle Inventory

Data collection takes place in close collaboration with the partners responsible for the technologies, to whom a specific questionnaire for LCA is sent.

A.1 Example of data sheet for unit process

Completed by:	Date of completion:			
Unit process identification:	Reporting location:			
Time period: Year	Starting month:	Ending month:		
Description of unit process: (attach additional sheet if required)				
Material inputs	**Units**	**Quantity**	**Description of sampling procedures**	**Origin**
Water consumption [a]	**Units**	**Quantity**		
Energy inputs [b]	**Units**	**Quantity**	**Description of sampling procedures**	**Origin**
Material outputs (including products)	**Units**	**Quantity**	**Description of sampling procedures**	**Destination**
NOTE The data in this data collection sheet refer to all unallocated inputs and outputs during the specified time period.				

[a] For example, surface water, drinking water

[b] For example, heavy fuel oil, medium fuel oil, light fuel oil, kerosene, gasoline, natural gas, propane, coal, biomass, grid electricity

Unit process identification			Reporting location
Emissions to air [a]	**Units**	**Quantity**	**Description of sampling procedures** (attach sheets if necessary)
Emissions to water [b]	**Units**	**Quantity**	**Description of sampling procedures** (attach sheets if necessary)
Emissions to land [c]	**Units**	**Quantity**	**Description of sampling procedures** (attach sheets if necessary)
Other releases [d]	**Units**	**Quantity**	**Description of sampling procedures** (attach sheets if necessary)
Describe any unique calculations, data collection, sampling, or variation from description of unit process functions (attach additional sheets if necessary).			

[a] For example inorganics: Cl_2, CO, CO_2, dust/particulates, F_2, H_2S, H_2SO_4, HCl, HF, N_2O, NH_3, NO_x, SO_x and organics: hydrocarbons, PCB, dioxins, phenols, metals: Hg, Pb, Cr, Fe, Zn, Ni.

[b] For example: BOD, COD, acids, Cl_2, CN^-, detergents/oils, dissolved organics, F^-, Fe ions, Hg ions, hydrocarbons, Na^+, NH_4^+, NO_3^-, organochlorides, other metals, other nitrogen compounds, phenols, phosphates, SO_4^{2-}, suspended solids.

[c] For example: mineral waste, mixed industrial waste, municipal solid waste, toxic wastes (please list compounds included in this data category).

[d] For example: noise, radiation, vibration, odour, waste heat.

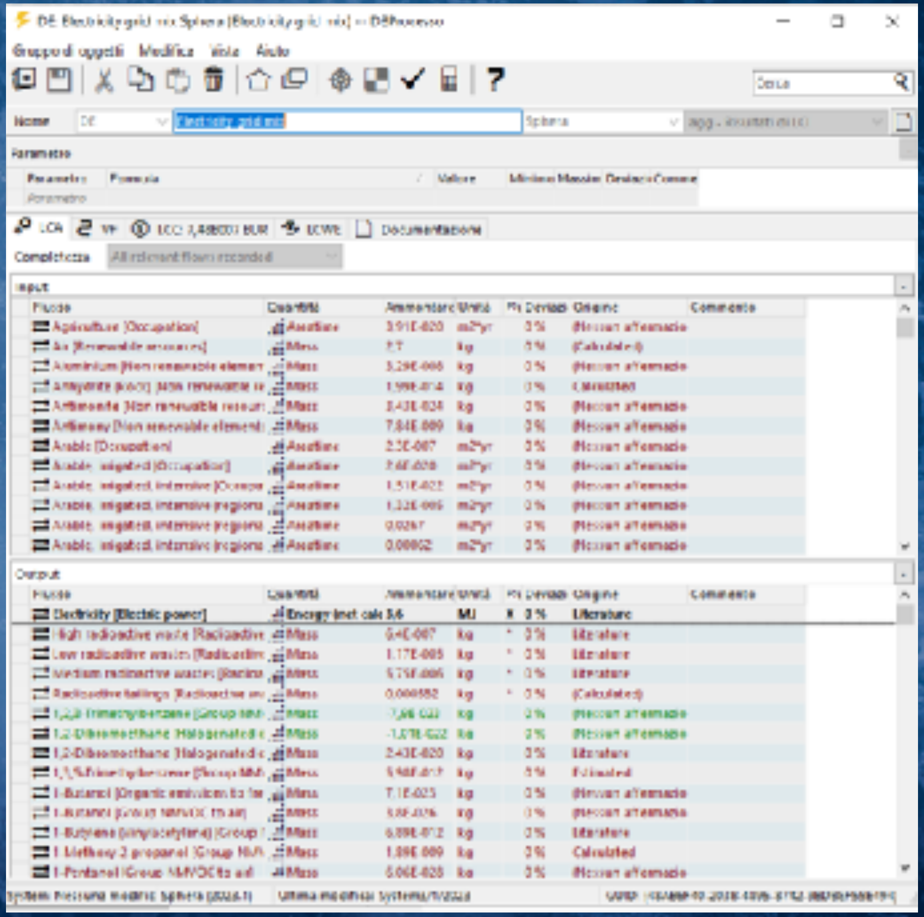
LCA – Life Cycle Inventory

Example of generic LCI

Category	Item	Unit	Quantity
Input	Solvents, ethanol	kg	0.05
	Water	L	15
	Crude oil	kg	0.95
	Electricity	kWh	100
	Heat	MJ	45
Output	Surfactant	kg	1
	Production waste	kg	0.01
	Wastewater	L	15
	Volatile organic compounds (VOCs)	g	5
	Particulate matter (PM)	g	10

Technosphere | Biosphere

Example of LCI for a specific dataset



LCA – Life Cycle Inventory

<u>System modelling</u>: using dedicated LCA software, all process/product inputs and outputs are associated with the most representative dataset. The dataset may already represent a complex product or process (e.g. 1 m² of copper sheet) or be just an elementary flow (e.g. input of a single raw material, output of a single emission)

Software for LCA

Sphera LCA for expert

SimaPro

LCI Databases

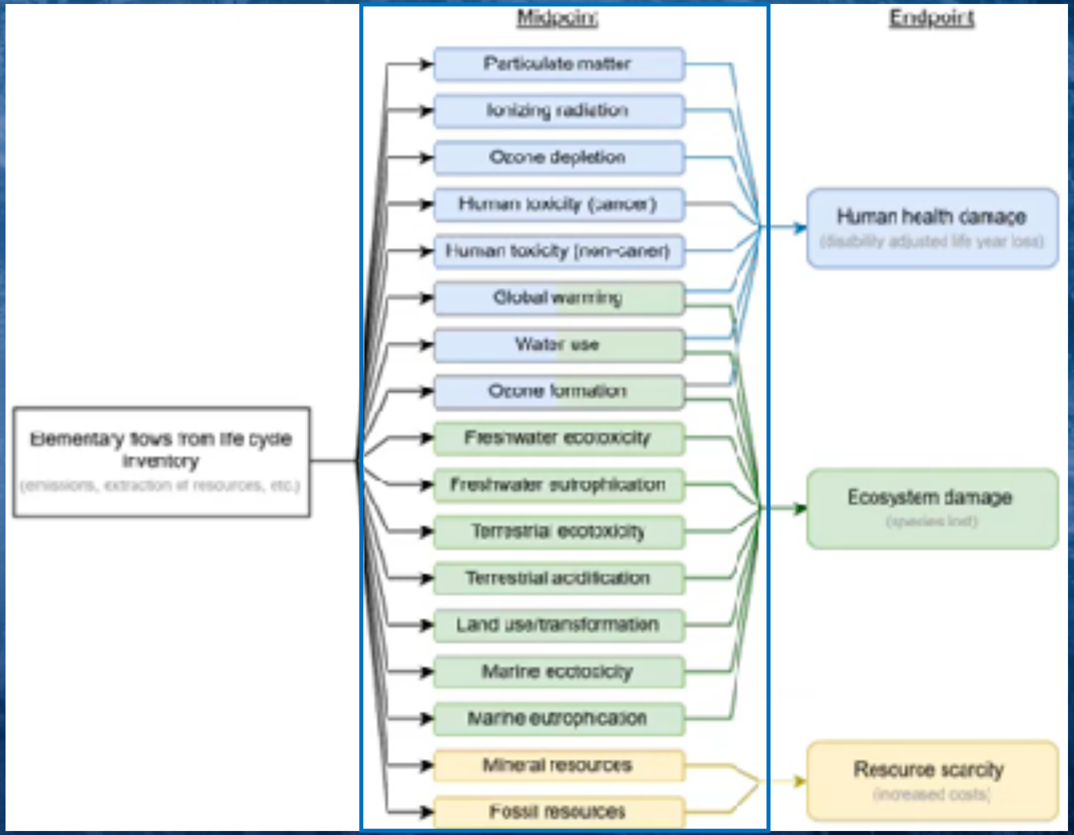
Sphera Database

Ecoinvent Database

LCA – Impact Assessment

Inventory data are translated into environmental impacts. Inventory data all boils down to elementary flow. Different impact assessment methods exist

