Giornata Nazionale di Lancio del Bando 2023

# Le applicazioni dell'idrogeno per la logistica portuale: il progetto H2Ports

**Elio Jannelli**

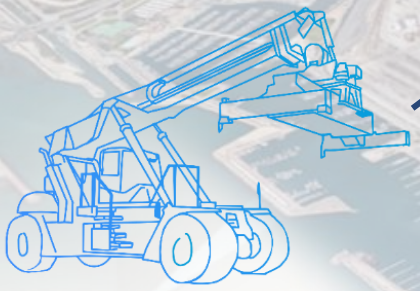
Full professor of Energy System, University of Naples "Parthenope"

CEO Atena scarl

**Roma, 8 febbraio 2023 - ore 9.30/13.30**

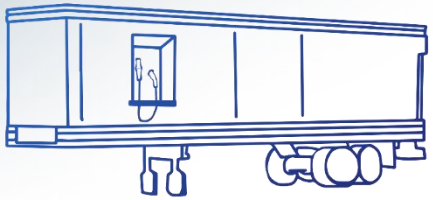
Sala Parlamentino | Villa Lubin, CNEL – Viale Lubin n. 4

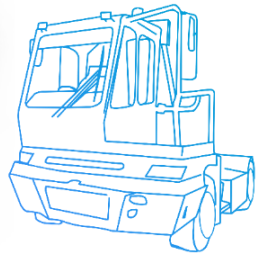
# H2Ports - Implementing Fuel Cells and Hydrogen Technologies in Ports



**Reach Stacker**
in Valencia MSC Terminal

Mobile Hydrogen Refueling Station





**Yard Tractor**
in Valencia Terminal Europa

Clean Hydrogen Partnership

**The first application of hydrogen technologies in port handling equipment in Europe.**

# H2Ports Project Partners

Coordination: FUNDACIÓN VALENCIAPORT

## Public authorities

valenciaport
Autoridad Portuaria de Valencia

## Research institutions

Centro Nacional del Hidrógeno

ATENA
FUTURE TECHNOLOGY

## End users

msc TERMINAL VALENCIA

GRIMALDI GROUP

## Industry

HYSTER-YALE GROUP

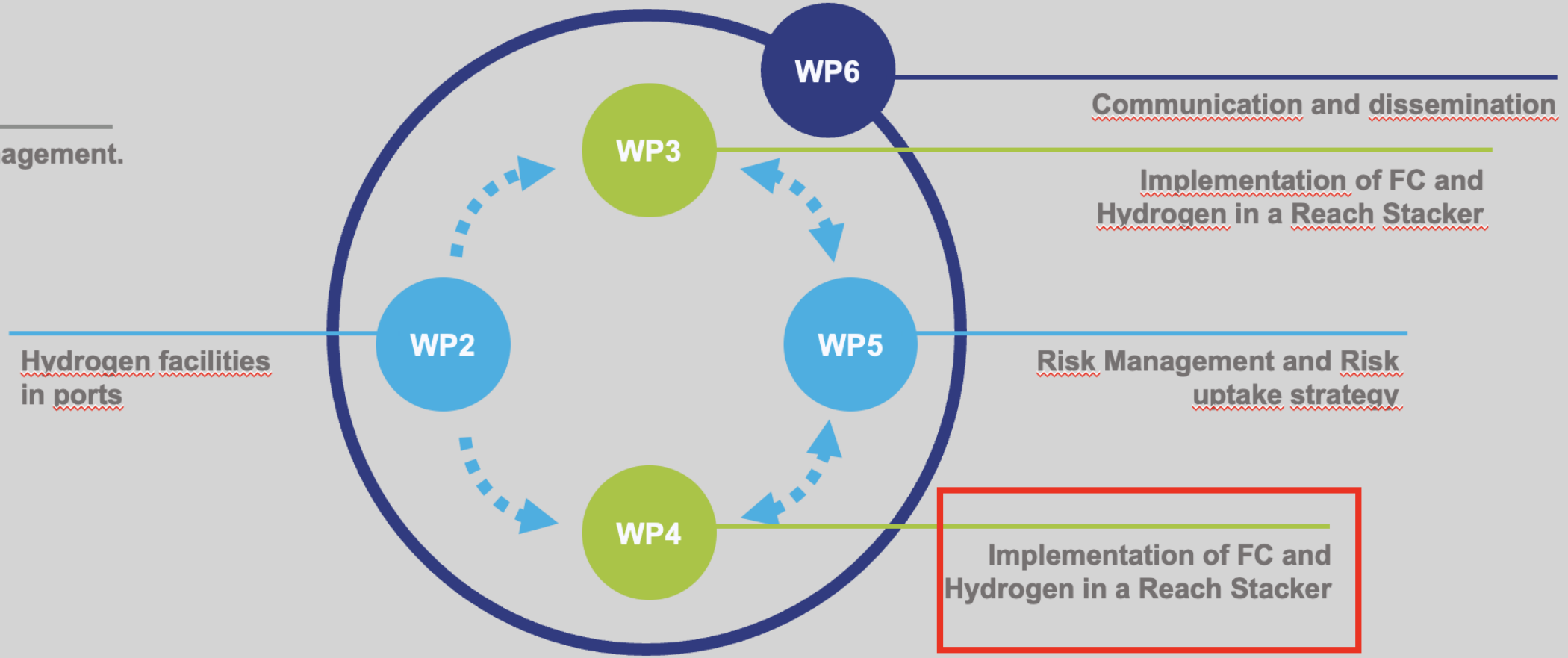
BALLARD

enagas

# Project Structure

**WP1**

Project Management.



# WP4 Goal: 4x4 FC RoRo Truck @ Grimaldi Terminal Europe



FCHJU funding € 1,100,000 approx.

ATENA, Grimaldi Group, Ballard, National Hydrogen Centre, Fundacion Valenciaport

Development and deployment a 4x4 Yard Tractor equipped with a Fuel Cells and test it in Valencia Terminal Europa (Grimaldi Group). It involves three tasks:

- Design of the new FCEV YT
- Assembling of new components in the YT
- Testing and Piloting of the FCEV YT in Valencia, Spain

# ATENA scarl – Distretto Alta Tecnologia ENergia e Ambiente

**COMPANIES**

***System Integrator***
- COELMO Spa
- MERIDIONALE IMPIANTI Spa
- MECOSER SISTEMI Spa

**Industrial & Civil construction**
- GRADED Spa
- IURO Srl
- AET sas

***Gas manufacturer***
- SOL GROUP S.p.A.

**Aeropsace, IT, Engineering & Consulting**
- PROTOM GROUP Spa
- TECHNOVA Scarl

**Engineering Design & Consulting**
- GREEN ENERGY PLUS Srl
- SRS ENGINEERING DESIGN Srl

***ShipYard***
- CANTIERI DEL MEDITERRANEO Spa

***Enviromental Industrial Activities***
- SUDGEST Scarl
- C.E.A. Spa
- RES NOVA DIE Srl

**RESEARCH INSTITUTIONS:**
- CRdC TECNOLOGIE ←- CNR STEMS
- ENEA

**UNIVERSITIES:**
- UNIVERSITÀ DI NAPOLI PARTHENOPE
- UNIVERSITÀ DEL SANNIO
- UNIVERSITÀ DI GENOVA
- UNIVERSITÀ DI PERUGIA
- UNIVERSITÀ DI PISA
- UNIVERSITÀ DI SALERNO

