ADVICE

advancing user acceptance of general purpose hybridized vehicles by improved cost and efficiency

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Call identifier: H2020-GV-03-2016
Grant agrrement number: 724095

Bernhard Brandstätter
Virtual Vehicle

# Administrative Information

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| Participant organisation name | Participant short name | Country |
|---|---|---|
| VOLVO PERSONVAGNAR AB (Coordinator) | VCC | Sweden |
| Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH | VIF | Austria |
| Alma Automotive srl | ALMA | Italy |
| AVL List GmbH | AVL | Austria |
| CENTRO RICERCHE FIAT SCPA | CRF | Italy |
| CESKE VYSOKE UCENI TECHNICKE V PRAZE | CTU | Czech Republic |
| FEV GmbH | FEV | Germany |
| FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV | IMS | Germany |
| GKN DRIVELINE ZUMAIA SA | GKN | Spain |
| GENERAL MOTORS POWERTRAIN - EUROPE SRL | GM | Italy |
| IDEAS & MOTION SRL | I&M | Italy |
| IDIADA AUTOMOTIVE TECHNOLOGY SA | IDIADA | Spain |
| IESTA - Institut für Innovative Energie- & Stoffaustauschsysteme | IESTA | Austria |
| IFP Energies Nouvelles | IFPEN | France |
| INFINEON TECHNOLOGIES AG | IFAG | Germany |
| SIEMENS INDUSTRY SOFTWARE SAS | SIE | France |
| FUNDACION TECNALIA RESEARCH & INNOVATION | TEC | Spain |
| UNIVERSITY OF SURREY | USR | UK |
| VALEO SYSTEMES DE CONTROLE MOTEUR SAS | VALEO | France |
| RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN | IKA | Germany |
| AVL Schrick GmbH | AVL-S | Germany |

**Project Start: April 1st 2017**
**Duration 36 months**

| Budget | |
|---|---|
| Total Costs: | 12, 694.011 € |
| Grant Amount: | 9.900.500 € |

# OBJECTIVES



- ✓ **Objective 1: Cost premium of 5% for mild and full hybrid and 15% for P-HEV compared to best in class non-hybrid diesel vehicles available on the market.**
- ✓ **Objective 2: Reduction of fuel consumption on WLTP cycle by 20% and 25% increase in electric driving range for P-HEV, respectively.**
- ✓ **Objective 3: Demonstrating the vehicles' noxious emissions RDE compliance with a 1.5 compliance factor.**
- ✓ **Objective 4: Improvement of vehicle performance according to proper performance index and the objective assessment of driveability.**
- ✓ **Objective 5: Verification and assessment along 3 vehicle classes and 3 hybrid vehicle architectures.**

# IMPACT



## COST

| | Premium to Diesel | Premium to Diesel after ADVICE |
|---|---|---|
| PHEV | 75% | 22% -7% long-term |
| HEV | 30% | 5% |
| Mild-hybrid | 10% | -11% |

