Long trip simulations and realisation – Part 1

Simulating long trips

- Driving from Stuttgart, Germany, to Nice, France, over the Alps > 830 km
- Using a FIAT 500e with **38** kWh – but simulating larger battery sizes, up to 68 kWh.
- And using fast charging infrastructure (50 kW to 85 kW) existing today.

Simulating a challenging long trip

- Some important relevant data when driving over the Alps

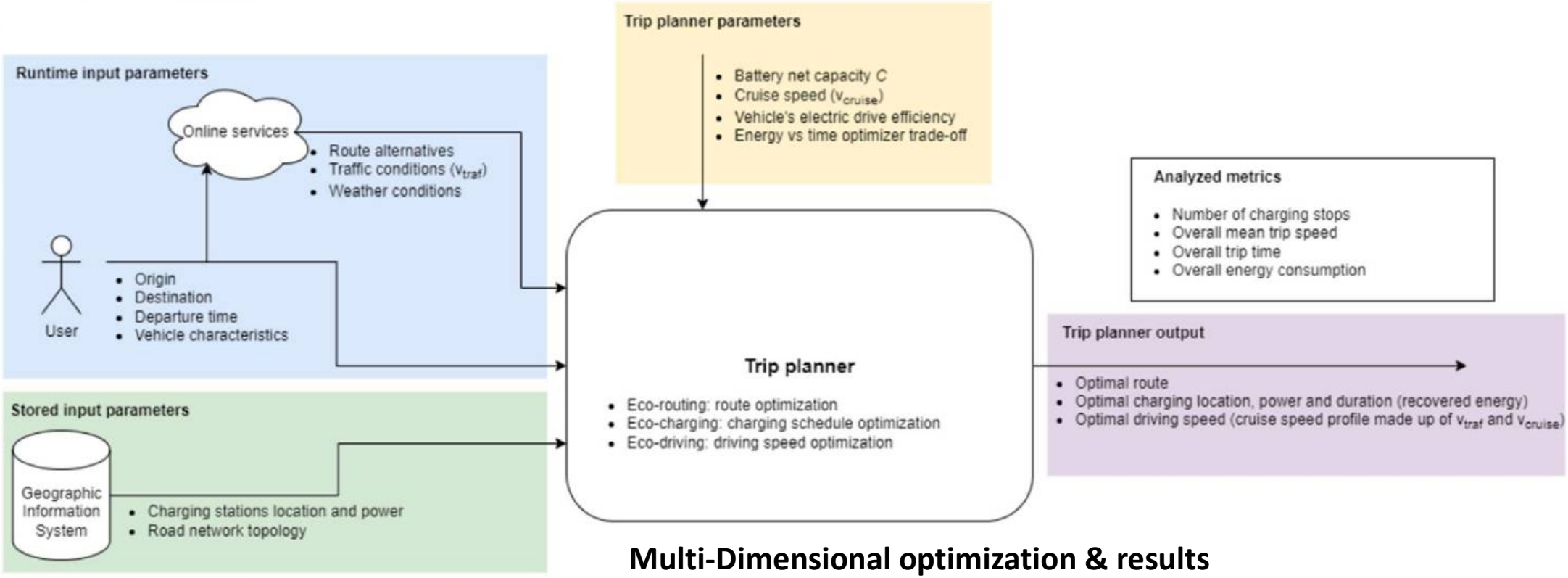
Stuttgart = [48.781072, 9.168463];
Nice = [43.697915, 7.266883];
Time = **15/03/2022 at 8am;**

