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# Analysis and assessment of the electrification of urban transport based on real-life mobility data

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**European Commission DG Joint Research Centre**

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# JRC at a glance

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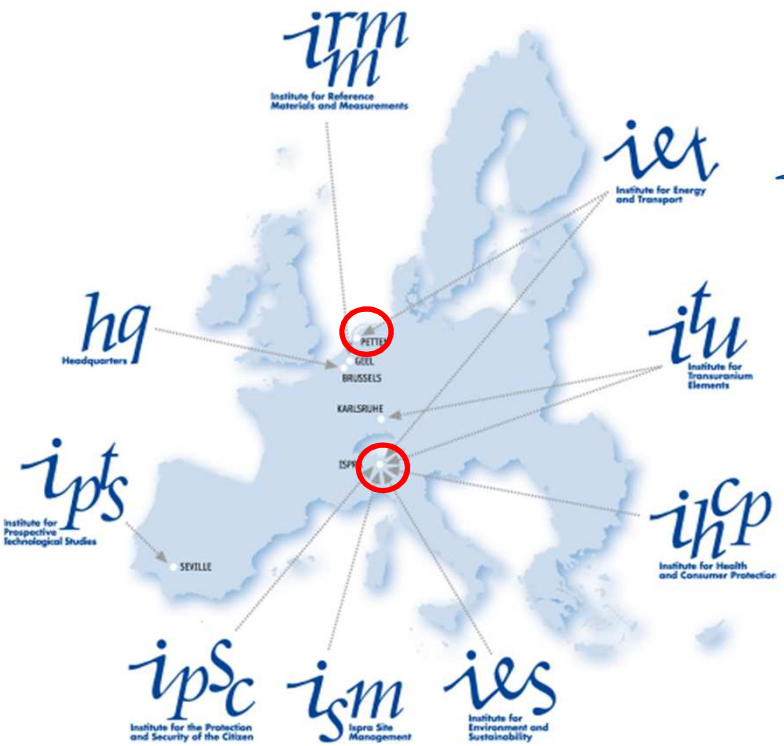


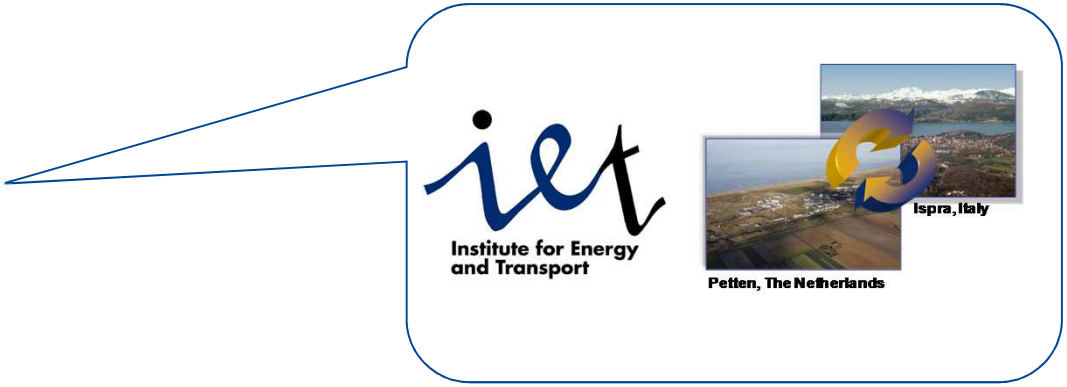


With its 7 institutes the JRC is the European Commission's in-house science service

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# Institute for Energy and Transport

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Joint Research Centre


Within the Sustainable Transport Unit of the IET we do:

-Pre-normative research on HEV/EVs.

- Experimental testing in the **V**ehicle **E**missions **LA**boratories (VELA).

- Desktop research on mobility and transport analyses.

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# Outlook

- Scope of the work
- Activity databases description
- E-mobility model features
- Results: Travel behavior
  EVs usability
  Impact on the electricity grid
  GIS-based spatial distributions
- Conclusions

# Scope of the work

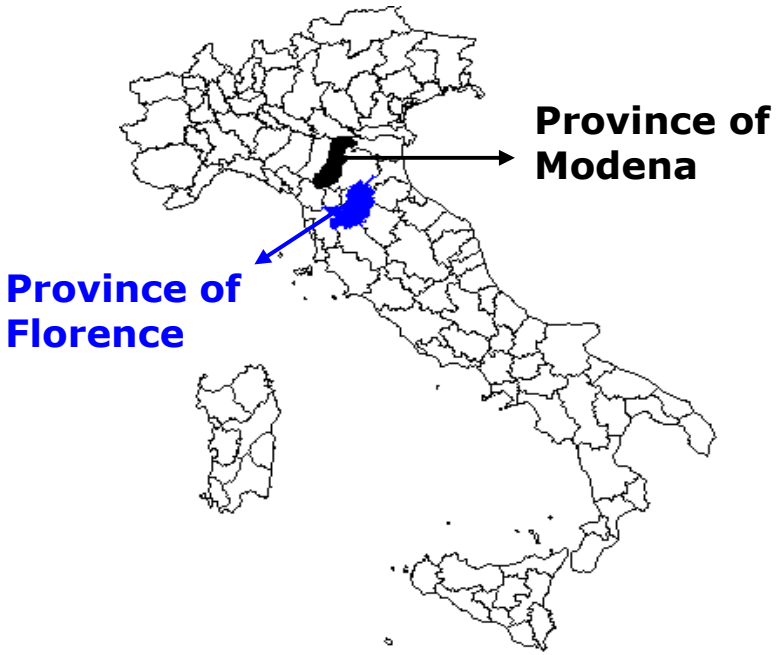
- Large-scale implementation of e-vehicles is a topic of interest to be addressed;
- Despite the progresses done in the last decades, there are still many open issues, e.g. limited range of BEV, life-cycle assessment of their parts and components, long-term sustainability of Li-ion batteries and their integration within urban environments and electricity grid.
- The DG JRC IET has initiated a new activity on electro-mobility, which includes supporting standardisation, addressing the interoperability between e-vehicles and smart grids, proving testing facilities for electric vehicles, smart grid, vehicles batteries and related equipments.
- Among all these activities a new study targeted to large scale activity databases analysis and EVs modelling has been initiated.