Different impact categories

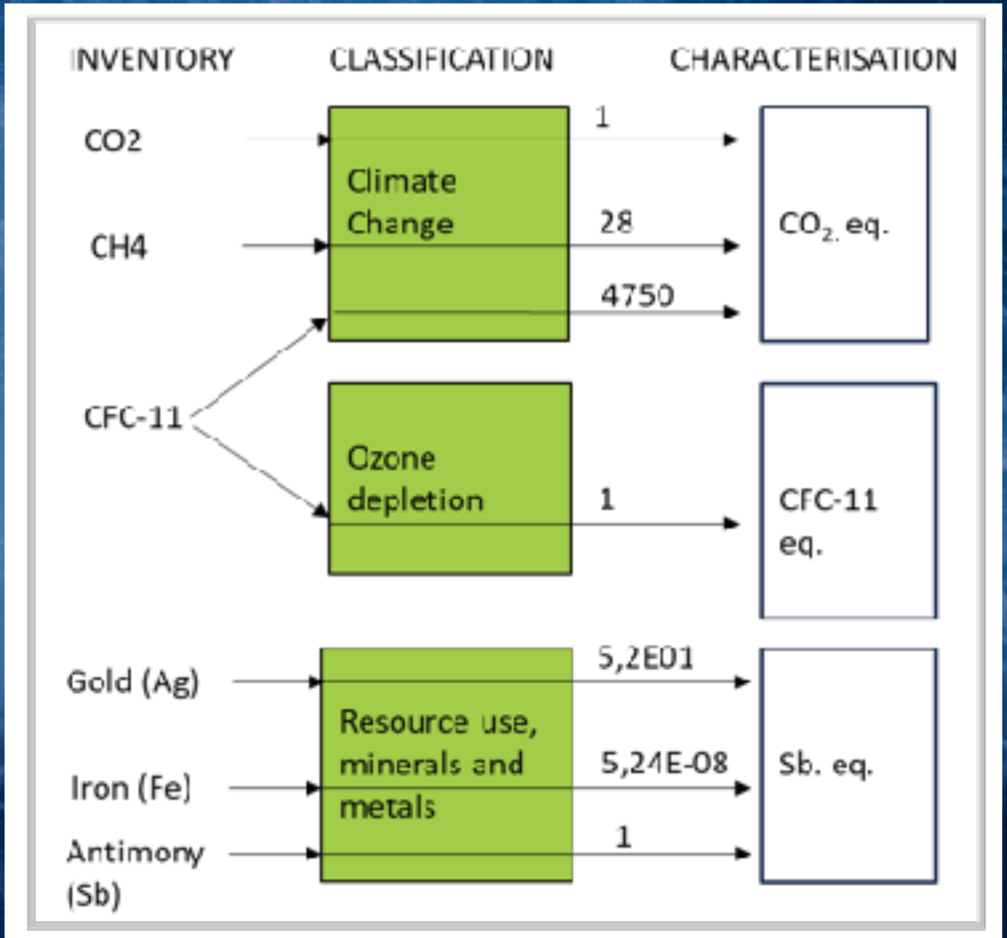


LCA – Impact Assessment

Classification → **Characterization** → **Normalization** →

Classification: attribution of LCI results to the impact category (e.g., CO_2 and CH_4 are assigned to the "Climate Change" category, while SO_2 contributes to "Acidification")

Characterization: Equivalence coefficients are used that relate the contributions of individual pollutants to each impact category in the same unit of measurement. These coefficients are called **characterization factors**



LCA – Impact Assessment

Normalization: LCIA results are divided by normalization factors, to compare the magnitude of their contributions to impact categories, compared to a baseline (e.g., the average environmental burden in a country or continent).

Weighing: The normalized results can be multiplied by weighting factors proposed by e.g. the European Commission and based on:

- Relevance of the impact: spread of impacts, the time frame of the impact generated, reversibility, land carrying capacity, severity on the ecosystem and human health
- Robustness of the data

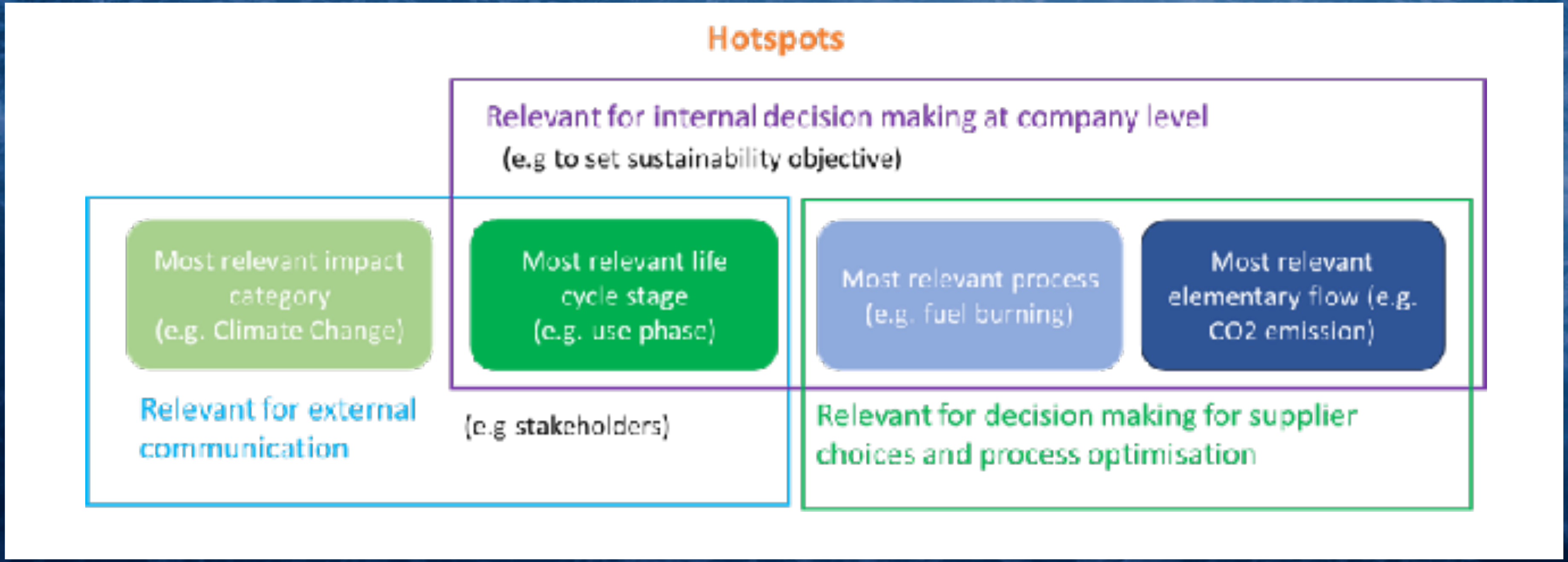
Impact Category	Unit	Global NF	WF (dimensionless)
Acidification	mol H^+ eq	3,83E+11	6,2
Climate change	kg CO2 eq	5,58E-13	21,06
Eutrophication, freshwater	kg P eq	1,11E+10	2,8
Eutrophication, marine	kg N eq	1,35E+11	2,96
Eutrophication, terrestrial	mol N eq	1.22E-12	3,71
Land use	Dimensionless (pt.)	5,55E-15	7,94
Ozone depletion	kg CFC-11eq	3,70E-08	6,31
Resource use, fossils	MJ	4,48E-14	8,32
Resource use, mineral, and metals	kg Sb eq	4,39E-08	7,55
Water use	m^3 world eq. deprived	7,91E-13	8,51

LCA – Interpretation

Interpretation is the phase of the LCA in which the results from the other phases are processed to:

- draw solid conclusions
- identify any limitations
- make recommendations
- perform ***hotspot analysis***

Interpretation is an **iterative process** of reviewing and reworking the purpose of the LCA, as well as the nature and quality of the data collected.



LCC Methodology and possible uses

LCC is a structured method that quantifies the economic impacts associated with the life cycle of a product or service

LCC Regulations and Guidelines

- **ISO 14040:2021**
- **SETAC Guidelines**: Environmental Life cycle Costing: A code of Practice, 2011
- **ISO 15686-5:2017:** Buildings and constructed assets - Service life planning - Part 5: Life cycle costing

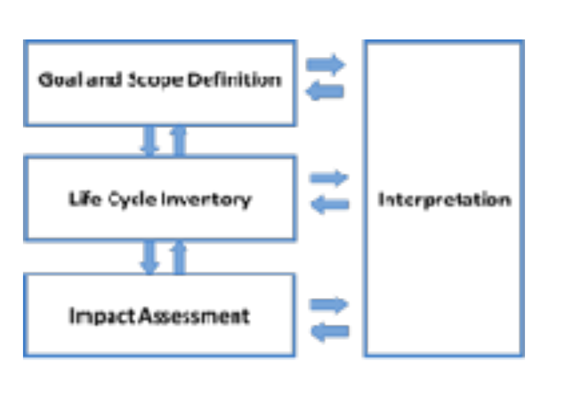
Possible uses of LCC

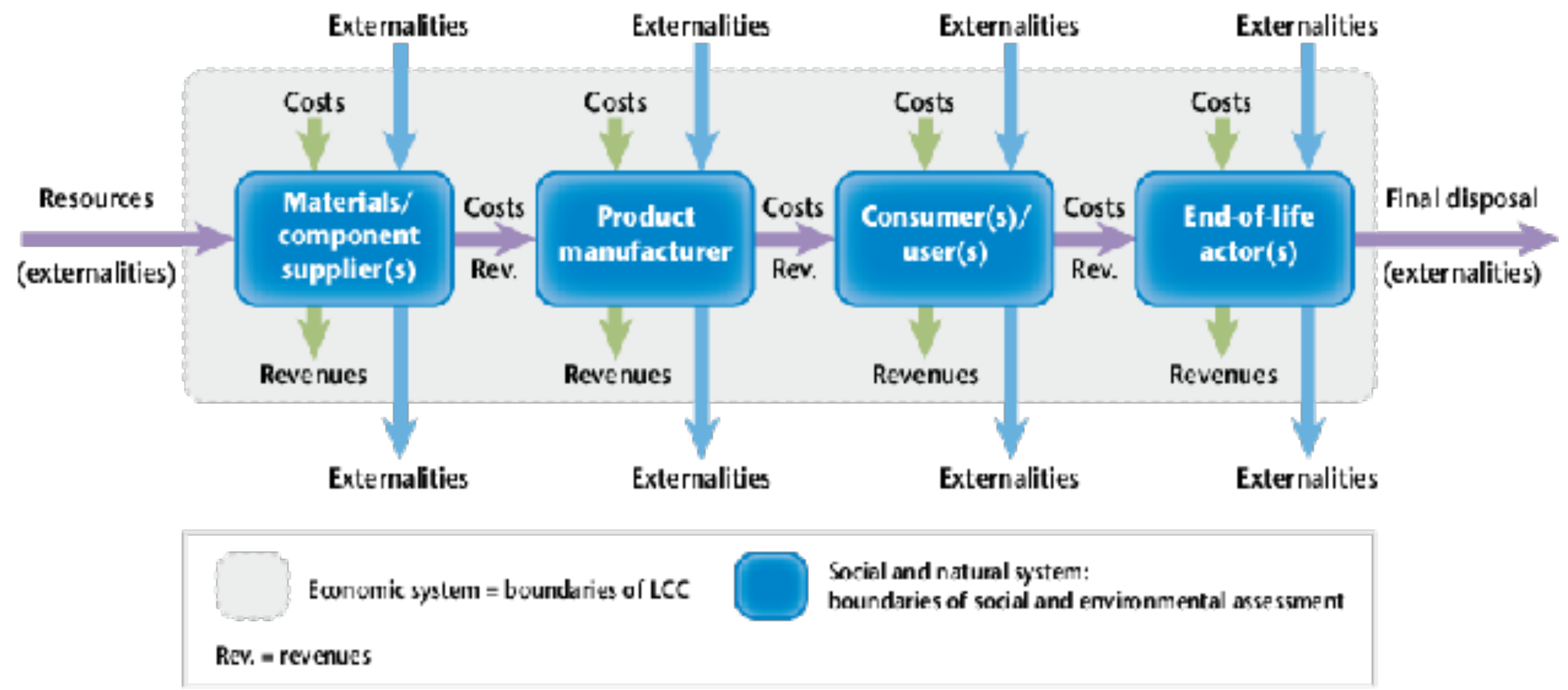
- **Feasibility and economic sustainability studies:** Measuring the impact of the life cycle of a product/process/project/system considering capital and operational costs
- **Studies for the selection/choice of sources of supply/supplies**: Compare costs over the life cycle using different suppliers or procurement systems
- **Define trade-offs:** Identify the design aspects of a plant / process / system that have the greatest impact on the life cycle
- **Product/Process Development:** Quantify the most impactful contributions and understand the cost of early failures in equipment selection and use

LCC – Goal and Scope

The definition of the goal and the scope of application is similar to the LCA analysis; what changes is the **point of view of the analysis**.

