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cea tech

FLEXIBILITY OF ELECTRIC VEHICLES: EXPERIMENTAL RESULTS @CEA

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International Energy Agency
Photovoltaic Power Systems Programme

Tenerrdis Workshop

15 November 2022, Jonage



ines
INSTITUT NATIONAL
DE L'ÉNERGIE SOLAIRE



AGENDA

- **Context & objectives**
 - Cadarache
 - EVCI & PV
 - EV charging demand
 - Objectives
- **Experimental setup**
 - EVs and users
 - Control architecture
 - User journey
- **Experimental results**
 - Global figure
 - Lessons



Associated R&D projects:
EvoIVE Project with RTE
 G. Vignal



Neemo Project with MCAST
<http://neemo-project.eu/>
 B. Azzopardi & R. Mikalauskiene

INES.2S
<https://www.ines-solaire.org/ines-2s/>

PV2e_Mobility
 M. Sechilariu





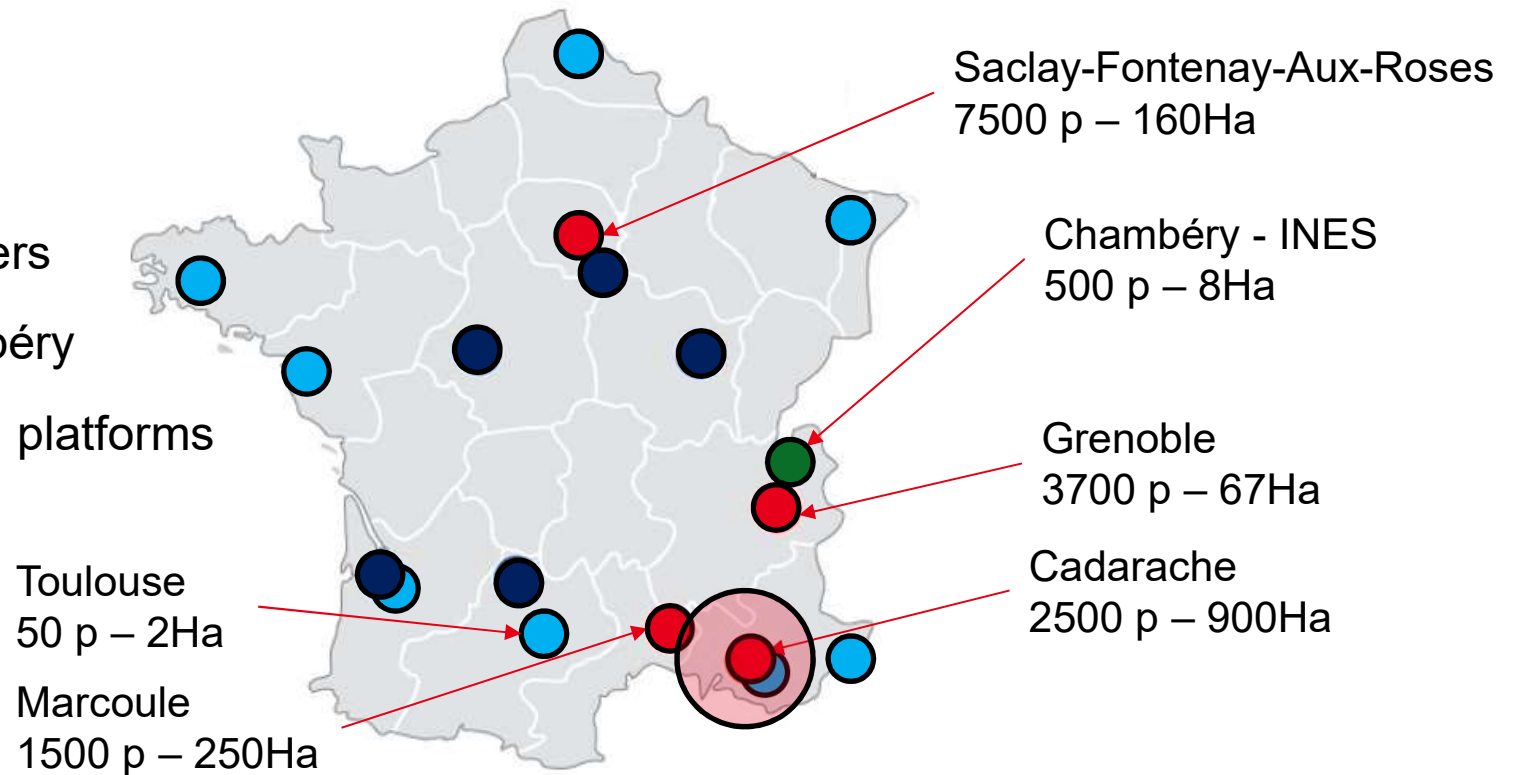
CEA CENTERS

● Civil centers

● Military centers

● INES Chambéry

● Technological platforms



- **9** research centers (4 civil / 5 military)
- **8** technological platforms
- **20 181** employees (included 1 233 PhD students and 176 postdoctoral researchers)
- Budget of **5 billion** euros



CEA CADARACHE – NEAR AIX-EN-PROVENCE

1600 Ha **900ha** fenced (22 km of fence)

5500 workers

480 buildings and **500 000** m2 of floor

70 km of paved roads, 6 km of landscaped footpath

29 bus lines carrying a thousand employees

75 km of water distribution network

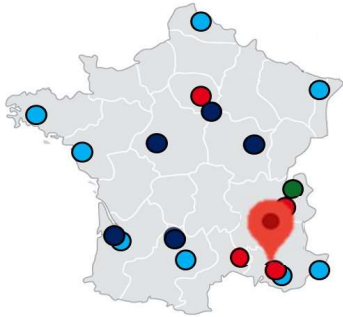
Heat network

Private medium voltage distribution power network

- 63kV / 15kV substation
- 18 MV loops (85km of 15kV underground lines)
- 3kV public lightning network
- EVCI : 80 charging points at 22kVA