# Plug-in Fuel Cell Electric Vehicles developed by Atena

ATENA
FUTURE TECHNOLOGY

## Bikes, Scooter, 3-Wheels Car, Commercial car, Yard Truck

atenaweb.com

2014

**FIRST HY-BIKE**
250 W
500 W FUEL CELL POWER
NO BATTERY PACK
METAL HYDRIDE (MH) AS H2 STORAGE

140 km RANGE

2015

**SPORT HY-BIKE**
500 W
HYBRID POWER UNIT
500 W FUEL CELL POWER
13Ah@36V BATTERY PACK
REMOVABLE MH CARTRIDGES
H2@15 BAR

90 km RANGE

2016

**HY-BIGA**
1000 W
HEAVY DUTY ELECTRIC TRACTOR
1000 W FUEL CELL POWER
METAL HYDRIDE (MH) AS H2 STORAGE

12 HOURS CONTINUOUS OPERATION

2017

**HY-SCOOTER**
2 kW
HYBRID POWER UNIT
1000W FUEL CELL POWER
20Ah@48V BATTERY PACK
REMOVABLE MH CARTRIDGES
H2@15 BAR

120 km RANGE

2018

**HY-APE**
6 kW
HYBRID POWER UNIT
2500W FUEL CELL POWER
55Ah@72V BATTERY PACK
REMOVABLE MH CARTRIDGES
H2@15 BAR

120 km RANGE

2019

**HY-QUBO**
50 kW
HYBRID POWER UNIT
30 kW FUEL CELL POWER
40Ah@148V BATTERY PACK
COMPRESSED HYDROGEN
H2@700BAR

500 km RANGE

2020


**HY-YARD TRUCK**
150 kW
HYBRID POWER UNIT
85 kW fuel CELL POWER
100Ah@680 V BATTERY PACK
COMPRESSED HYDROGEN H2@350BAR

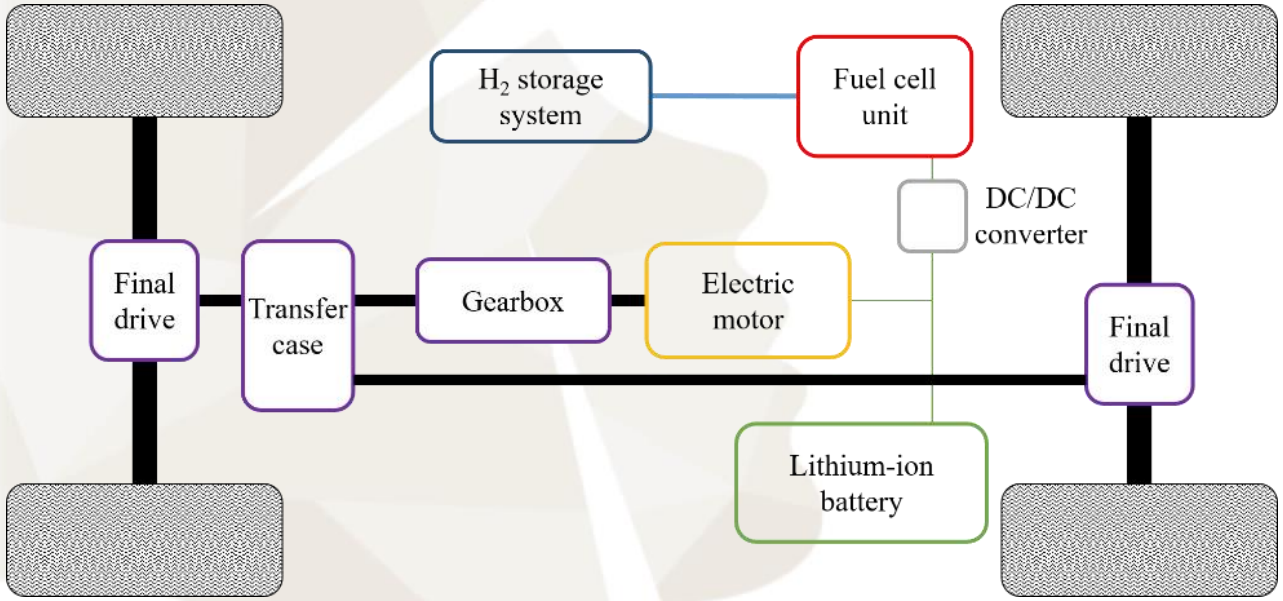
16 HOURS CONTINUOUS OPERATION

## Hybrid Power Units from 250 W to 180 kW

# HyTruck - The PFCEV concept design and architecture

- The **FC stack** has to provide the requested mean power in order to avoid the battery SoC depletion under continuous vehicle operation.

- The **battery pack** has to:
  - deal with transient operations
  - recover kinetic energy during braking;
  - ensure an adequate AER




## Main requirements

The hydrogen-powered vehicle has to accomplish the same tasks as the Diesel vehicle:

- same power/torque at wheels as the ICE vehicle
- 6 hours of continuous operation before refueling

| | | |
|---|---|---|
| **Electric Motor** | Max. Continuous Torque | 938 Nm |
| | Rated Torque (with one 350A inverter) | 1300 Nm @ 1900 rpm |
| | Nominal Efficiency | 96 % |
| **Fuel Cell** | Rated Power | 70 kW |
| | Peak Efficiency | 57 % |
| **Battery pack** | Nominal Voltage | 25.6 V |
| | Nominal capacity | 40 Ah |
| | N. of modules | 24 |
| | Battery Overall Energy Capacity | 25 kWh |

# CAD modeling

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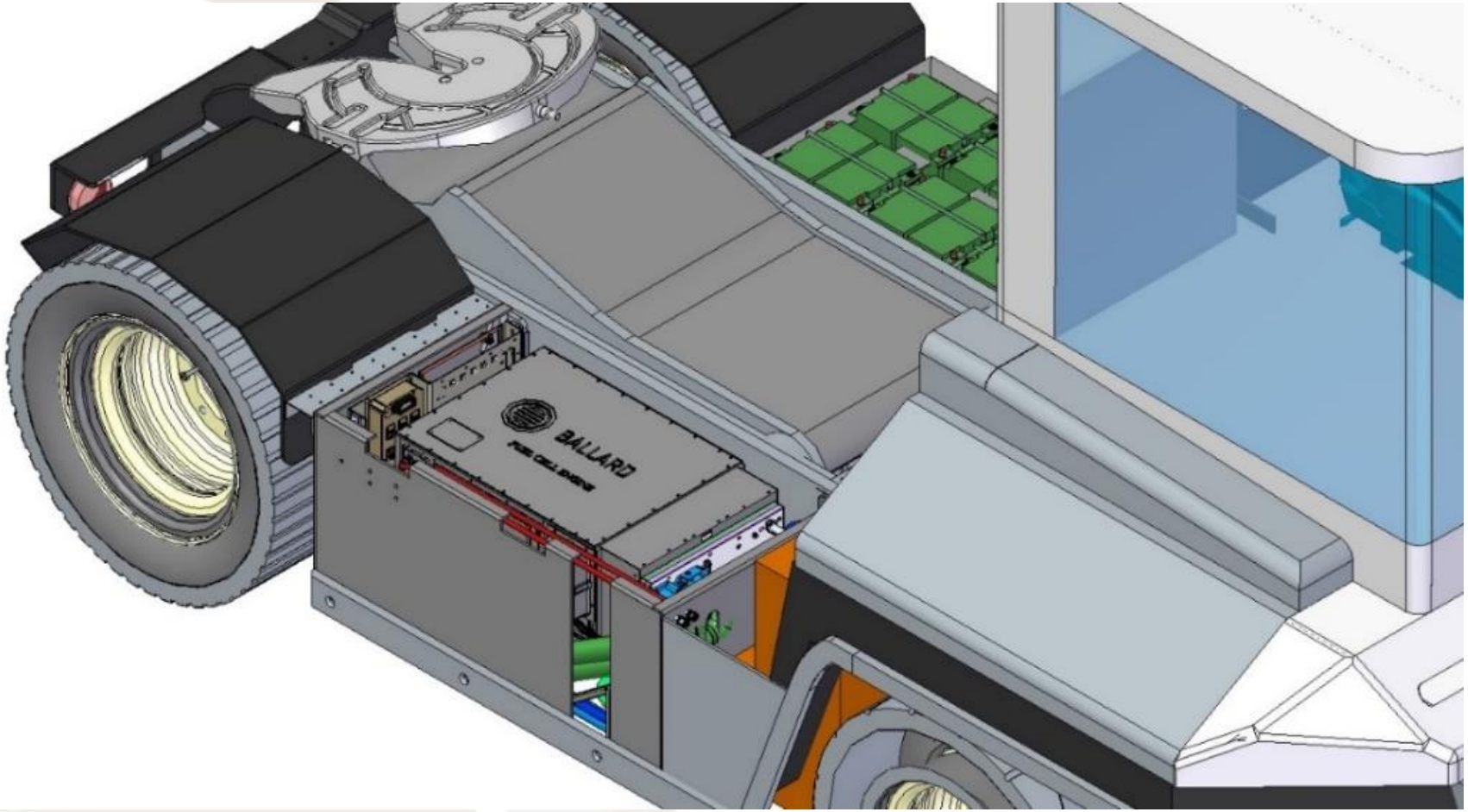
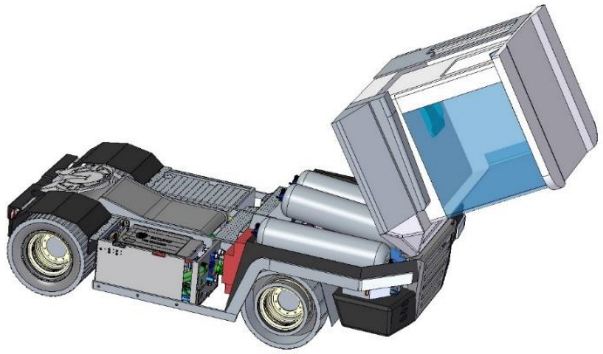
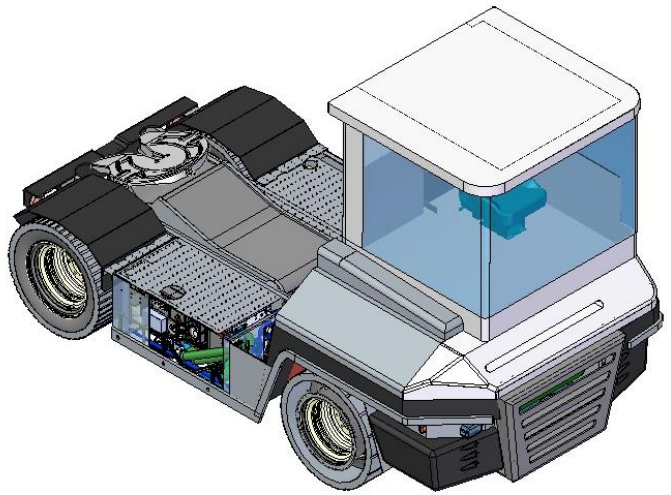
FUTURE TECHNOLOGY



