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Electric vehicle user-centric design for optimised energy efficiency

GRANT AGREEMENT No. 769902

Design OptiMisation for efficient electric vehicles based on a USer-centric approach

DOMUS – Deliverable Report

Deliverable NO.2.4 and Domus Mock-Up

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1 Purpose of the document

1.1 Deviations from the original description in the Grant Agreement Annex 1- Part A

1.1.1 Description of work related to deliverable in GA Annex 1 – Part A

Task 2.4 Cabin mock-up (IDIADA) M32-36

The objective of this task is to demonstrate the impact that the disruptive cabin design approach presented by DOMUS has in Electrical Vehicle (EV) cabin shapes and layouts when there is no constraint as a pre-defined baseline vehicle. The aim is to reveal the results of following the design guidelines considered in the holistic comfort model and the assessment framework (WP1) to define unprecedented cabin designs fully committed to the excellence in user centric comfort perception and energy efficiency. Disruptive cabin design proposals developed in 2.1 will be assessed to determine which will be physically represented in mock-up form.

The underlying idea is that the inclusion in non-traditional parameters in the holistic comfort model and the adoption of subjective perception factors in the assessment framework will indicate significant modifications to the cabin design, construction, and layout. These modified guidelines can be used by OEMs in a near future to maximize EV's driving range through the stimulation of comfort perception in non-traditional ways.

Outputs: Mock-up representations of design optimizations to demonstrate the influence of maximizing efficiency by means of enhancing comfort perception in the context of EV's cabins.

Partner contributions: IDIADA will be responsible for building the physical mock-ups based on the disruptive cabin designs developed by TME and assessed by COV in previous tasks.

1.1.2 Time deviations from original planning in GA Annex 1 – Part A

This task was scheduled to be finished in M36 but it was finished in M43 of the project as it took longer than expected to agree on the final design between partners, find the supplier and finish the production process.

1.1.3 Content deviations from original planning in GA Annex 1 – Part A

There is no content deviation.

2 Introduction

This report explains the work done under Task 2.4 “Cabin Mock up” of the DOMUS project. The main objective or this task was to reproduce in full scale a disruptive cabin design proposed by the consortium under task 2.1 “Novel cabin design”.

Task 2.1. proposed several cabin Design Variants (DV) after carrying out three in-person workshops where the following criteria were applied during the creative process:

1. European mobility situations, constraints and on ongoing national and international planning activities.
2. Achieving effective, safe, and comfortable experiences by vehicle occupants.
3. Overall DOMUS objective: to increase the range of EV by 25 % .
4. Future projections of mobility need landscapes and expected user needs.

As a result, several possible cabin DV were developed from a baseline vehicle: the current Fiat 500E:

- DV 1a consists of the baseline Fiat 500e with enhancements based on the DOMUS project innovations such as novel insulation materials, windshields, heat-radiation panels, and a novel dashboard.
- DV 1b: consists of more radical design modifications and include vehicle tailoring, dual zone separation and automated driving.
- DV2: originates from a further reduction of the conditioned cabin volume.

An initial energy saving assessment of these cabin designs was performed to determine whether the changes were coming close to achieve the DOMUS project objective of increased driving range. The results showed that the disruptive design changes of DV 2 could reach a range increase of 30 %.

Being DV2 the most radical design and the most energy efficient, it was chosen by the partners involved in WP2 as the one to translate in a full-scale Mockup in Task 2.4.

The final lay out for the full-scale mockup (DV2) also considered the different cabin configurations suggested under task 2.1 which contemplated the possible future cabin functionalities that autonomous driving could enable, such as:

- **Office cabin** : intended to serve as an office for a single vehicle occupant so that a steering wheel is not necessary for some trips. Therefore, the steering wheel can be folded away and the place is freed for a small desk. The small desk can be collapsed if not needed and removed when the steering wheel was extended. Behind the driver’s seat, a separation wall reduces the size of the air volume that needs to be cooled or warmed (Figure 1).
- **Relax cabin** vehicle is adapted for lay-flat seat that facilitates sleeping during longer travels (Figure 2). The adjustable divider is moved toward the back to allow space for the seat. In addition, the cabin can be divided along the long axis of the vehicle to optimize the space (Figure 3). This allow to carry more luggage or other loads while accommodating the increased size of the lay-flat chair.

