EvolVE: Smart charging at CEA

Bruno Robisson, Sylvain Guillemin, Gérald Vignal, Alexandre Mignonac

NEEMO
Networking for Excellence in Electric Mobility Operations

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SCHOOL

NEEMO SCHOOL-1: e-Mobility on Islands

EVOLVE: SMART CHARGING AT CEA

Bruno Robisson[*], Sylvain Guillemin[*], Gérald Vignal[+], Alexandre Mignonac[*]
[*]*CEA Cadarache*
[+]*RTE*

Tuesday 16 March 2021, 16:00-18:00 (UTC+1)

MCAST Malta College of Arts, Science & Technology
ANEL Nicosia Development Agency
AIT Austrian Institute of Technology
cea

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

AGENDA

- **EvolVE Project**
- **CEA EVCI & PV**
  - CEA EVCI
  - Charging modes
  - EvolVE @INES
  - EvolVE @Cadarache
- **Transaction analysis**
  - Transactions
  - Energy Consumption v. Transaction Duration (EC v. TD)
  - Flexibility definition & estimation
  - Beginning / end of transactions
- **Load curves**
  - Reconstruction
  - Analysis
- **Smart charging**
  - IT infrastructure
  - Autoconsumption rate
  - Examples of simulation results
  - First experimental results

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EVOLVE PROJECT

Partners

RTE : Réseau de Transport d'Electricité

CEA: Commissariat à l'Energie Atomique et aux Energies Alternatives

Objective

This project aims to synchronize the charge of a fleet of EVs with an "off-site" photovoltaic production.

Tasks

1. Defining the experimental framework
2. Design and setup equipments, IT infrastructure and control algorithms
3. Monitor and evaluate the experiments

Planning

Kick-off: January 2020
Tasks 1 & 2 : 01/2020 -> 05/2021
Task 3 : 06/2021 -> 05/2022

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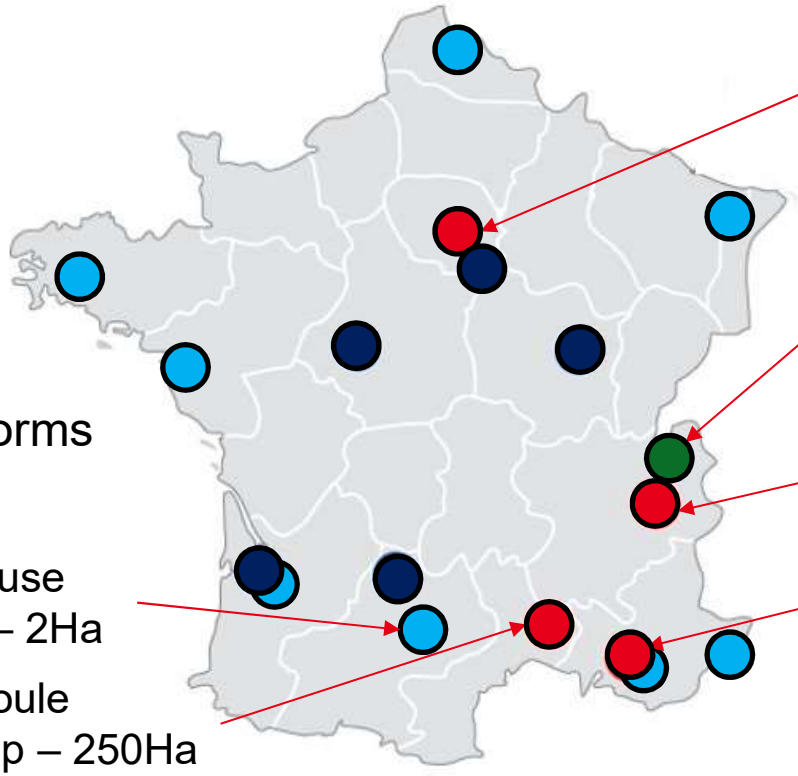
CEA CENTERS

liten
cea tech

- Civil centers
- Military centers
- INES Chambéry
- Technological platforms



Saclay-Fontenay-Aux-Roses
7500 p – 160Ha

Chambéry - INES
500 p – 8Ha

Grenoble
3700 p – 67Ha

Cadarache
2500 p – 900Ha

Toulouse
50 p – 2Ha

Marcoule
1500 p – 250Ha

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

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CEA : ELECTRIC VEHICLES CHARGING INFRASTRUCTURE (EVCI)

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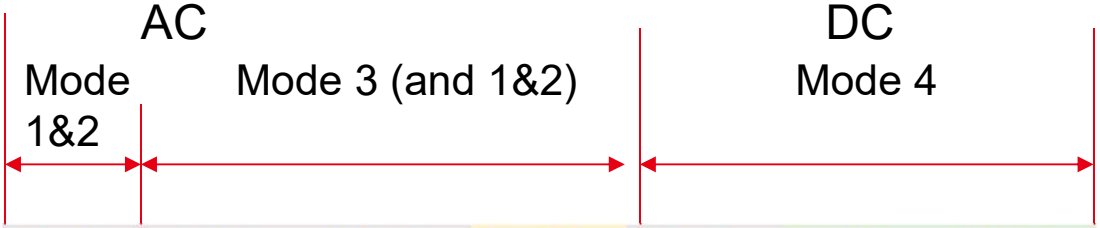
INES

Toulouse

Grenoble

Cadarache

Normal	<11kW
Accelerated	>11kW & <24kW
Fast	>24kW



CEA employees	Surface (Ha)	Center		3kW AC	7kW AC	11kW AC	22kW AC	10kW DC	30kW DC	50kW DC	TOTAL
2500	900	Cadarache					81				81
50	2	Toulouse	Actual				3				3
			Forecast		4		2	1		2	9
7500	160	Saclay			40						40
500	8	Ines					20		1		21
3700	67	Grenoble		70	51		4				125
1500	250	Marcoule		22		16					38
		TOTAL		92	95	16	110	1	1	2	317

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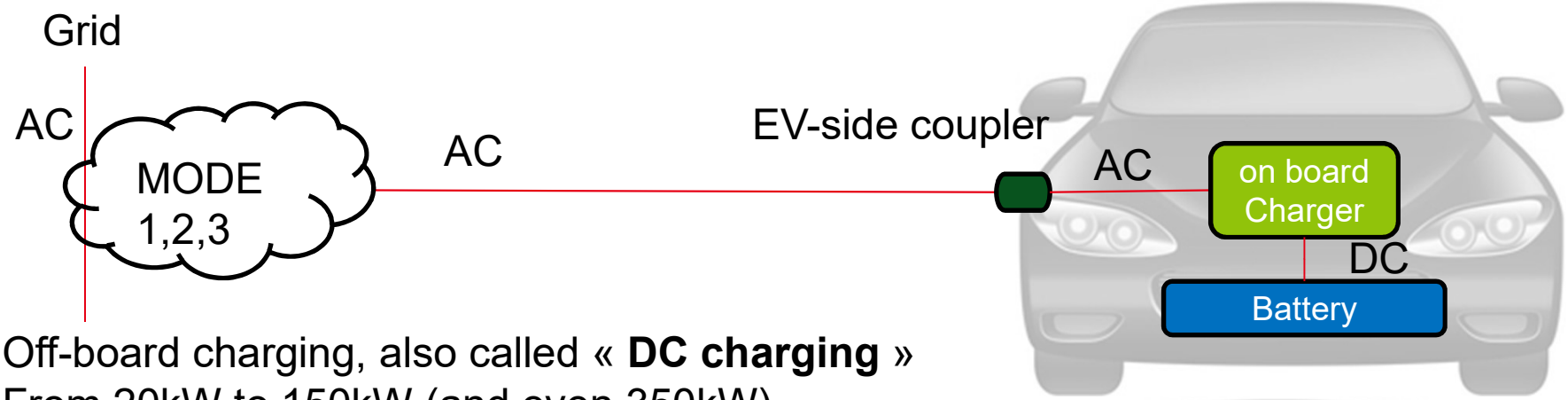
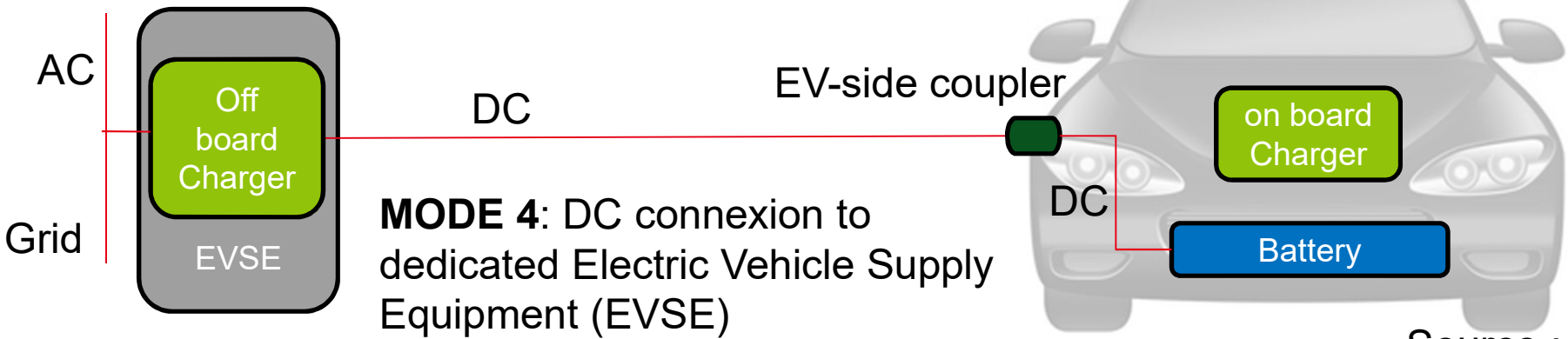
CHARGING MODE (IEC 61851 STANDARD)

On board charging, also called « **AC charging** »
From 3kW to 22kW (and even 43kW for Zoé first generation)



Off-board charging, also called « **DC charging** »
From 20kW to 150kW (and even 350kW)



MODE 4: DC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

Source : [1]

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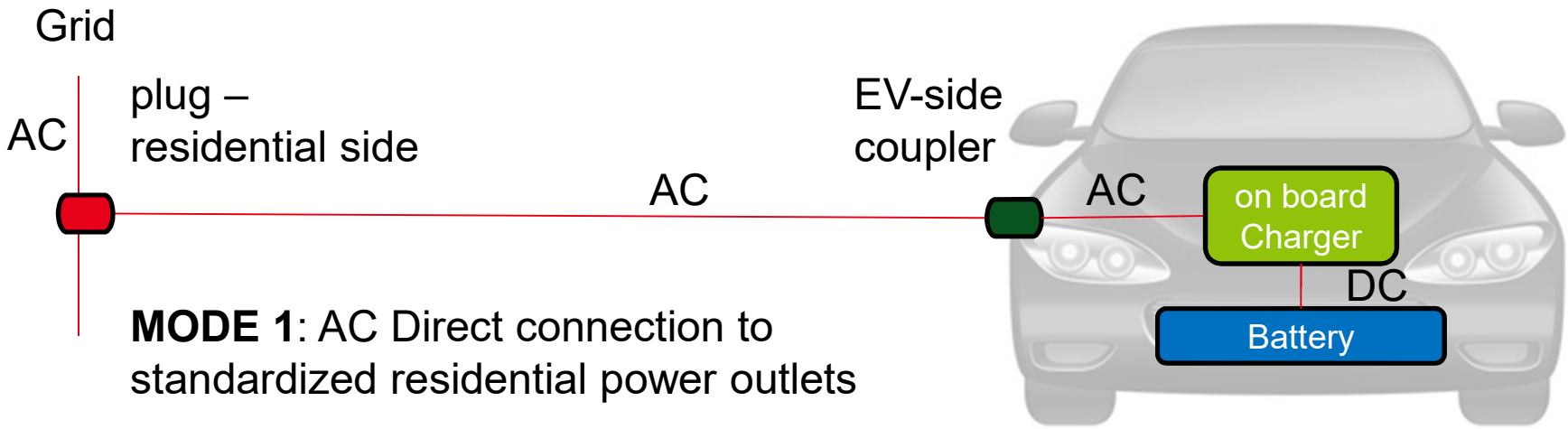
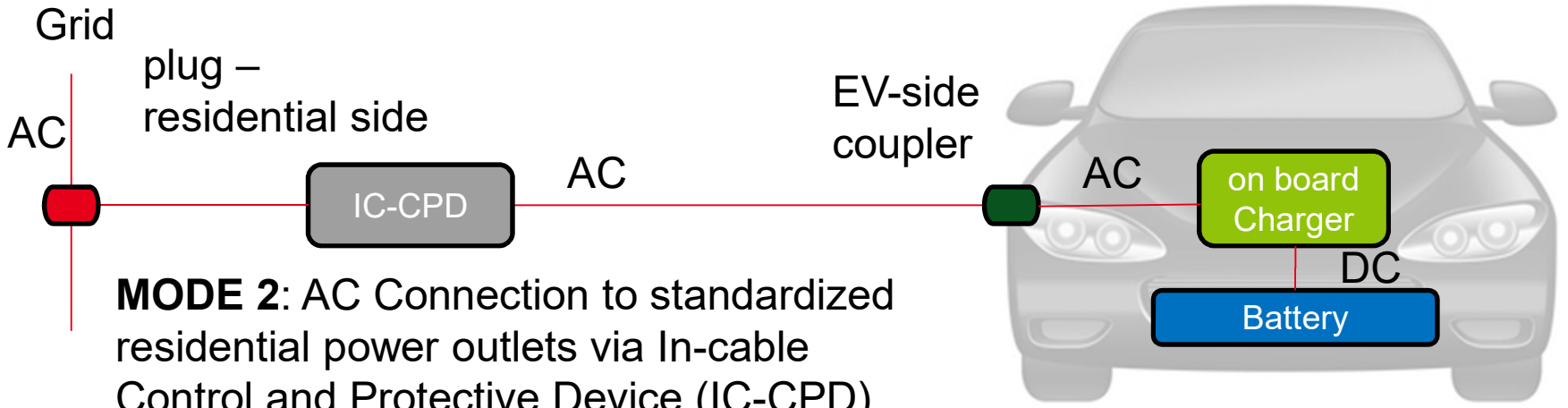
AC CHARGING MODE: MODE 1, 2



MODE 1: AC Direct connection to standardized residential power outlets



MODE 2: AC Connection to standardized residential power outlets via In-cable Control and Protective Device (IC-CPD)

Source : [1]

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THE PLUG AND SOCKET ZOO – MODE 2

Type E (CEE 7/17) Mono-ρ 230V

70@Grenoble

22@Marcoule

Blue: « camping » socket Mono-ρ 230V

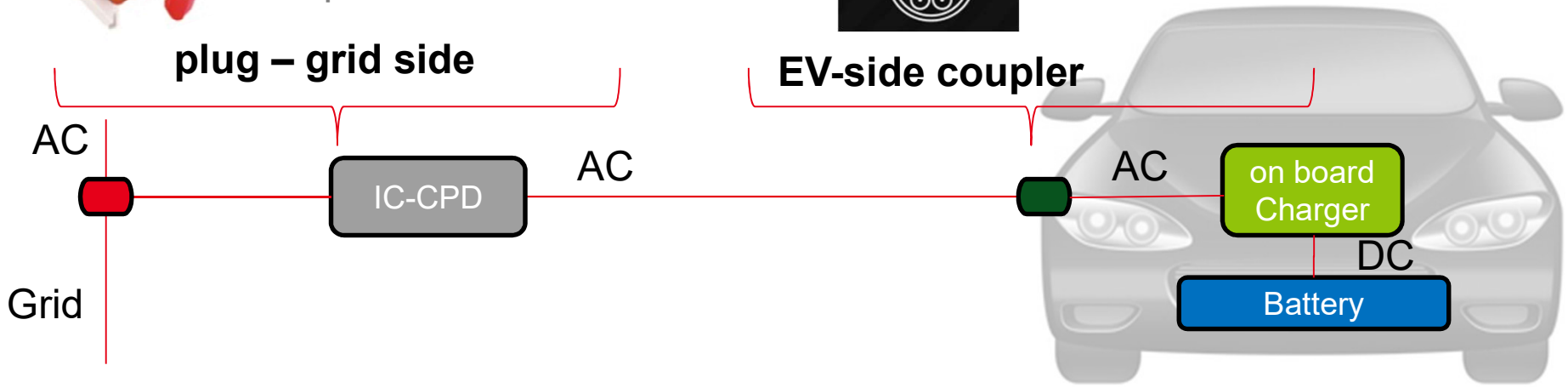
Red: Industrial socket Tri-ρ 400V

Tesla coupler

Type 1 coupler

Type 2 coupler

Depends on the vehicle



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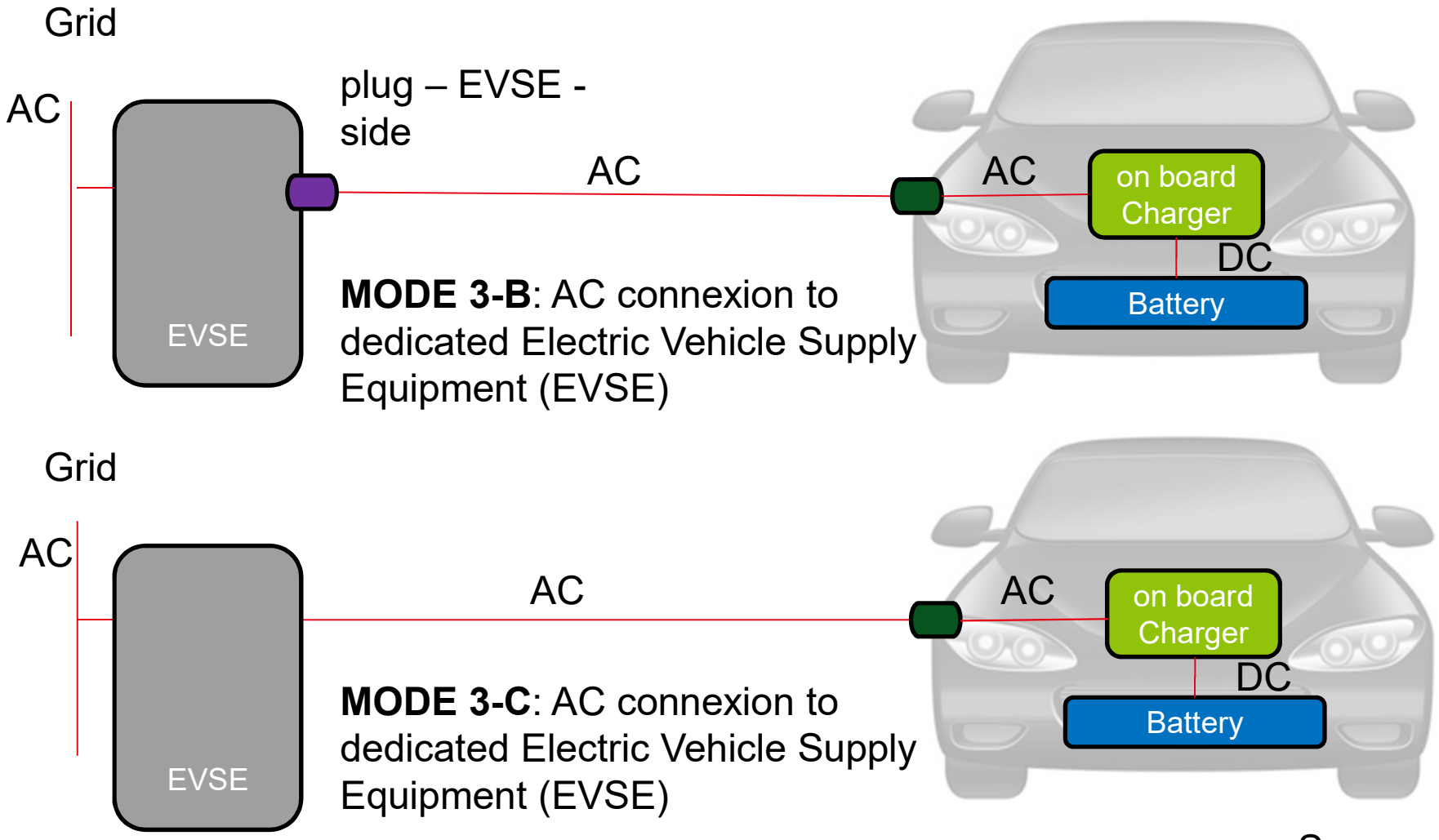
AC CHARGING MODE: MODE 3



MODE 3-B: AC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

MODE 3-C: AC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

Source : [1]

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THE PLUG AND SOCKET ZOO – MODE 3 B

Type 2 outlet

7@Toulouse
42@Grenoble
18@INES
40@Saclay
81@Cadarache
16@Marcoule

Type 3 outlet

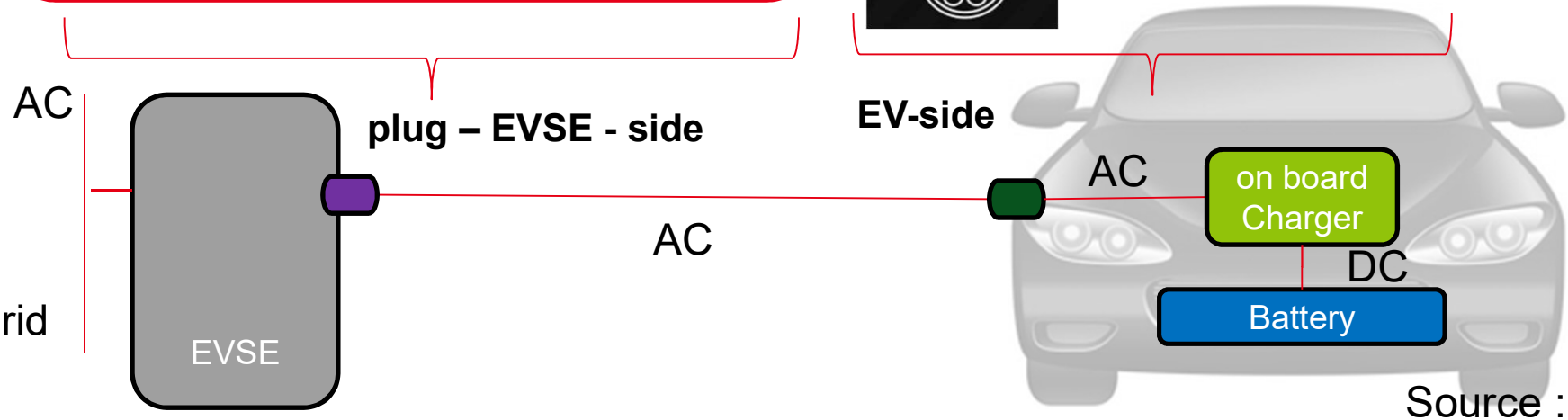
9@Grenoble

Tesla coupler

Type 1 coupler

Type 2 coupler

Depends on the vehicle



Source : [1,2]