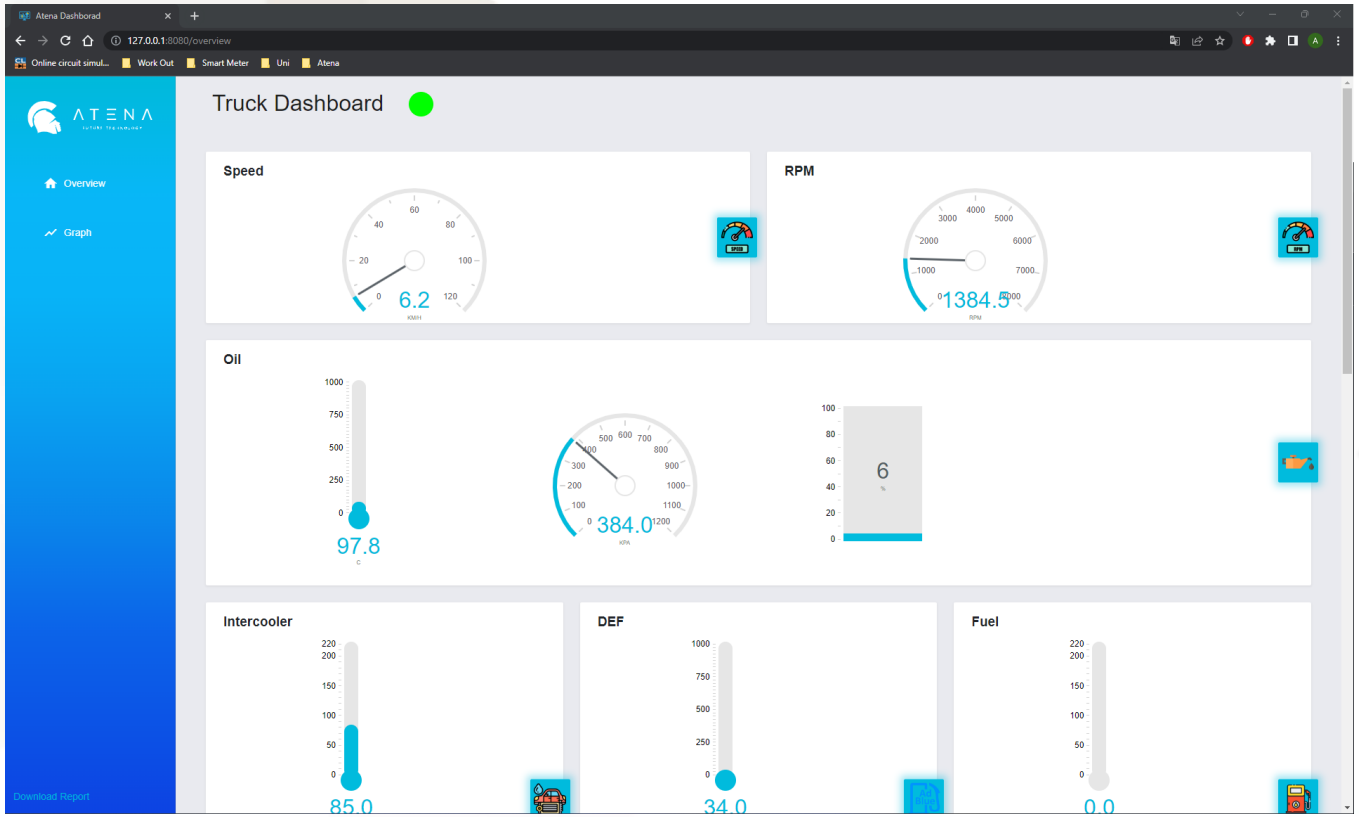



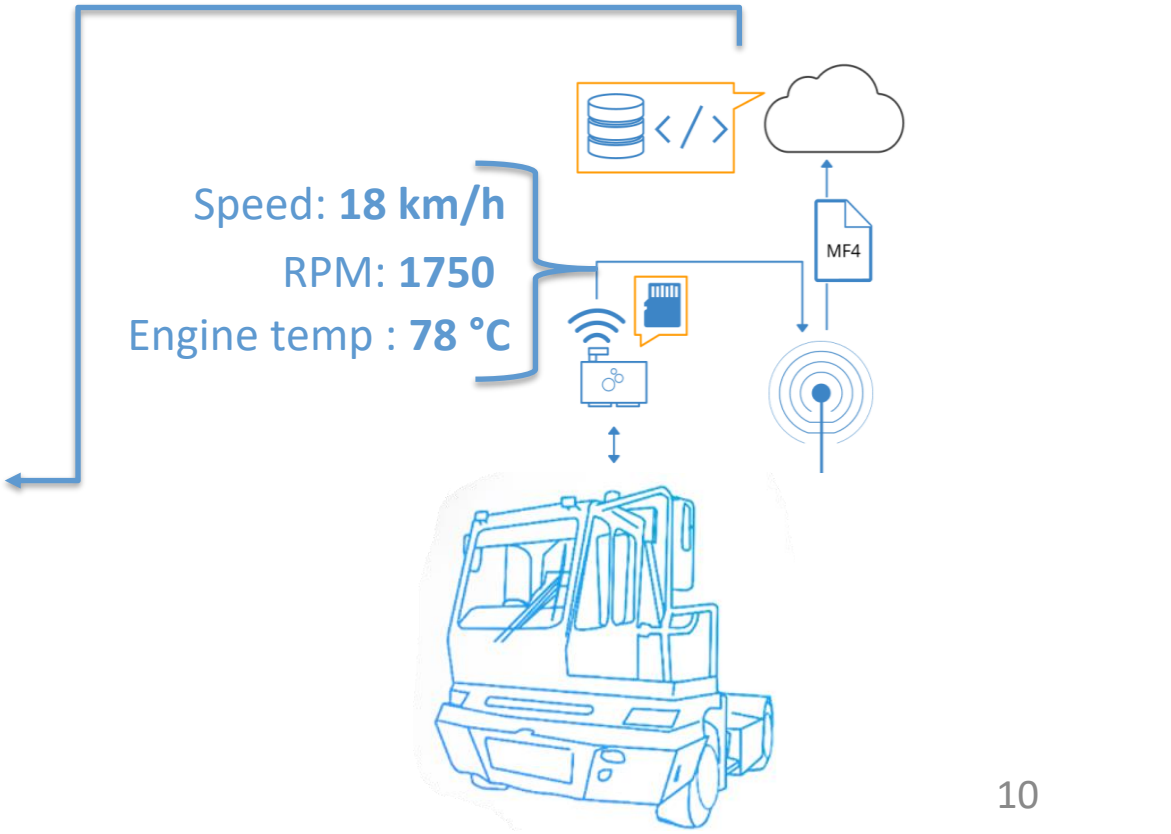


# Diesel Vehicle Performance Data Acquisition

- On-field measurement campaign to acquire typical duty/driving cycles for the Diesel-engine vehicle
- Designed a CAN Communication System for truck's telemetry and control.
- Developed a dashboard for the online data control and management.

10 Yard Tractors could be equipped for recording performance (torque, speed, power, fuel consumption, etc.) during real roll off/roll on operations.