# Activity databases description

Activity databases ⟺ databases of GPS driving patterns

- Vehicle ID number (anonymous, private/commercial conventional fuel vehicles)
- Calendar date and time [sec]
- Latitude and Longitude (GPS accuracy)
- Engine and travel data (e.g. engine status, distance driven, etc.)
- Acquisition frequency variable (≈ 0.01 Hz, but it always ensures the trips reconstruction).

# Activity databases description




| | Population (total) | Province Area | Population (density) |
|---|---|---|---|
| Province of Modena | 706,509 (31/03/2012) | 2,688.7 km$^2$ | 262.77/km$^2$ |
| Province of Firenze | 1,002,831 (31/07/2011) | 3,514.0 km$^2$ | 285.38/km$^2$ |

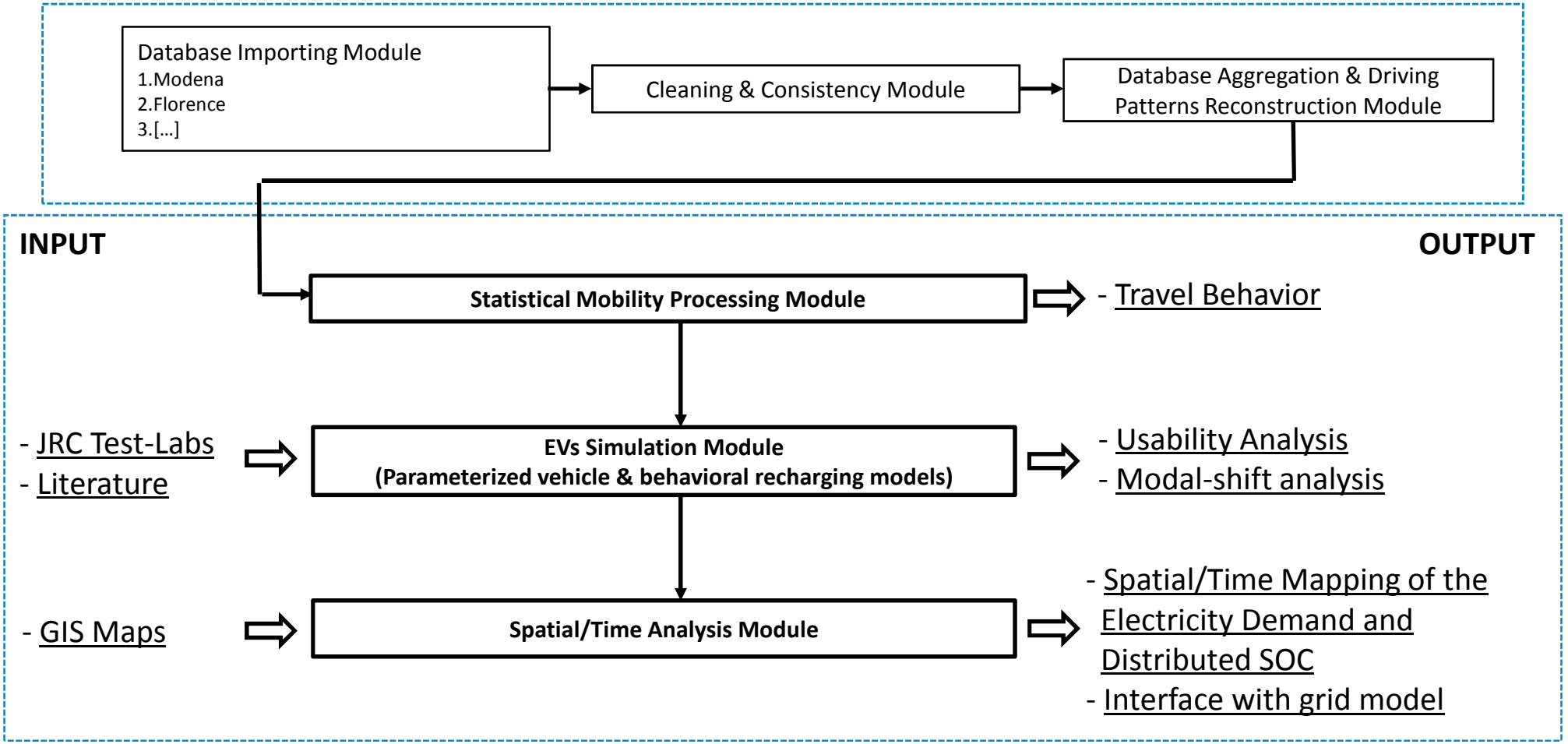
| Registered Vehicles Vehicles per Person | Surveyed Vehicles (% of the total) | Analysed Sample (% of the surveyed) |
|---|---|---|
| 441,609 – 0.62 (31/12/2011) | 52,834 (12.0%) | 16,263 (30.7%) |
| 684,005 – 0.68 (31/12/2011) | 40,459 (5.9%) | 12,478 (30.8%) |