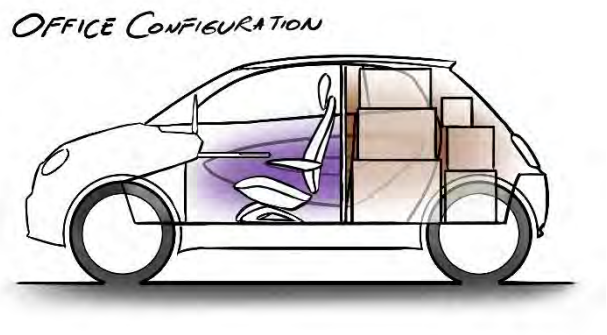

Figure 1: Office configuration cabin

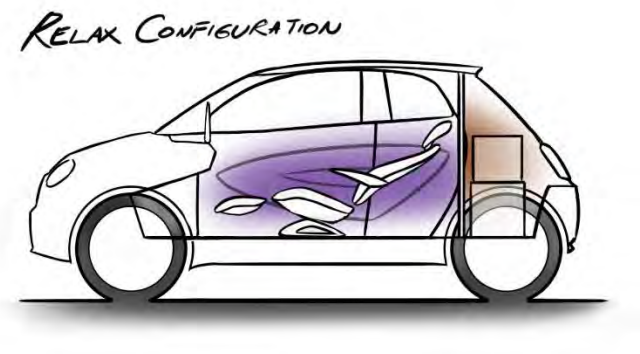

Figure 2: Relax Configuration, schematic

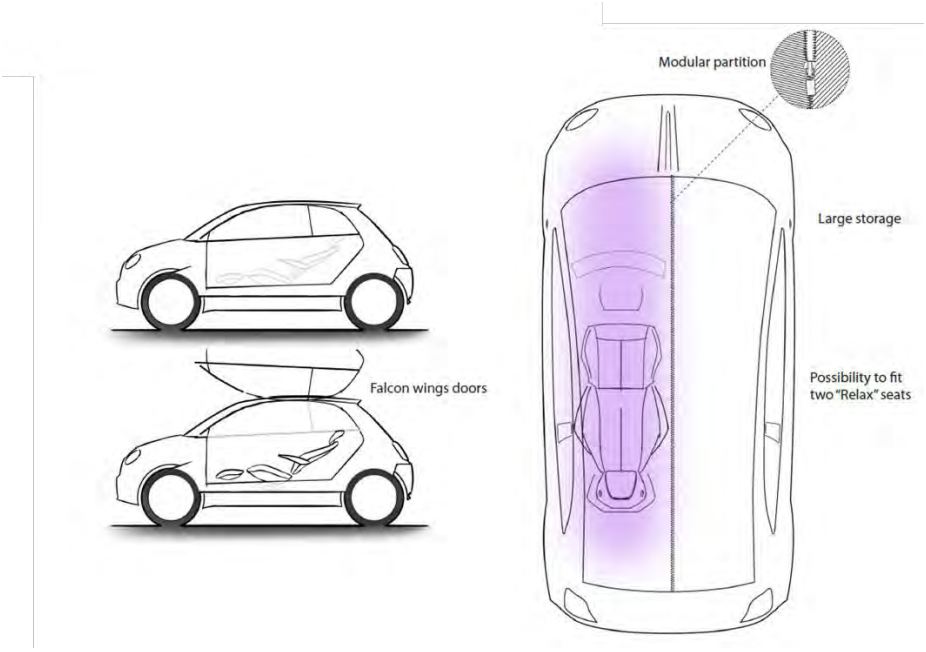

Figure 3: Alternative Arrangement Option

3 Methodology

The steps involved in the production of the Mock-up were:

1. CAD Cabin construction
2. Selection and reception of real parts to integrate on the mock-up
3. Construction of the model
4. Setting up of a tablet for the activation of possible cabin configurations

3.1 CAD Cabin Construction

The first was recollecting the CAD files and background documentation in order to define the basic tubular structure made by metallic extrusion (Figure 4).

Figure 4: Basic tubular structure

After the basic cabin design was completed IDIADA started developing the exteriors and the splits to show the interiors. (Figure 5, Figure 6, Figure 7).

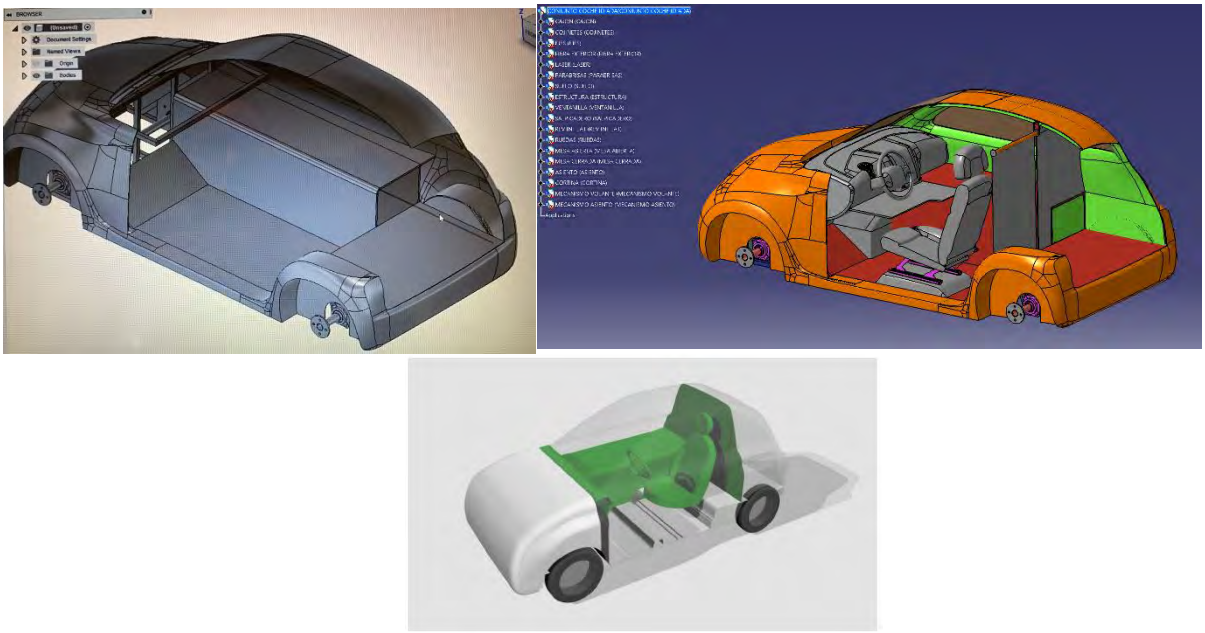

Figure 5: Interior and exterior cabin CAD development

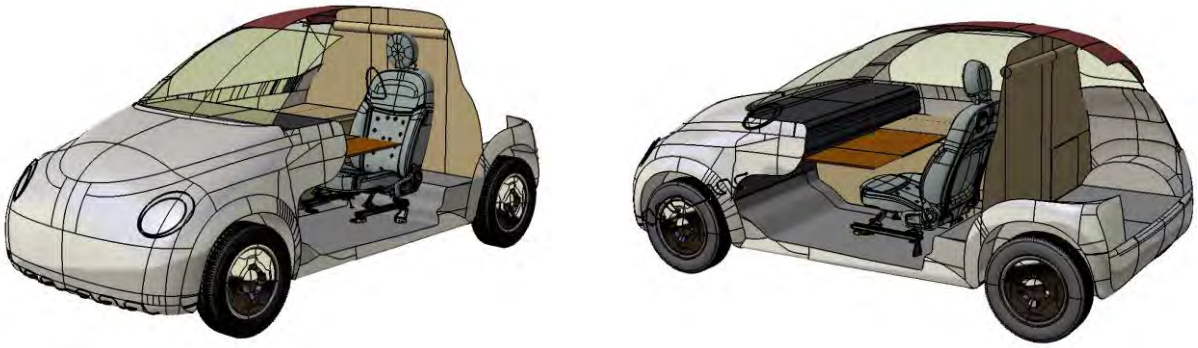

Figure 6: Final CAD cabin definition

Figure 7: Final CAD cabin definition (II)

With the support of CRF, next step was to choose the color and trims for the car (Figure 8).

