

Market design for Electromobility

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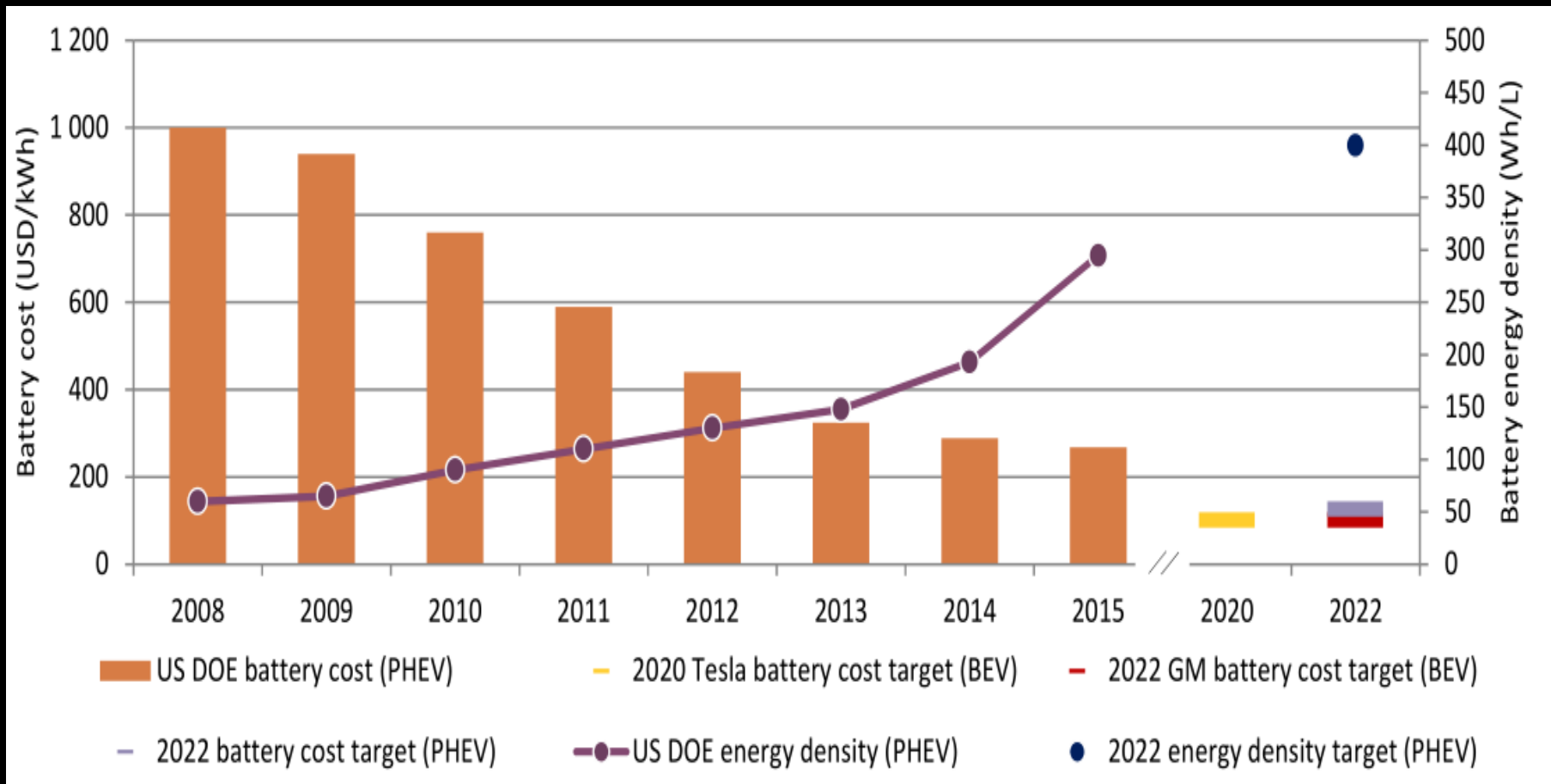
Motivations (1)

- EVs are very broad and interesting economic subject to study.
- **Regulation driven change** : more and more stringent rules toward CO2 emission per manufacturer fleet
 - Dieselgate shows that it is really difficult objective
- **Urban Local pollution standards** are also becoming stronger
 - No old diesel car (or buses or trucks) in some polluted cities (Paris more than 10 years old)
 - Tendency to have smart cities projects with only electric engines
 - If not today, in 5 years...

Motivations (2)

	EVs	ICVs
Price per new car	Minimum 22k€	Minimum 7500€
Driving range	150-200 km	400 km-600km
Time to refuel	From 20 min to 6 hours	6 min
Life time	6-8 years Warranty	X Years
CO2 emissions	0 emission while running; Some according to the energy mix while charging	From 90 g to 250g/km
Noise pollution inside and outside the car	Very low	Function of the technology
Energy cost for 100 km	1€to 2€/100 km	4-15 liters/100km * price per liter
Provider flexible ressources to the grids	Positive contribution if managed efficiently	None

