Webinar #4 “Laboratory Validation Campaign of the ZHENIT Project” – February 10th 2026

zhenit

ZHENIT – E-learning program

Funded by
the European Union

This project has received funding from the European Union's Horizon Europe research and Innovation programme under grant agreement No 101056801. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the CINEA. Neither the European Union nor the granting authority can be held responsible for them.

THE PROJECT

The ZHENIT project develops a strategy that contributes to *decarbonising maritime transport* by using innovative *waste heat recovery – WHR –* solutions, already available for terrestrial and maritime applications, to be exploited more extensively onboard to reduce pollutants and also in hoteling/harbour conditions.
ZHENIT combines the *zero waste heat solutions* with *ICT monitoring* and *energy management solutions, thermal energy storage* and a *hybrid propulsion system* aiming to reduce ship emissions both in the harbour areas and the open sea.
ZHENIT will prove the capabilities of different WHto-X solutions and their crucial role in the shipping sector by validating on board a pilot cargo vessel and in laboratory conditions.

11 Partners

42 Months

7 countries

4.4M Funding

AMBITION

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.

Digital

Sustainable

7 countries

FUNDAMENTALS

T<C°100

Isobaric Expansion (IE) Engine
WH-to-mechanical work

70°<T<100°C

Adsorption System WH-to-cooling and Desalination

T>100°

Innovative ORC integrated with HP with ejector WH-to-Trigenetayion

INTEGRATED CONTROL FOR WHR MAXIMISATION

HYBRID PROPULSION (WINGSAIL)

ON-BOARD ADVANCED MONITORING

THERMAL ENERGY STORAGE (TES) FOR OPTIMAL WHR

THE APPROACH

Thanks to its validation campaign on-board of a cargo vessel and in laboratory conditions, ZHENIT will showcase how WH-to-X, if properly integrated with Digital Solutions (energy monitoring and optimized management) and hybrid propulsion (wingsail), can bring up to a 25% reduction of vessel energy consumption. Validation results will drive a replication roadmap (at regulatory and economic level) towards 2027-2030 marketability of ZHENIT solutions.

during zhenit

beyond zhenit

	2022	2024	2026	2028	2030
RESULTS	• Design and realization of WH-to-X technologies • WH and Energy audit Tools	• Validation Campaign • Business Model, Environomics Analysis	• Further Replicability Studies • WH-to-X technologies at TRL9 and further integrability with on-board systems • I ligher Scale Demonstration on board	Targeting «Zero WH vessel» ready to sail integrating digital solutions too	zhenit on the market

tecnalia

MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Webinar #4– February 10th 2026

zhenit

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Vittorio Oliveri - Relatech

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- Reception of ZHENIT technologies (visual inspection and reception approval)
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3. INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA'S LABORATORY
- Laboratory setup and control architecture
- Validation campaign definition
- Stand-alone tests
- Parallel testing
- Data analysis

INTRODUCTION

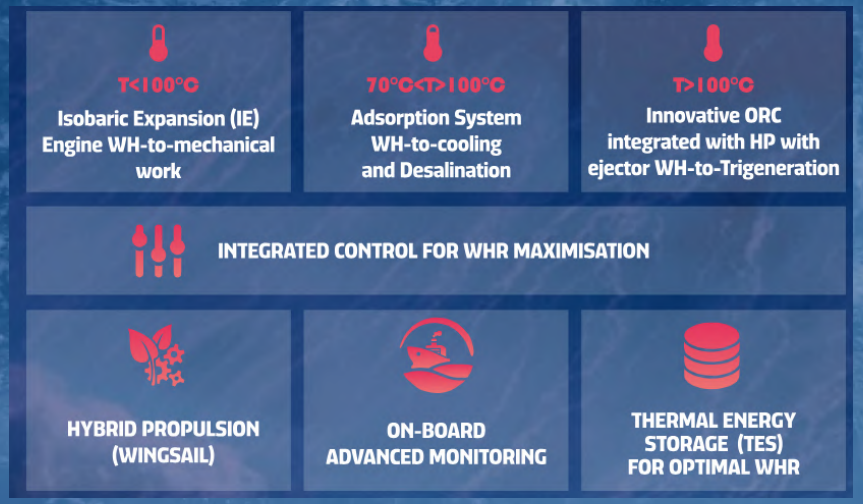
WEBINAR OBJETIVES

- Introduce the ZHENIT Project and its goals
- Present the laboratory validation campaign
- Describe the preparation and integration of the test site
- Explain the SCADA and control architecture
- Present the integrated pilot testing activities
- Highlight TECNALIA's and RELATECH's roles

INTRODUCTION

OVERVIEW OF THE LABORATORY VALIDATION CAMPAIGN WITHIN THE ZHENIT PROJECT

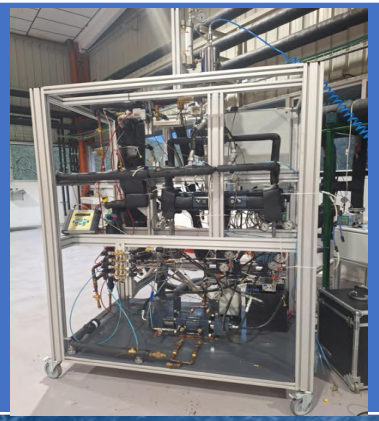
The **ZHENIT Project** develops and validates innovative **Waste Heat Recovery (WHR) technologies for the maritime sector** with the objective of reducing greenhouse gas emissions and improving ship energy efficiency in line with IMO and EU decarbonization targets.



At **TECNALIA's laboratory**, these technologies are **installed, interconnected, and operated as a single integrated system** under controlled but realistic conditions that emulate ship operation.

INTRODUCTION

TECNALIA´S ROLE IN ZHENIT PROJECT



Development of the Isobaric Expansion Engine (IEE)

Integrated validation of ZHENIT WH-to-X systems at TECNALIA’s laboratory

The laboratory includes **3 main water/ fluid pipe rings** that supply different test areas for the thermal characterisation of equipment and systems, with high-precision regulation, control and monitoring systems.

INTRODUCTION

RELATECH´S ROLE IN ZHENIT PROJECT

Relatech’s role in the **ZHENIT** consortium focused on the project’s digital layer, delivering a **supervision platform** and a **control platform** to monitor energy flows and optimize the operation of onboard waste-heat recovery systems. Over the course of the project, we also took full ownership of the **supervision platform**. Through our group company **SIGLA**, Relatech contributed to a tailored controller implementation and the tuning of key energy parameters across the integrated ship systems.

INTRODUCTION

RELATECH´S ROLE IN ZHENIT PROJECT in points

- **Relaech contribution to the project**
  - Implemented the **monitoring platform** for real-time supervision of plant/process performance
  - Enabled **centralized management of systems** through a unified control approach
- **What was delivered**
  - **Centralized PLC-based architecture** coordinating monitoring and control
  - **Single point of supervision** for key process variables, system states, and alarms
  - **Standardized automation logic** (setpoints, sequences, interlocks) across subsystems

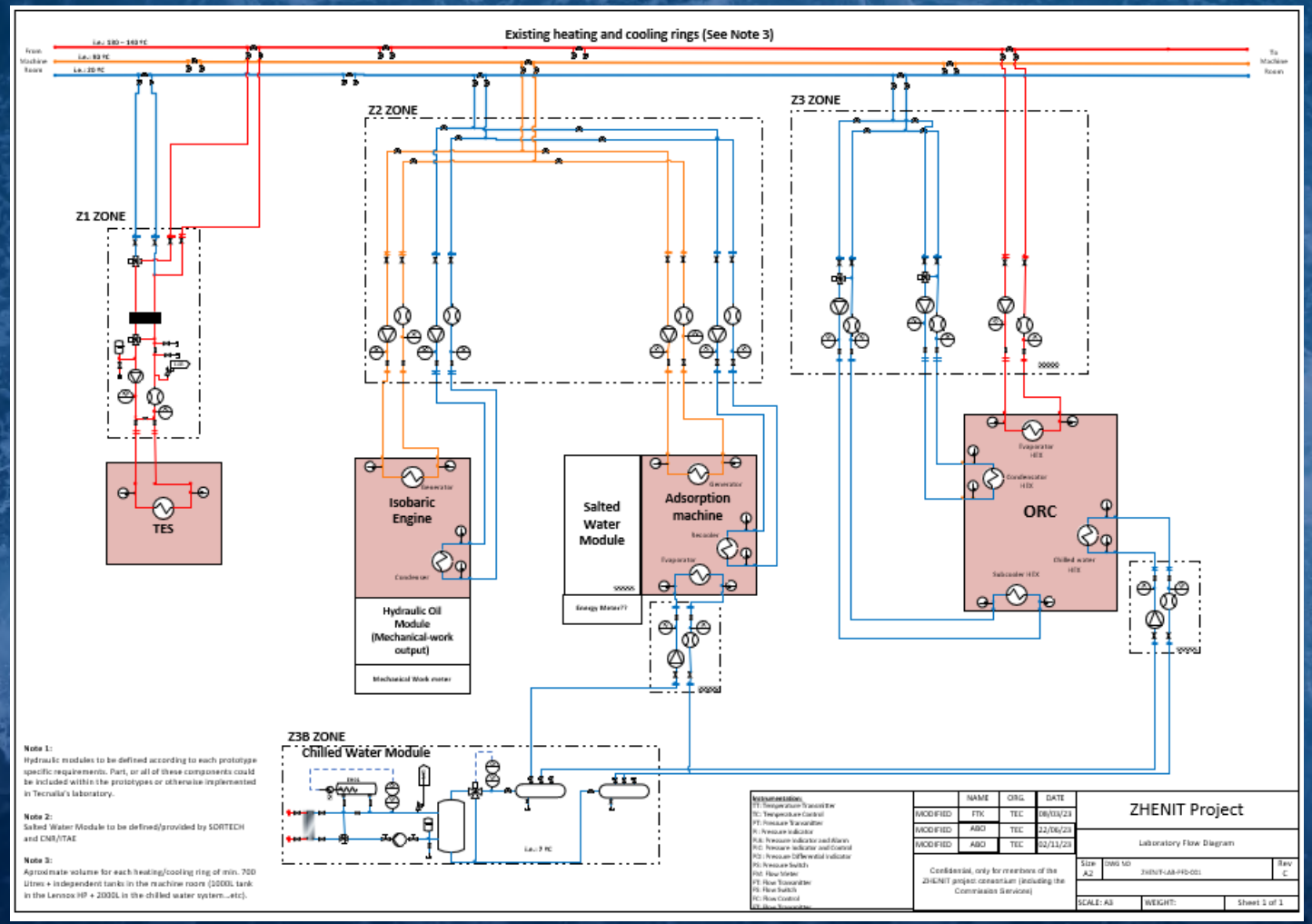
PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