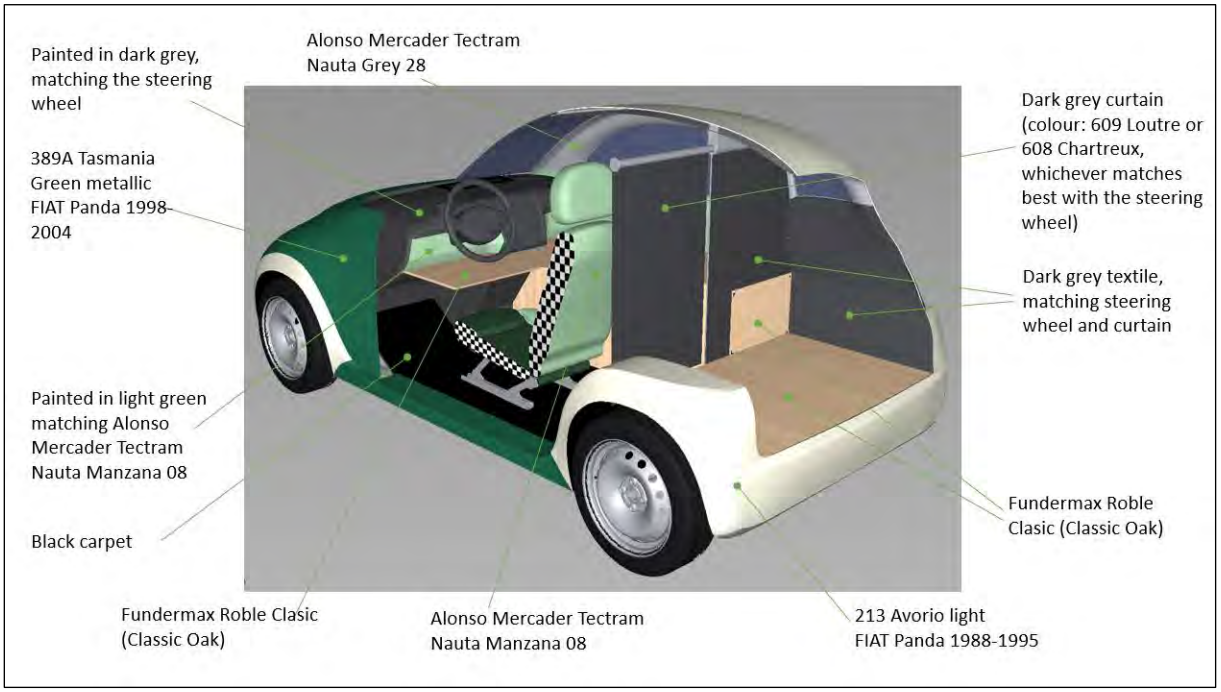

Figure 8: Selection of colours and trims for the interior and exterior of the mock-up

Before closing the CAD design phase and starting the construction of the actual mockup, it was discussed the level of functionality that the different components of the mock up should have in order to recreate the different cabin configurations defined for DV 2 in task 2.1 For that end it was agreed that the following components would have movement:

- Seat: Height movement
- Desk: Longitudinal movement (in-out)
- Steering wheel: Drive position to driverless
- Curtain: Roll / Unroll movement

3.2 Receipt of real parts from partners

Several partners from the consortium agreed to provide samples of the hardware parts they have produced for the demo car of the project to install and demonstrate them also on the Mockup.

3.2.1 Insulation panels

Hutchinson had several samples of insulation panels for the rear quarter, but in the DOMUS DV 2 this area is not present, this variant only has the luggage space in the rear end. For that reason, Hutchinson Team decided to build a dedicated sample to install in the Roof area (Figure 9).