**Urban Vehicles**

Modena Only

16223 EVs ⇨ $16 \cdot 10^6$ Records ⇨ $14.9 \cdot 10^6$ Kms ⇨ $2.6 \cdot 10^6$ Trips

# E-mobility model features



# E-mobility model features

**EV Simulation Model**

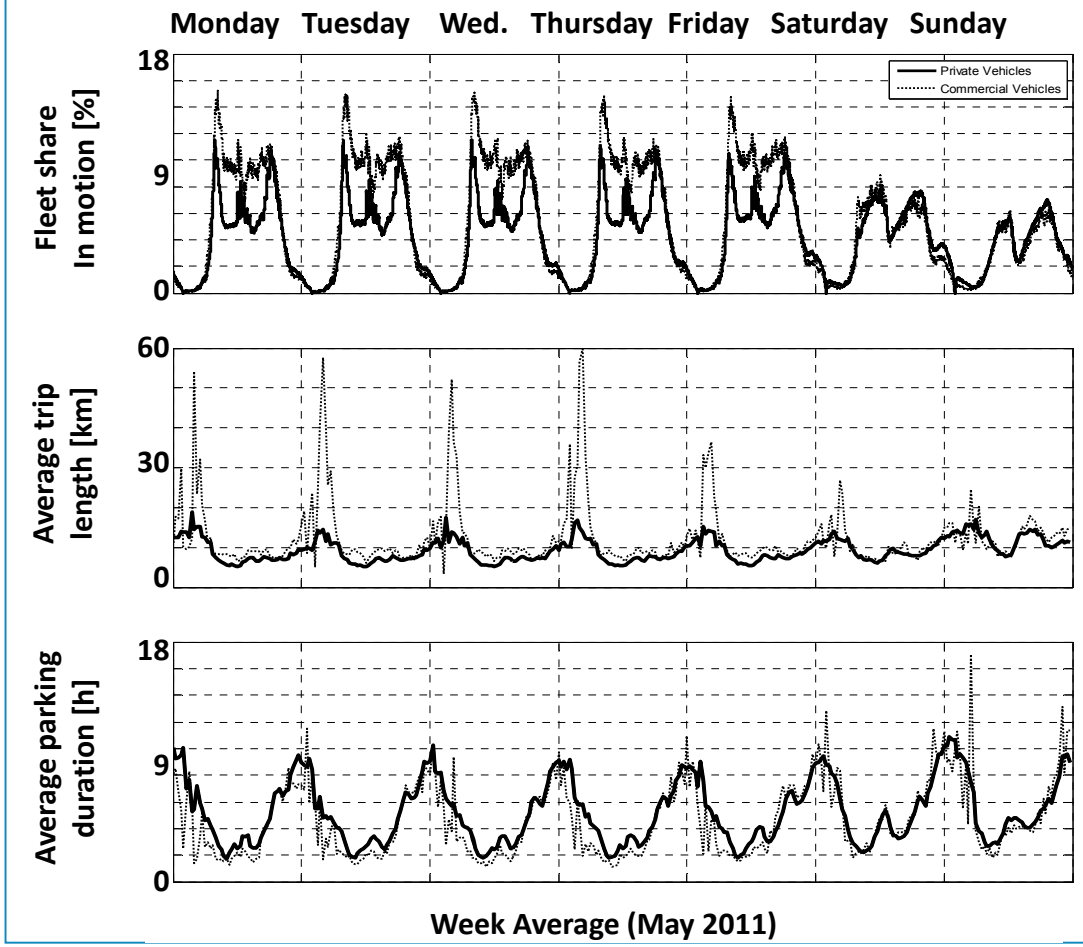
•All the conventional fuel vehicles in the databases are replaced by EVs.
6 EVs models are implemented, the results of 2 of them are presented:

- Small size (4 seats) passenger car: 1080 kg - 47 kW Eng. - 16 kWh Batt. - 185 Wh/km;
- Medium size (5 seats) passenger car: 1520 kg - 80 kW Eng. - 24 kWh Batt. - 210 Wh/km;

•Each trip is considered as a **discharge event** and each parking as a **recharge opportunity**;
15 behavioral recharges models are implemented, the results of 3 of them are presented:

- Long-Stop Random AC (2 kW): Stop > 120 minutes AND Random threshold > 0.6;
- Short-Stop Random DC (40 kW): Stop > 20 minutes AND Random threshold > 0.6;
- Smart AC (2 kW): Stop within 4 hrs (+/-2 hrs) from the minimum of electric demand peak load.