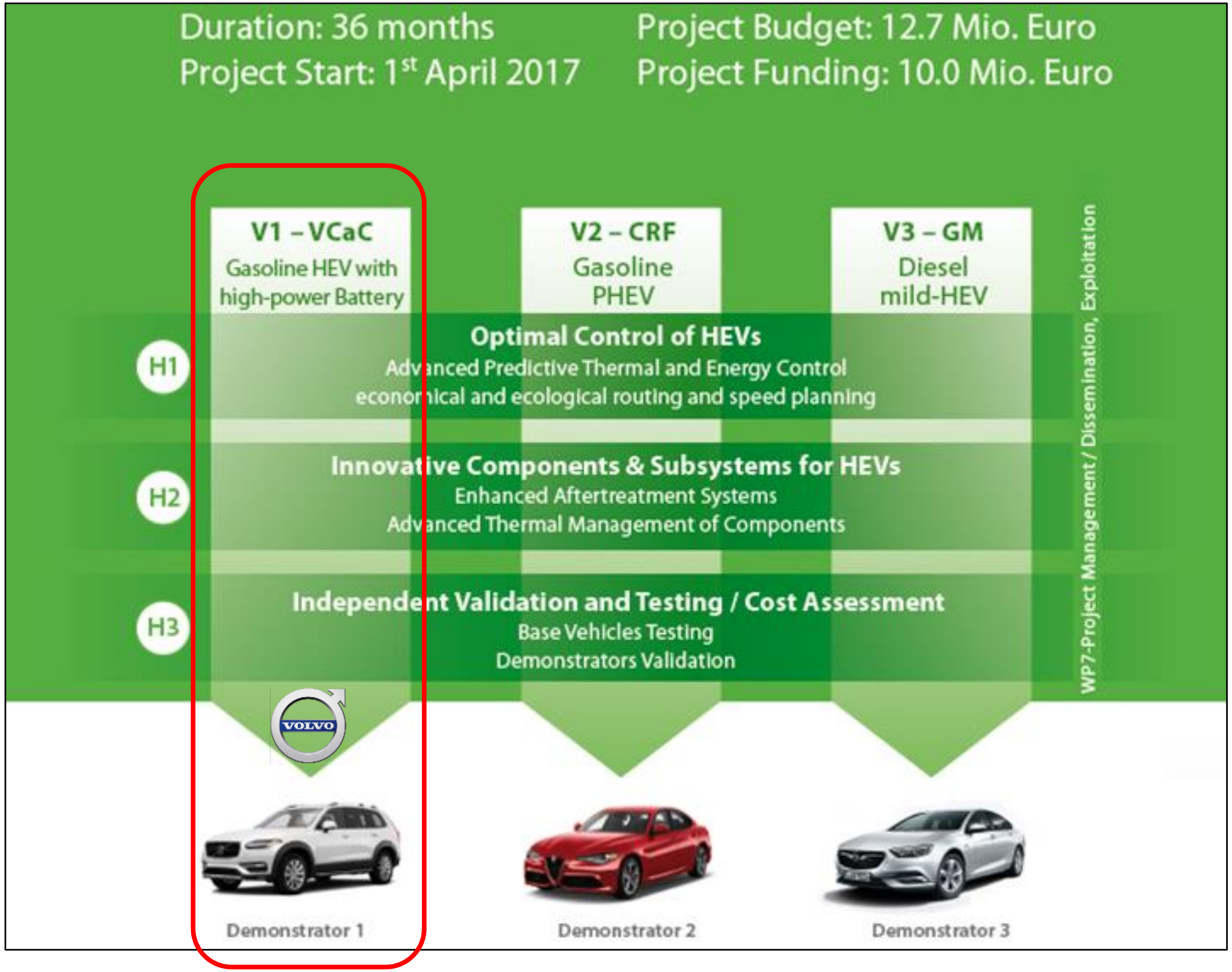
## Efficiency

| measure | Impact on efficiency |
|---|---|
| E-Turbo + ICE downsizing | 20% |
| Advanced control + Eco Routing/Driving | 10-15% |
| Optimal torque split | 3% |
| Comprehensive energy management | 1-2% |

## Emissions

| measures |
|---|
| Simplification + downsizing of engines |
| Battery high energy/high power |
| Advanced control, ECO-Routing |
| Electrically heated catalyst |

# Battery achievements @ V1



# V1 - Gasoline HV Full HEV (Volvo Cars)

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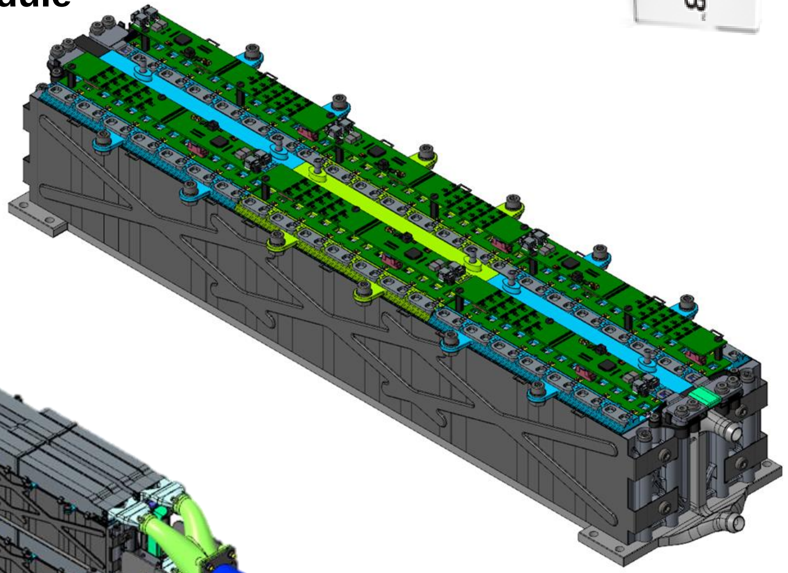
## High-Performance Hybrid Battery

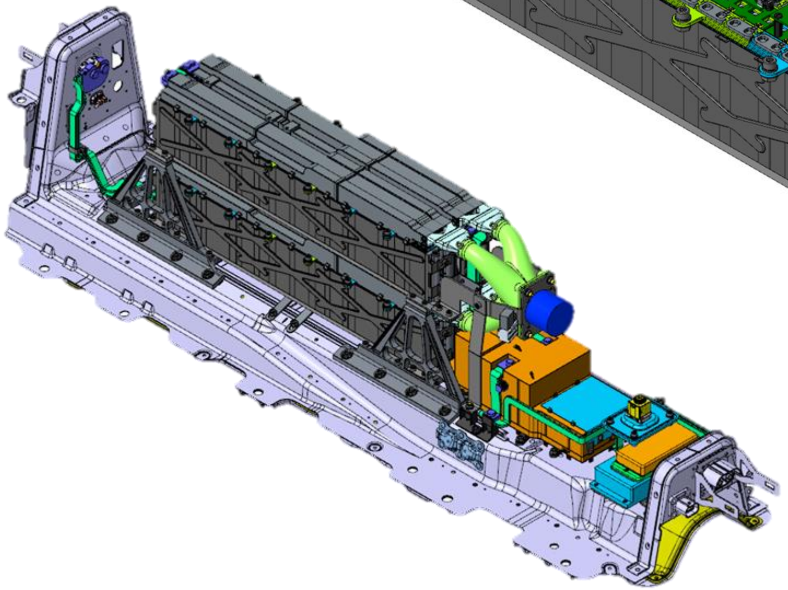
VOLVO FEV Fraunhofer ILT

**Toshiba high power LTO cells**


**Module**



**Pack**



| Module / Pack |
| --- |
| Module dimension:<br>■ Length: 635 mm<br>■ Width: 140 mm<br>■ Height: 140 mm<br>■ Weight: < 20 kg<br><br>Pack performance (2 modules):<br>■ Capacity: 2 kWh<br>■ Nominal Voltage: 400 V<br>■ Discharge (10s): 100 kW<br>■ Continuous: 60 kW<br>■ Charge (10s): 100 kW |