# Diesel Vehicle Performance Data Acquisition System

- On-field measurement campaign to acquire typical duty/driving cycles for the Diesel-engine vehicle
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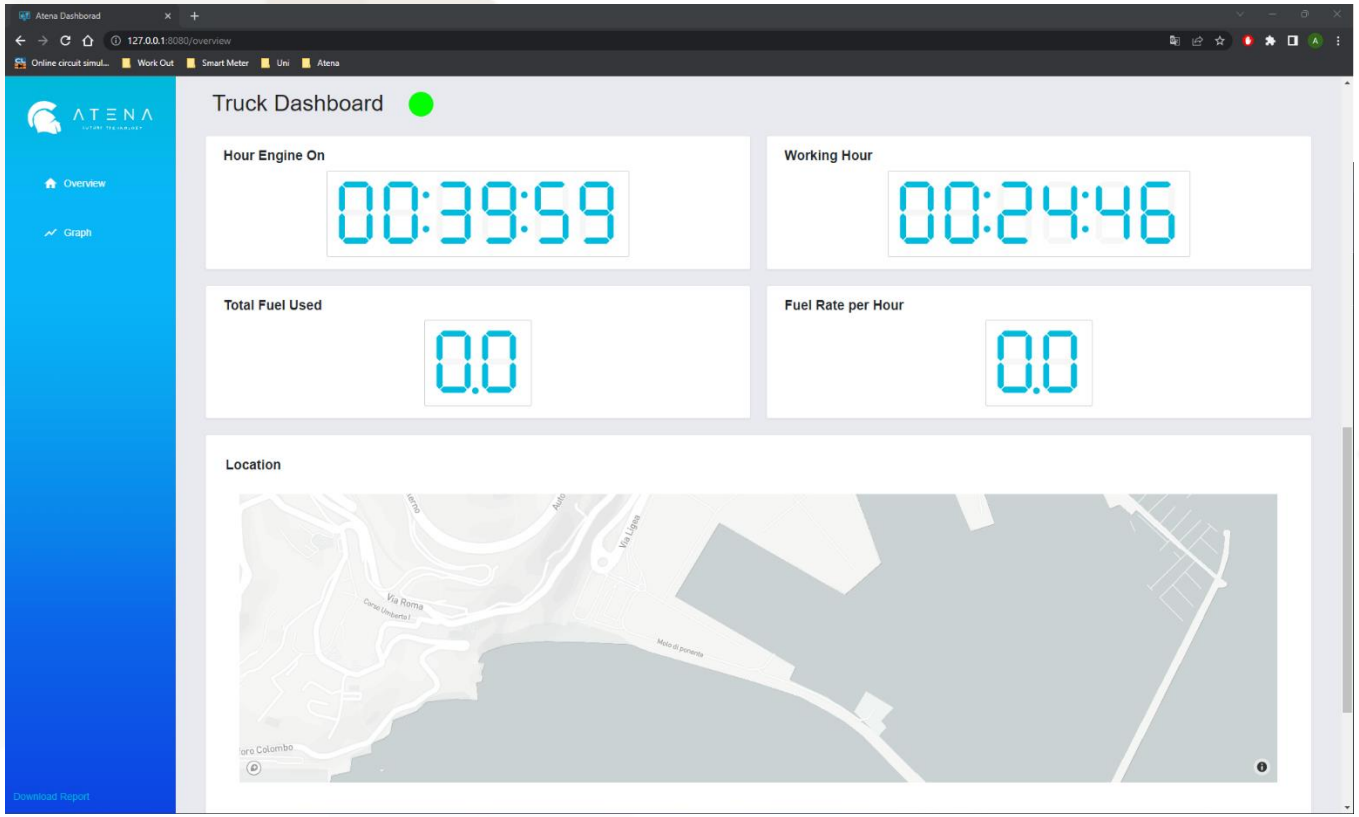
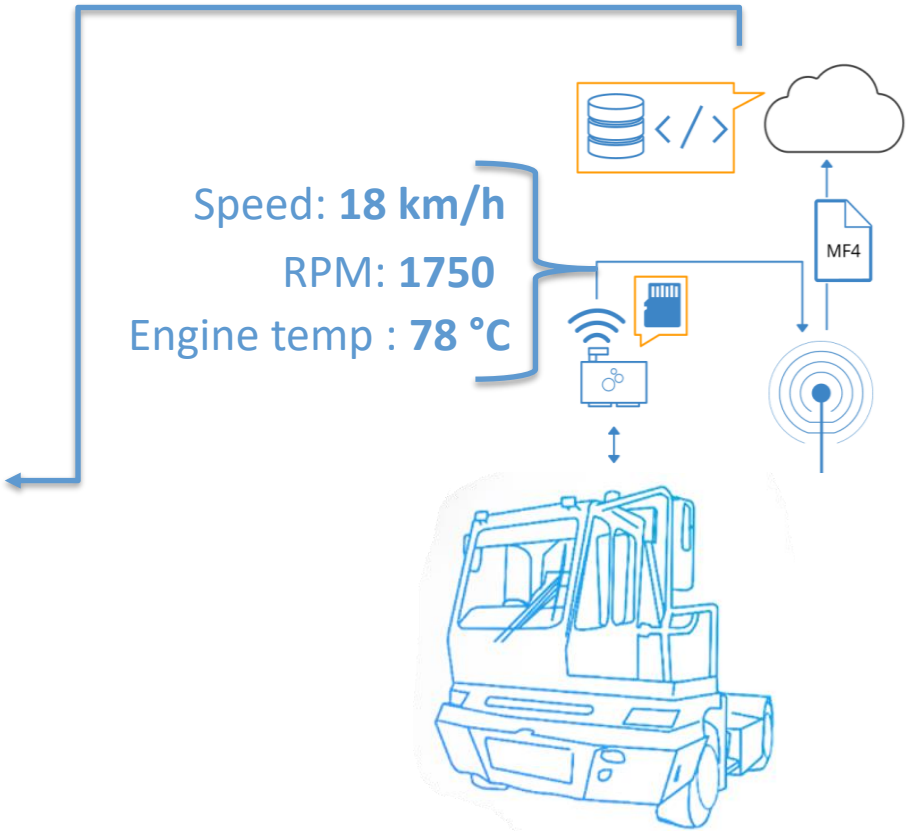
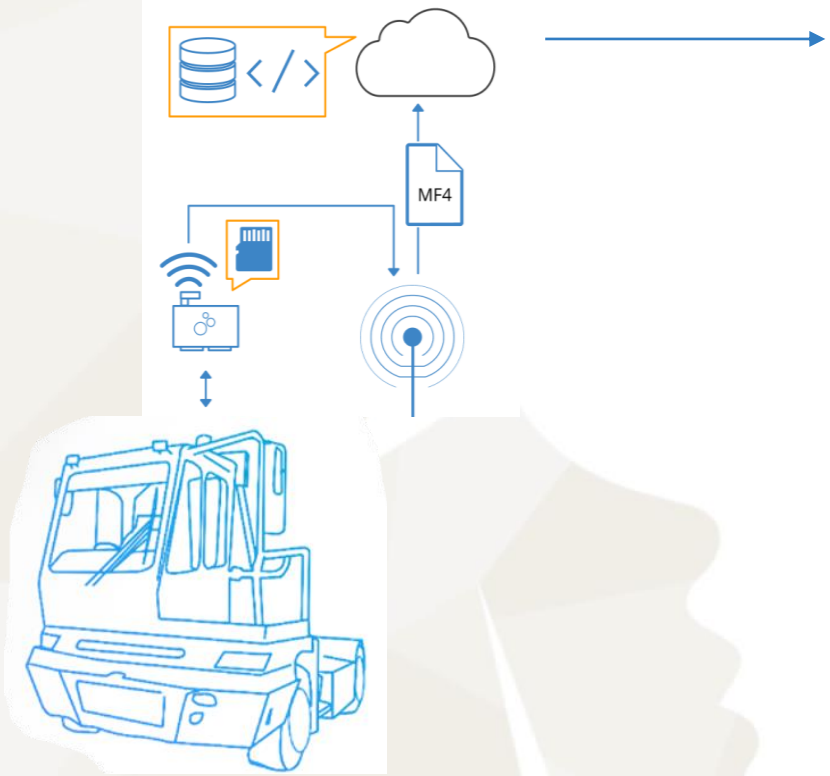


# Diesel Vehicle Performance Data Acquisition System

ATENA
FUTURE TECHNOLOGY

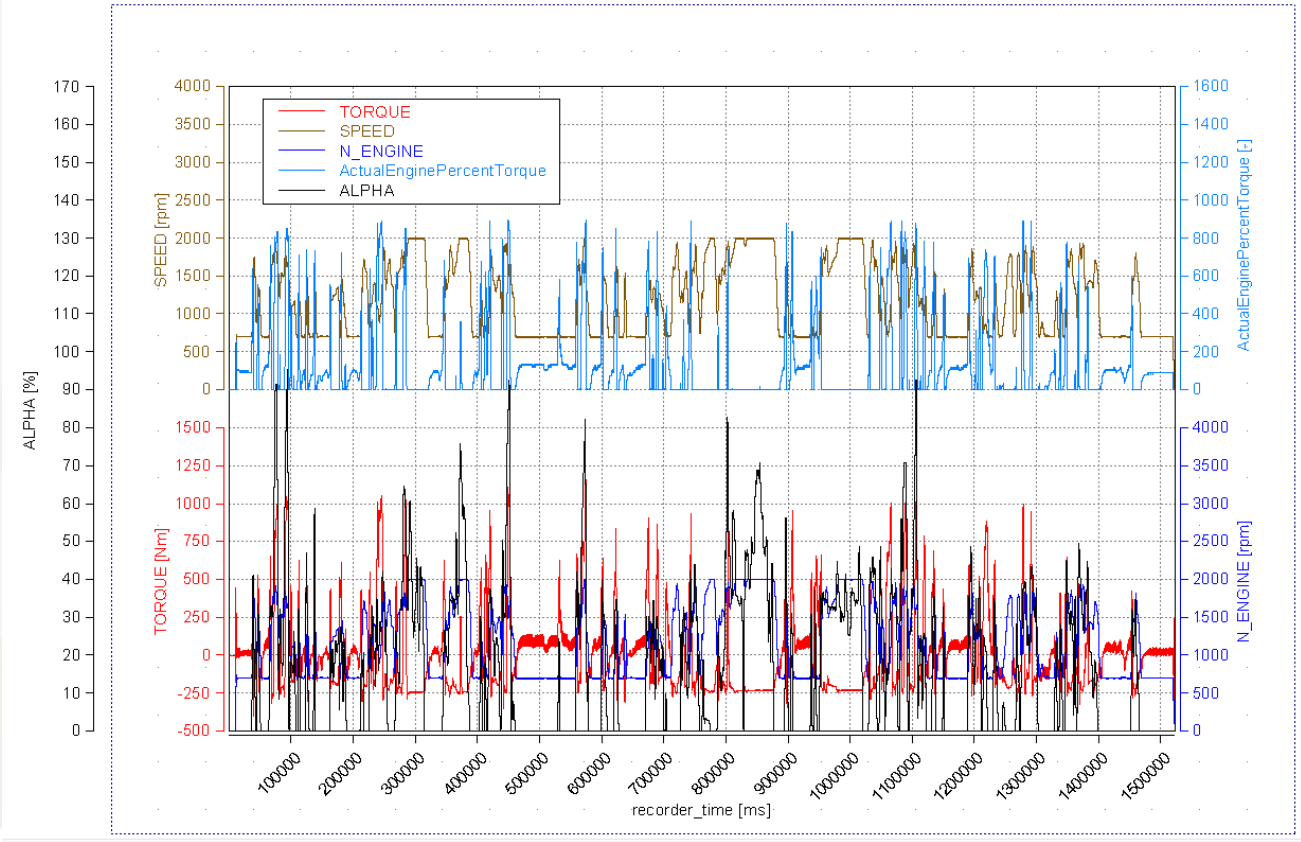
## Duty Cycle Acquisition and Visualization



# Experimental campaign - Dynamic test-rig

## Cycle analysis of ICE

- Experimental testing of the working cycles acquired by the Engine Control Unit (ECU) on a dynamic test bench
- Comparison of the data acquired on-field with those measured at the engine test bench (controlled lab conditions)



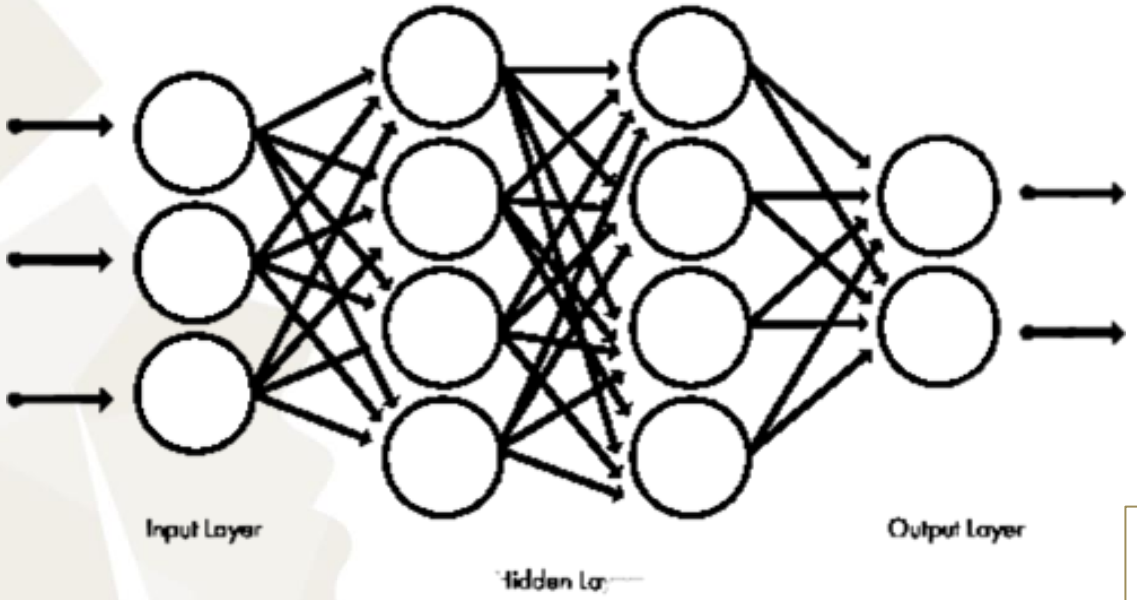

Diesel engine installed on a test bench for a complete performance characterization and for assessment of data acquired on-field

# Modeling – virtual dynamic testing

- Use of **Artificial Neural Networks** to predict electric motor duty cycles.
- Machine learning techniques learn (or are trained) by processing examples, each of which contains a known "input" and "result," forming probability-weighted associations between the two.
- Deep learning networks can have many layers, even hundreds.
- Regression models describing the relationship between a response variable (output: torque) and one or more explanatory variables (input: engine speed and pedal position).