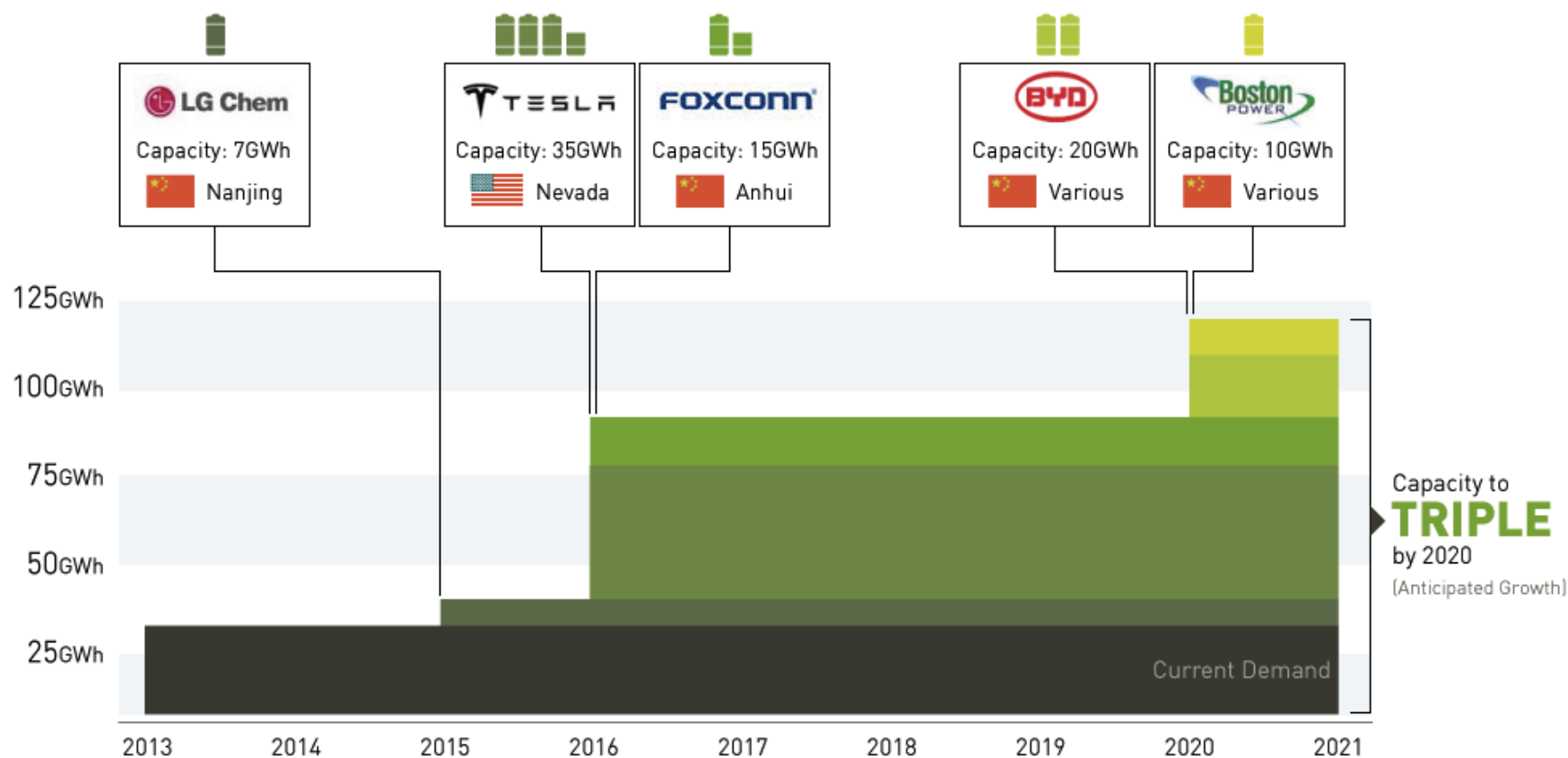
Motivation (3) Evs enjoy a Double dynamic: Increase in ENERGY DENSITY & decrease of COST



Source: IEA Global EV Outlook 2016

THE LITHIUM-ION BATTERY MEGAFACTORIES ARE COMING

Production capacity of lithium-ion batteries is anticipated to more than triple by 2020