# V1 - Gasoline HV Full HEV (Volvo Cars)

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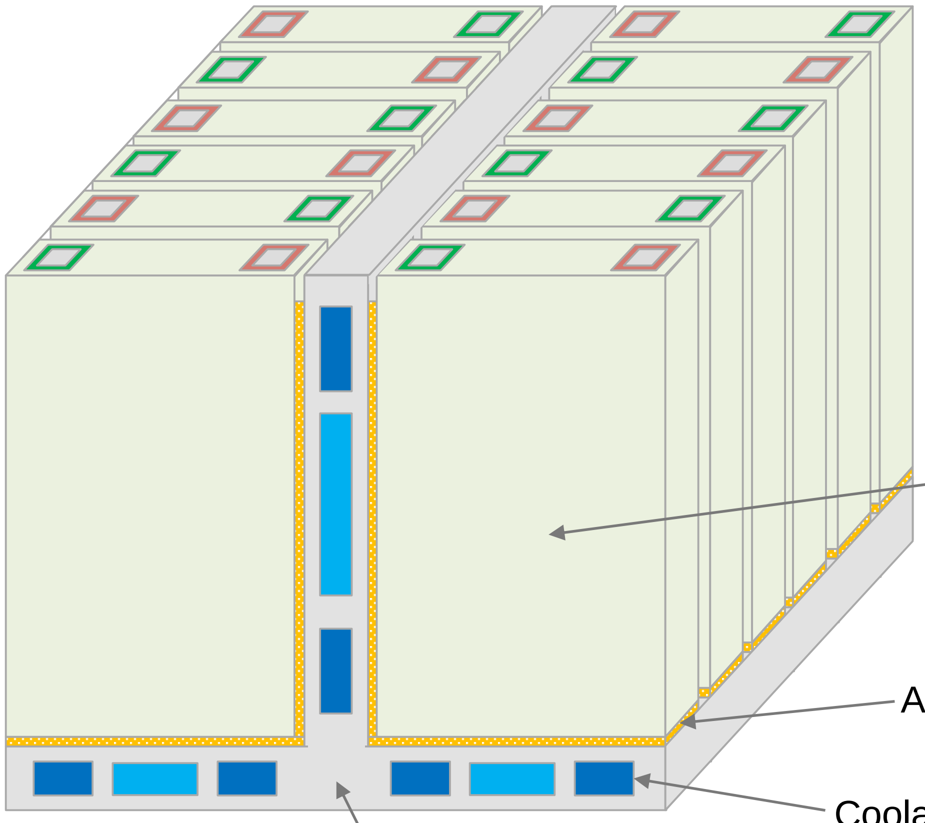
## High-Performance Hybrid Battery

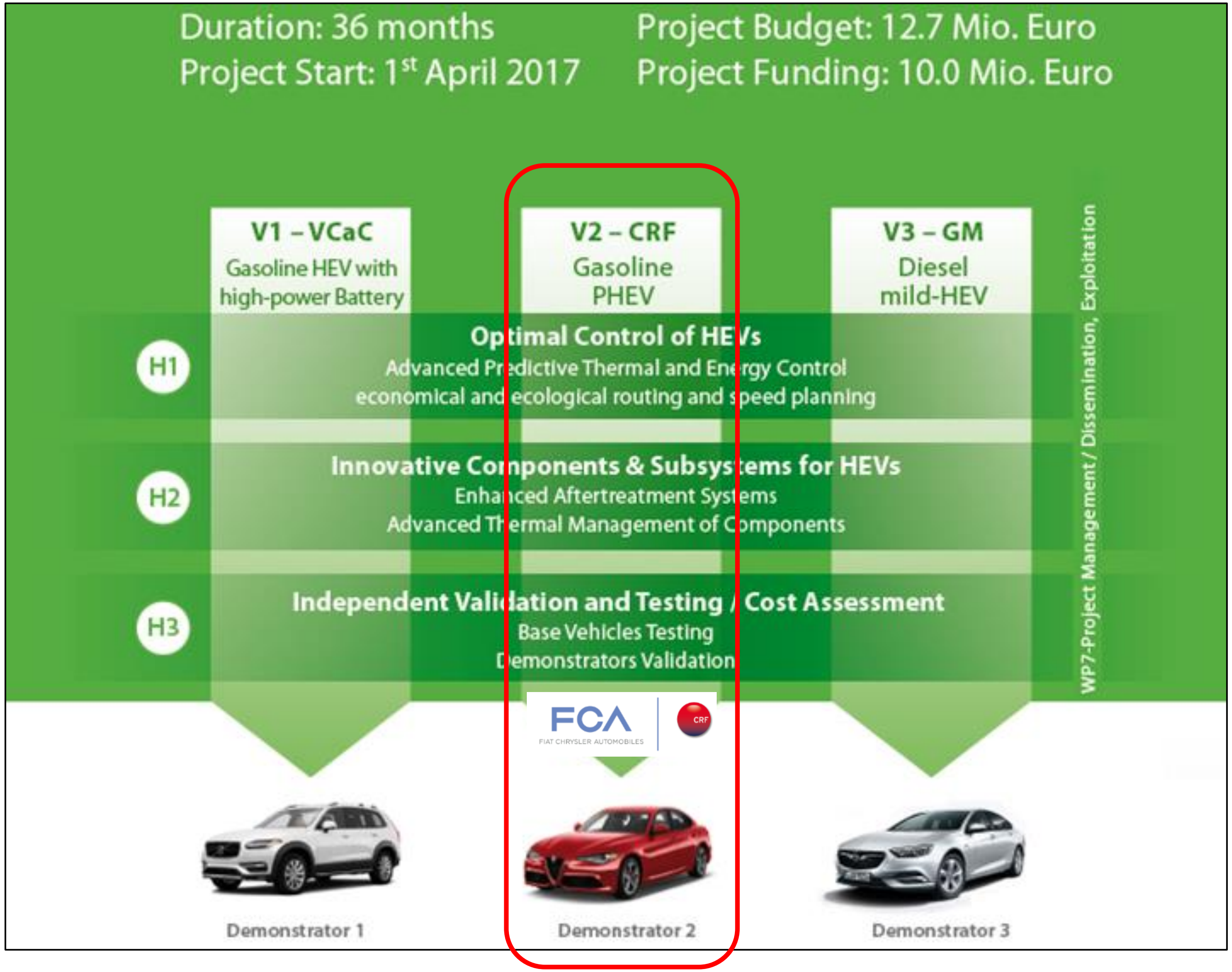
### COOLING DESIGN




| Description |
| --- |

- Cell amount: 168 cells serial
- Cell losses: 38.4 W
- Busbar losses: 0.7 W
  - Losses in battery ($\dot{Q}$): **6.6 kW**
- Target temp. spread coolant ≤ 5.0 K
- Specific heat capacity of the coolant ($c_p$): 3300 $\frac{J}{kg*K}$
- Density of the coolant: 1073 $\frac{kg}{m^3}$
  - Flowrate: **12 l/min**

