FABRIC

Feasibility analysis and development of on-road charging solutions for future electric vehicles

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Impact of dynamic EV wireless charging on the grid

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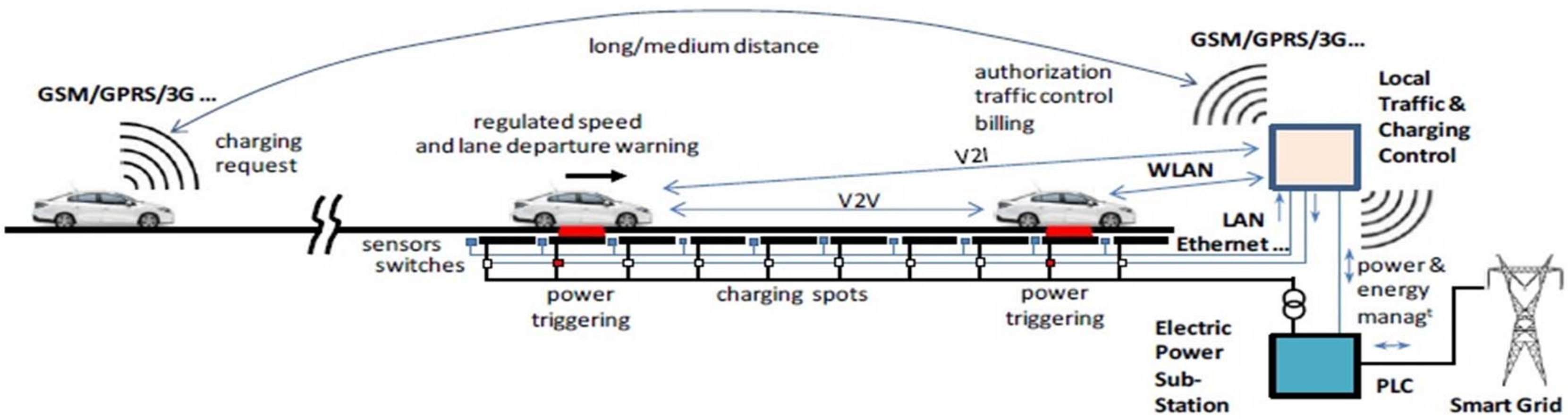
Outline

- Dynamic wireless charging
- Grid impact
- Simulation approaches
  - Mesoscopic
  - Macroscopic
- Energy Storage System
- Conclusions