Engine speed [rpm]

Accelerator pedal position [%]

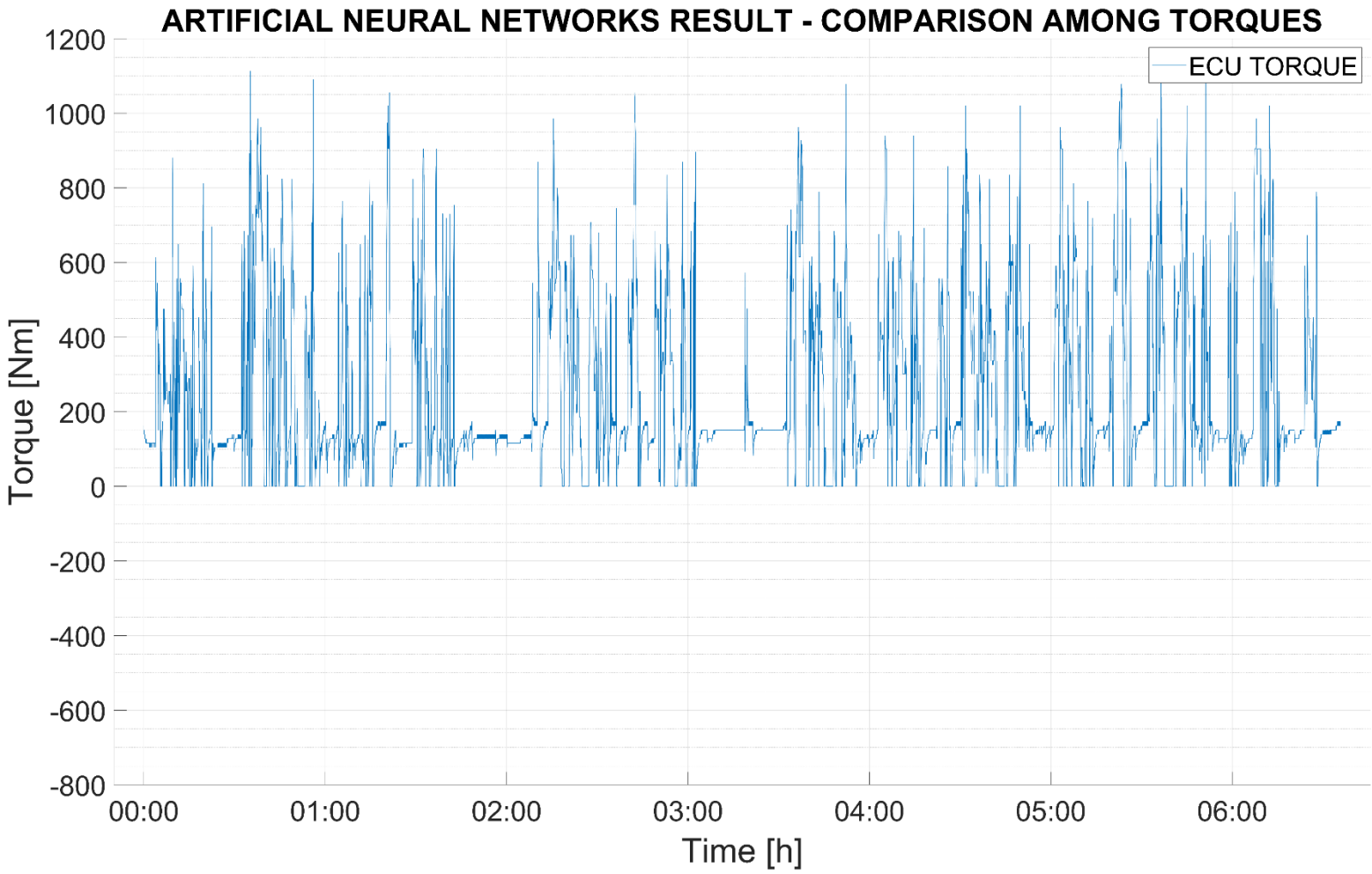



Torque (including breaking torque) [Nm]

- Estimation of the kinetic energy recovery
- Time and cost saving
- Benchmark for vehicle dynamic models

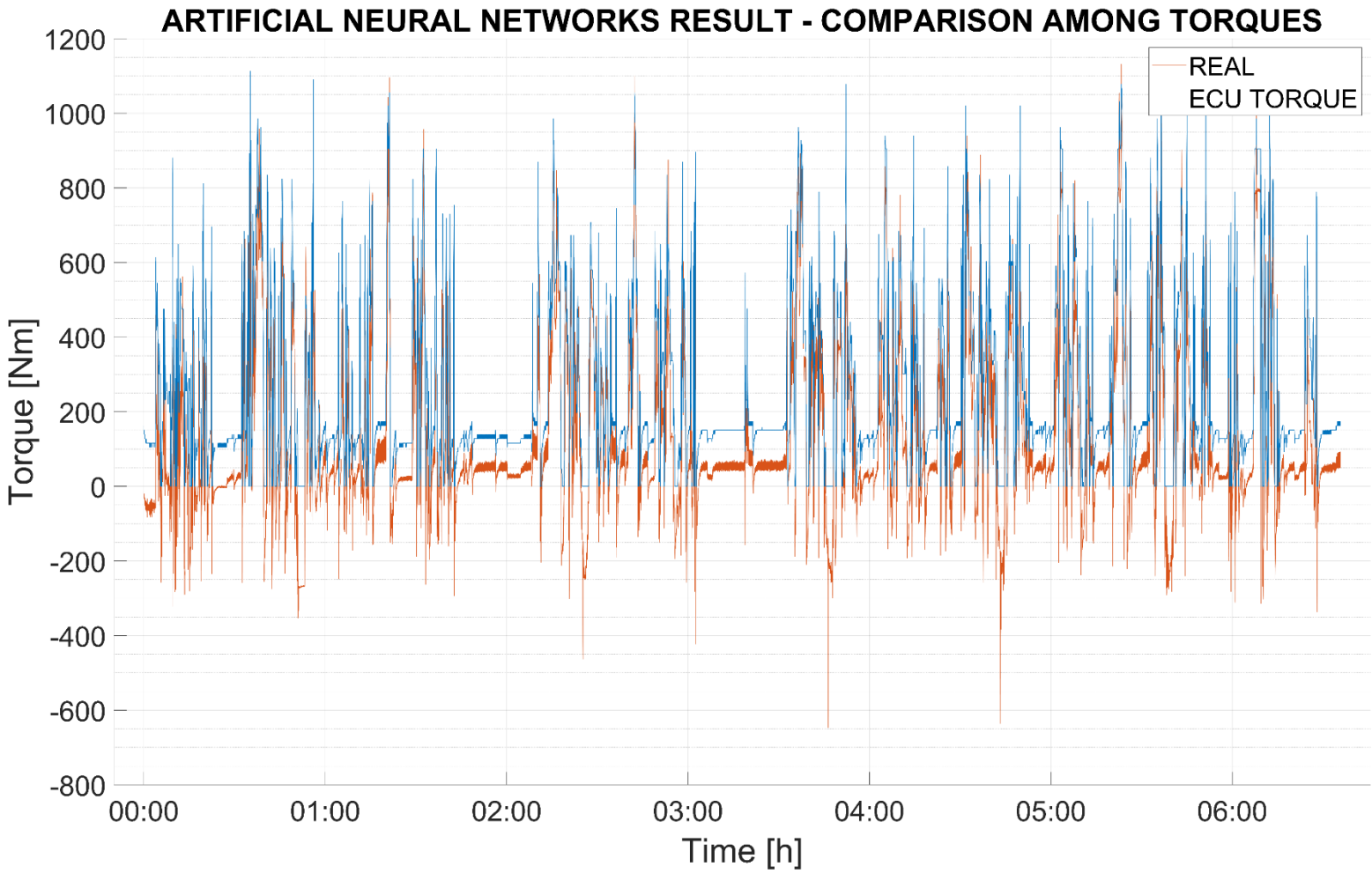
# Modeling – virtual dynamic testing


- ~40 Roll-on/Roll-off operations in a 6 hour work shift
- Trailing of variable loads at different decks of the ship