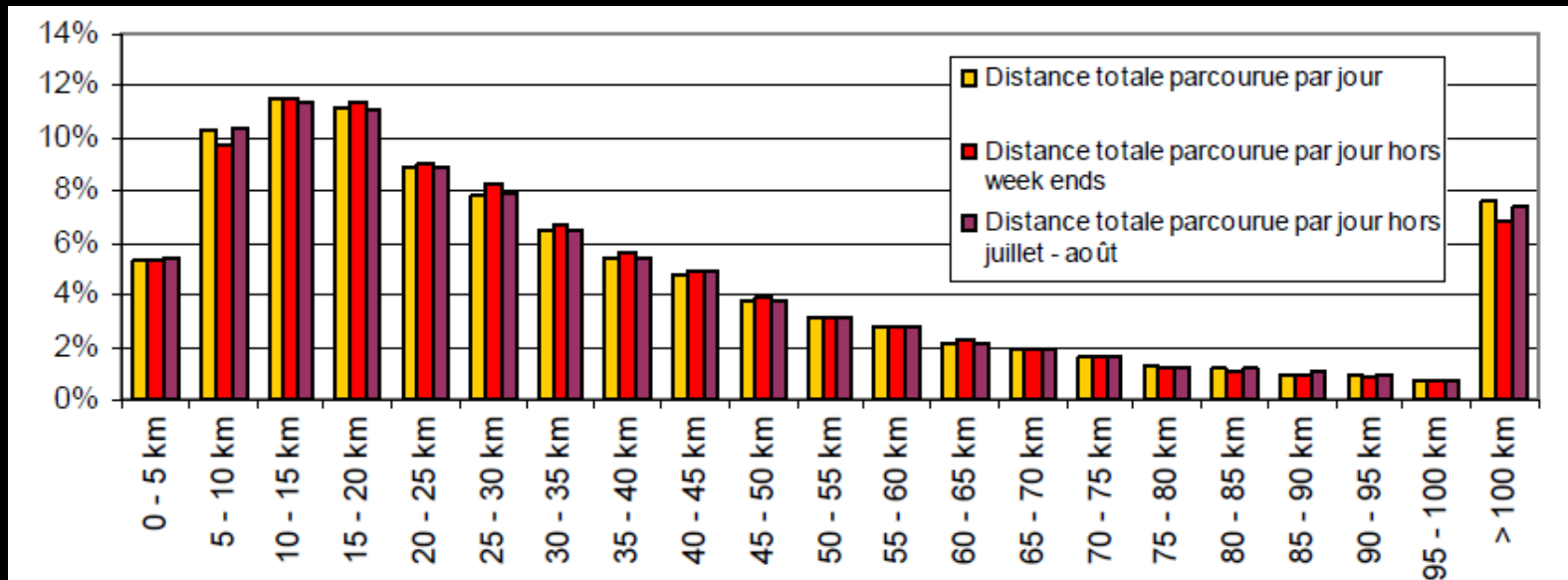
*Benchmark estimates, not all data disclosed by companies **Instant planned capacity stated for graphical purposes, slower ramp up expected

Data by:



Motivations (4)

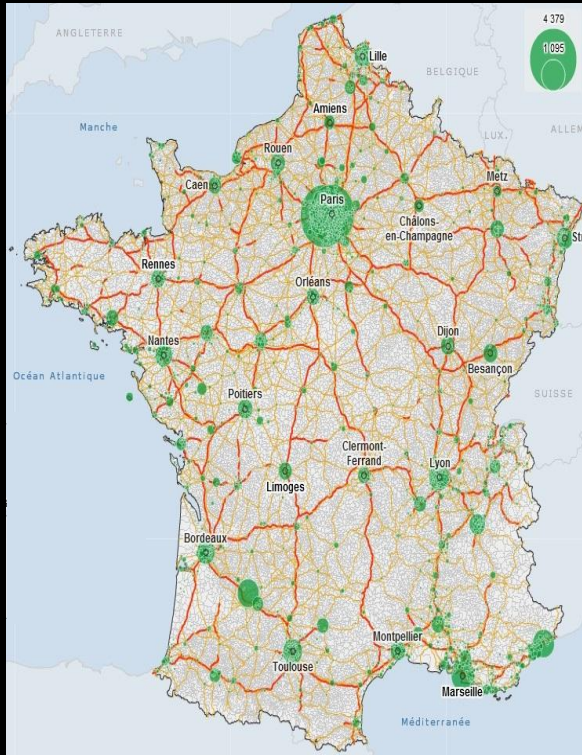
Distribution of the Thermal car uses per day in France



80% trips < 60km → Mean = 12 km → 24 km/Day

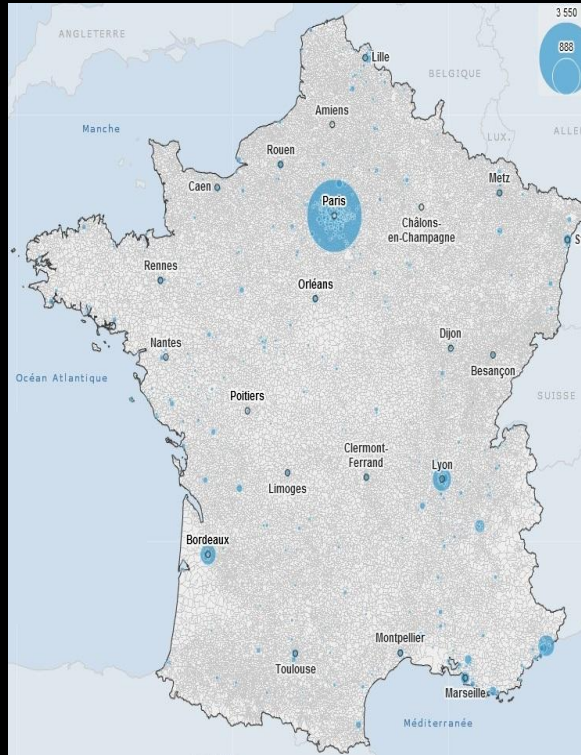
Current deployment in continental France (June 2016)