# Results: Travel behavior



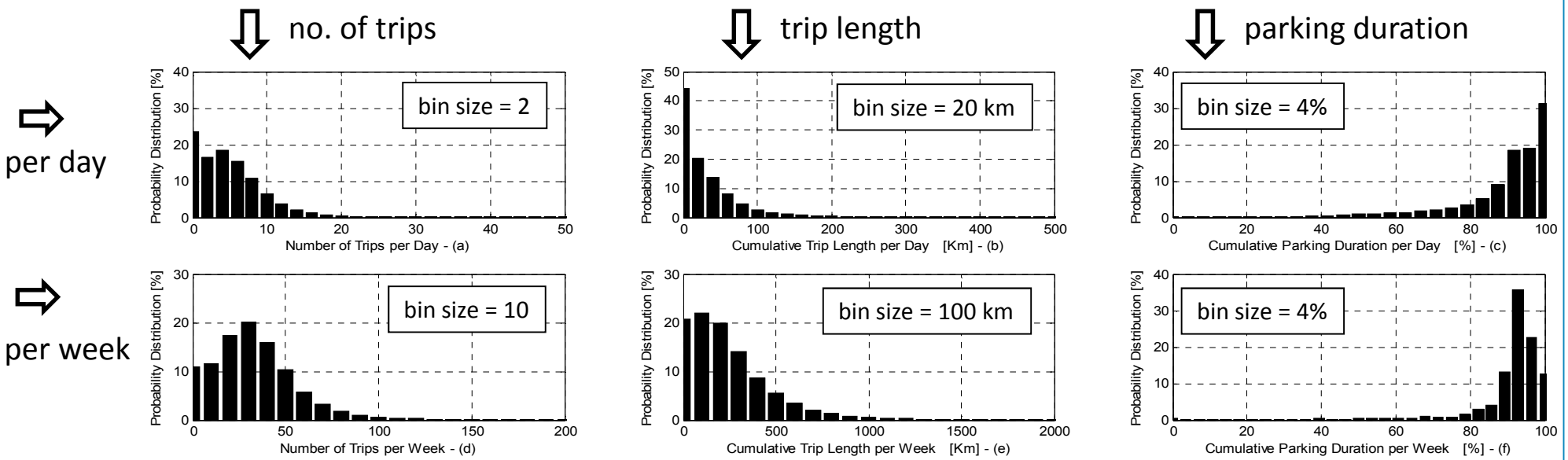

- 3 peaks from Monday to Friday
- 2 peaks on Saturday on Sunday
- private < 11.5%, commercial < 15.2%

Private vehicles (≈ 91%):
- trip between 5 and 20 km
- parking between 2 and 12 hrs

Commercial vehicles (≈ 9%):
- trips between 5 and 60 km
- parking between 2 and 16 hrs

# Results: Travel behavior

## Probability Distributions



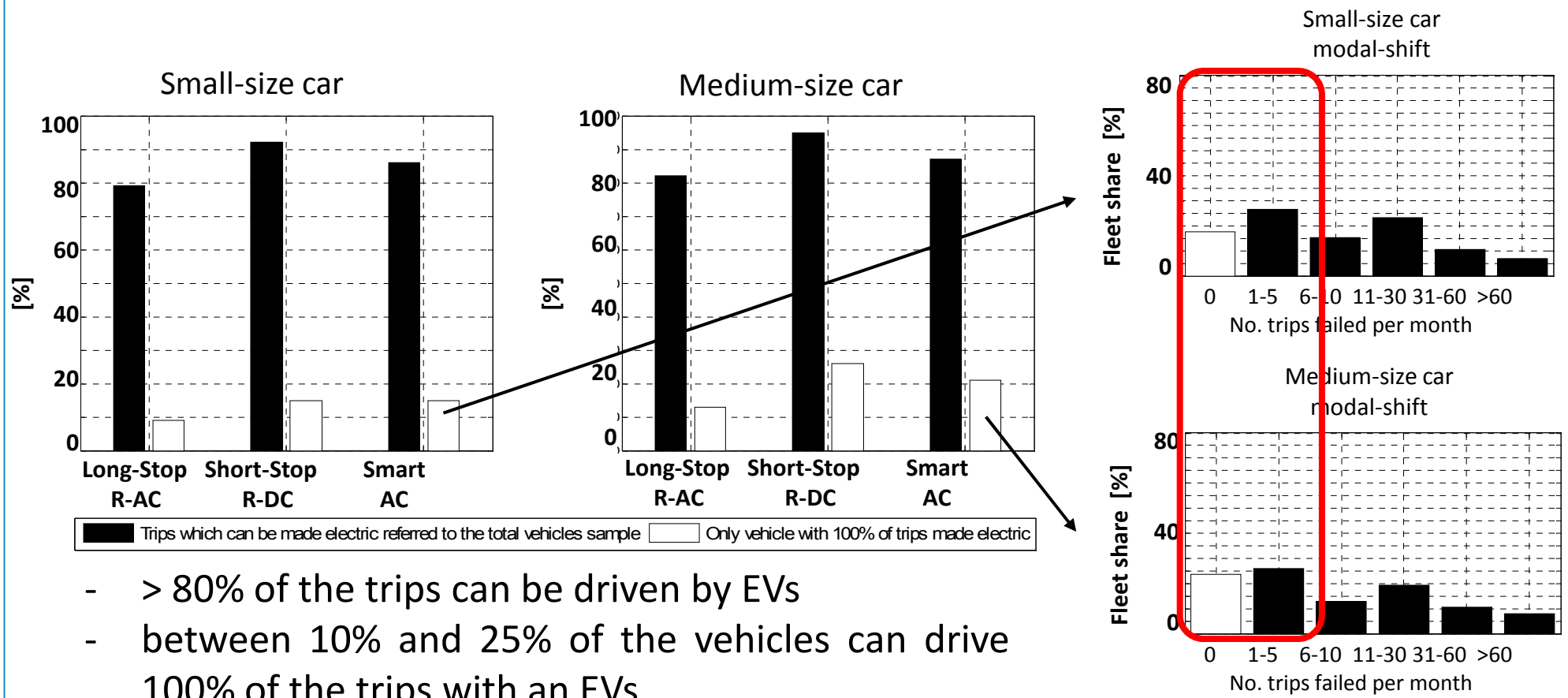

more than 50% sample does:

- < 6 trips/day AND < 20 km/day → < 60 km/day (75%)
- < 20 trips/week AND < 200 km/week → < 300 km/week (75%)

**> 70% cars are parked for more than 90% of the time**

**9 % of the sample exceeds 100 km/day, reducing to 3% exceeding 150 km/day!**

# Results: EVs usability




- > 80% of the trips can be driven by EVs
- between 10% and 25% of the vehicles can drive 100% of the trips with an EVs