ICE: Trip time from HERE WeGo is 9h:41min

831km➔ + 1h 15min = **10h56min allowed**
w/o Bio & Safety Stops

Optimizer and simulation environment

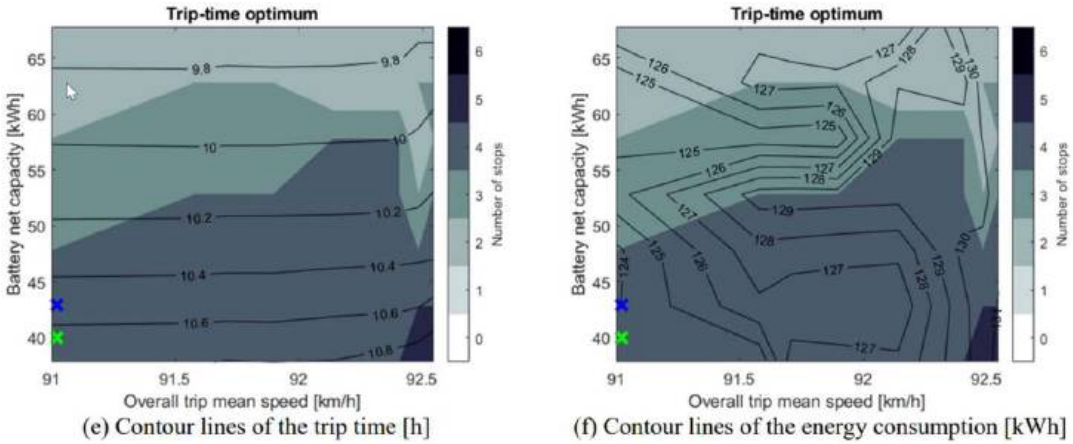
- Simulation environment built up by IFPEN (in OPTEMUS and CEVOLVER)



Multi-Dimensional optimization & results

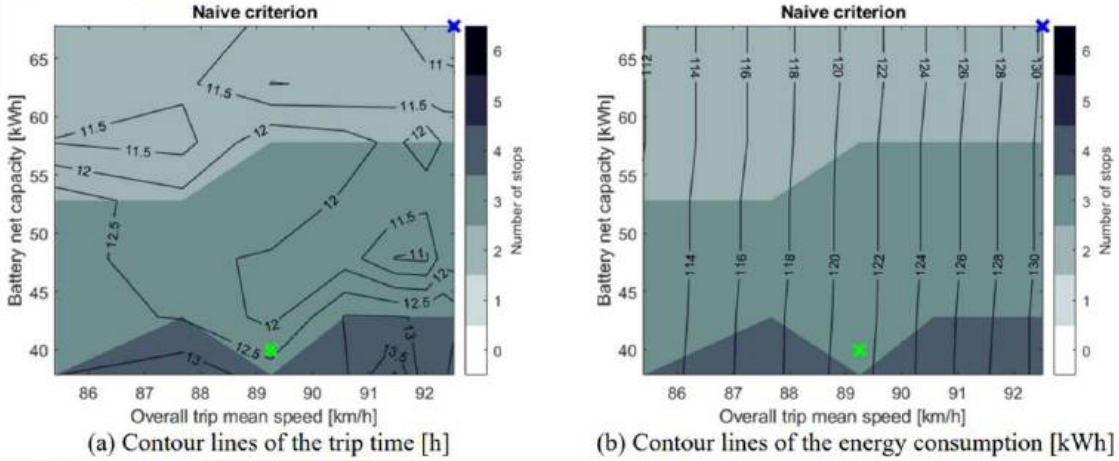
Results of two simulation scenarios

- The unsupported driver vs. the supported driver
- Challenge → plotting multi-dimensional results
- Plots show:
  - Variation of battery size
  - Number of stops
  - Mean trip speed
  - Trip duration (and energy consumption)



(e) Contour lines of the trip time [h] (f) Contour lines of the energy consumption [kWh]

Unsupported driver



(a) Contour lines of the trip time [h] (b) Contour lines of the energy consumption [kWh]

