

ECOGEN

Cooperative Advanced Driver Assistance System for Green Cars

M. Masikos, F. Cappadona, K. Demestichas, E. Adamopoulou, S. Dreher

PROJECT OBJECTIVES

- To render the FEV capable of reaching the desired destination(s) through the most **energy efficient route(s)** possible
- To render the FEV **fully aware of the surrounding recharging points/stations** while travelling

CONSORTIUM MEMBERS

- 8 countries
- 11 partners



CONSORTIUM MEMBERS

FEV Manufacturers



Transport Organizations



Mapping Industry



Research Institutes



Application Developers



Network Operator



The integration over the last ten years of Advanced Driver Assistance Systems (ADAS) has contributed to the improve safety and comfort.

According to recent report of the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) the increased availability of ADAS systems resulted from 2008 to 2009, despite increasing overall vehicle travel.

EcoGem ADAS is tailored-for-Fully-Electric-Vehicles (FEVs) and is equipped with Monitoring, learning, reasoning and management capabilities that will help increase a FEV's autonomy and overall electrical energy efficiency.

To this end, EcoGem's approach is based on the following two primary goals:

- To render the FEV capable of reaching the desired destination(s) through the most energy efficient route(s) possible;
- To render the FEV fully aware of the surrounding recharging points/stations while travelling.

As far as vehicle's autonomy, a significant reduction can be achieved:

- in cases in which a heavily congested route is avoided
- when a route comprising steep roads (i.e., high slopes) is bypassed.

As far as energy efficiency, Ecogem will make the everyday use of an electric car more robust by:

- enabling efficient scheduling of battery recharges
- preventing battery depletion while on the move.

The second point is greatly important for a large percentage of plug-in electric vehicles, especially when domestic recharging is not an option or is insufficient.

The remainder of the paper presented at AMAA 2011 is structured as follows:

1. Section 2 provides an analysis of ADAS systems and categorizes the ADASs developed up to today.
2. A more detailed presentation of the state-of-the-art ADASs is given in Section 3.
3. The proposed EcoGem ADAS is described in detail in Section 4 reporting all functionalities provided by the EcoGem ADAS in order to fulfil its purpose.
4. The paper is finalised with a conclusion chapter.

Advanced Driver Assistance Systems (ADAS)

ADASs are in-vehicles systems that allow the driver to reach his destination in a less stressful, safer, more comfortable and efficient way.

Most of the Driver Assistance Systems currently on the market are mainly comfort applications, aiming at

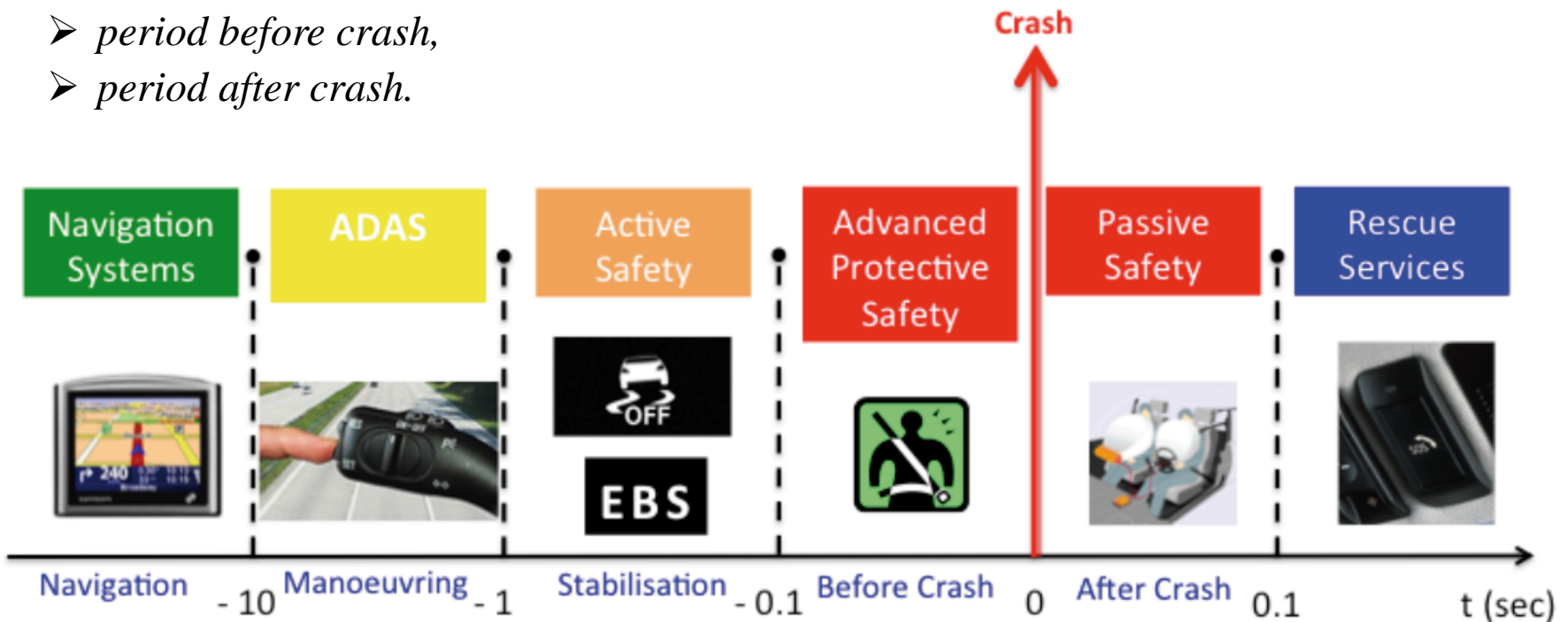
- reducing the driver workload
- Allow the driver to focusing on secondary tasks,
- safety applications to prevent or minimize collisions.