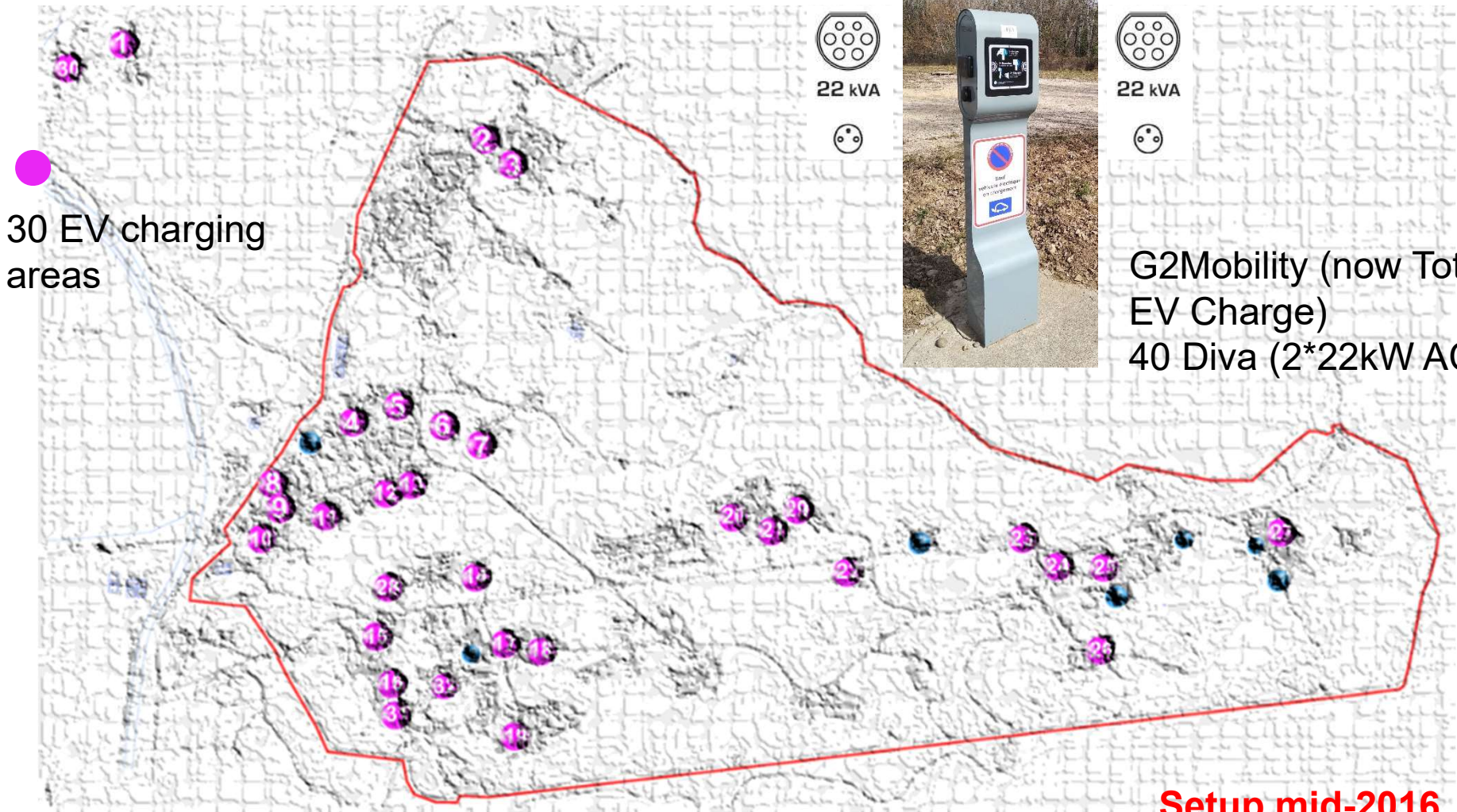


63kV / 15kV substation





EVCI CADARACHE – CHARGING STATION



CEA = Charging Point Operator, e-Mobility Service Provider, DSO and fleet operators





LOG OF CHARGING SESSIONS – JUNE 2016 / MAY 2020

HD: Date/Time at the beginning of the session (UTC)

HF: Date/Time at the beginning of the session (UTC)

Name of the charging station

ID: Value of the powermeter at the beginning of the session (Wh)

IF: Value of the powermeter at the end of the session (Wh)

of the user

DebutSessionUTC	FinSessionUTC	PointdeCharge	Badge	IndexDebut	IndexFin	TypedePrise
07/06/2016 11:38	07/06/2016 13:31	CU-BAT1011-13CEA-3	7490E56D	75873	80847	T2
08/06/2016 06:15	08/06/2016 11:43	CU-BAT1511-13CEA-3	CE14EB7E	74156	76878	T2
08/06/2016 11:47	08/06/2016 11:52	CU-BAT1011-13CEA-3	7490E56D	80906	81679	T2
08/06/2016 12:02	08/06/2016 13:46	CU-BAT1011-13CEA-3	7490E56D	81679	91062	T2
08/06/2016 12:22	08/06/2016 17:17	CU-BAT1011-13CEA-2	D527CEE3	29009	35782	T2
08/06/2016 12:34	08/06/2016 15:23	CU-BAT1511-13CEA-3	85F1D2E3	76878	81364	T2
08/06/2016 12:42	08/06/2016 12:57	CU-BAT8371-13CEA-2	6468EB6D	2686	3142	T2
08/06/2016 12:59	09/06/2016 08:38	CU-BAT8371-13CEA-2	6468EB6D	3145	66192	T2
08/06/2016 13:04	08/06/2016 13:08	CU-BAT8371-13CEA-6	6503DCE3	765	1566	T2

Transaction Duration (h)=(HD – HF)

Energy Consumption (kWh)=(IF – ID)/1000

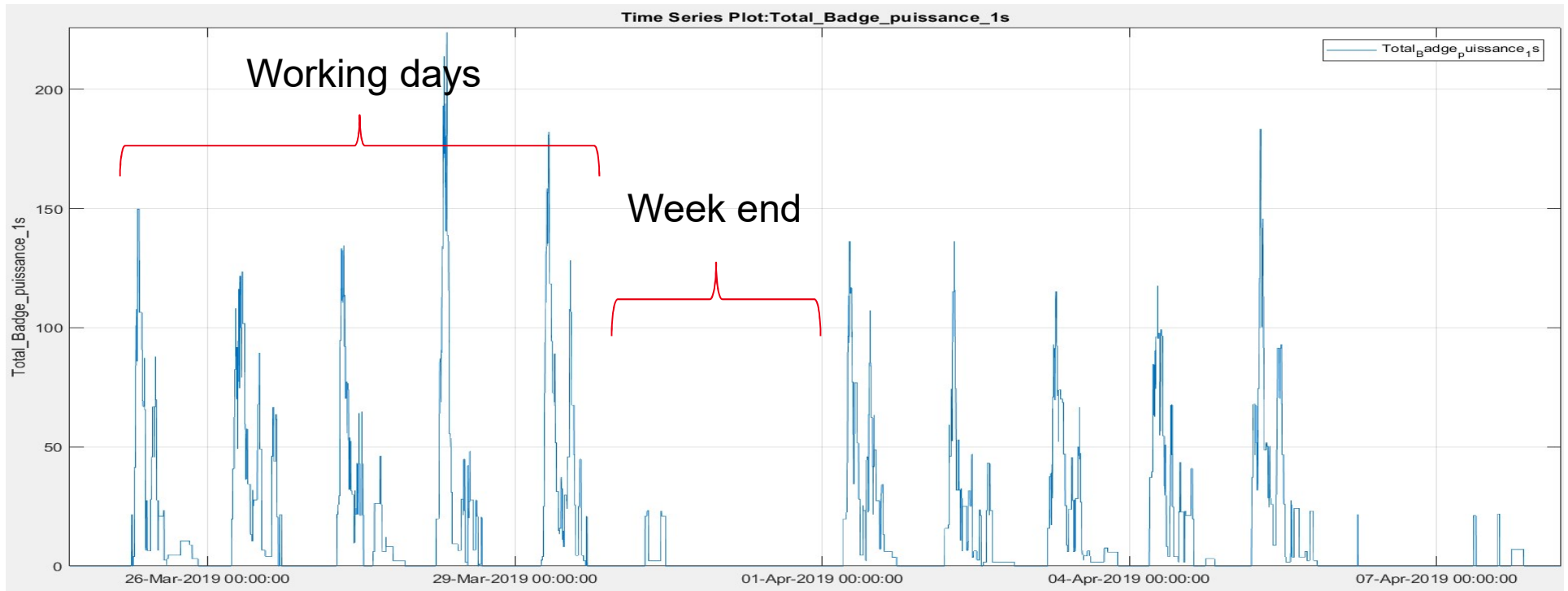
Unreliable





MAX CHARGING POWER HYP. : LOAD CURVES

Total load curve (i.e. the sum of the power consumption of the EVs) during 2 weeks:

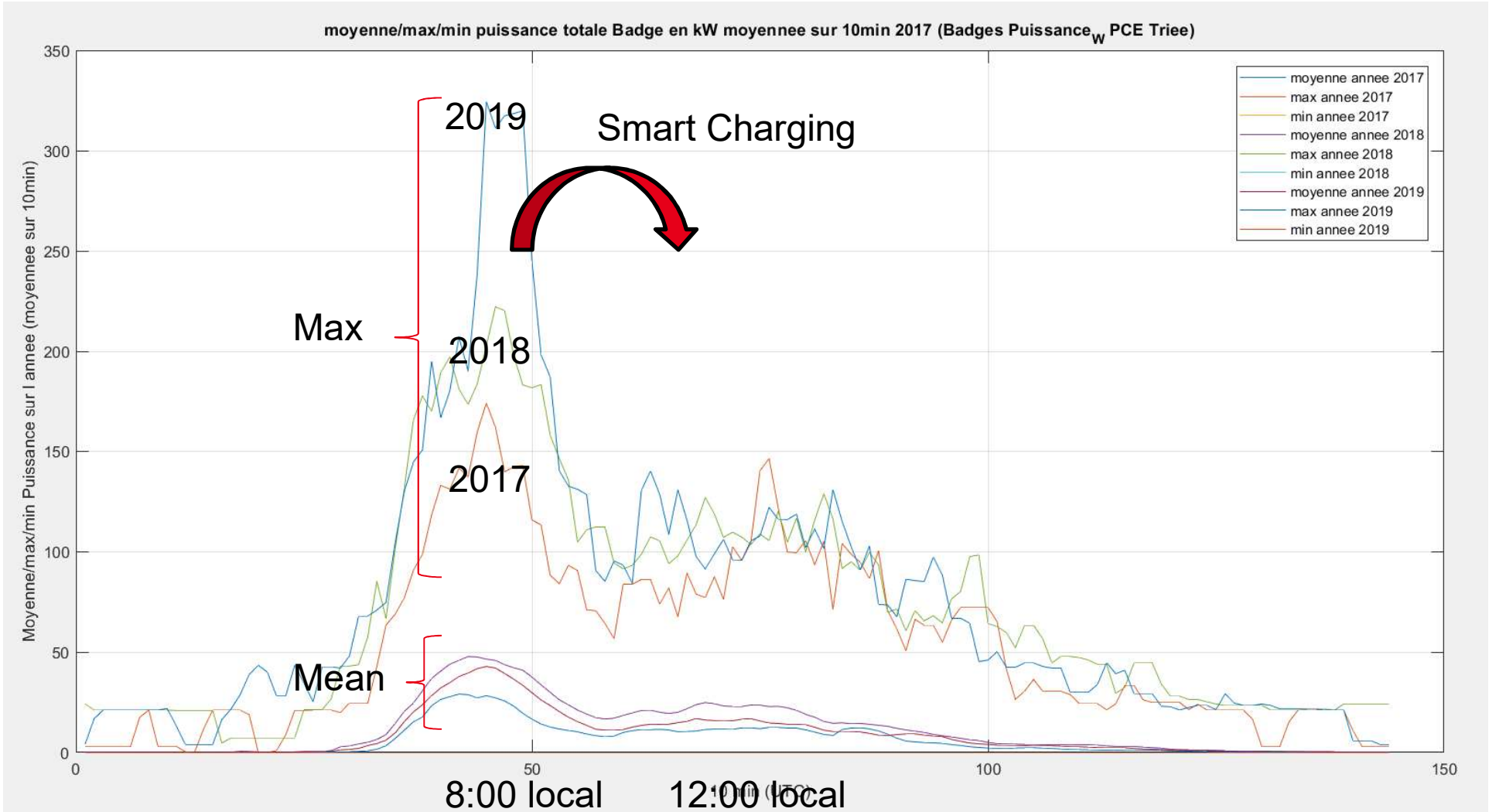


Hypothesis:

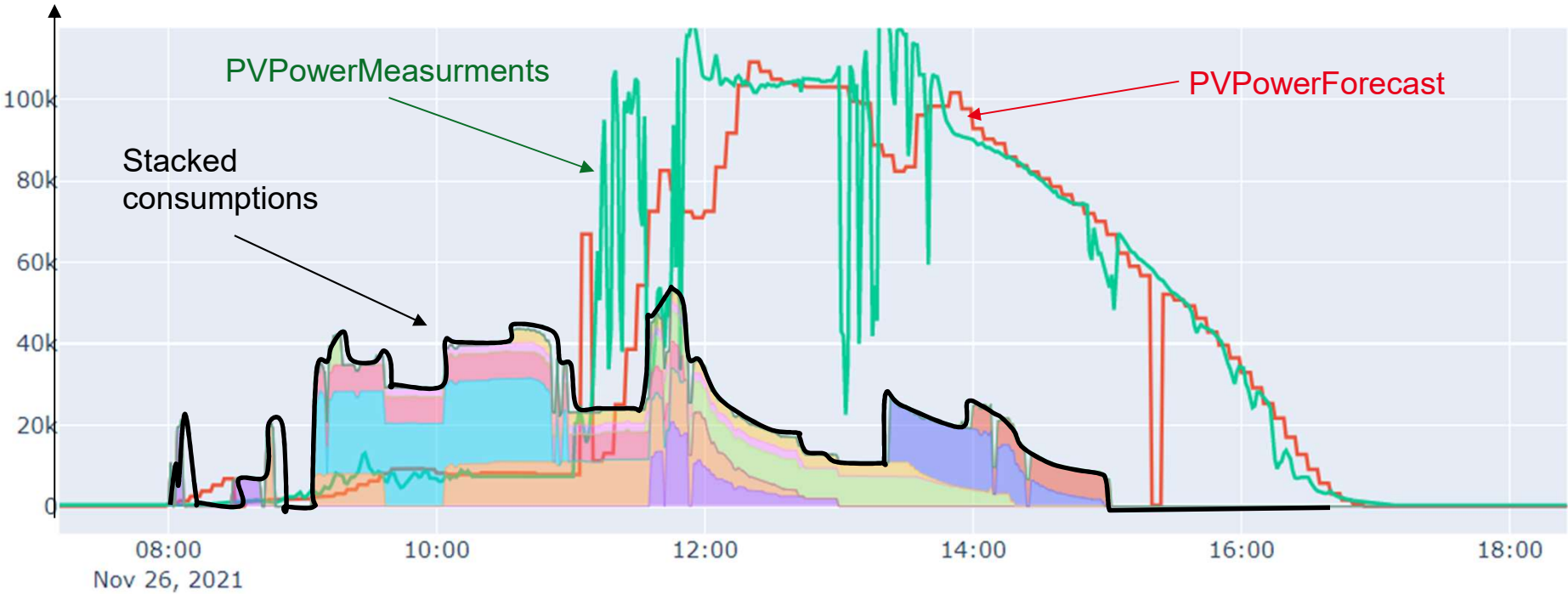
- the charge is carried out at constant power and this power is the maximum charging power of the car
- the charge begins as soon as the car is connected to the charging station



MAX CHARGING POWER HYP. : MEAN LOAD CURVES PER HOUR



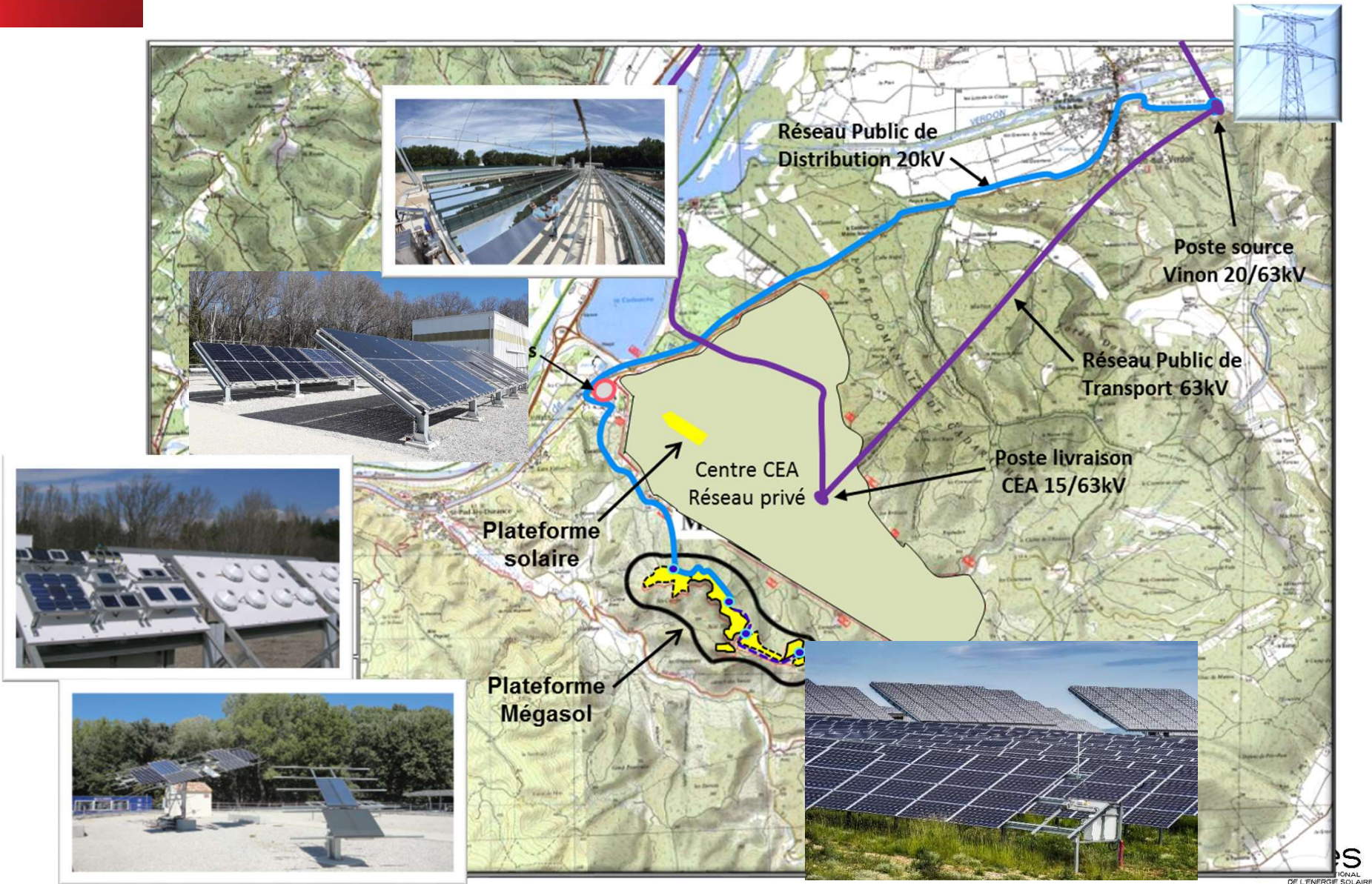
OBJECTIVES



→ Increase the self-production rate
 = (energy consumption under red curve) / total energy consumption

