E-mobility for a clean future:

Interaction of EV charging with the grid and future trends

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TRI's 7th Annual Electric Vehicle Event 'Electric vehicle revolution across the globe' - Wednesday 13th October

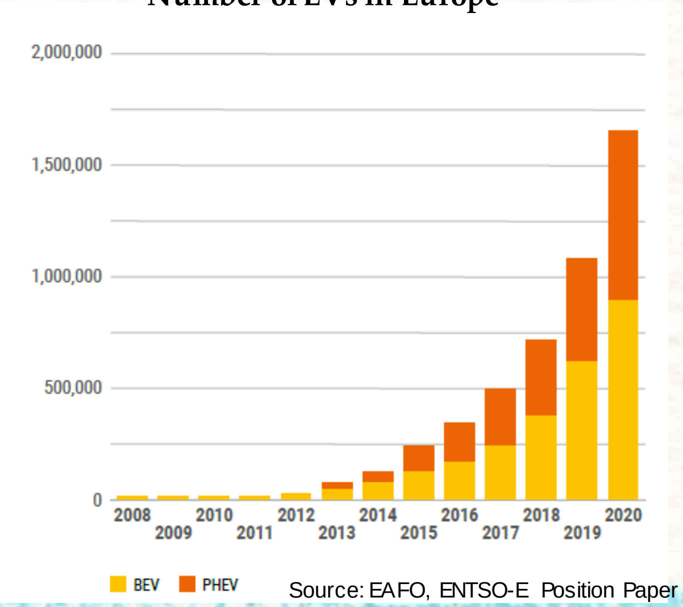
Environmental Impact of Transportation

- EU towards significantly reducing greenhouse gases **2019 – EU Green Deal & 2030 Climate Target Plan** [1]:
  - ✓ Zero net emissions of greenhouse gases by 2050
  - ✓ Reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels
  - ✓ Clear path needed for a 90% reduction in transport-related GHG emissions by 2050.

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/transport-and-green-deal_en

Image: https://www.mscsoftware.com/Adams-eMobility

Number of EVs in Europe



Source: EAFO, ENTSO-E Position Paper on Electric Vehicle Integration into Power Grids

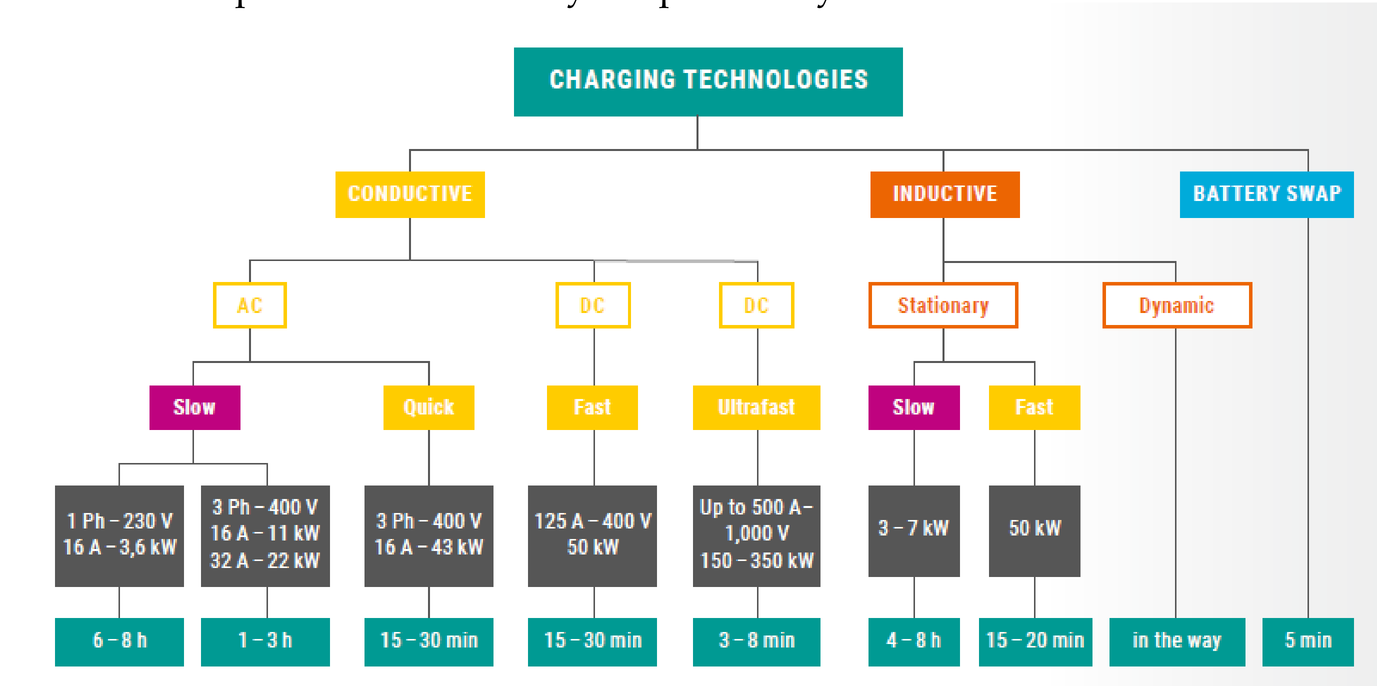
- Increase noted in the number of EVs in Europe
- EV users may select among 28 EV models in the 'standard' section and 13 EV models in the 'premium' sector (with a higher purchase cost) available in the market:

	Battery Capacity	Range	Purchase Cost
Standard segment	18 - 50 kWh	100 – 400 km	25.000 – 40.000€
Premium segment	50 - 100 kWh	500 - 700 km	70.000 - 100.000 €

Source: ENTSO-E Position Paper on Electric Vehicle Integration into Power Grids

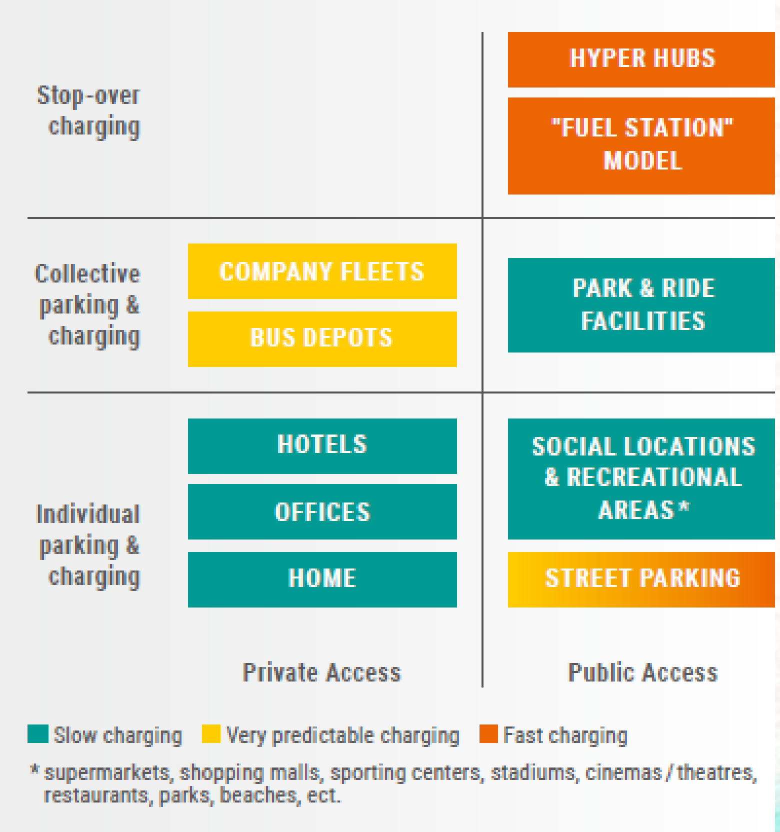
Interaction of EV Charging with the grid
Charging Infrastructure

- Variety of technologies for EV charging:
  - ✓ *Conductive Charging*: AC (Slow and Quick) and DC (Fast and Ultra-Fast)
  - ✓ *Inductive Charging*: Wireless charging of the vehicle, even when it is moving on the road (at an early stage of development, applications mainly of research interest)
  - ✓ *Battery replacement*: The vehicle is parked for a short time, with the aim of replacing its battery with one that is fully charged. This charging option has been considered in the past but is not widely adapted today.



Source: RSE, ENTSO-E Position Paper on Electric Vehicle Integration into Power Grids

- Variety of *charging locations*: (public, private, etc.)