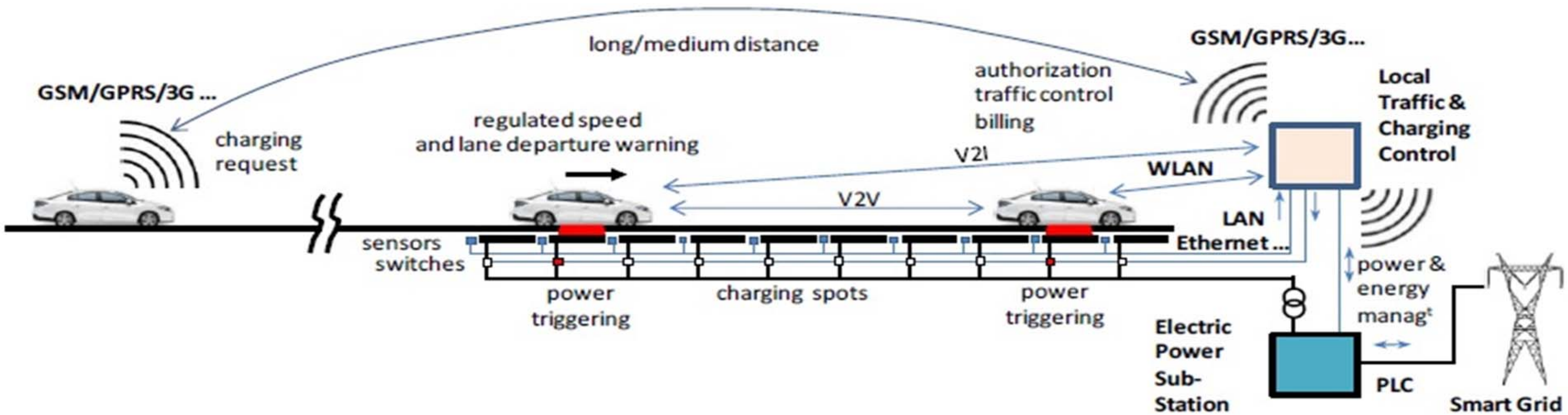
Dynamic wireless charging: Concept

- Charging process
  - Vehicle authorization
  - Charging profile negotiation
  - Power transfer while vehicle over the pads
  - Billing, payment, etc…



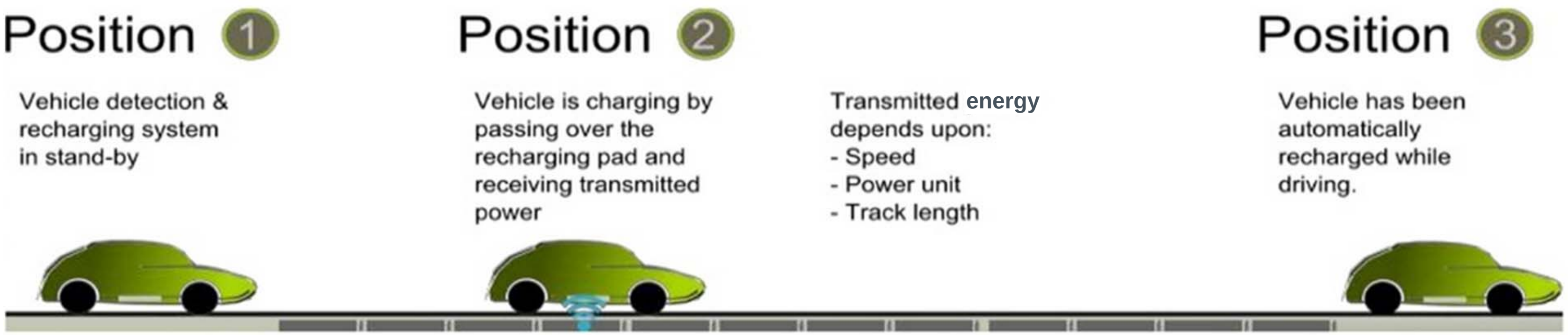
Dynamic wireless charging: how much Dynamic?

- Charging process similar to static… but FASTER!
  - 2meters coil 20kW
  - 10m/s -> **36km/h** (@108km/h)
  - Charging time **200ms** (66ms)
  - Energy @η=1 **4kJ** (1.2kJ)
  - Billing, payment, etc… there is always time to pay…



Grid impact?

- How does this procedure affect the power grid?
- What kind of power demand patterns are generated?
- Which parameters affect transmitted power in a macroscopic scale?



Source: SAET

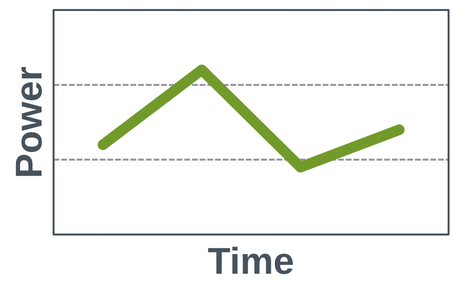
Simulation methodology

Parameters:

1. Charging lane & pad lengths
2. Vehicle and its speed
3. Traffic conditions
4. Maximum charging pad power level

Charging events are created according to traffic, pad/lane length

Charging events are translated to a power level according to the vehicle's speed and pad length



Source: SAET

Simulation approach 1: Mesoscopic

- Single vehicle trajectories introducing detailed time resolution
  - 20m charging zones separated by 30m road segments.
  - 30EV/km/lane, 1.5-2.5 minimum traffic headway
  - 50kW/m