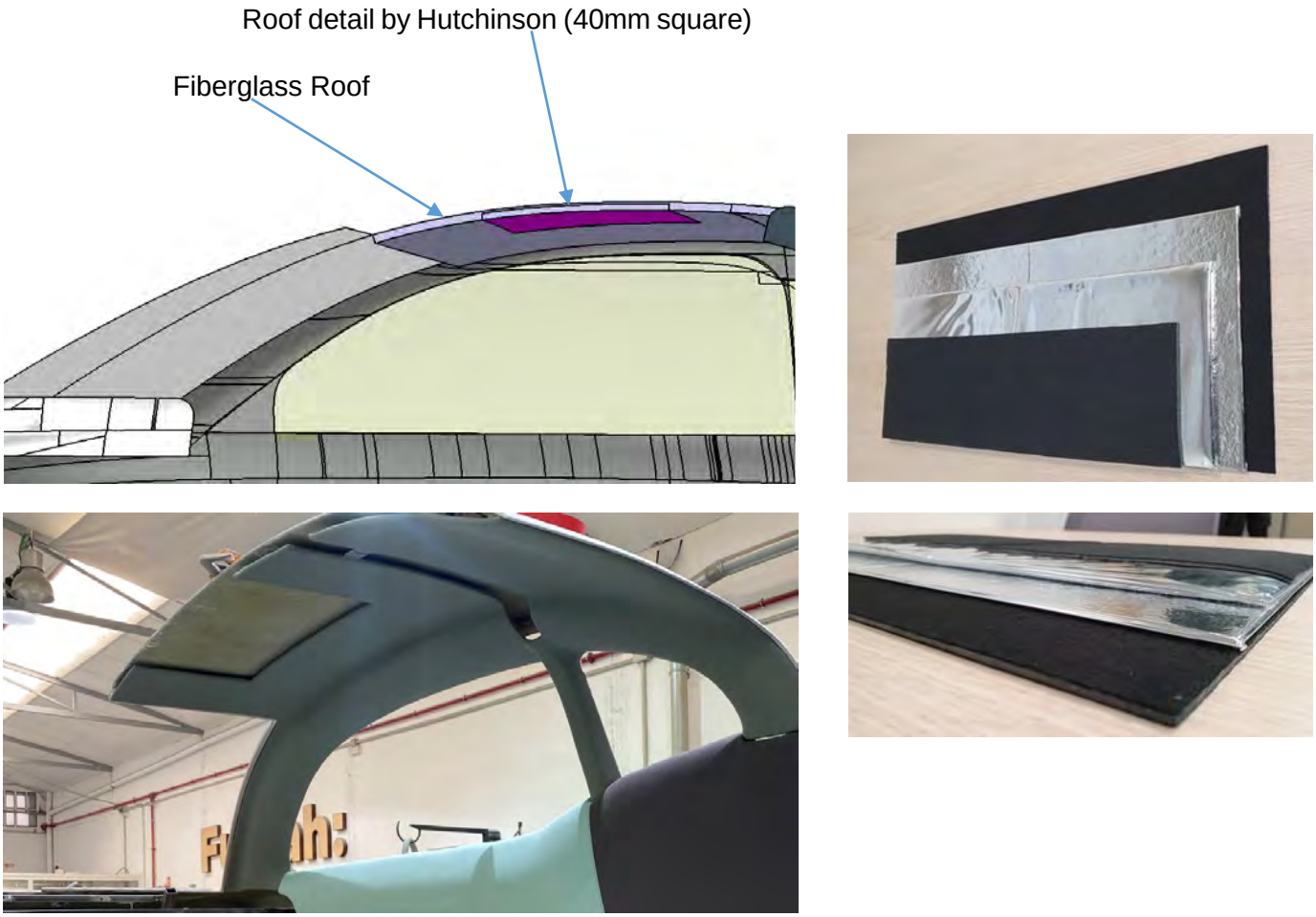

Figure 9: Insulation panel provided by HUT and installed on the Roof

3.2.2 Smart outlet

Denso provided a grid with motors, ducts and a blower to recreate the smart outlet of the cabin (**Error! R eference source not found.**, Figure 10, Figure 11).

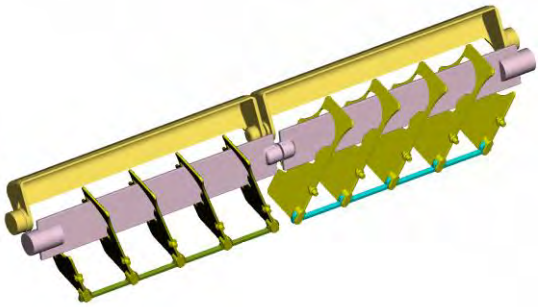

Figure 10: Cad filed of the grid

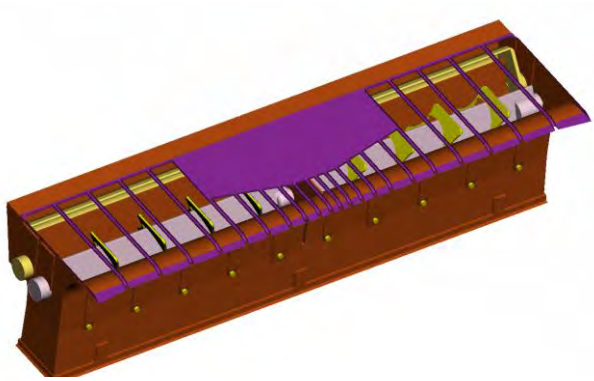

Figure 11: CAD files of the grid (II)

3.2.3 Sensors

IDIADA provided the thermal and radiant temperature sensors for the Dash board, the B pillar, the seat and the Headrest (Figure 12, Figure 13).

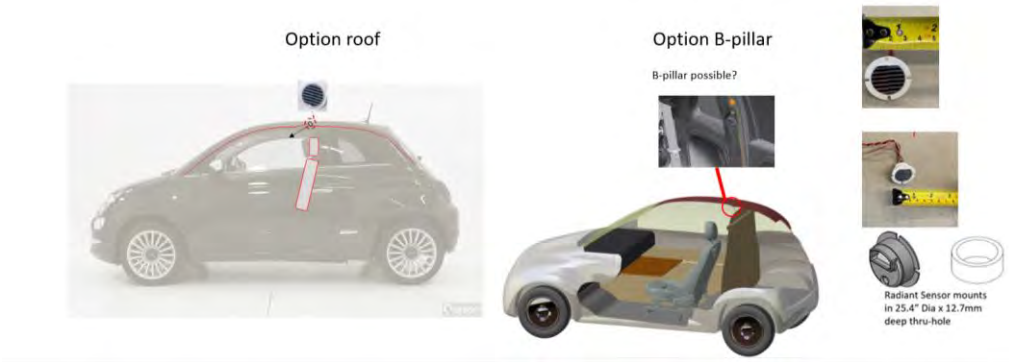

Figure 12:Location of mean radiant temperature sensor

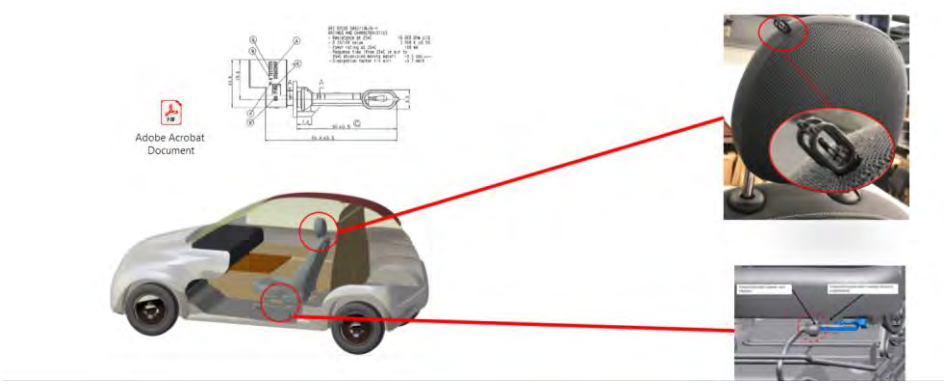

Figure 13: Detail and location of air temperature sensor

3.2.4 Radiant panels

IEE provided a sample of the radiation panels which were installed on top of red LED lights to simulate the heat effect (Figure 14).