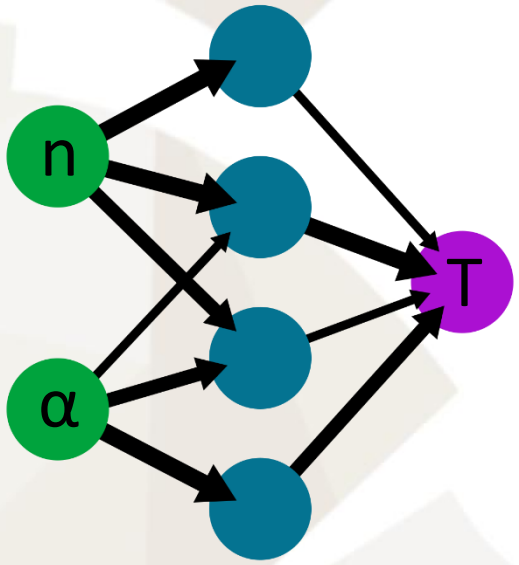


# Modeling – virtual dynamic testing

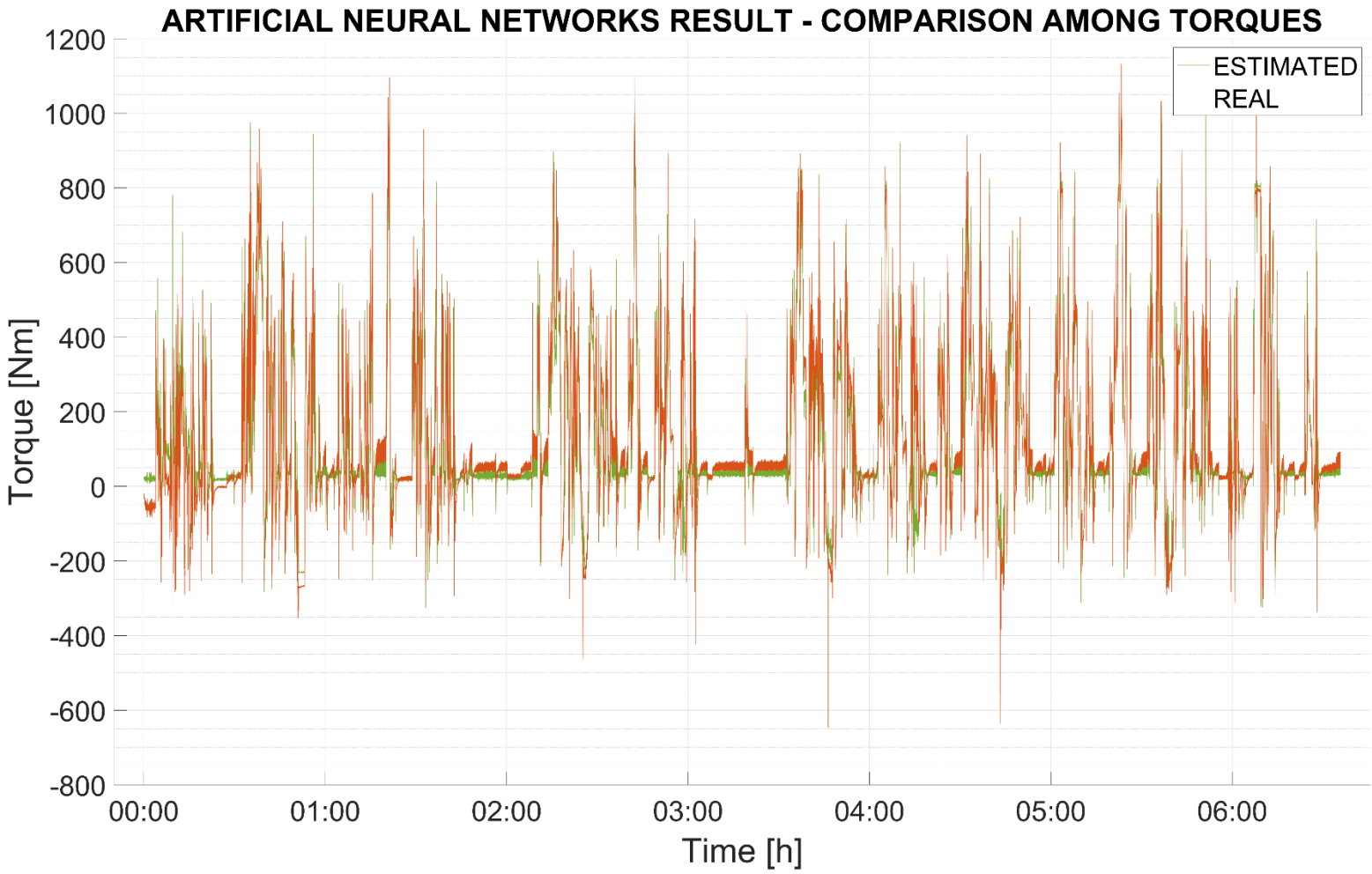
- Experimental testing of ICE on dynamic test bench with data acquired from ECU



# Modeling – virtual dynamic testing

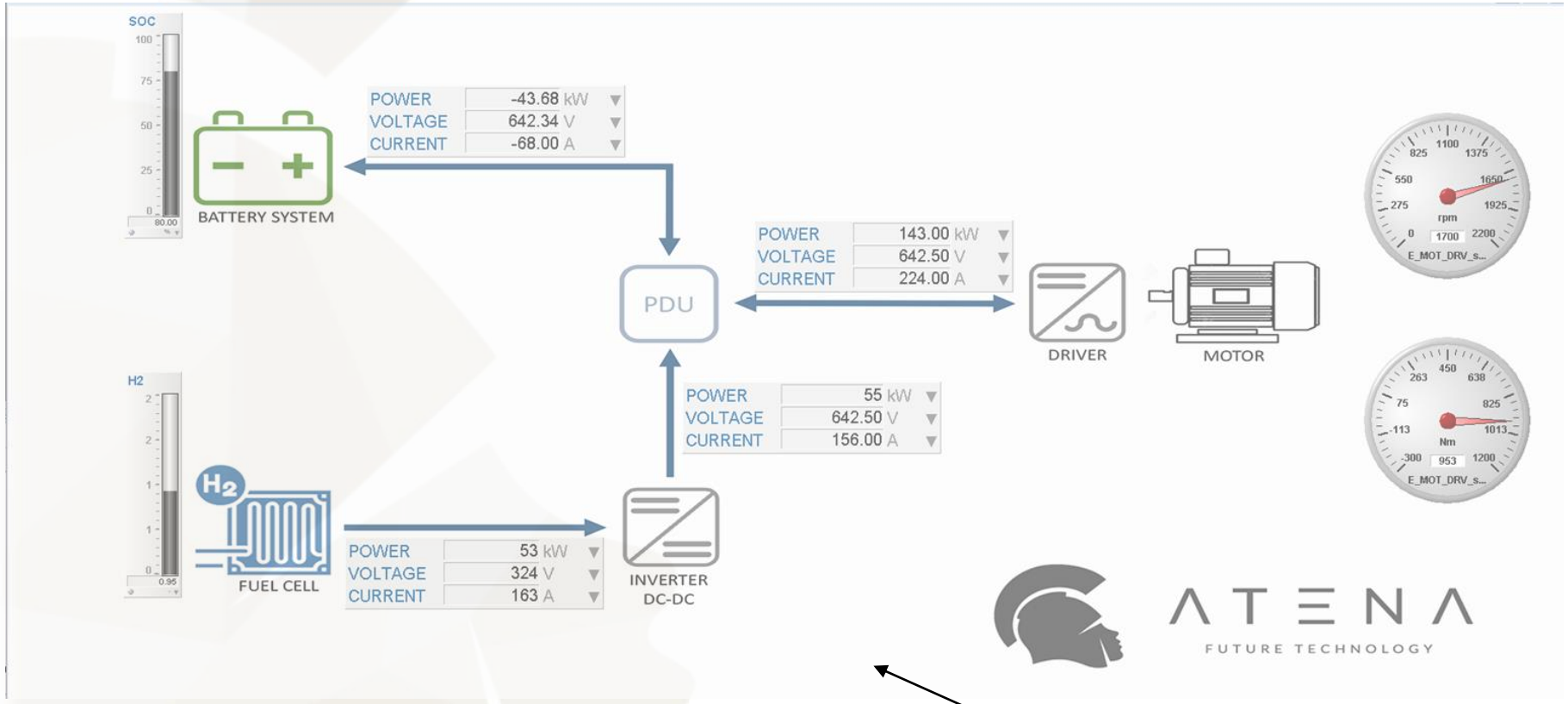


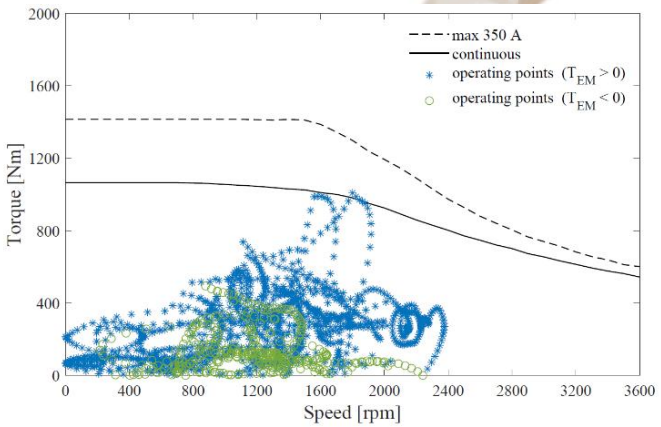

- ANN modeling and validation
- Estimation of realistic duty cycles for testing of hybrid power unit