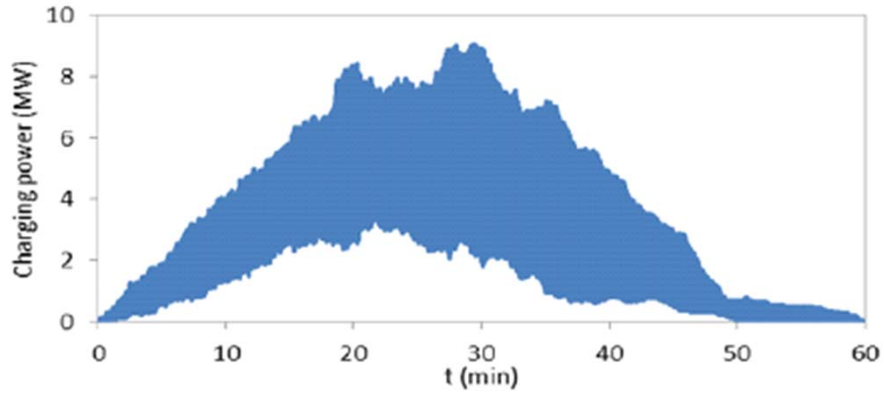
Description	Value	Units
Avg traffic density	10	EV/km/lane
Critical density corresponding to max capacity	30	EV/km/lane
Number of simulated vehicles	500	EV
…	…	…
Minimum traffic headway	1.5	s
Lane length	20	km
Charging zone length	20	m
System efficiency	0.85	
Power per unit of length	50	kW/m

Source: SAET

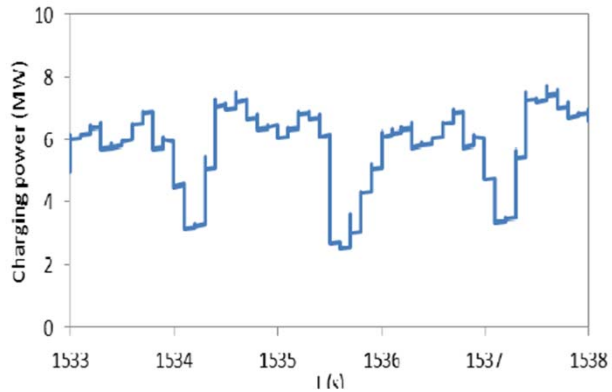
Demand results

- Substantial amount of switching associated to vehicles passing over charging pads
- Demand fluctuates from 2-8 MW in some seconds
- Unrealistic power jump in the grid load
- Max step 4MW in 100ms

Mesoscopic: Demand 1h

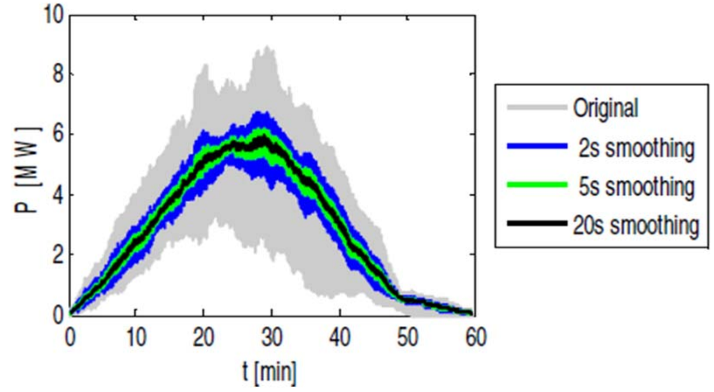


Mesoscopic Demand 5s



Requirements for energy storage system

- Energy Storage System modeled as a low pass filter to reduce fluctuations



- 5 seconds smoothing window reduces fluctuations substantially
- PSS almost independent of window size and dependant on traffic
- ESS increases linearly with the size of the smoothing window