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THE PLUG AND SOCKET ZOO – MODE 3 C

Tesla coupler

Type 1 coupler

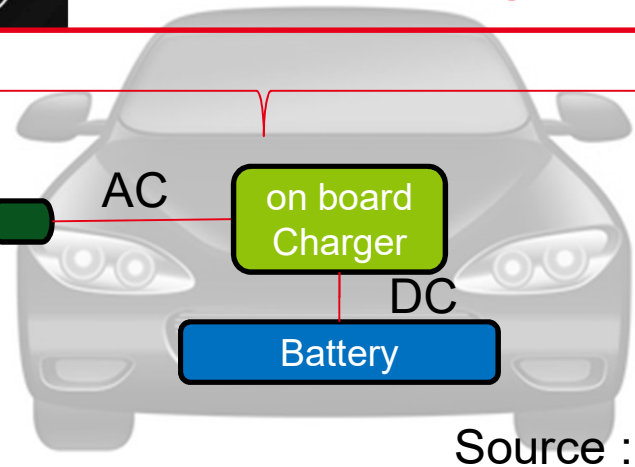
1@INES

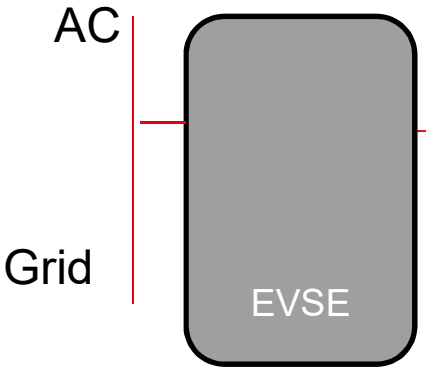
Type 2 coupler

1@INES

2@Toulouse

EV-side





Source : [1,2]

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THE PLUG AND SOCKET ZOO – MODE 4

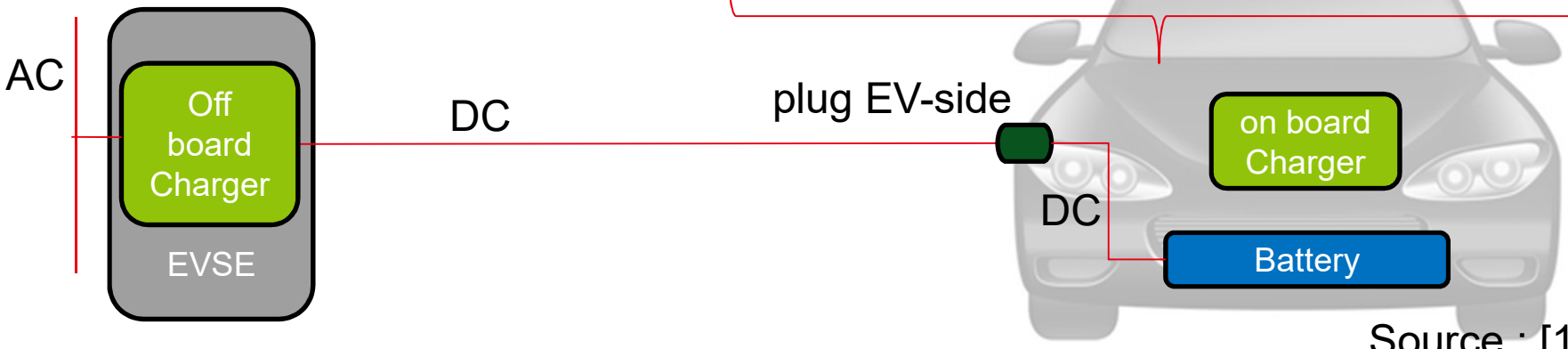
Tesla plug

CHAdeMO
(DC only)

2@Toulouse
1@INES

Combo 2 : Combined Charge System CCS (DC+type 2)

1@Toulouse



Source : [1,2]

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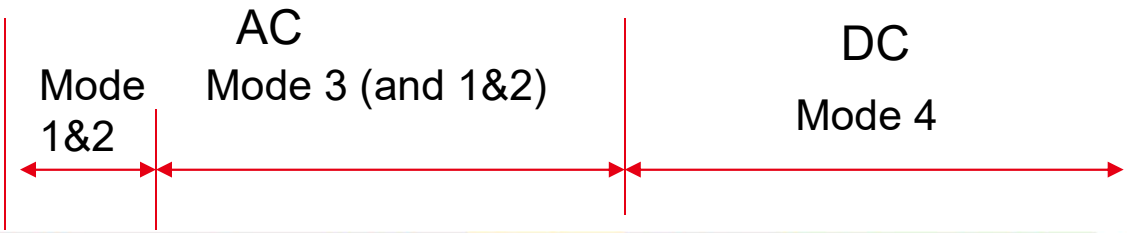
ELECTRIC VEHICLE CHARGING INFRASTRUCTURE (EVCI)



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3700	67	Grenoble		70	51		4				125
1500	250	Marcoule		22		16					38
		TOTAL		92	95	16	110	1	1	2	317

EvolVE

¼ of the 81 AC-EVSE in INES : 20 EVSE

100% of the 20 AC-EVSE in Cadarache : ~ 20 EVSE

➡ INES + CADARACHE = 40 * 22kW AC mode 3 (and mode 1&2)

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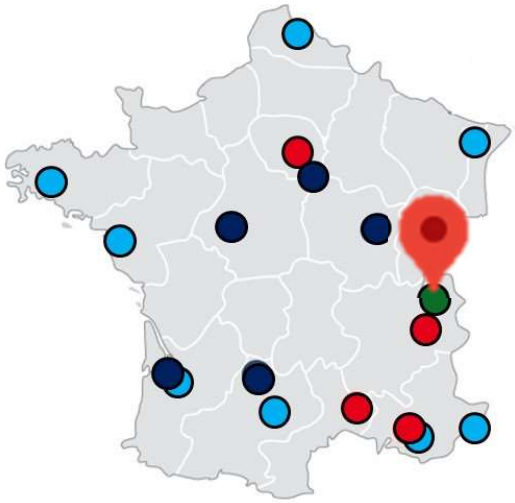
EVCI & PV @CEA-INES



INES research center
@Chambéry

- 20 parking places
- 12 of them are above a 21kWp solar carpot
- 10-15 EV users

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EVCI CEA-INES

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9 e-totem (e-smart 1*22kW)	3 Driveco (Kino One 1*22kW)	2 Driveco (Kino One 2*22kW)	1 Hager (Witty Park 2*22kW)	1 Cahors (Access 2*22kW)
				
Mode 3B	Mode 3B	Mode 3B & 3C	Mode 3B	Mode 3B

20 * 22kW EVSE

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CEA CADARACHE – NEAR AIX-EN-PROVENCE

5500 workers

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

480 buildings and **500 000** m2 de planchers

70 Km of paved roads, 6 km of landscaped footpath, around 5500 people / day on site

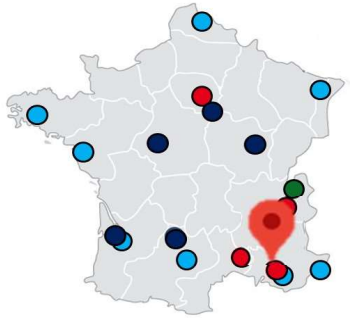
29 Bus lines carrying a thousand employees

75 km of water distribution network (drinking water station, industrial water, purification station)

Private power network

- 63kV / 15kV substation
- 18 MV loops (85km of 15kV underground lines)
- EVCI : 81 charging points at 22kVA
- 3kV public lighting network

63kV / 15kV substation



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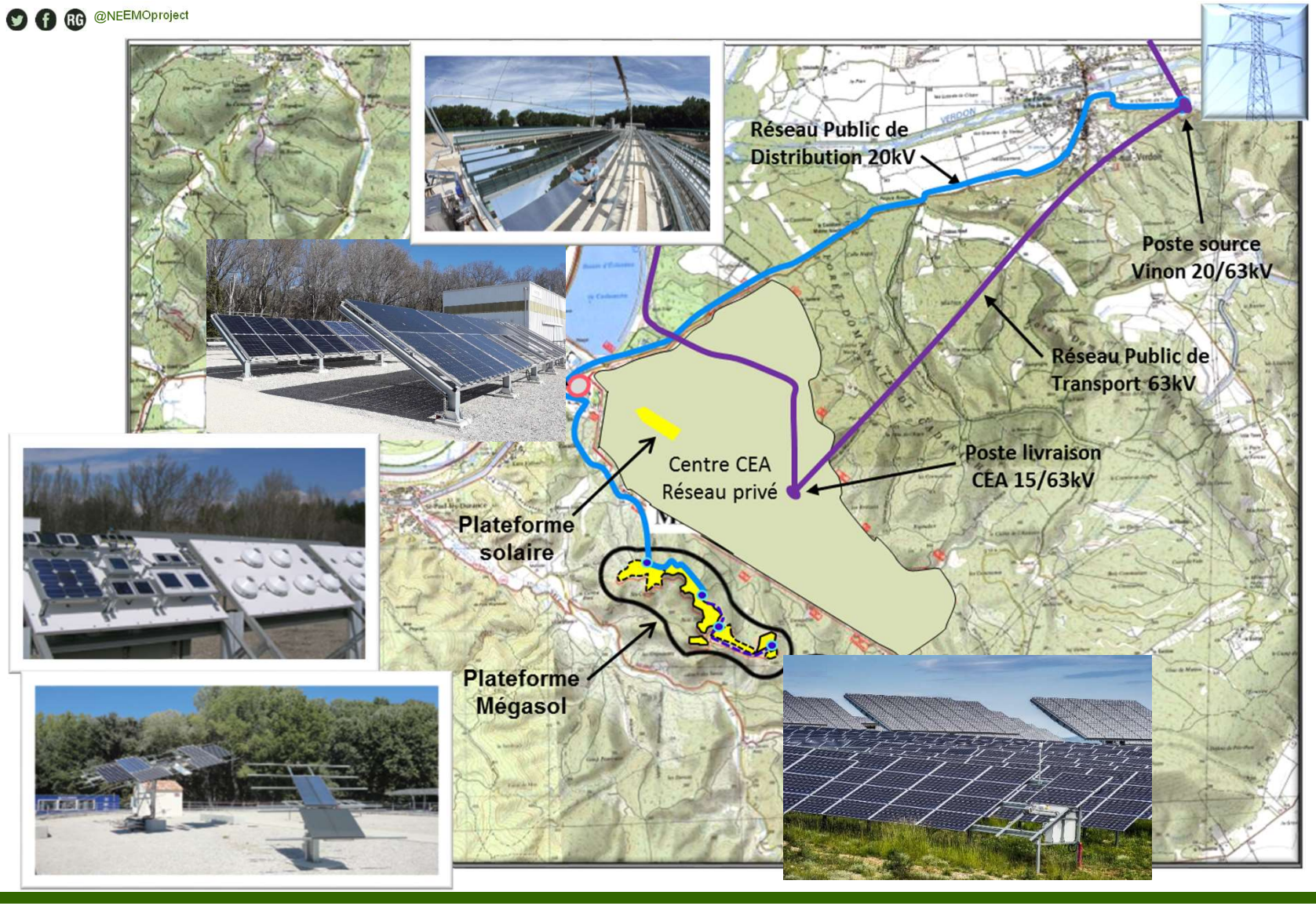
CEA CADARACHE – SOLAR R&D



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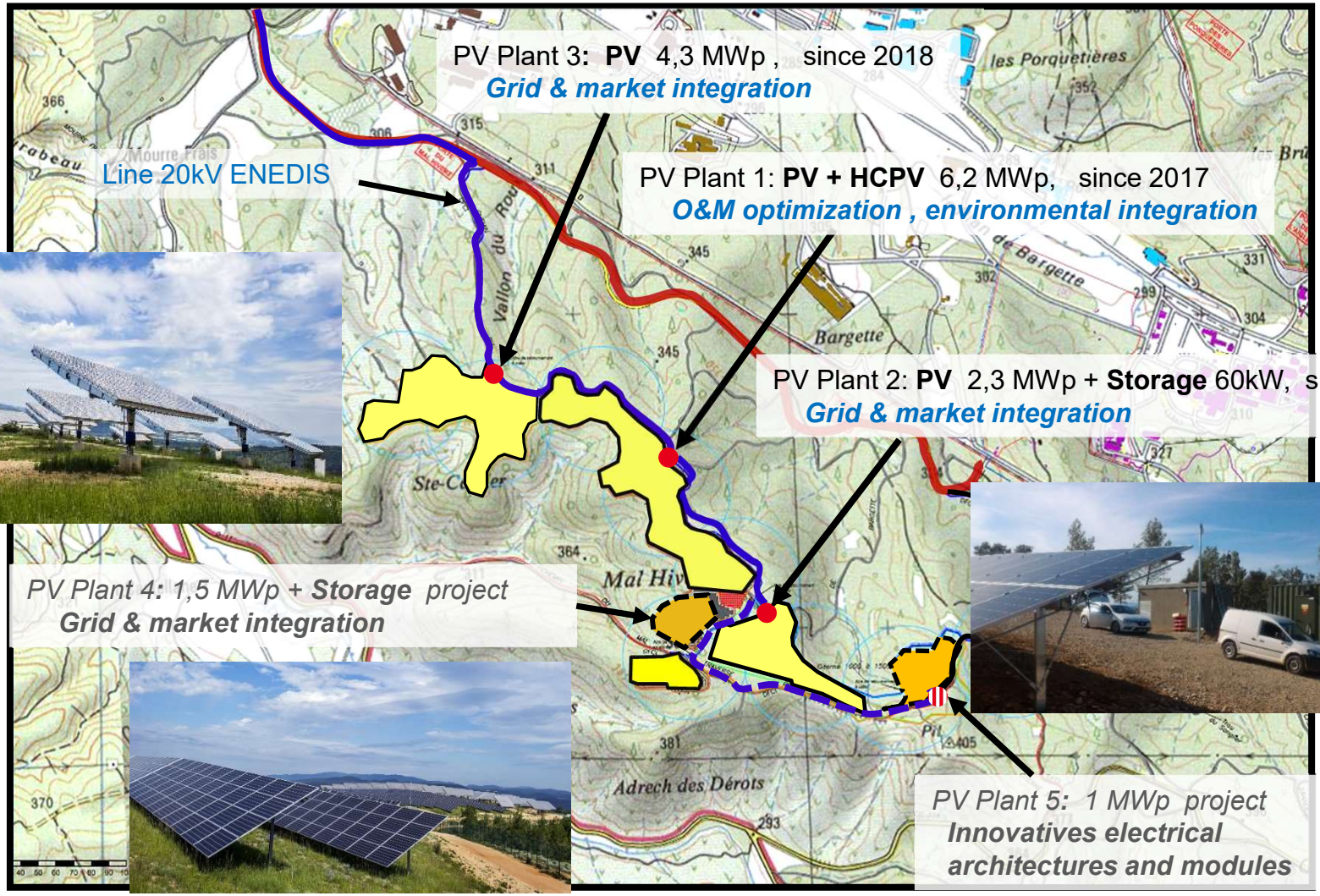
MÉGASOL PLATFORM (13 MWP)



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EVCI CADARACHE – CHARGING STATION

30 EV charging areas

5 areas participating at EvolVE

G2Mobility (now Total EV Charge)
Diva (2*22kW)

Setup mid-2016

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EVCI CADARACHE – EV

Modele	Nombre
Zoé	126
M3	4
MS	3
Kangoo	14
Golf GTE	3
Twizy	4
Fortwo	2
Leaf	11
Berlingo	4
Autre	14
e208	2
Ion	1
Partner	1
Ioniq	2
C-Zéro	1
330e	1
E-Niro	1
Outlander	2
Think city	1

67 service vehicles
51 personal vehicles
3 taxis
5 external companies vehicles

Type	#
External companies	17
Personal	85
Service	90
Taxi	3
	TOTAL= 195

Figures at march 2020
Increase ~50 EV /year

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EVCI CADARACHE – EV

	Mode 1 et 2	Mode 3
Diva	Up to 3,7kW (AC)	Up to 22kW (AC)

Model	Battery capacity (kWh)	Max AC charging power (kW)
Zoé	{22;41;52}	**22** or 43 (Mode 3) or **2.3** (Mode 2)
Leaf	{24;30;40;60}	**6.7** or 3.3 or **2.3**
Tesla M3	{52;77}	**11** or **2.3**
Tesla MS	{40;60;70;75;85;90;100}	**22** or **16.5** or **11** or **2.3**
Smart	17.6	**22** or **2.3**
Golf GTE	35.8	3.6 or 2.3
Twizzy	{6;8}	3.3 or **2.3** (mode 1)
Berlingo	22.5	6.7 or **3.3** or **2.3**
Kangoo	{22;33}	**7** or **3.7** or 3.2 (mono)

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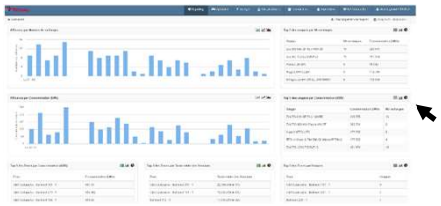
EVCI CADARACHE - DATA COLLECTION



User Interface

GRID

Cloud
TOTAL EV Charge

Ocpp

Charge request, state, Power

…

…

Power flow

Ocpp

IEC 61851

RFID

Tcp/IP

Information flow

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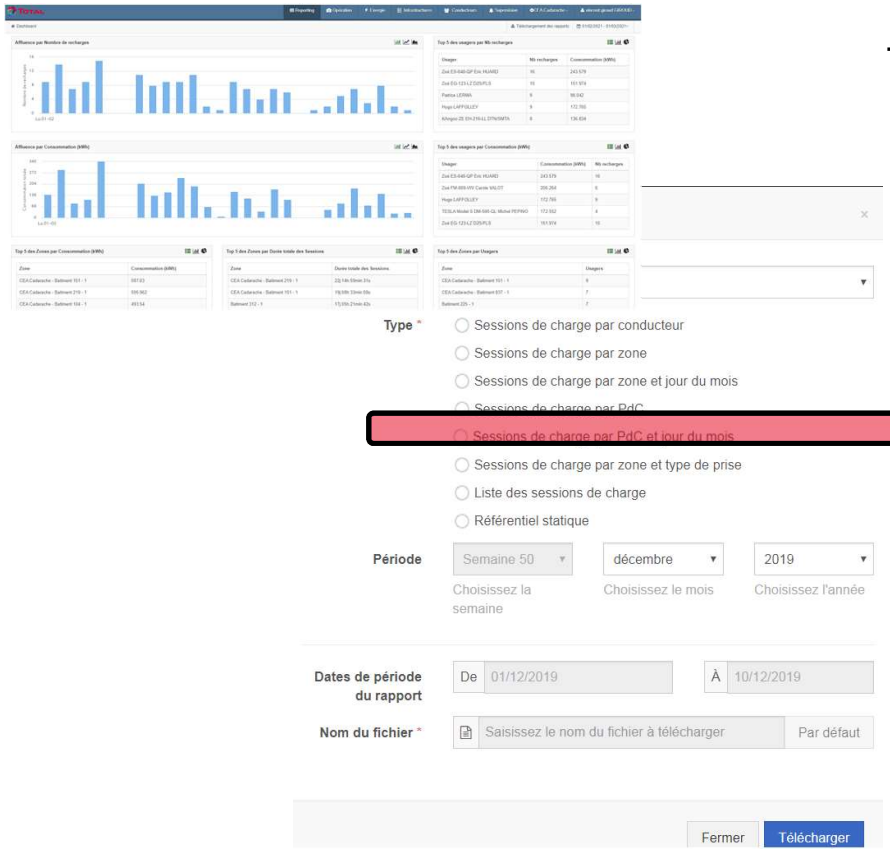
EVCI CADARACHE - DATA COLLECTION



Raw data can be downloaded from the user interface

Log of charging sessions (.xls) :

Mois	Jour	Transactio	ZoneId	Nom de la PdC	Badge	Début Session	Fin Session	Début Pow	Fin Power	Consomm	Type de pr	Emsp
août 2018	01/08/2018	CU-BAT31	CEA-CADA	Batiment :	CU-BAT31	1EC84366	01/08/2018 06:52:54	01/08/2018 13:33:45	1697218	1710825	13.607	T2	G2M
août 2018	01/08/2018	CU-BAT12	CEA-CADA	Batiment :	CU-BAT12	00000000	01/08/2018 07:23:00	01/08/2018 15:49:13	1649877	1655158	5.281	EF	G2M
août 2018	01/08/2018	CU-BAT21	CEA-CADA	Batiment :	CU-BAT21	DEFB4466	01/08/2018 07:36:25	01/08/2018 16:05:38	3261776	3266772	4.996	EF	G2M
août 2018	01/08/2018	CU-BAT51	CEA-CADA	Batiment :	CU-BAT51	4EFB4466	01/08/2018 08:01:15	06/08/2018 08:16:38	1361887	1372896	11.009	EF	G2M
août 2018	01/08/2018	CU-BAT78	CEA-CADA	Batiment :	CU-BAT78	DE254566	01/08/2018 08:04:46	01/08/2018 13:26:03	886570	904657	18.087	T2	G2M
août 2018	01/08/2018	CU-BAT35	CEA-CADA	Batiment :	CU-BAT35	00000000	01/08/2018 08:09:14	01/01/1970 01:00:00	4019320	-1	-4019.32	EF	G2M
août 2018	01/08/2018	CU-BAT15	CEA-CADA	Batiment :	CU-BAT15	CE9D4366	01/08/2018 08:22:13	01/08/2018 16:04:57	5818841	5845881	27.04	T2	G2M
août 2018	01/08/2018	CU-BAT51	CEA-CADA	Batiment :	CU-BAT51	2EC44366	01/08/2018 08:22:40	01/08/2018 12:48:43	4125127	4146367	21.24	T2	G2M
août 2018	01/08/2018	CU-BAT15	CEA-CADA	Batiment :	CU-BAT15	1E6C4566	01/08/2018 08:27:02	01/08/2018 08:27:03	1217299	1217299	0	T2	G2M
août 2018	01/08/2018	CU-BAT15	CEA-CADA	Batiment :	CU-BAT15	1E6C4566	01/08/2018 08:27:23	01/08/2018 17:39:36	1217299	1247841	30.542	T2	G2M
août 2018	01/08/2018	CU-BAT85	CEA-CADA	Batiment :	CU-BAT85	8E05E97E	01/08/2018 08:48:50	01/08/2018 12:36:07	876509	884835	8.326	EF	G2M
août 2018	01/08/2018	CU-BAT27	CEA-CADA	Batiment :	CU-BAT27	3ECED25A	01/08/2018 08:51:41	01/08/2018 18:28:49	2708165	2733006	24.841	T2	G2M
août 2018	01/08/2018	CU-BAT51	CEA-CADA	Batiment :	CU-BAT51	AE954366	01/08/2018 09:12:56	01/08/2018 11:22:42	4232119	4239817	7.698	T2	G2M
août 2018	01/08/2018	CU-BAT31	CEA-CADA	Batiment :	CU-BAT31	CEDE4366	01/08/2018 09:15:53	01/08/2018 15:30:36	2015542	2058889	43.347	EF	G2M
août 2018	01/08/2018	CU-BAT23	CEA-CADA	Batiment :	CU-BAT23	253CE6E3	01/08/2018 10:56:57	01/08/2018 11:54:08	685929	700308	14.379	EF	G2M
août 2018	01/08/2018	CU-BAT27	CEA-CADA	Batiment :	CU-BAT27	0EC74366	01/08/2018 11:26:24	01/08/2018 12:09:45	1314629	1327456	12.827	T2	G2M
août 2018	01/08/2018	CU-BAT35	CEA-CADA	Batiment :	CU-BAT35	3E8D4566	01/08/2018 11:55:55	01/08/2018 14:27:26	5334336	5371005	36.669	EF	G2M
août 2018	01/08/2018	CU-BAT15	CEA-CADA	Batiment :	CU-BAT15	AE493666	01/08/2018 12:14:56	01/08/2018 16:35:40	2976024	3004133	28.109	T2	G2M
août 2018	01/08/2018	CU-BAT22	CEA-CADA	Batiment :	CU-BAT22	9E8E4566	01/08/2018 12:33:22	02/08/2018 10:34:36	1444657	1453020	8.363	EF	G2M
août 2018	01/08/2018	CU-BATB5	CEA-CADA	Batiment :	CU-BATB5	8E05E97E	01/08/2018 12:42:58	01/08/2018 16:46:45	884835	893789	8.954	EF	G2M