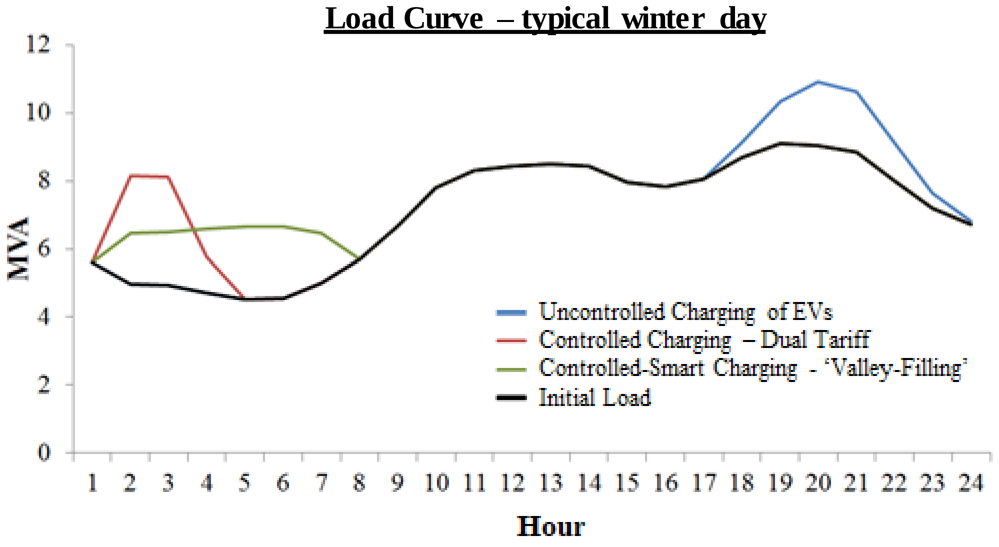
Source: ENTSO-E Position Paper on Electric Vehicle Integration into Power Grids

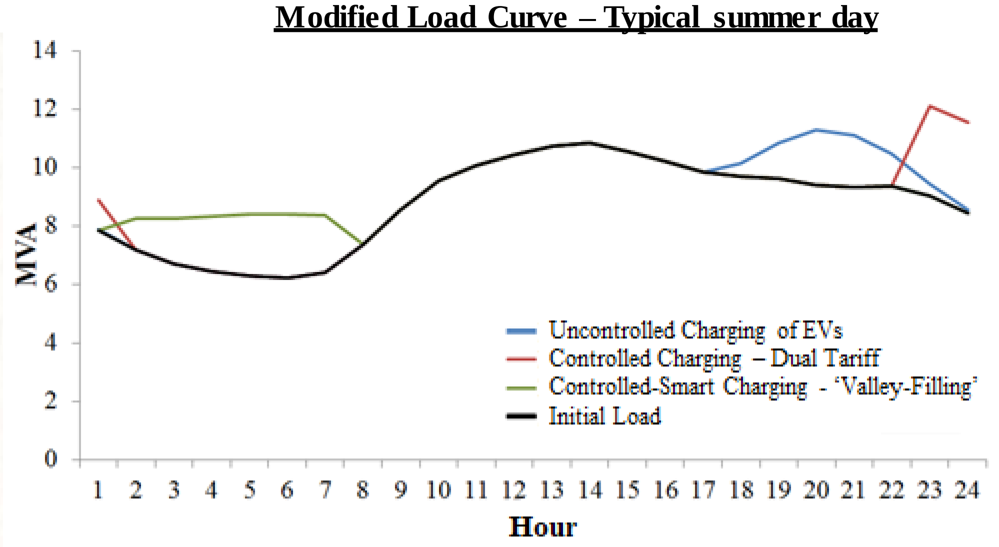
Interaction of EV Charging with the grid

- A massive deployment of charging infrastructure is expected to introduce a significant increase in the charging power:
  - ✓ 'Slow' chargers at home: 3.3kW - 22kW. (Compared to a typical home demand of 2kW)
  - ✓ Fast Chargers: up to 350 kW

<u>Urban distribution grid in Katerini - North Greece (1200 EVs)</u>

- *<u>Uncontrolled Charging</u>* of EVs:
  - ✓ Charging power is determined by the power supply capacity of the station (additional limitations may be considered, according to technical capabilities of the vehicle to charge at a specific power level).
  - ✓ The charging process finishes as soon as possible, with the highest possible power requirements
- *<u>Controlled Charging – Dual Tariff</u>*: Charging occurs during hours with smaller tariffs (night hours):
  - ✓ Problems are not expected in winter when the network demand is low during the night hours
  - ✓ The synchronization of charging at specific night hours in the summer introduces a new peak in the network
- *<u>Controlled-Smart Charging - 'Valley-Filling'</u>*:
  - ✓ EV charging is distributed during the hours with lower load
  - ✓ Load distribution prevents load spikes both during winter and summer