Suppliers, consumers, producers and waste manager are involved in the assessment.





**Rebitzer and Hunkler (2003)*

Single economic impact indicator expressed in €

LCC – Inventory Analysis

Inventory analysis involves **collecting data** for quantifying system inputs and outputs and modeling the system using Excel

Data collection

- ✓ Process description, block flow diagram and general information about the process (annual production, operating hours)
- ✓ Equipment costs and lifetime
- ✓ Quantity of input and output flows and their costs
- ✓ Number, type and annual rate of the staff employed

Cost cut-off	
OPEX	Land renting
	Building rent
	Technical support
CAPEX	Land expenditure
	Building construction
	Office items, Protective equipment, etc.

Cost type		Comment
OPEX	**Raw materials**	Acquisition cost of raw materials
	Energy	Operating costs related to the electricity, heating and fuels consumption on-site
	Ancillary	Acquisition or operating cost of ancillary materials
	Transport	Operating costs related to transport of raw and ancillary materials and products/services, including fuel and personnel costs
	Packaging	Acquisition cost of packaging materials and operative costs related to packaging processes
	Waste treatment	Operating costs related to the treatment of waste (before recycling, reuse and recovery)
	Waste disposal	Operating costs related to the disposal of waste, landfilling or incineration
	Personnel	Personnel costs, including wages and working costs
	Maintenance	Operative costs related to the maintenance of equipment, building, site and transport means
CAPEX	**Equipment**	Investment costs related to equipment, building, site and transport means

LCC – Inventory Analysis

Data source

- Primary data: directly provided by the person involved in the analysis
- Secondary data: generic data from databases (e.g. Eurostat), literature data, market reports

LCC – Impact Assessment and Interpretation

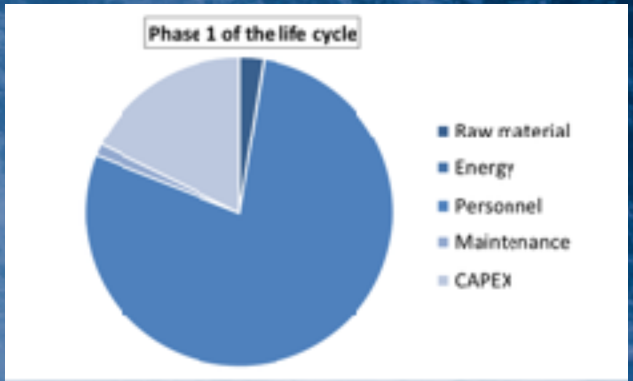
Economic impact assessment

Taking as a reference the annual production and the capacity of the machinery involved in the production process, the **total cost per functional unit** can be calculated according to the following formula:

$$C1 = \frac{CAPEX\ 1}{T * P1} + \frac{L1}{P1} + \frac{(A1 * R1 + A2 * R2 + A3 * R3)}{P1}$$

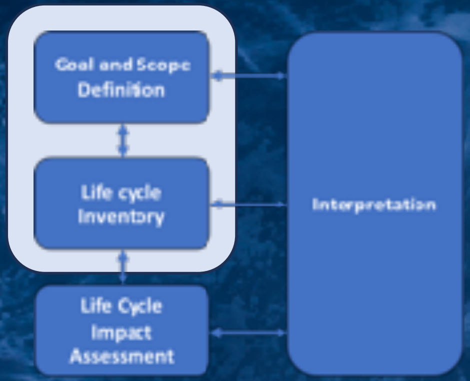
C1 = Cost of product 1
CAPEX 1 = Investment costs for the machinery involved in the product 1 production process
P1 = Annual production of product 1
T = Lifetime of the machinery
L1 = Man-hours for production and maintenance operations

R1 = Raw materials per product 1 [m^3/y or kg/y]
R2 = Electricity [kWh e / y]
R3 = Thermal Energy [kWh th/y]
A1 = Cost of raw materials [€ / m^3]
A2 = Cost for electricity [€ / kW el]
A3 = cost for thermal energy [€ / kW th]



Interpretation of results

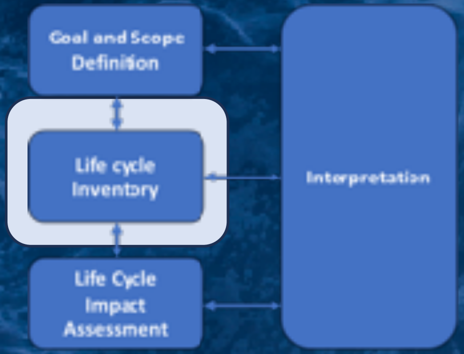
- ✓ Verification of the completeness of the data and results
- ✓ Identification of economic criticalities
- ✓ Projection on comparison and improvement scenarios
- ✓ Sensitivity analysis
- ✓ Identification of limitations in the study



GOAL AND SCOPE & LIFE CYCLE INVENTORY

One-to-one meetings and communications via email with technology providers took place, in order to:

1. Define the System Boundary and the Functional Unit
2. Show the LCA and LCC questionnaires
3. Discuss the collected data
4. Review and complete the data collection



LIFE CYCLE INVENTORY

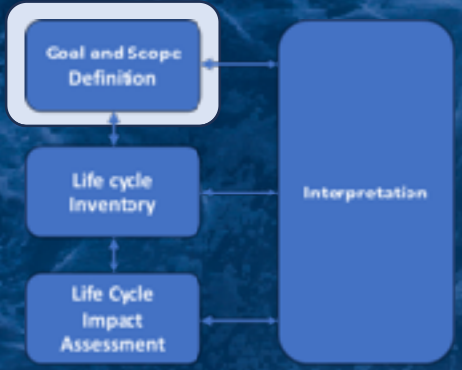
LCA&LCC questionnaire have been circulated to the technology developers. Data collection included:

- System composition (in terms of main components and subcomponents)
- Components and subcomponents life-spans
- Components and subcomponents costs
- Components and subcomponents materials
- Energy, fuels and water consumptions
- Main outputs

WHtoX System						
Subcomponent	Amount	Amount Unit	Cost per unit [€]	Life-span [years]	Maintenance/Replacement at the end of the life-span [M/R]	Replacement/Maintenance cost [€]
Main component 1: *Name*						
Subcomponent 1a	*e.g.1*	*e.g. piece*				
Subcomponent 1b	*e.g.100*	*e.g. kg*				
Subcomponent 1c						
…						
…						
…						
Main component 2: *Name*						
Subcomponent 2a	*e.g.1*	*e.g. piece*				
Subcomponent 2b	*e.g.100*	*e.g. kg*				
Subcomponent 2c						
…						
…						
…						
Main component n: *Name*						
Subcomponent na	*e.g.1*	*e.g. piece*				
Subcomponent nb	*e.g.100*	*e.g. kg*				
Subcomponent nc						
…						

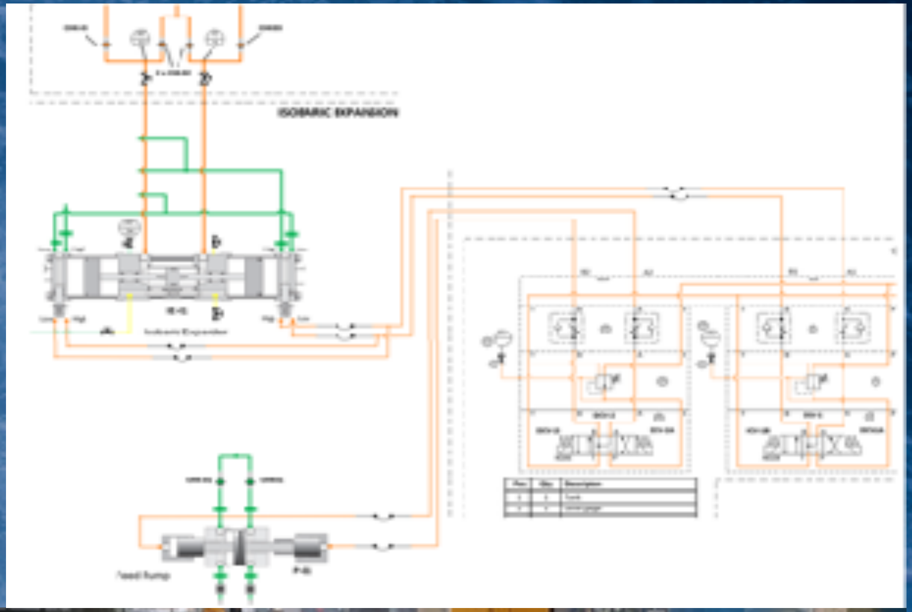
WHtoX System					
Subcomponent	Materials	Amount	Amount Unit	Distance from supplier to manufacturing site [km]	Type of transport
Main component 1: *Name*	-	-	-		
Subcomponent 1a	*Material 1*				
	Material 2				
	Material …				
	Material n				