DEFINITION AND ACQUISITION OF THE NECESSARY EQUIPMENT, GOODS AND SERVICES

- PHASED ACQUISITION PLAN
- DETAILED PLANNING AND COORDINATION PROCESS
- HARMONIZED SENSING STRATEGY

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

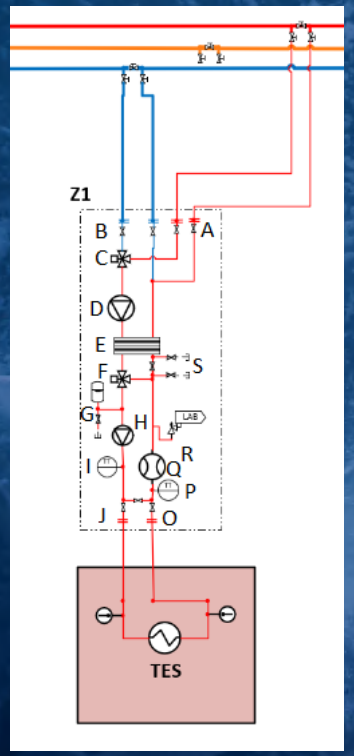
PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES



PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

TES

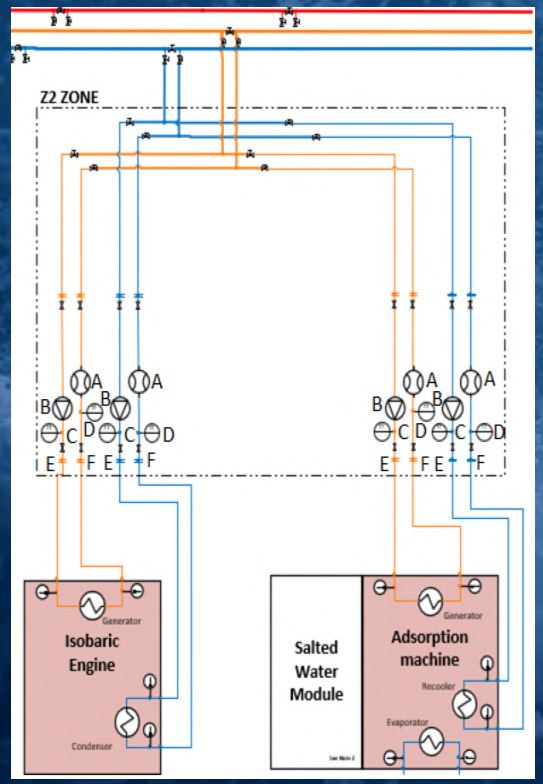


TES phases			
Unit	Inlet Water Temperature [°C]	Outlet Water Temperature [°C]	Thermal Power [kW]
Charging	90	70	40
Discharging	70	90	
TES Mechanical Integration			
Presence of hydraulic modules	Yes		
Number of Hydraulic modules (critical)	1		
TES Electrical Integration			
Power Supply [kWe]	n.a.		
Presence of Energy Meter	n.a.		

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

Isobaric expansion engine & Adsorption machine



IEE Specification			
Unit	Inlet Water Temperature [°C]	Outlet Water Temperature [°C]	Thermal Power [kW]
Heating (source)	90	84	25-30
Cooling (sink)	20	26	20-25
IEE Mechanical Integration			
Presence of hydraulic modules	Yes		
Number of Hydraulic modules (critical)	2		
IEE Electrical Integration			
Power Supply [kWe]	0.1 (max)		
Presence of inverter	No		

Adsorption Machine Specification			
Unit	Inlet Water Temperature [°C]	Outlet Water Temperature [°C]	Thermal Power [kW]
Generator	90	70	20
Recooler	25	35	30
Evaporator	15	10	10
Adsorption Machine Mechanical Integration			
Presence of hydraulic modules	Yes		
Number of Hydraulic modules (critical)	3		
Adsorption Machine Electrical Integration			
Power Supply [kWe]	3 (max)		
Presence of Inverter	Yes		

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

Isobaric expansion engine & Adsorption machine

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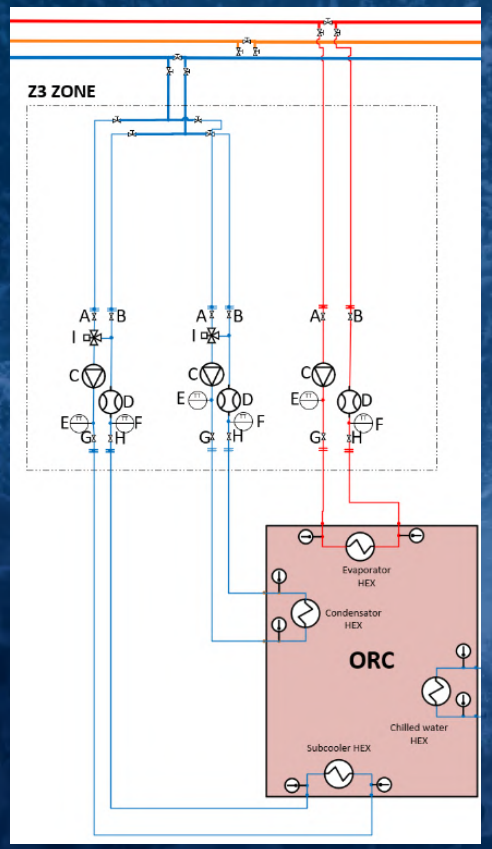
Recooler	25	35	30
Evaporator	15	10	10
Adsorption Machine Mechanical Integration			
Presence of hydraulic modules	Yes		
Number of Hydraulic modules (critical)	3		
Adsorption Machine Electrical Integration			
Power Supply [kWe]	3 (max)		
Presence of Inverter	Yes		

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

ORC

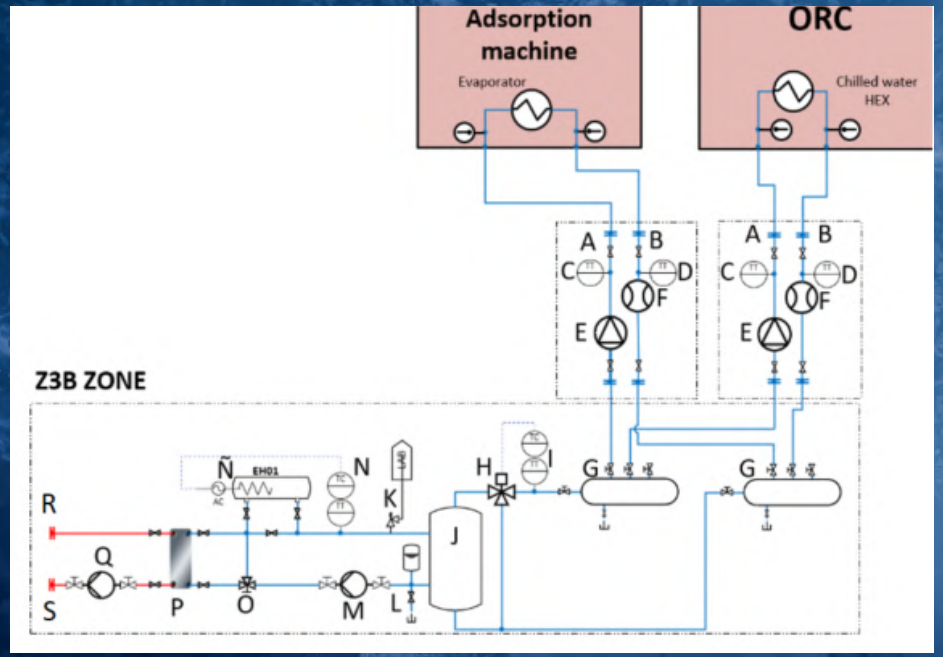


ORC-HP circuit			
Unit	Inlet Water Temperature [°C]	Outlet Water Temperature [°C]	Thermal Power [kW]
ORC Evaporator	140	130	100
ORC Condenser	35-40	40/55	86.21 (min) - 91 (max)
ORC Subcooler	35-50	40/55	2.86 (min) - 3.01 (max)
Heat pump Evaporator	15	10	2.2 (min) - 3.1 (max)
ORC-HP Mechanical Integration			
Presence of hydraulic modules	Yes		
Number of Hydraulic modules (critical)	4		
ORC-HP Electrical Integration			
Power Supply [kWe]	1.42 (max)		
Power generation [kWe]	11.32 (max)		
Presence of Inverter	Yes		