Interaction of EV Charging with the grid

V2G Capabilities

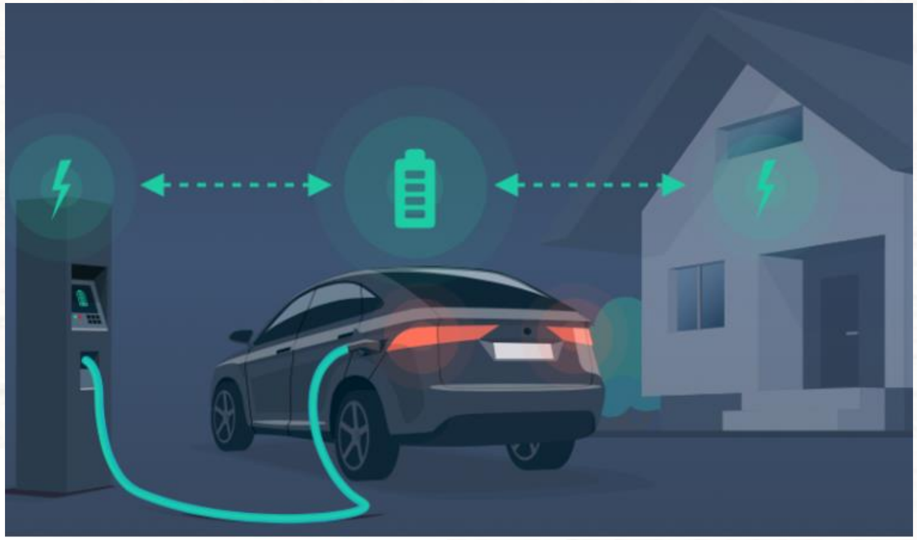
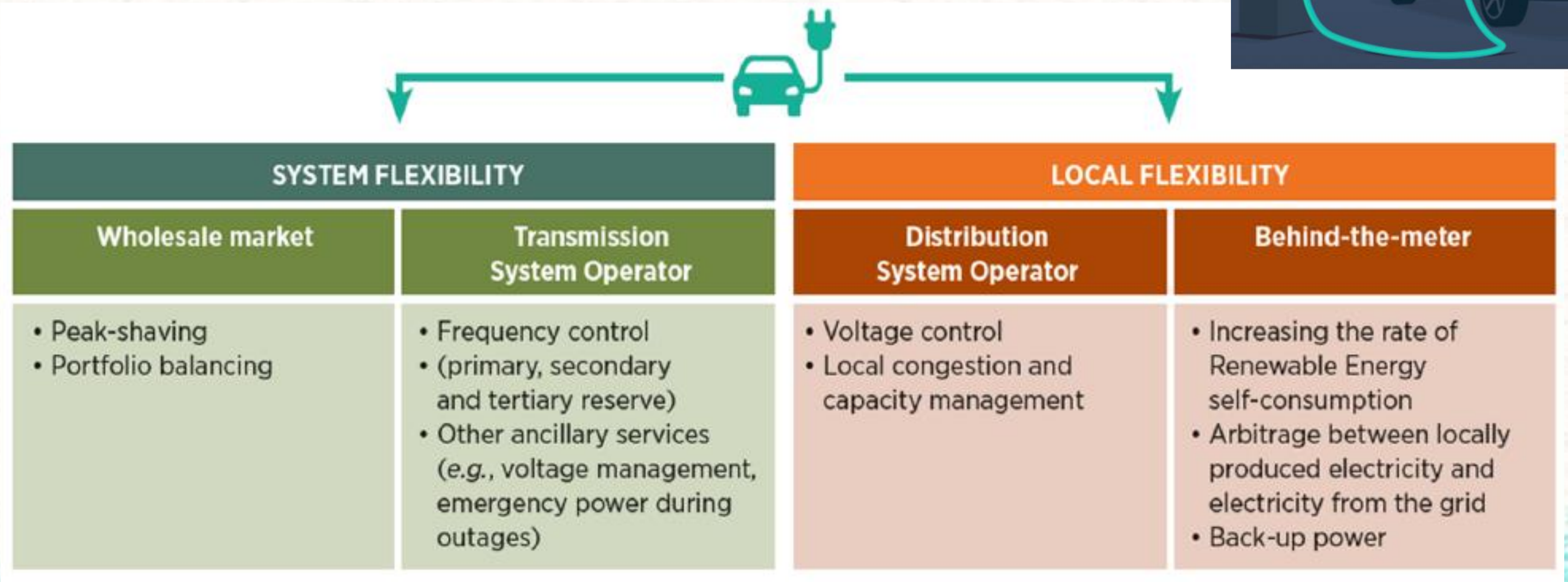


