EUROPEAN COMMISSION

HORIZON 2020 PROGRAMME - TOPIC H2020-LC-GV-01-2018
Connected Electric Vehicle Optimized for Life, Value, Efficiency and Range

GRANT AGREEMENT No. 824295

CEVOLVER
Connected Electric Vehicle Optimised for Life, Value, Efficiency and Range

CEVOLVER – Deliverable Report

D7.5 Input to the E-Volve cluster common book and common policy recommendations and advice towards the EC

Deliverable No.	CEVOLVER D7.5	
Related WP	WP7	
Deliverable Title	Input to the E-Volve cluster common book and common policy recommendations and advice towards the EC	
Deliverable Date	2023-01-09	
Deliverable Type	REPORT	
Dissemination level	Public (PU)	
Written By	Christof Schernus (FEV Europe GmbH)	2022-11-24
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Status	Final	2023-01-09

Disclaimer/ Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824295. The information and views set out in this publication does not necessarily reflect the official opinion of the European Commission. Neither the European Union institutions and bodies nor any person acting on their behalf, may be held responsible for the use which may be made of the information contained therein.

Publishable summary

CEVOLVER is one of the projects under the Horizon 2020 call of the year 2018 on Smart, green and integrated transport, addressing the topic LC-GV-01-2018 titled "Integrated, brand-independent architectures, components and systems for next generation electrified vehicles optimised for the infrastructure".

Initially, six projects related to this topic formed a cluster of projects aiming at synergies from exchange of high-level information about content and progress of the projects, occurring challenges and solutions. A further purpose was to increase impact of dissemination by organising joint publications and dissemination events.

The initial group of projects consisting of ACHILES (Grant Agreement No. 824311), CEVOLVER (824295), EVC1000 (824250), FITGEN, (824335), SELFIE (824290) and SYS2WHEEL (824244), two further projects joint the cluster: TELL (824254), addressing the same topic, and Multi-Moby (101006953) related to the 2020 call's topic LC-GV-08-2020 – Next generation electrified vehicles for urban and suburban use.

Apart from joint workshops, social media publications, presentations, some peer-reviewed papers were edited and, among others, were selected to SAE Journals. Finally, a joint book will be published in 2023, to which each of the eight projects was to provide input.

The content of this deliverable reflects the input provided to the coordinator of the cluster, Stella Arapoglou at Vrije Universiteit Brussel (VUB and ACHILES project), who compiles the inputs from the different projects together with Prof. Bernhard Brandstätter from Virtual vehicle (ViV, Sys2Wheel project) for publication as a book with Springer editors. This process is still ongoing at the time of submitting this deliverable. The reference to the book will be provided to the European Commission later for publication on Cordis.

Because the space in the book available for each project is limited, the CEVOLVER project decided to focus its contribution on the chapters and sections

- project overview,
- Energy efficiency and performance
- Connectivity
- Roadmap on evolution of e-mobility
  and
- Policy Recommendations

The reader is asked for understanding, that all headlines created by the editors remained in the deliverable even in the case CEVOLVER did not provide any content to make it easier for the book editors to compile the contributions of the eight different projects. In this case, a box explaining this circumstance is placed under the headline instead of longer text. This does not necessarily mean that CEVOLVER did not work on the theme of that section, but either its contribution to this aspect is already mentioned in another section or the place is purposefully left to other projects to use the room to showcase their highlights.

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Abbreviations

Symbol / Shortname	
BEV	Battery Electric Vehicle
CAN	Controller Area Network
CRU	Compact Refrigeration Unit
HMI	Human-Machine Interface
LIN	Local Interconnect Network
OEM	Original Equipment Manufacturer
PTC	Positive Temperature Coefficient (here: material whose resistance increases with temperature)
SoC	State of Charge (of the Battery)

1 Introduction

To be completed by editors

2 The E-VOLVE Cluster

2.1 What is it

NOTE: The text in this and similar boxes is not input to the common book of the E-VOLVE cluster but serves as information for this deliverable only. The book section on this topic will be provided by the project ACHILES and the main editors.

Initially, six projects granted under the topic LC-GV-01-2018 “Integrated, brand-independent architectures, components and systems for next generation electrified vehicles optimised for the infrastructure” decided to form a cluster of projects and collaborate on high level to exchange information about important findings (considering the confidentiality requirements set out in the consortium agreements), boundary conditions, and to work together on joint publications and dissemination events. The cluster was named “E-VOLVE” referring to Electric Vehicles Optimised for Life, Value and Efficiency.