50% EVs by shifting < 5 trips per month

# Results: Impact on the electricity grid

## No. of recharges per day/month

| Strategy / EV type | | Averaged number of recharges | | |
|---|---|---|---|---|
| | | Str. 1 Long-Stop R-AC | Str. 2 Short-Stop R-DC | Str. 3 Smart-AC |
| Small size car | *d:* | 0.44 | 0.95 | 0.64 |
| | *m:* | 13.51 | 29.31 | 19.60 |
| Medium size car | *d:* | 0.52 | 1.09 | 0.68 |
| | *m:* | 16.24 | 33.64 | 20.97 |

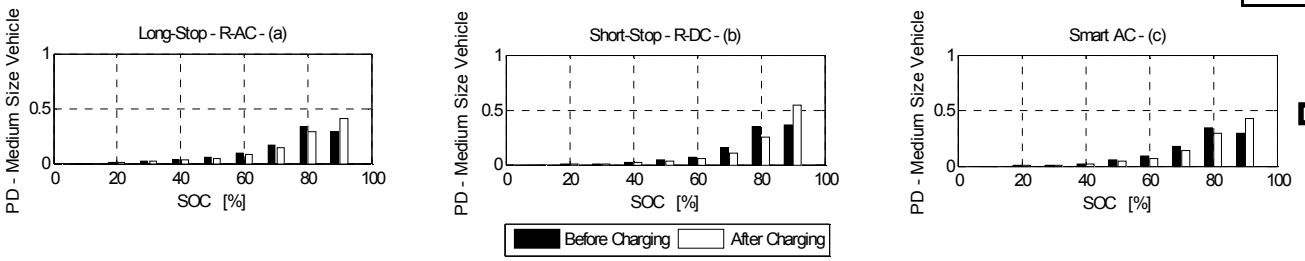
**d:** per day
**m:** per month

⇨ between ½ and 1 per day
→ 15 and 30 per month

## Energy stored per recharge

| Strategy / EV type | Data | Str. 1 Long-Stop R-AC | Str. 2 Short-Stop R-DC | Str. 3 Smart-AC |
|---|---|---|---|---|
| Small size car | ΔSOC | 0.173 | 0.144 | 0.189 |
| | ΔEn. [Wh] | 2764.6 | 2304.4 | 3016.5 |
| Medium size car | ΔSOC | 0.159 | 0.133 | 0.160 |
| | ΔEn. [Wh] | 3816.0 | 3192.0 | 3840.6 |

⇦ between 8% and 16% SOC per recharge
→ 2.3 kWh and 3.8 kWh per recharge




⇨ > 80% vehicles have a SOC > 80%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# Results: Impact on the electricity grid

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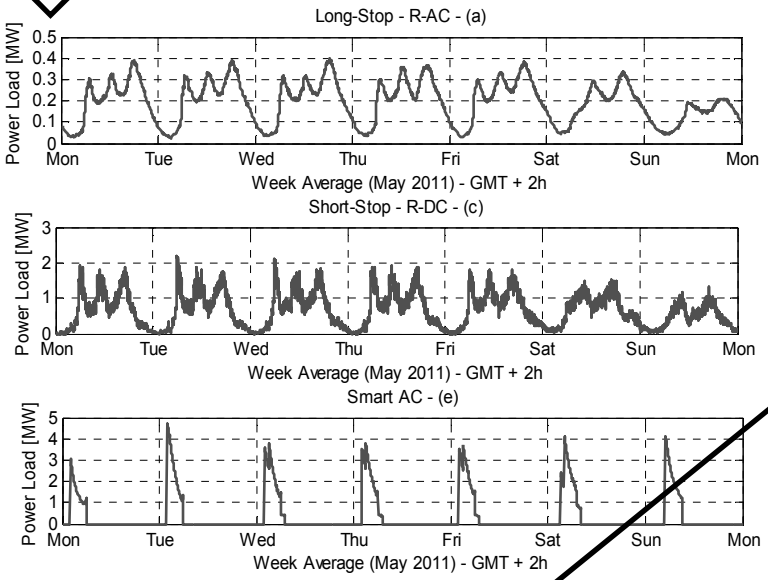
Long-stop R-AC

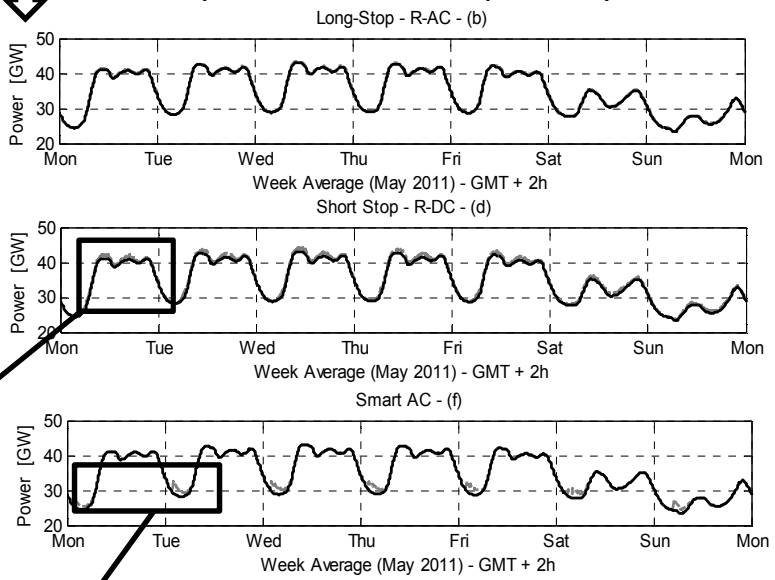
Short-stop R-DC

Smart AC

Electricity demand of the sample [MWh]