Image: www.offgridenergyindependence.com

- V2G technologies allow energy to be transferred from the EV's battery to the grid
- Alongside smart charging techniques, they support the network:
  - ✓ Balancing market, Flexibility provision, ancillary services, etc.



Source: Towards zero emission road transport (2ZERO) Strategic Research and Innovation Agenda (SRIA)

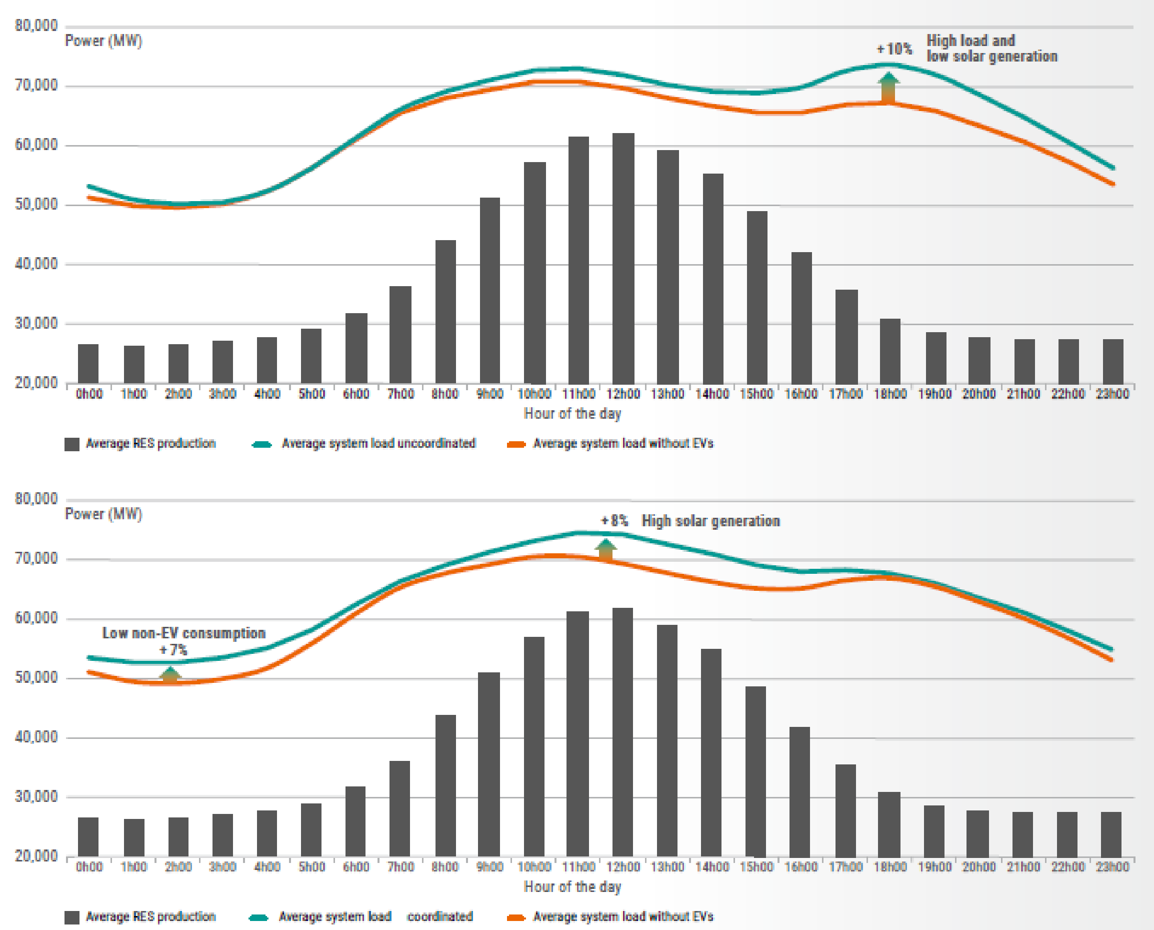
Interaction of EV Charging with the grid