Supported driving

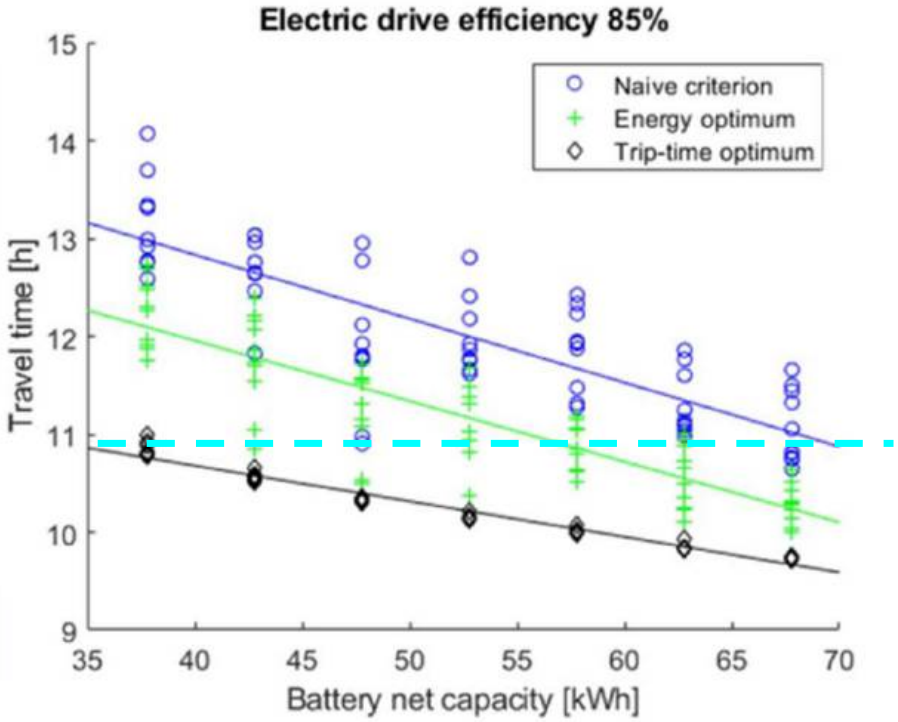
- Significant **advantages** for supported driving
- Reduction of trip time (for appr. 830km)
  appr. 50 min. using 63kWh vs. 38kWh battery
  (in trip time optimization - mode)

Summary of long time simulation results

- Supported driving reduces dependency on battery size.
- Travel time plotted for varying battery capacities and variations of the cruise speed, at each battery size.

Current drivers

CEVOLVER Solutions



831km➔ + 1h 15min = **10h56min allowed**
w/o Bio & Safety Stops

Summary of simulating long trips

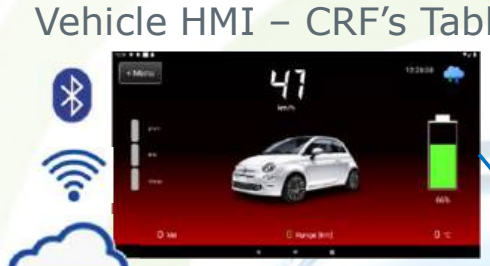
- It is clear why *unsupported* drivers today are dependent on larger batteries
  - **Current driving habits** make long trips only doable with large batteries
    - Speed control has contradictory targets: save energy and minimize trip time
    - Fast charging based on SoC "comfort zone" – Don't get below *XX*% SoC
- Large batteries are necessary today for occasional long trips, but not needed for daily use

- With CEVOLVER solutions it is possible to visualize tradeoffs and make **conscious decisions**
  - Save money by choosing a smaller battery and accepting additional stops
  - Or spend more money on larger battery if an additional stop is not acceptable

- **Intelligent CEVOLVER solutions** tackle both speed control and smart charging
- Decreasing battery size is possible if one or two additional stops are acceptable
- Long trips are doable with smaller batteries – even today.
- **Users** must **always have a choice** to select the solution that best fits their needs