- Number of Electric (EV) and plug-in electric vehicles (PHEV) registered



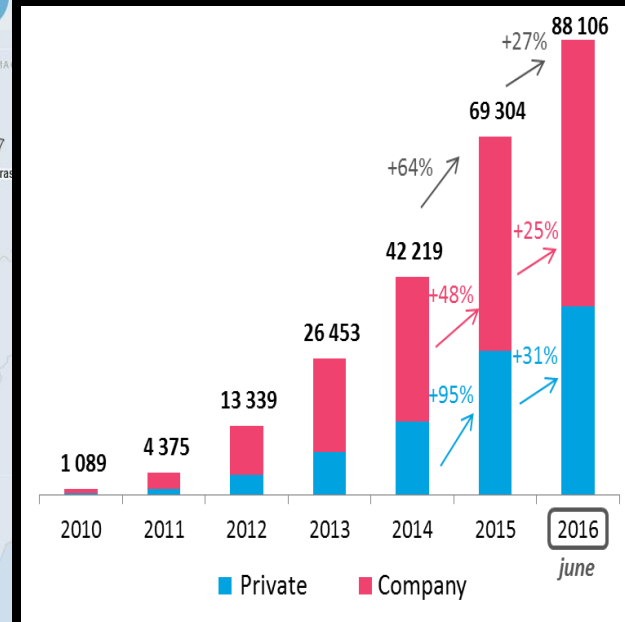
Almost 90 000 vehicles registered in more than 13 000 towns (85% are EV)

- Number of public charging points installed



More than 14 000 public charging points located in almost 2 000 towns

- EV and PHEV: only 0,2% of the total French car fleet... but a sharp growth since 2010

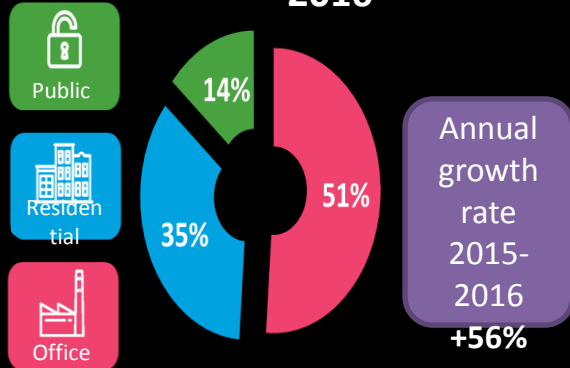


Increase of private owners higher than companies

Source: Enedis, AAADa, Gireve

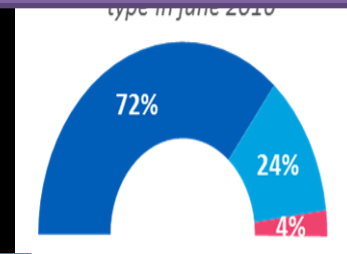
The Energy Transition Law sets an ambitious target of 7 million charging points by 2030, and 1 million by 2020

104 626 charging points in June 2016

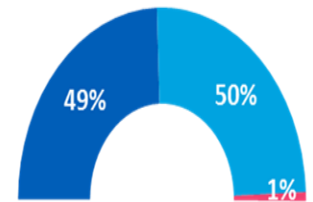


Installed capacity is growing faster than the number of charging points due to the development of quick public charging points

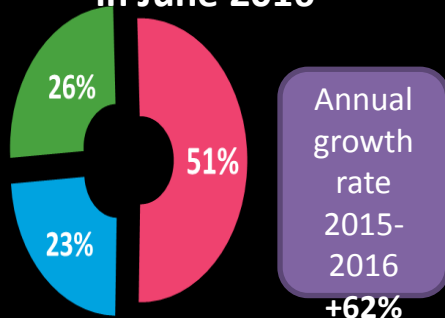
14 509 public points in June 2016



55 000 public points in 2019



625 MVA of installed capacity in June 2016



■ The number of public charging points should be increased almost fourfold by 2020 (14 000 to 55 000)

■ Installed capacity of the public charging points will grow even faster

And the window of opportunity is open ...

EDITION
US

NEWS

TRENDING



THE LIVERPOOL POST

2030 devrait voir la fin du diesel et de l'essence en Allemagne

© 10/10/2016 à 12h51



ALL SECTIONS

g Point in



David van der Mark/Flickr

The Netherlands is making moves to ban all non-electric vehicles by 2025

No fumes in the future.