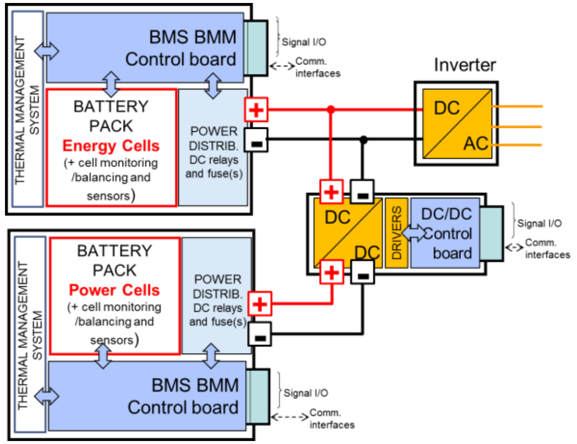
# Achievements @ V2



# Hybrid Battery Solution

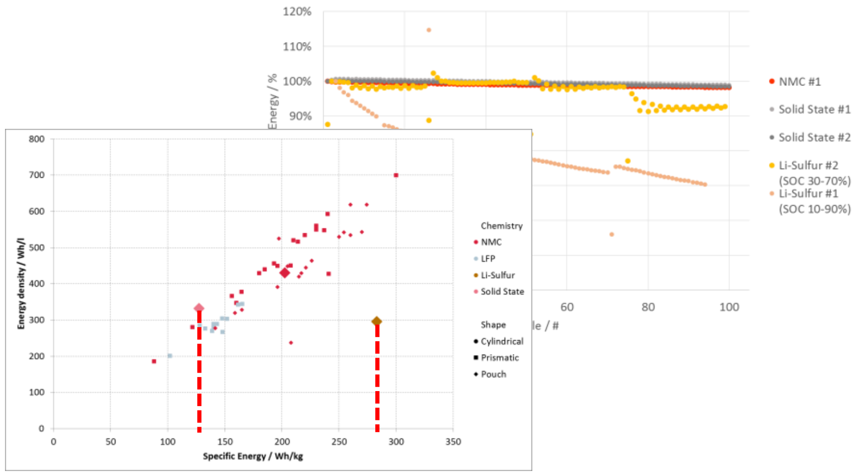
- investigating a battery solution for V2 vehicle demonstrator, consisting of **high energy modules and high power modules.**
- scouting, supply and test bench measurement of post **Li-ion lithium-sulfur and solid-state** technology cells.
- Commercially available post Li-ion cells did not yet meet energy density levels reported in literature. Cycle life stability for lithium-sulfur was poor, but good for solid-state cells.
- Current **NMC-Graphite cell** technology will probably prevail in the foreseeable future.

## Dual Battery System




Just for research purposes and not to be implemented in WP5 vehicle demonstrator

## Post Li-Ion High Energy Technology



# Alternative identification and virtual validation of e-4WD architectures

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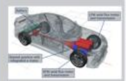
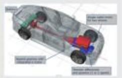
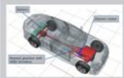
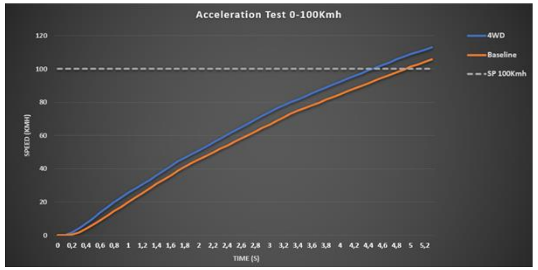
- **OBJECTIVES:**
  - Alternative identification and benchmarking of possible architectures for e-4WD solution.
  - Virtual integration of E/E components (mainly ECUs) for simulation, test and validation

| Sys Arch | Layout | Advantages | Disadvantages |
|---|---|---|---|
| 0 |  | Efficiency: OK | torque converter gearboxes usually add 2-3gCO2/km. |
| 1 |  | Integration: Easy, straightforward integration into GB housing due to flat motor | Handling: reported understeer in existing vehicles. Weight: significant system weight, ZF transmission. |
| 2 |  | Efficiency: good regeneration potential for energy recovery at front axle due to load transfer. Handling: Full torque vector capability. Integration: Easy in the front truck. | Cost: High. |
| 3 |  | Efficiency: good regeneration potential for energy recovery at front axle due to load transfer. Handling: Half torque vector capability. | Integration: Difficult integration in the front truck. Cost: Very High. |
| 4 |  | Efficiency: good regeneration potential for energy recovery at front axle due to load transfer. | Handling: No torque vectoring capabilities. Cost: Medium. |