Matlab

Data analysis

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LOG OF CHARGING SESSIONS

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)

of the user

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

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)

Unreliable

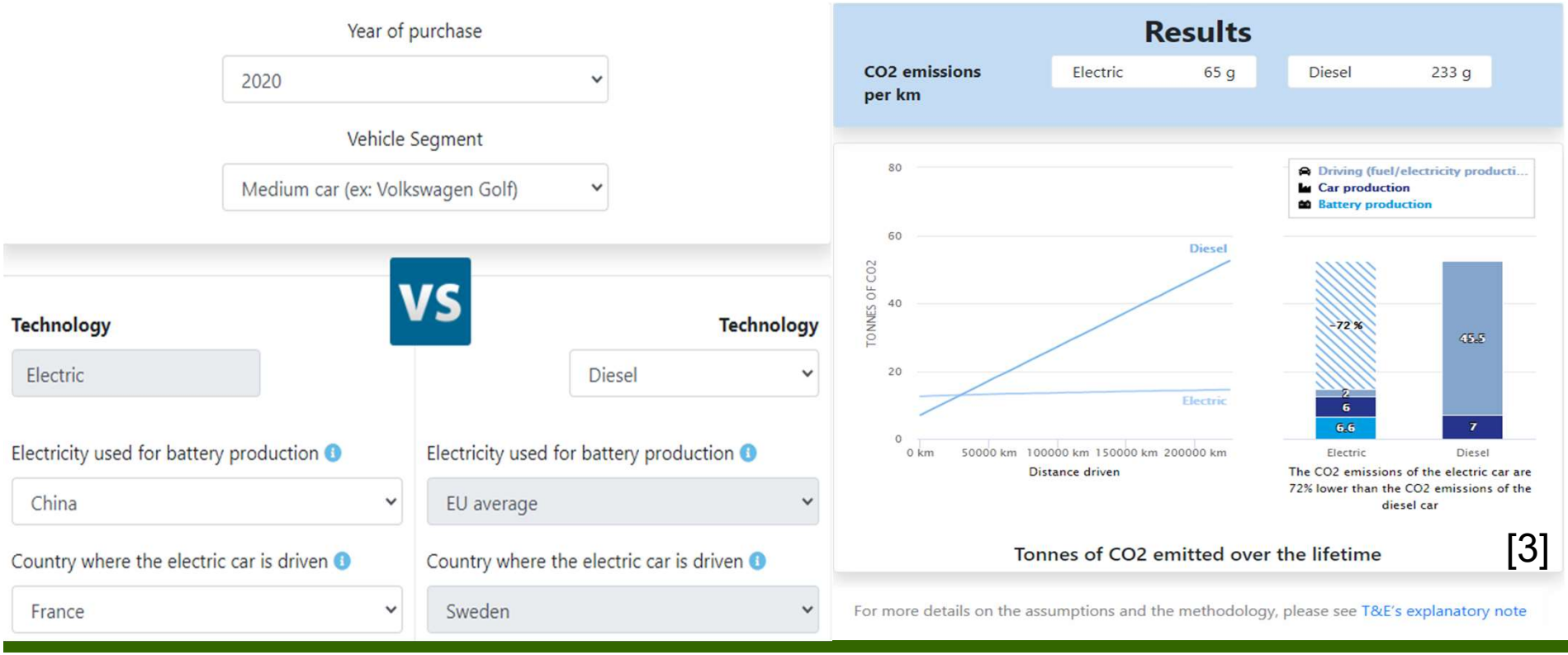
Energy Consumption (kWh)=(IF – ID)/1000

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

GLOBAL STATISTICS

Period 01/06/2016 to 31/05/2020 :

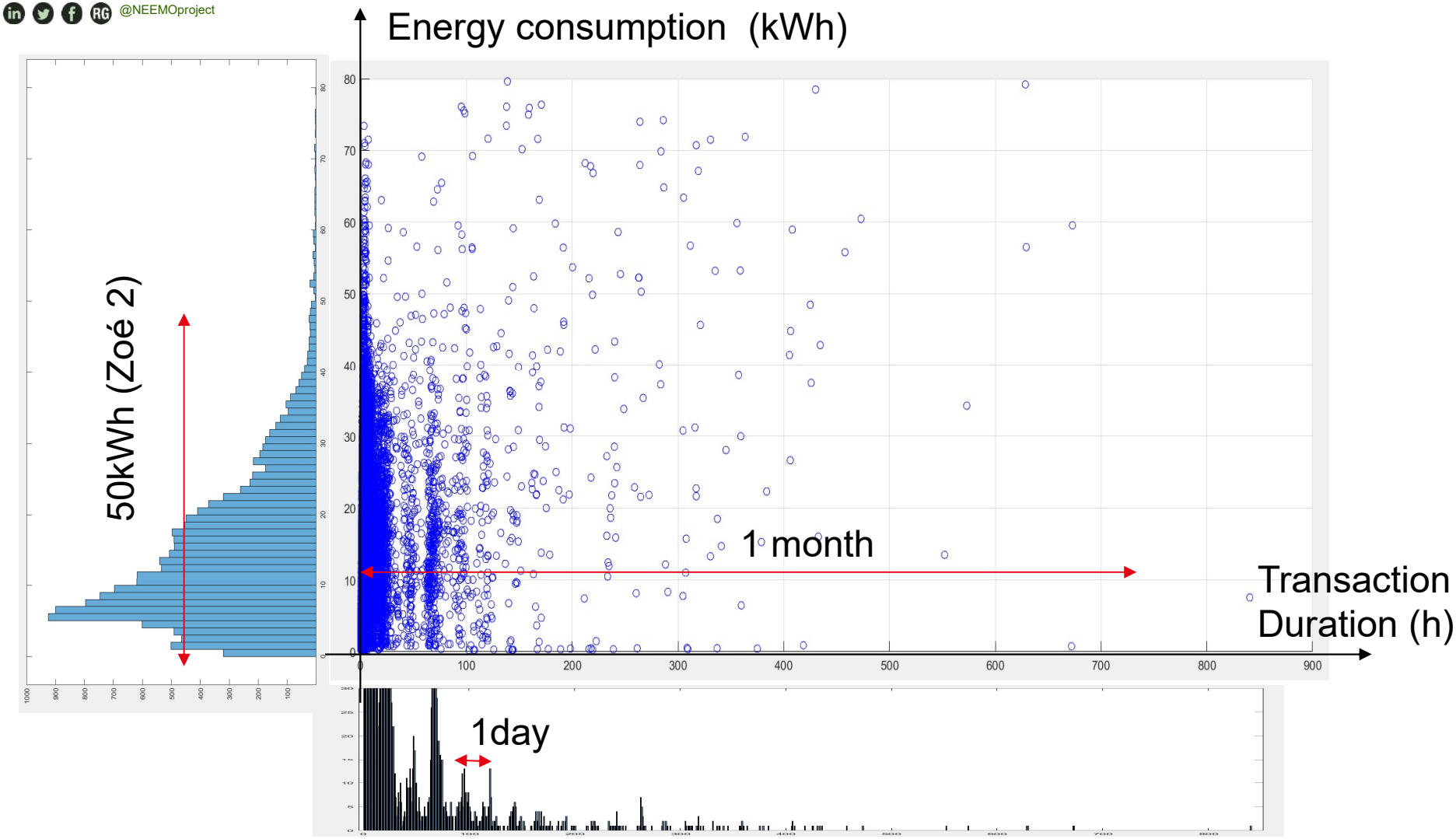
- 17045 transactions
- Sum of consumptions : 253.2 MWh
- ~1500000km @17kWh/100km
- 252 t de CO_2 avoided



[3]

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

STATISTICS ON TRANSACTIONS



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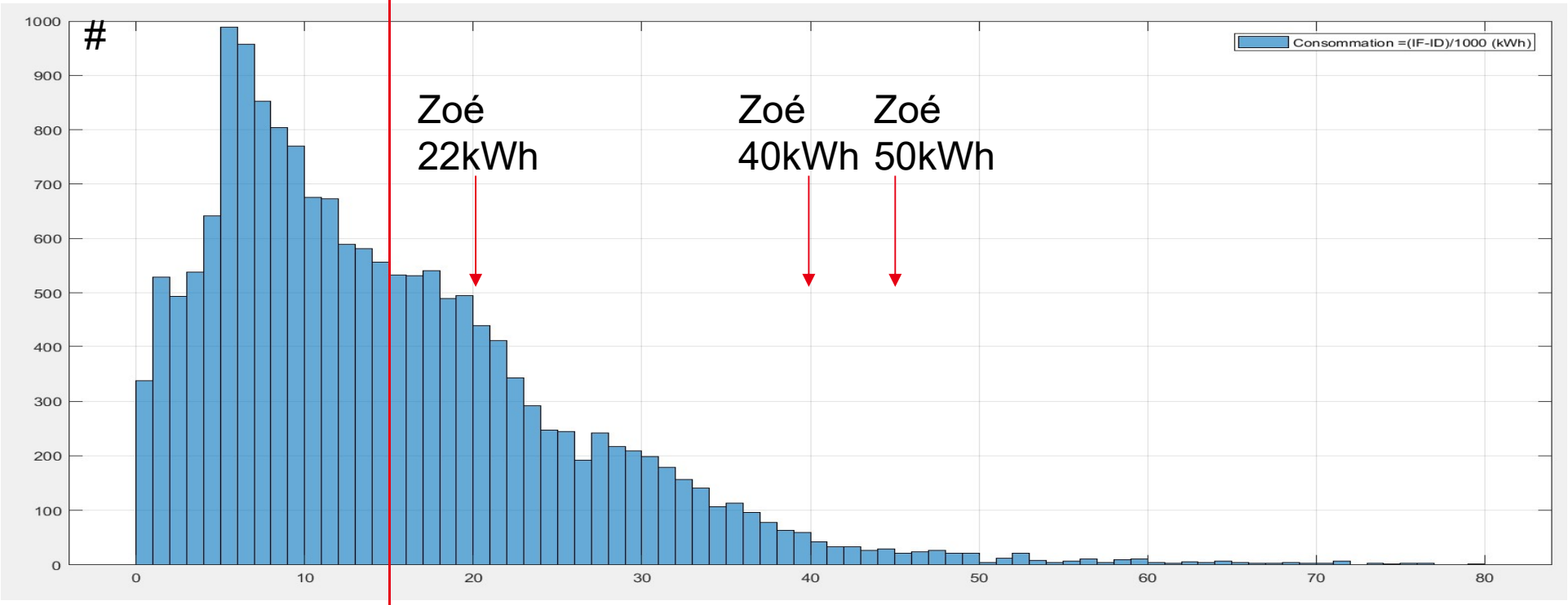
ENERGY CONSUMPTION / TRANSACTION

Mean of the energy consumption per transaction : 14.8 kWh



Energy consumption (kWh)

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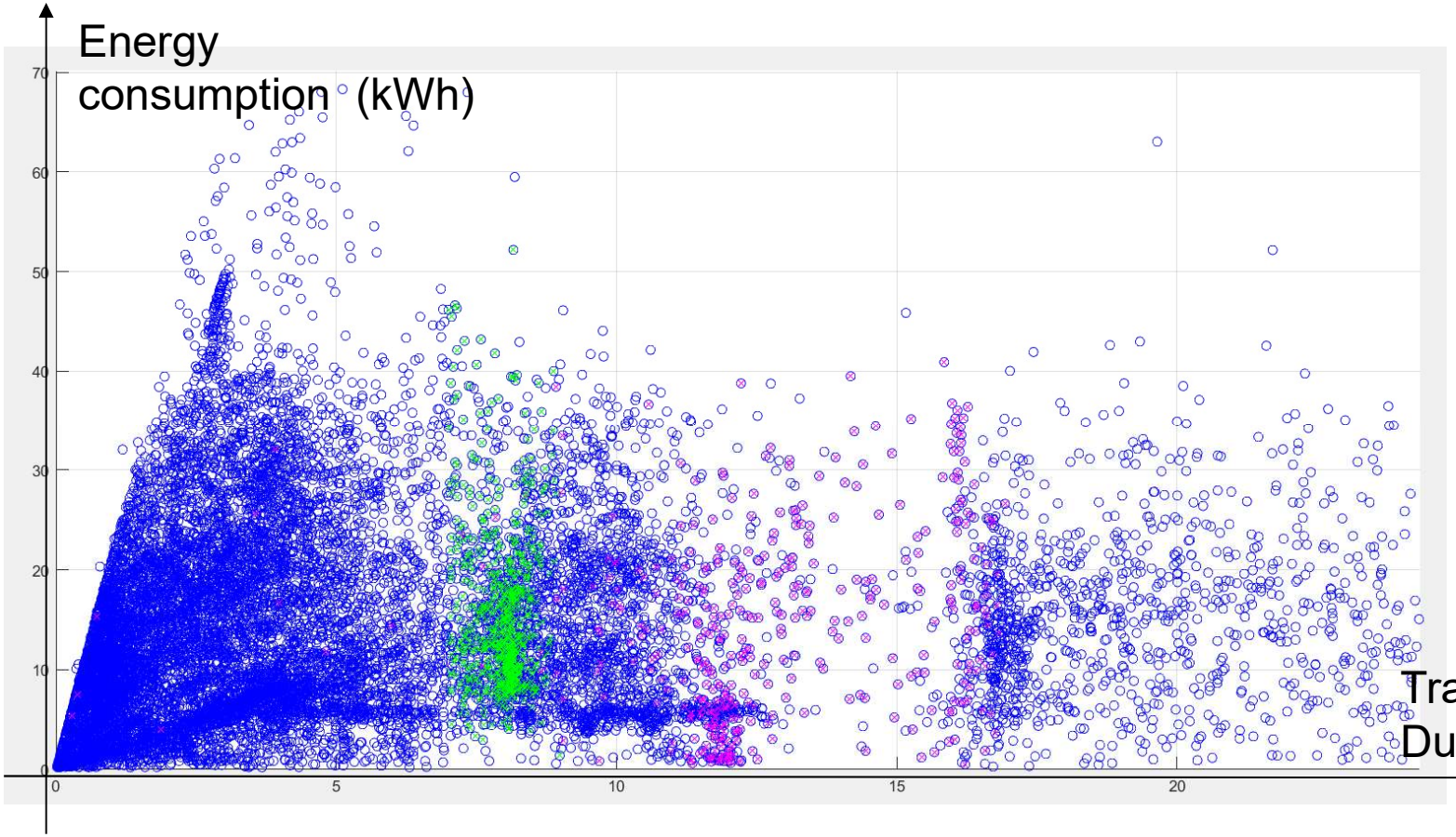
STATISTICS ON TRANSACTIONS

Full workday charging i.e
-start after 7h and finish before 17h the same day
-and charge duration greater than 7h
(743 occurences (4.7%))

Full night charging i.e
-start after 15h and finish before 9h the following day
(430 occurrences (2.7%))



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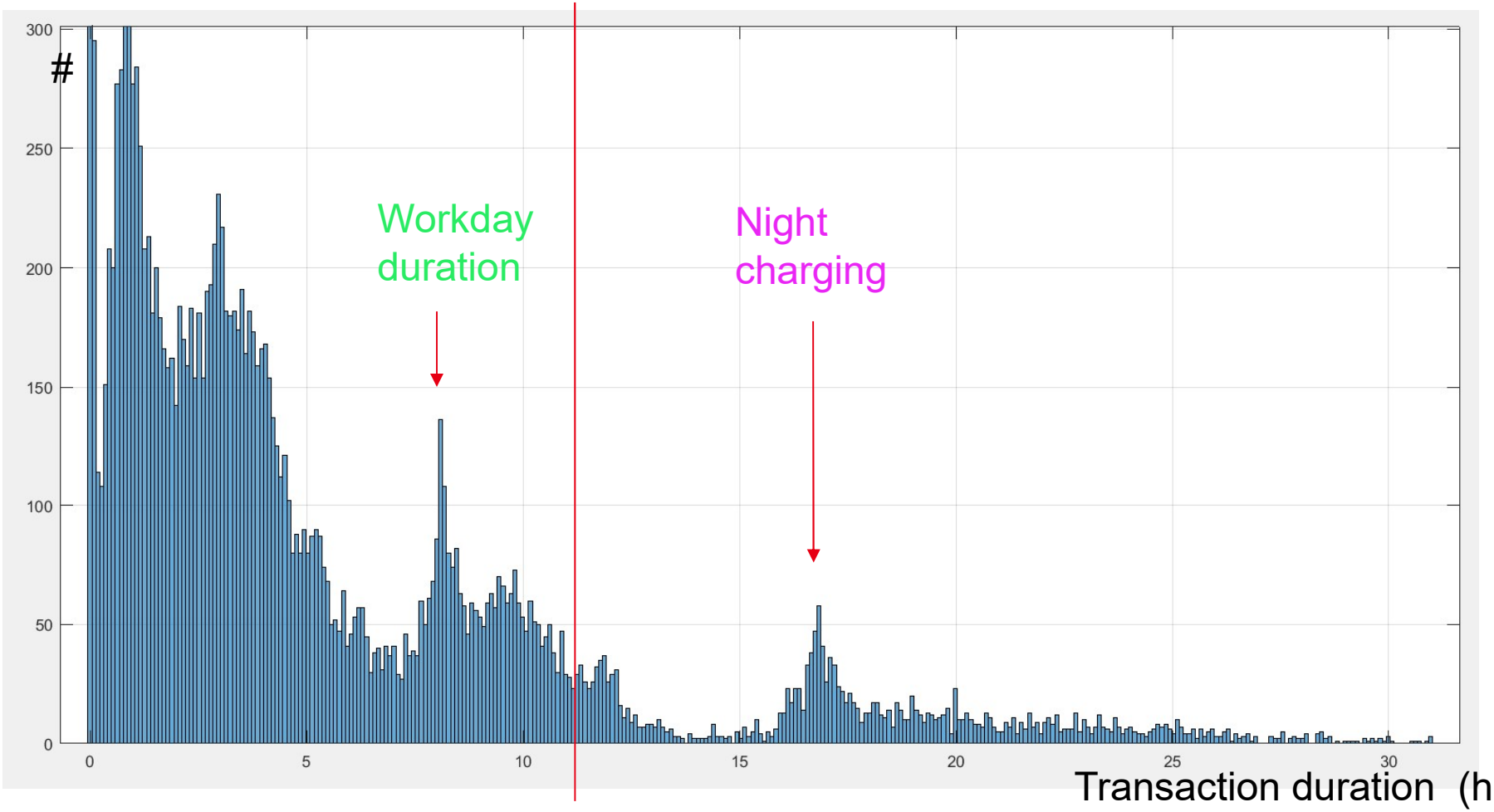
DURATION OF TRANSACTION

Mean of the transaction duration : 12.4h



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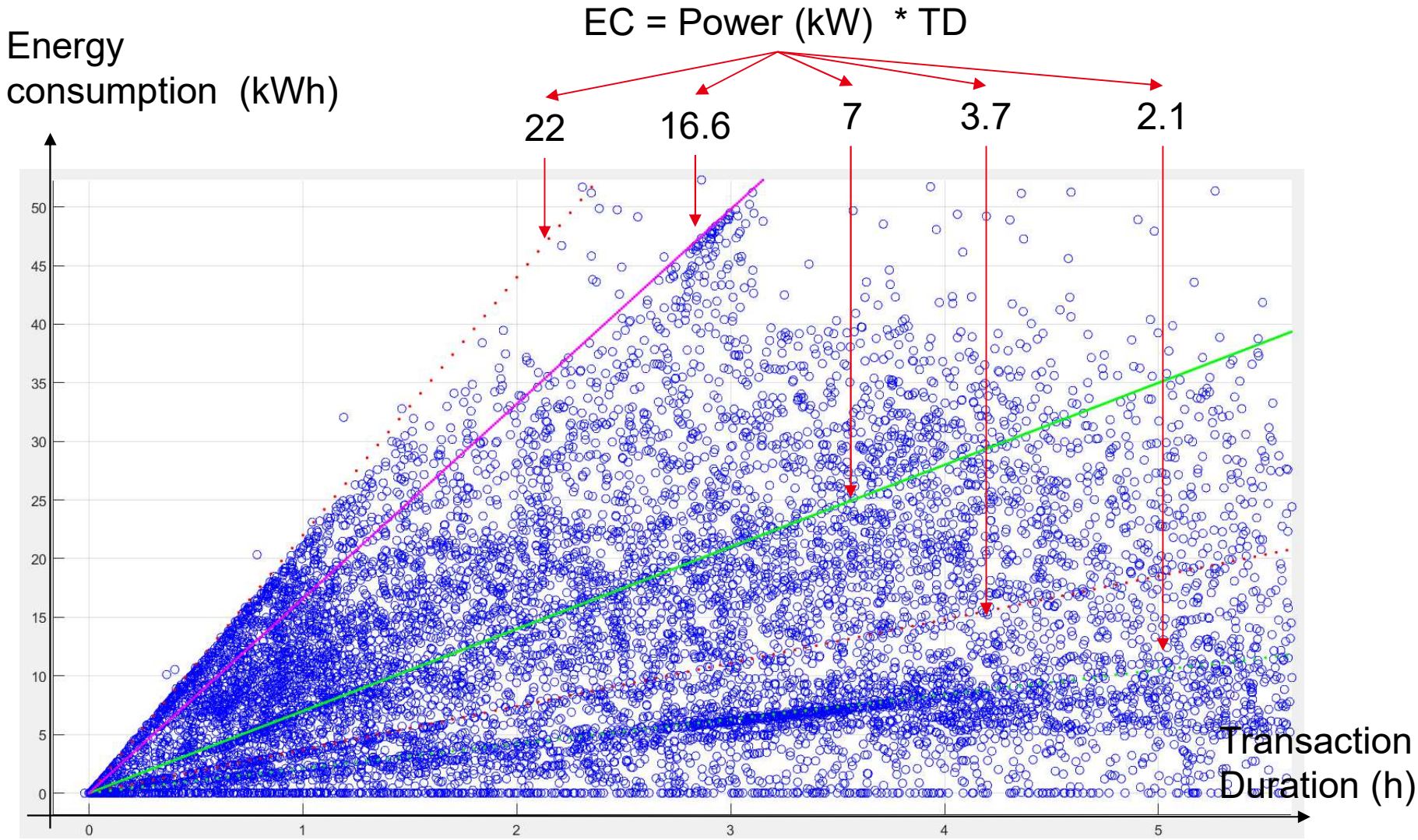
STATISTICS ON TRANSACTIONS