Smoothing	PSS (MW)	ESS (kWh)	TSS (s)
1	5.2	0.8	0.6
2	4.3	1.0	0.8
5	3.8	1.1	1
10	3.8	1.3	1.2
20	3.8	1.8	1.8
30	3.7	2.5	2.4
60	3.8	4.84	4.5

Simulation approach 2: Macroscopic

- High level probabilistic model for various scenarios:
  - Coordinated vehicle traffic
  - Non-coordinated vehicle traffic in low speed
  - Non-coordinated vehicle traffic at high speed
  - 24h non-coordinated

Source: SAET

Scenario 1

Coordinated charging scenario:

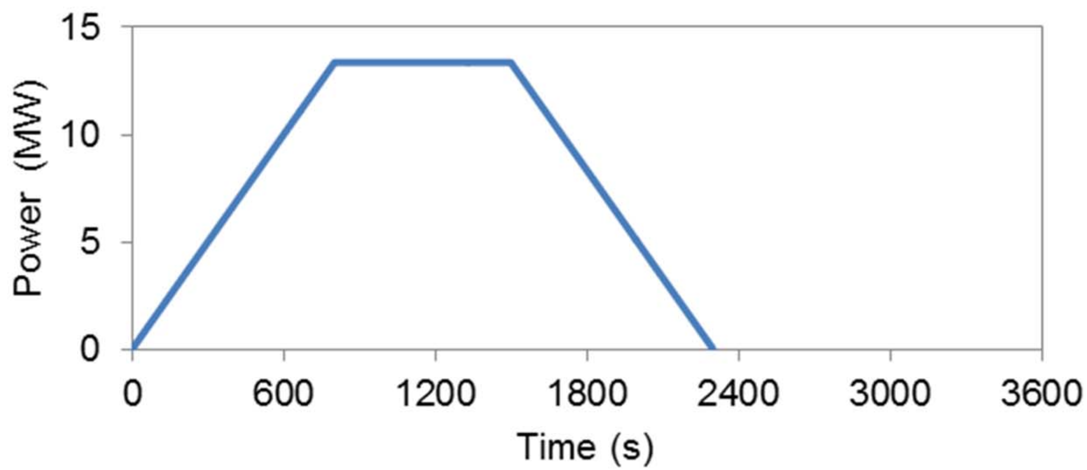
- Vehicles gradually enter and exit the charging lane. (platoon)
- Vehicles stay in the charging lane without overriding or skipping any charging pads.

Description	Value	Units
Total length of the road	8	km
Average slope	0	
Length of charging zones	30	m
Distance between charging zones	0	m
Power per unit of length	50	kW/m
Minimal technical headway in CWD lane	3	s
Vehicle speed	36	km/h
Number of vehicles	500	

Demand results

Outcome:

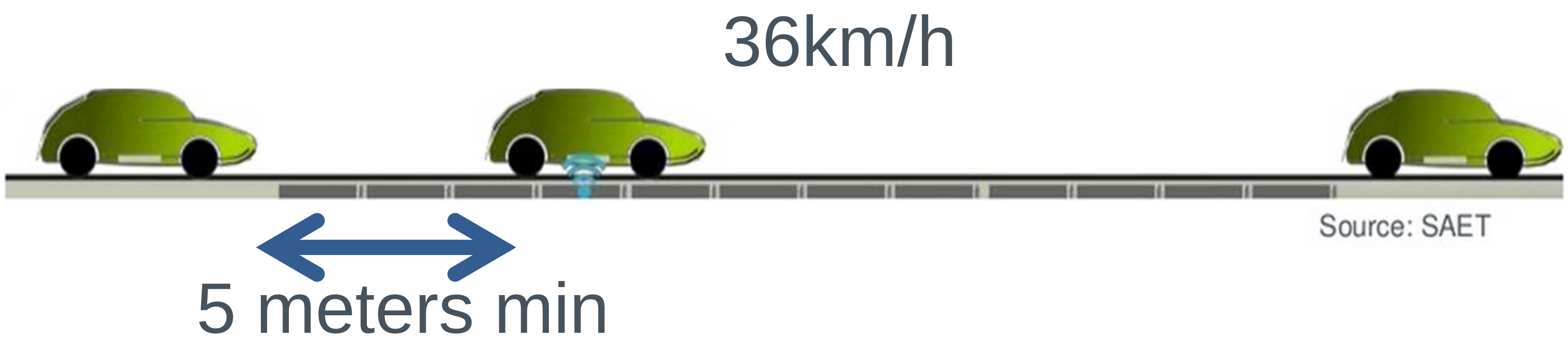
- Demand pattern is grid friendly.
- No variations or spikes imply fewer requirements on grid infrastructure! (Less smoothing, load balancing, etc...)