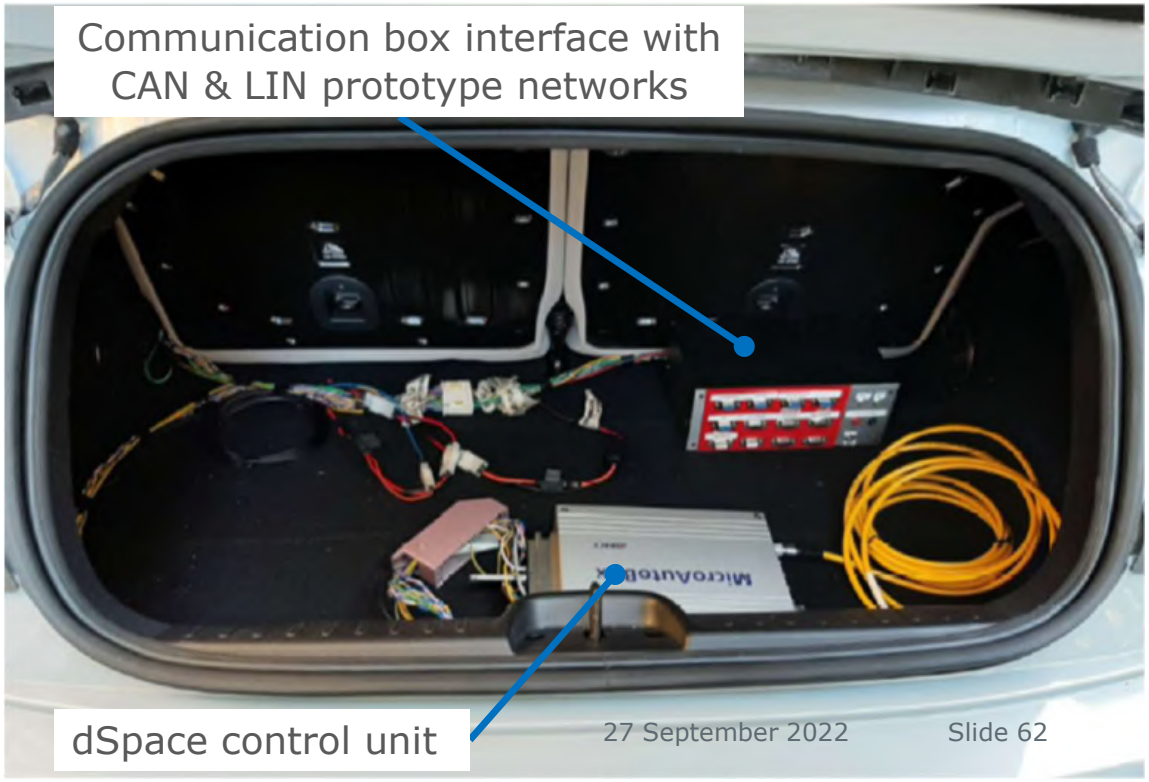
Long trip simulations and realisation – Part 2

Vehicle Validator 2: Extended Vehicle Architecture Topology



Vehicle Validator 2 (based on New Fiat 500e High RANGE)