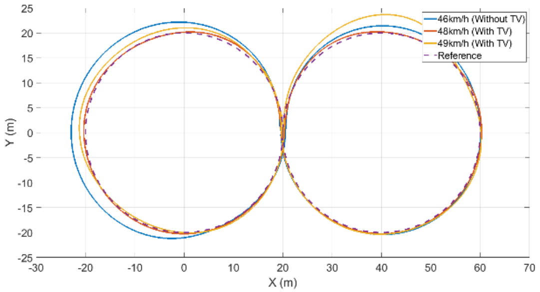
| Name | Topology |
|---|---|
| Sys Arch 0 | Base Line. Alfa Rome Giulia Architecture. |
| Sys Arch 1 | Hybrid ZF 8 speed gearbox 4WD automatic. |
| Sys Arch 2 | Front eTwinster axle capabilities and Torque Vectoring. |
| Sys Arch 3 | Front eAxle dual motors with epycicloidal gears. |
| Sys Arch 4 | Front axle with differential and eMotor longitudinal. |

| Weight Suggestion | 20 | 10 | 15 | 15 | 10 | 15 | 15 | |
|---|---|---|---|---|---|---|---|---|
| System Architecture | Efficiency | Performance | Handling | EV Mode | Cost | Weight | Integration | Score |
| 0 | 2 | 3 | 2 | 2 | 4 | 4 | 4 | 270 |
| 1 | 3 | 4 | 2 | 3 | 4 | 3 | 4 | 320 |
| 2 | 4 | 4 | 4 | 4 | 2 | 3 | 4 | 360 |
| 3 | 4 | 4 | 4 | 4 | 2 | 4 | 2 | 350 |
| 4 | 3 | 4 | 3 | 4 | 3 | 3 | 3 | 325 |

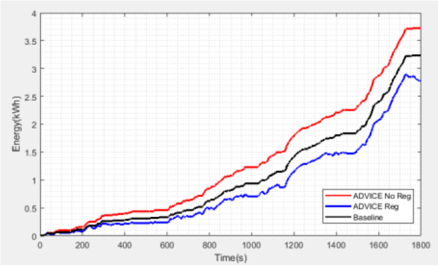
## Longitudinal Test




## Lateral Test



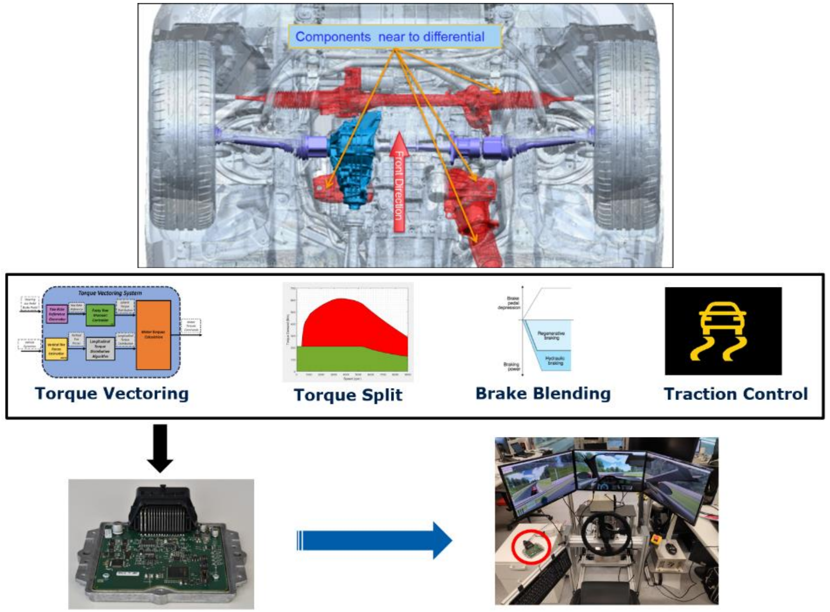

## Efficiency Test



# Integration and Test rig validation.



- Integration study of the solution and Testing in operational environment: GKN´s test rig with I&M and GKN HW.




- **Results**
  - Lateral acceleration improvement due to torque vectoring algorithms.
  - Longitudinal acceleration improvement with the same traction power.
  - Efficiency improvement due to the regenerative braking.
- **Partners**

tecnalia Inspiring Business · CRF · GKN DRIVELINE · i&m · infineon

# Achievements @ V3

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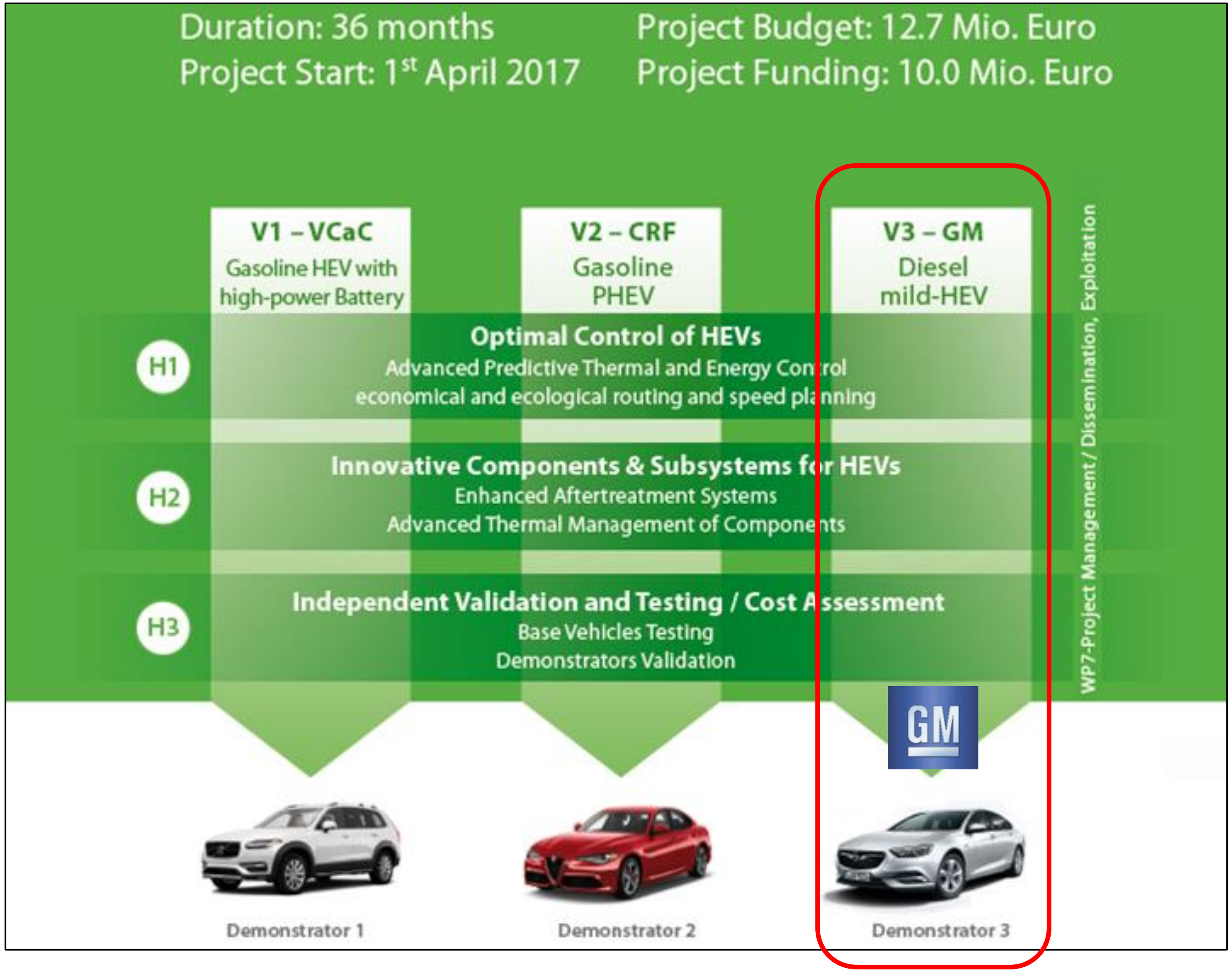