The management of the cluster was taken over by the project ACHILES under the coordination of Vrije Universiteit Brussel (VUB).

Later, the projects TELL (LC-GV-01-2018) and MULTI-MOBY (LC-GV-08-2020) joint the cluster at different times. It is planned to continue the joint dissemination activities under the management supported by newly granted projects of corresponding technical fields after the ending of the first generation of projects.

2.2 Objective

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2.3 Working groups

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2.4 Results / Experience

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3 The projects

The project summary descriptions will be provided by the individual projects. As a short reference, this deliverable will point out to the project pages at the EU portal CORDIS

3.1 ACHILES

Please find further information at https://cordis.europa.eu/project/id/824311

3.2 EVC1000

Please find further information at https://cordis.europa.eu/project/id/824250

3.3 SYS2WHEEL

Please find further information at https://cordis.europa.eu/project/id/824244

3.4 TELL

Please find further information at https://cordis.europa.eu/project/id/824254

3.5 MULTI-MOBY

Please find further information at https://cordis.europa.eu/project/id/101006953

3.6 FITGEN

Please find further information at https://cordis.europa.eu/project/id/824335

3.7 SELFIE

Please find further information at https://cordis.europa.eu/project/id/824290

3.8 CEVOLVER

The current generation of electric vehicles has made significant progress during the recent years; however, user acceptance still lacks the level needed to support broader main-stream market uptake. Major reasons for the customers' reluctance are seen in high prices of electric vehicles compared with conventional ones and so-called range anxiety prior to purchases, i.e., users' concerns that they could become constrained in their mobility by insufficient battery capacity, unreliable range prediction, limited availability of infrastructure and long charging times.

Temporary action to mitigate ownership costs with incentives such as cash supplements to the purchase price and tax waivers, several member states took, did support recent rises of sales values. However, without such governmental incentives, these vehicles still remain generally too expensive.

With the battery being the main cost driver, customers find themselves in a dilemma between the high price for a large battery capacity and comfortable range on the one hand side, and potential range limitations due to a smaller battery on the other hand side. This dilemma may prohibit BEVs of present generations from being used as the first car for a typical family at large scale with a sustainably fast increasing market share. As mentioned before, concerns about inconvenient long charging times and uncertainties in range prediction are common as further barriers to broader market success.

To overcome the barriers given by cost and range anxiety, the CEVOLVER project takes a user-centric approach to create battery-electric vehicles that are usable for occasional long trips whilst the installed battery is dimensioned for affordability. Furthermore, the vehicles will be designed to take advantage of future improvements in the fast-charging infrastructure that many countries are now planning or building up, respectively.

CEVOLVER tackles the challenge by making improvements in the vehicle itself to reduce energy consumption as well as maximizing the usage of connectivity for further optimization of both component and system design, as well as control and operating strategies. This will encompass measures that range from the on-board thermal management and vehicle energy management systems to connectivity that supports range-prediction for driver assistance functionality using eco-routing, eco-charging and eco-driving (Figure 3-1).