Scenario 2

Non-Coordinated charging scenario:
36km/h, 5m min headway

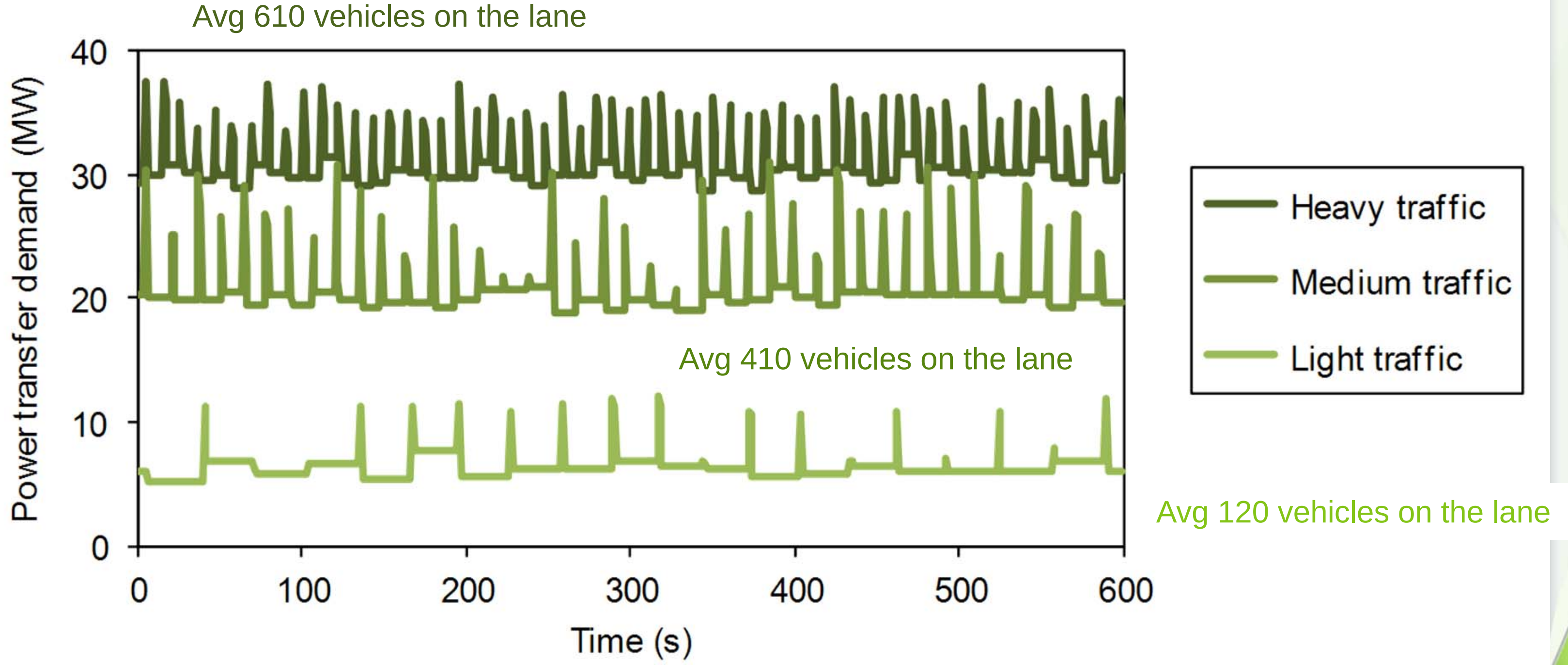
- Vehicles could enter the charging lane at any point of it!
- Vehicles are free to override, stay on the lane as long as they desire!