# V3 - Diesel 48V mild-HEV (GM)

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AVL

## 15/30 kW Battery System

| Item | Units | Variant I | Variant II |
|---|---|---|---|
| Pack Configuration | - | 12S2P (1x12S2P module) | 12S4P (2x6S4P modules in series) |
| Nominal Voltage | [V] | 44 | 44 |
| Nominal Energy | [kWh] | 5,3 | 10,6 |
| 10s Discharge Current | [A] | 600 | 1.200 |
| Continuous Discharge Current | [A] | 200 | 400 |
| 10s Charge Current | [A] | 225 | 450 |
| Continuous Charge Current | [A] | 135 | 270 |
| Weight | [kg] | 42 | 73 |
| Dimensions (LxWxH) | [mm] | 690x387x142 | 932x492x142 |

*Indicated values are minimal and based on 50% SOC and 25℃*

# V3 - Diesel 48V mild-HEV (GM)

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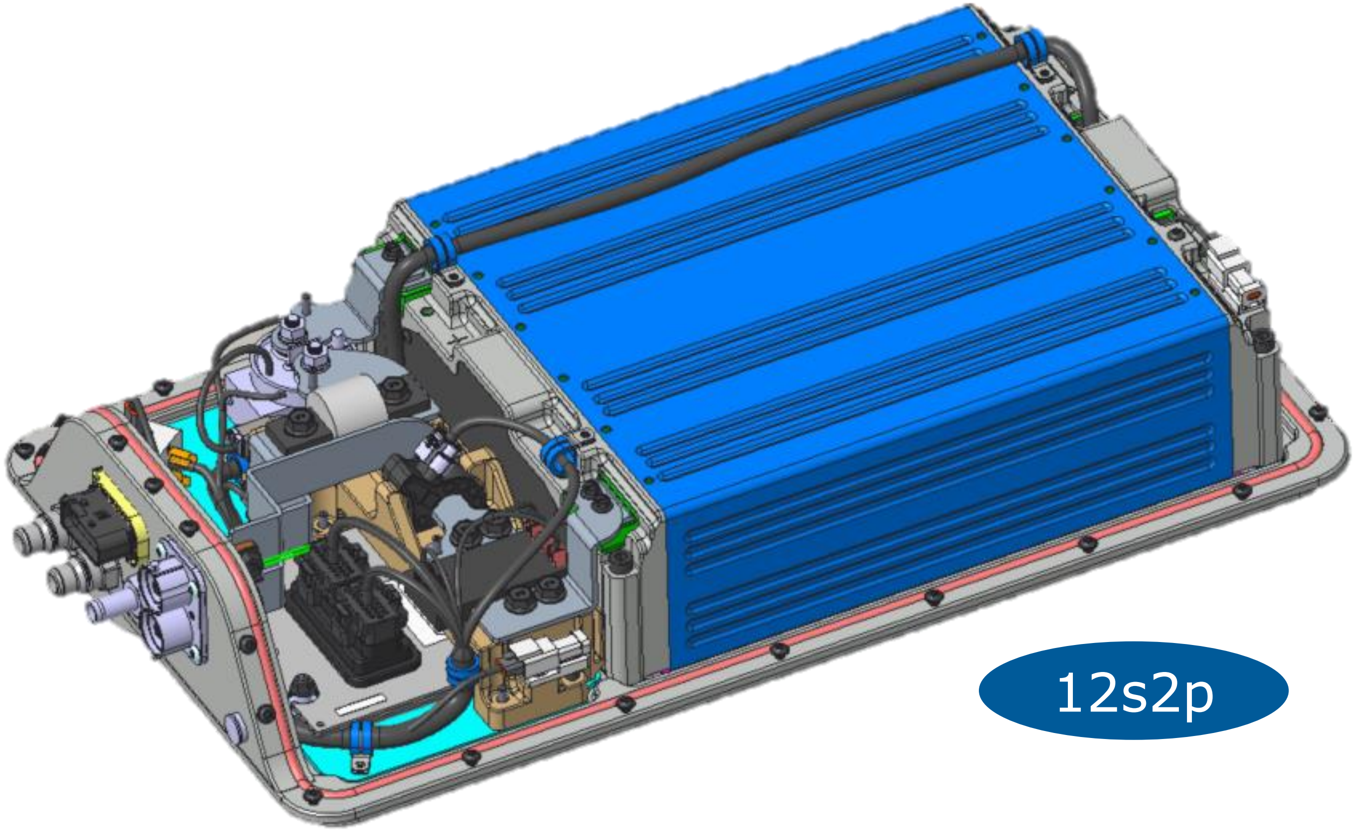
AVL