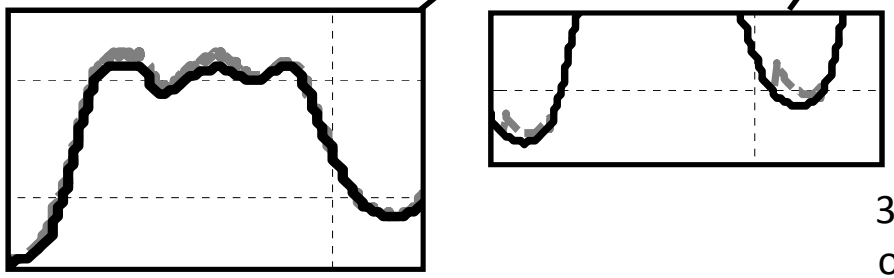



Electricity demand scaled-up to Italy [GWh]




Medium-size vehicle

Fleet share capable to drive only electric



Total demand between 35 and 331 GWh (from 0.1% to 1.2% of the national demand, i.e. 27 TWh)

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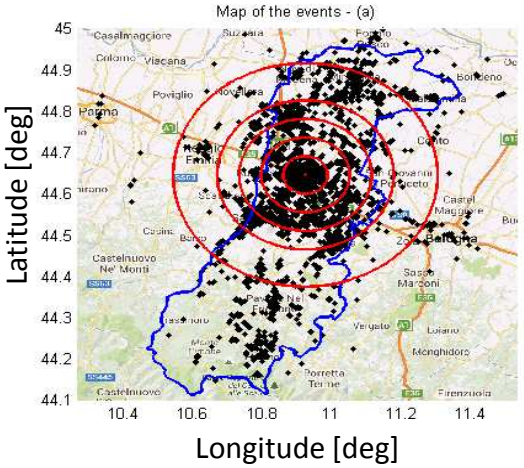
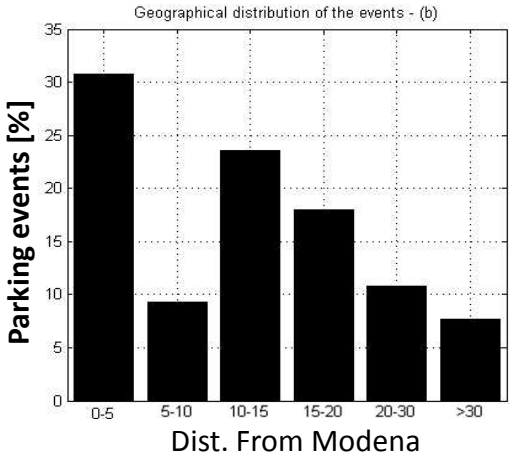
# Results: GIS-based spatial distribution

**Small size** vehicle – Smart-AC recharges



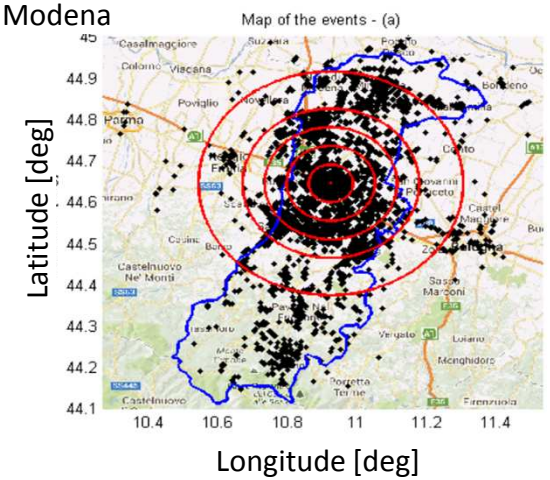



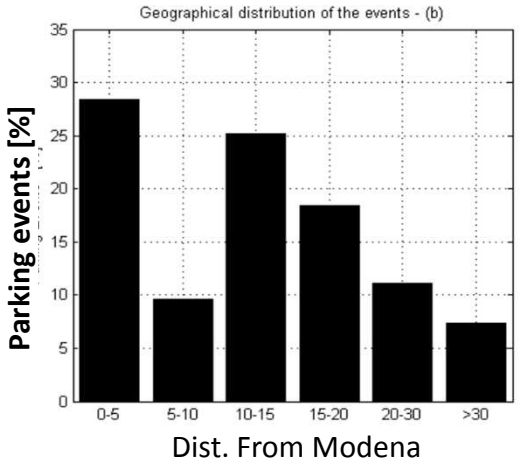

7400 km$^2$ analysis terrain window

Circles placed at 5, 10, 15, 20, and 30 km from Modena

65% of the events within 15 km from Moder

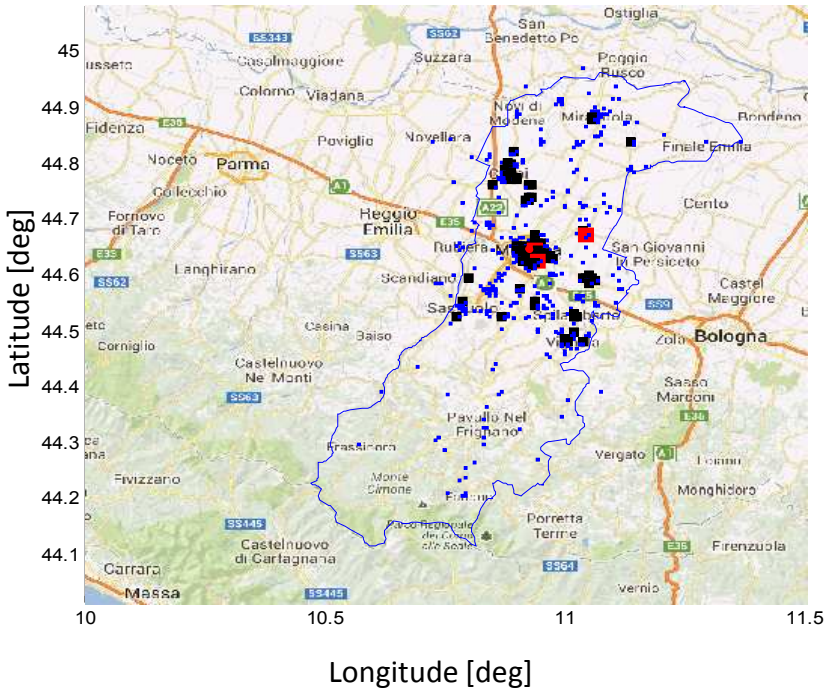
**Medium size** vehicle – Smart-AC recharges