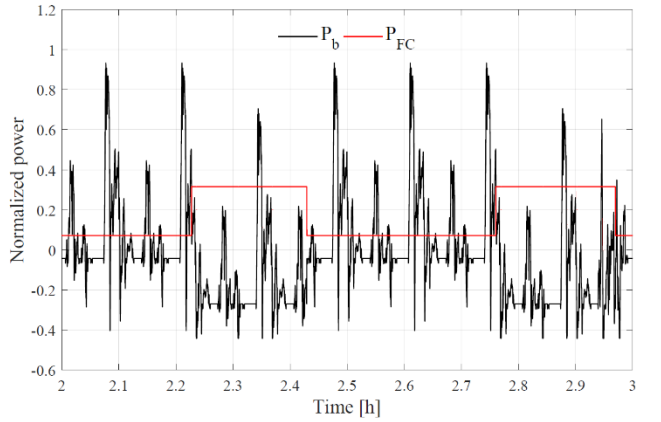


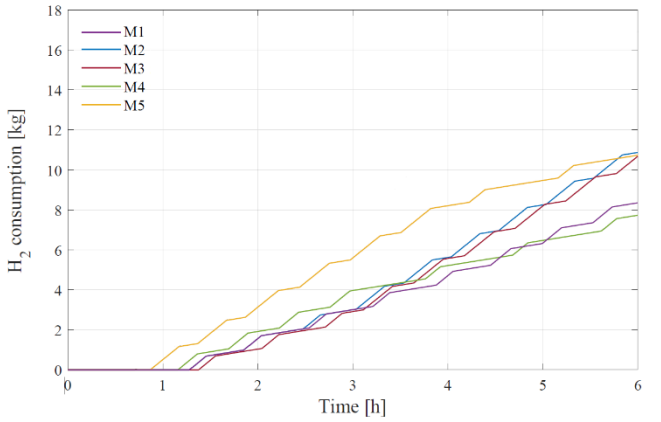
# Testing of hybrid powertrain

## Experimental testing of whole hybrid power unit



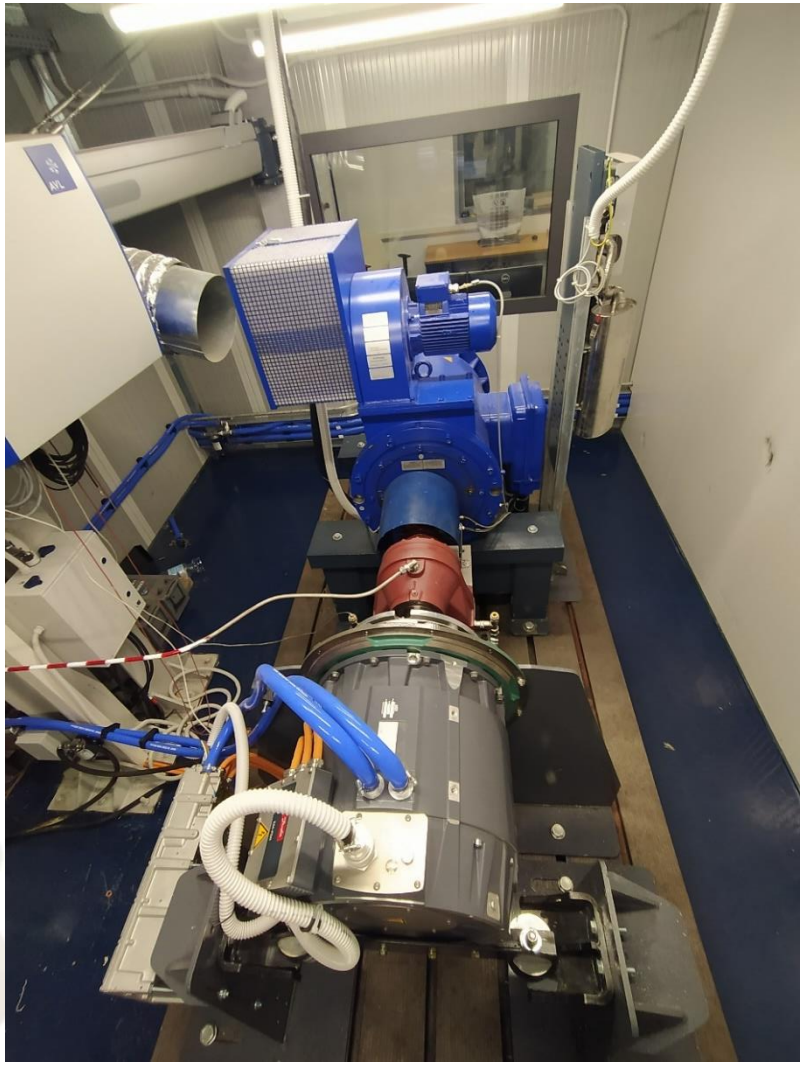



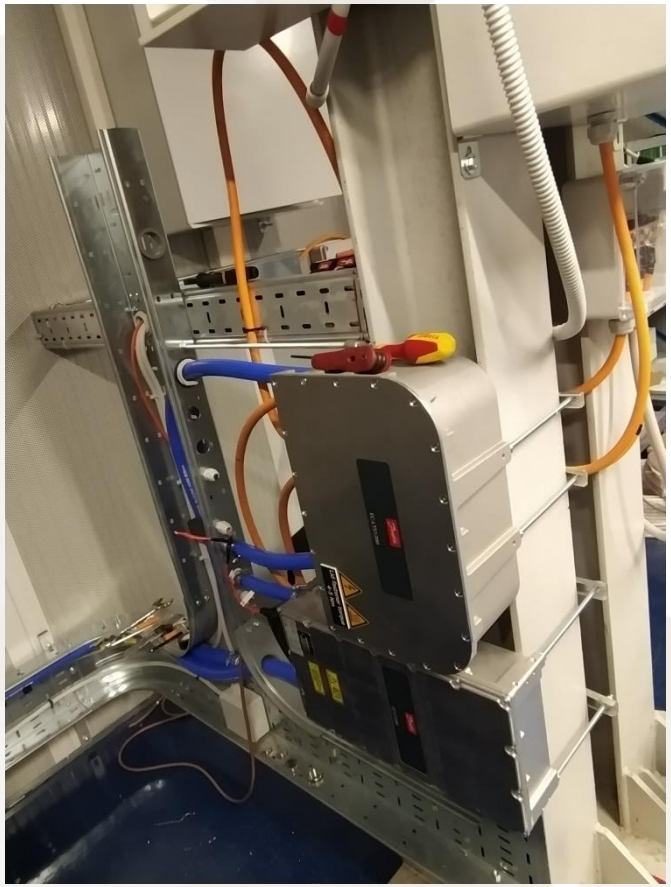



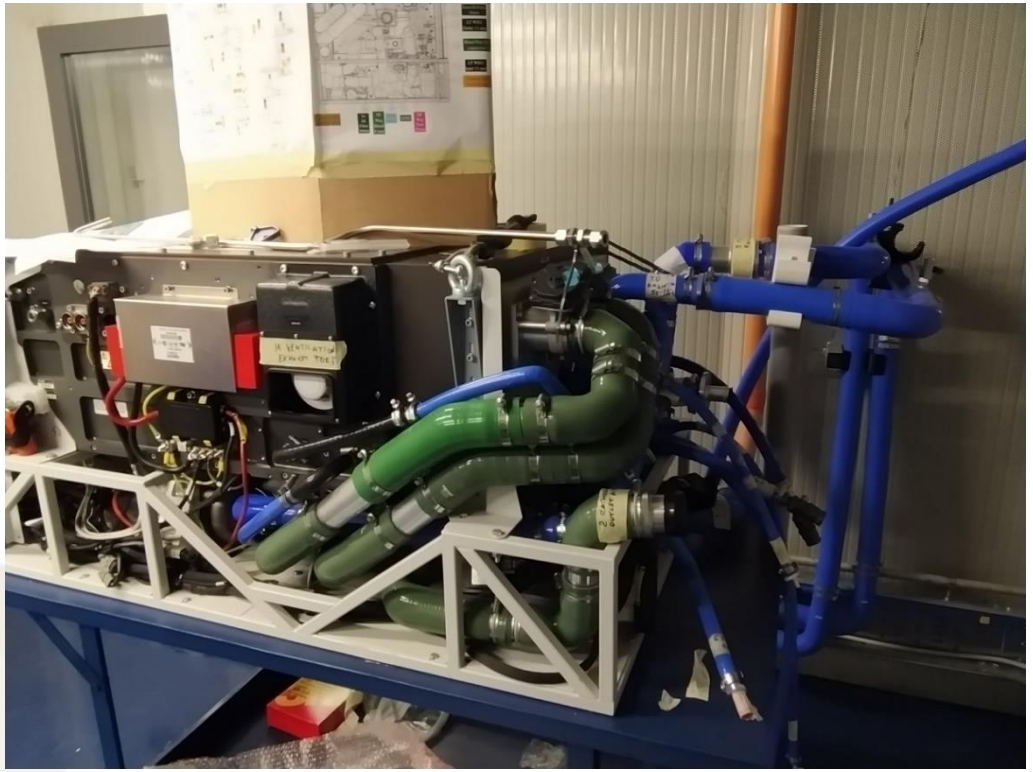

BALLARD
HD/XD Series
SPEED
TORQUE
ALPHA
P_OIL
TWO
AVL
AVL TEST SYSTEM
DELL

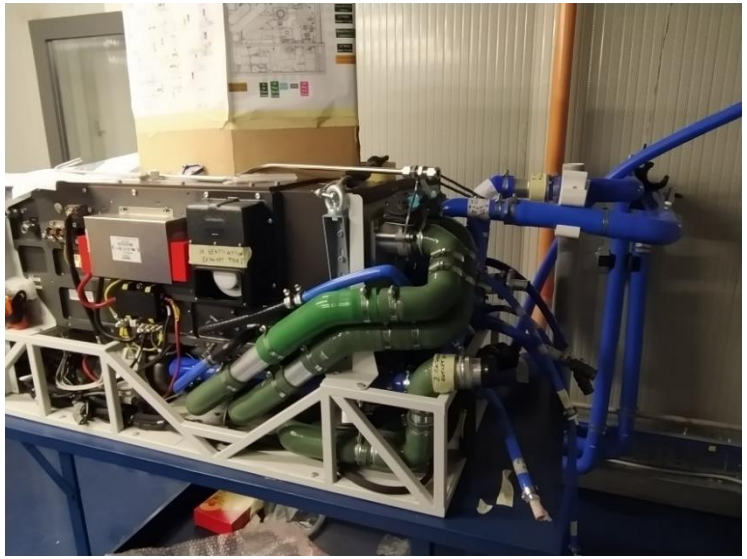
# Hybrid power lab - electric drive-train test-rig