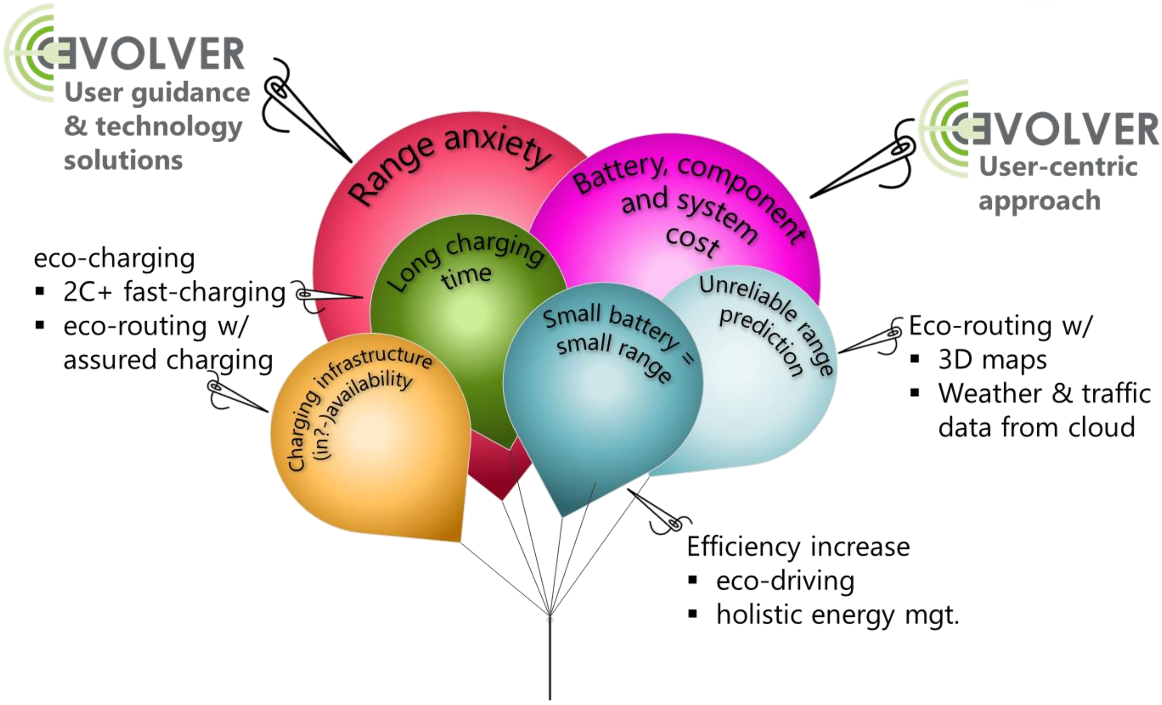

Figure 3-1: CEVOLVER's most important approaches to increase user acceptance ("blasting the bubbles of worry")

Within the project, it is demonstrated that long-distance trips are achievable even without further increases in battery size that would lead to higher cost, or, even better, reducing battery size to lower cost. The driver is guided to fast-charging infrastructure along the route that has been holistically optimized to ensure a minimum number of stops and sufficient charging power is accessed, so the trip can be completed with only minimal additional time needed for the overall trip. The efficient transferability of the results to further vehicles is ensured by adopting a methodology that proves the benefit with an early assessment approach (e. g. numerical simulation) before implementation in OEM demonstrator vehicles.

CEVOLVER's user-centric objectives are to

- Ensure a leap forward in user's confidence, functionalities and energy efficiency of future EVs
- Ensure the affordability of future electric vehicles by a user centric development approach

From these two user-centric objectives descend the technological and operational objectives

- to validate advanced components and systems, novel connected control strategies and functionalities, and
- to assess the impact of the technical advancements of CEVOLVER and their applicability in different EV types and vehicle classes

In this sense, the project aims at creating solutions for Connected Electric Vehicles Optimised for Life, Value, Efficiency and Range that overcome the customer's reluctance and support a faster market run-up of affordable and resource efficient BEVs that, despite their modest battery size, are convenient to be used even as a first family car.

3.8.1 Energy and Thermal management

As outlined above, CEVOLVER takes a holistic approach to energy management. The simulation campaign was accompanied by testing campaigns using different demonstrator vehicles from Bosch, Ford and CRF.
Bosch investigated two prototype vehicles, a rolling chassis prototype and a full-body prototype vehicle, with different sophistication of thermal management on the roller dyno. The more complex thermal management system of the full-body vehicle is shown in Figure 3-2.