	INPUT					OUTPUT		
Component	**Energy type (e.g. electricity, thermal energy, …)**	**Operational Energy consumption [kWh/year]**	**Fuel type (e.g. diesel, LPG, heavy fuel oil, wood, …**	**Operational Fuel consumption [kg/year]**	**Operational Water consumption [m^3/year]**	**Output type**	**Operational Output production**	**Amount Unit**
Main Component 1						-	-	-
Main Component 2						-	-	-
Main Component 3						-	-	-
…						-	-	-
Main Component n						-	-	-
WHtoX System - Total								



GOAL AND SCOPE

Isobaric Expansion Engine - Tecnalia



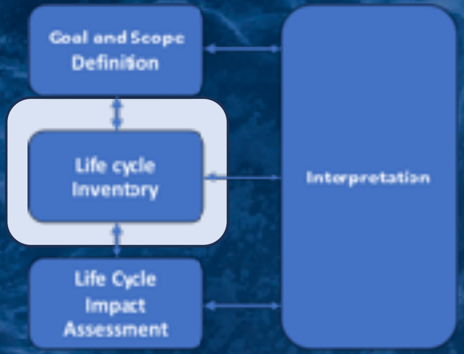
Goal: Evaluate the environmental and economic benefits and/or burdens arising from the production of the 1kW Isobaric Expansion Engine developed by TECNALIA in the Zhenit Project

System Boundaries: Manufacturing of the IEE module (A1-A3 of EN 15804)

Functional Unit: 1 kW of mechanical work

Temporal Scope: 15 years, which is the lifespan of the IEE

Benchmark for comparison: A hydraulic pump on market has been identified by technology provider as benchmark

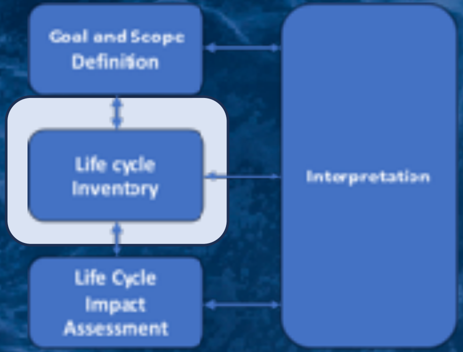


LIFE CYCLE LCA INVENTORY*

Isobaric Expansion Engine - Tecnalia

Module A1 Raw materials supply	Module A2 Transport	Module A3 Mechanical processing and Assembly
Isobaric expander Feed pump Heat Exchanger Check Valves for refrigerant Check Valves for oil Pressure Sensors Temperature sensors Piping Connectors/feetings Refrigerant Lubricating oil	Transport by Truck Transport by Train Transport by Ship	Fabrication of components Assembly

* *Details on mass and energy quantities, including economic data, cannot be publicly disclosed due to their sensitive nature*

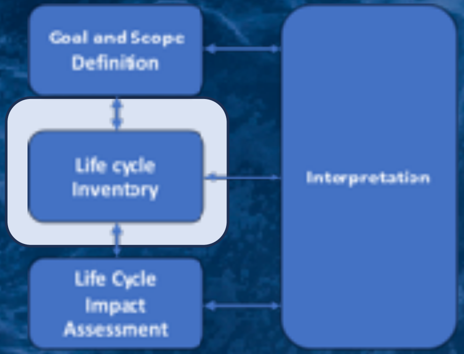


LIFE CYCLE LCA INVENTORY

Isobaric Expansion Engine - Tecnalia

BENCHMARK Inventory

Main component	Materials declared	Quantity [kg]
Pump housing	High-strength aluminum	9,05
Shafts and gears	Hardened steel	3
Seals	Nitrile or Viton	0,1
Section gaskets	Teflon and elastomers	0,0325
Bolts and fasteners	Stainless steel	0,75
Coating/Paint	Zinc coating	0,2



LIFE CYCLE LCC INVENTORY*

Isobaric Expansion Engine - Tecnalia

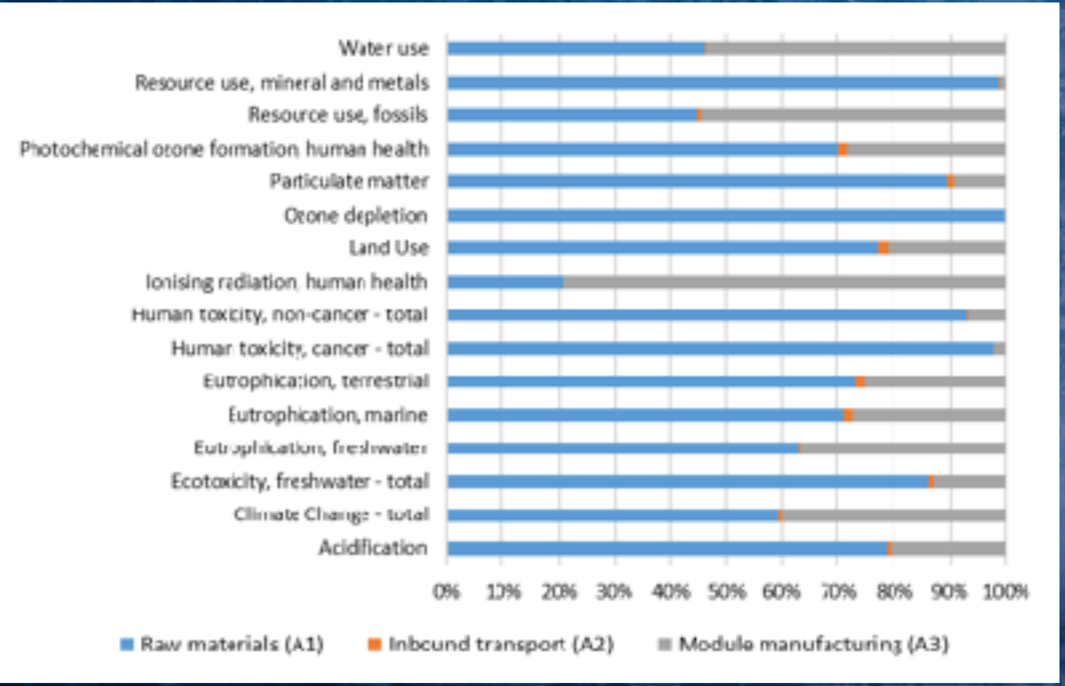
CAPEX	OPEX (Personnel)	OPEX (utilities)
Components costs	Blue collant R&D specialists	Electrical power Thermal power Sea water

* *Details on mass and energy quantities, including economic data, cannot be publicly disclosed due to their sensitive nature*

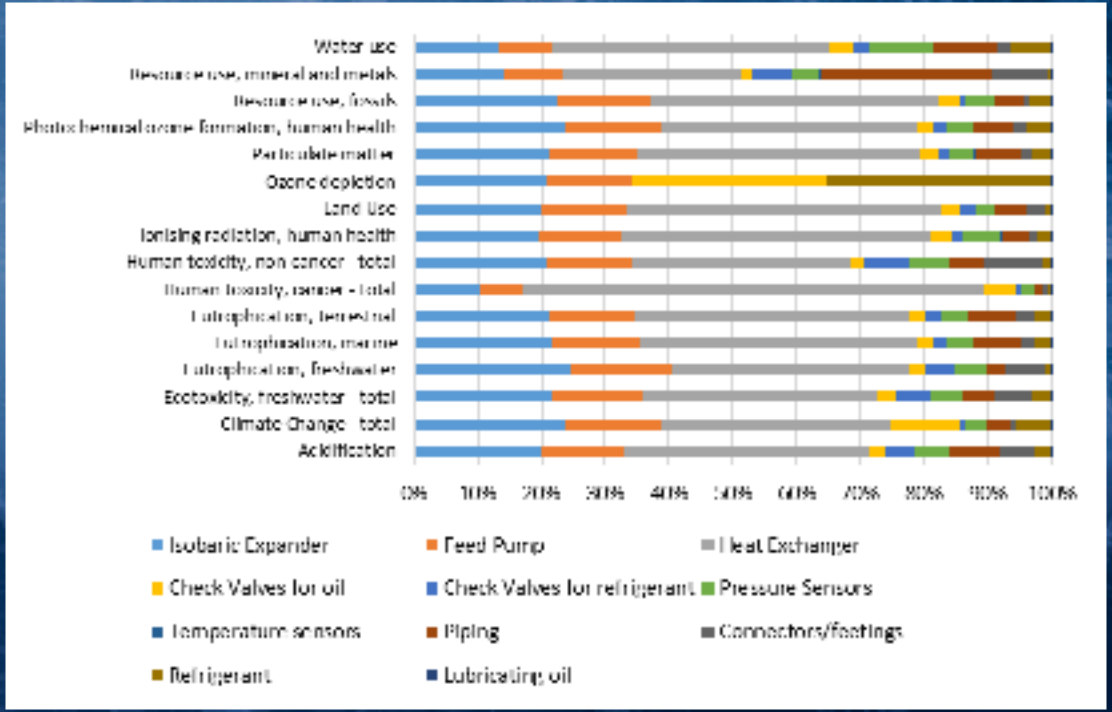
LIFE CYCLE IMPACT ASSESSMENT

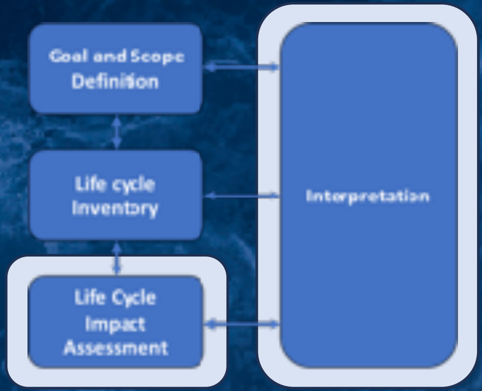
Isobaric Expansion Engine - Tecnalia

Within Module A1, Heat Exchanger contributes from 28% (Resource use, mineral and metals) to 73% (Human toxicity, cancer – total) → due to steel and related metal working. Other relevant contributors are the Isobaric Expander and Feed Pump. The significant contribution to the Ozone depletion is from Refrigerant (35%), Check Valves for oil (30%) and Isobaric Expander (21%), → due to the presence of tetrafluoroethylene in sealings, and the refrigerant itself.