→ Satisfy the EV user, i.e., his EV battery is fully charged at his forecast departure time.

CEA CADARACHE – SOLAR R&D





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EVCI CADARACHE – EV & USERS

Model	Brand	Number of EV on site
Zoé	Renault	163
e-208	Peugeot	43
Twingo	Renault	30
Model 3	Tesla	28
Leaf	Nissan	21
Kangoo	Renault	16
E-Niro	Kia	9
e-2008	Peugeot	6
ID3	Volkswagen	6
Berlingo	Citroën	5
Ioniq	Hyundai	5
Golf-GTE	Volkswagen	4
Twizy	Renault	4
Kona	Hyundai	4

...

...

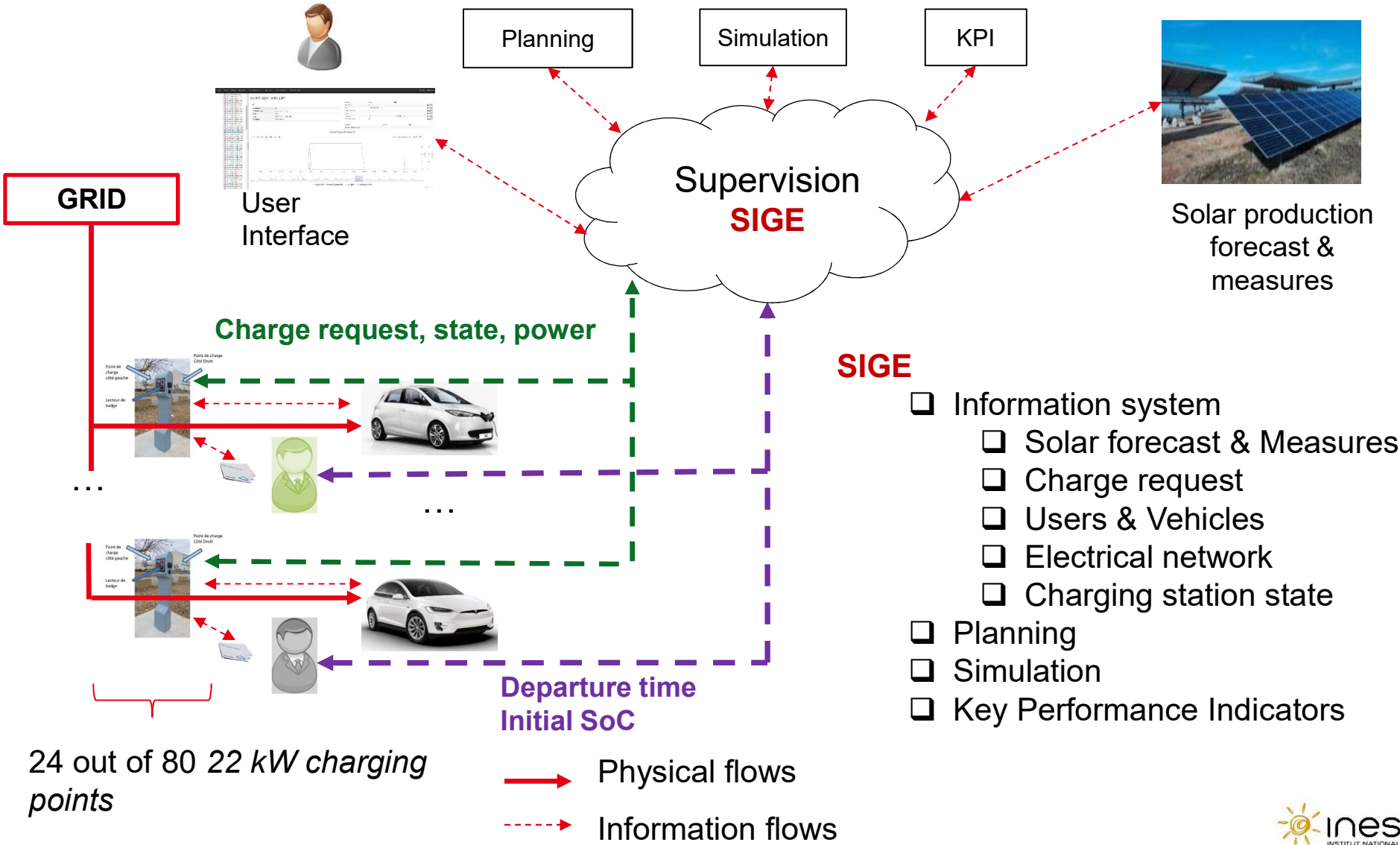
...

Type	#
External companies	29
Personal	260
Service	84
Taxi	3
TOTAL= 376	



3 involvement levels :
 Control, information (SOC and forecast departure time) = 83 people
 No control, information = 21 people
 No control, no information = 272 people

CONTROL ARCHITECTURE



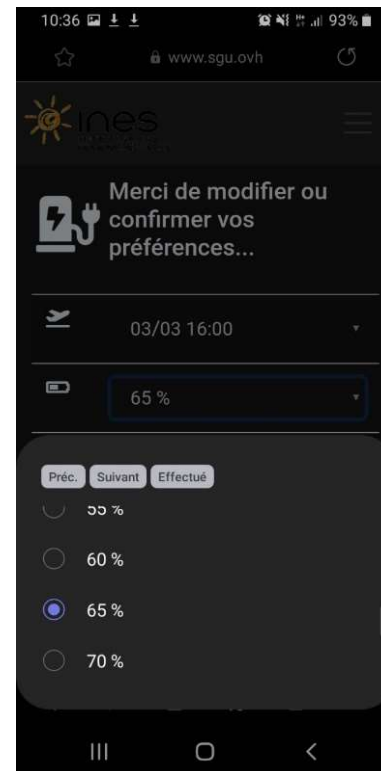
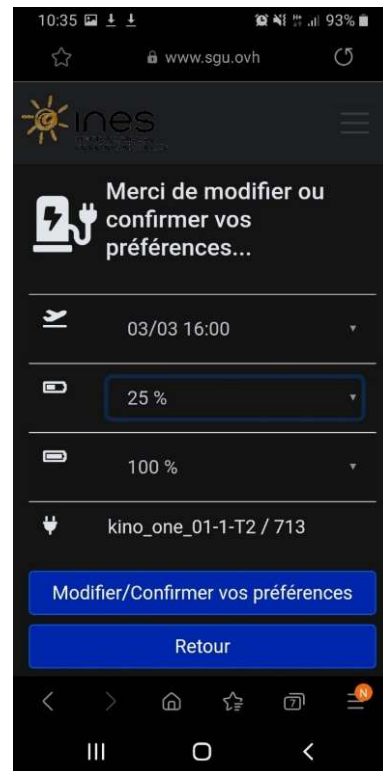
24 out of 80 22 kW charging points

→ Physical flows
 - - - - - Information flows



USER JOURNEY

- The user connects his EV and passes his badge
- The supervision software sends an SMS inviting the user to confirm his departure time and the SOC of his car (default values are proposed).
- Scheduling and recharge are made on the basis of these data