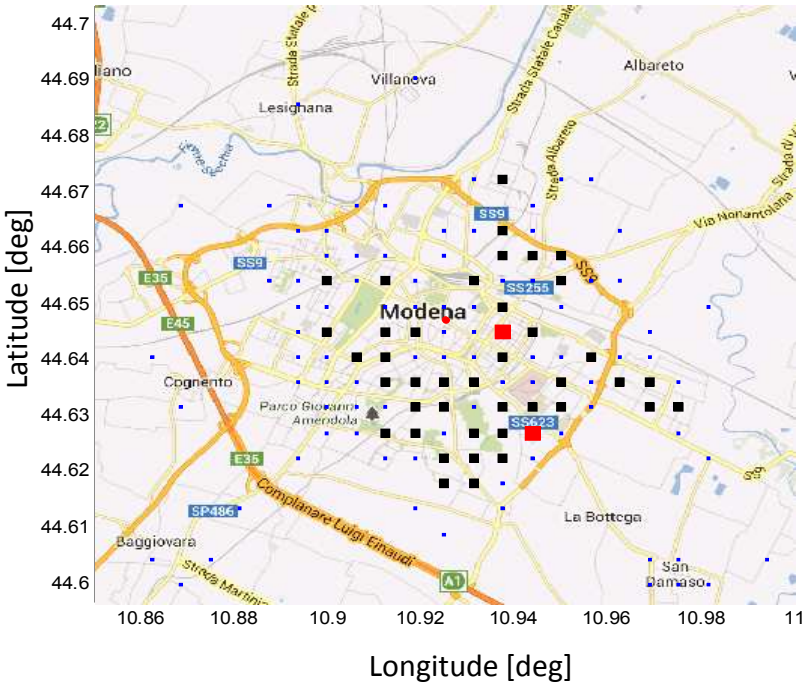


# Results: GIS-based spatial distribution

**Small size** vehicle – Smart-AC energy request integrated over 250 m/edge squared terrain tiles




20 < kWh/day < 100 | 100 < kWh/day < 250 | kWh/day > 250

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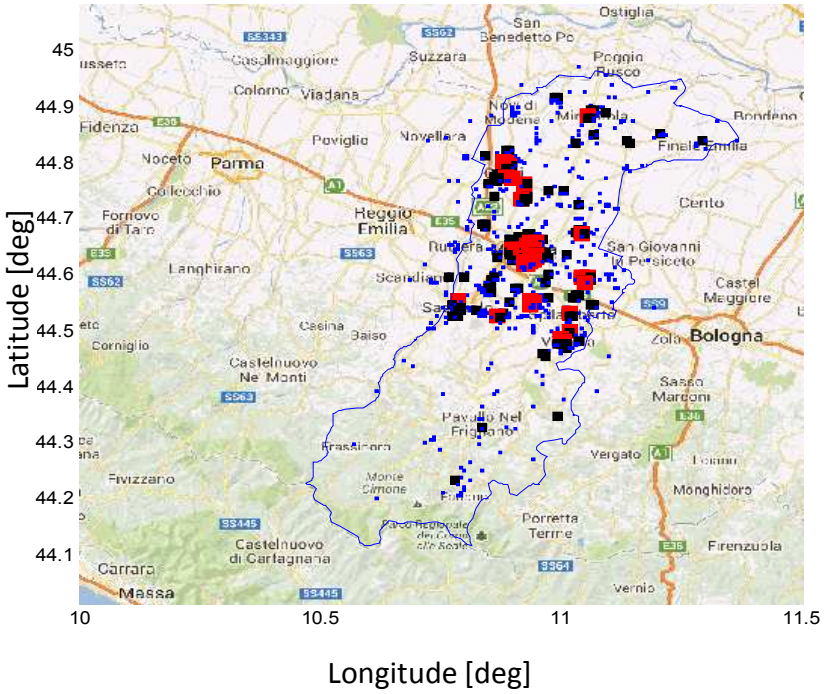
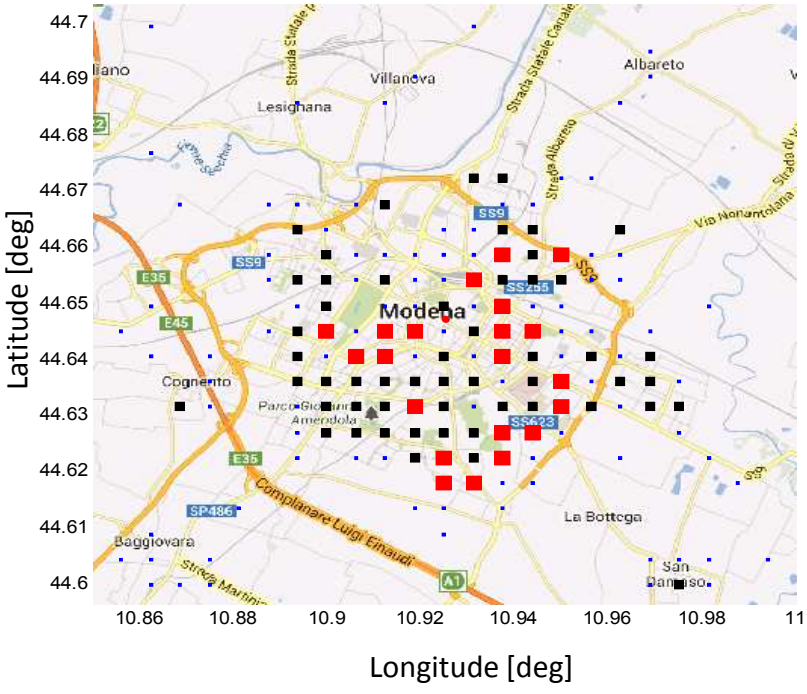
# Results: GIS-based spatial distribution