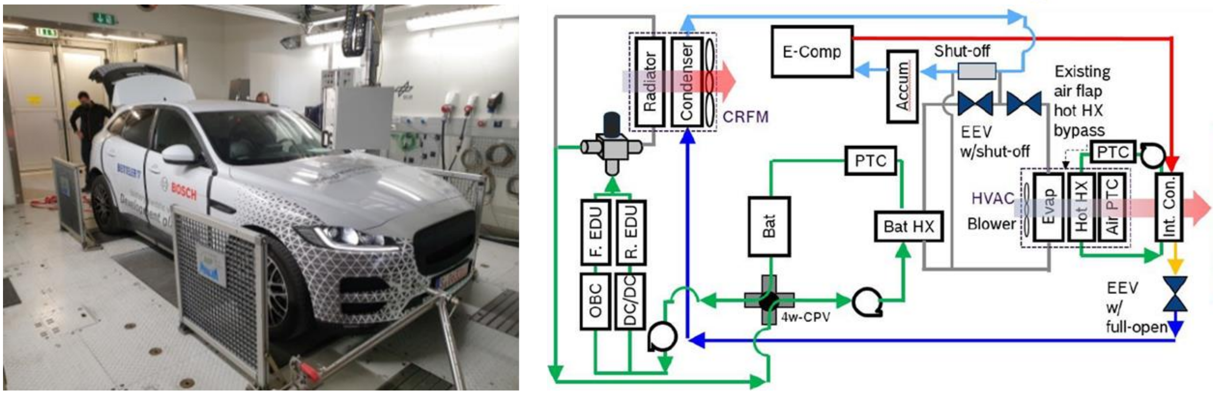

Figure 3-2: Bosch full body vehicle demonstrator and its thermal management system. (Source: "Advanced Thermal Management"; Alexander Wahl, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

Concerning vehicle measurements, focus of the measurements on the first vehicle was a comparison of measurement results with simulation models built in the simulation platform that was adopted from a predecessor H2020 project HIFI-ELEMENTS and upgraded for the investigations in CEVOLVER. For this purpose, measurements at constant speeds and various standardized test cycles were carried out on a roller test rig. In addition to the temperature levels on component surfaces and in the cooling water side, a loss-/ efficiency chain between the battery and "the road", i.e., the rollers were evaluated as well as a determination of the coefficient of friction for roller conditions at different speeds.
In case of the second vehicle (Figure 3-2), the focus was on improvements through technical measures at low temperatures (-7°C as reference, generally -15 … +7°C). Therefore, measurements were carried out with waste heat recovery from power train losses to battery and the use of a heat pump for a typical long-distance driving profile.
Under these conditions, energy benefits of approximately 5% were determined for long trip conditions and potentials for improvement are identified.

For the use case of a parcel delivery vehicle involves frequent opening of the doors and exchanging the cabin air with the ambient. Therefore, cabin air heating makes less sense because the warm air will be lost when the driver leaves and re-enters the cabin. Therefore, the already widely established heating of steering wheel and seat surface is completed by heat panels installed surrounding the driver. I.e., a heated floor mat was combined with heating panels below the dash and radiative surfaces on door panel and door tap, arm rest, sun visor and behind the driver's neck to create an instant comfortable warmth without wasting energy (Figure 3-3). For the supply of warm air, when needed e.g., for defogging, a standard PTC heater is installed. This combination appears better suited for the use case of a parcel delivery service and is less costly than a heat pump.

Figure 3-3: Ford delivery van and heating panels installed around the driver (Source: "Advanced Thermal Management"; Alexander Wahl, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

The CRF Validators 1 and 2 (Figure 3-4) implemented different energy and thermal management installations for experimental validation:

- Vehicle Validator 1: realized starting from the Fiat 500e (North America) with in addition the OPTEMUS project heat pump system (CRU - Compact Refrigeration Unit)
- Vehicle Validator 2: realized starting from the new Fiat 500e with DC fast charge functionality

The two validators share the same cloud-vehicle bidirectional communication hardware and software architecture and are specialized to investigate in deep the effectiveness of different cloud-based functions developed in CEVOLVER. In particular:

- Vehicle Validator 1: the integrated energy and thermal management (cabin comfort and e-powertrain components thermal management)
- Vehicle Validator 2: the HV Battery thermal preconditioning before the DC fast charge (preheating or precooling depending on the conditions) with the aim to minimize the charging time but respecting the expected vehicle range and its battery life target (optimized charging)