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 - Lessons from examples

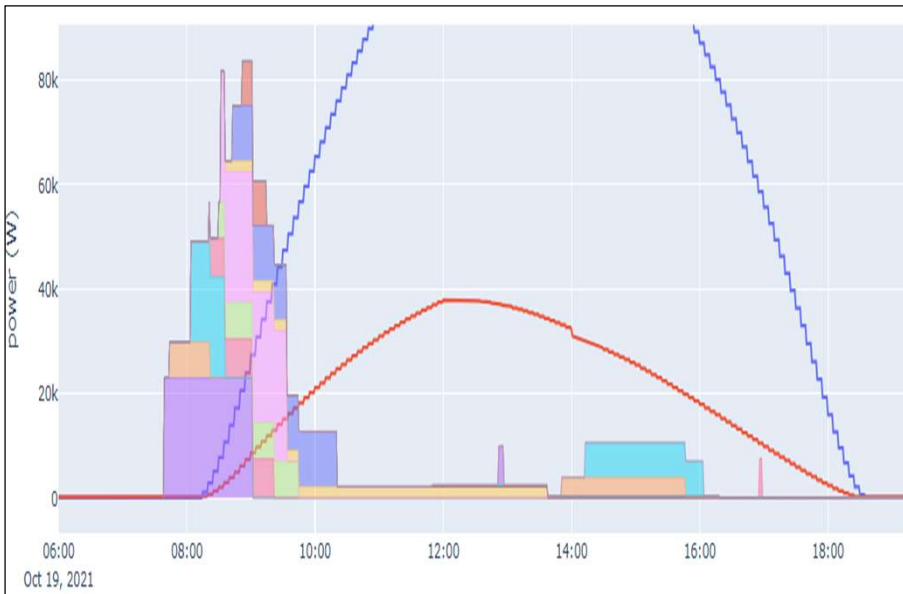


GLOBAL FIGURE

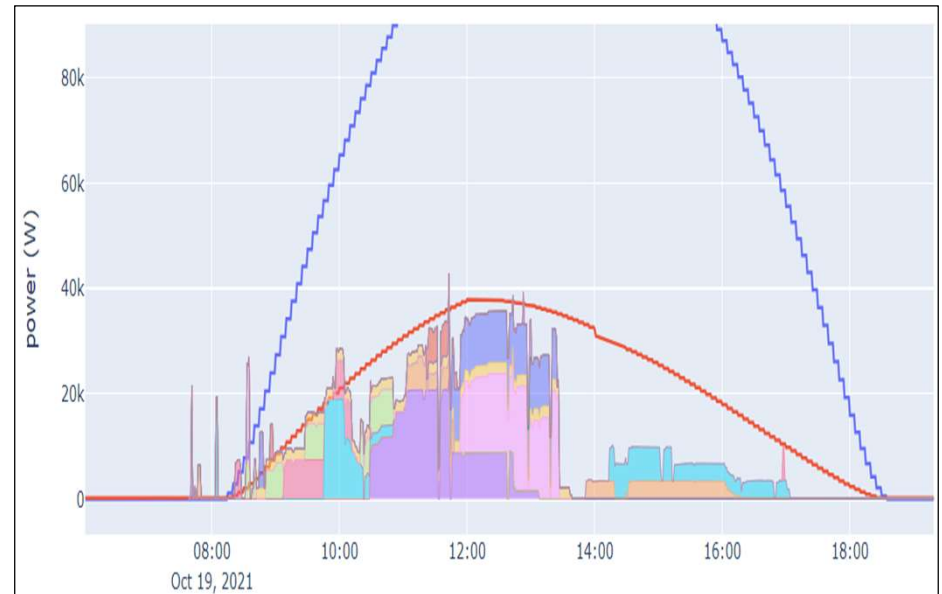
- **244 days between October, 1st 2021 and May, 31th 2022**
 - 130 days with exploitable data
 - 65 days without charging sessions
 - 49 days with measurements/control errors
- **Up to 24 - 22kW AC charging points have been controlled**
- **104 users have participated to the field tests**
- **1362 exploitable charging sessions**
- **1.1 year of cumulated EVCI use (mean ~7.3 h per charging session)**
- **24.4 MWh consumed by the EVs (mean ~18 kWh per charging session)**
- **117.0 MWh produced by the 160 kWc PV plant**

LESSON 1 : SELF-PRODUCTION INCREASE

- 19 Oct. 21 : Cloudy day
- 17 charging sessions (141kWh)
- PV plant = 160kWc (221kWh)
- Self-production rate **34%** (without control) and **90%** (with control)



Without control (simulation)



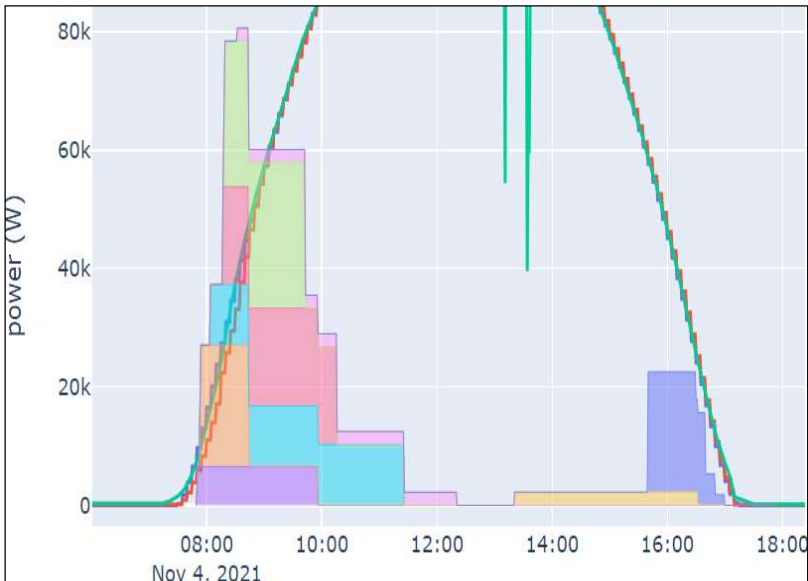
With control (measures)



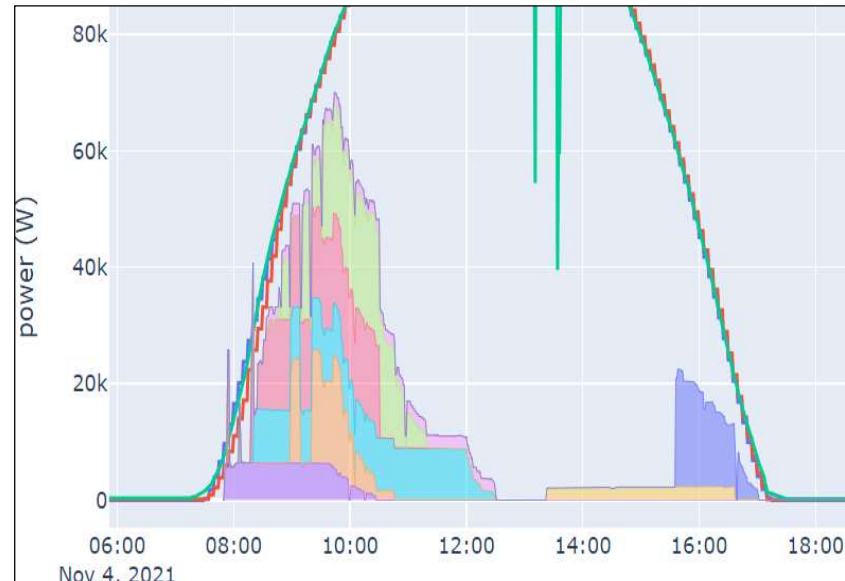
Some days, the control increases drastically the self-production ratio

LESSON 2 : « NATURAL » SELF-PRODUCTION

- 4 Nov. 21 : Sunny day
- 9 charging sessions (165kWh)
- PV plant = 160kWc (715kWh)
- Self-production rate **83%** (without control) and **97%** (with control)



Without control (simulation)