**Medium size** vehicle – Smart-AC energy request integrated over 250 m/edge squared terrain tiles




20 < kWh/day < 100 ■ 100 < kWh/day < 250 ■ kWh/day > 250

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# Conclusions

- Large-scale analysis of travel behaviour has been carried out deriving:
  - Fleet share in motion at the same time < 11.5 % (private), <15.2% (commercial);
  - 50% of the sample < 20 trips/week, < 200 km/week. Only 3% > 150 km/day;
- EVs usability results show that 80% of the trips can be driven with a small/medium sized electric vehicle and that a fleet share between 10% and 25% can drive 100% of the trips by small/medium sized EVs, increasing to 50% by accepting to shift < 5 trips/month.
- The impact on the electricity demand derived is rather limited, with no. of recharges between 15 and 30 per month, and 2.3 kWh to 3.8 kWh of energy per recharge, (max . 1.2% of the monthly demand of Italy).
- GIS-based analysis shows how the electric energy demand is distributed over the province area, highlighting how to design/size recharge infrastructure network.

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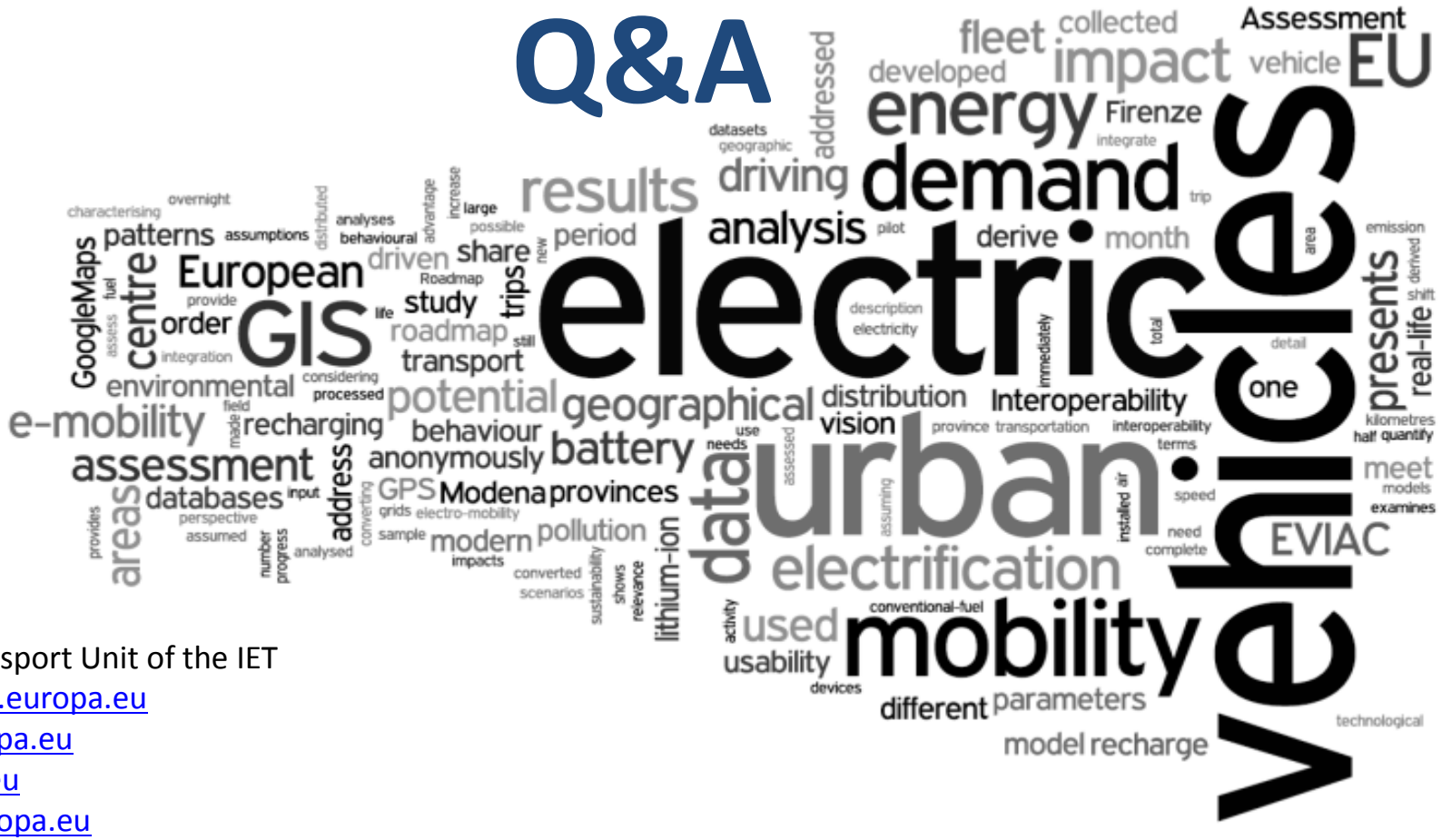



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