PETER DOCKRILL 13 APR 2016

GLOBAL EV FORECAST COMPARISON

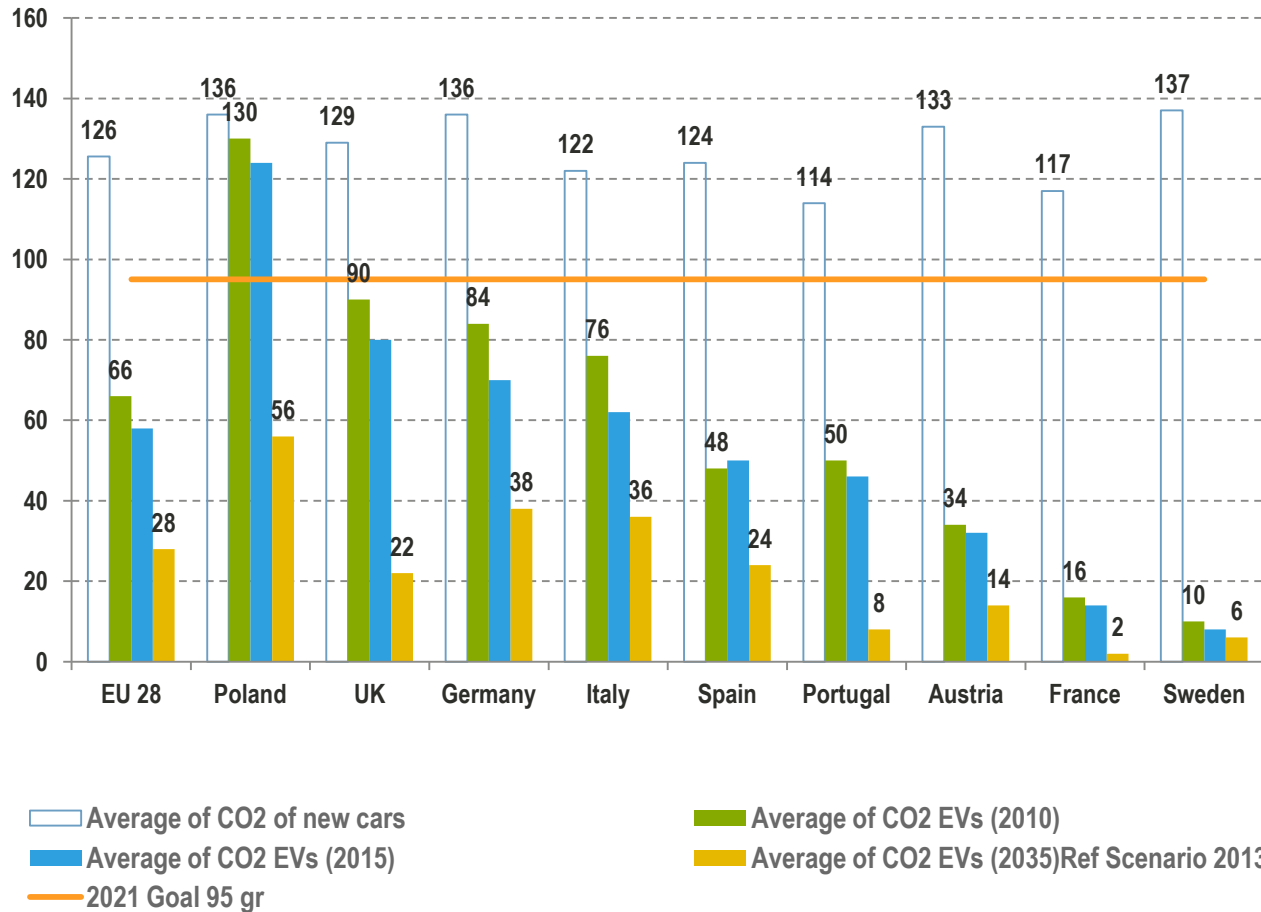
Sales				
Scenario	Powertrain	2020	2025	2030
BIPE Green Constraint	BEV	1 351 434	2 270 912	3 401 518
Bloomberg	BEV	936 455	3 745 819	13 110 368
BIPE Green Constraint	PHEV	1 265 130	4 171 103	8 457 032
Bloomberg	PHEV	1 404 682	4 214 047	7 959 866

BUT

Motivation (6)