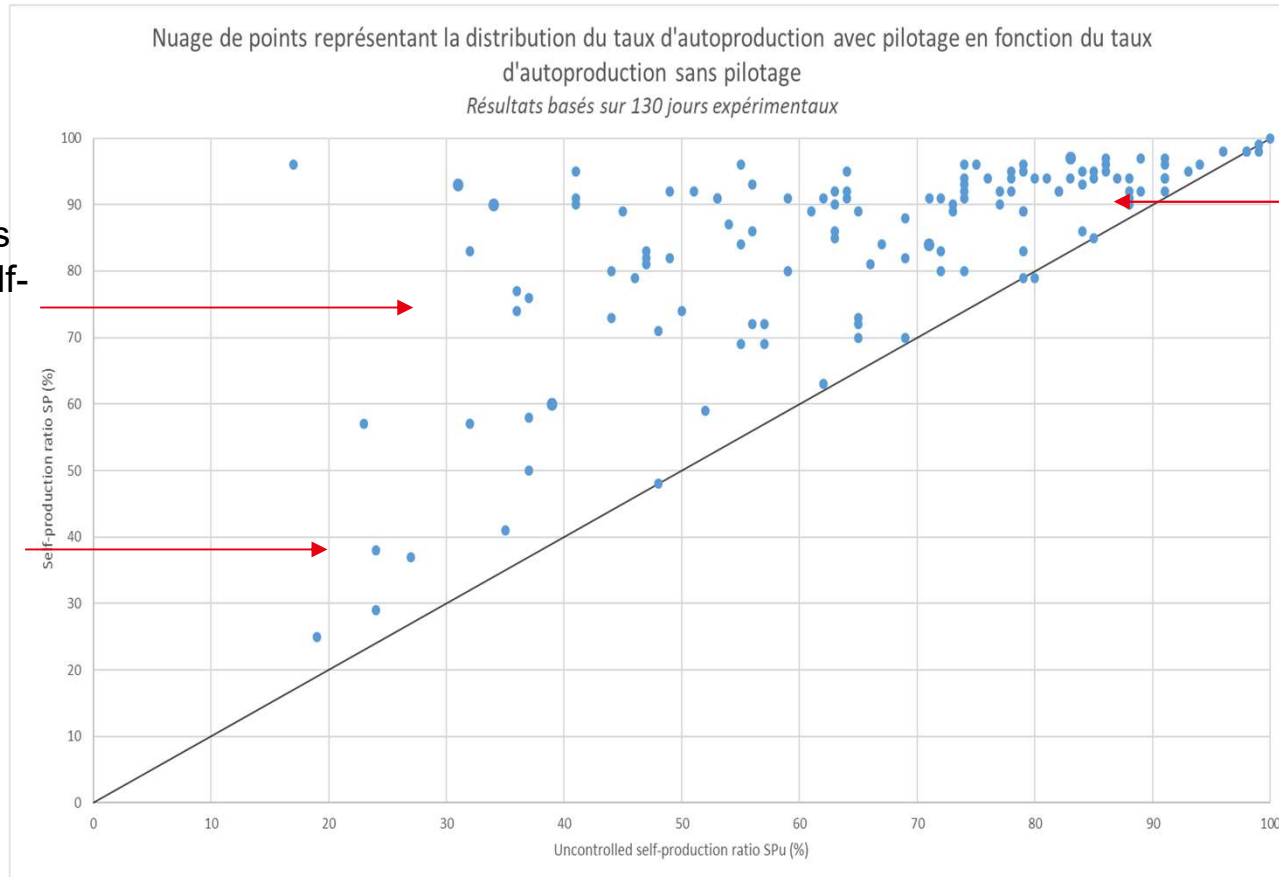
With control (measures)



Some days, the self-production rate is high, even without control



LESSON 3 : AVERAGE SELF-PRODUCTION RATIO



Control increases drastically the self-production ratio

Low self-production ratio with or without control

High self-production ratio with or without control

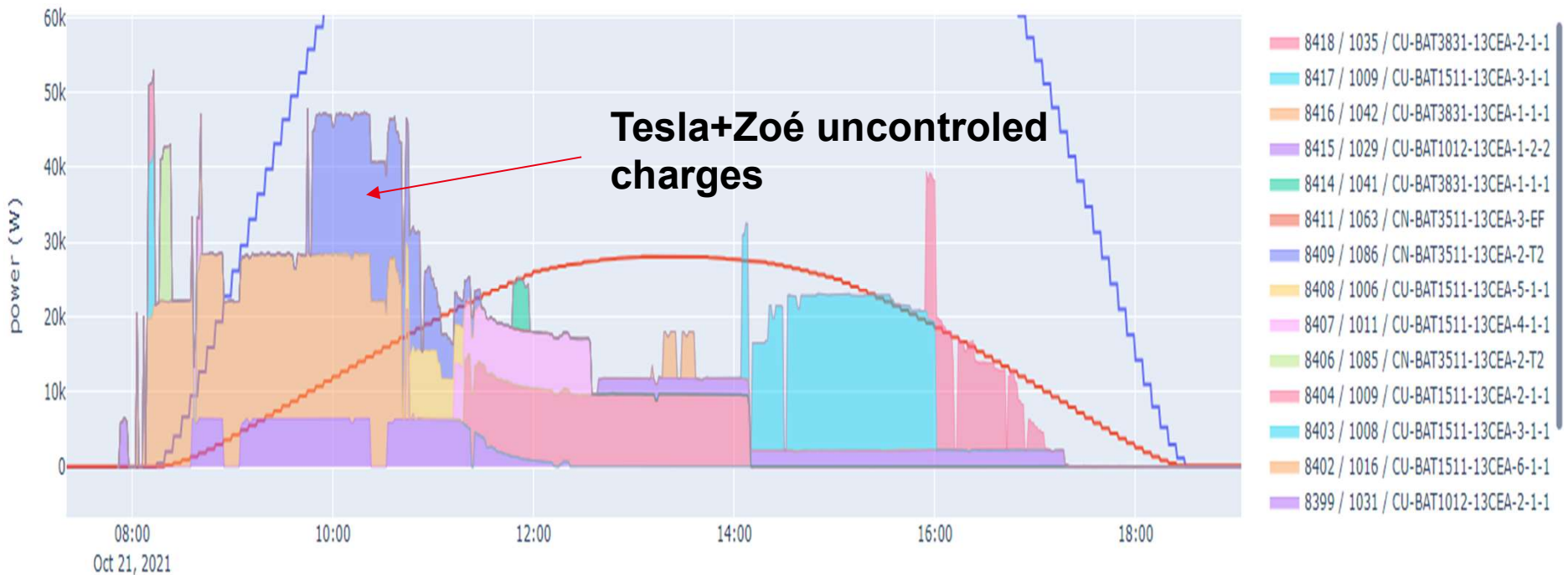
Self-production ratio without (x-axis) or with (y-axis) or control (one point per day)



In average, the self-production rate increases from 66% without control to 84% with control

LESSON 4 : USERS' BEHAVIOUR

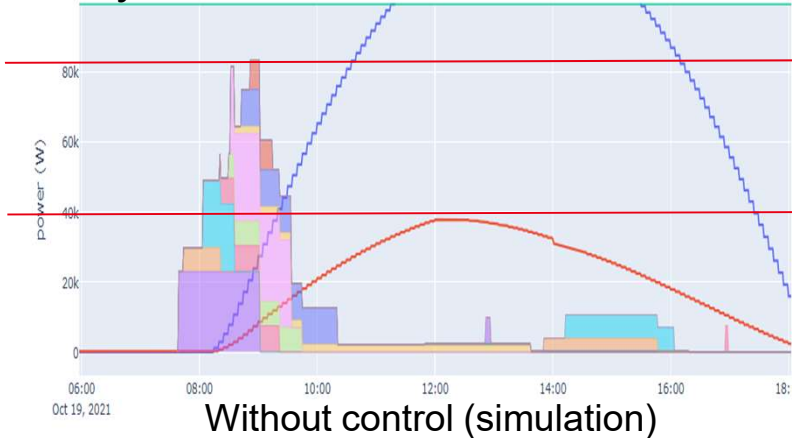
- 21 Oct. 21: Cloudy day
- 19 charging sessions (215kWh)
- PV plant = 160kWc (174kWh)
- Self-production rate **39%** (without control) and **60%** (with control)