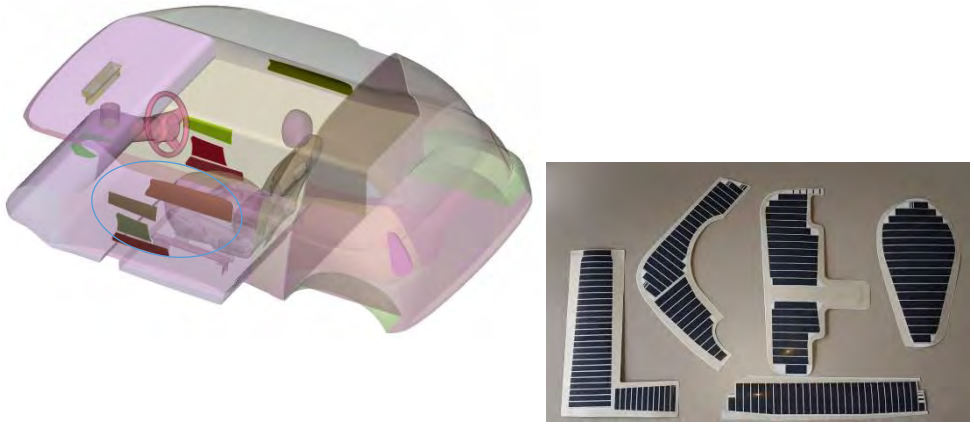

Figure 14: Location of the radiant panels in the mock up & detail of the printed foils sent by IEE

3.3 Model Construction

IDIADA selected the external provider by the end of December 2020 and the production process was finished the end of May 2021. The production sequence is explained below.
The contractor started with a Fiberglass body made from a milled polyurethane mould (Figure 15).

Figure 15: Fiberglass body made from a milled polyurethane mould.

The body was assembled to the tubular structure and the interiors. The instrument panel and the central console were built in hard model and furnished. The entire interior has been made in fiberglass and the side box in wood (Figure 16).

Figure 16: Assembly of the body and dashboard to the tubular structure

Below it is shown the installation of the Smart Outlet from DNTS on the dashboard (Figure 17, Figure 18)

Figure 17: Grid sent by DNTS

Figure 18: Smart Outlet attached to the dashboard of the Mockup

The seats of the mock-up were constructed following the example of the seats designed by Faurecia Germany for the Demo car of the project. With that in mind, red and blue LED lights were installed in the seat cushion and seat back to simulate heating and ventilation functions (Figure 19).

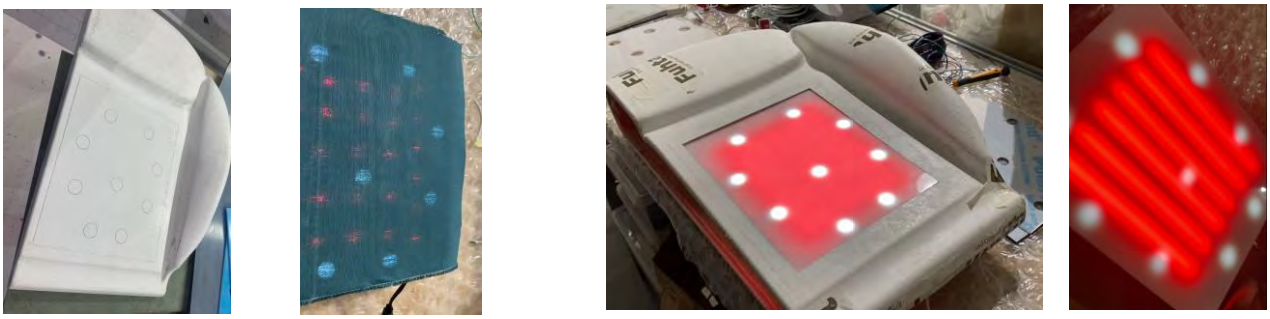

Figure 19: Red and blue LED lights on the seats cushion and back

The seat was built with a crosscut section on the left side to demonstrate the air circulation system (Figure 20).

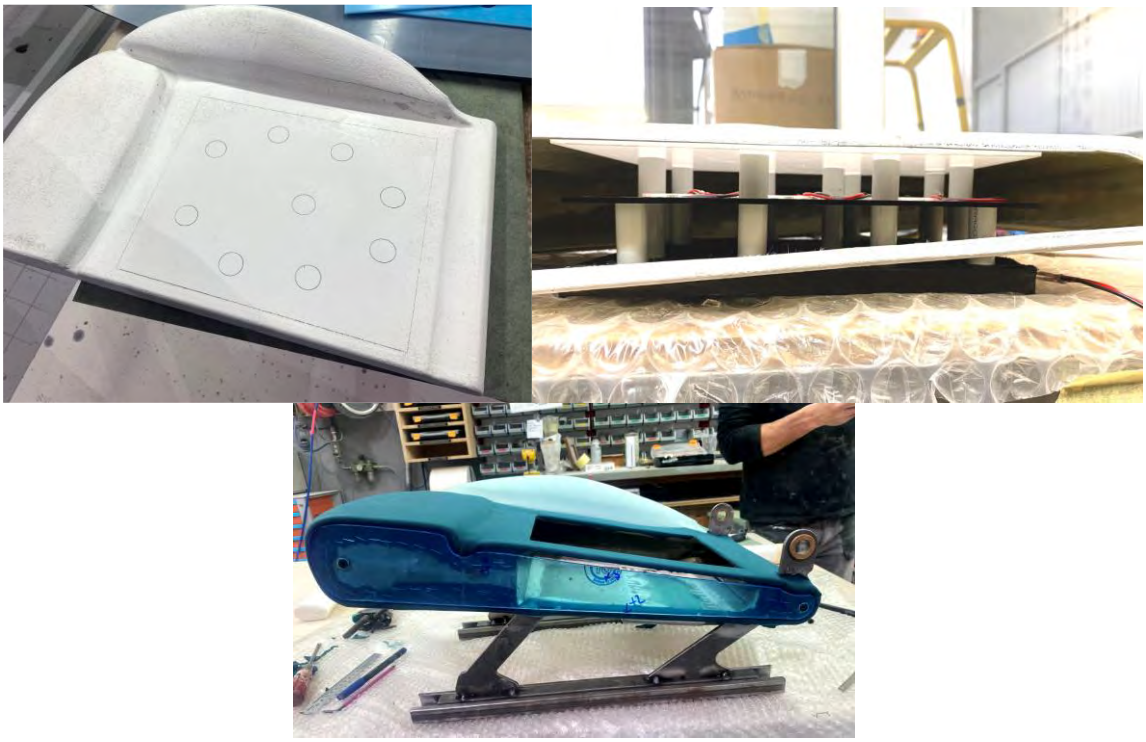

Figure 20: Crosscut section of the seat showing the air circulation system

The steering wheel was attached to a mechanism to move it from driver position to rest position up to the Interior Panel (IP) (Figure 21).