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

CHILLED WATER MODULE



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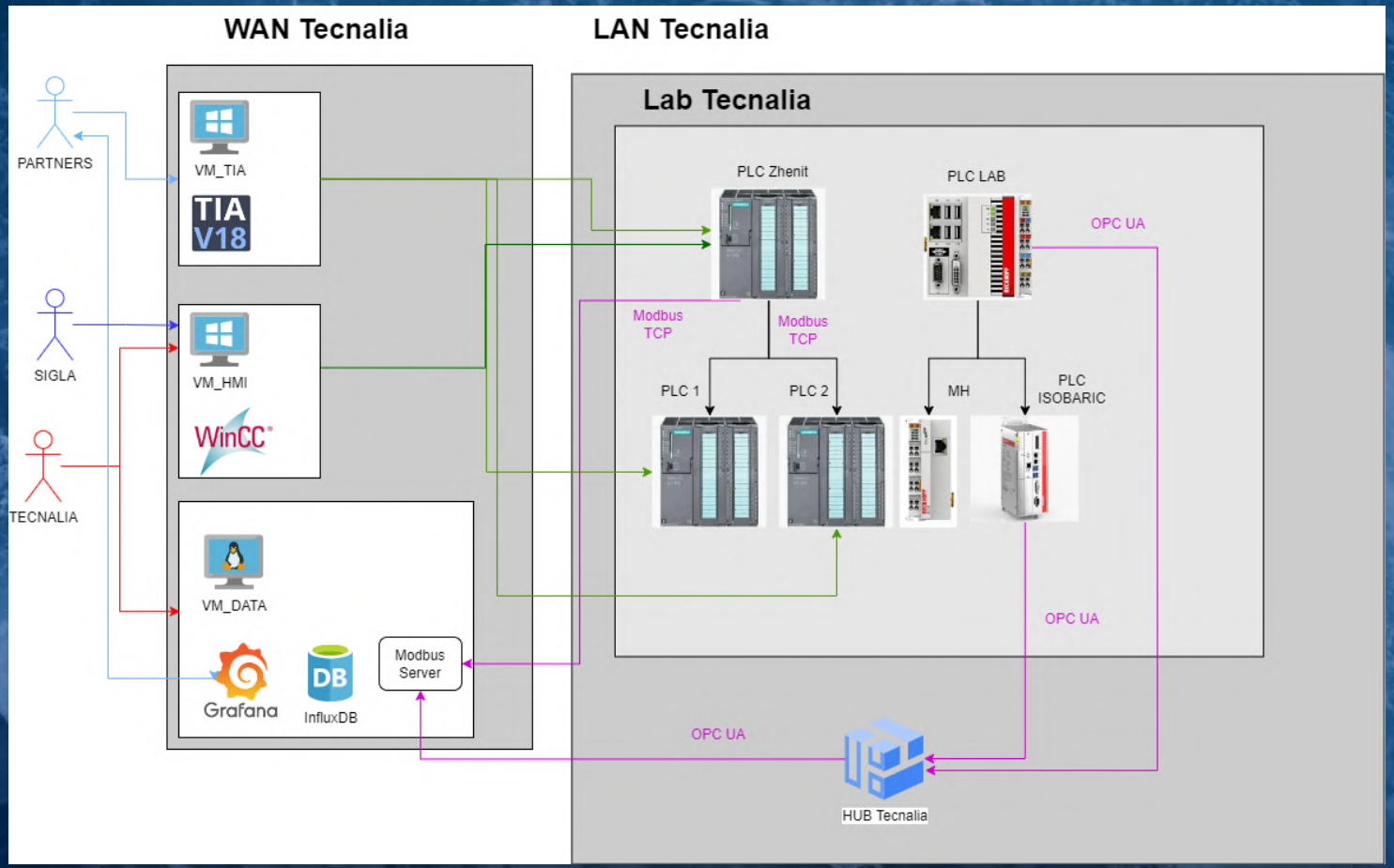


PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

PRECONDITIONING OF THE LABORATORY FOR THE RECEPTION AND INTEGRATION OF ZHENIT TECHNOLOGIES

SAFETY REQUIREMENTS, DOCUMENTATION AND OPERATION

SAFETY REQUIREMENTS DEFINED

- Tecnalia's Quality Department established the safety criteria for the reception of ZHENIT prototypes.

DOCUMENTATION REQUIREMENTS COMMUNICATED

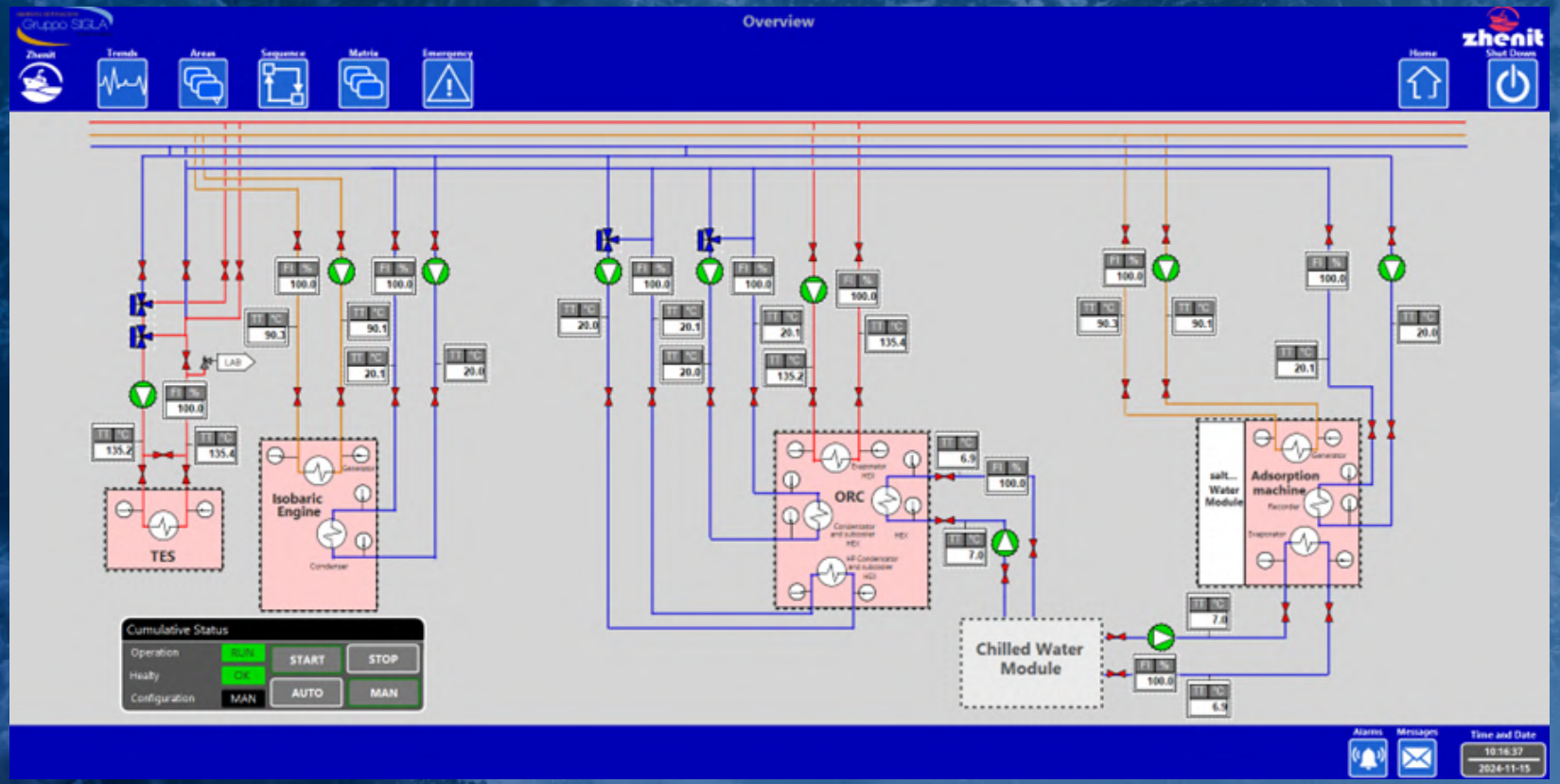
- Each prototype must provide an **Operation & Maintenance Manual** and a **Risk Assessment** before arrival. These documents cover operational limits, safety measures, maintenance procedures, and mitigation of mechanical, electrical, and thermal risks.

OPERATIONAL APPROACH ESTABLISHED

- Prototypes will follow a **"Plug & Play"** setup. Partners were responsible for operating, commissioning, and configuring their prototypes. Tecnalia will provide **remote access and monitoring support**.

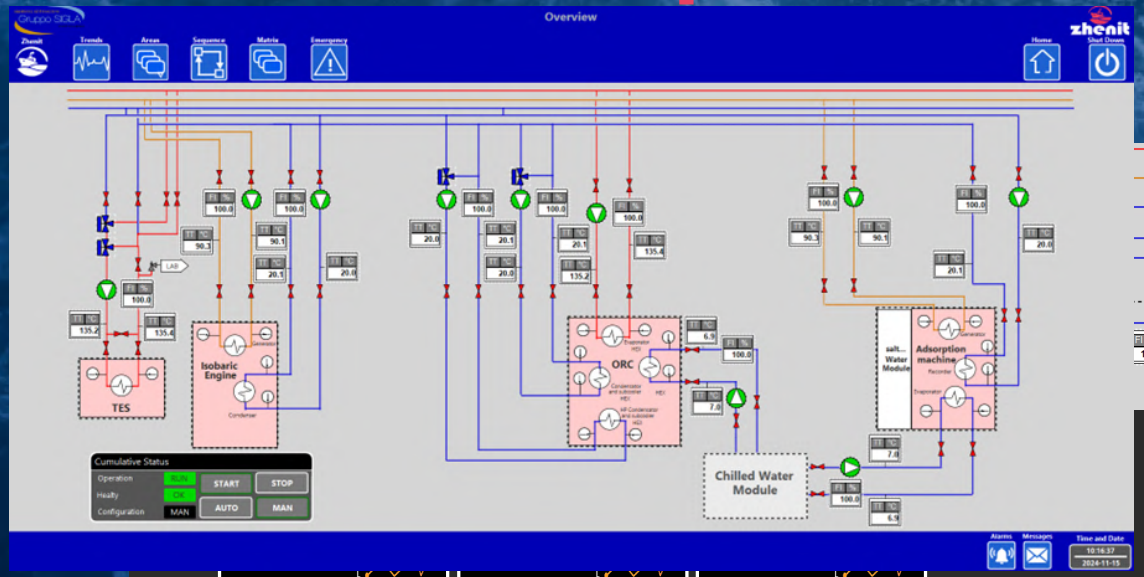
RESULT: The laboratory is now prepared to safely receive, integrate, and monitor the prototypes, with clear responsibilities and documentation requirements in place.