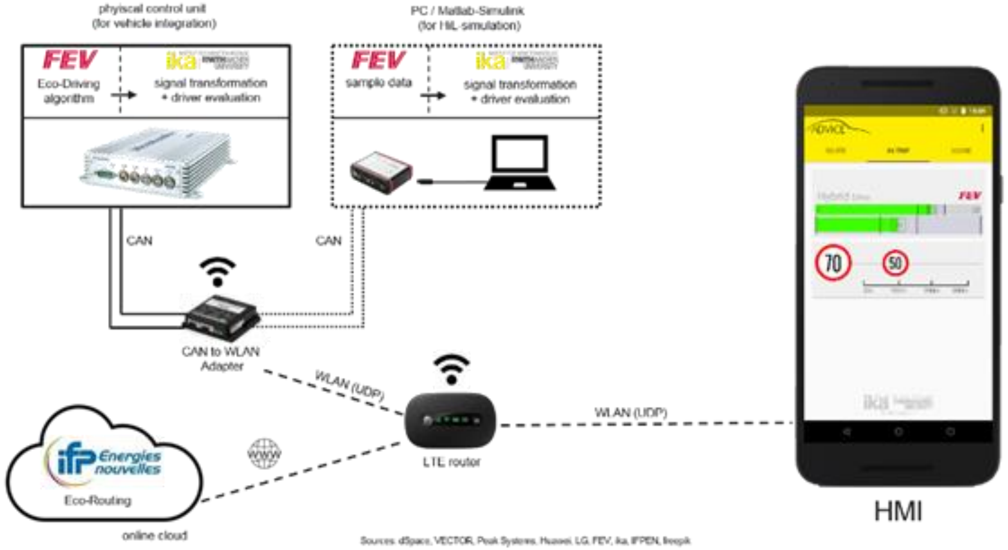
## 15/30 kW Battery System

### VARIANT I



12s2p

# HMI – ECO Routing/Driving




The first **tab (pre-trip)** accesses Eco-Routing functionality. The second one **(in-trip)** presents the output of the Eco-Driving function. Via the **post-trip** tab the user gets a score for his performance based on the energy demand during the trip and on how good the speed advice was followed.

# ADVANCED CONTROL

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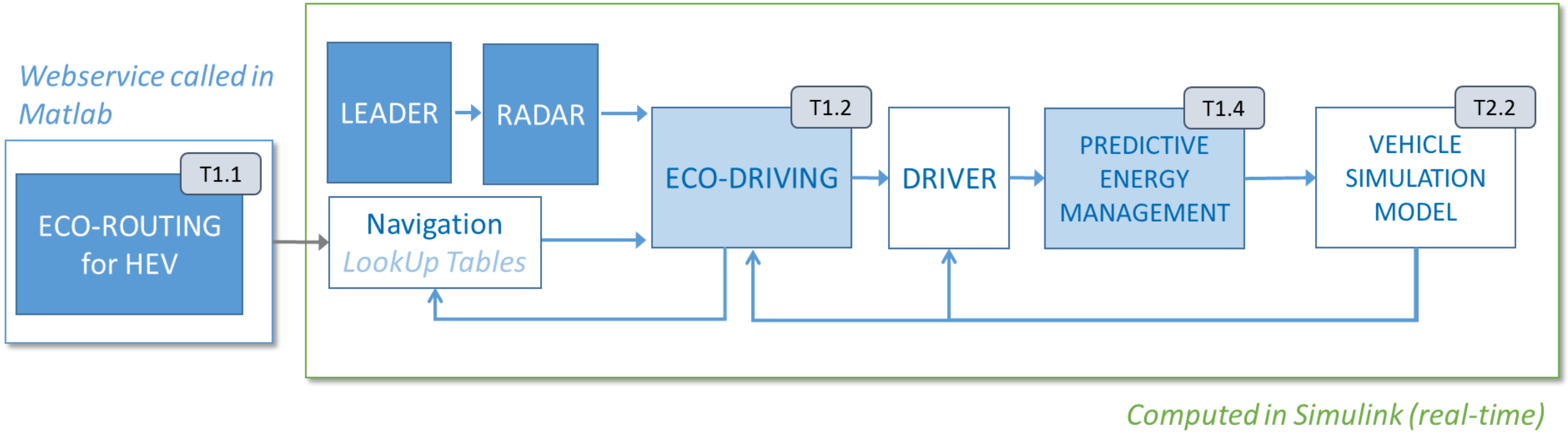


- **ECO Routing**: more complex than for ICE or EV due to additional degrees of freedom in the energy management system
- **ECO driving**: speed profile
- **HMI** providing the driver real time information on the Eco-Routing and Eco-Driving functionalities
- Powertrain Energy Management strategy considering input from the optimized predictive control and driver request ➔ reducing energy consumption and emissions production (reducing the AdBlue consumption)
- Thermal management including prediction of energy demand by the auxiliaries