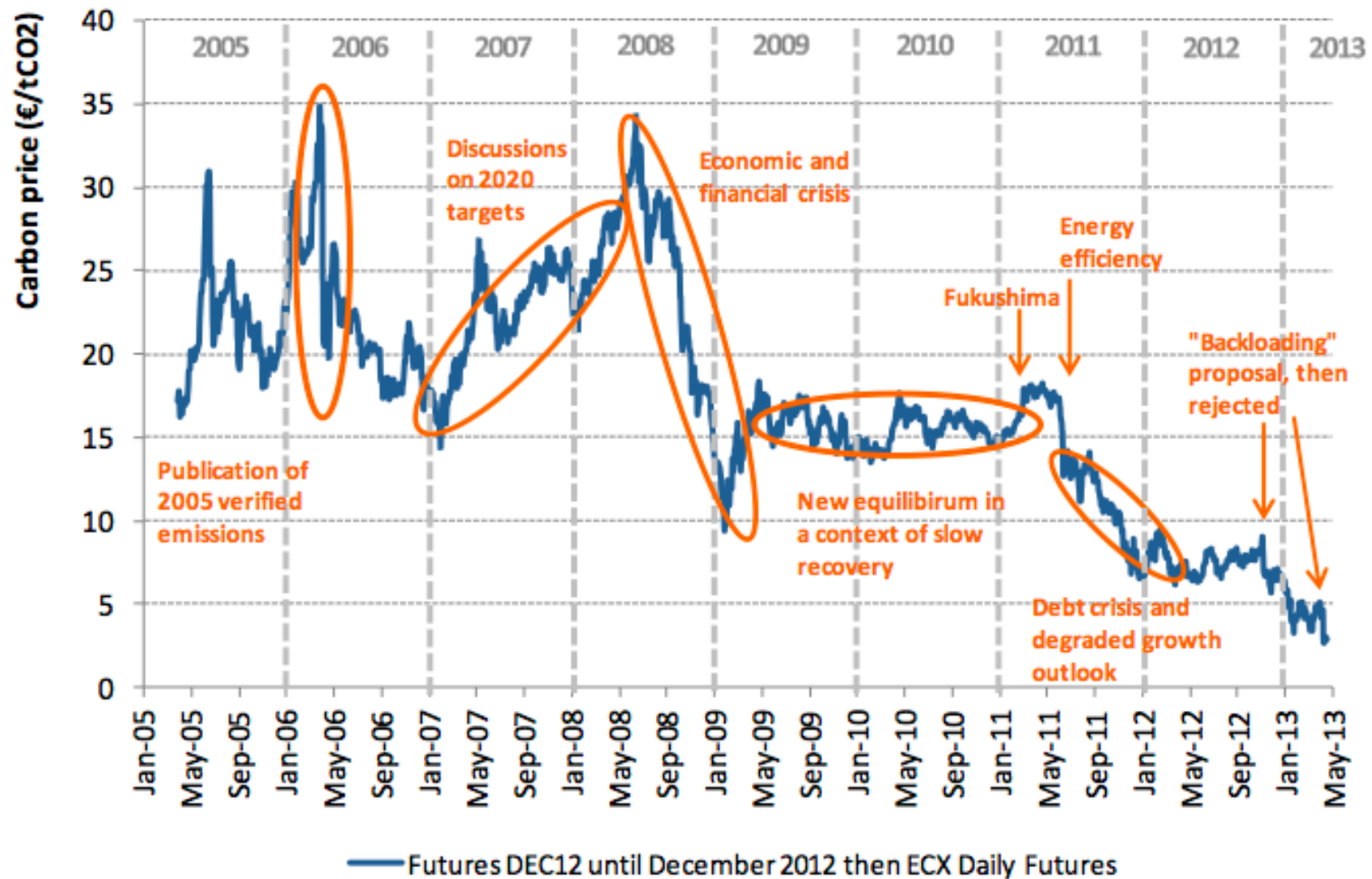
- EV drawbacks are partially due to Market Failures
 - Positive externalities are not paid at real value
 - CO2 reduction : How much, in terms of grams and € ?

EVs emit less CO₂ than conventional cars



- With the 2010 carbon intensity, a typical EV emits about 66g CO₂/km
- EVs will be even cleaner in the future as the power sector continues to decarbonise by 2050

Figure 1: CO₂ allowances price since 2005



Source: Climate Economics Chair from ICE ECX data

Motivations (6)

- EV drawbacks are partially due to Market Failures
 - Positive externalities are not paid at real value
 - CO2 reduction => CO2 markets are not efficient : 4-10 euros per ton for 2 units per year
 - Health benefits by reducing toxic emission => measures?

Motivations (6)

- EV drawbacks are partially due to Market Failures
 - Positive externalities are not paid at real value
 - CO2 reduction => CO2 markets are not efficient
 - Health benefits by reducing toxic emission => measures?
 - Oil import reduction => saving for purchaser, benefit for society in terms of independence?
 - Industrial/Services job and local wealth creations
 - Need more precise evaluation of Willingness to Pay for Electric vehicles characteristics in different environments

What is the EV « Chicken and Egg » problem ?



- Average EV can not run for more than 150-200 real km
- So little sales
- So no need to build a charging network for Evs
- So EVs can not be largely sold...

Disclaimer

Only successfull cases are treated here!

- Better place is not treated
- PSA 1941- 1996 experiment with EVs
- ...



And not dealing with deep history of innovation...

L'ELECTRICITE D'HER

COLONNE DE CHARGE
POUR AUTOMOBILE ELECTRIQUE

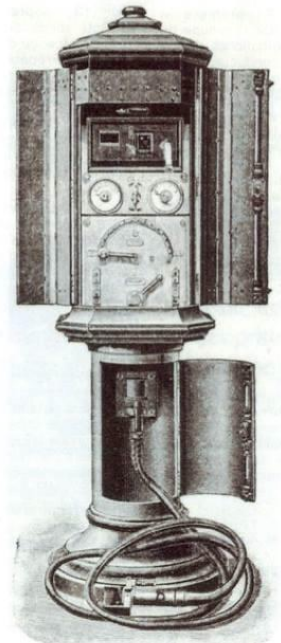
Une voiture se présentant pour charger ses accumulateurs, le préposé ouvre les deux portes du coffret, sort la garniture et la branche sur la voiture (l'autre extrémité restant habituellement branchée sur la partie du fût), met un jeton dans le compteur, ferme les coupe-circuits intérieurs du compteur, ferme l'interrupteur bipolaire, et, à l'aide du commutateur du rhéostat, fournit à la batterie l'intensité de charge qui lui convient, intensité qui, pour les diverses batteries peut varier de 25 à 80 ampères. Le préposé fournira à la voiture l'énergie qui lui est nécessaire en mettant successivement dans le compteur un nombre de jetons convenables.

La charge terminée, le préposé doit couper l'interrupteur bipolaire, après avoir ramené le commutateur du rhéostat à la position de résistance maxima. »

Bien entendu, cela supposait que la borne soit alimentée en courant continu par le réseau, ce qui était le cas à l'époque.