Demand results

Outcome:

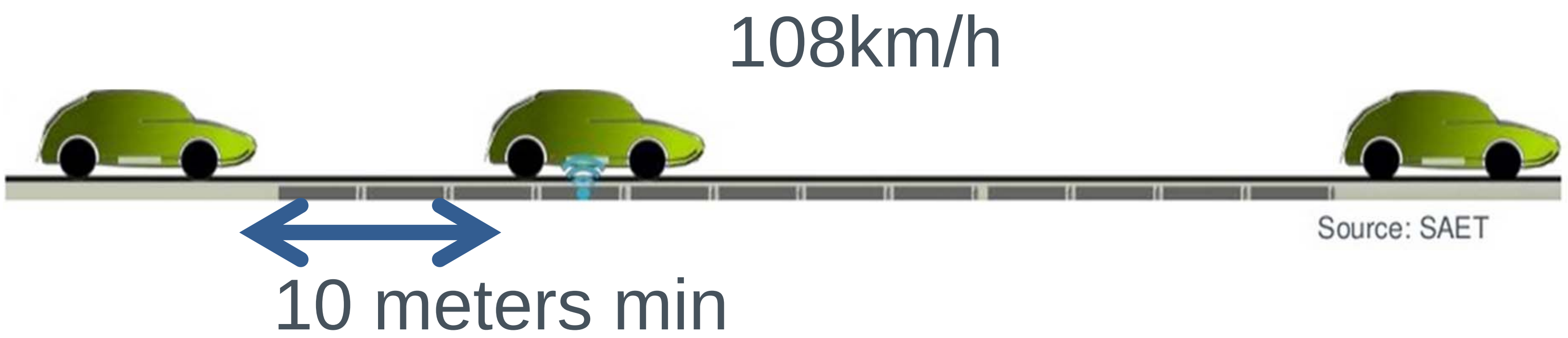
- Non-coordinated charging causes demand fluctuation. Investment in energy systems is required in order to "smooth" out demand patterns.