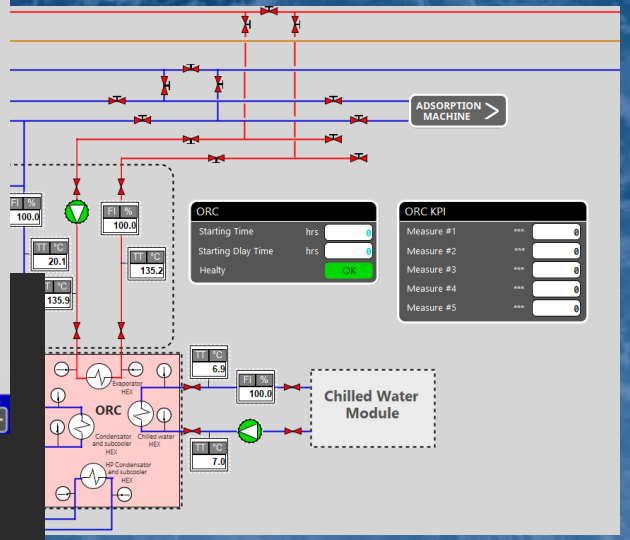
Supervision HMI interface

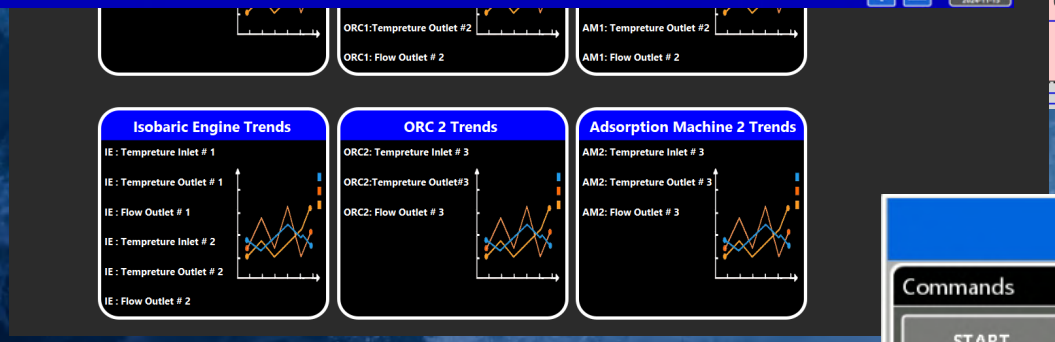


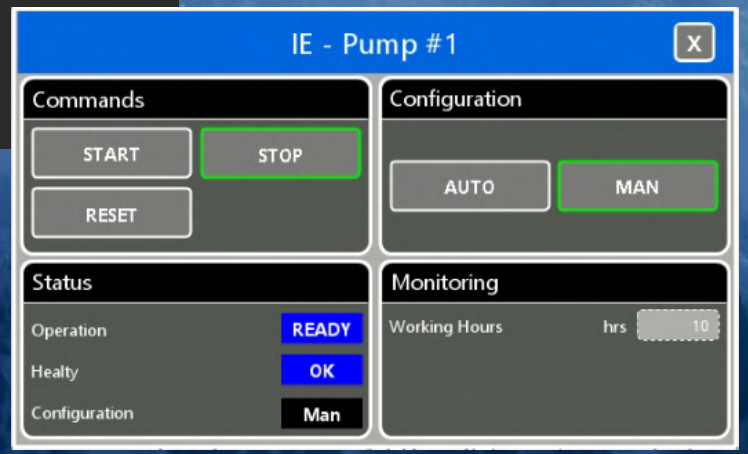
- What is an HMI (Human–Machine Interface)?
  - The HMI is the operator-facing interface used to monitor and control the system.
- In this project context
  - Provides a single dashboard to view key process variables, operating modes, and system status
  - Displays alarms and diagnostics to support fast troubleshooting and safe operation
  - Allows operators to start/stop functions, acknowledge alarms, and adjust setpoints according to permissions
  - Communicates with the central PLC to read real-time data and send control commands