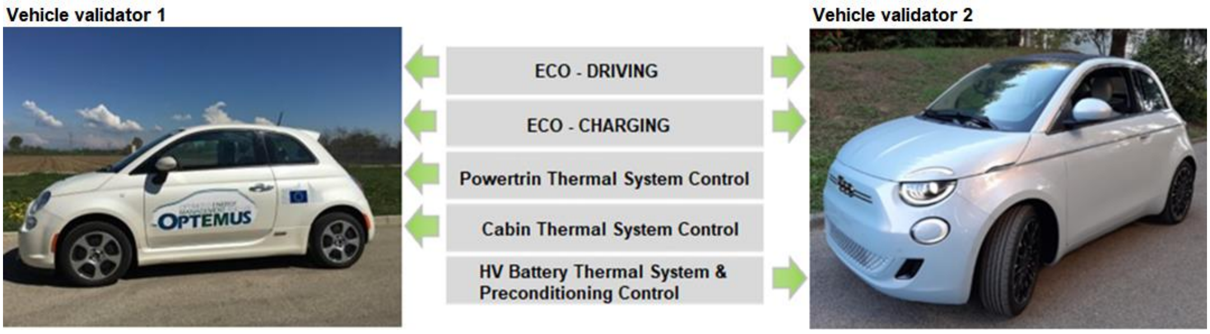

Figure 3-4: CRF Validators and their functionalities

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As further notable result, the CEVOLVER project demonstrated the viability of using the vehicles for long-distance day trips of 700 km with not more than 60 minutes additional travel time for charging compared to using a conventional vehicle.
Merriam Websters Dictionary defines a **day trip as**

"a journey in which a person goes to visit a place
and then returns home on the same day"

The same meaning is supported by other references.
Accordingly, the 700 km total length of the journey can be split in two legs of 350 km each. ADAC and other associations recommend to drivers taking at least one recreational break on such a distance, the duration of which is assumed to be not less than 15 minutes. Adding the allowed 30 additional minutes for charging on each way forth and back results in a total acceptable time of 90 minutes for charging during the travel on such a 700 km day trip. Nevertheless, the time of the visit to the destination can also be used to charge the battery, provided that a ubiquitous charging infrastructure is available in a future EV-friendly world.
Under these assumptions, both the CRF validator 2 and the Ford demonstrator vehicle realised the challenging demonstration with their limited battery capacity. In one case, though, the commercial vehicle on its cross-border trip through three EU member states missed the target by a few minutes, because an unplanned detour was necessary to find an alternative to a dysfunctional fast-charging station that was not indicated on the internet as defective.

This leads to the following conclusions:

- Better real-time information about the status of charging infrastructure must be made accessible by charging providers.
- A higher density of (fast-)charging stations will be inevitable to support the ramp-up of the EV fleet for private and commercial use. The current pace of installation does not match the growth of the EV fleet currently taking place.

In addition, a study performed as part of this project and published in Lisbon at the TRA2022 conference (Giovanni de Nunzio, Volger Döge, Ian Faye, Vittorio Ravello, Antonio Sciaretta, Patrizio Turco, 2022) demonstrated that integrating features of CRF's validator 1 and validator 2 in one vehicle would also enable traveling to a destination 700 km away from home still not extending the travel time by more than 90 minutes.

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Further contributions to this section will be made by other projects of the cluster

4 Powertrain

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CEVOLVER's contribution to powertrain development are discussed in other deliverables but were not further considered as a separate detailed contribution to the joint book beyond the information given in other sections of the book.

5 Energy efficiency and performance

CEVOLVER, like other projects of the E-VOLVE cluster, has investigated different means for providing comfortable warmth in the cabin. Providing warm air to the cabin using heat-pump at the same comfort instead of a PTC heater has shown to save approx. 30% of electric energy for heating or approx. 5% energy in WLTC at -7°C on battery level, respectively. For certain applications like a parcel delivery vehicle, heat panels have been found to be more efficient as they provide warmth without transferring to much heat to the air that becomes frequently exchanged when the driver opens the door to jump off and on, while for longer travels reusing waste heat from powertrain and battery with a distributed heat pump like applied in CRF's Validator 1 has shown its benefits.
Apart from its holistic thermal management described in section 3.8.1, CEVOLVER's connected Eco-Charging and Eco-Driving functions support the minimisation of operational energy expenditure and enhance the electric driving range from a single charge of the battery. Eco-Charging comprises the selection of an Energy- and time-optimal route with minimal detours to fast-charging stations. CEVOLVER's Smart Fast Charging enables controlled preconditioning of the battery prior to a fast-charging event, by using the battery temperature operating window in an optimal way. Thereby it can achieve a higher average charging power which more than offsets the energy expenditure for preconditioning and reduce the overall trip time.
Eco-Driving in turn coaches the driver to follow an energy-saving speed profile optimal for the next route segment based on 3D map data, i.e., considering the influence on energy expenditure to overcome ascending road grade and the possibility to recuperate potential energy on falling slopes within the limits given by the powertrain. It also makes use of in-vehicle information like distance and speed of the vehicle in front, traffic flow, traffic light information, as far as available, to smoothen-out acceleration and deceleration with best possible use/recuperation of kinetic energy.