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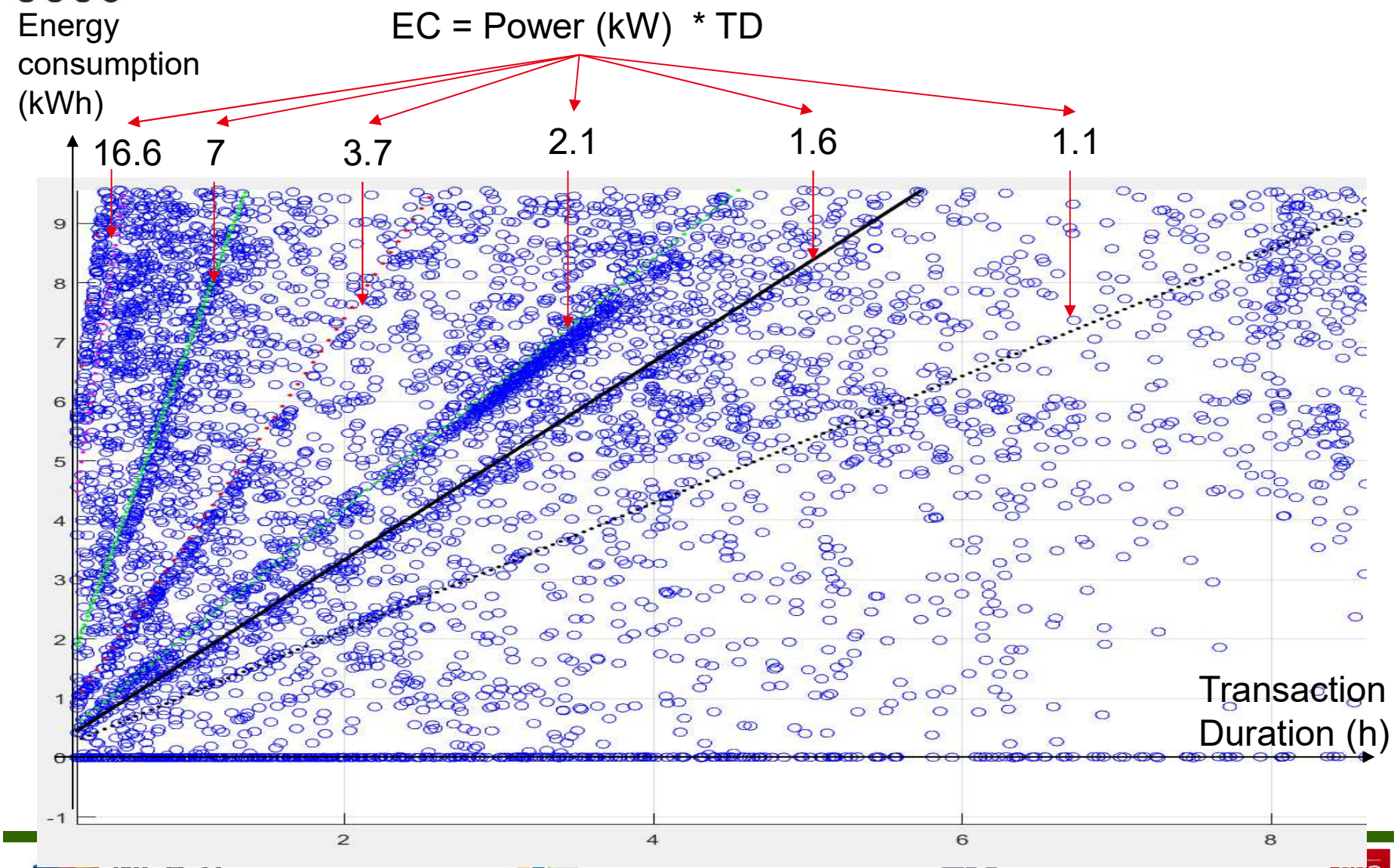
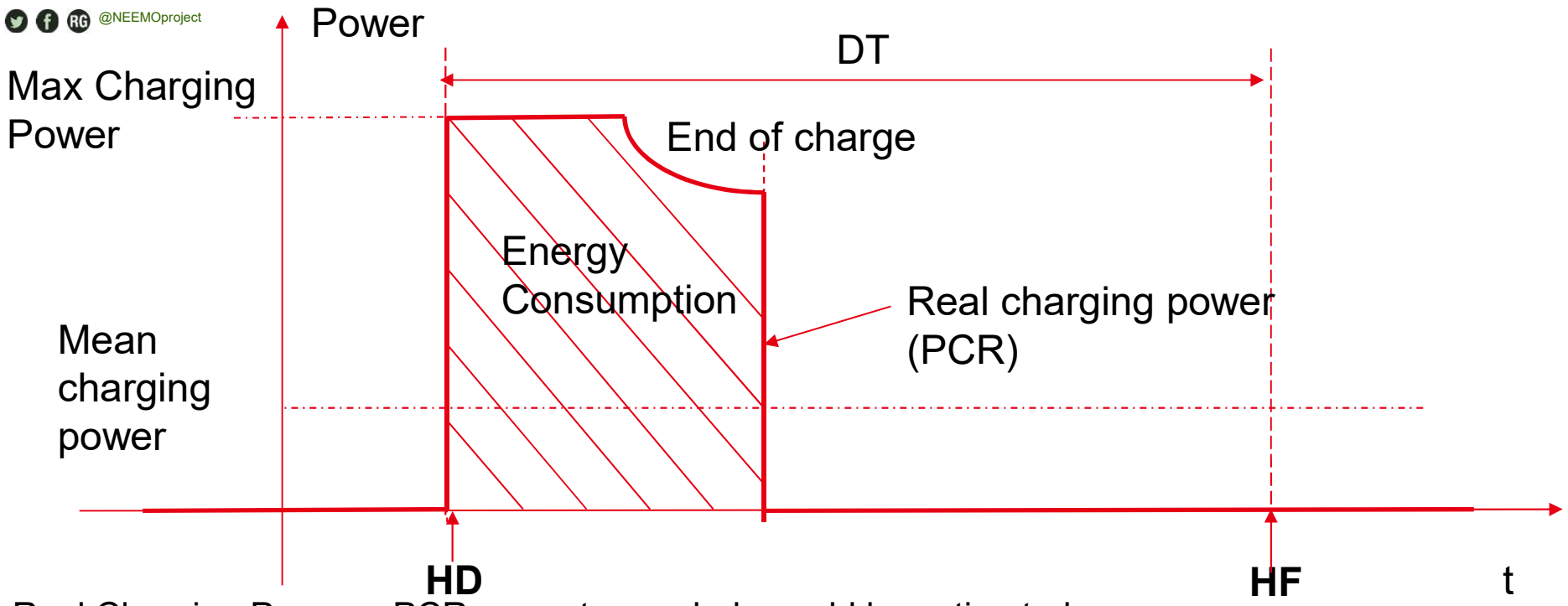
STATISTICS ON TRANSACTIONS



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

DEFINITIONS : PARAMETERS OF CHARGE



Real Charging Power = PCR => not recorded ; could be estimated

Transaction duration= DT=HF-HD => recorded in the transaction file

Energy Consumption = EC = **ID** – **IF** => recorded in the transaction file

Battery capacity = Max of energy consumption = ECMax => depends of the EV model

Max Charging Power = PCM => depends of the EV model

Mean charging power = PCMean = EC/DT => can be calculated

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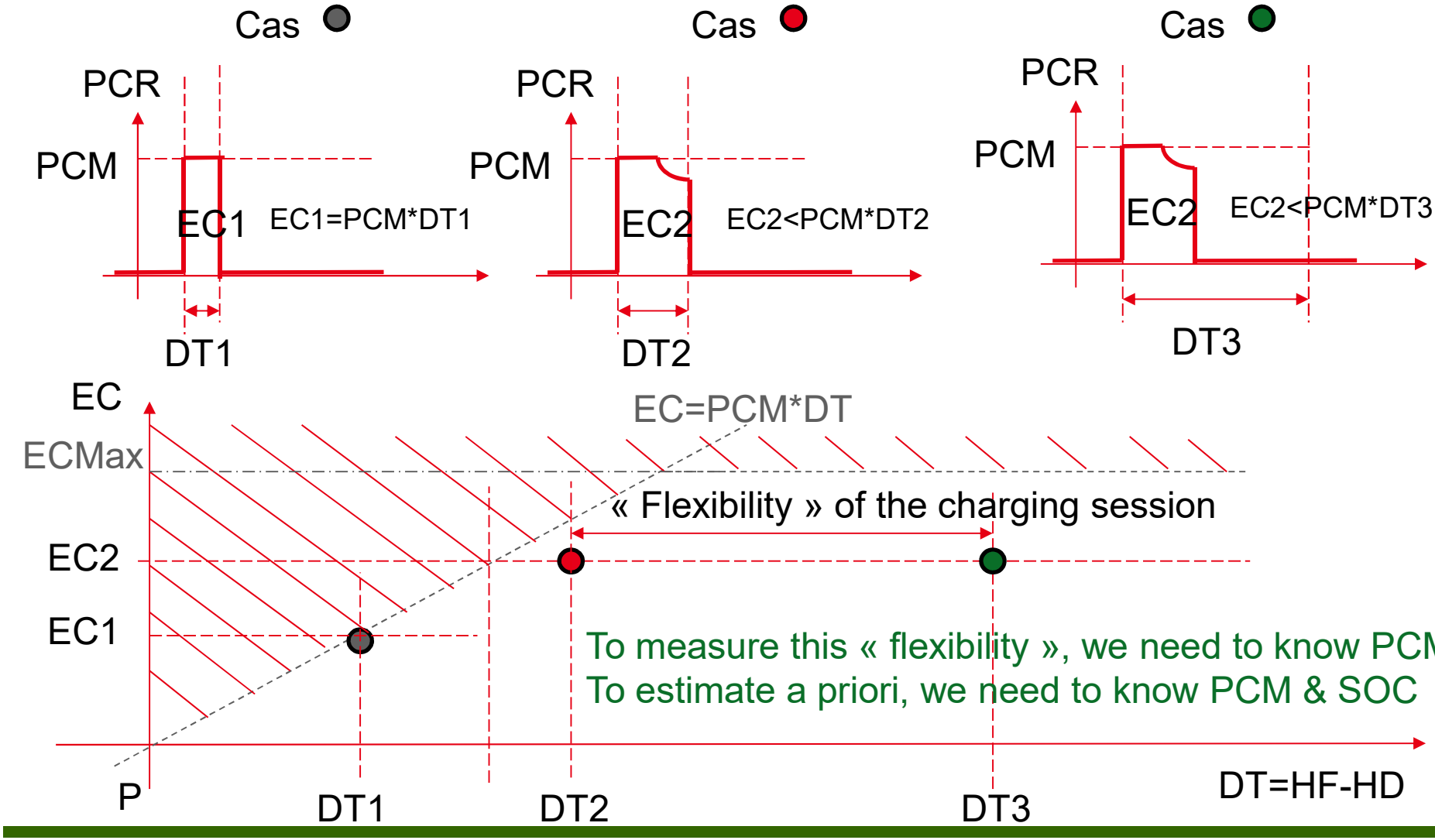
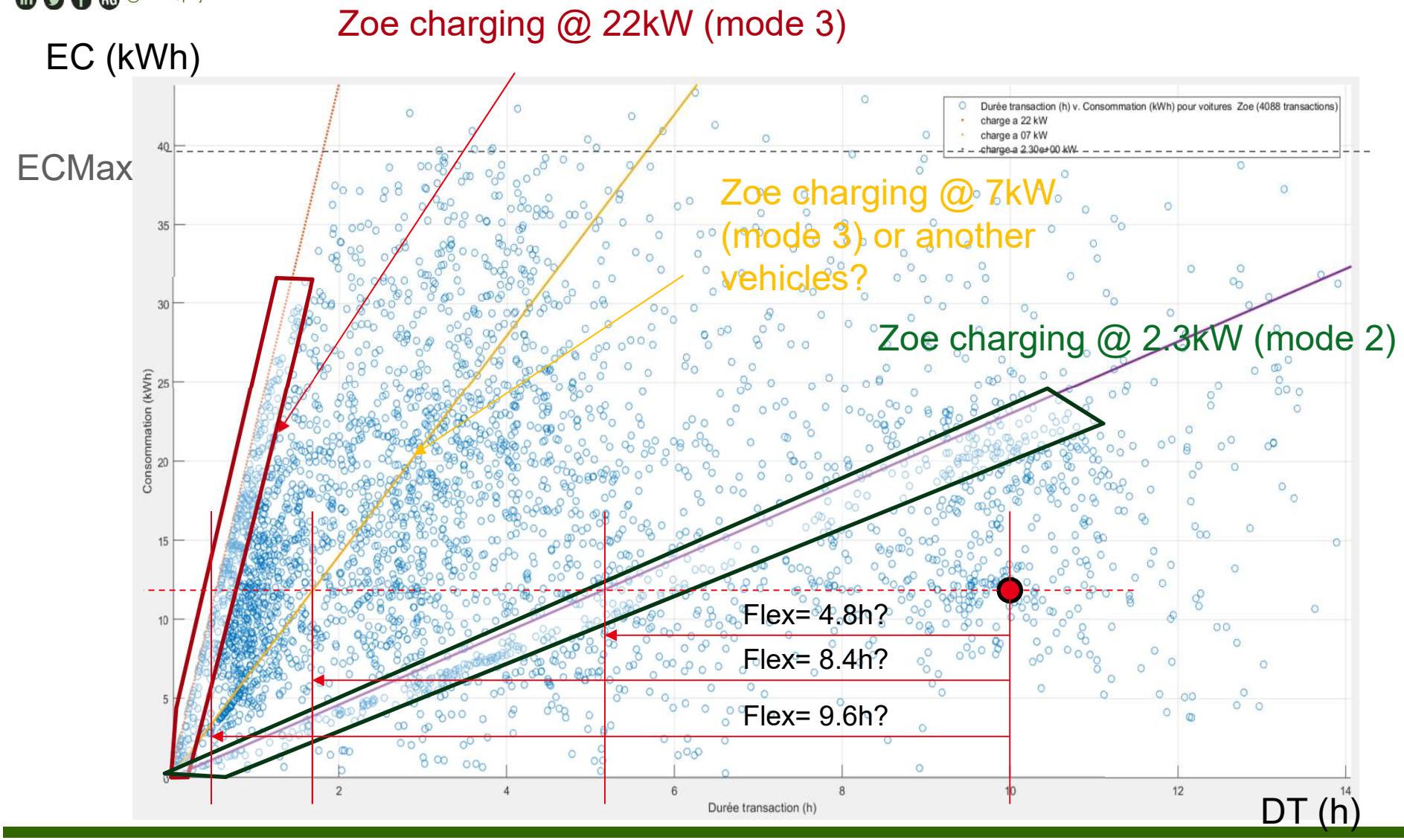
DEFINITION : FLEXIBILITY



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

EXAMPLE : ALL THE ZOE



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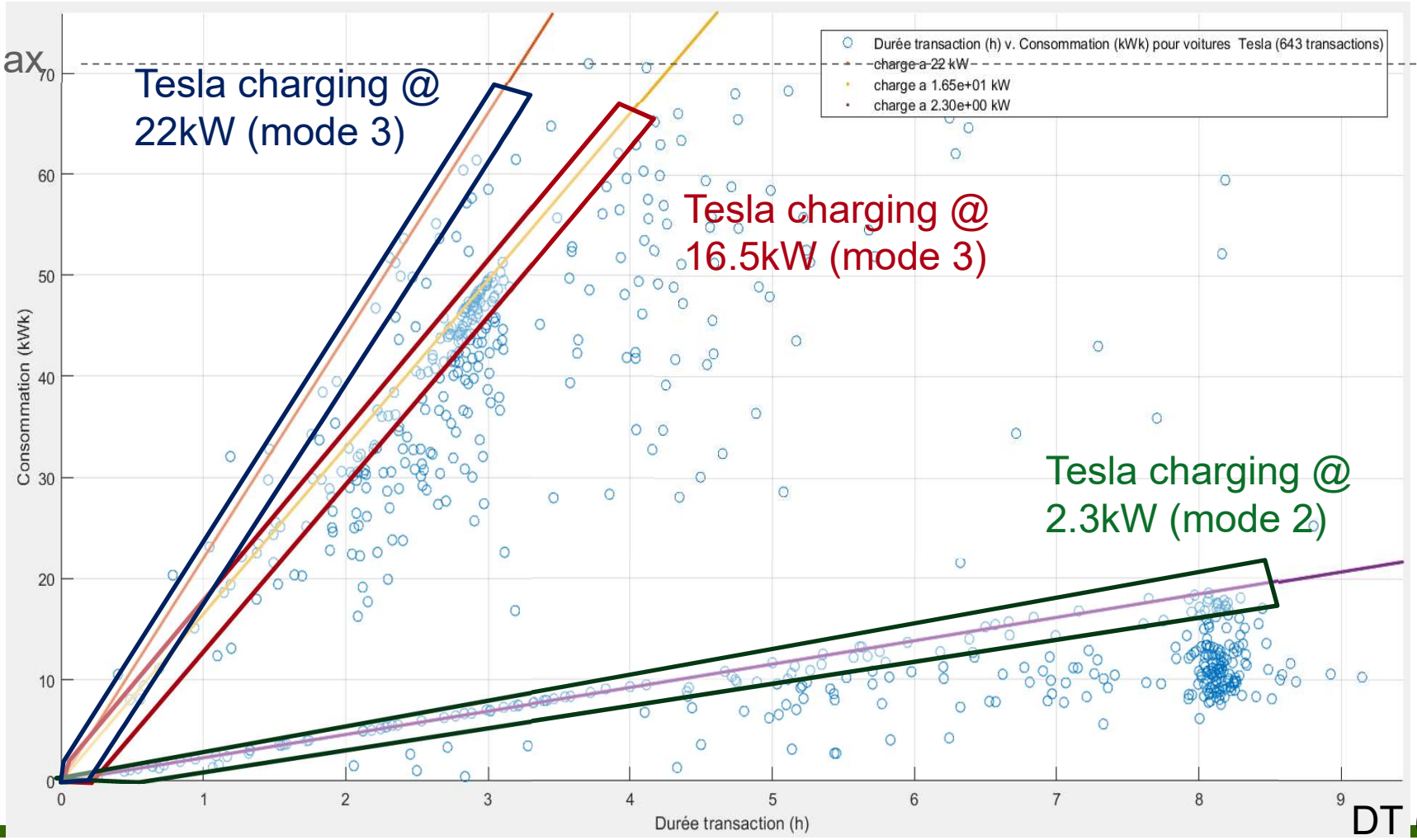
EXAMPLE : ALL THE TESLA

EC (kWh)

ECMax



DT (h)

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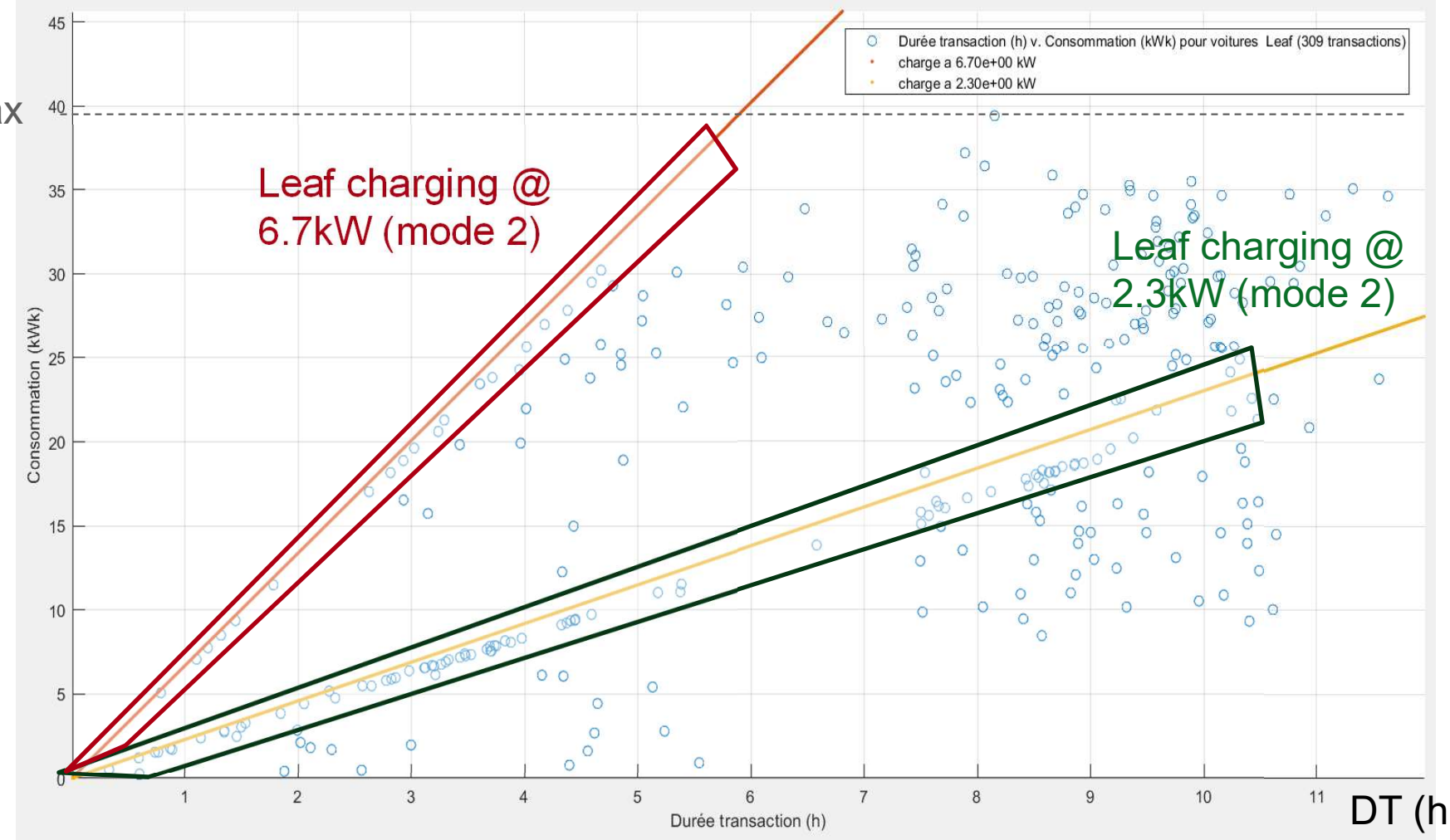
EXAMPLE: ALL THE LEAF