# Achievements Component Level

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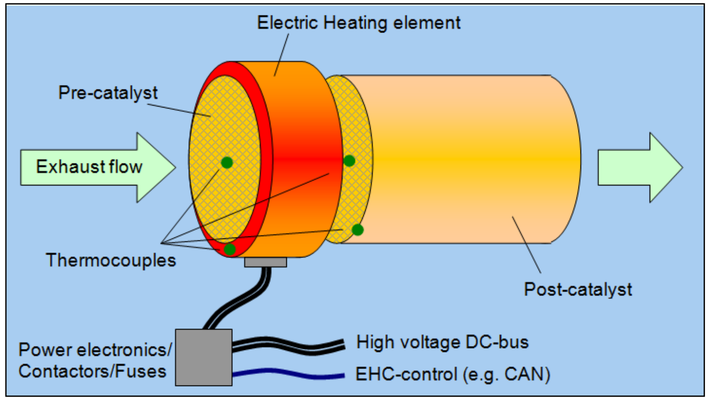
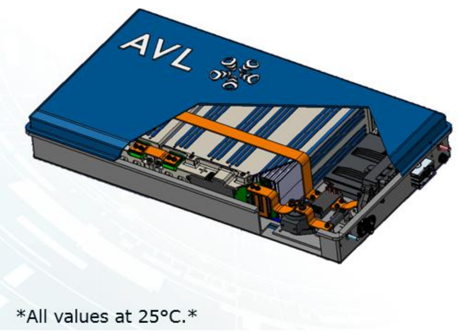



eHC concept definition


eHC Driver

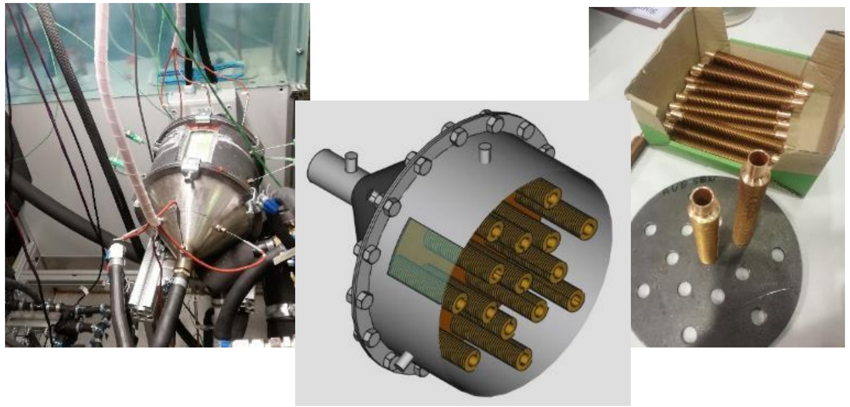



48V battery development for Opel Insignia


48V P4 development for Opel Insignia

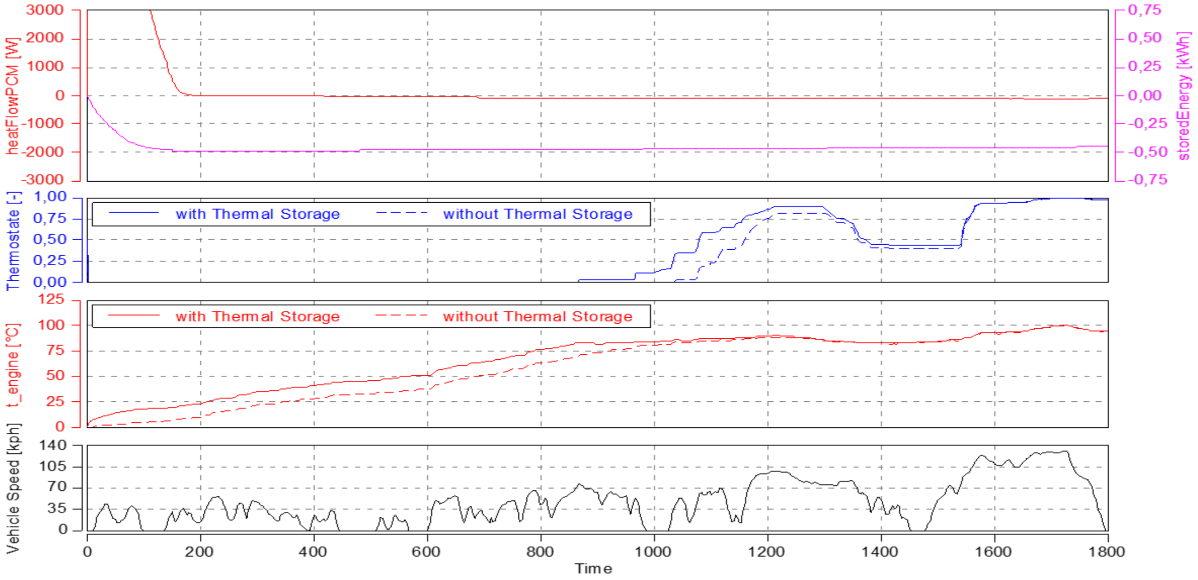
# PCM as heat storage

- PCM as heat storage (preconditioned thermal storage for conditioning the engine)



PCM test set-up: copper tubes for seperating PCM from coolant and heat transfer

**➔ Reducing heat-up time for ICE**




**Boundary conditions**

- $T_{amb}$ = 0°C
- Driving cycle = WLTC
- Thermal Storage preconditioning to 85°C
- Components initialized at $T_{amb}$

# Overall ADVICE validation and demonstration concept

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*for route planning*

Eco Routing/ Driving (H1)


HMI (H1)

Driver

Thermal/Energy Management
(H1, H2)
e. g. eHC/advanced aftertreatment
+ other component level innovations

*for prediction*
*shown in co-simulation (level 0)*

Objectives:

- Fuel efficiency/ Emissions
- Cost
- drivability

Layout/ Components (V1-V3)

**Levels for demonstration:**

0: Co-Simulation for extrapolation
1: ADVICE
1.5: implementation of some interactions
2: fully integrated (Post-ADVICE)

Hybrid typology: HEV – V1 (VCC)

Hybrid typology: P-HEV – V2 (CRF)

Hybrid typology: HEV – V3 (GM)