Supervision HMI interface





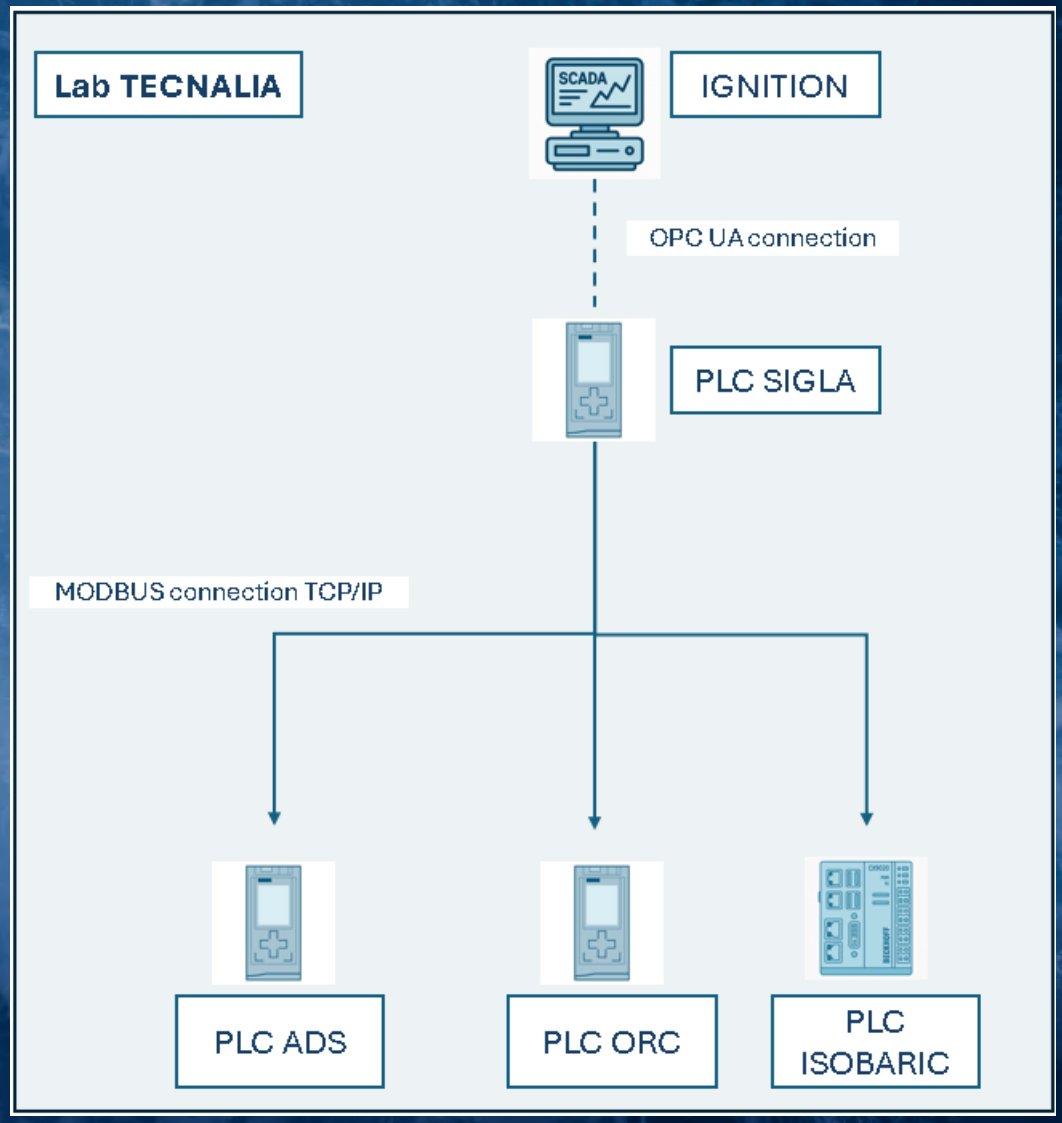




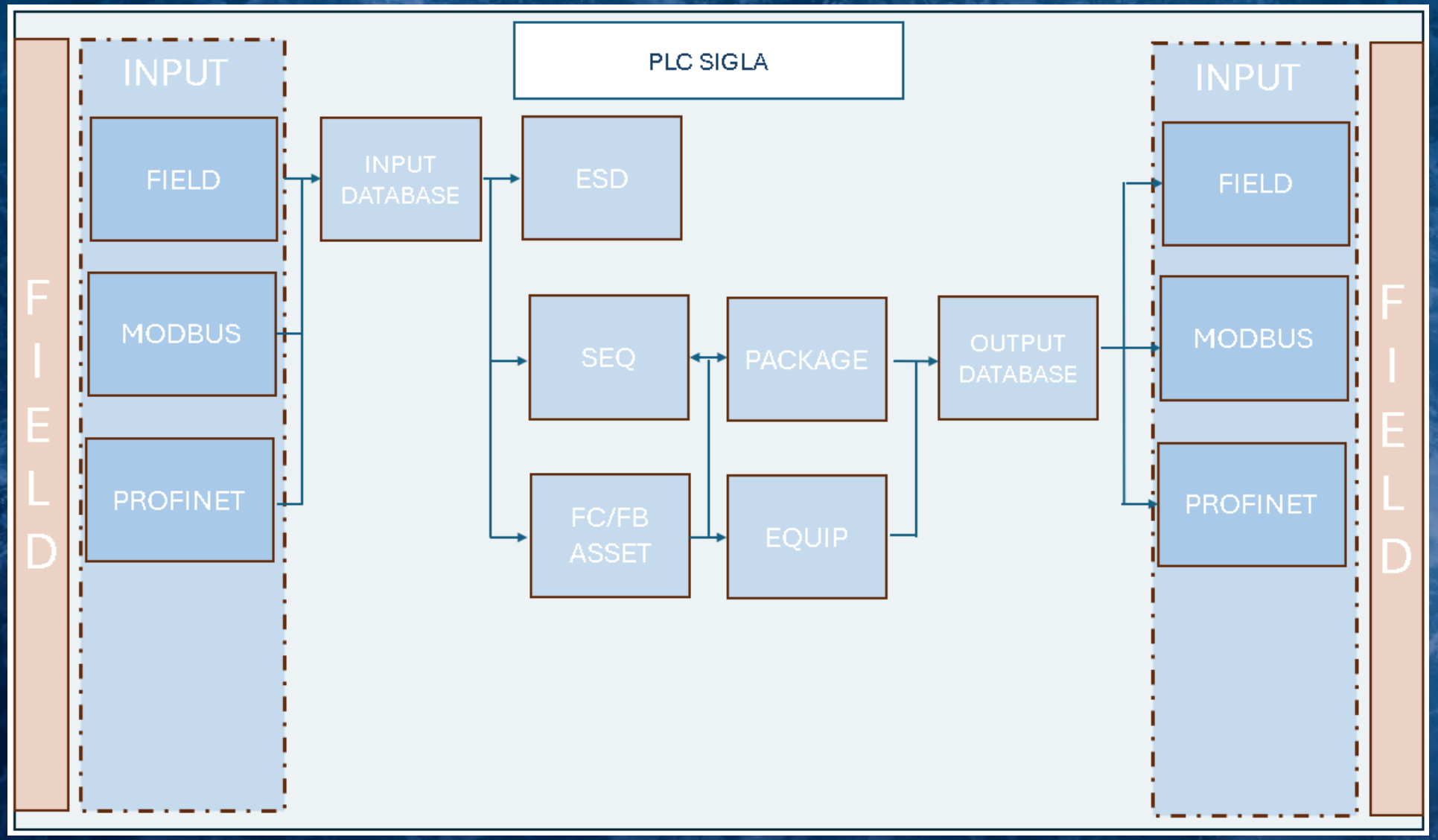
- Main elements of an HMI
  - Process overview screens (plant layout, system status)
  - Real-time values & trends (live data, historical charts)
  - Alarms & events (active alarms, history, acknowledgements)
  - Controls & setpoints (start/stop, mode selection, parameter tuning)
  - User management (roles, permissions, audit trail)
  - Diagnostics & maintenance pages (I/O status, device health, messages)

Control Platform

- PLC – Central Control and Coordination
  - Acts as the core of the control system, collecting and processing field signals (sensors, actuators, devices)
  - Manages process data required for safe and efficient operation (status, measurements, interlocks)
- Field integration
  - Acquires real-time inputs from the plant and distributes control outputs to field equipment
  - Performs signal conditioning, logic execution, and safety checks (limits, alarms, permissives)
- HMI request handling
  - Receives operator commands from the HMI (start/stop, mode selection, setpoints)
  - Routes and validates requests based on permissions, system state, and active process conditions
- Automatic sequences
  - Depending on the current operating mode/process phase, the PLC triggers and supervises automatic sequences
  - Ensures deterministic execution, correct step progression, and

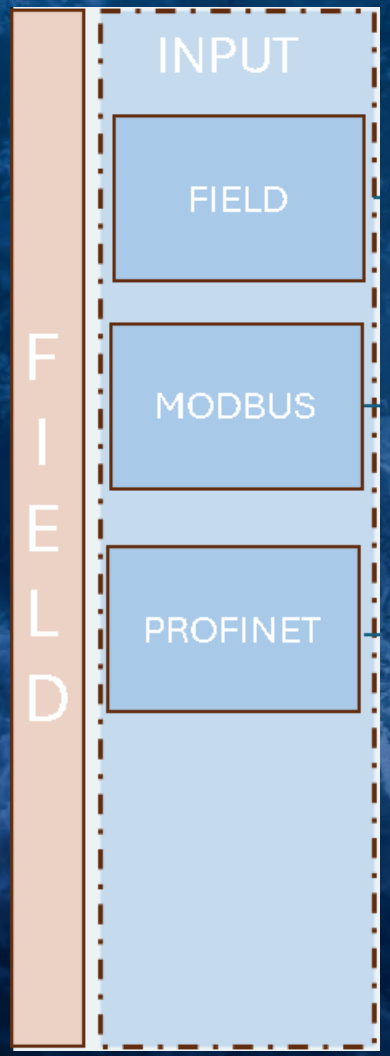


DATA FLOW



- **Schematic representation of the data flow and processing on the PLC (Sigla).**

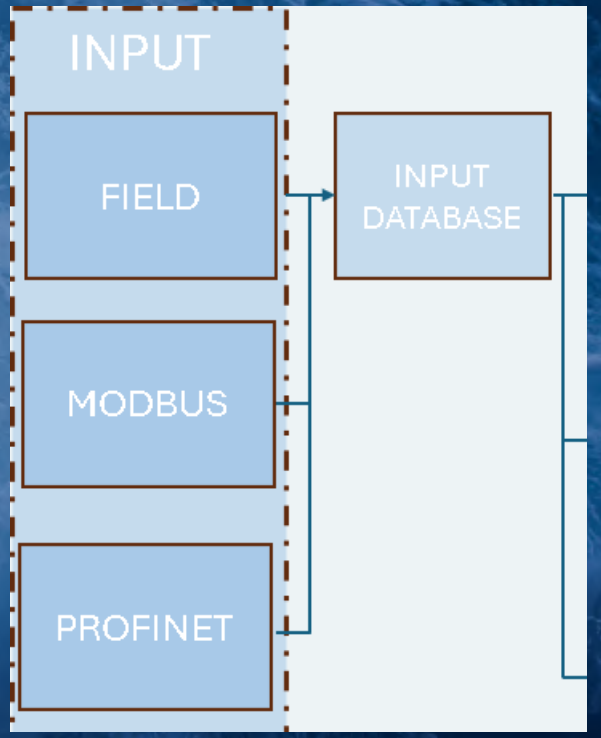
Automation software development



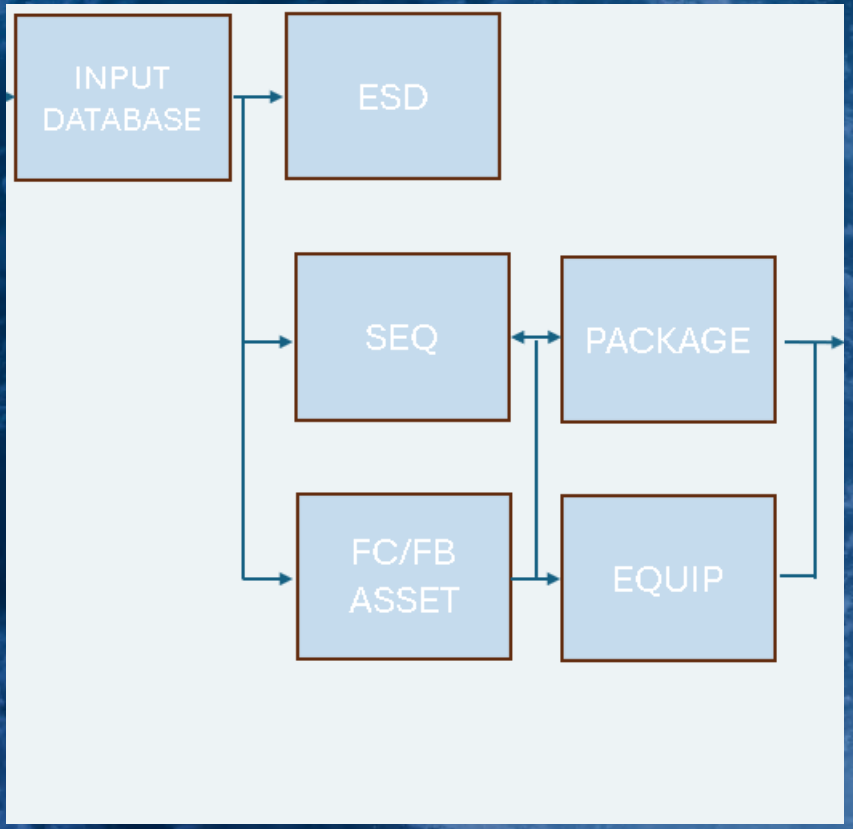
- The software is designed to accept data inputs coming from the field either via hardwired signals or via network protocols such as Modbus or Profinet.
- A swap/mapping logic enables fast reconfiguration, allowing the software to be quickly adapted to different system requirements.

- Field data, also referred to as the *process image*, is stored in a dedicated memory area that holds the collected values.
- In this case it is called a *Data Block (DB):* it contains the *tags* used by the automation logic.

A tag is more than just a variable—it represents an information point. A tag can be simple or structured (with different data types), and it can convey meaning both through its value and through its name/ identifier.