ADAS systems can be divided in four categories:

1. Active Safety (Adaptive Front Lightning-AFL, Traffic Sign recognition (TSR), Forward Collision Warning-FCW and collision mitigation)
2. Driver Support (Curve Speed Warning-CSW, Lane Departure Warning-LDW)
3. Driver Information (Speed information and Speed Limit Advisor, Black Spot Warning available in Japan)
4. Energy Efficiency (Adaptive Cruise Control-ACC, Powertrain Efficiency, Fuel Efficiency Advisor-FEA, Eco Routing and Eco Driving)

The safety ADAS can also be classified into categories according to the time before a potential impact. These categories are:

- *navigation period,*
- *maneuvering period,*
- *stabilization period,*
- *period before crash,*
- *period after crash.*



ADAS STATE-OF-THE-ART

Since 2000, ADAS systems have been the main focus of EU-funded research, mainly in the framework of the **eSafety** initiative and the EU-funded **SafeSpot** project.

eSafety systems are Intelligent Vehicle Safety Systems that use information and communication technologies in intelligent solutions, in order to increase road safety and reduce the number of accidents on Europe's roads.

The eSafety initiative was launched by the Commission in April 2002 with the aim to accelerate the development, deployment and use of eSafety systems bringing together:

- *European Commission,*
- *Member States,*
- *Road and safety authorities,*
- *Automotive industry,*
- *Telecommunications industry,*
- *Service providers,*
- *User organizations,*
- *Insurance industry,*
- *Technology providers,*
- *Research organizations and*
- *Road operators*

The aim of the EU-funded **SafeSpot** project was to develop a Safety Margin Assistant to:

- detects in advance potentially dangerous situations
- extends in space and time drivers awareness of the surrounding environment
- provide warnings in critical or dangerous situations on an on-board HMI.

SafeSpot has developed a set of technologies like:

- data fusion to combine information from different vehicle and roadside sensors
- Local Dynamic Map
- dynamic data store for safety critical location-based information, to enable intelligent cooperative systems to prevent road accidents.

Several prototype vehicle and infrastructure based applications have been developed based on the SafeSpot core technologies.

These applications constitute realistic examples of what could be the basic set of safety-related services available for connected vehicles in the near future and include:

- *Road Intersection Safety,*
- *Lane Change Manoeuvre,*
- *Safe Overtaking,*
- *Head On Collision Warning,*
- *Rear End Collision,*
- *Speed Limitation and Safety Distance,*
- *Frontal Collision Warning,*
- *Road Condition Status*
- *Slippery Road,*
- *Curve Warning and Vulnerable Road*
- *User Detection and Accident Avoidance.*

The market adoption of these systems is still very low due to the use of expensive sensors like radars.

However, today several driver assistance solutions can be provided based on simple cameras with sophisticated image processing techniques.

Mobileye is developing a vision-based ADAS targeted at collision avoidance and mitigation. Their image processing techniques can support applications like:

- *Vehicle detection,*
- *Forward Collision Warning,*
- *Lane Departure Warning,*
- *Pedestrian detection,*
- *Traffic Sign Recognition*
- *Intelligent Headlight Control.*

Mobileye is currently also providing a standalone portable device with built-in camera for autonomous recognition and warning applications.

Eco-driving enabled ADAS

Eco-driving assistance systems are applications that encourage economical driving behaviours and support the driver in optimizing his driving style to achieve fuel economy and consequently emission reduction.