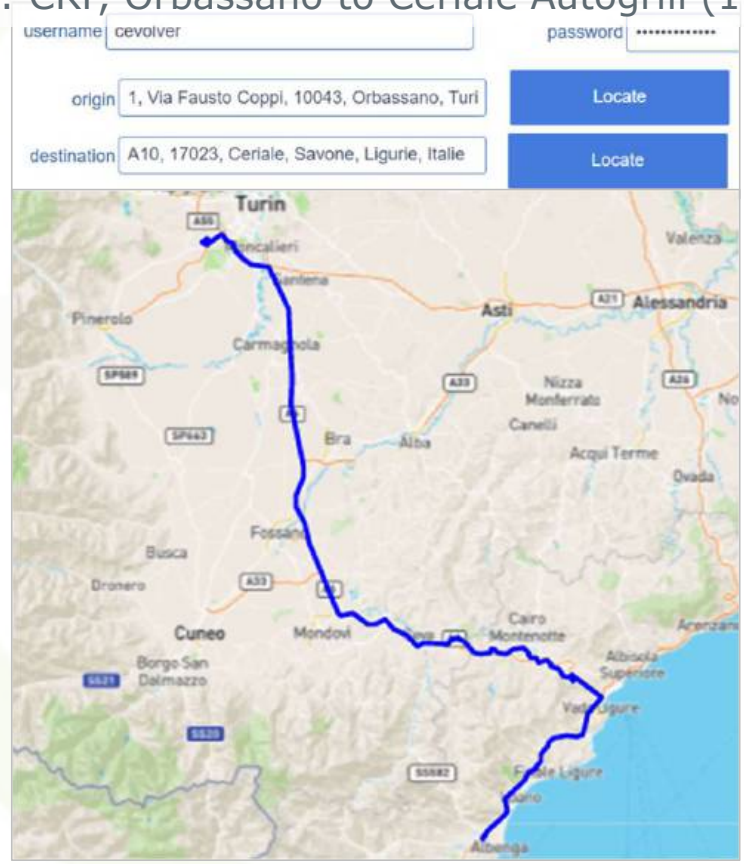
- DC fast charging (85 kW peak) & 42 kWh battery pack
- resistive heater-based control
- cloud connection
- vehicle HMI with wireless communication with dSpace dedicated CAN



Long Trip realization

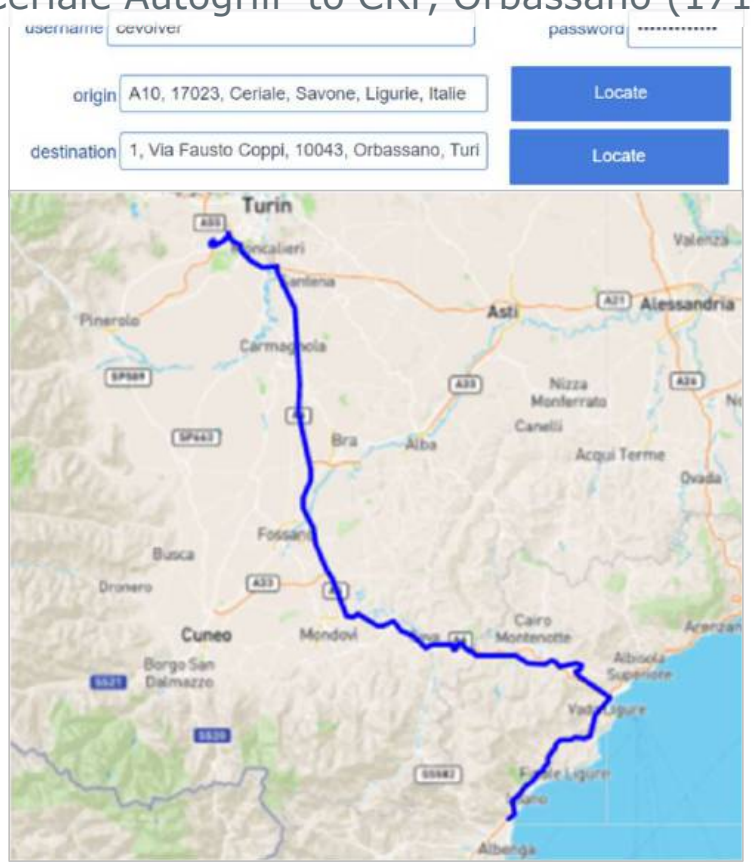
Use case: Private visit to relatives (350+350 km)

From: CRF, Orbassano to Ceriale Autogrill (179 km)