Appareil primé au
Concours de Juillet 1899,
par la Commission mixte
chargée de déterminer les
conditions dans lesquelles
les automobiles pourront se
ravitailler en énergie élec-
trique.

Adopté par l'AUTOMOBILE CLUB de FRANCE



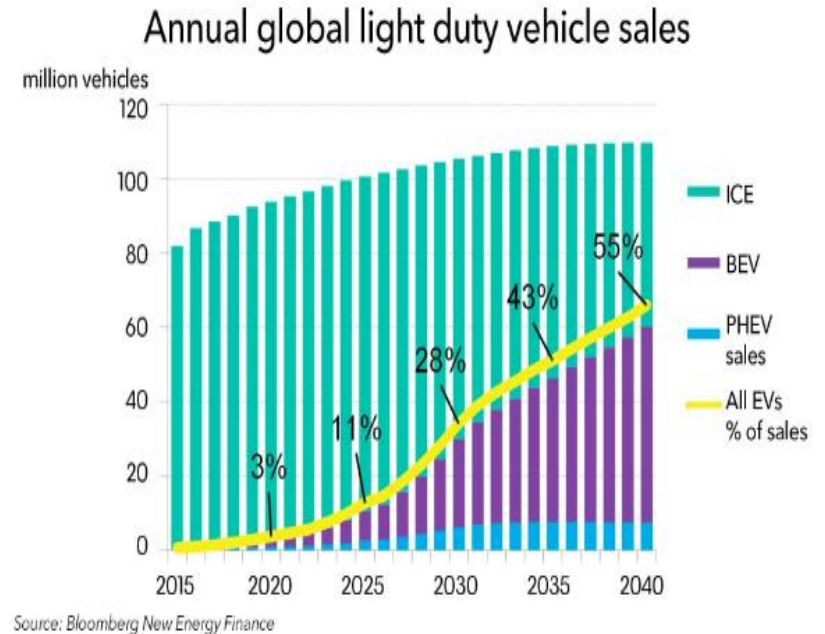
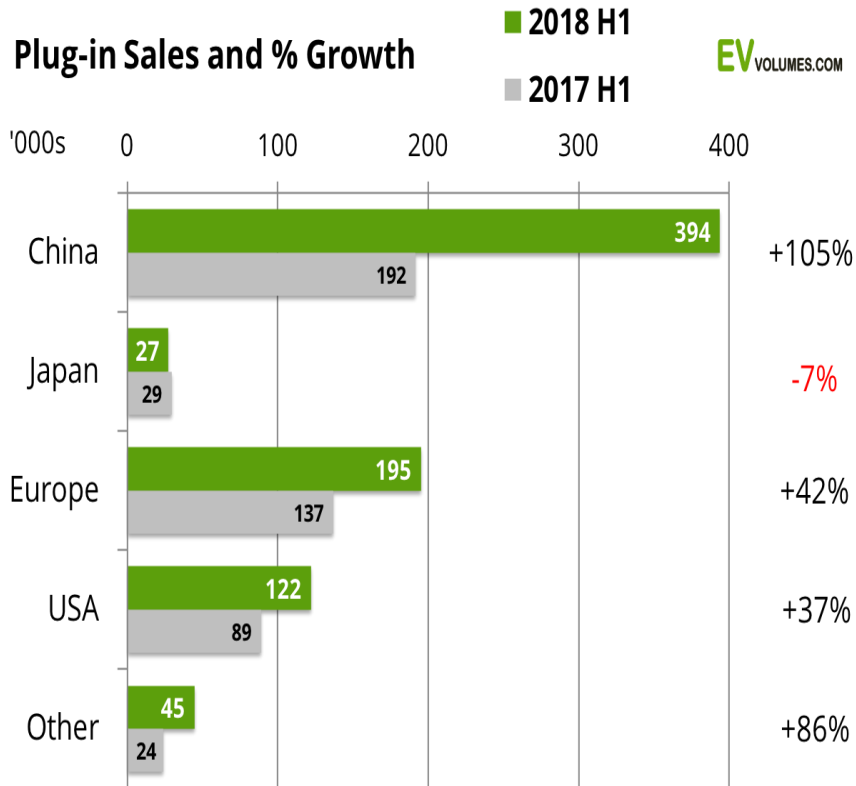
Outline of the presentation

- Why Electromobility is starting?
- Why is it promising for Grids ?
- Why is it promising for Users?

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EV sales for personal cars + Electric buses



Source: <http://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/>

Why it is starting?