EV-RES Synergy: Increasing the RES penetration

Image: https://ec.europa.eu/, EV-Smart Grid Interoperability Centers in Europe and the U.S

- ***<u>EV charging can be shifted towards hours with increased RES penetration</u>*:**
  - ✓ EVs are charged at hours when the network is not overloaded
  - ✓ EV charging exploits the available RES production that, otherwise, would not be utilized

Average total electricity load in Germany with uncoordinated (up) and smart charging (down), considering the PV production.

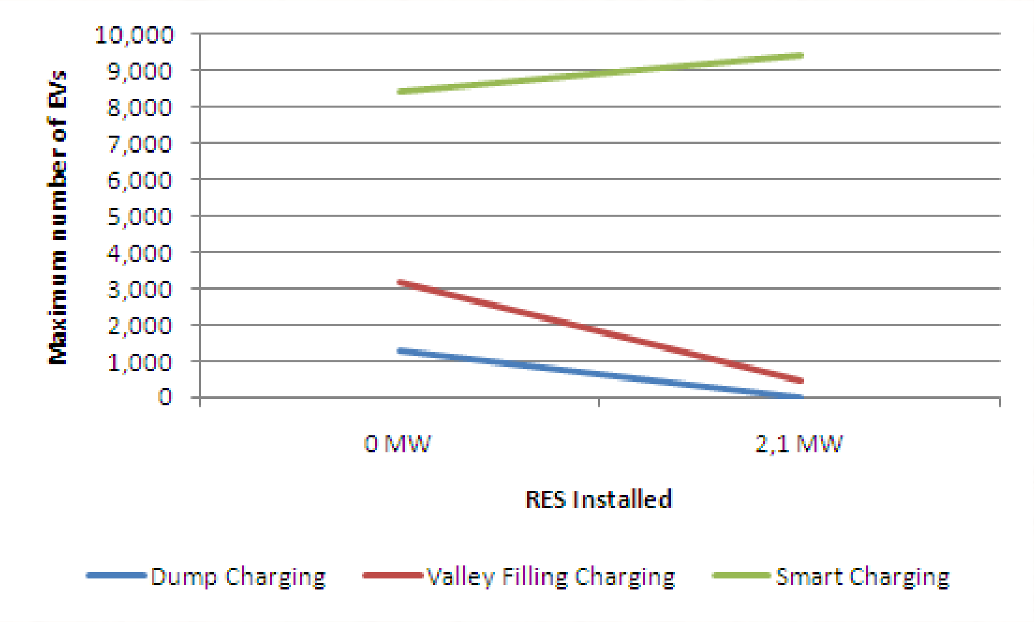


Source: Elia Group

Interaction of EV Charging with the grid

EV-RES synergy: RES and EV hosting capacity increment

- Increased RES penetration reduces the environmental impact of the transportation sector, when electrified.
  - ✓ The energy storage capacity of the EVs' battery can contribute towards achieving these goals.
- Increase in RES hosting capacity can result in a decrease in the maximum number of EVs that can connected to the grid, mainly due to voltage deviation limits – red and blue lines in the diagram correspond to uncontrolled charging.
  - ✓ Effective smart charging strategies exploiting V2G capabilities (green line) can lead to an increase in RES hosting capacity together with increasing EVs penetration.



Source: E. Karfopoulos, N.Hatziargyriou, "Distributed Coordination of Electric Vehicles Providing V2G Services", IEEE Trans. on Power Systems, 2015