# Hybrid power lab - fuel cell test-rig





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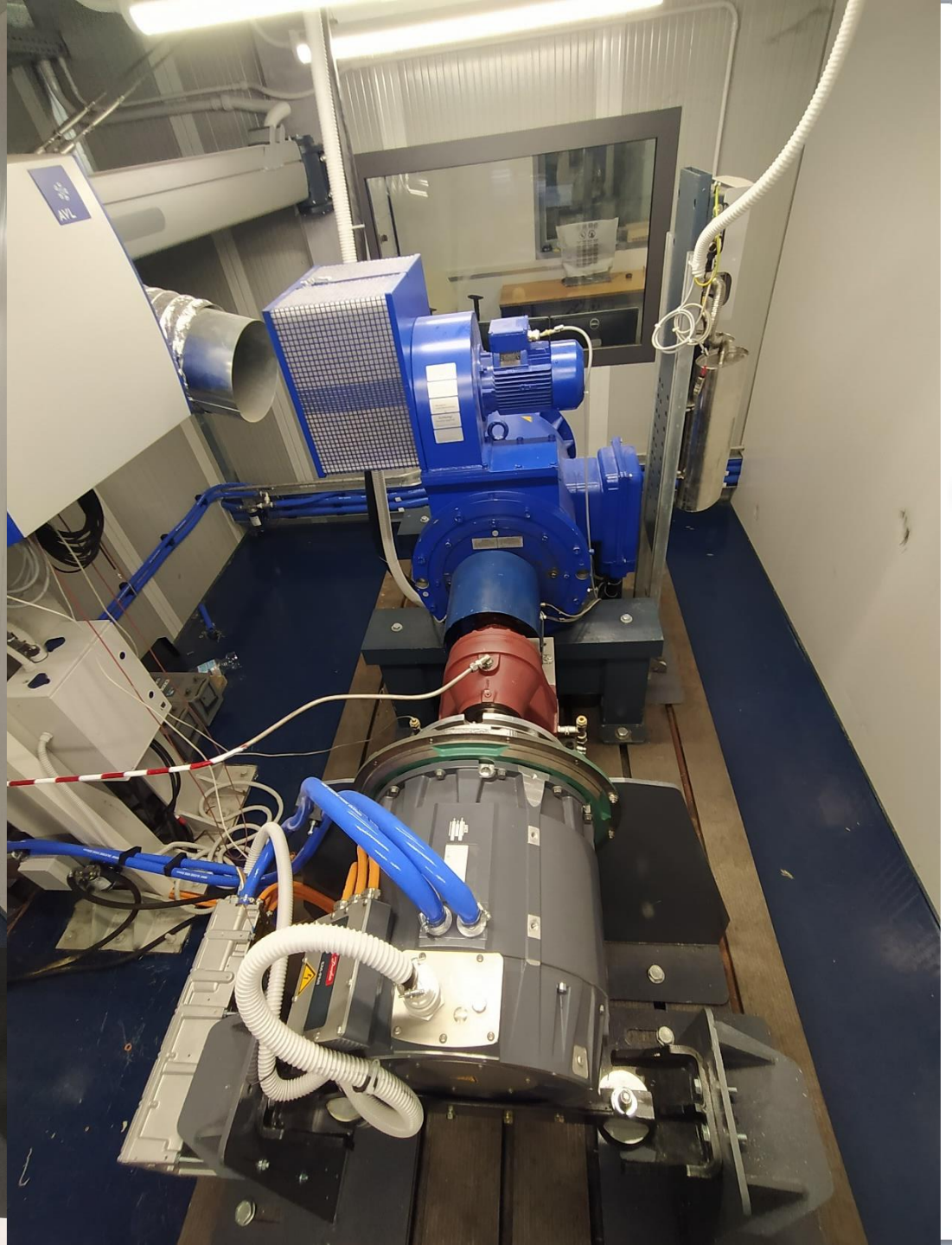

AVL


EM-PMI


BALLARD
BALLARD

# Atena Research Center

**HYBRID POWER LAB**
Transient testing of FC Hybrid Electric vehicles up to 160 kW.
- AVL Puma Data Acquisition System;
- AVL Load Unit System (Dynodur);
- AVL Blow By and oil consumption meter;
- AVL BTE for testing and emulating battery Pack and fuel cell devices
(E-STORAGE HV 160kW@1000V –max 250A)

**LT FUEL CELL LAB**
Single Cell PEM Test benches, gas chromatography unit, Up to 2kW PEM stack Test bench

**HT FUEL CELL LAB**
5 kW SOFC Test Bench
Single Cell SOFC and SOEC Test Benches
Single Cell MCFC Test benches

**METAL HYDRIDE LAB**
Glovebox, Electrolyser, Suction hoods

**PROTOTYPING LAB**
Workstation and 3d Printers

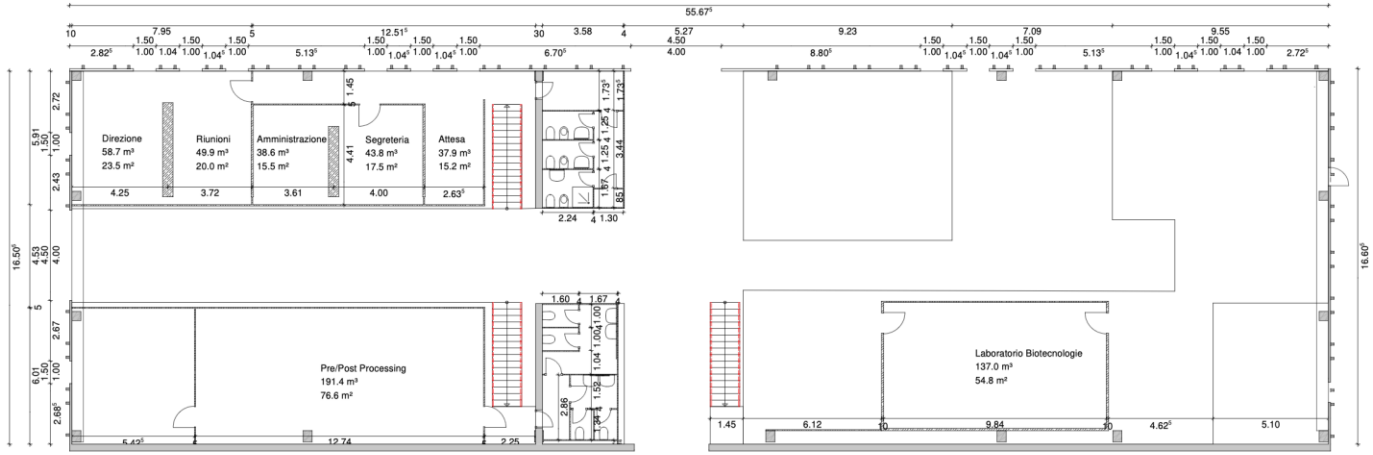
**BIOTECH LAB**
MFC &MEC Testing equipment

**LIGHT VEHICLES DEVELOPMENT LAB**

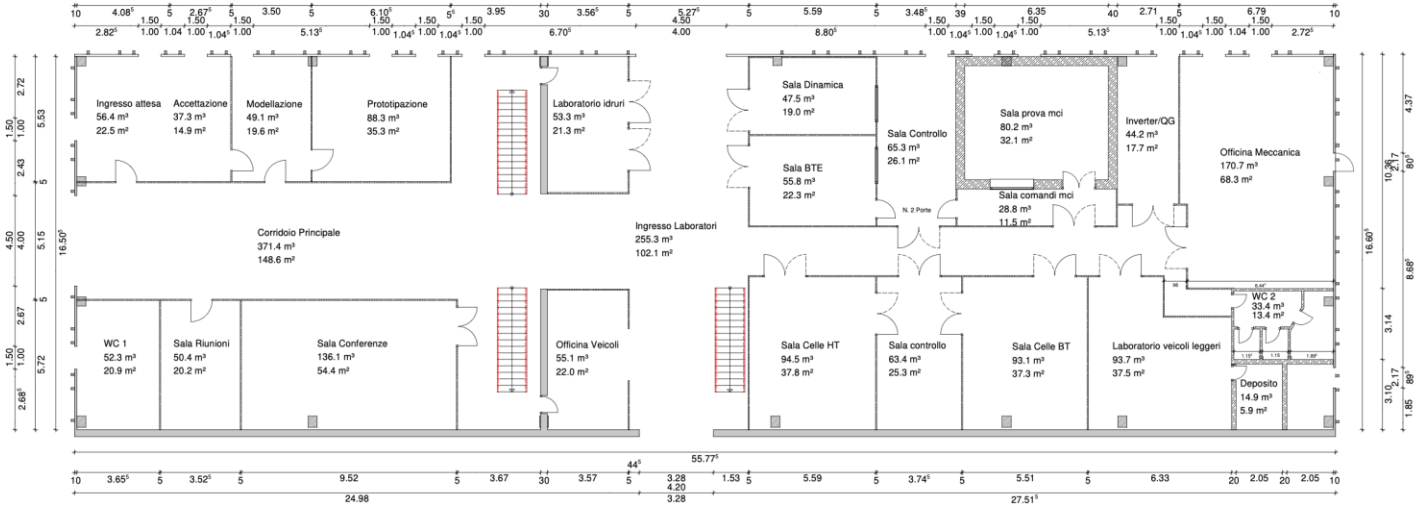
**HD VEHICLES DEVELOPMENT AREA**

**90 kW PV Plant**

**Meeting Rooms, Offices, etc**




1st Floor




Main Floor

# Prototype Development

ATENA
FUTURE TECHNOLOGY

# ATENA Research Center



# Thank you for your attention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- **elio.jannelli@uniparthenope.it**


ATENA
FUTURE TECHNOLOGY

**And all the Research Group**

**Atenaweb.com**