Figure 21: Steering wheel of the Mock and its movement mechanism

The power units and the main board that has been programmed to control the Car functionalities has been placed in the Dash bord area (Figure 22).

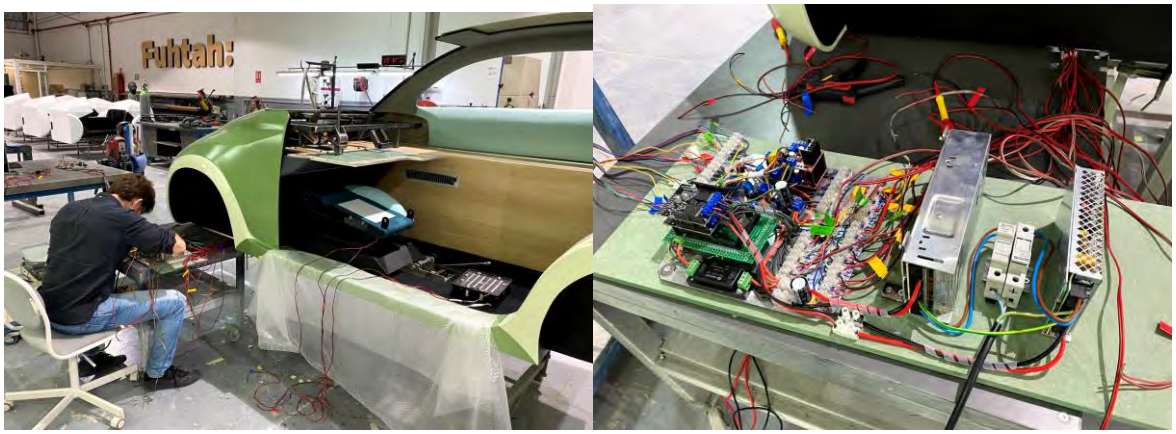

Figure 22: Built and installation of the power circuits

Interior trims were made by glass fiber and upholstered (Figure 23).

Figure 23. Interior of the Mockup

The windows has been assembled and the model has been finished by sealing & trims to cover the motors and the mechanisms (Figure 24).

Figure 24: Window fixation process on the mockup

The curtain was attached to a roll up/ down mechanism (Figure 25)

Figure 25: Roll down/up mechanism and curtain

The last step was to paint the exterior (Figure 26)

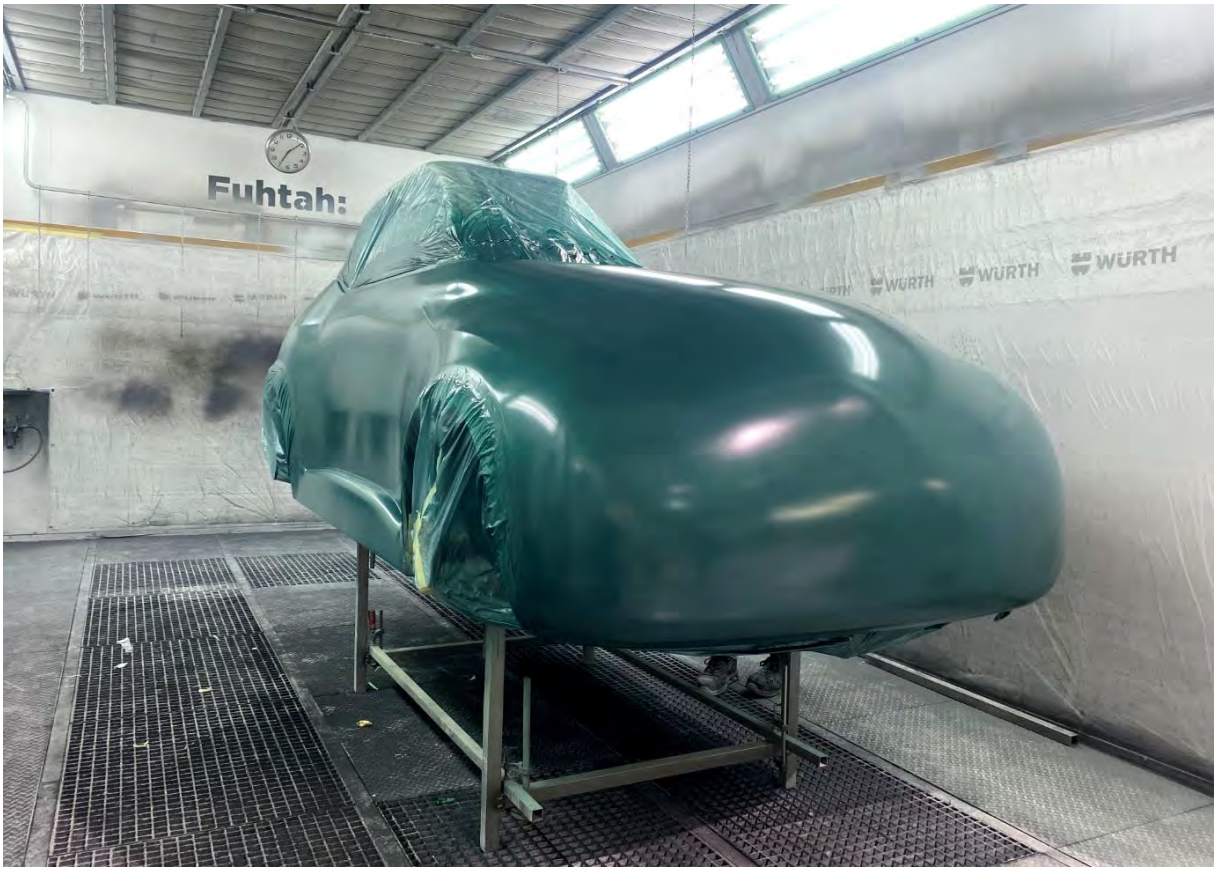

Figure 26: Painting of the exterior

3.4 Tablet & APP

An application was developed in order to activate:

1. The seat movement up and down.
1- The desktop table inside and out of the IP.
2- The steering wheel up and down.
3- The curtain rolling up and down.
4- Activation of smart outlet blower and vent directions.
5- Red/Blue LEDs lights of the interiors.