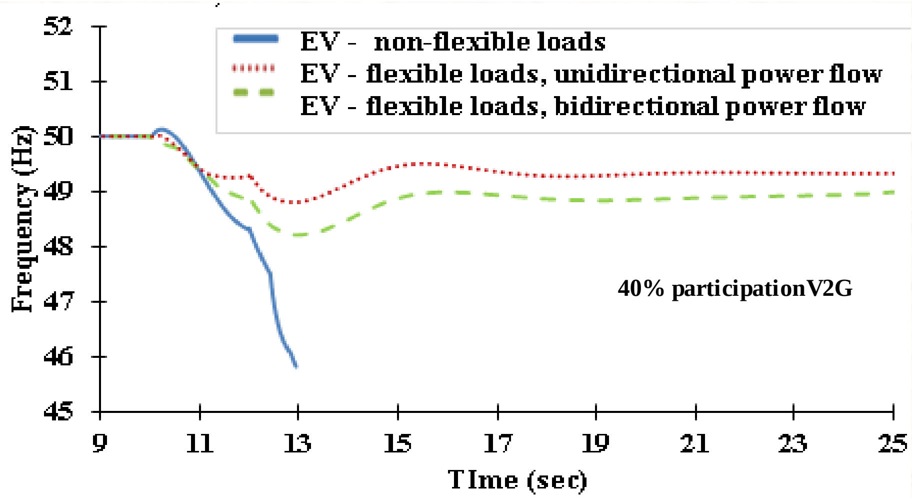
Interaction of EV Charging with the grid

Ancillary Service Provision

EVs Support in grid disturbances

- EVs can support the frequency regulation in case of disturbances.
- Simulation of a three phase short-circuit at a high voltage bus with simultaneous loss of two generators in Crete:
  - ✓ Without demand flexibility by EVs (blue line), the frequency drops at unacceptable levels, relay protections of conventional units are tripped and the system collapses.
  - ✓ This blackout can be prevented when EVs offer frequency support either by curtailing their charging demand (green line) or by injective power to the grid (red line).

Grid's frequency: Three phase short-circuit at a high voltage bus with simultaneous loss of two generation units connected at the same bus in Crete (simulation).



Source: Karfopoulos, E.L.; Voumvoulakis, E.M.; Hatziargyriou, N.," Steady-state and dynamic impact analysis of the large scale integration of plug-in EV to the operation of the autonomous power system of Crete Island", Medpower, 2014

Future Trends on E-mobility

Vast Installation of Charging Infrastructure

- Charging infrastructure developed considering the ability of the network to support charging points, alongside socioeconomic parameters and large scale urban development processes.
- The contribution of *Heavy Duty Vehicles* to greenhouse gas emission is quite significant: Develop fast chargers that consider both the needs of Heavy Duty Vehicles and smaller EVs (reducing charging infrastructure costs).

Alternative Charging Technologies

- *Wireless charging* & *Dynamic charging solutions*: EVs charge while moving on the road (inductive charging, overhead power supply or conductive lines placed on the road)

Image: emobilitysimplified.com

Grid Interaction

- Exploitation of the available charging flexibility (Smart Charging and V2G) in order to reduce grid investments required to support the deployment of new charging infrastructure and cover the significantly increased demand of EVs.

Future Trends on E-mobility

<u>Integrated system approach</u>: electric vehicles - charging infrastructure - service provision - business activities

- Synergies among urban development, distribution network development and transportation system organization
- Effective transportation developments in order to optimally exploit *<u>smart charging and V2G capabilities</u>*, while covering transportation needs

Image: www.goodnewsfinland.com

<u>Interoperability</u>

- Interoperability, among all charging solutions: EV users shall be able to charge their vehicle (smart charging and V2G) anywhere in EU in an easy and efficient way

<u>Circular Economy Solutions</u>

- Use of sustainable solutions and effective Life Cycle Assessment (LCA) procedures

Image: https://new.siemens.com/global/en/products/energy/medium-voltage/solutions/emobility.html

<u>The EV user at the center of e-mobility</u>:

- EV users are the main provider of flexibility, 'sacrificing' part of their EV's battery life. Understanding the users' preferences and related charging needs (cost, ease of using infrastructure, etc.) is crucial.

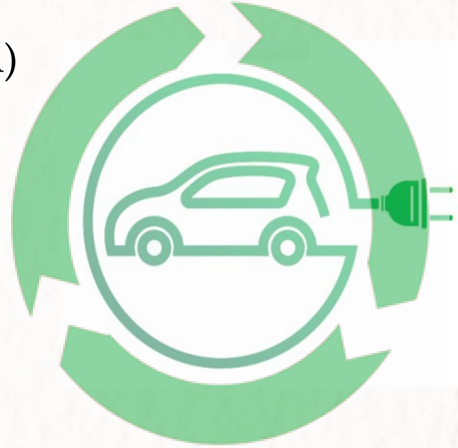


Image: grotonutilities.com

Thank you very much for your attention!

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