They constitute an essential feature for hybrid vehicles and have been introduced by several manufacturers for their hybrid vehicle range. For example:

- The **Honda Insight Eco Assist** is a sophisticated feedback system that teaches the driver to drive more efficiently;
- **Ford Fusion** and **Mercury Milan Smart Gauge display** eco-driving related information along with fuel and battery power levels;
- **Fiat eco:Drive** provides the ability to record the journey on a USB stick while driving and allows to check the journey data on a computer

In this context, navigation system manufacturers have recently introduced the first driver assistance systems with support for fuel economy. For example,

- **Garmin** provides the **ecoRoute** software for its **nüvi devices**, which allows: the driver to calculate the most fuel-efficient route, based on road speed information and vehicle acceleration
- **TomTom** provides a device called **ecoPLUS** that measures and benchmarks vehicle fuel efficiency and carbon footprint,
- **Crambo labs** provide the **Econav** software, which gives real time indications about efficient gear and optimal speed to achieve up to 30% fuel and CO2 savings.

MAP-ENABLED ADAS

Sensors commonly used in ADAS applications help provide relevant contextual information to a vehicle, including road conditions in front of the vehicle.

The range of these sensor inputs is confined to a relatively close proximity around the vehicle's path. If compared to the depth of road information available in a map,

Map attributes can be thought as a type of sensor which enhance the performance of Driver Assistance Systems providing enabling contents such as:

- *Geometry,*
- *Curvature,*
- *Height/Slope,*
- *Speed limit*
- *Lane information*

For eco-driving or eco-routing applications, traffic lights and stop signs can be additionally useful. Applications where the Map attributes are necessary include:

- *Speed Limit Warning,*
- *Hazard or Black Spot Warning,*
- *Curve Speed Warning,*
- *Dynamic Pass Prediction,*
- *Ecodriving based on road geometry,*
- *Adaptive Front lights,*
- *Predictive Cruise Control*
- *Hybrid Powertrain Management*

Commercial products that exploit Map attributes are:

- **NAVTEQ's Green Streets map** product that provides green driving and green routing applications, along with Traffic patterns and Real-Time Traffic information,
- the **BMW ACC system** launched in 2005,
- the **Daimler RunSmart Predictive Cruise Control (PCC)** system launched for the Freightliner Trucks in 2009. This system:
 - *evaluates upcoming road profile one mile ahead*
 - *anticipates road grades by using GPS and 3D digital map technology*
 - *adjusts the actual speed of the truck for maximum fuel efficiency based on the terrain while staying within 6% of the set speed.*
- Another solution of **NAVTEQ** dedicated to map-based ADAS is the **Map and Positioning Engine (MPE)** which consists of:
 - *an embedded ADAS map*
 - *an Electronic Horizon used for applications ranging from driver assistance to active safety and enhanced fuel economy.*

EcoGem ADAS

All of the ADAS systems described previously were developed:

- primarily to enhance driver safety and comfort,
- secondarily to help reduce fuel consumption.

The EcoGem project goes one step further by proposing an ADAS especially designed for Fully Electric Vehicles (FEVs).

FEVs present some special characteristics due to their electrical nature. In particular, the following factors should be taken into consideration as they effect the vehicle range autonomy:

- their energy storage capabilities are limited,
- their recharging time are long

EcoGem is designed to provide extra functionalities that ensures a comfortable and relaxed driving. The attempt is to eliminate the driver anxiety regarding:

- the distance to charging station,
- the next time of charging,
- the destination reachability,

The EcoGem ADAS renders the FEV capable of reaching the desired destination(s) through the most energy efficient route(s) by:

- autonomous optimised route planning exploiting vehicle's own tracked records,
- cooperative optimised route planning exploiting vehicle-to-vehicle (V2V) interactions to share its route selection experiences with other EcoGem FEVs..
- cooperative optimised route planning exploiting vehicle-to-infrastructure (V2I) communication in case for instance, of Centralised fleet management.

In all planning schemes, the most energy efficient route calculation is achieved by applying machine learning algorithms on past tracked data records. These data records include:

- energy consumption information per entire route and per route segment,
- time-related information like time-zone and month,
- vehicle-specific information like battery info and consumption rate,
- map-related information like road segment inclination and length,
- weather-related information like humidity.

The EcoGem ADAS is also responsible for:

- continuous awareness of recharging points
- optimised recharging planning.

Based on the current battery levels, energy consumption rate and contextual information (desired destination, present location, daytime, traffic, user agenda, etc.), the EcoGem ADAS can prompt the driver, whenever necessary, to:

- select a recharging option (normal or fast recharging, or battery replacement)
- to book the most convenient recharging point.