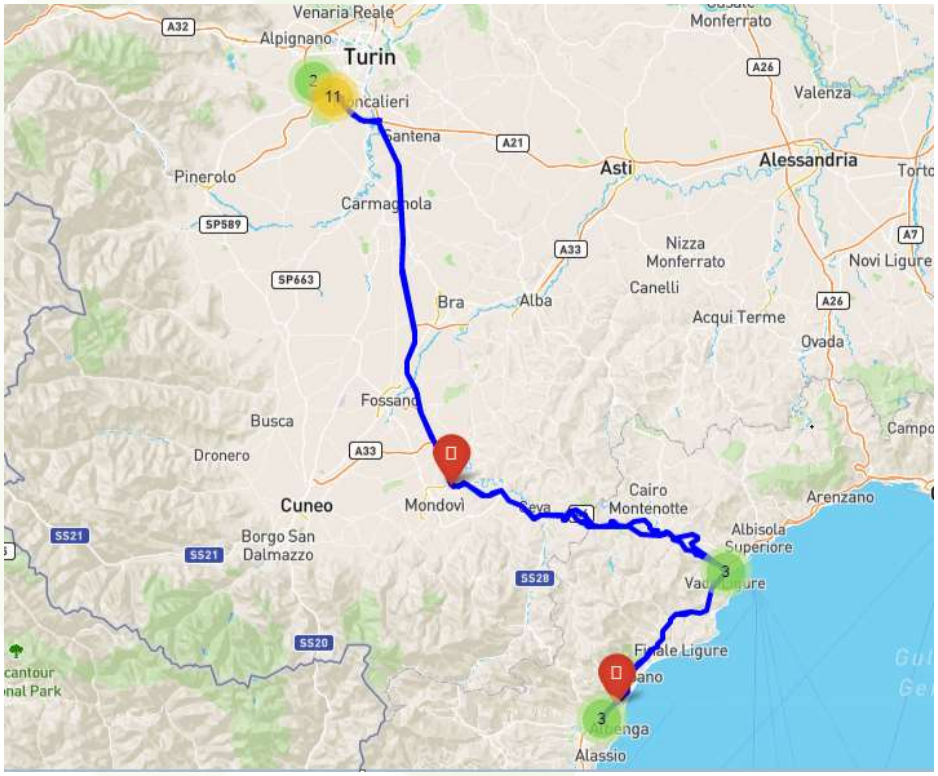
Total: 350 km
Twice to reach 700km

From: Ceriale Autogrill to CRF, Orbassano (171 km)