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6 Connectivity

CEVOLVER uses connectivity in two ways: The first approach is to make use of (big) data collected in the OEM cloud about load collectives from use cases, to improve optimise component dimensions to the needs of those use cases. Of particular concern is the battery capacity as a major cost driver. But also, the selection of appropriate cabin climatization equipment and their control plays in this field. For example, this resulted in the Ford parcel delivery van being set up with surface heating prioritised over a heat pump for cost and energy efficiency and the choice of a modest battery capacity (Figure 6-1).

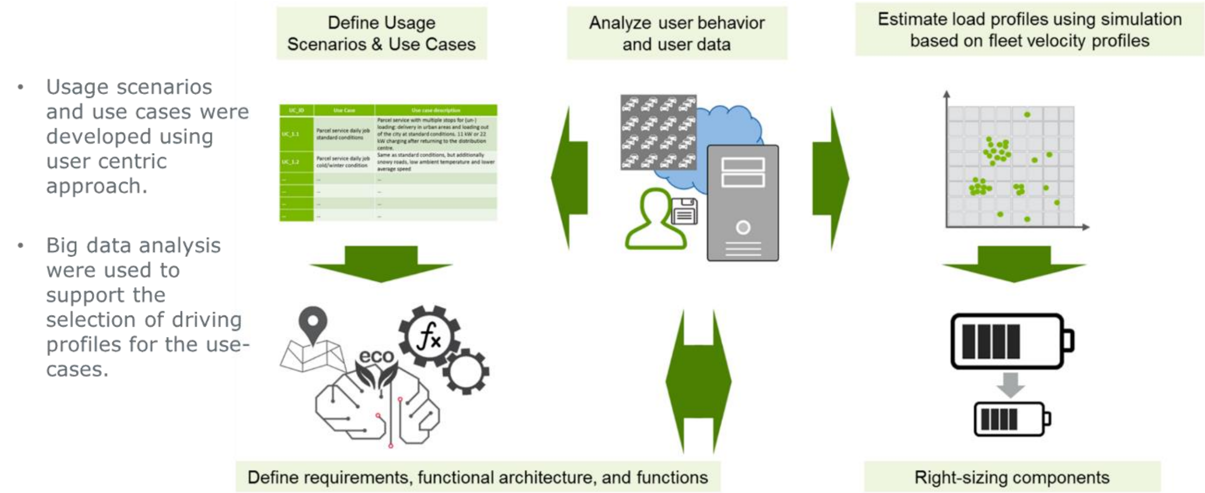

Figure 6-1: CEVOLVER approach to use OEM cloud connectivity to obtain big data for right-sizing of components (Source: "Development of Use Cases for Battery Electric Vehicles"; Hans Günter Quix, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

Secondly, the connectivity to the OEM cloud was complemented by the independent MOBI Cloud (https://mobicloud.ifpen.com/) of partner IFPEN that provided the information for "Eco-Charging", i.e., the planning of an energy- and time-optimal route with respect to energy usage considering distance, traffic, weather conditions and (fast-)charging opportunities (Figure 6-2). The Eco-Driving algorithm was implemented to provide the driver with vehicle speed recommendations for optimal driving efficiency.
It was shown in a simulation study that traffic flow has indeed the biggest influence on trip time (Giovanni de Nunzio, Volger Döge, Ian Faye, Vittorio Ravello, Antonio Sciaretta, Patrizio Turco, 2022). And that finding will apply independent of powertrain whether electric or traditional with internal combustion engine.