Scenario 3

Non-Coordinated charging scenario:
108km/h, 10m min headway

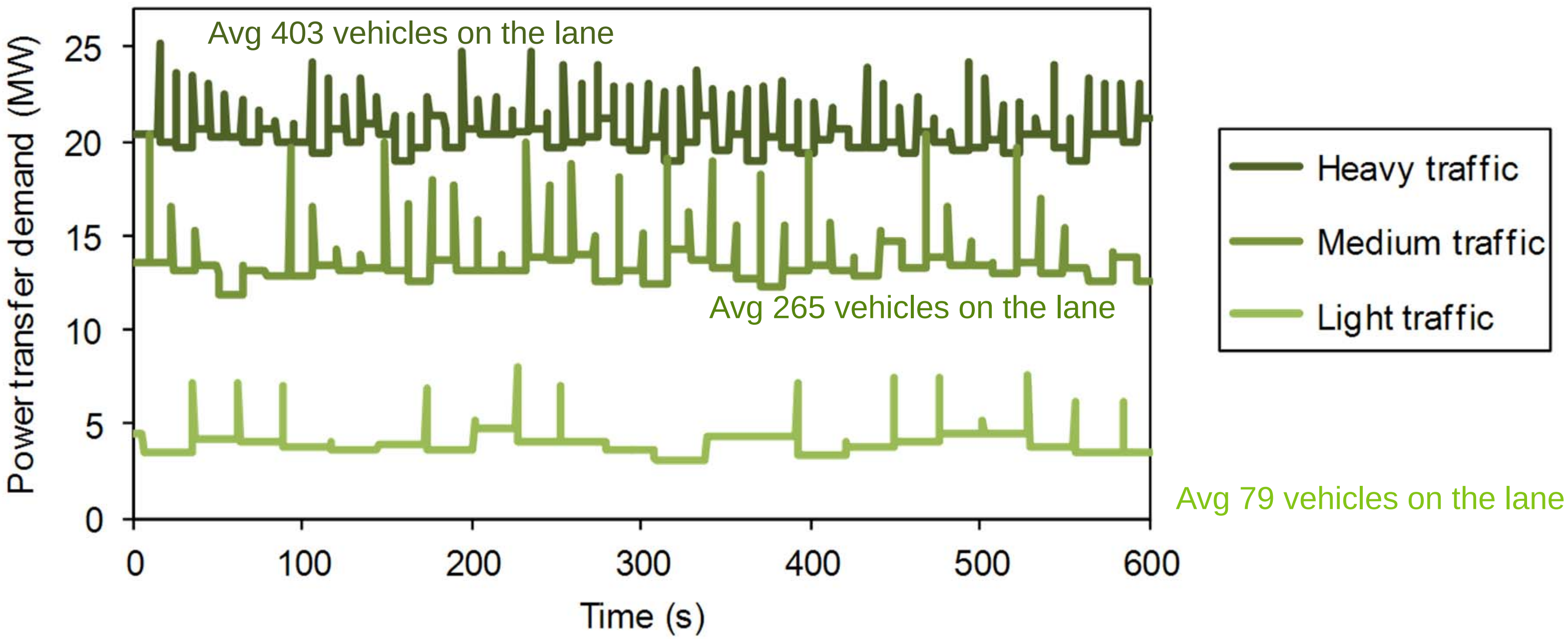
- Impact of higher speed on demand is assessed
- Vehicles leave more space when they go faster, so headway has been adjusted accordingly



Demand results

Outcome:

- Higher speed leads to less demand as vehicle density decreases (headway increases)
- Less demand variation in comparison to the slow speed case.



Scenario 4

24h charging pattern

- Traffic based on data provided by the NHTS (2009 survey)
- Scenario based on the hypothesis that there is an analogy between the overall traffic and the traffic that flows over a charging lane.
- High speed case (108km/h)

Source: SAET

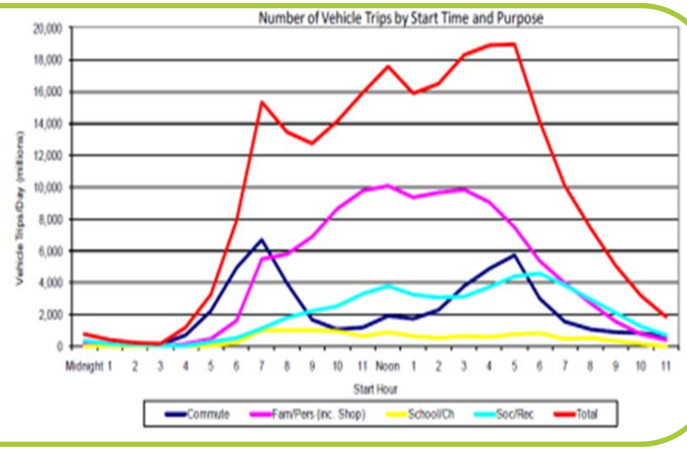
24h simulation

Demand results

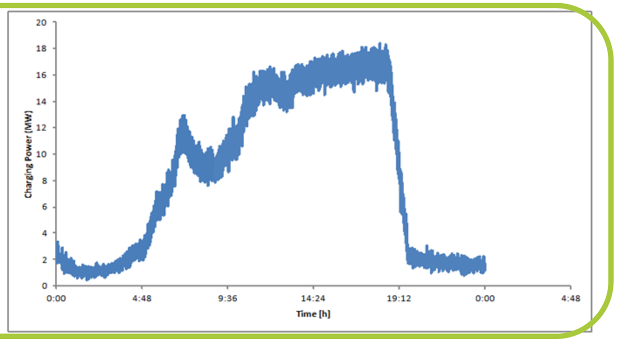
Outcome:

- There is a natural coordination mechanism between the demand of a charging lane and solar irradiance
- **Attractive self consumption scenario!**

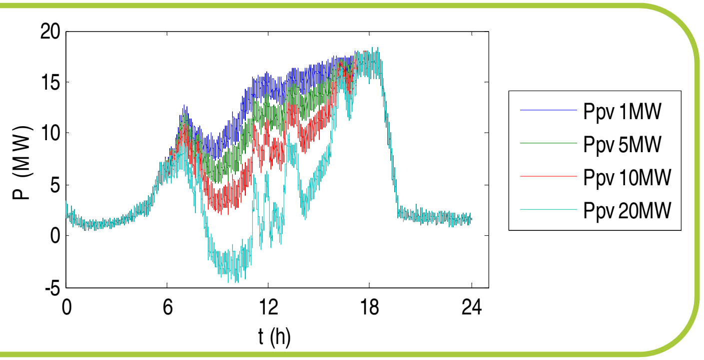
DAILY TRAFFIC



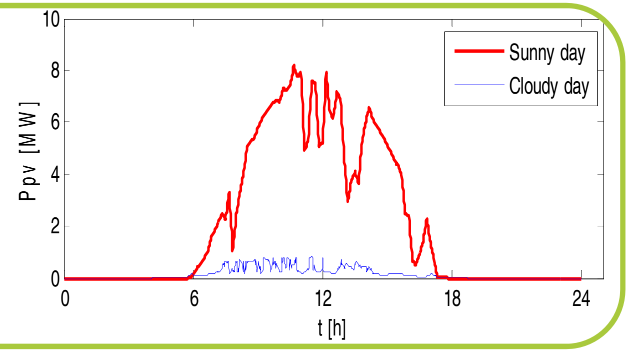
DAILY DEMAND



DECREASED DAILY DEMAND



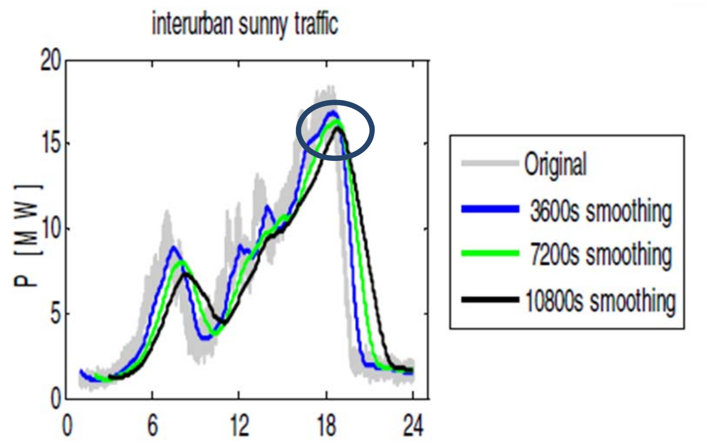
SOLAR SUPPLY



Energy Storage System requirements

- Impact of Energy storage system smoothing window size
- Small storage windows help to mitigate high frequency variations
- Larger smoothing windows help to reduce the daily demand peak
  - from 18.4 to 15 MW but it costs!
- Combination of ESS with other methods load shaping/shaving **must** be deployed.

Smoothed demand



Conclusion

1. The dynamic nature of wireless charging may stress existing infrastructure due to
   – Increased energy and power demand
   – Highly variable demand
2. Energy Storage Systems can minimize demand variability up to an extent in high fluctuation reduction. However:
   – Overall peak reduction with ESS is expensive
   – Combination of ESS with load shaping & shaving in order to avoid peaks
3. Solar energy integration with charging infrastructures is an attractive solution in minimizing grid demand especially during morning high traffic hours.

FABRIC

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Thank you!

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