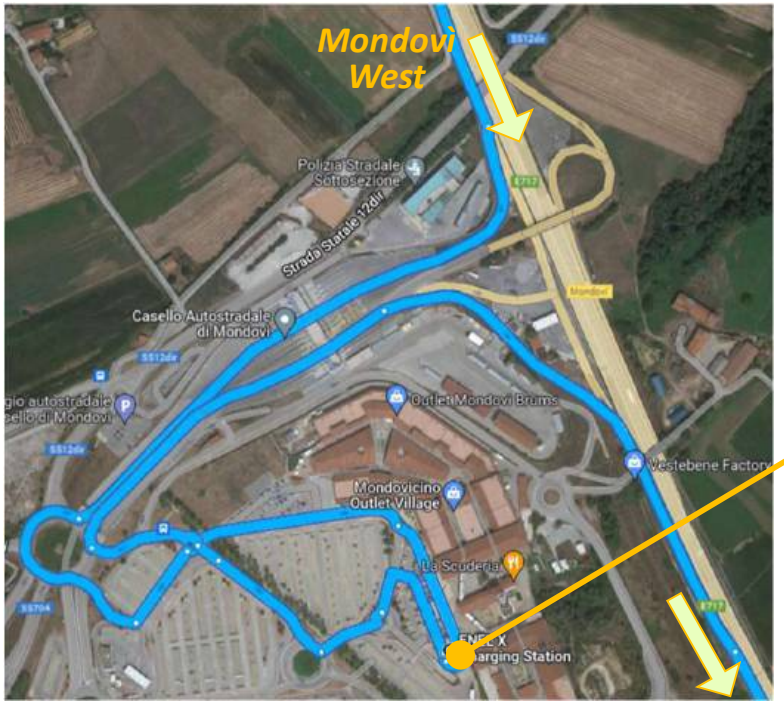


Long Trip realization

Eco-charging route definition 1#2



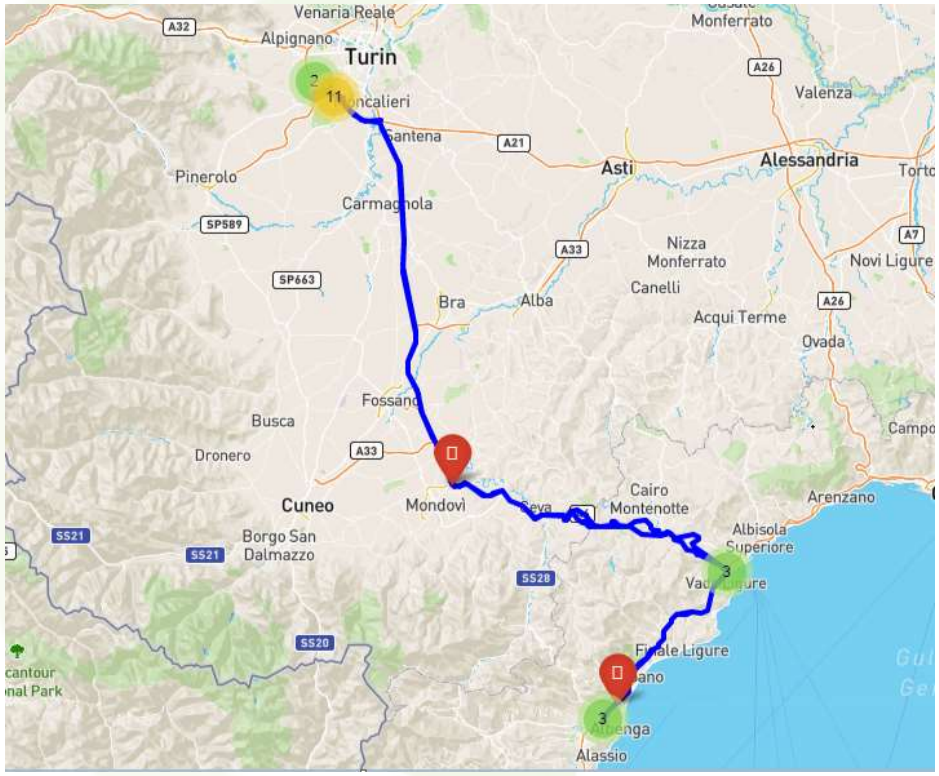
Start: CRF, Orbassano



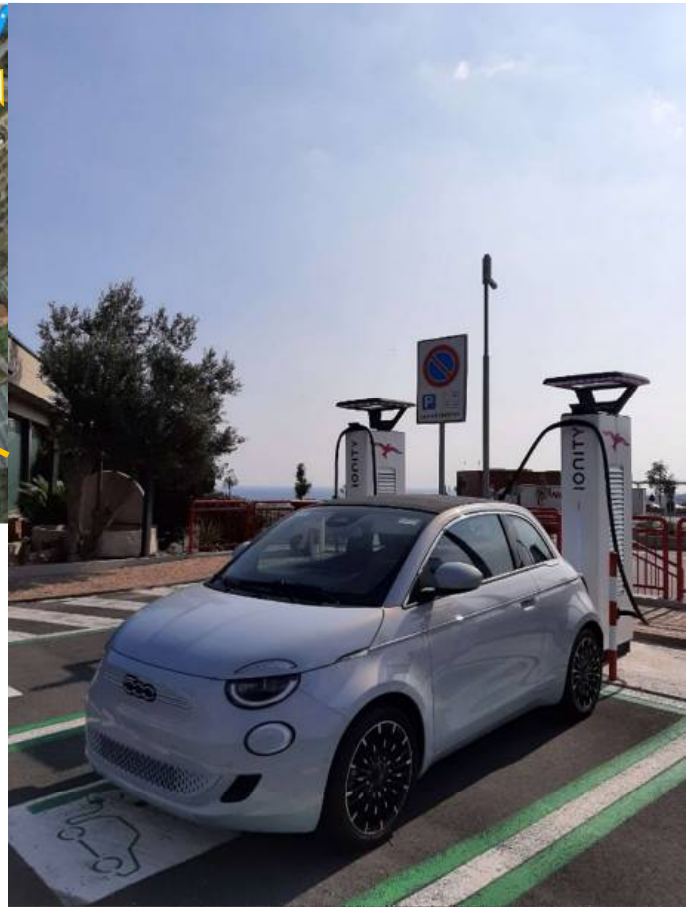
Charging in Mondovì

Long Trip realization

Eco-charging route definition 2#2



Charging in Ceriale



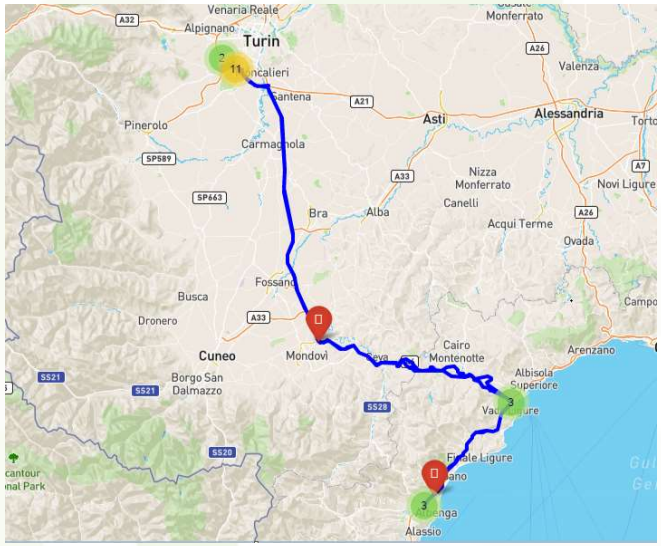
- Charging in Mondovì East
- Return in CRF

Long Trip with Vehicle Validator 2

CEVOLVER Advanced Functions implemented on CRF's Vehicle Validators 2

- ECO – CHARGING (ECO - Routing + Charge Stop Planning)
- BATTERY THERMAL PRECONDITIONING for DC Fast Charge
- ECO – DRIVING

Long Trip with Validator 2: Experimental Results



$$\eta_{E_{batt}} = \frac{E_{batt,bsl} - E_{batt,eco}}{E_{batt,bsl}} \times 100$$

$$\eta_t = \frac{t_{tot,eco} - t_{tot,bsl}}{t_{tot,bsl}} \times 100$$

Eco-Charging Evaluations

$\eta_{E_{batt}}$ = **7,6%**

η_t = **- 9,7%**

CHARGING TIME **- 47%**

Eco-Driving Evaluations

$\eta_{E_{batt}}$ = **11,6%**

η_t = **+3,7%**

Average results on a set of XYZ testing days

Long Trip with Validator 2: Experimental Results

$$TT_{\text{RelChargeTimeGain}} = \frac{\Delta t_{\text{baselinecharge}} - \Delta t_{\text{smartfastcharge}}}{\Delta t_{\text{baselinecharge}}} \cdot 100\%$$

Smart fast Charge

$TT_{\text{RelChargeTimeGain}}(10°C) =$ **13,7%**

$TT_{\text{RelChargeTimeGain}}(0°C) =$ **29,2%**

Summary of realization long trips

- Eco-Driving speed indication 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 **11,6%**, compared with a fast charging based on SoC "comfort zone". Even more relevant effect at charging time level, reduced by an half (**-47%**)
- Battery Thermal Preconditioning offer a further charging time reduction, especially in cold conditions: **13,7%** @10°C and **29,2%** @0°C

- The **intelligent CEVOLVER solutions** tackled both speed control and smart charging, making long trip realization possible with one or two additional stops
- The smaller available battery allowed long trips realization with reduced effect on final user, while saving cost/resources due to a larger battery (and relative energy consumption) not needed for daily use

Video of vehicle validators and test realization