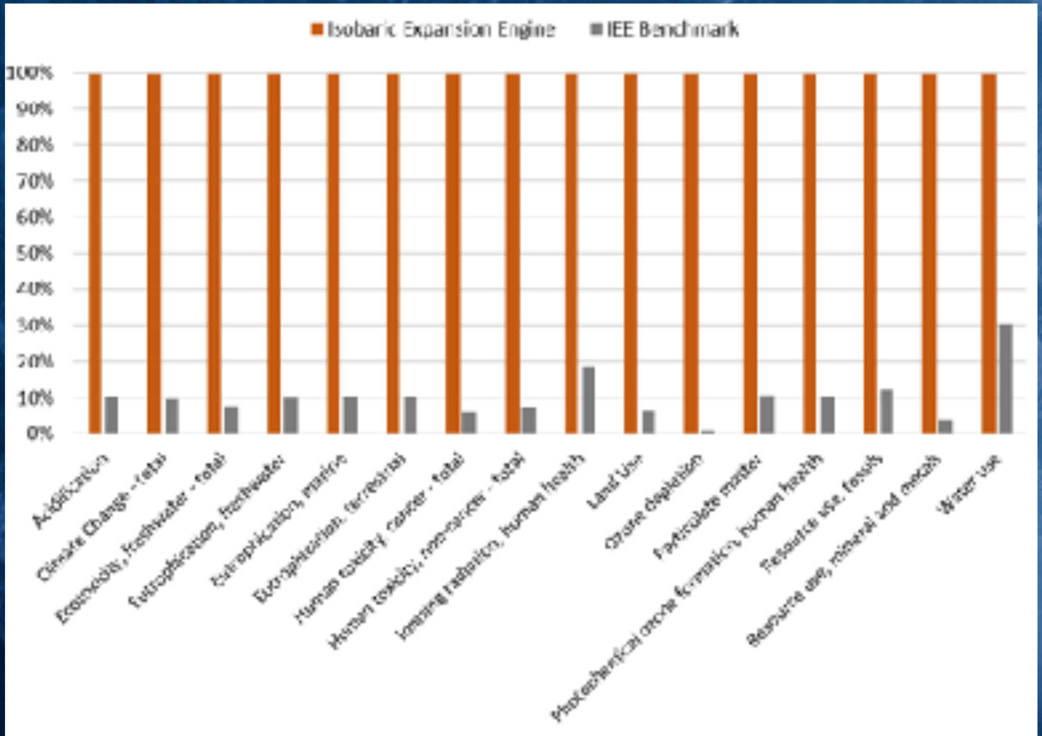
Stage A1 results the major contributor to all the environmental impact categories



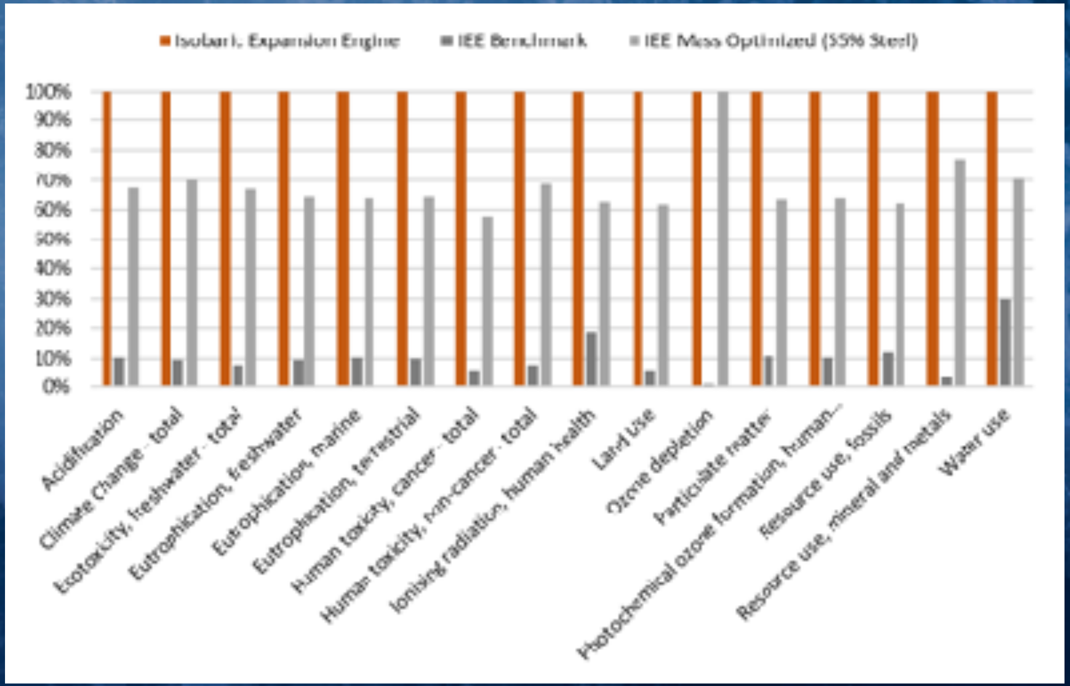


LIFE CYCLE IMPACT ASSESSMENT and INTERPRETATION

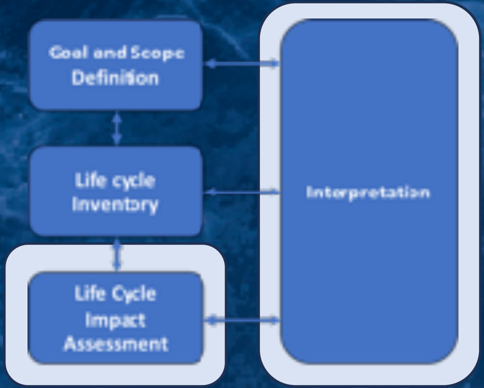
Isobaric Expansion Engine - Tecnalia



An additional analysis regarding the impact of the reduction of 45% of steel and related metal working has been carried out



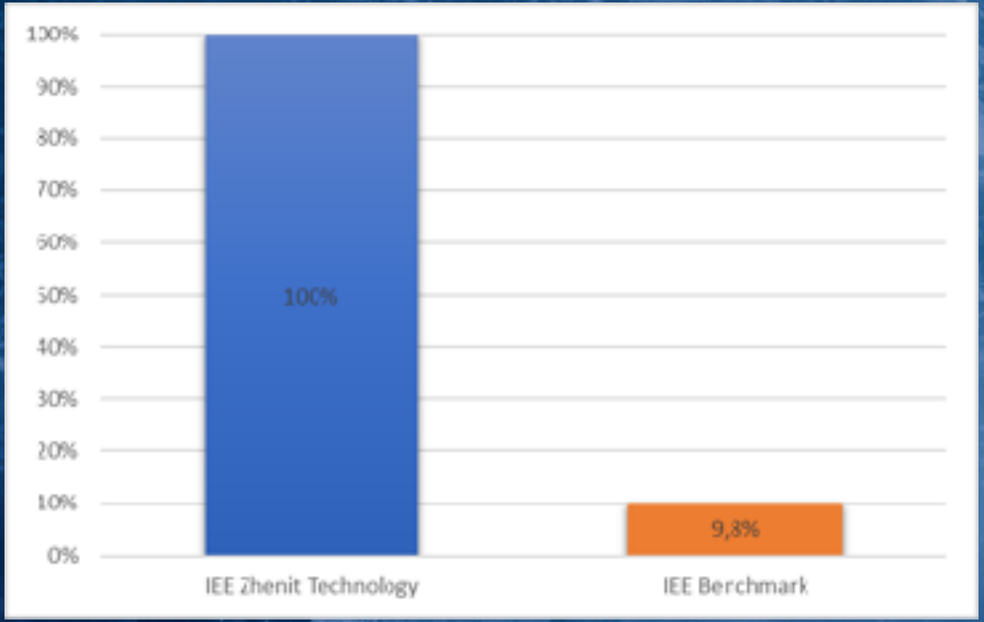
The IEE technology has a lower environmental performance, while compared to equivalent alternatives on the market, which generate environmental impacts, on average, equal to 12% of the IEE impacts

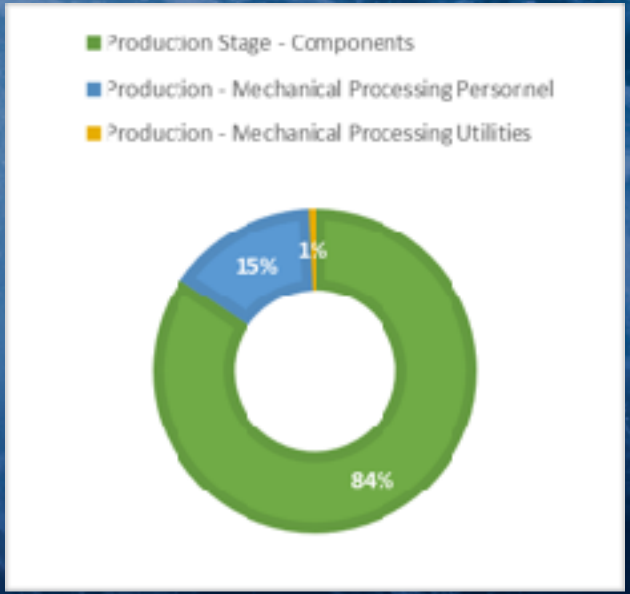


LIFE CYCLE IMPACT ASSESSMENT

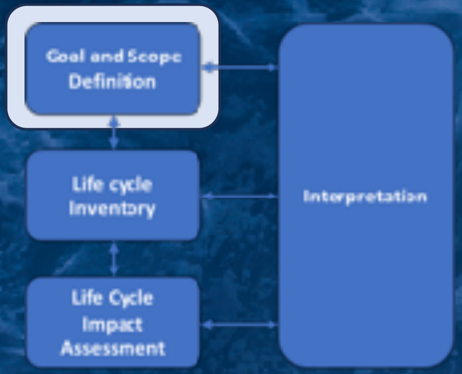
Isobaric Expansion Engine - Tecnalia

Corresponding to the 85% of the total cost, **materials and purchased parts** are the primary cost driver.
The technology is constituted by heavy components, therefore a meaningful cost reduction would result from a weight reduction





Given that the IEE Zhenit Technology is not optimized being a prototype, it performs worse than the benchmark, which is already at commercial level. The technology, in its current configuration, is not yet cost-competitive, in accordance to the fact that it is still in a developmental or pre-industrial stage