➔ **Users' behaviour strongly influences the results**

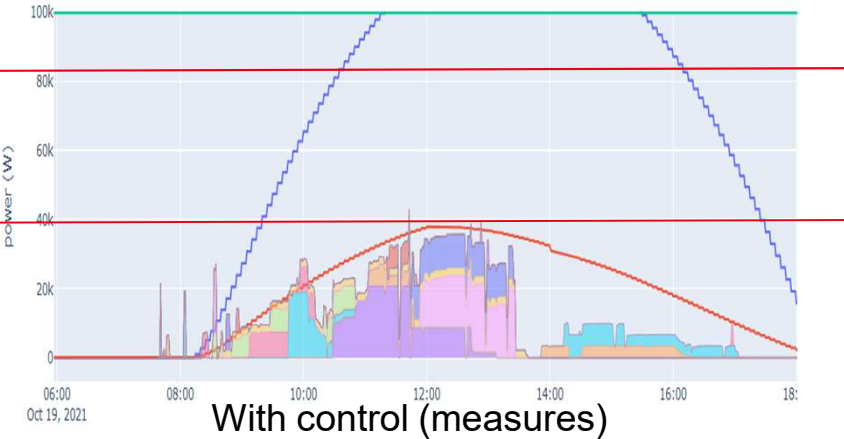
LESSON 5 : MAX POWER CONSUMPTION

Day 19 Oct. 21

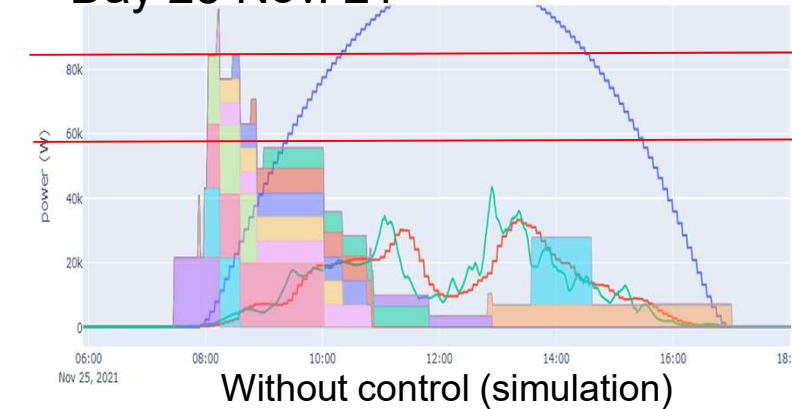


85kW

40kW

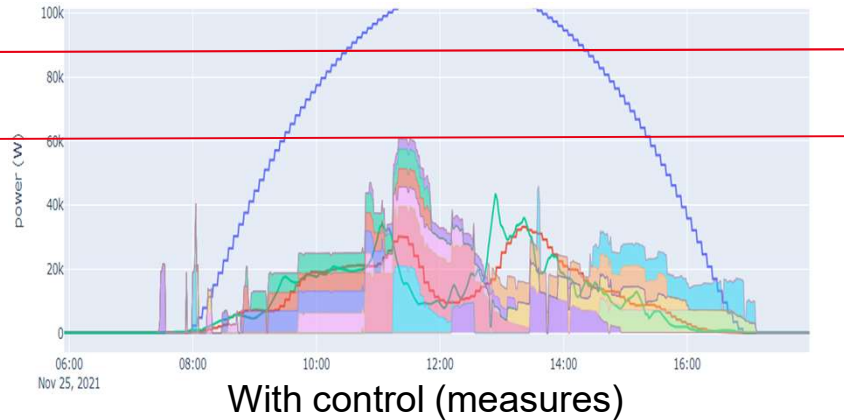


Day 25 Nov. 21



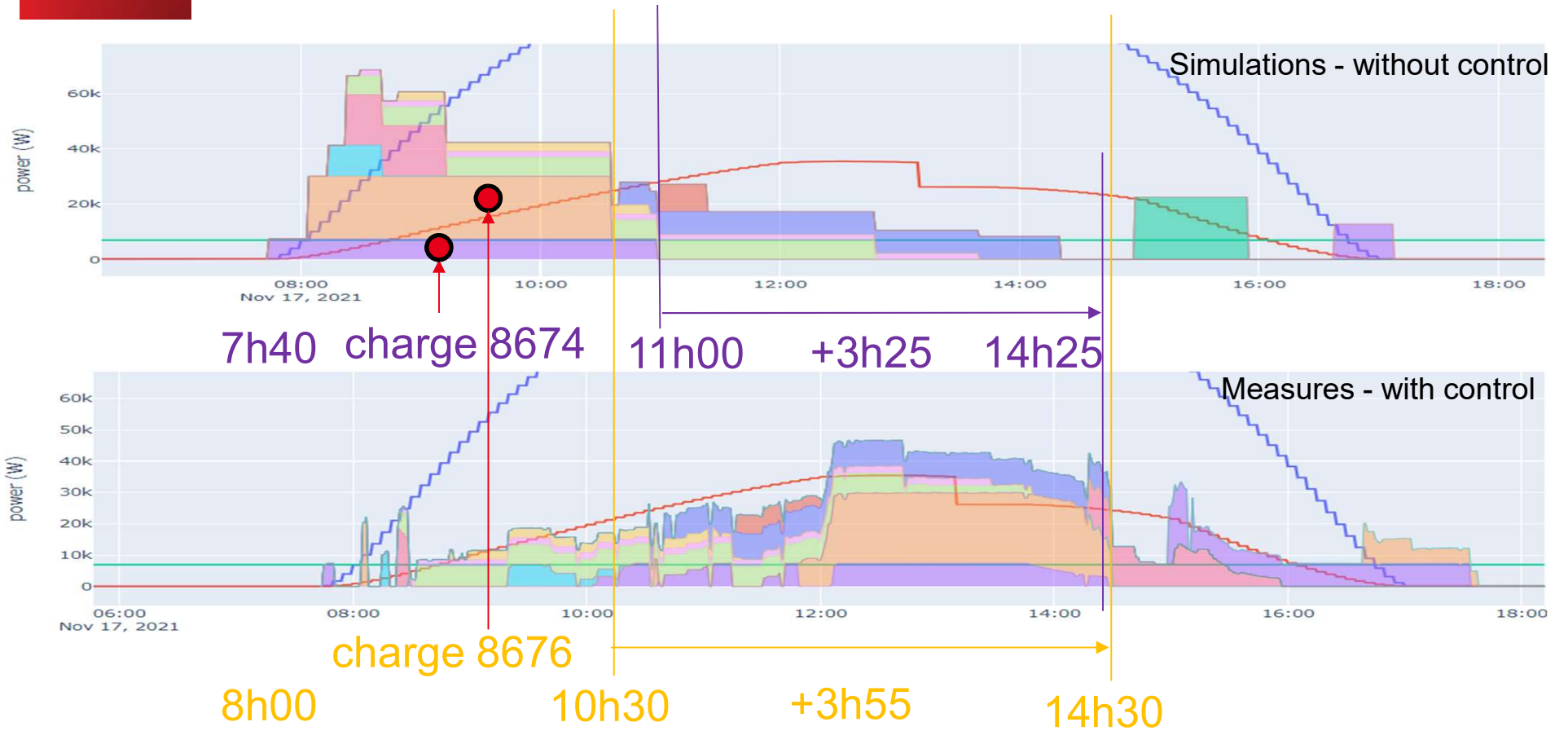
85kW

60kW



Increasing self-production rate may decrease the maximum value of the power consumption of the EVs