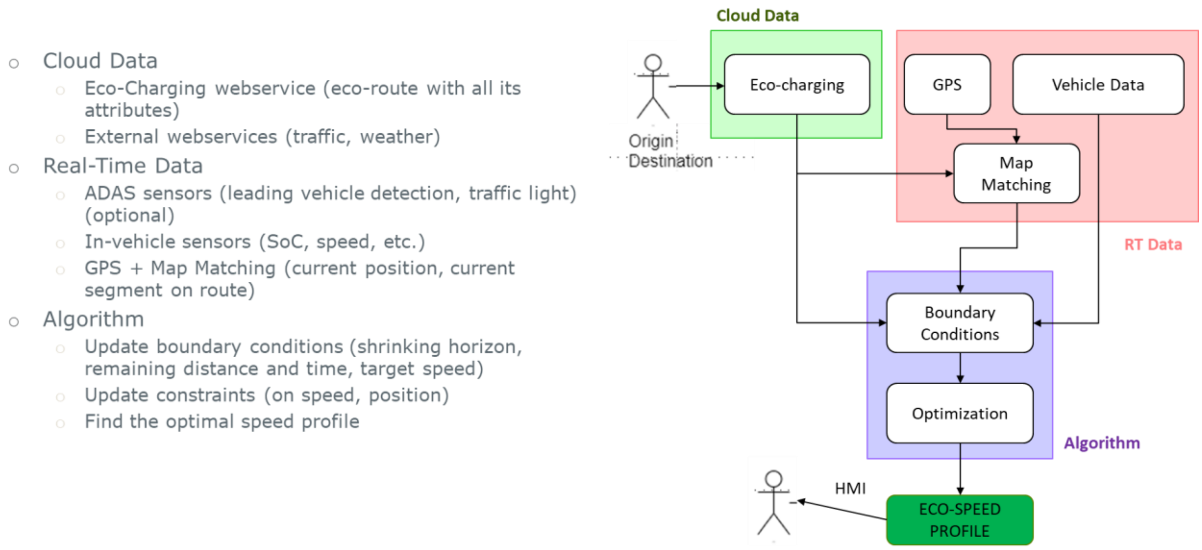

Figure 6-2: OEM independent cloud services supporting the Eco-Driving algorithm (Source: "ECO-CHARGING"; Antonio Sciarretta, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

CRF implemented some of the CEVOLVER Advanced Functions in Vehicle Validator 2 (Figure 6-3), i.e., ECO-CHARGING (ECO – Routing + Charge Stop Planning), Battery thermal pre-conditioning for DC Fast Charging and ECO-DRIVING. Eco-Driving speed indication has shown a relevant energy saving (11.6%) with a reduced effect on trip time (+3.7%). Eco-Charging shown an overall trip time reduction of 7.6%, compared with a fast charging based on SoC "comfort zone". Even more relevant effect at charging time level, reduced by a half (-47%). Battery Thermal Preconditioning offered a further charging time reduction, especially in cold conditions: 13.7% at 10°C and 29.2% at 0°C for charging from 21% to 75% SoC.

Partner Bosch developed a cloud connected Trip Itinerary (TI) function that uses information from Eco-Charging and Eco-Driving algorithms that enables monitoring of the energy usage and its deviation against the plan and according rescheduling of charging stops during travel (Figure 6-4).

The potential benefit from combining user centric right-sizing and Eco-Charging/Trip Itinerary Manager is analysed in a peer-reviewed paper for TRA2022 (Giovanni de Nunzio, Volger Döge, Ian Faye, Vittorio Ravello, Antonio Sciaretta, Patrizio Turco, 2022). It demonstrates the viability of an 800+ km travel from Stuttgart to Nizza across the Alps in less than 10.6 hours in a Fiat 500e with a battery capacity of approx. 40 kWh and four charging stops.

Figure 6-3: Connectivity and HMI features installed in CRF's Validator 2. (Source: "Long trip simulations and realisation Part 2"; Patrizio Turco, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