Booking in advance allows for exclusive access to the recharging point at the time of arrival. The ADAS must:

- ensure that the recharging point is reached on time, by informing the driver about the optimal route to the recharging station,
- also minimise the detour caused to the driver.

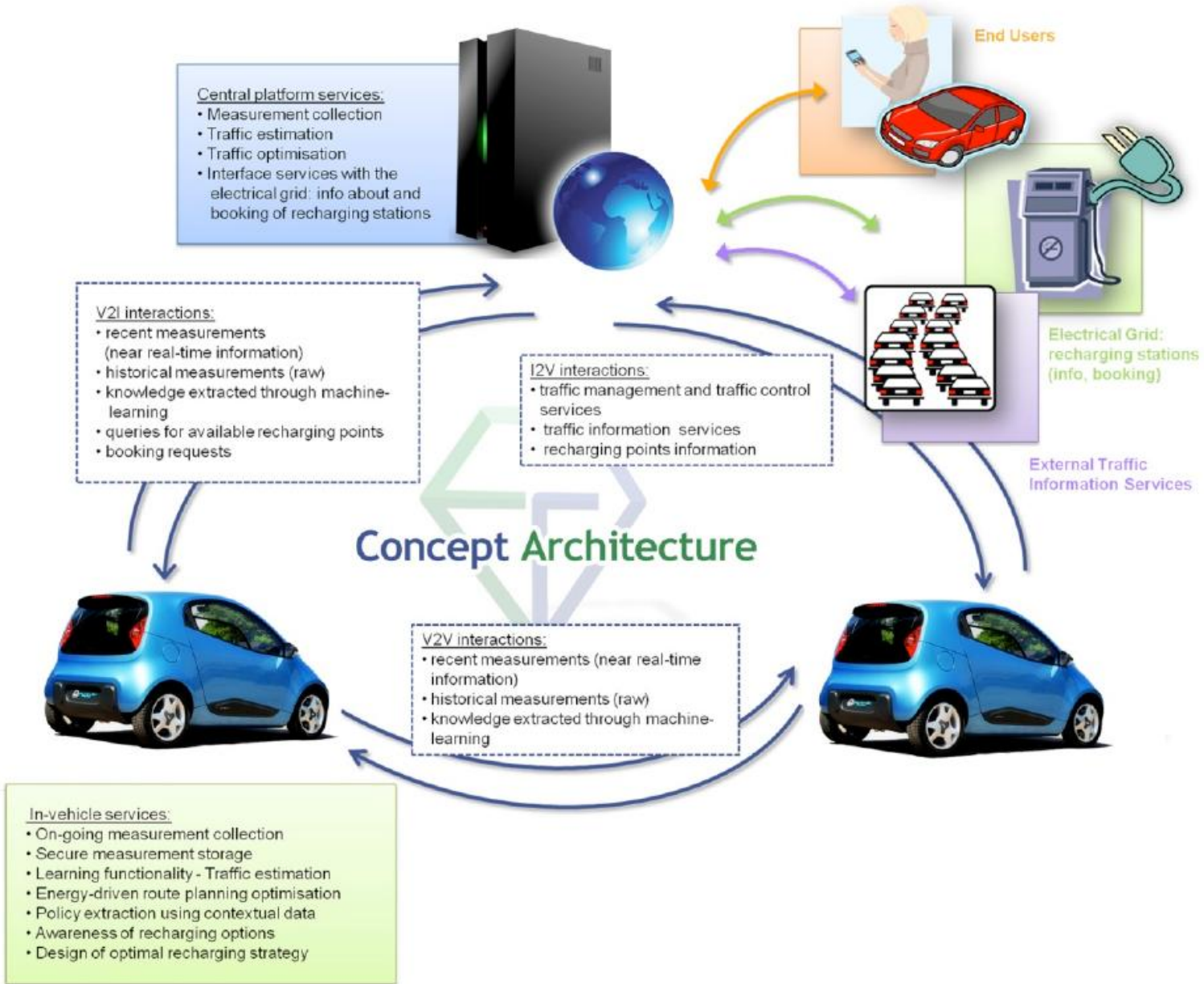
Recharging management is a very critical issue considering the sensitivity and vulnerability of rechargeable electrical batteries. The lifetime and usable energy level of the battery are effected by:

- Timing of charging, state-of-charge (SOC) level at the moment of charging,
- SOC target at the end of charging process,
- frequency of charging

Thus, **EcoGem** provides an important tool for both the vehicle and battery manufacturer to predict much more precisely the SOC levels at distances ahead.