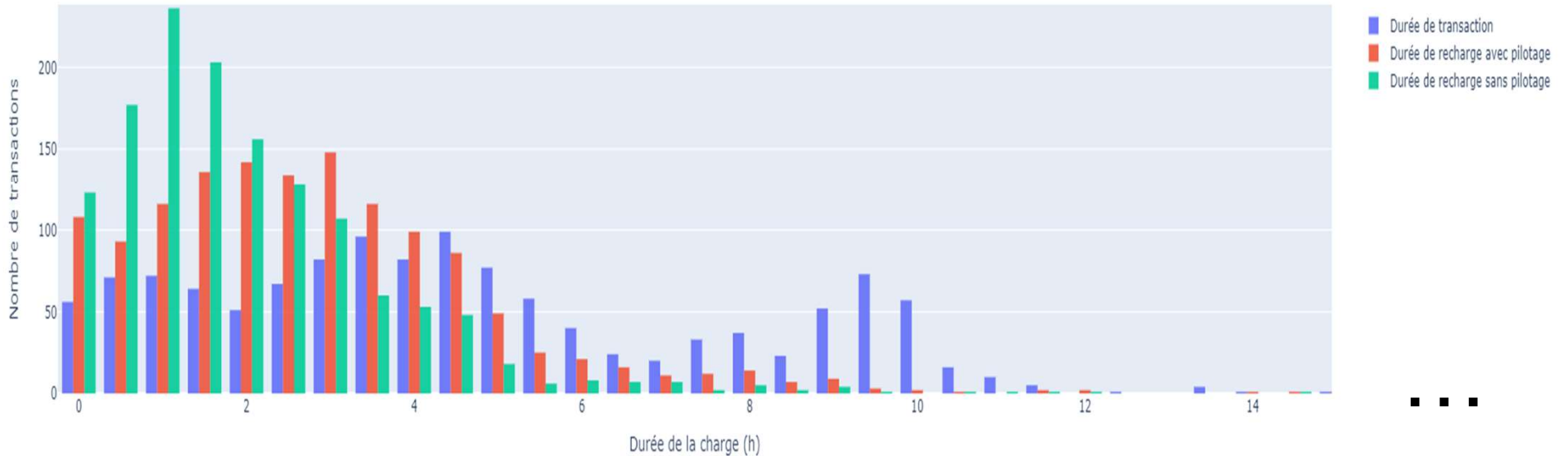
LESSON 6 : DELAYS




Increasing self-production rate may increase drastically the charging time (and so parking pressure), in particular when the weather is cloudy.

LESSON 7 : DELAYS

Comparaison des durées de transaction, de recharge avec pilotage, et de recharge sans pilotage

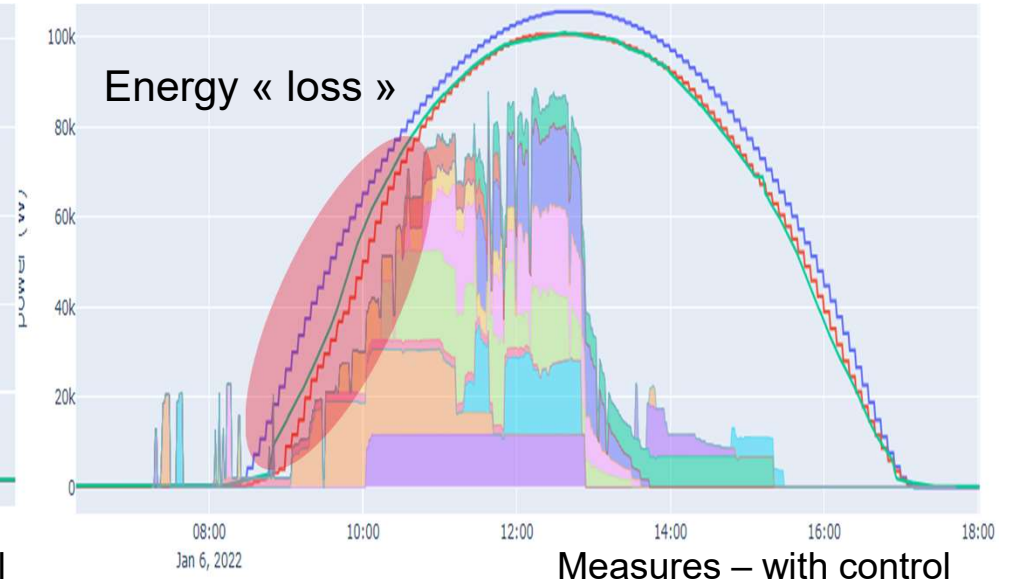
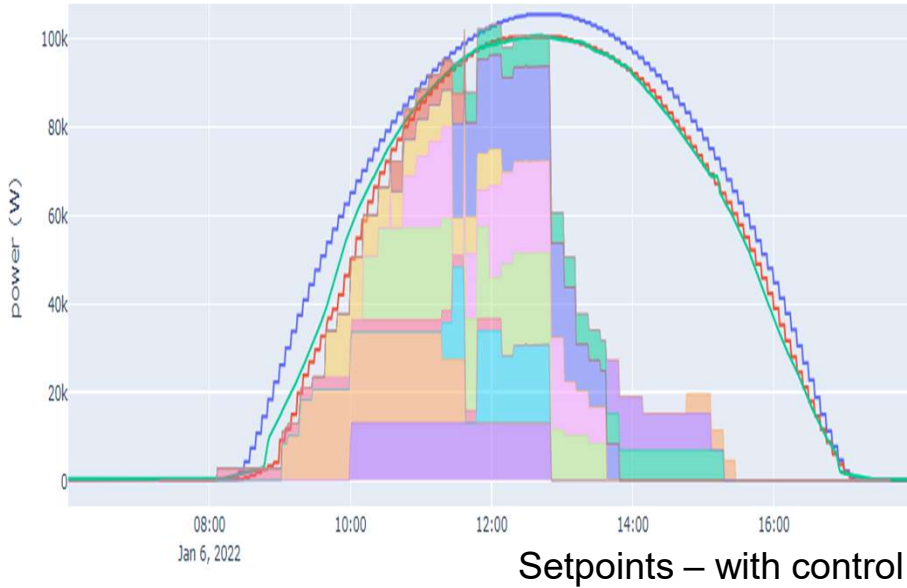


- Mean charging duration without control 2.1h
 - Mean charging duration with control 3.0h
 - Mean of the transaction 7.3h
-  +55min



The main reason of high parking pressure is the fact that the user doesn't free the parking place when the charge is finished

LESSON 8 : IMPORTANCE OF MODELS



Gap between setpoints and charging power :

- Car model
- Onboard charger size
- Type of connection, cable
- Battery : Temperature, age, SOC
- User setpoints
- Etc.



Accurate charging models are essential to improve charging control



LESSON 9 : USERS' FEEDBACK ABOUT CADARACHE EVCI

Survey Replies : 33 replies (out of 102 people contacted)

Career → Engineer/researcher: 21 | Administrative and financial : 4 | Technician: 4 | Manager: 4

- Overall user satisfaction : free service and practical to charge its EV on the worksite
- Charging frequency : more than 3 out of 4 people charge their EV at least once a week, more than half of them charge their EV at least twice a week
- Occupancy rate: many charging areas seem to be saturated as 1 out of 4 people do not find easily a EV parking spot to charge their EV near their working office

- *Significant increase in purchases of EV while no new charging station is settled*
- *Many people do not unplug their EV from the charging station once their EV is fully charged*



LESSON 9 : USERS' FEEDBACK ABOUT SOLAR CONTROL

Survey Replies : 33 replies (out of 102 people contacted)

- Overall user satisfaction : more than 9 out of 10 people recommend to be part of the Smart Charging experiments
- More than 4 out of 5 people completely let the smart charging control their charge
- Participants' motives:
 - Scientific approach
 - Solar charging and reducing carbon emissions

Areas of improvement

- Getting access to the programmed load power curve
- Getting access to Portion of solar energy used for EV charging
- Receiving an SMS at the end of the charging session to incite people to disconnect their EV



PERSPECTIVES

- Technical Tools
 - Add Key Performance Indicator : health of the batteries, user's satisfaction, parking pressure, etc.
 - Improve the charging models and parameters estimation
 - Forecast the charging needs of single vehicles and of a fleet of vehicles
 - Update the control architecture to act as a Smart Charging Service Provider
 - Integrate emerging technologies such as Vehicle-Integrated PV (VIPV) and V2X
 - Develop investment and operation cost analysis tools
- Use-cases & business models
 - Propose, develop and test new services for CPOs and EV users : reducing parking pressure, power cost optimization, custom charging profiles, “battery friendly” charging profile, etc.
 - Propose, develop and test new grid flexibility services : optimization of self-consumption/self-production rate, demand/response, voltage control, peak shaving, etc.
- Experiments
 - eCharge4Drivers: coupling EVs and PV @INES ; coupling EVs and local grid (underground parking) @Barcelona

Thank you for your attention

Contact : bruno.robisson@cea.fr

**Details on algorithm and experimental
setup available at:**

***“Solar Charging of Electric Vehicles:
Experimental Results”, Robisson, B.;
Guillemin, S.; Marchadier, L.; Vignal, G.;
Mignonac, A. Appl. Sci. 2022, 12, 4523.***

<https://doi.org/10.3390/app12094523>

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