Automation software development



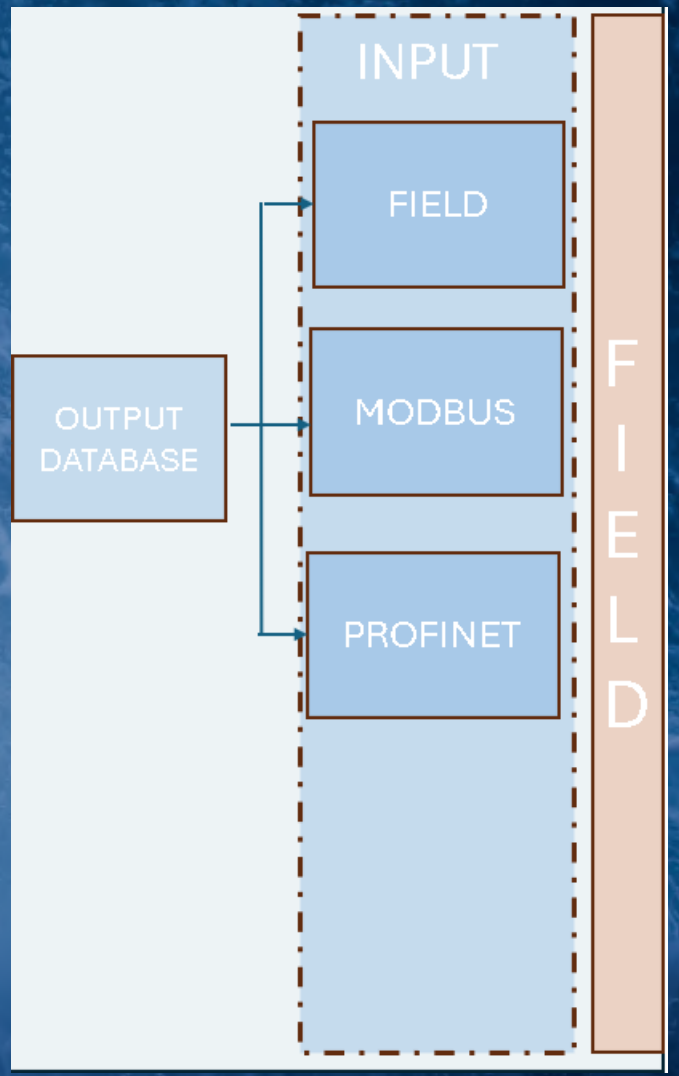
- The control logic is organized by area; each WHt-x device is associated with a dedicated asset, which contains the related actuation/control logic.
- Different actuators are managed differently depending on the selected mode (Auto / Manual).
- The overall software is designed to be modular and easy to modify, enabling the implementation of safety or process interlocks during the testing phase (naturally, within the PLC development IDE only).

- For monostable and bistable actuators, dedicated control and supervision macros were developed specifically for this project. These macros differ from the standard approach and allow additional actuator information to be managed and monitored.

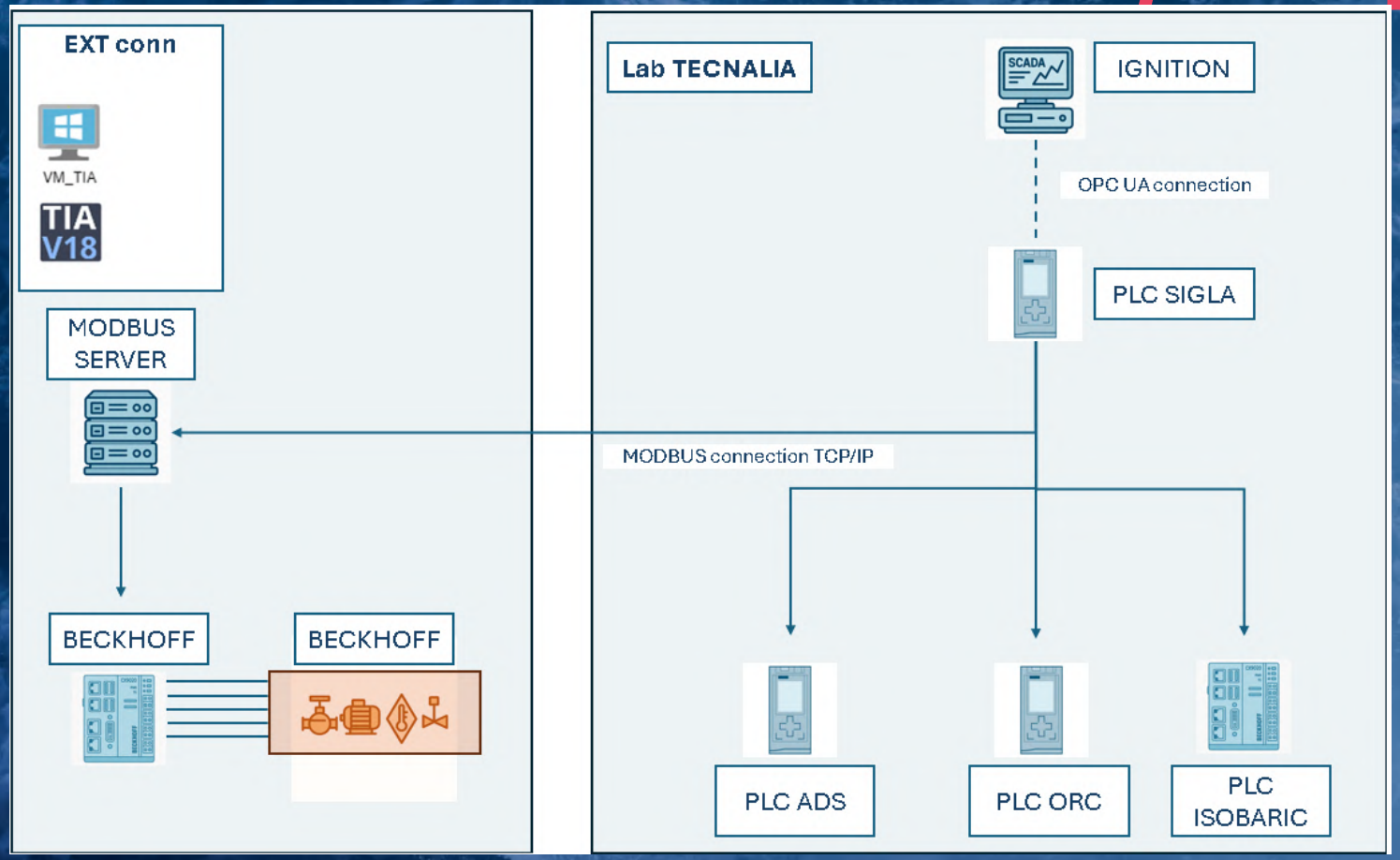
Automation software development

- The processed information and requests are then written to the Data Block (DB), which interfaces with the outputs to the field. Here as well, different configurations are supported: a hardwired interface to the field, and a software-based interface to the field via protocols such as Profinet and Modbus.

- At each PLC scan cycle, field data is updated and the control logic instructions are executed. These values and measurements are also forwarded to another recipient: the supervisory layer (Supervision Platform).

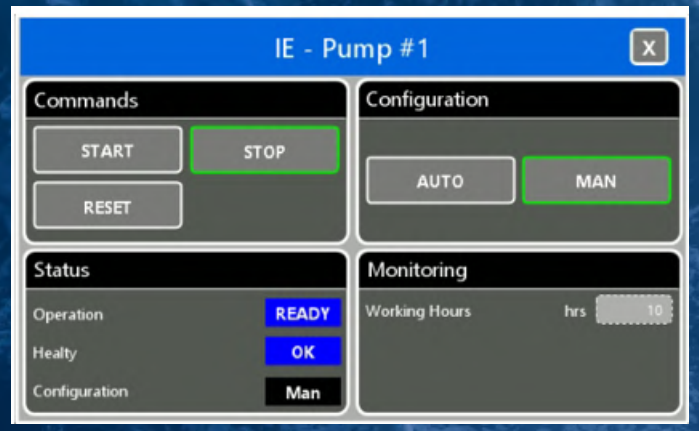


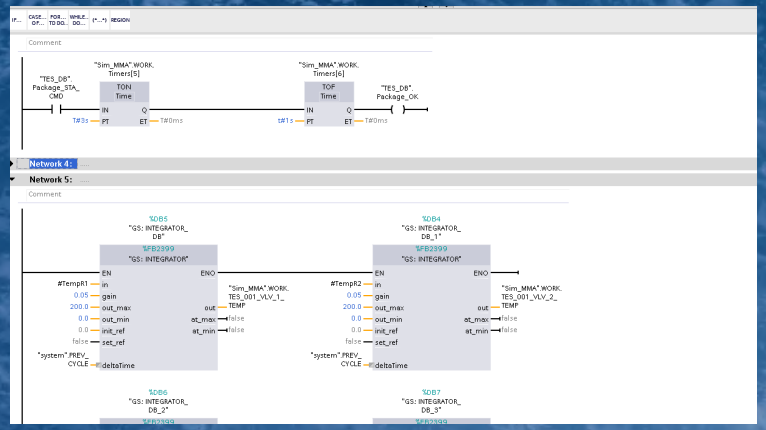
Laboratory setup

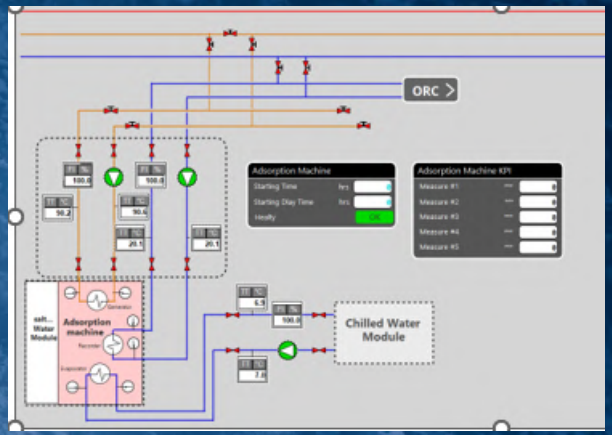


- This diagram shows the laboratory test setup used for validation.
- Field interface (orange): data exchange with the field is handled via Modbus communication.
- Controller: the interface and data handling are managed by a Beckhoff PLC.
- Software-based field connection: this is a representative case where the “field” is not hardwired I/O, but a network (SW) connection.
- Standardized data packaging: process information (e.g., states, measurements, commands) is encoded and grouped into a Modbus data map, so it can be exchanged in a consistent, standard protocol format.
- Outcome: this approach enables a repeatable test configuration, easier integration, and faster adaptation of the setup during lab activities.