EC (kWh)

ECMax



DT (h)

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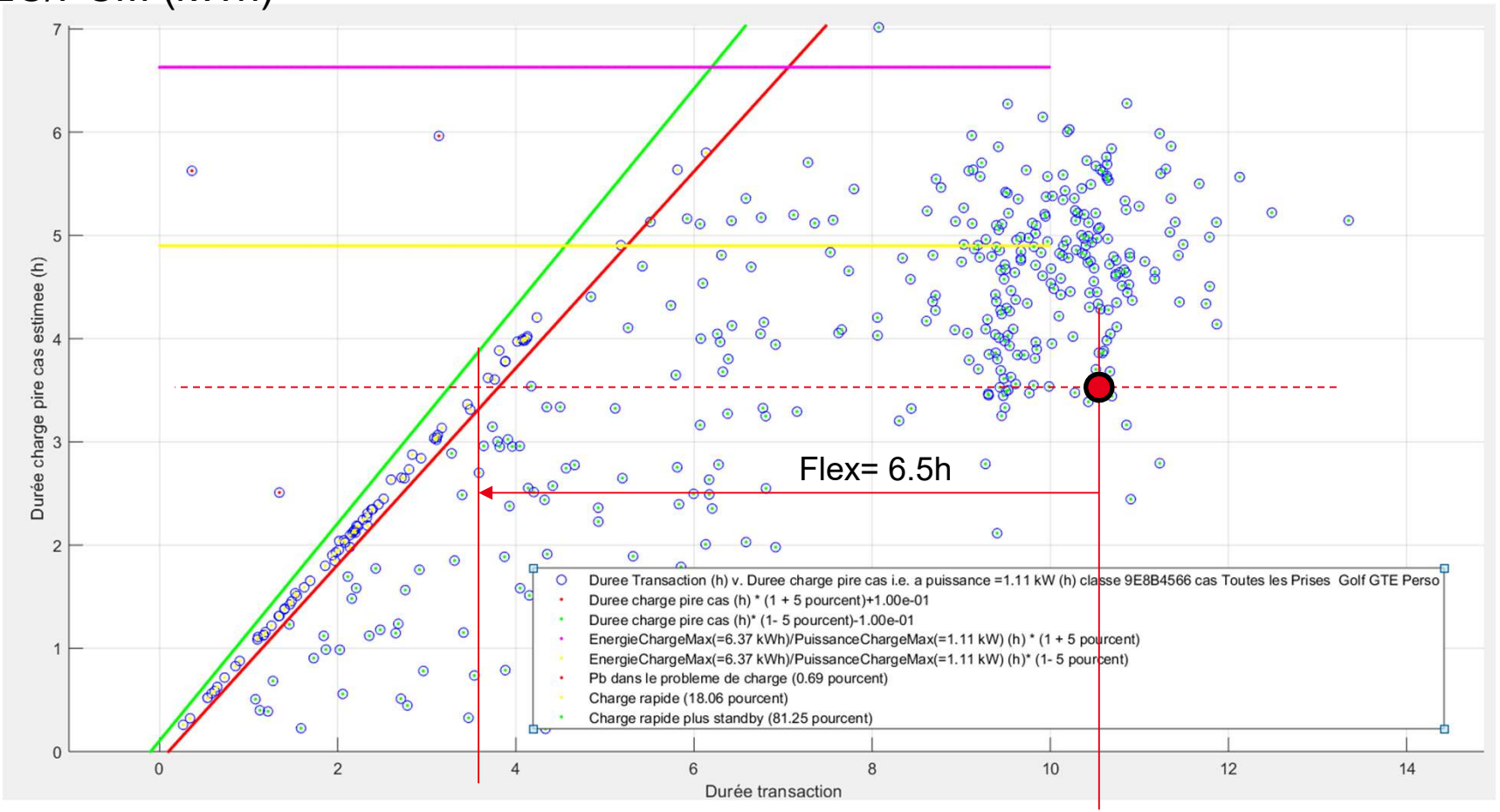
EXAMPLE: ONE GOLF GTE (PHEV)

Estimation of PCM = 1.1 kW (mode 3 with T2 connector)

EC/PCM (kWh)



TD (h)

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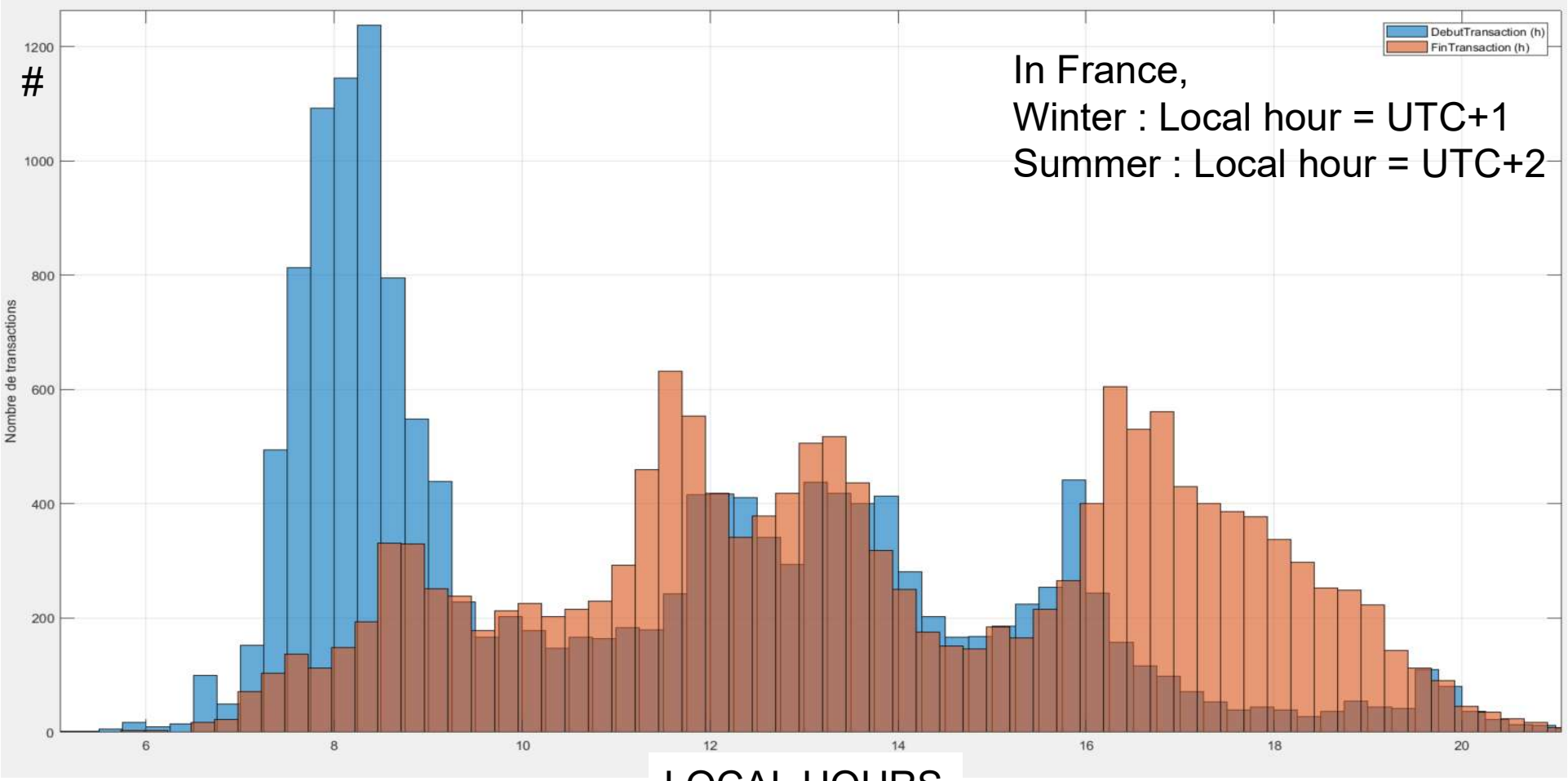
START/END OF TRANSACTIONS



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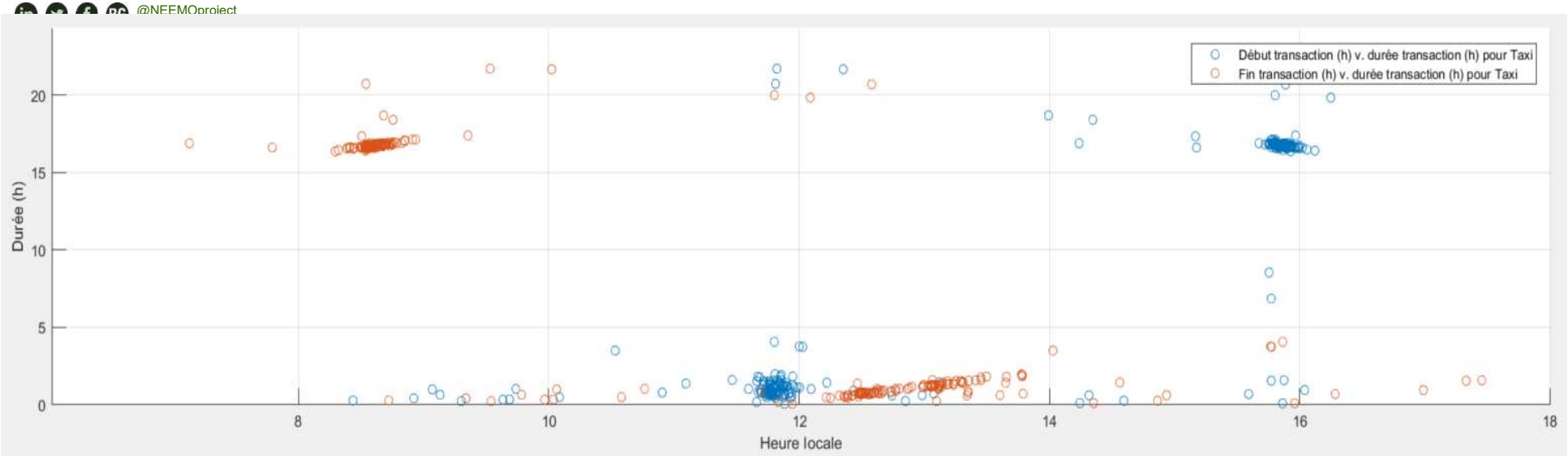
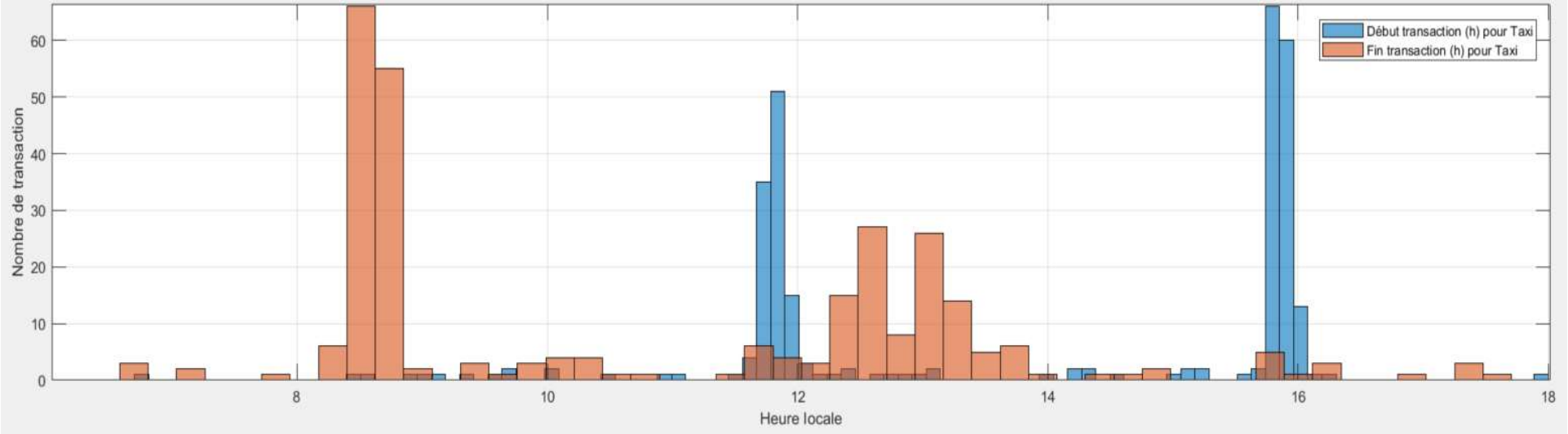
START/END OF TRANSACTIONS : 'TAXI'



« night » charge

« midday » charge

« night » charge



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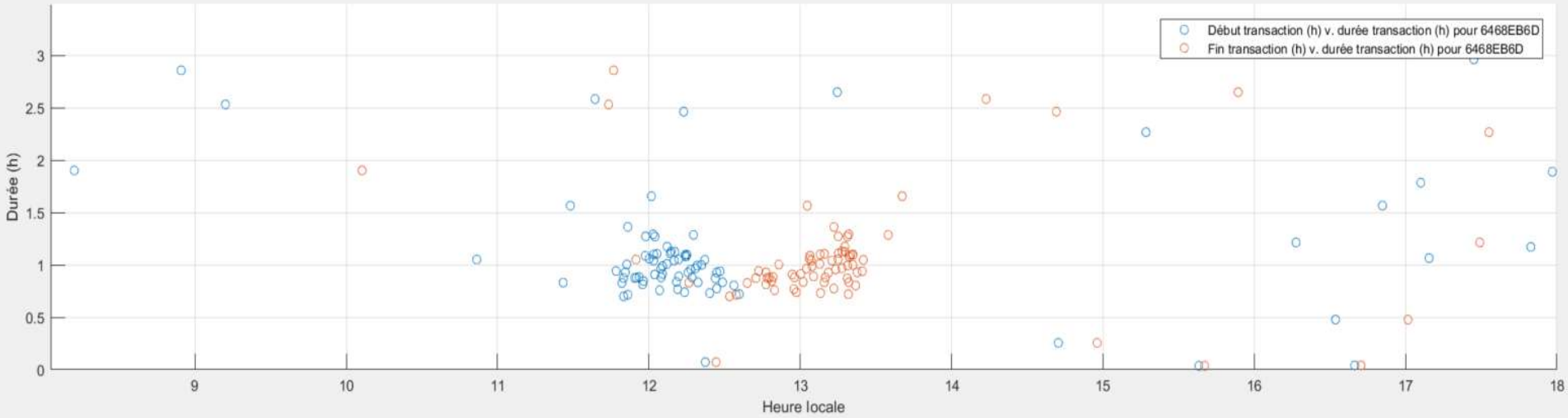
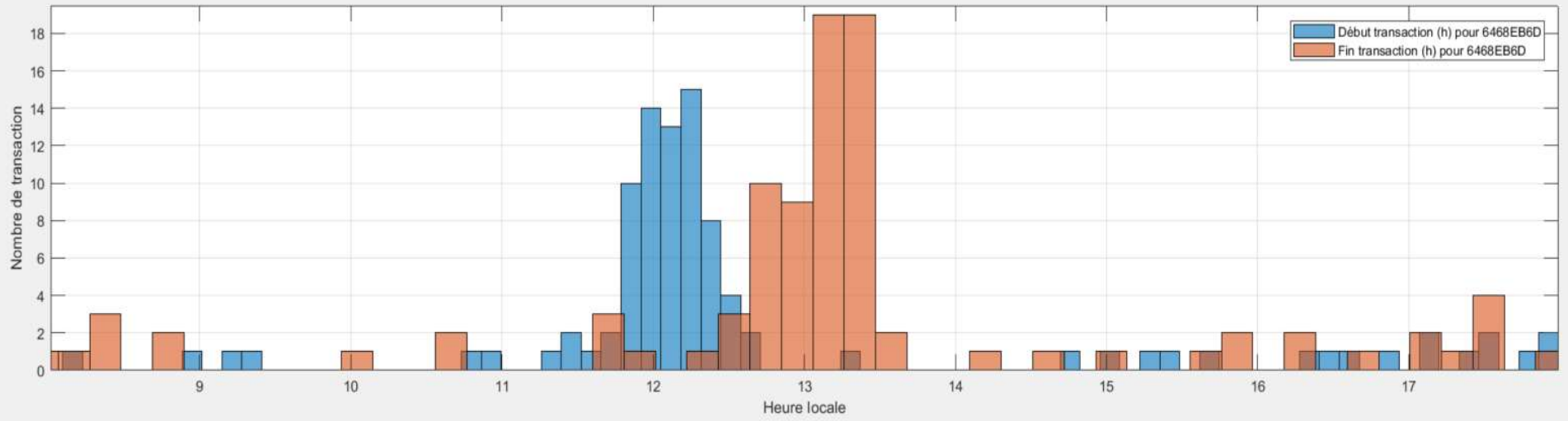
START/END OF TRANSACTIONS : SERVICE VEHICLE



« midday » charge



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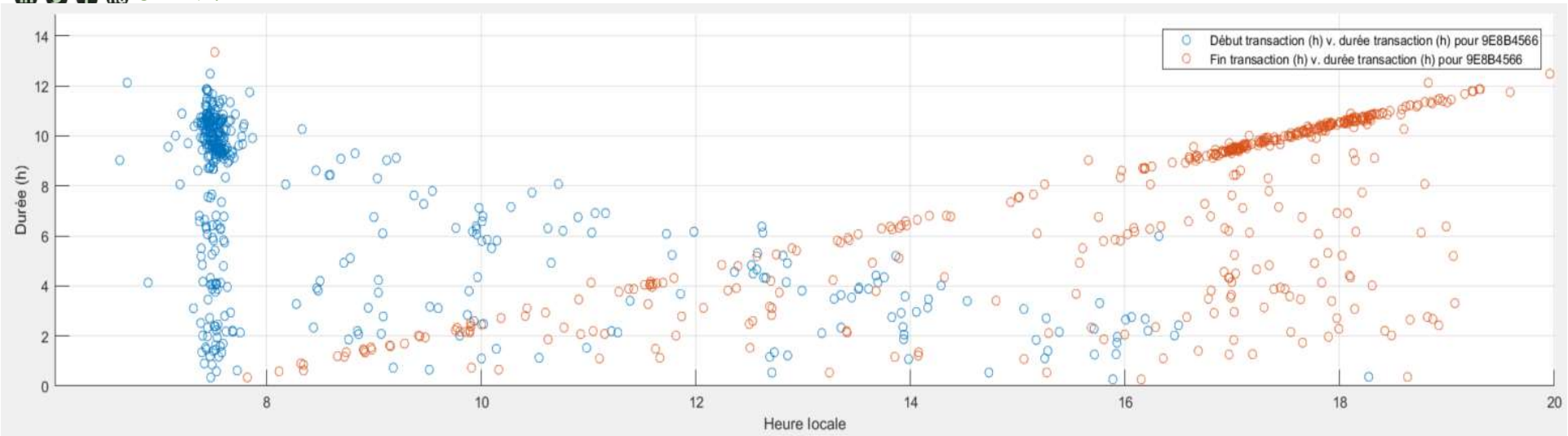
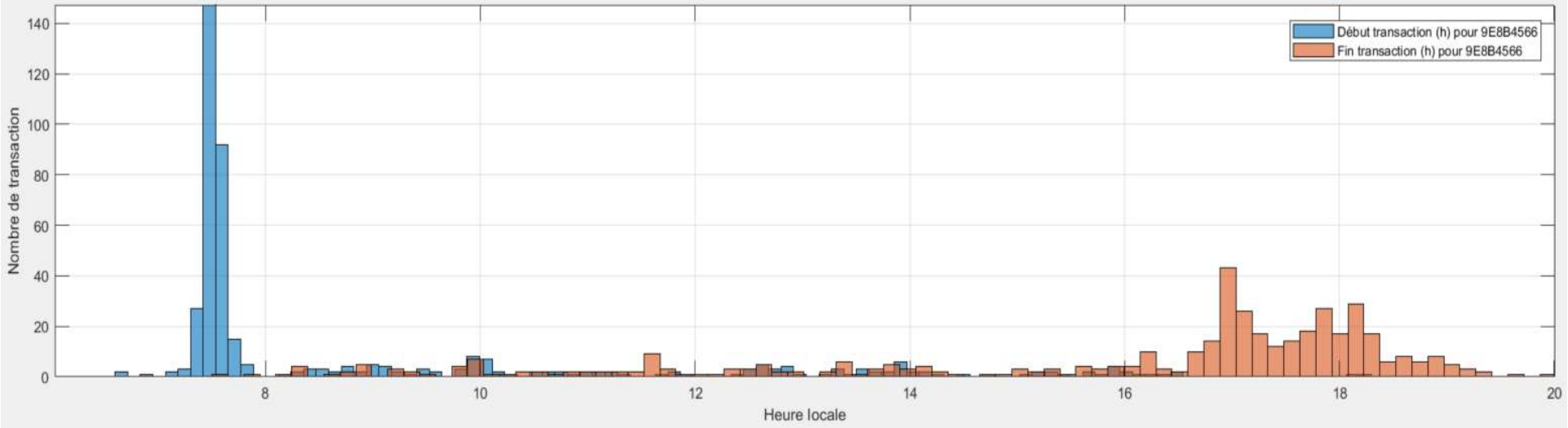
START/END OF TRANSACTIONS : PERSONAL VEHICLE