Data regarding the availability of the nearest charging stations, as well as the traffic and road conditions data in alternative paths, can give the input required to choose the best alternative station, taking into account:

- the minimum charging level required,
- the actual condition of the battery cells
- the amount of time available for charging.
- Different charging methods (fast charging, standard charging, or battery swapping).



In-vehicle functionality:

- on-going on-board collection of measurements (i.e., travelled routes, time spent on each route, battery consumption, etc.);
- on-going collection of measurements and knowledge extracted by cooperating EcoGem vehicles or received from the central platform;
- secure storage of the gathered, multi-source measurements and information;
- learning and reasoning on the available information for automatic classification of potential routes according to their degree of congestion (traffic estimation), which allows for optimal route planning;
- extraction of policies, i.e. traffic-related conclusions and decisions according to the current context, based on past experience;
- sharing of local information with the platform and other EcoGem vehicles;
- energy-driven optimised route planning based on road characteristics from the ADAS map database (e.g., road slopes) and the estimated degrees of congestion;
- continuous awareness of surrounding recharging points (estimated distances, availabilities, etc.);
- design of the best recharging strategy, based on available battery levels, current position, desired destination, recharging point availability, traffic, daytime, user agenda, etc.

Central **platform functionality** targeted for:

- collection of measurements and knowledge from the EcoGem-enabled vehicles;
- integration and joint exploitation of additional traffic data originating from other, alternative traffic monitoring systems;
- large-scale traffic prediction, through processing of gathered multi-source information;
- optimal traffic distribution (traffic optimisation), based on the traffic estimations;
- optimal traffic control/management actions (instructions and suggestions) and enhanced traffic information services;
- online monitoring and management of recharging points;
- provision of access to the rich information of the platform (service-enabling functionality) to external entities, such as end-users and electrical recharging point providers.

V2V and V2I interactions for conveying:

- recent measurements (recently acquired traffic data that most probably are still valid);
- historical measurements (that mainly serve as training data for the machine-learning engines of the EcoGem vehicles);
- knowledge extracted through machine-learning based processing (route classifications, route selections, derived policies).
- V2I/I2V interactions are responsible for enabling awareness of recharging options and booking of recharging points,
- I2V one-way interactions may provide traffic control instructions and suggestions.

Based on the functionality described above, the EcoGem ADAS calculates several routes to the desired destination based on different parameters. These alternatives are presented to the driver via a user-friendly interface and he is responsible for the final choice.

Furthermore, the EcoGem ADAS may recommend modifications in the operation of the electrified auxiliaries, in order to reduce vehicle's energy consumption and enable it to reach the desired destination.

The selections that are made by the driver each time may be saved in order to constitute his/her profile characteristics. A selected route may be saved to the EcoGem ADAS in order to allow the driver to load it at a later time and avoid new calculations.

This functionality imposes the necessity for support of multiple user profiles as several drivers may use the same vehicle. Each driver usually has his/her own set of preferences and saved routes. Thus, the EcoGem ADAS shall recognise each driver in order to load the corresponding preferences and routes, and make the trip more comfortable.

The user profiling feature of the EcoGem ADAS also enforced the development of security and privacy mechanisms.

Future work includes:

- simulated testing of the EcoGem ADAS (using a micro-simulation method)
- trial sites testing using real vehicles.

Vehicles that will be used include Pininfarina's Nido, an urban 2-seater FEV, and TEMSA's electric bus.

Trials will help:

- systematically quantifying the benefits stemming from the use of the EcoGem ADAS
- make any improvements necessary for promoting user adoption.



Structure: **aluminium alloy space frame integrated with light composite modules**

Exterior : **thermoplastic panels or not painted (solid mass colour)**

Powertrain: **permanent magnet electric motor at rear axle, inverter & AC/DC converter integrated, max output 60 KW**

Battery: **Li-Ion capacity 22 KWh**

Chassis: **front Mc Pherson suspension, rear trailing arms**

Configurations: **car / van / (pick-up)**

Seats: **2+1**



Target description	Conditions	Unit	Value
Weight	Odm, no OPT, no battery	Kg	700
Battery		kg	150
% mass A std.	(rear axle)	%	54
% mass full load (3 people)	(rear axle)	%	56
Acc. 0-50 Kph	Driver only, full charged battery (100%)	s	6.9
Vmax	Driver only, full charged battery (100%), level road	kph	120
Max power	continuously	kW	30
Max torque		Nm	140
Battery rated energy		kWh	22-23
Time to fully recharge battery		h	7
Autonomy	Full charged battery (100%), NEDC cycle	km	140
Max slope	Full load, full charged battery (100%)	%	20