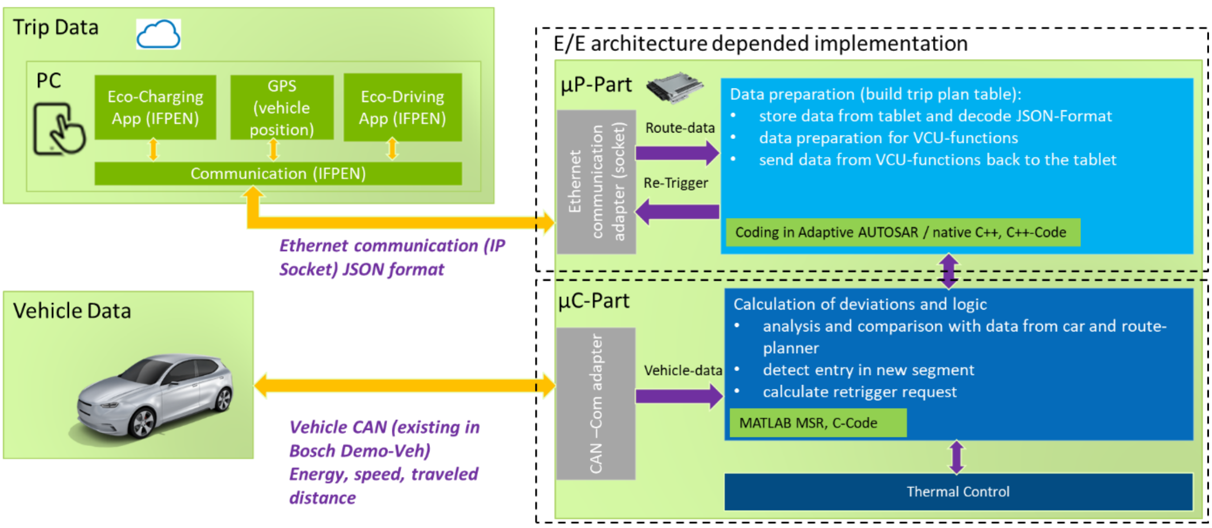

Figure 6-4: Interface of TI function with MOBI Cloud and vehicle (Source: "Trip Itinerary Manager"; Engelbert Trunner, CEVOLVER Final Event, 2022-09-27, Aldenhoven Testing Center, Germany)

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7 Control Architecture

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CEVOLVER's contribution to control architecture beyond the information given in other sections of the book are discussed in other deliverables but were not further considered as a separate detailed contribution to the joint book.

8 Roadmap on evolution of e-mobility

CEVOLVER employed Eco-Driving through an HMI coaching the driver to an energy-efficient driving style. Within the budgetary boundary conditions and the time frame of the project, a safe and secure coupling of the algorithms with the motion controller could not be performed. Nonetheless, to fully exploit the potential of the algorithms, the full integration of Eco-Driving and Eco-Charging with a level-3 ADAS system is key. It must take full control of the propulsion for time- and energy-optimal traveling until the driver interferes or the vehicle leaves its operational design domain.

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9 Policy Recommendations

On-road tests of CEVOLVER made clear that a further build-up of reliable fast-charging infrastructure along the travel routes but also in urban and rural areas is inevitable to improve the viability of smooth travels with electric vehicles. The availability of fast-charging facilities put significant constraints on the choice of routes to demonstrate the long-distance trip in Italy, and a dysfunctional charging station exacted a detour during the cross-border travel demonstrated in Belgium, The Netherlands and Germany to charge the van at another fast-charging station.

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In addition to the above, the project has shown that policy makers need to push for further expansion of fast charging infrastructure, with a focus on expansion along long-distance routes, without neglecting urban and rural areas. In residential areas, however, further expansion of slow charging (AC) infrastructure in garages and along parking lanes will be necessary.

As advice to the EC for future work programmes, the authors would like to appreciate the way the topic description was set. The LC-GV-01-2018 topic description (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/lc-gv-01-2018) requested that "Proposals will have to address one or more of the following technical areas" followed by a list of four different scopes. The degree of freedom given by this wording enabled the projects responding to the call and forming this cluster with different complementary approaches. This way, the cluster was able to show a large spectrum of solutions and a very comprehensive technological answer to the call.

10 References

Giovanni de Nunzio, Volger Döge, Ian Faye, Vittorio Ravello, Antonio Sciaretta, Patrizio Turco. (2022, November). Smart Driving and Charging Can Help Reconciliate Limited Battery Size and Long-Distance Trips for Electric Vehicles Without Compromising on Trip time. *TRA2022 - Transport Research Arena* . Lisbon, Portugal: www.science-direct.com.

11 Acknowledgement

The author(s) would like to thank the European Commission for financial support and their partners in the project for their valuable comments on previous drafts and for performing the review. Further, the authors would like to thank the partners in the E-VOLVE cluster, in particular Ms Stella Arapoglou for the excellent collaboration in four years of joint dissemination and information exchange activities.

Project partners:

#	Partner	Partner Full Name
1	FEV	FEV Europe GmbH
2	BOSCH	Robert Bosch GmbH
3	FORD	Ford-Werke GmbH
5	IFPEN	IFP Energies Nouvelles
6	RWTH	Rheinisch-Westfaelische Technische Hochschule Aachen
7	VUB	Vrije Universiteit Brussel
8	UNR	Uniresearch BV
9	I2M	I2M Unternehmensentwicklung GmbH
10	RBOS	Robert Bosch AG
11	CRF	Centro Ricerche Fiat

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 824295