Full workday charge



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  - CEA EVCI
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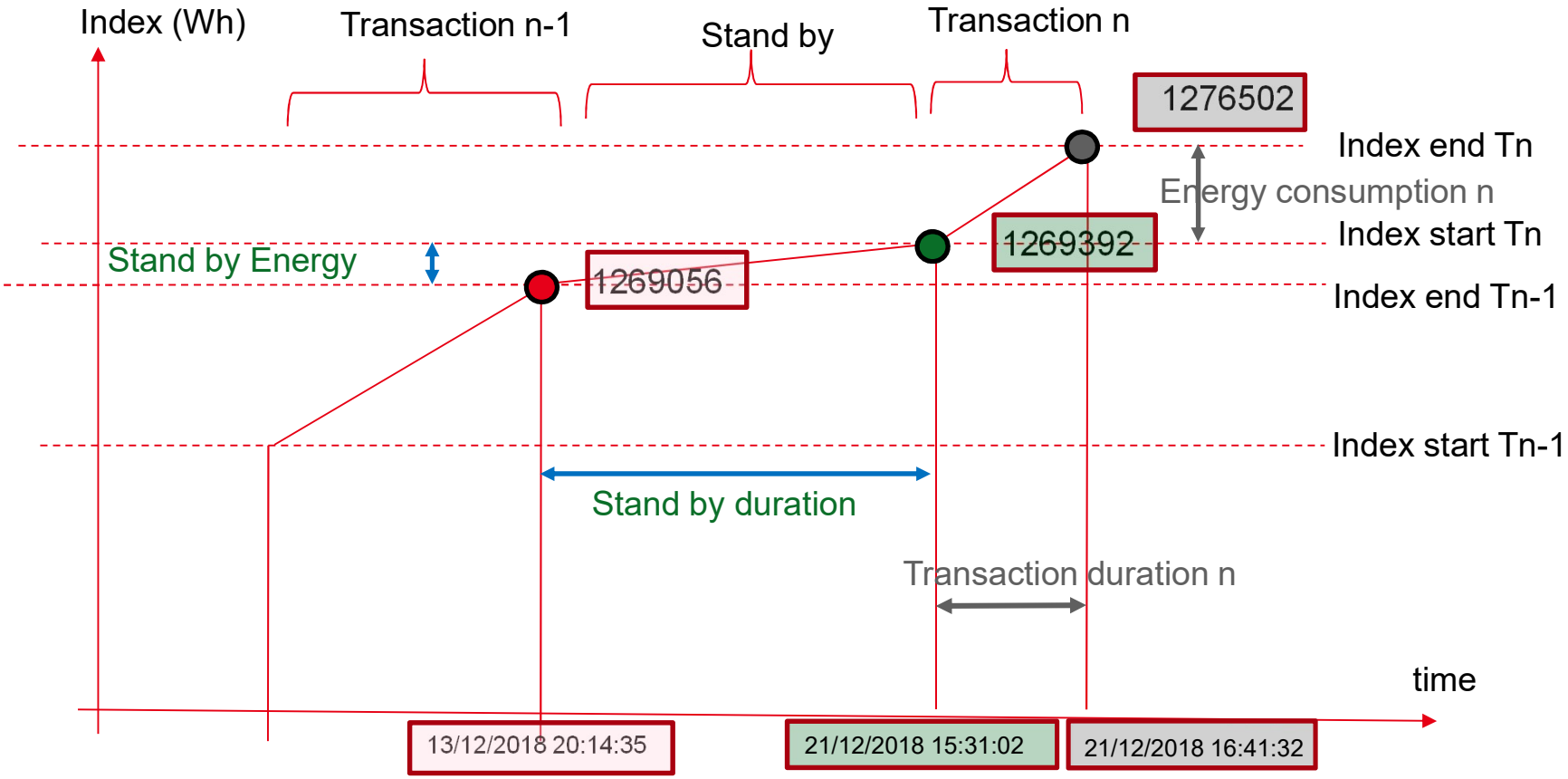
MEAN CHARGING POWER HYP. : PRINCIPLE OF RECONSTRUCTION

liten cea tech

	Mois	Jour	Uui	Tran	ZoneIc	Nom de la Zone	PdC	Badge	Début Session	Fin Session	Début Pow	Fin Power	Consomm	Type de pr	Emsp
2	######	05/12/2018	b81	CU-E	CEA-C	Batiment 101 - 1	CU-BAT1011-13CEA-1	7490E56D	05/12/2018 14:50:37	05/12/2018 16:03:58	1227407	1238878	11.471	T2	G2M
3	######	06/12/2018	20b	CU-E	CEA-C	Batiment 101 - 1	CU-BAT1011-13CEA-1	1E974366	06/12/2018 10:12:27	06/12/2018 13:48:08	1238909	1258302	19.393	T2	G2M
4	######	13/12/2018	749	CU-E	CEA-C	Batiment 101 - 1	CU-BAT1011-13CEA-1	4E8E4566	13/12/2018 16:13:56	13/12/2018 20:14:35	1258601	1269056	10.455	T2	G2M
5	######	21/12/2018	6d4	CU-E	CEA-C	Batiment 101 - 1	CU-BAT1011-13CEA-1	3EF7EB7E	21/12/2018 15:31:02	21/12/2018 16:41:32	1269392	1276502	7.11	T2	G2M

n-1
n



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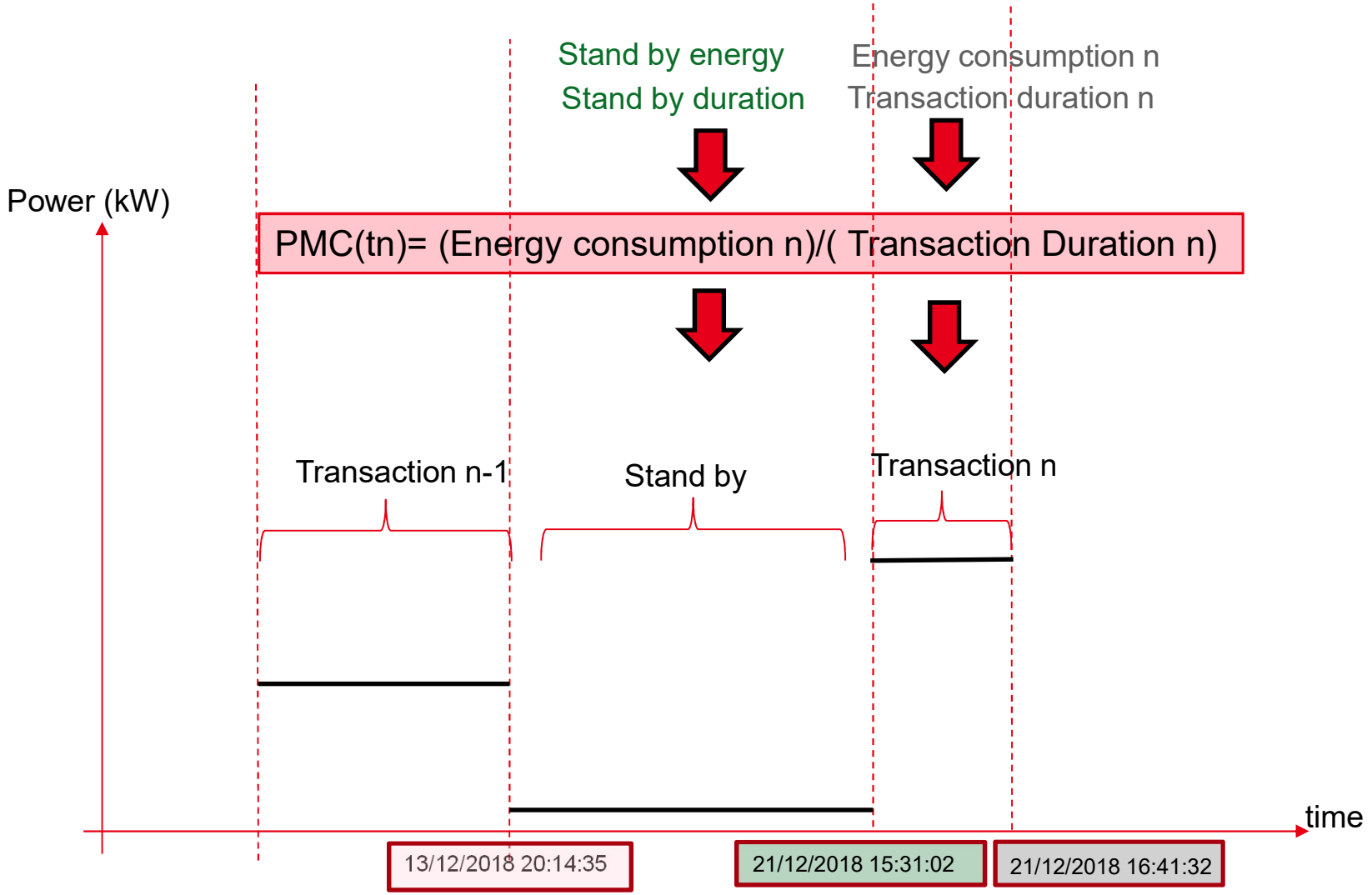
MEAN CHARGING POWER HYP. : PRINCIPLE OF RECONSTRUCTION



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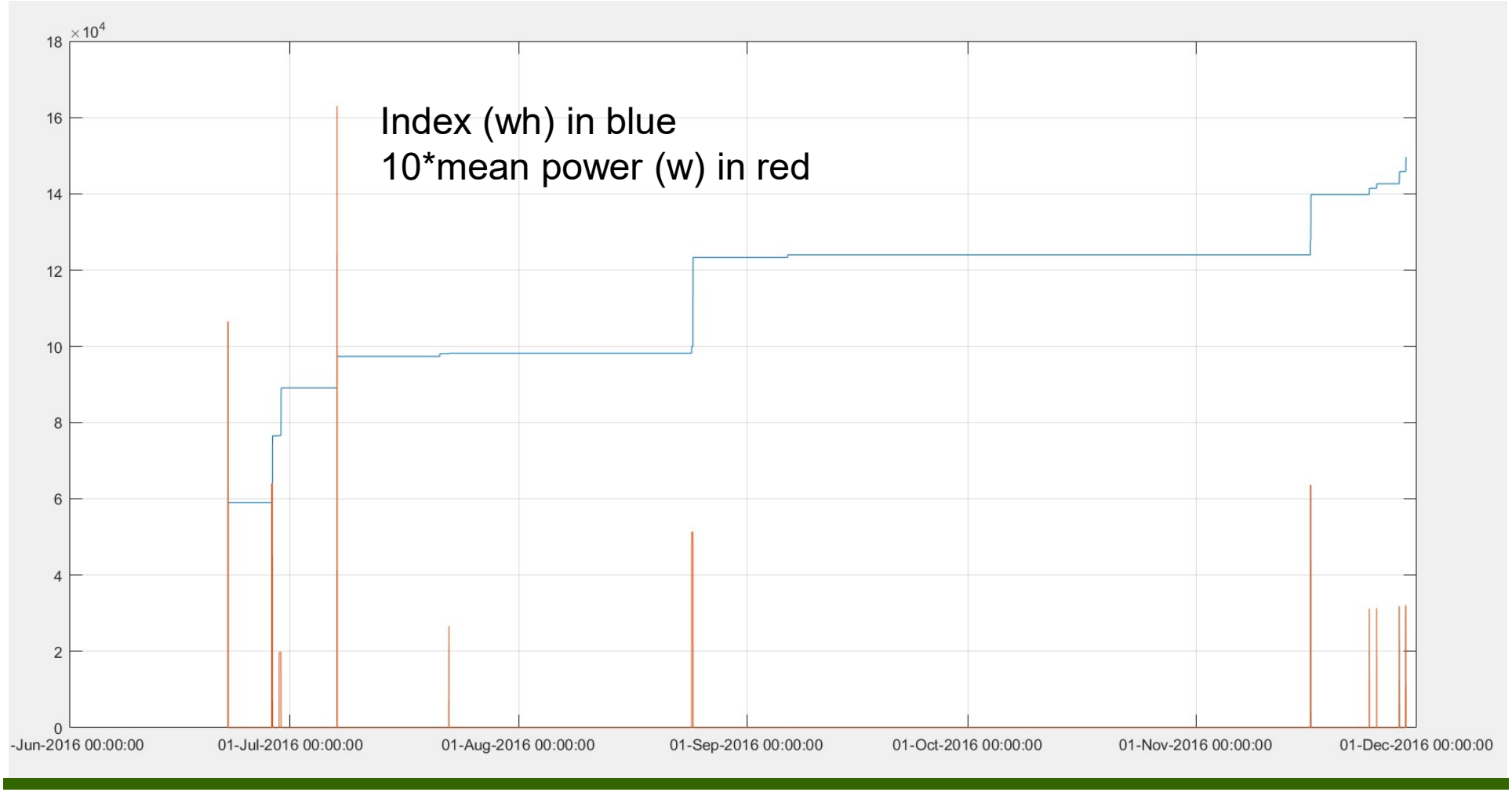
MEAN CHARGING POWER HYP. : EXAMPLES

PdC: CU_BAT1011_13CEA



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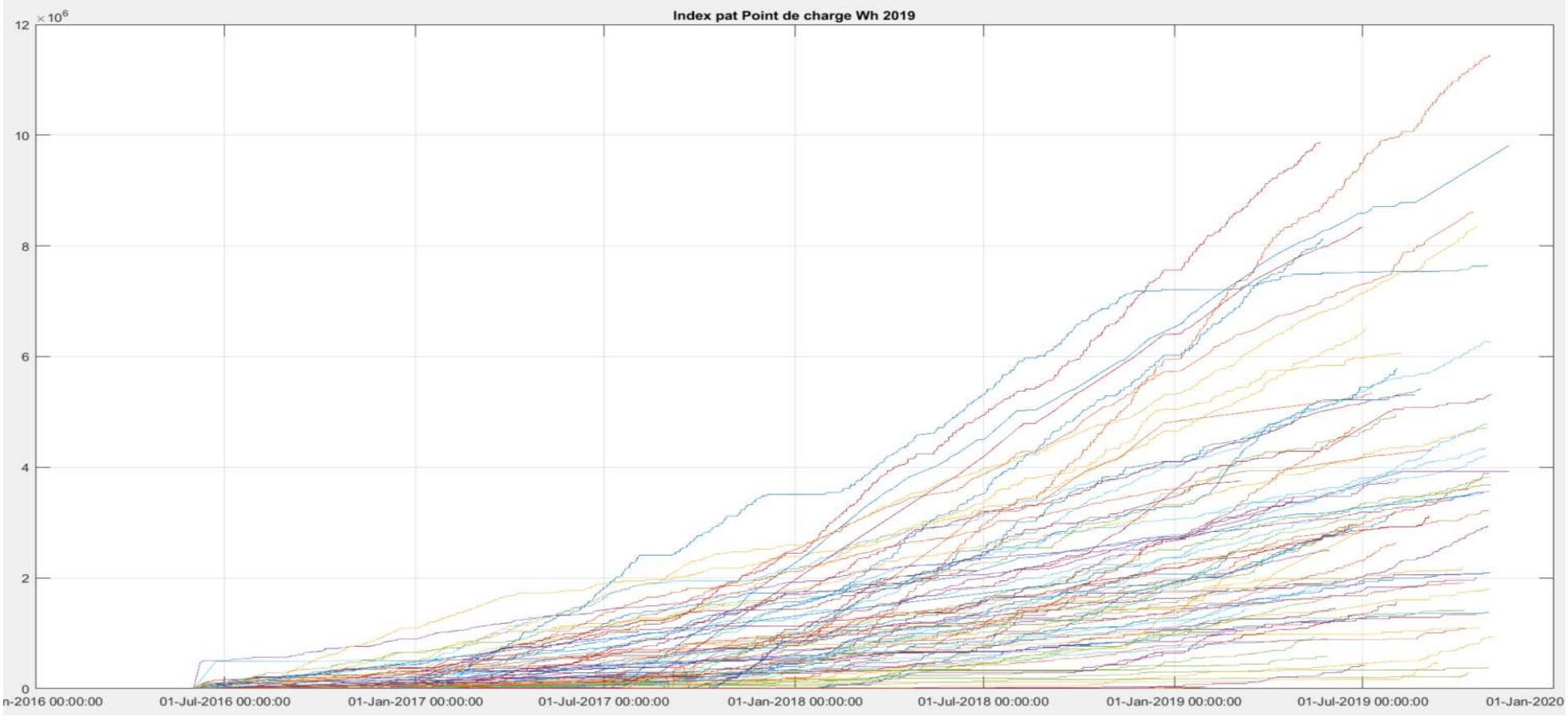
MEAN CHARGING POWER HYP. : INDEX CURVES

Energy indexes of the 81 charging stations (Wh)



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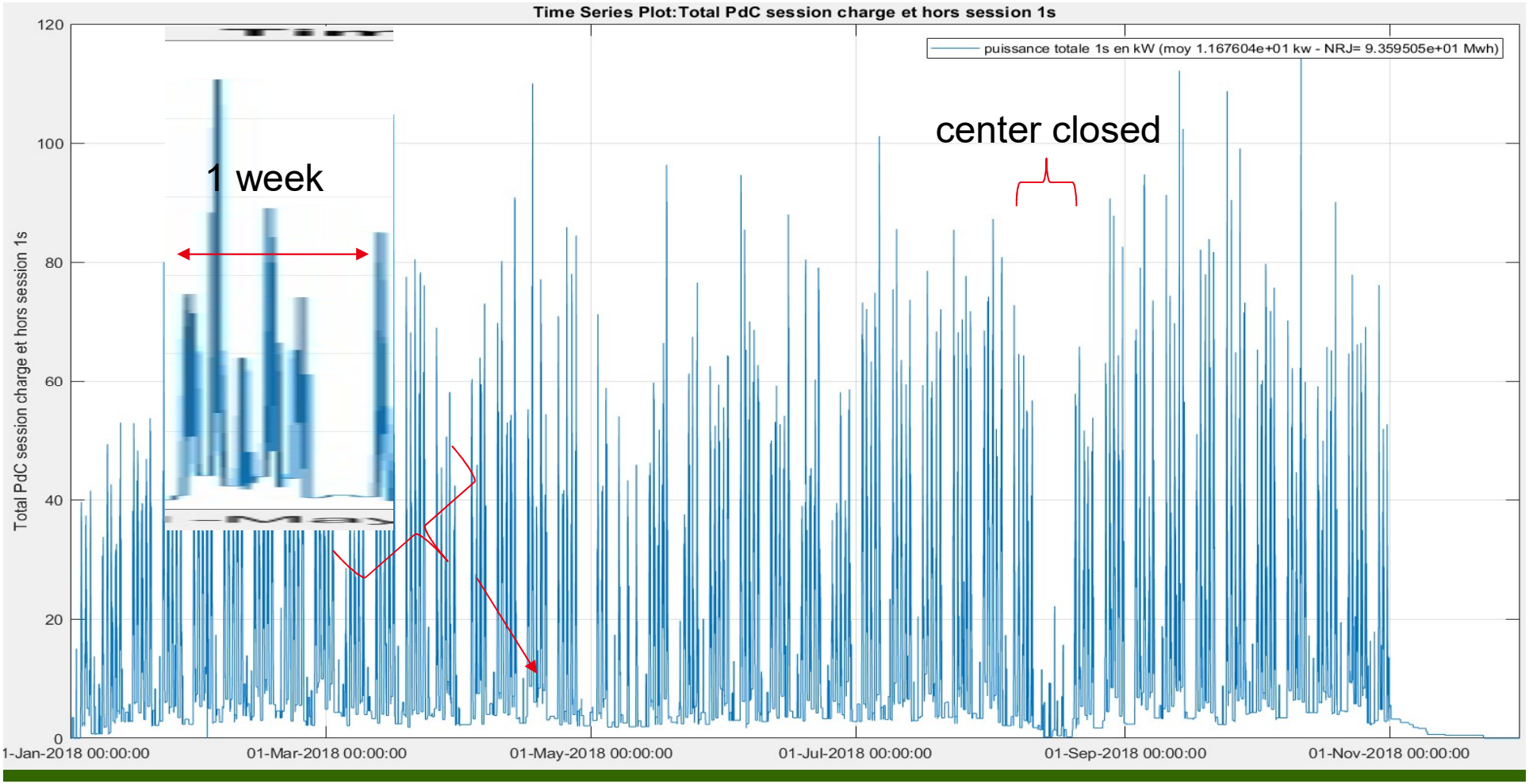
MEAN CHARGING POWER HYP. : AGGREGATED LOAD CURVE

Total of the mean power for 81 charging stations (year 2018)



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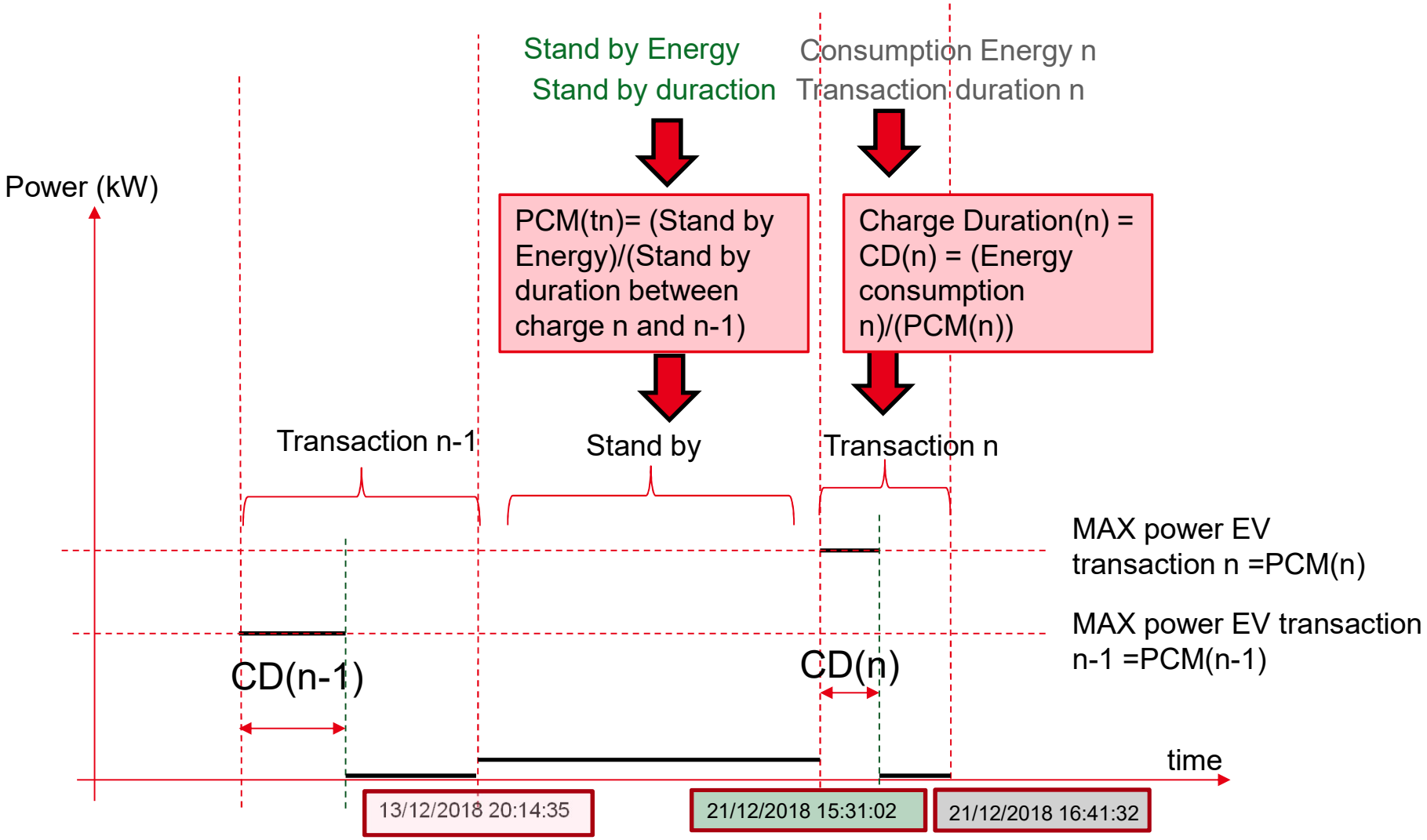
MAX CHARGING POWER HYP. : PRINCIPLES OF RECONSTRUCTION