Loop check







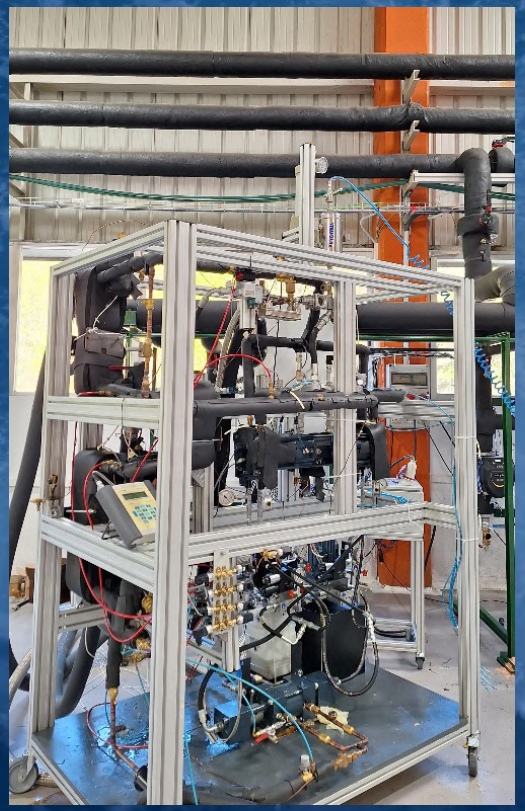
To verify the correctness of the control logic and the consistency of the information, it is necessary to validate the entire control loop—from operator requests and on-screen validations, through the automation logic, all the way to the field devices.

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

RECEPTION OF ZHENIT TECHNOLOGIES (VISUAL INSPECTION AND RECEPTION APPROVAL) &
Mechanical, electrical, and control integration at TECNALIA's laboratory

TES

IEE



AM

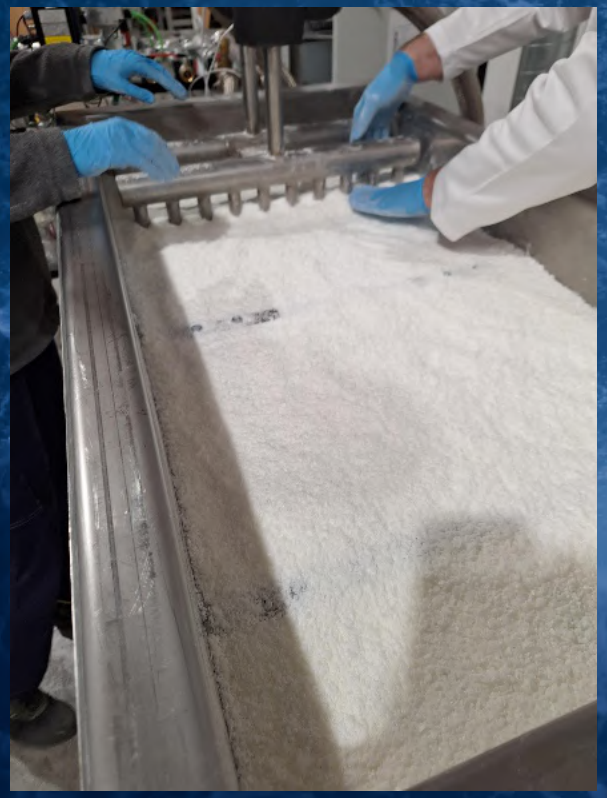
ORC

the ORC-ejector heat pump has been remotely demonstrated at NTUA lab and not shipped to TECNALIA

PREPARATION OF THE TEST SITE FOR THE INTEGRATION OF PROTOTYPES

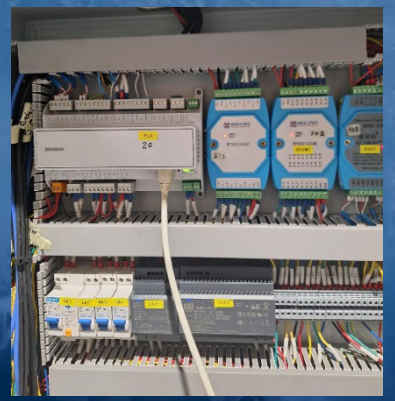
COMMISSIONING AND START-UP OF EACH INDIVIDUAL TECHNOLOGY AND OF THE COMPLETE LABORATORY SETUP

TES



IEE

AM

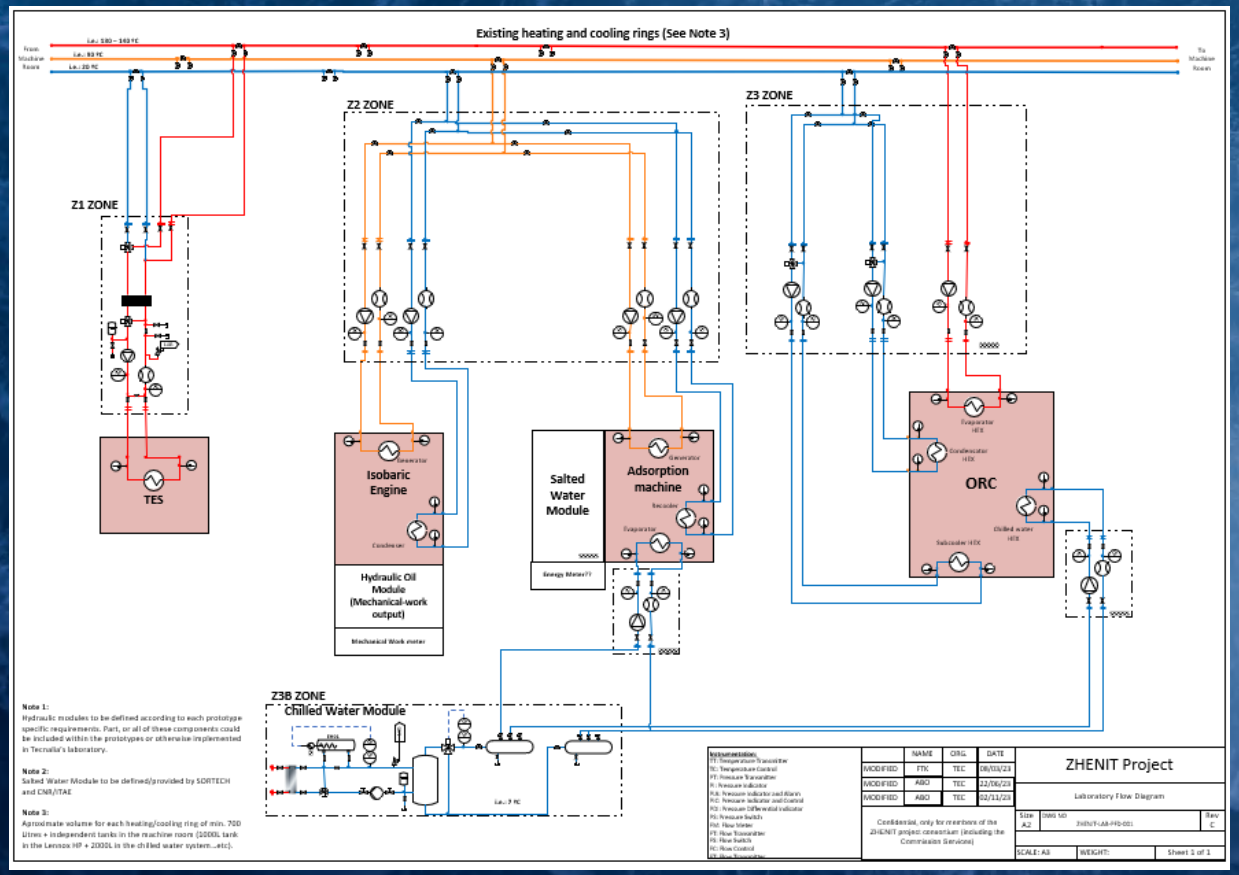


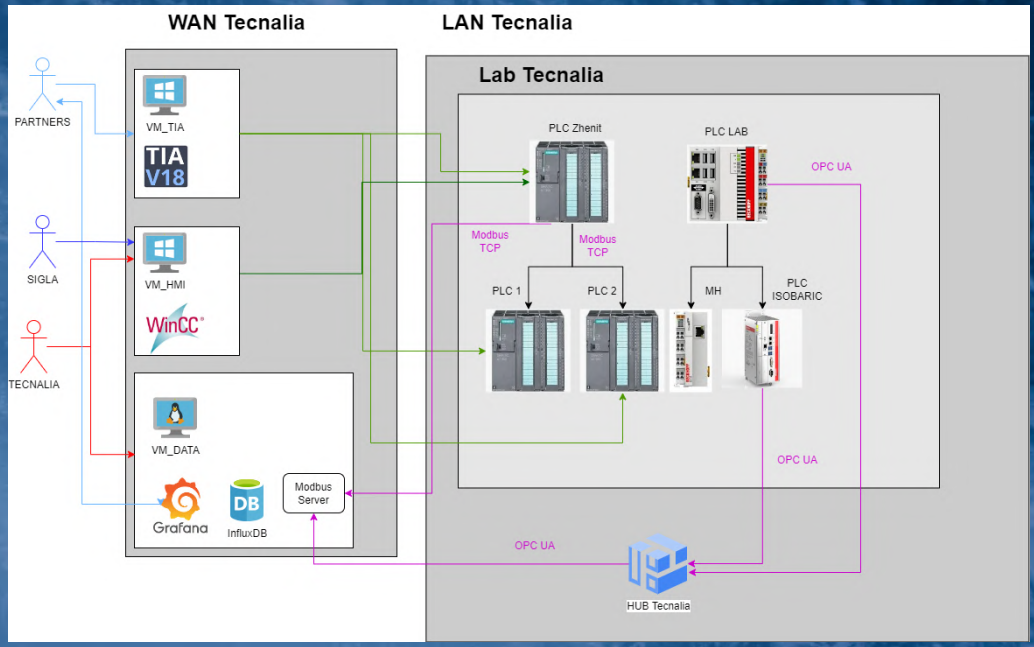
ORC

the ORC-ejector heat pump has been remotely demonstrated at NTUA lab and not shipped to TECNALIA

INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA´s LAB

LABORATORY SETUP AND CONTROL ARCHITECTURE





INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA´s LAB

VALIDATION CAMPAIGN DEFINITION

- Designed an experimental framework to test ZHENIT prototypes under representative maritime conditions
- Configured TECNALIA's laboratory with three pressurized water circuits (–10 °C to 150 °C) to emulate low-, medium-, and high-temperature streams on vessels
- Defined testing scenarios for two vessel types—tuna fishing vessel and ferry—covering key applications: heating/cooling, desalination, electricity generation, mechanical work, and DHW production
- Reproduced standard vessel temperature profiles and varied waste-heat availability to test system performance under both favorable and constrained conditions
- Conducted stand-alone and parallel testing of all prototypes (ORC, TES, AM, IEE), including TES charge/discharge cycles for domestic hot water supply
- Integrated the effect of innovative technologies (e.g., e-Sail) to evaluate their impact on waste-heat availability and energy savings
- Established a comprehensive plan to assess prototype performance, quantify energy-saving contributions, and identify operational constraints, synergies, and lessons for future onboard application.

INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA´s LAB

STAND-ALONE TESTS

Purpose	Objective	Testing Conditions:	Outcome:
• Evaluate individual performance of each prototype under controlled, isolated conditions.	• Verify thermal, hydraulic, mechanical, and electrical performance before full system integration.	• Steady-state operation • Predefined inlet temperatures and flow rates • Scenarios cover high, medium, and low-temperature marine waste-heat streams	• Establishes baseline performance for integration phase • Supports parallel testing under simulated vessel operating conditions

INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA´s LAB

PARALLEL TESTING

Objetive

- Evaluate integrated performance of ZHENIT prototypes under realistic vessel conditions.
- Assess interactions and synergies of ORC, TES, AM and IEE systems

CASE OF STUDY 1

- **Tuna Fishing Vessel** (4-hour lab emulation, Indian Ocean conditions)
- **HT:** 130–140 °C → ORC electricity generation
- **MT:** 86.3 °C → Adsorption cooling / isobaric engine
- **LT:** 41.9 °C → minimal use
- **Seawater:** 24–30 °C
- **Purpose:** Evaluate simultaneous system performance and energy efficiency contribution.

CASE OF STUDY 2

- **Ferry Vessel – Summer** (4-hour lab emulation, Mediterranean conditions)
- **HT:** 180–200 °C → ORC electricity generation
- **MT:** 91 °C → Isobaric engine / motor pumps
- **LT:** 47 °C → Absorption cooling
- **Seawater:** 24–28 °C → TES DHW demand

CASE OF STUDY 3

- **Ferry Vessel – Winter** (4-hour lab emulation, Mediterranean conditions)
- **HT:** 180–200 °C → ORC electricity generation
- **MT:** 91 °C → Isobaric engine / motor pumps
- **LT:** 47 °C → Absorption cooling
- **Seawater:** 12–16 °C → TES DHW demand

Outcome:

- Established system performance under realistic operational and seasonal conditions.
- Identified interactions, synergies, and constraints between prototypes.

INTEGRATED PROTOTYPES PILOT CAMPAIGN AT TECNALIA´s LAB

DATA ANALYSIS

Objetive

- Scale laboratory prototype performance to real vessel conditions.
- Evaluate how each ZHENIT system (ORC, TES, Adsorption Machine, IEE) can meet energy demands using available waste heat.

Waste heat assignment

- Prototypes assigned to waste-heat streams matching their operational needs:
- **HT (high temperature):** ORC (electricity) and TES (DHW/ thermal storage)
- **MT (medium temperature):** Adsorption Machine (cooling) and IEE (mechanical power)
- **LT (low temperature):** Not considered due to limited or unsuitable availability.

Allocation of Competing Heat Streams

- Medium-temperature heat shared conservatively between cooling and auxiliary mechanical demand (e.g., 90/10 or 80/20 split).

Linear Scaling of Laboratory Data

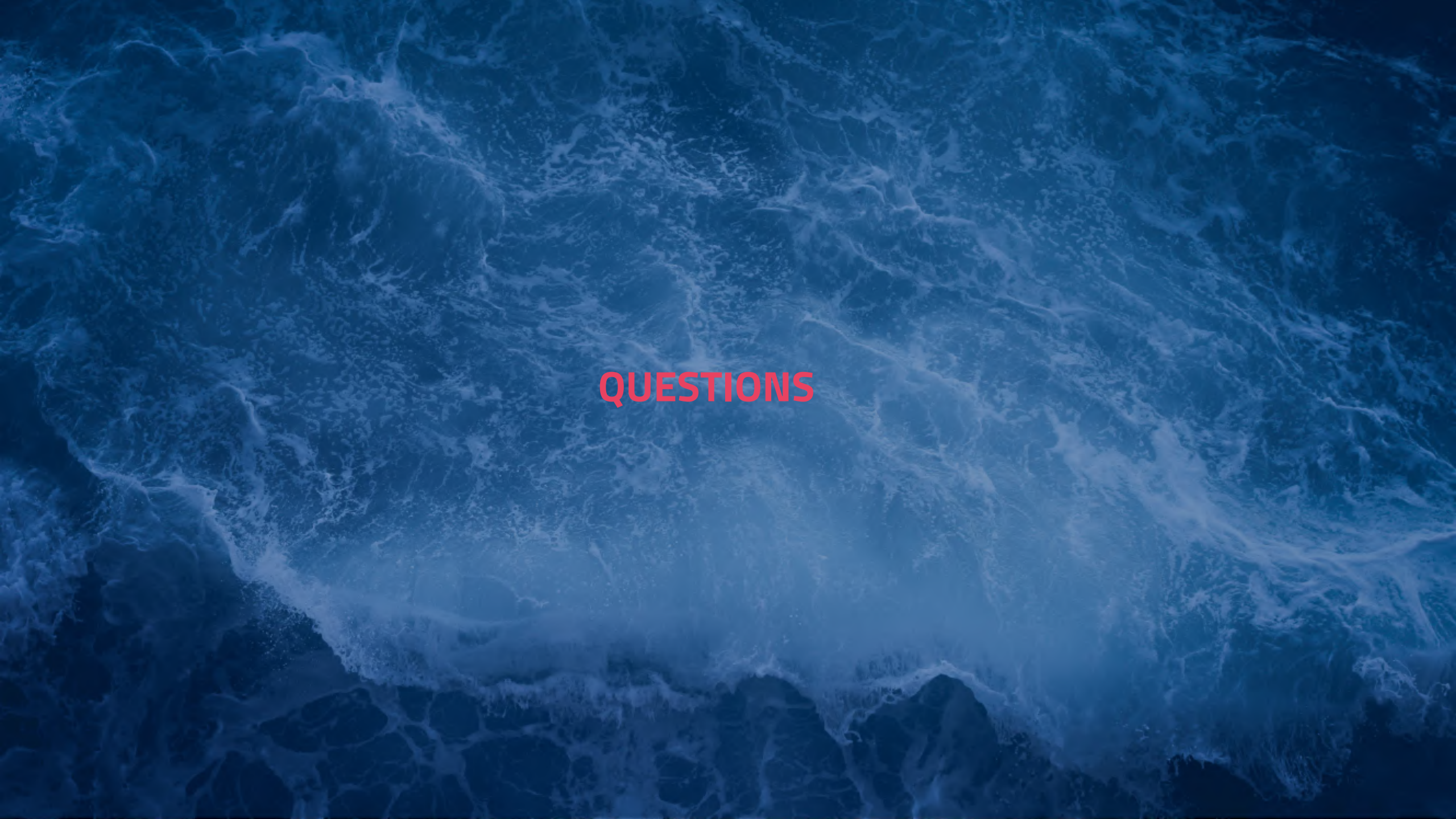
- Prototype outputs scaled proportionally to the available waste heat on the vessel.
- Efficiency measured in the lab is preserved.
- Example: ORC prototype consuming 90 kW_{th} to produce 8 kW_e → scaled to vessel HT heat for total electrical output.

Result calculation:

- Scaled outputs compared with vessel energy demands:
- **Electricity demand:** fraction covered by ORC
- **Cooling demand:** fraction covered by Adsorption Machine
- **Mechanical auxiliary demand:** fraction covered by IEE
- **Domestic hot water:** covered by TES units

Outcome

- Quantified how each prototype contributes to vessel energy needs.
- Provides a baseline for system integration and full-scale implementation.


QUESTIONS

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the European Union

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