GOAL AND SCOPE

Sorption Refrigeration and Desalination (SR&D) system - CNR

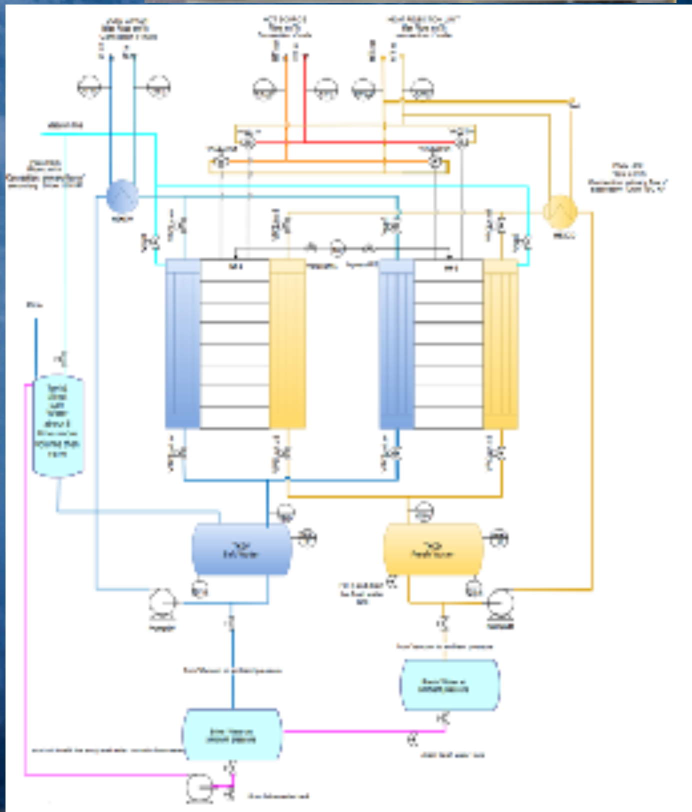
Goal: Evaluate the environmental and economic benefits and/or burdens arising from the production of the Sorption Refrigeration and Desalination (SR&D) developed by CNR in the Zhenit Project

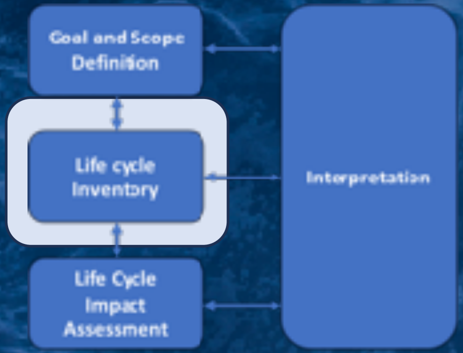
System Boundaries: Manufacturing of the SR&D module (A1-A3 of EN 15804)

Functional Unit: 1 kWh of cooling, corresponding to 0,001593 m^3 of desalinated water, evaluated through water enthalpy of vaporization equal to 2,26 MJ/kg

Temporal Scope: 20 years, which is the lifespan of the SR&D

Benchmark for comparison: Considering both the twofold function of the SR&D, the cooling function in the benchmark scenario is performed through a heat pump. The desalination function is modelled through a seawater reverse osmosis technology with a conventional pretreatment.



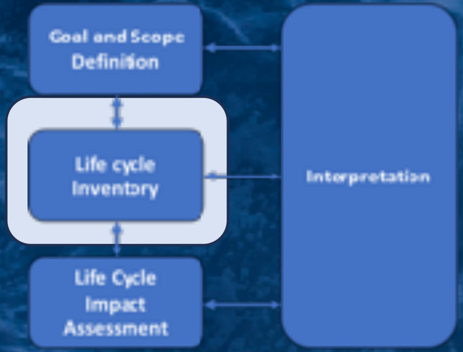


LIFE CYCLE LCA INVENTORY*

Sorption Refrigeration and Desalination (SR&D) system - CNR

Functionality	Module A1 Raw materials supply	Module A2 Transport	Module A3 Mechanical processing and Assembly
Sorption Refrigeration + Desalination	Hydraulic pumps Vacuum Vessel Electrical cabinet Piping connection Valves Vacuum Tanks	Transport by Truck Transport by Train Transport by Ship	Mechanical cutting Welding Assembly & commissioning

* *Details on mass and energy quantities, including economic data, cannot be publicly disclosed due to their sensitive nature*



LIFE CYCLE LCA INVENTORY

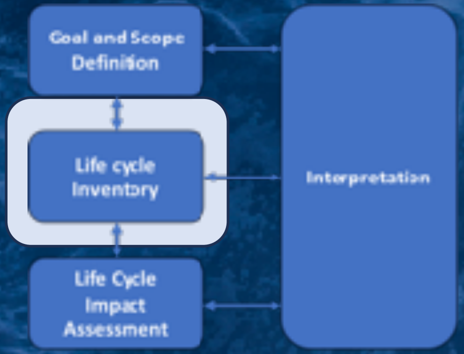
Sorption Refrigeration and Desalination

(SR&D) system - CNR

BENCHMARK Inventory

The cooling function in the benchmark scenario is performed through a heat pump. The available dataset of 30kW heat pump is scaled considering the COP of the pump and the functional unit.
The desalination function is modelled through a seawater reverse osmosis technology with a conventional pretreatment. The available dataset is modified by cutting off the datasets related to the recarbonation stage (leading to the production of drinking water).

Functionality	Module A1, A2 and A3		
	Amount	UoM	Dataset
Cooling	0,05	pieces	GLO: market for heat pump, 30kW
Desalination	1,593	kg	RoW: market for water, decarbonised
	-5,34E-05	kg	ROW: market for carbon dioxide, liquid
	-6,93E-05	kg	ROW: market for lime, hydrated, packed
	-3,78E-05	kg	GLO: market for sodium hydrogen sulfite

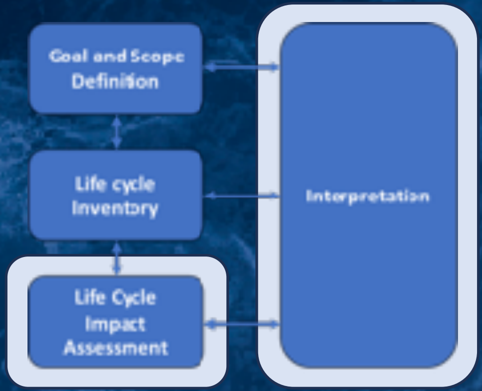


LIFE CYCLE LCC INVENTORY*

Sorption Refrigeration and Desalination (SR&D) system - CNR

CAPEX	OPEX (Personnel)	OPEX (utilities)
Components costs	Blue collant R&D specialists	Electrical power Thermal power Sea water

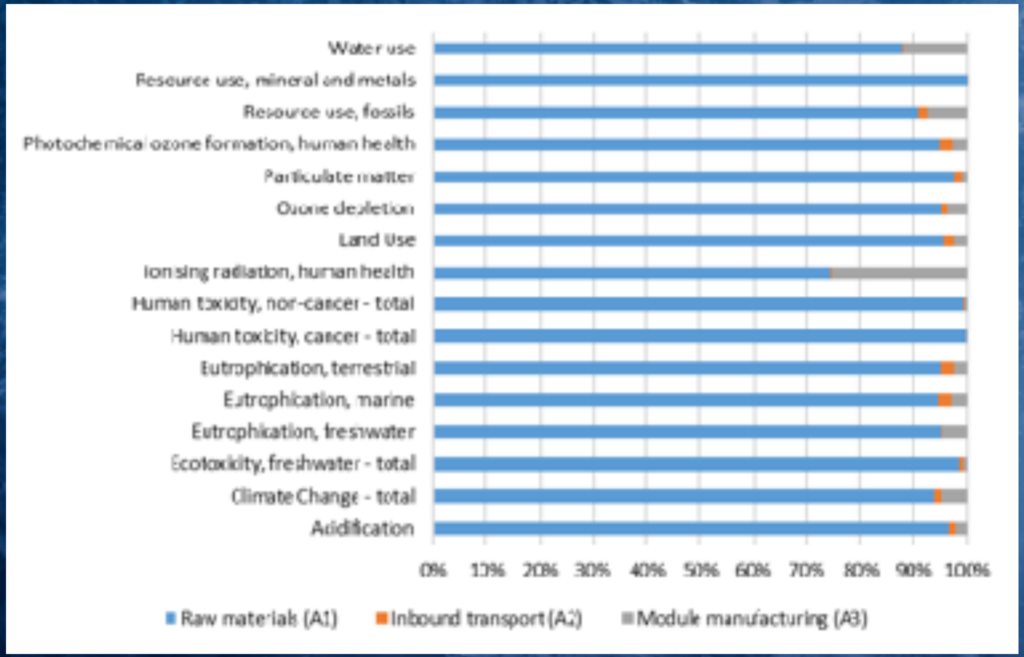
* *Details on mass and energy quantities, including economic data, cannot be publicly disclosed due to their sensitive nature*



LIFE CYCLE IMPACT ASSESSMENT and INTERPRETATION

Sorption Refrigeration and Desalination

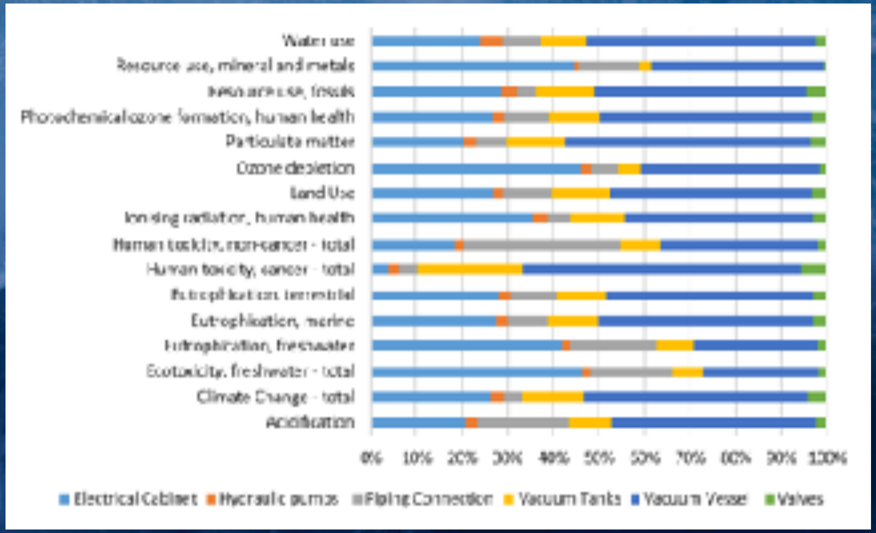
(SR&D) system - CNR

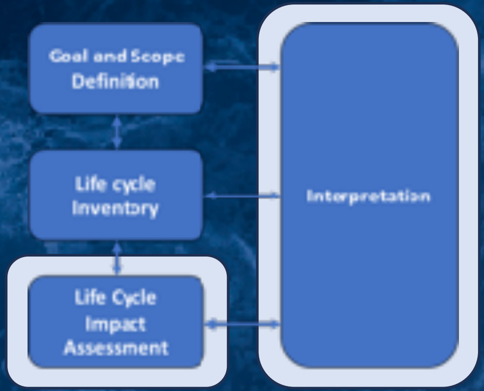


Module A1 results the major contributor, with a minimum contribution of 75% for the Ionising radiation, human health indicator

Vacuum Vessel is the most impactful component in almost every Impact Categories, accounting for approximately 50-70% of total impacts, due to the steel constituting the component and its working.