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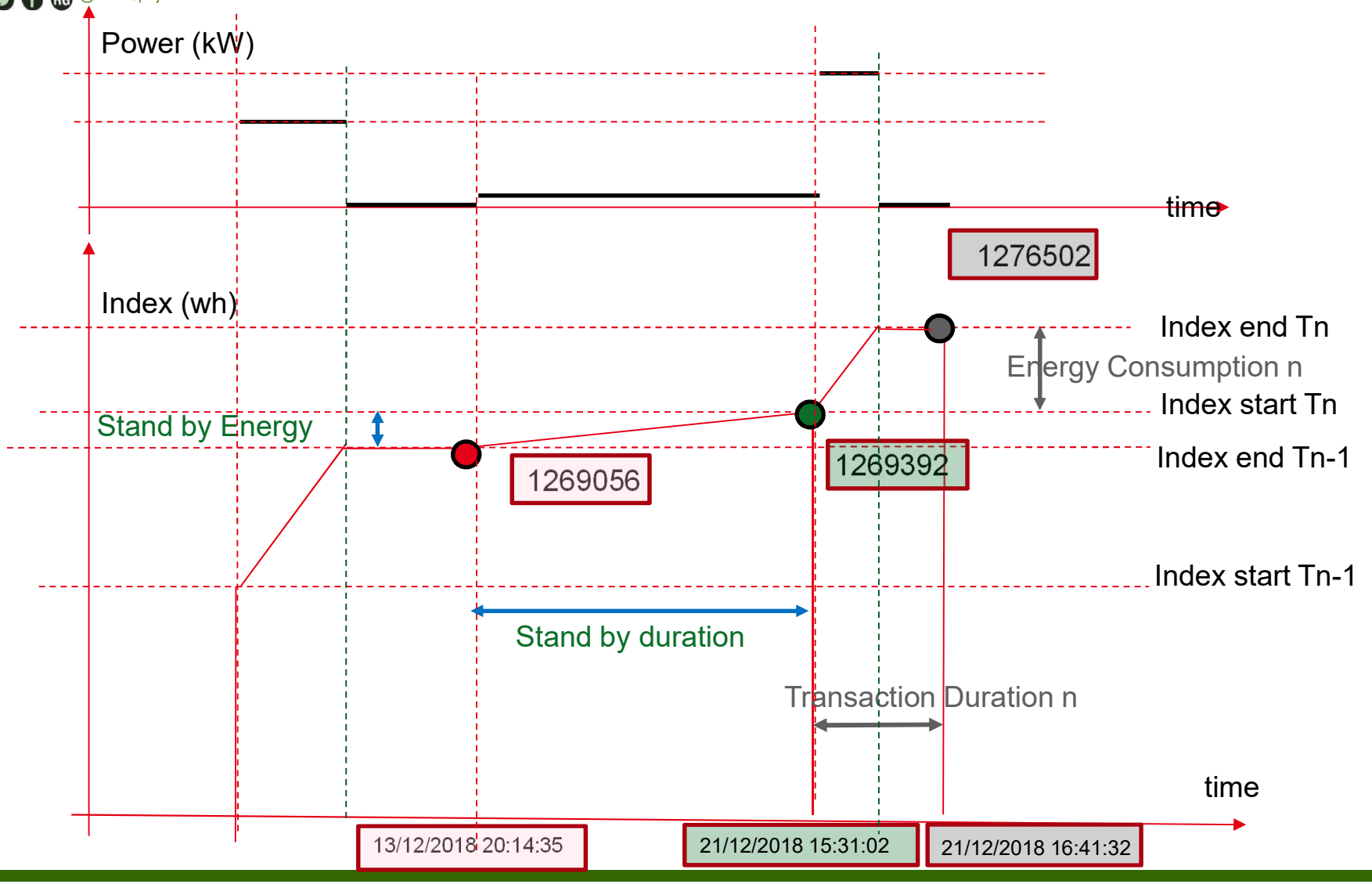

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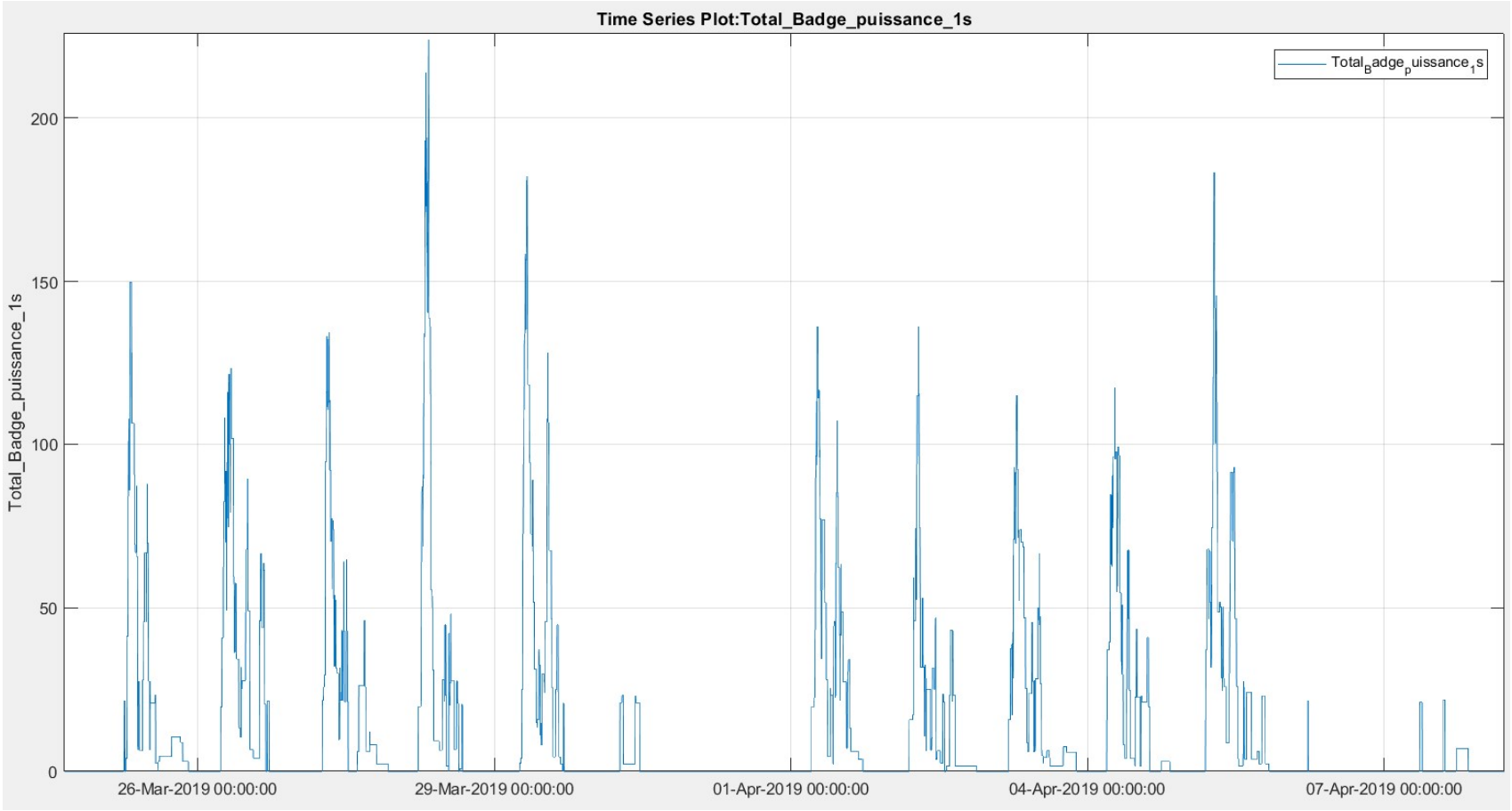
MAX CHARGING POWER HYP. : LOAD CURVES

Charging power curves during 2 weeks:



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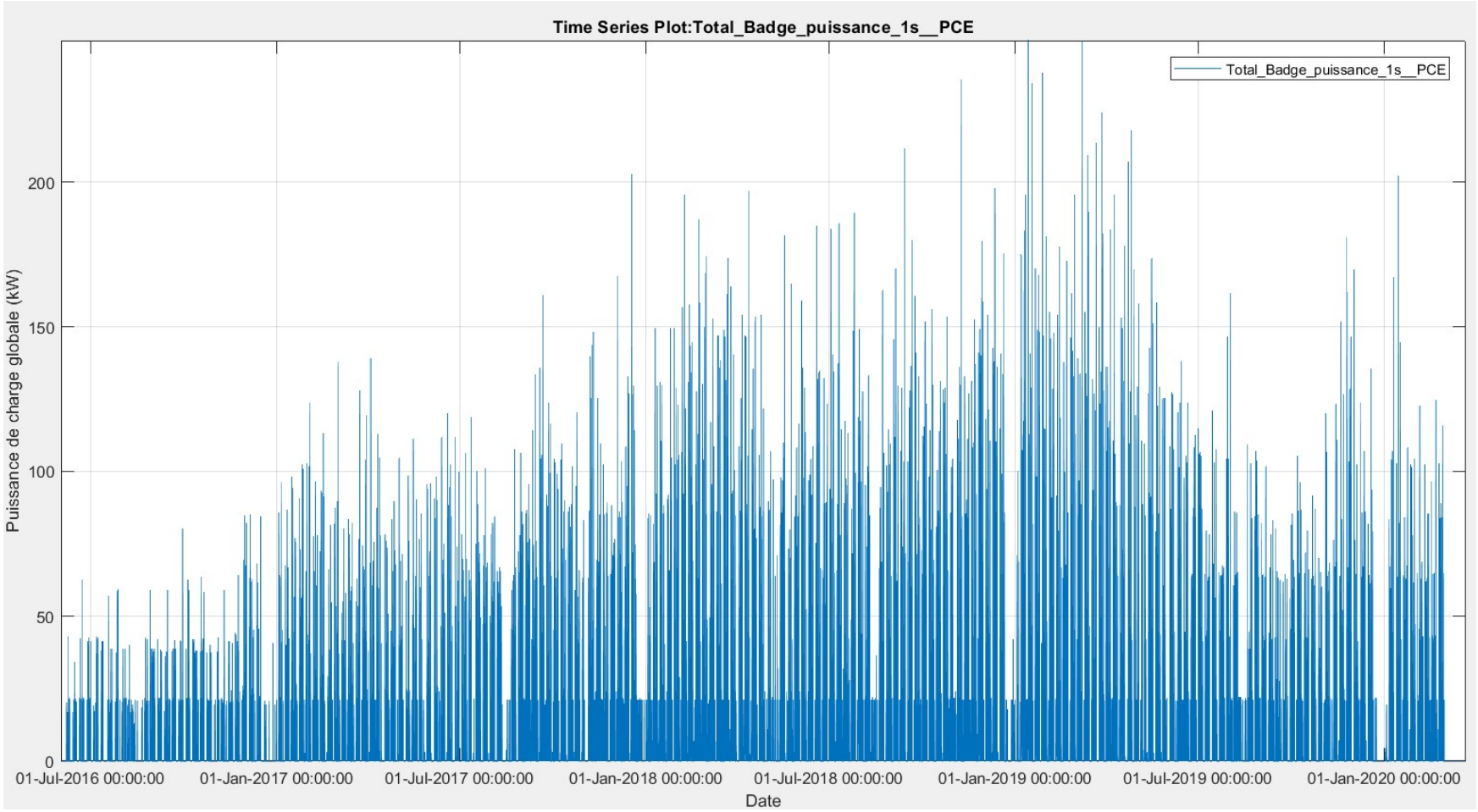
MAX CHARGING POWER HYP. : LOAD CURVES

Charging power curves during 3.5 years:



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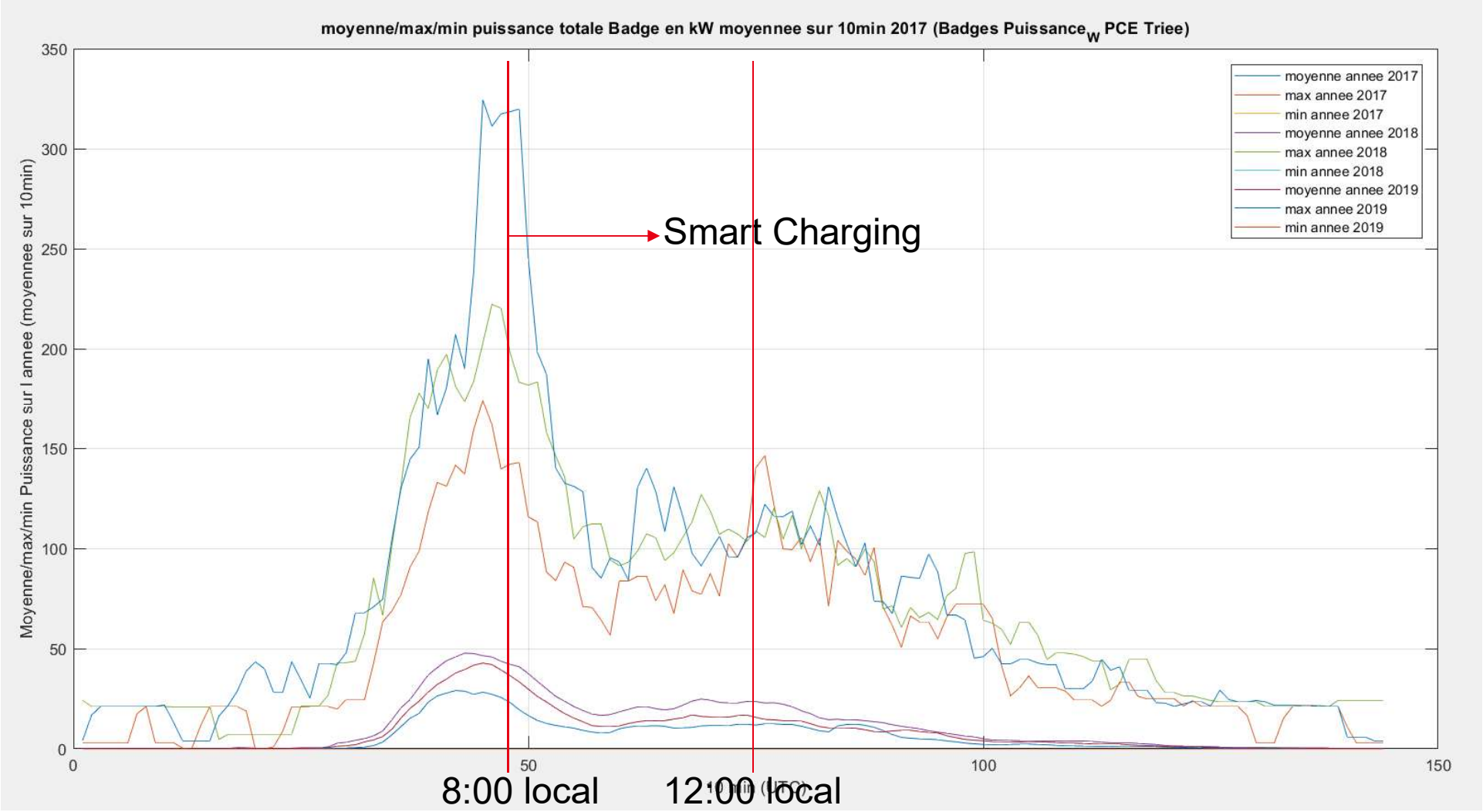
MAX CHARGING POWER HYP. : MEAN LOAD CURVES PER HOUR



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GLOBAL ARCHITECTURE

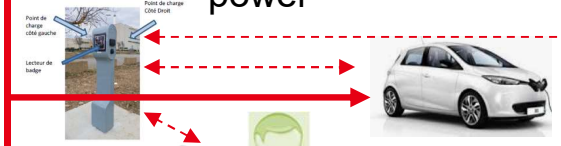
User Interface

GRID

Cloud 'CEA'
SIGE

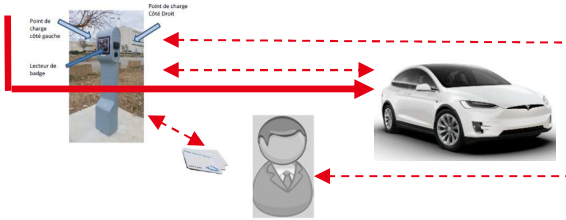
Solar production forecast

Charge request, state, power



…

…



Departure time
Initial SoC

→ Physical flows

⇢ Information flows

ICPM

- ❑ Information system
  - ❑ Solar forecast
  - ❑ Charge request
  - ❑ Users
  - ❑ Vehicles
  - ❑ Electrical network
  - ❑ Charging station state
- ❑ Control law
  - ❑ Max power of charging stations

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TELEMATICS

liten cea tech

EV

IEC 61851

Badge

NFC
Mifare 1k

Zigbee

Energy,
Power,
#Badge

Ocpp
protocol

G2box

Gateway

Production
forecast

IRVE
management
and analysis

3G

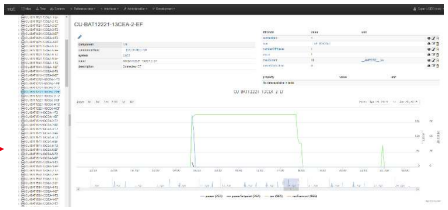
3G

SMS

Departure time
Initial SoC

Cloud 'CEA'
SIGE

Tcp/IP



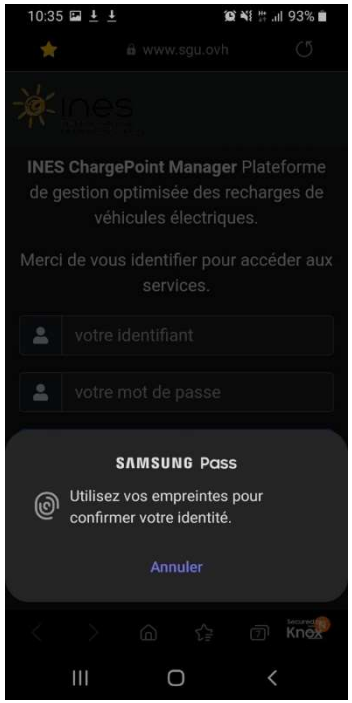
EV user

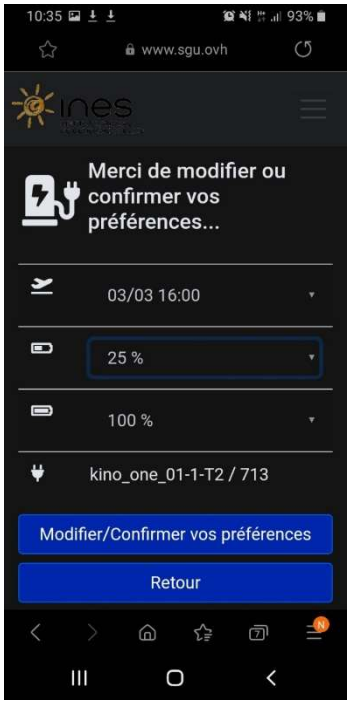
Graphical User Interface

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

EVOLVE @INES: 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).
- The EV is supplied with a test profile.
- Optimization and recharging are made on the basis of these data





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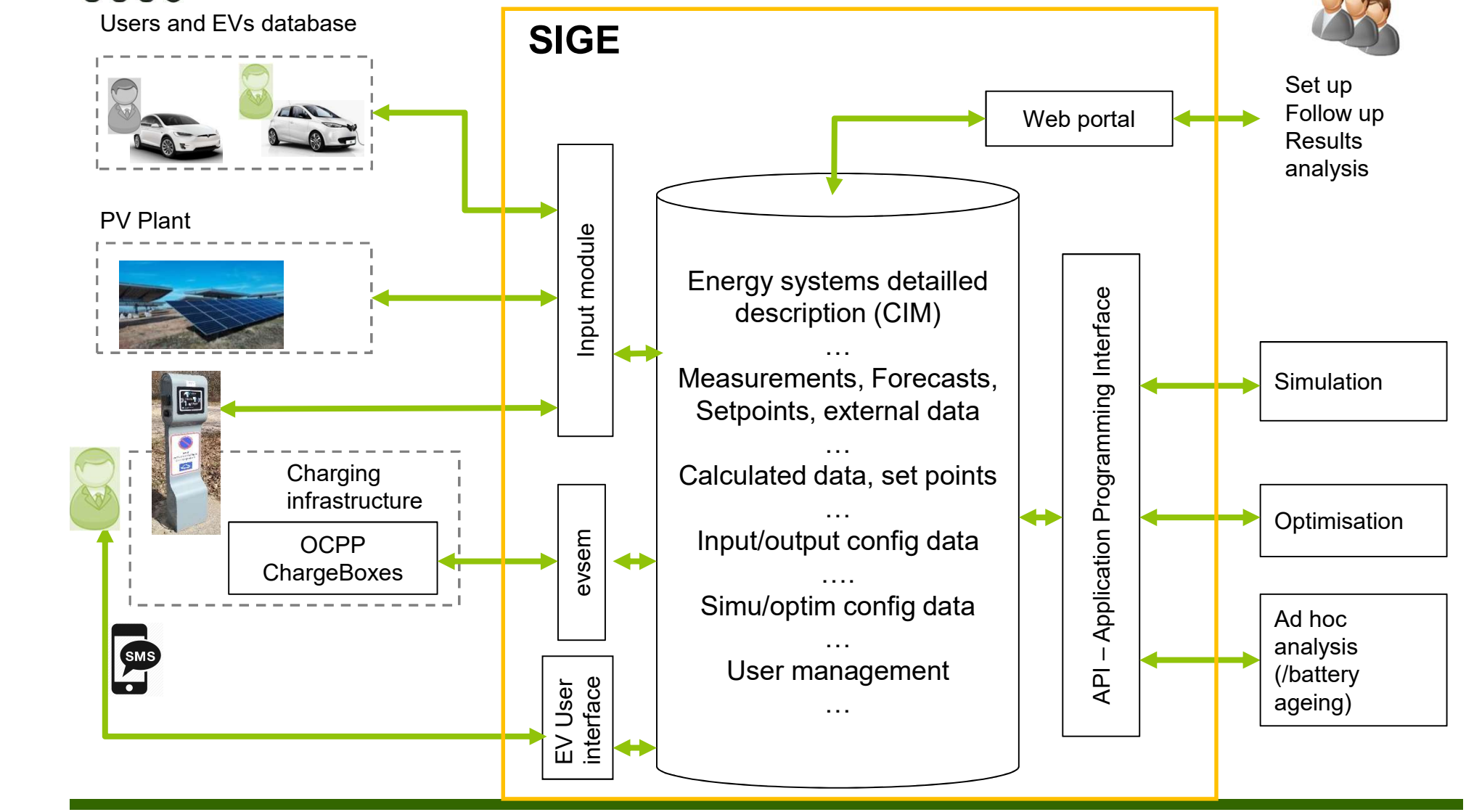
SOFTWARE ARCHITECTURE