The app has three pages:

First page: Allows you to choose among the different cabin configurations (Figure 27)

- Configuration go: Curtain down, seat and steering wheel in driving position, desktop table in the interior of the IP.
- Configuration office: curtain down, the steering wheel up inside the Instrument Panel and desktop table out.
- Configuration driver: desktop table inside the IP, the steering wheel go in the driver position.
- Configuration bed: curtain rolls up, the seat goes down to horizontal position and the steering wheel goes up inside the instrument panel.
- Configuration for automatic drive: steering wheel goes up and inside the IP, the curtains roll down and the seat goes to driving position.

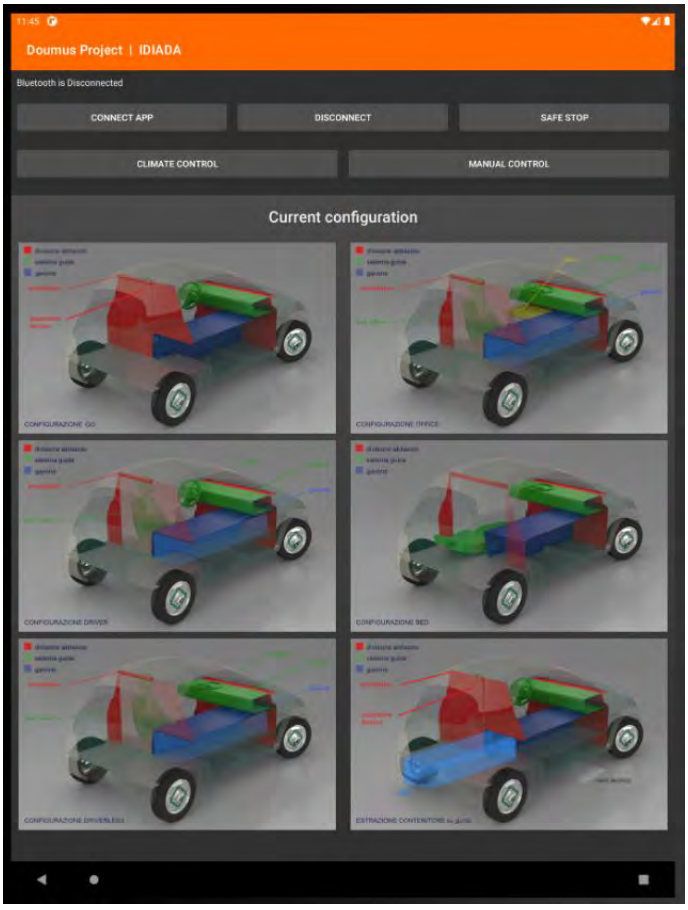

Figure 27: Display of the APP first page

Second page: Allows you to manage the different climate control options (Figure 28):

- Switch on or off they the blower.
- Choose the velocity of the air.
- Move the Smart Outlet Vanes to change the air direction in different cabin areas.

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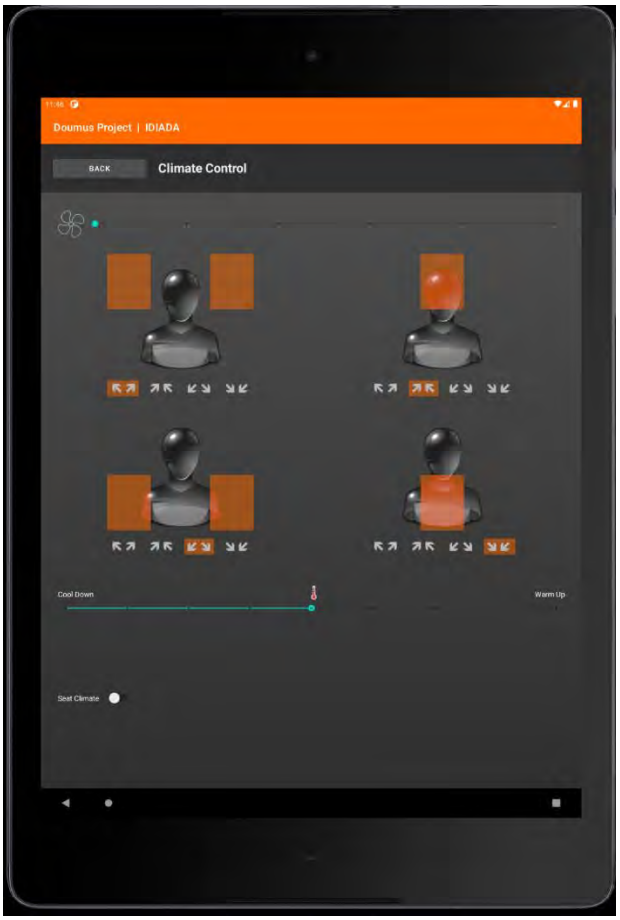

Figure 28: Display of the APP second page

Third page: Allows to manually control (Figure 29):

- The position of the seat, the curtain the desktop table and the steering wheel
- The swift on/off of the blue and red LED light of the cabin