The electrical cabinet represents the second most relevant contributor; in particular, it contributes to Ecotoxicity and Resource use, minerals and metals, both as per 45%.

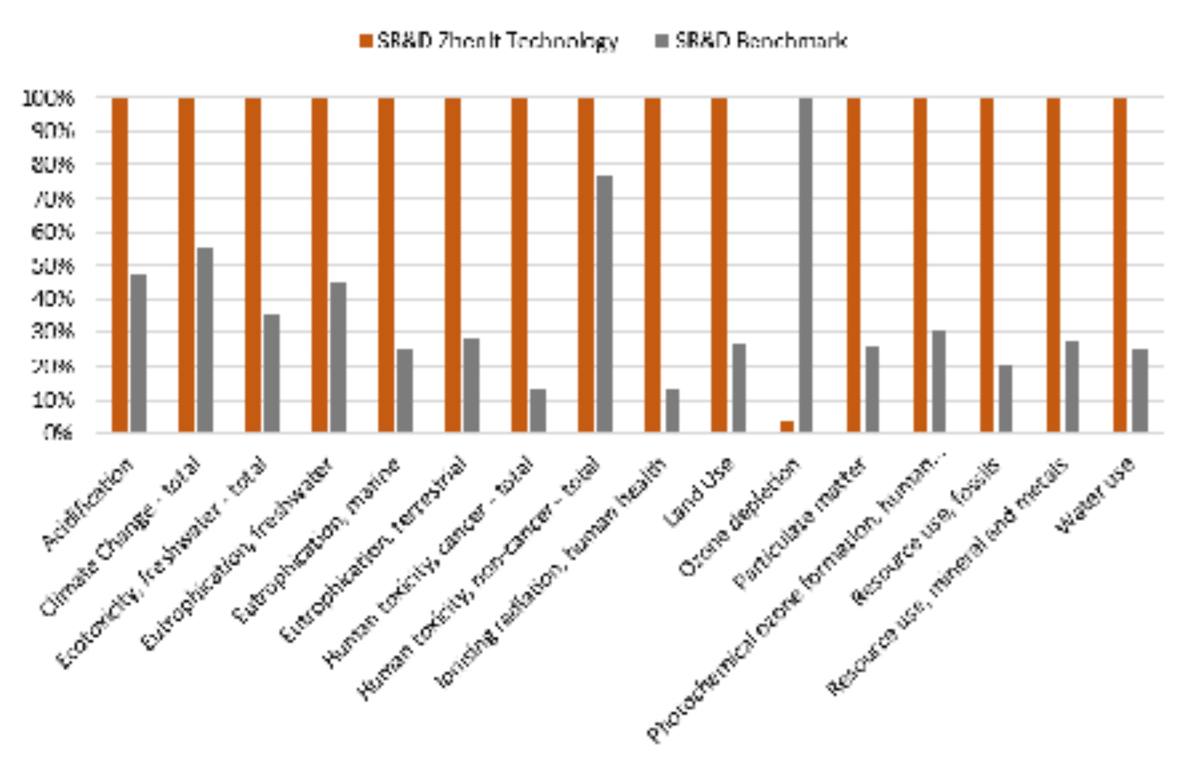




LIFE CYCLE IMPACT ASSESSMENT and INTERPRETATION

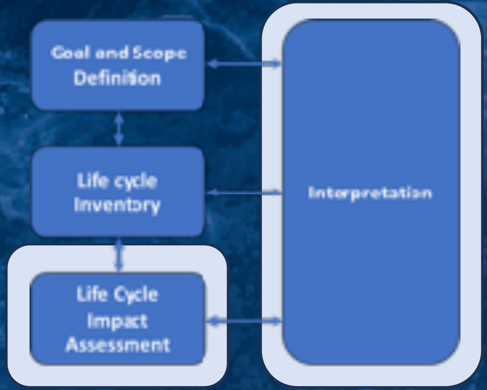
Sorption Refrigeration and Desalination

(SR&D) system - CNR



The **SR&D technology has a lower environmental performance**, while compared to the equivalent alternative, with the **exception of Ozone Depletion**. In particular, the environmental impacts of the benchmark technology are on **average equal to 64%** of the environmental impacts of the Sorption Refrigerator and Desalinator.

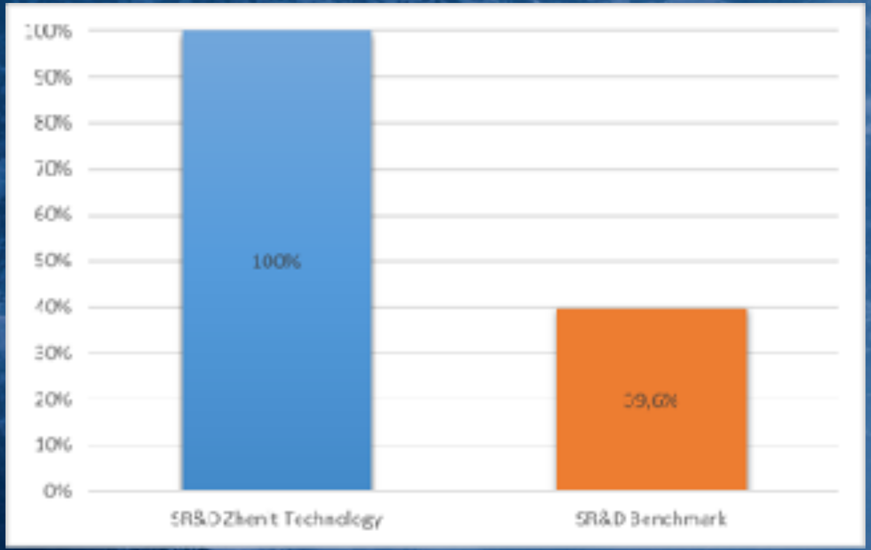
The contribution of SR&D **to Ozone Depletion is equal to 4%** of the impact generated by the benchmark technology, due to the refrigerant used in the heat pump.



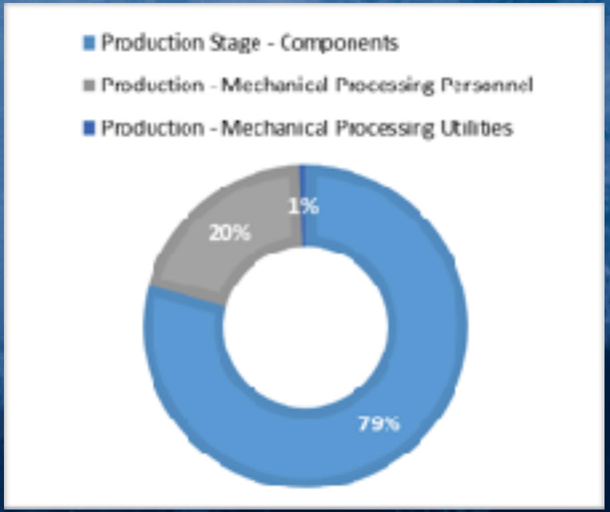
LIFE CYCLE IMPACT ASSESSMENT

Sorption Refrigeration and Desalination

(SR&D) system - CNR



Corresponding to the 79% of the total cost, **materials and purchased parts,** including their transportation to manufacturing site, are the primary cost driver.
Relevant cost (20%) are referred to blue collant and R&D personnel involved in the mechanical processing and assembly of the technology. The technology is constituted by heavy components, sorption materials and electronic parts, having high unit costs.



Given that the SR&D Zhenit Technology is not optimized being a prototype, it performs worse than the benchmark, which is made of components already at commercial level. The technology, in its current configuration, is not yet cost-competitive, in accordance to the fact that it is still in a developmental or pre-industrial stage

ENVIRONMENTAL IMPACTS OF VESSELS WITH ZHENIT TECHNOLOGIES

- The LCA and LCC analyses have been performed considering data provided by Zhenit partners and assumptions;
- Relevant data regard: fuel type, fuel consumption of the vessel and its reduction due to Zhenit technology installation, Fuel combustion emissions (according to **FuelEU Maritime emission factors**)

Phases	Modules
Product Stage	Raw Materials, Production and transport to the production facility
Installation	Transport to the installation site
	Production of materials and components for installation (A5)
Use Phase	Replacement (B4)
	Operational Energy Use (B6)

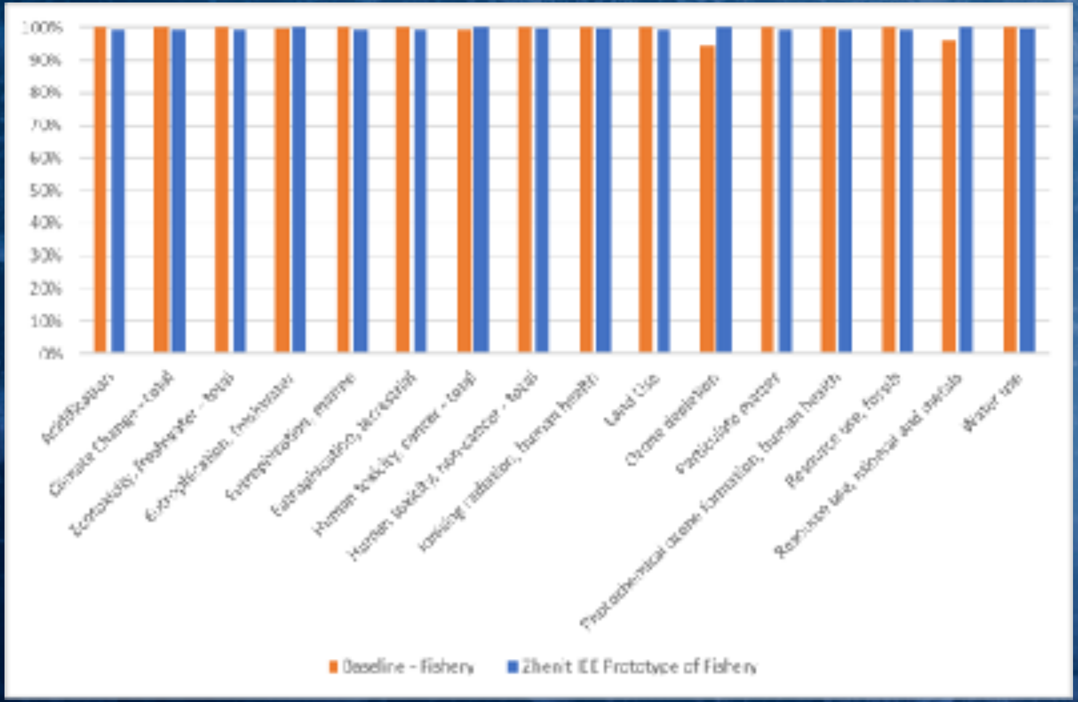
The horizontal inventory includes:

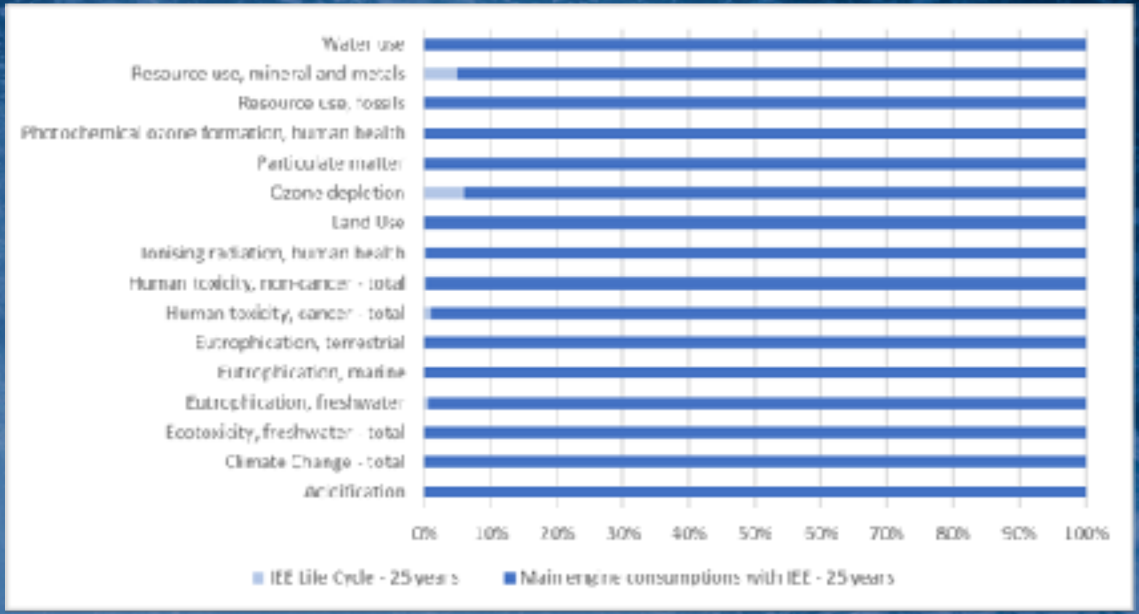
- ✓ **Production of the prototype**, corresponding to the completed LCA model
- ✓ **Manufacturing of replacement components** during the vessel's 25-year lifetime
- ✓ **Transport of the prototype** from its assembly location **to the vessel**

ENVIRONMENTAL IMPACTS OF VESSELS WITH ZHENIT TECHNOLOGIES

Fishery Vessel & Isobaric Expansion Engine

The average reduction is equal to 0,4% (for 12 out of 16 indicators), whilst the average increase is 2,6% (for only 4 indicators)





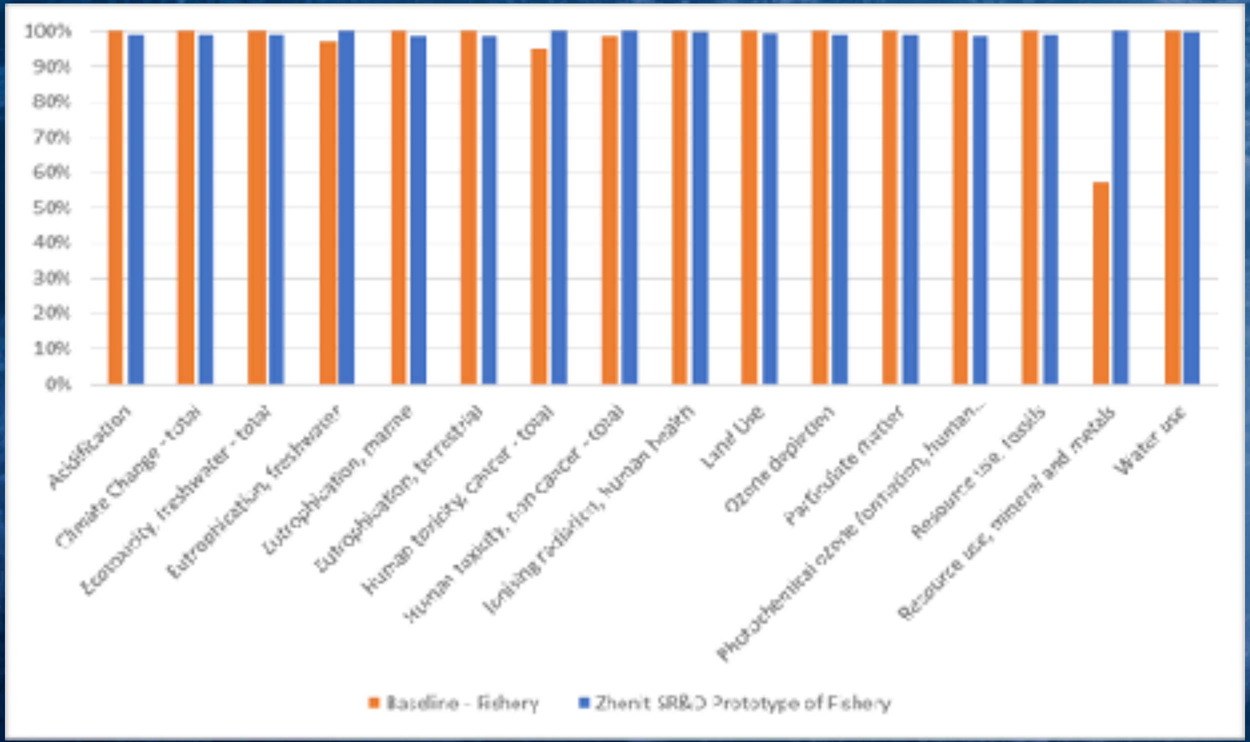
For all the environmental impacts, the fuel consumption during 25 years vessel lifetime represents the most relevant contributor, if compared with the technology production and maintenance

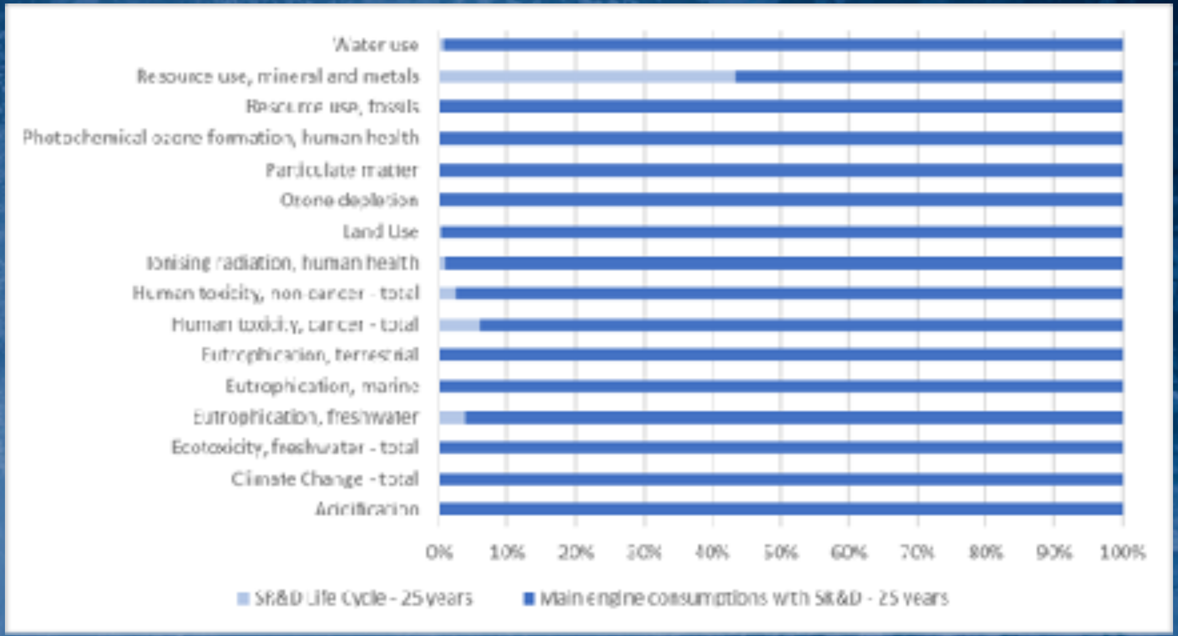
Results could be not definitive, since data used for the analyses might change. Moreover, analyses on other types of vessels, having bigger dimensions, is still ongoing and might lead to better potential benefits of the Zhenit technologies

ENVIRONMENTAL IMPACTS OF VESSELS WITH ZHENIT TECHNOLOGIES

Fishery Vessel & Sorption Refrigeration and Desalination (SR&D) system

The average reduction is equal to 1% (for 12 out of 16 indicators), whilst the average increase is 12,9% (for only 4 indicators)





For almost all the environmental impacts, the fuel consumption during 25 years vessel lifetime represents the most relevant contributor, if compared with the technology production and maintenance

**Results could be not definitive, since data used for the analyses might change. Moreover, analyses on other types of vessels, having bigger dimensions, is still ongoing and might lead to better potential benefits of the Zhenit technologies* zhenit

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Funded by
the European Union

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