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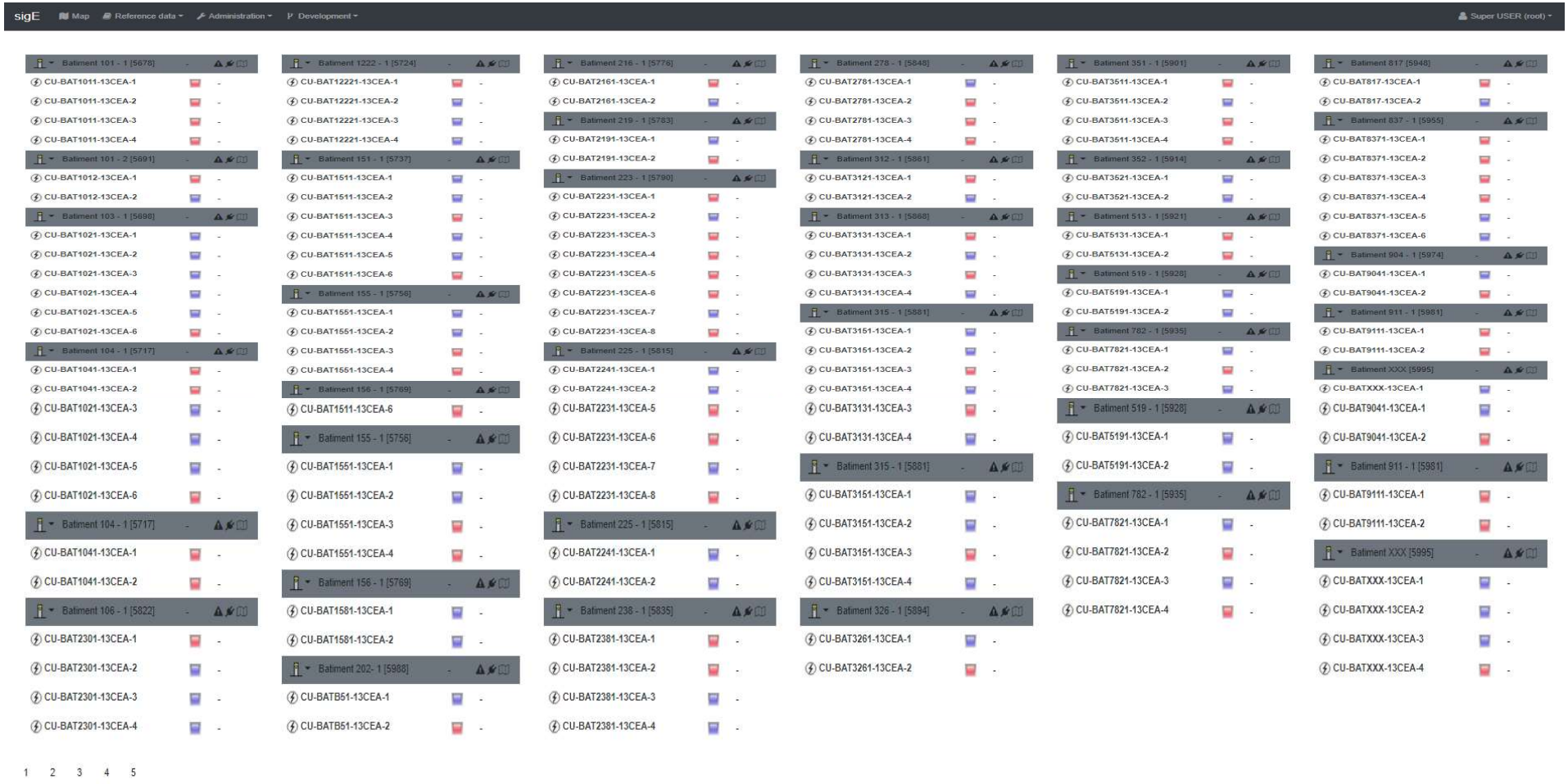
USER INTERFACE (WEB PORTAL)

View « state of the EVC»



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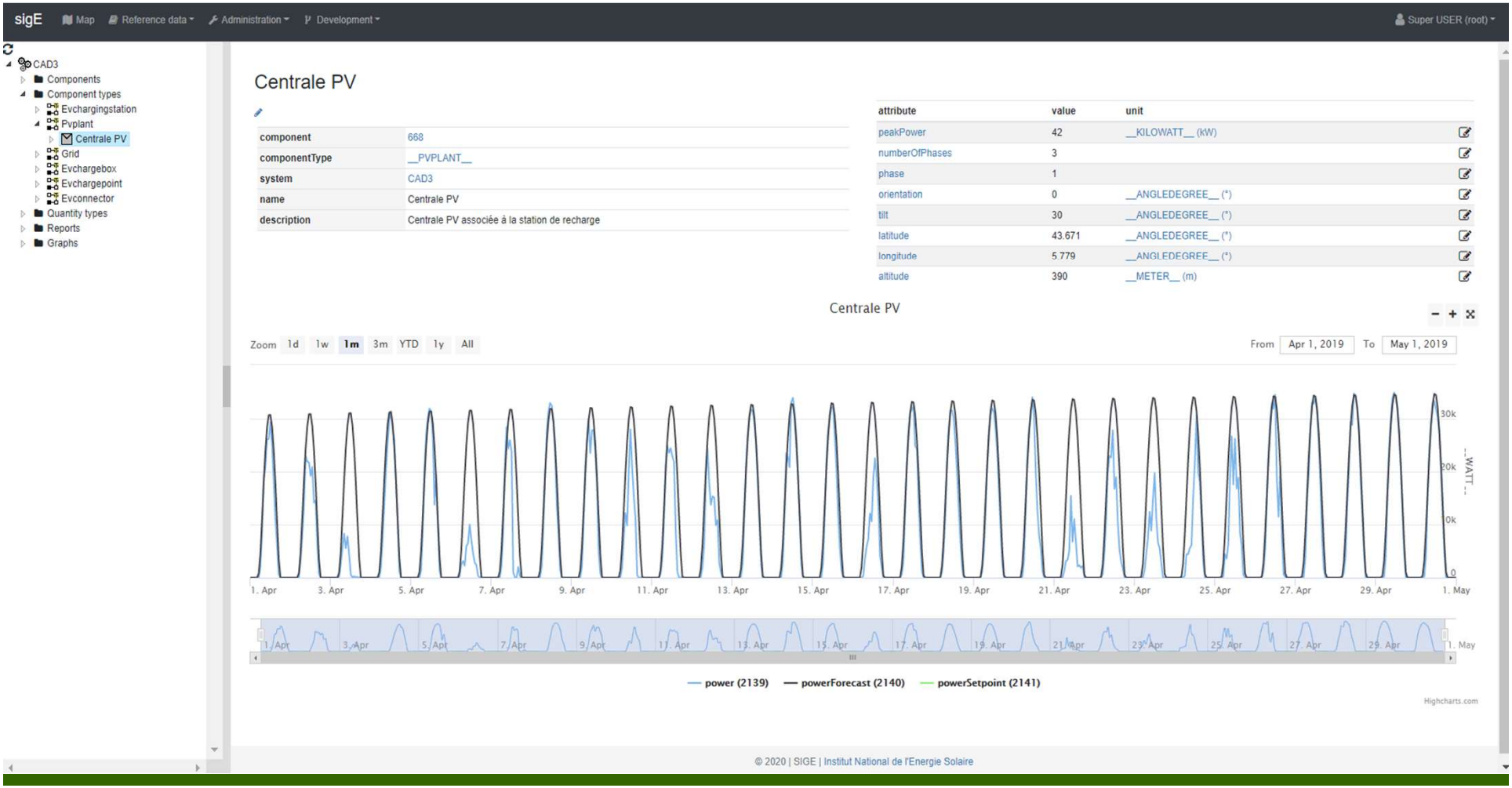
USER INTERFACE (WEB PORTAL)

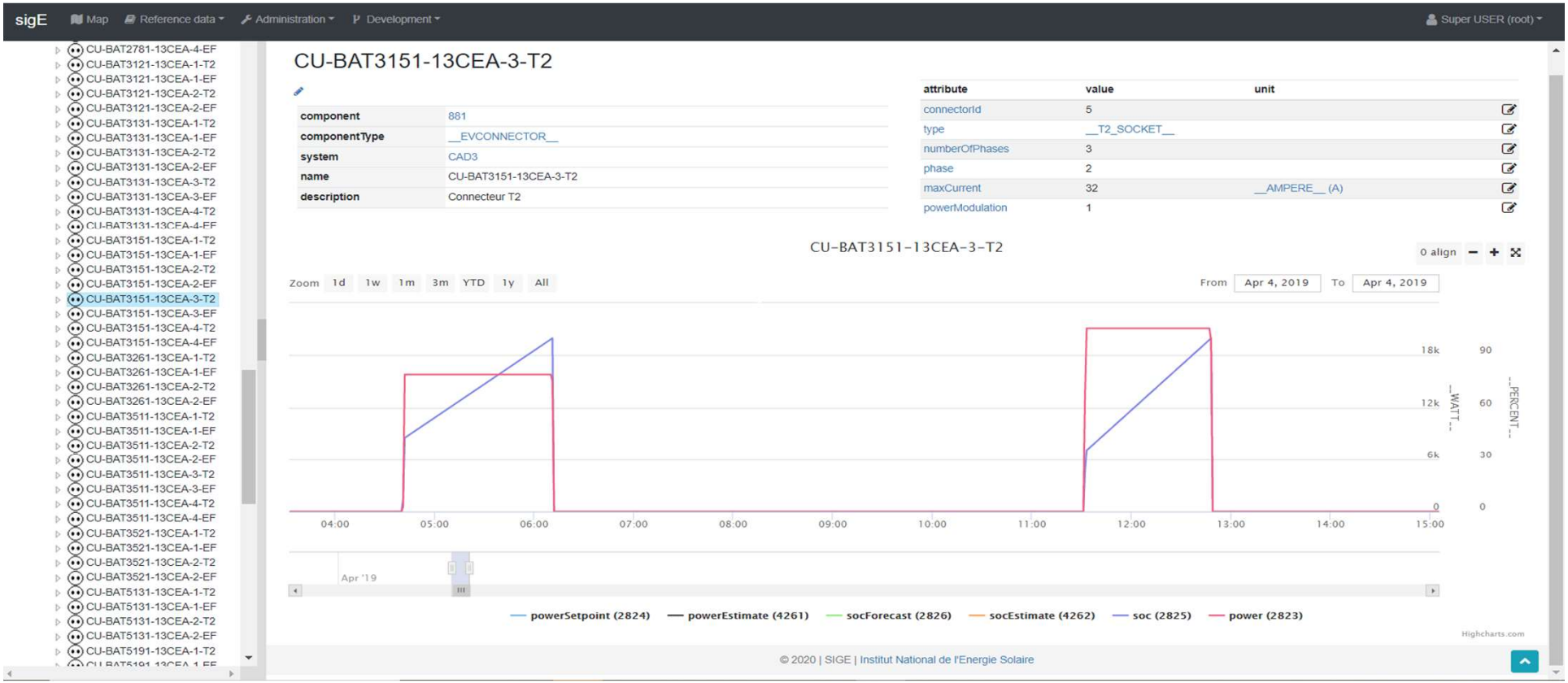
View « PV plant »



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857484

USER INTERFACE (WEB PORTAL)

View « charging station functionning »



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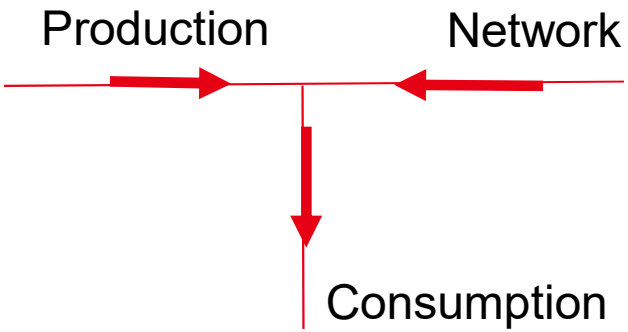
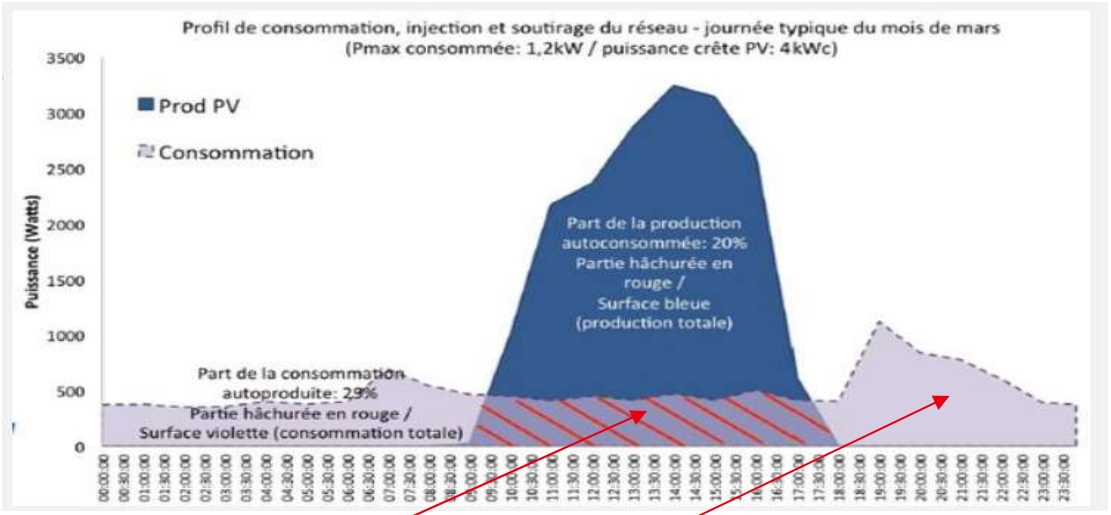
RECALL AUTOCONSUMPTION/AUTOPRODUCTION





Network + Production=Consumption

Optimisation process: maximize

autoproduction rate = (PV&consumption)/consumption

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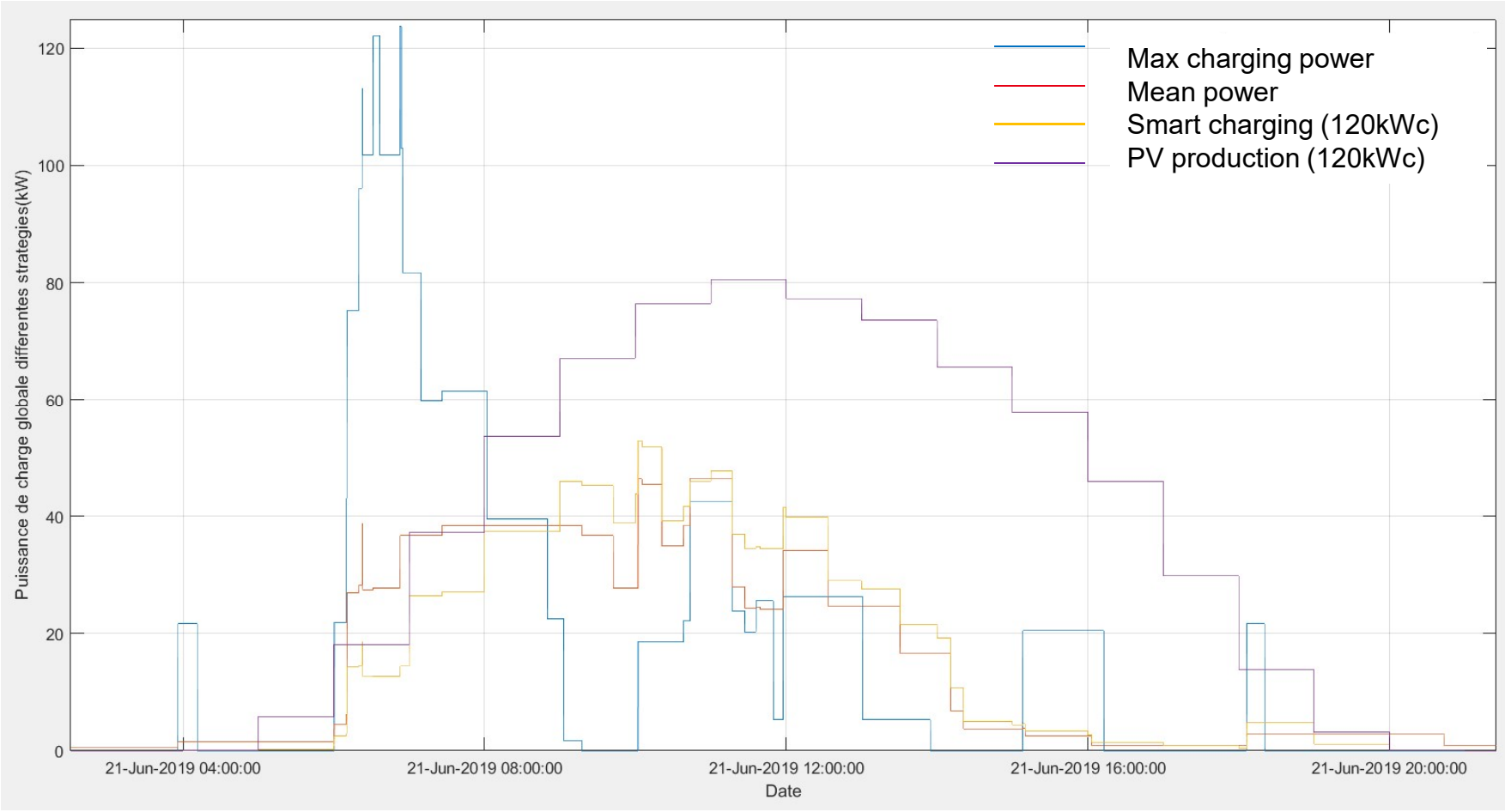
OPTIMIZATION ALGORITHM

liten cea tech

Simulation results



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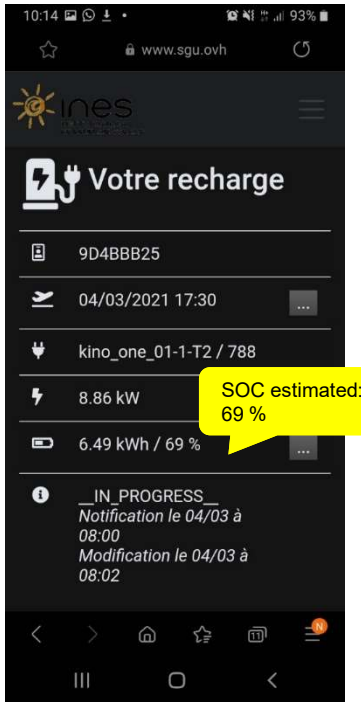
FIRST TESTS

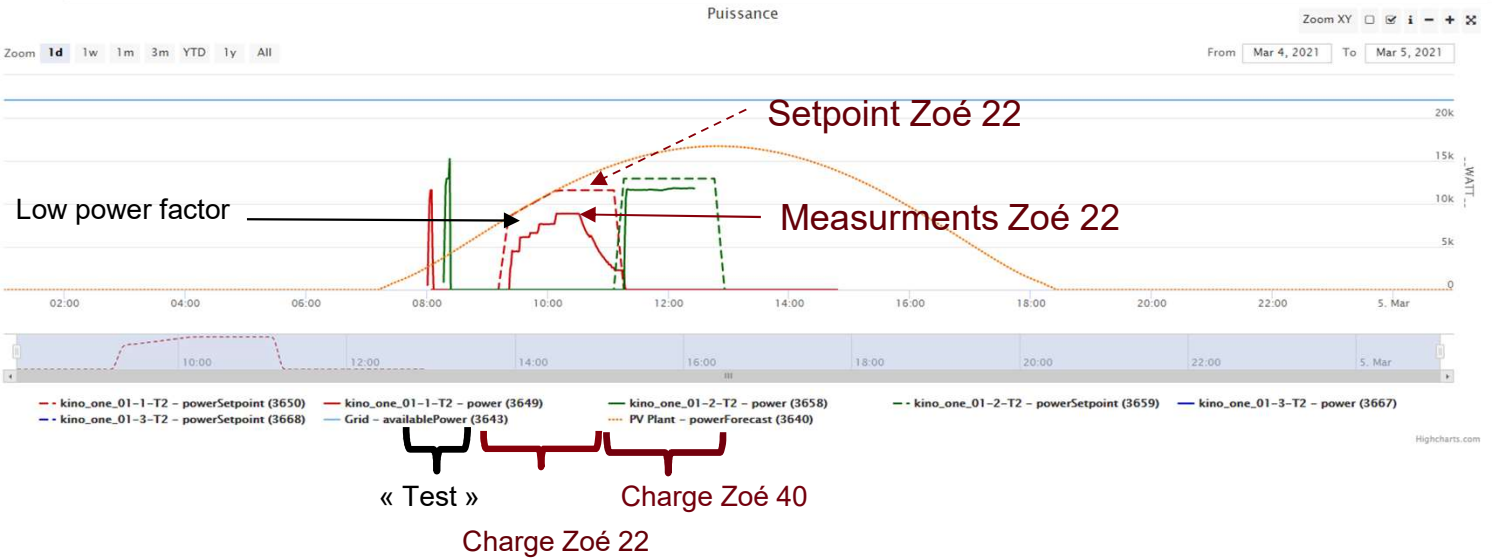
Web portal of the charging station

Energy Monitor

Voltage	231 | 231 | 230 V
Current	15,17 | 15,33 | 15,23 A
RealPower | PowerFactor	**8,80 kW | 83,5 %**
Energy (present session)	**6,89** kWh

User web interface





« Test »

Charge Zoé 40

Charge Zoé 22

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REFERENCES / SOURCES

- [1] http://www.hrvojepandzic.com/wp-content/uploads/2019/09/Lecture_4_EVs.pdf
- [2] http://ev-institute.com/images/charged_mag.pdf
- [3] https://www.transportenvironment.org/what-we-do/electric-cars/how-clean-are-electric-cars

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