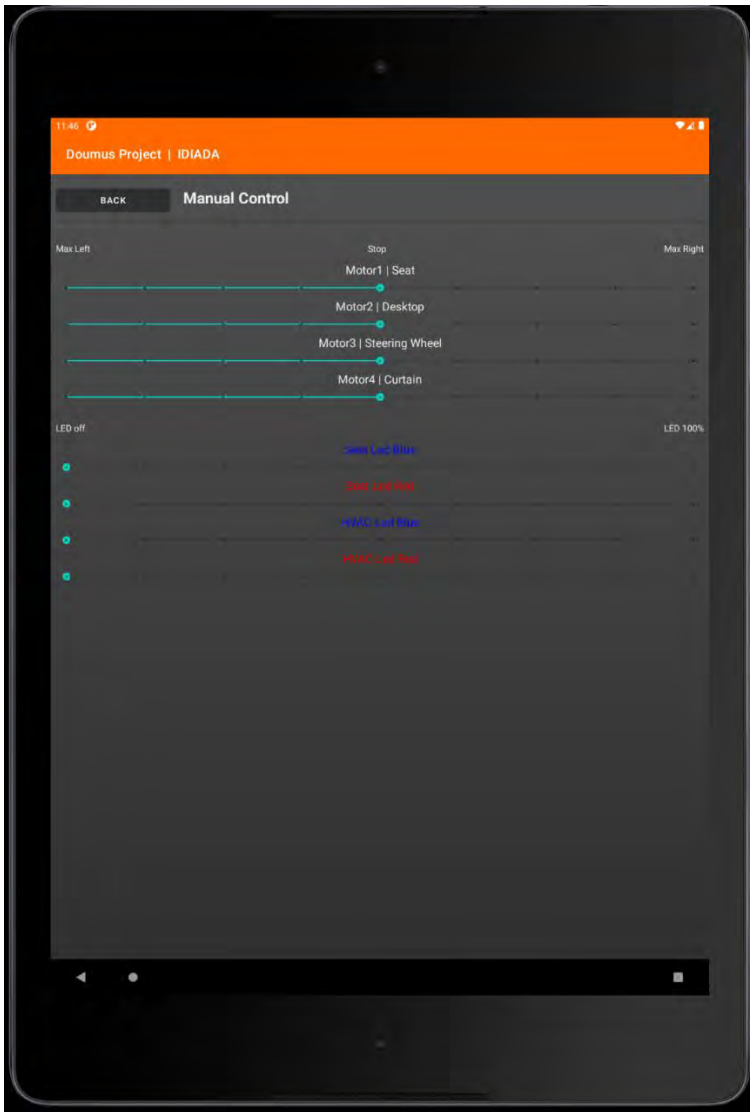

Figure 29: Display of the APP third page

When the app is inactive the display of Figure 30 is shown.

Figure 30: Display of the app when is in passive mode

4 Final result

The final mockup (Figure 31) includes the following elements:

- STRUCTURE: Metal tubular structure build. Mechanism to allow the rotation of the wheels back and forward. No steering movement.
- EXTERIOR: No Class A surfaces. Fiberglass body made from a milled polyurethane mold. No door panels on both driver-and trunk doors. Fixed co-pilot door panel.
- WHEELS: Supplied by IDIADA.
- GLASSES: 2 thermoformed methacrylate glasses: Windshield + Right Side.
- PILOTS: Fake lights/Simulated lights (Painting, vynil, tape…).
- INTERIOR/PEDALS: Non-functional. Built with metal and rapid prototyping parts.
- INTERIOR/DASHBOARD: New shape made in hard model and furnished. It includes details of the "HVAC" + "VANES". These parts are rapid prototyping and non-functional. LED lights will be added.
- INTERIOR / CARPETS: Existing stock models.
- INTERIOR / CURTAIN: Functional. Able to roll up and down. Made with commercial fabric.
- INTERIOR / REAR STORAGE: Functional. Hard model. Removable on the rear side.
- INTERIOR / OFFICE DESK: Functional. Hard model.
- INTERIOR / SEAT: Supplied by Idiada. Functional height regulation. The seat will be modified to allow showing the parts made with rapid prototyping in its interior. LED lights will be added.
- INTERIOR / STEERING WHEEL: Functional. Supplied by Idiada.
- INTERIOR / RADIATION PANELS: Simulated to reflect the temperature changes with LED lights.
- TABLET CONTROL: Design and develop an APP to control the mechanisms (seat, desk, steering wheel and curtain) and the color changing LEDs.

Figure 31: Mockup view from different angles

5 References

- Deliverable 2.2 of the DOMUS project “Approach and Results of User Centered Design of Novel Cabin Design Models through Disruptive Approaches”

6 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

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3	TME	TOYOTA MOTOR EUROPE
4	Volvo Cars	VOLVO PERSONVAGNAR AB
5	AGC	AGC GLASS EUROPE SA
6	DNTS	DENSO Thermal Systems S.p.A.
7	Faurecia	Faurecia Sièges d'Automobile
8	HUTCH	HUTCHINSON SA
9	IEE	IEE International Electronics & Engineering S.A.
10	LIST	LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY
11	COV	COVENTRY UNIVERSITY
12	Fraunhofer	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V.
13	IKA	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN
14	TECNALIA	FUNDACION TECNALIA RESEARCH & INNOVATION
15	VIF	Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH
16	UNR	UNIRESEARCH BV
17	FIS	Faurecia Interieur Industrie
19	FCA	Fiat Chrysler Automobiles Italy SPA

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7 Appendix A – Quality Assurance

The following questions should be answered by all reviewers (WP Leader, peer reviewer 1, peer reviewer 2 and the technical coordinator) as part of the Quality Assurance Procedure. Questions answered with NO should be motivated. The author will then make an updated version of the Deliverable. When all reviewers have answered all questions with YES, only then the Deliverable can be submitted to the EC.
NOTE: For public documents this Quality Assurance part will be removed before publication.

Question	WP Leader	Peer reviewer 1	Technical Coordinator
	VIF	Gustav Kumlin Groth (Volvo Cars)	IDIADA
1. Do you accept this deliverable as it is?	Yes	Yes The delivarable is a full scale principle model of the design proposals developed in WP 2.1/2.2	Yes
2. Is the deliverable completely ready (or are any changes required)?	Yes	Yes If prototype functionality is according to specification and plan	Yes
3. Does this deliverable correspond to the DoW?	Yes	Yes	Yes
4. Is the Deliverable in line with the DOMUS objectives?	Yes	Yes The deliverable decreases the energy use of the vehicle according to energy assessments	Yes
a. WP Objectives?	Yes	Yes	Yes
b. Task Objectives?	Yes	Yes, Design proposals has been developed with specific parameters and design principles to reach the overall goal, as well as assessment models to verify both comfort as well as energy efficiency assumptions. *"develop a radical and innovative cabin design maximize energy efficiency, and utilize and parameterize the generic vehicle, comfort, and efficiency models in order to assess the virtual cabin model. "*	Yes

Question	WP Leader	Peer reviewer 1	Technical Coordinator
5. Is the technical quality sufficient?	Yes	Yes The fullscale model follows output from WP 2.1 in full detail. *The main objective or this task was to reproduce in full scale a disruptive cabin design proposed by the consortium under task 2.1 "Novel cabin design".*	Yes