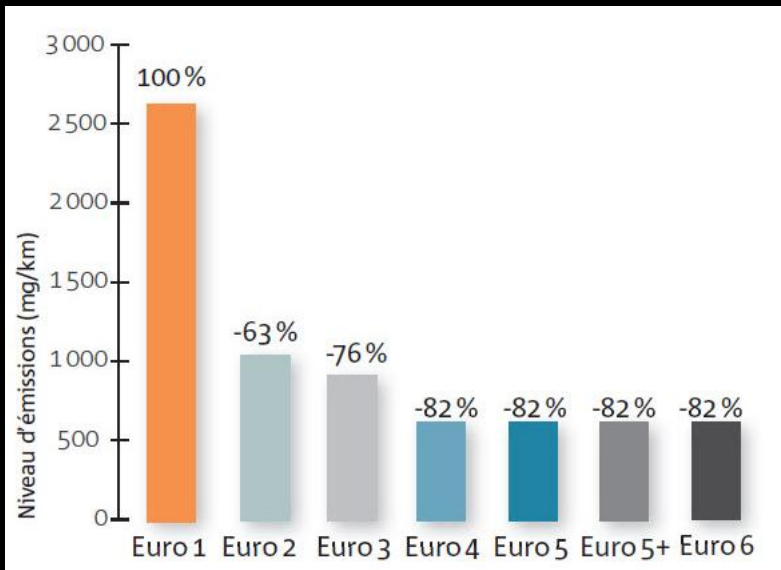
Public action: Sticks and Carrots

Range anxiety decrease

Basic infrastructures exist

Sticks and carrots

Sticks: Banning policies @ local level+ emission reductions for cars



Carrots

- Public subsidies
 - EV PHEV selling subsidies (State level + local)
 - Charging infrastructure subsidies
 - R&D subsidies

TCO comparison

PETITES CITADINES



CITADINES



COMPACTES



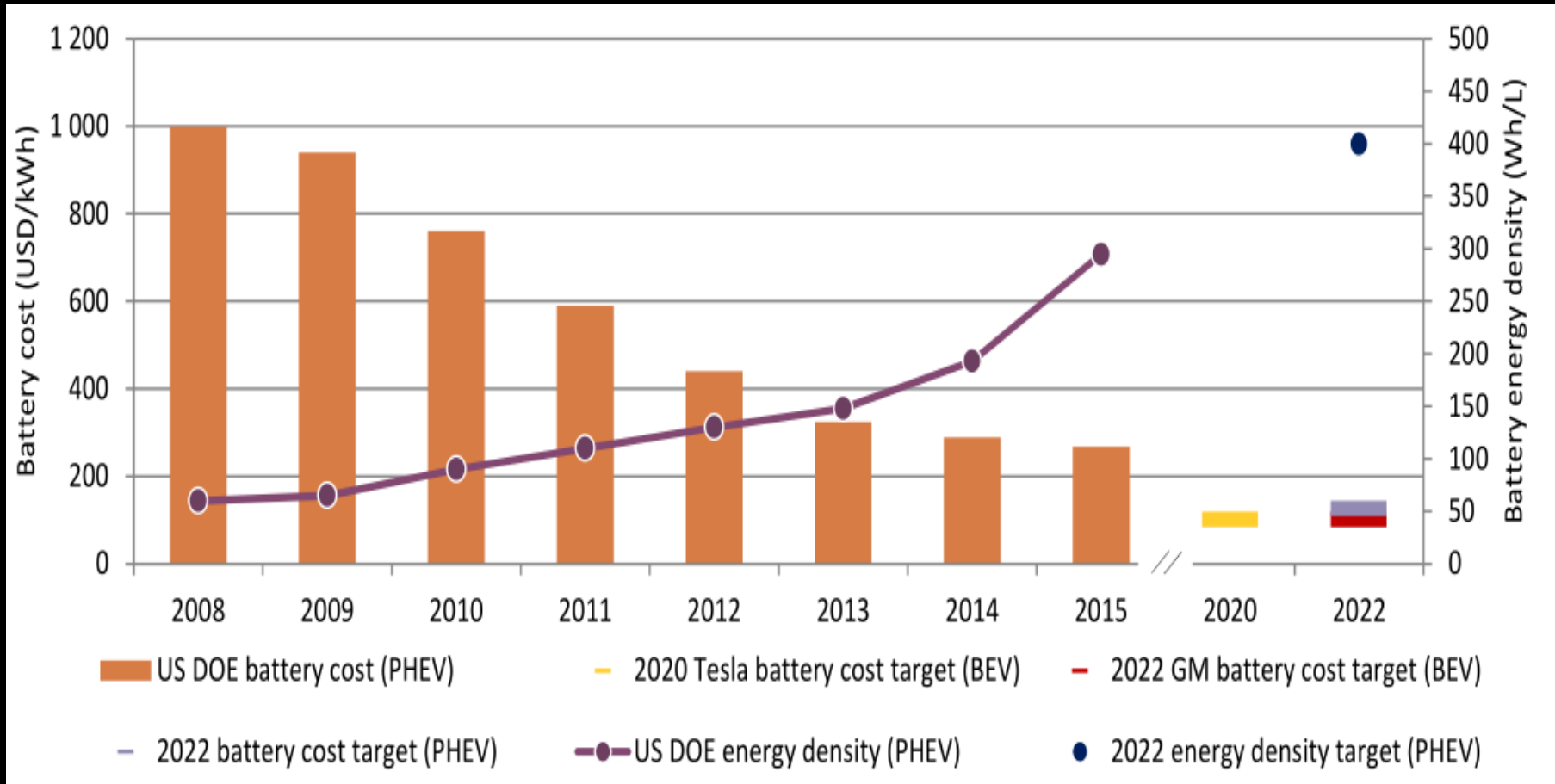
Why it is starting?

Public Subsidies

Range anxiety decrease

Basic charging infrastructures exist

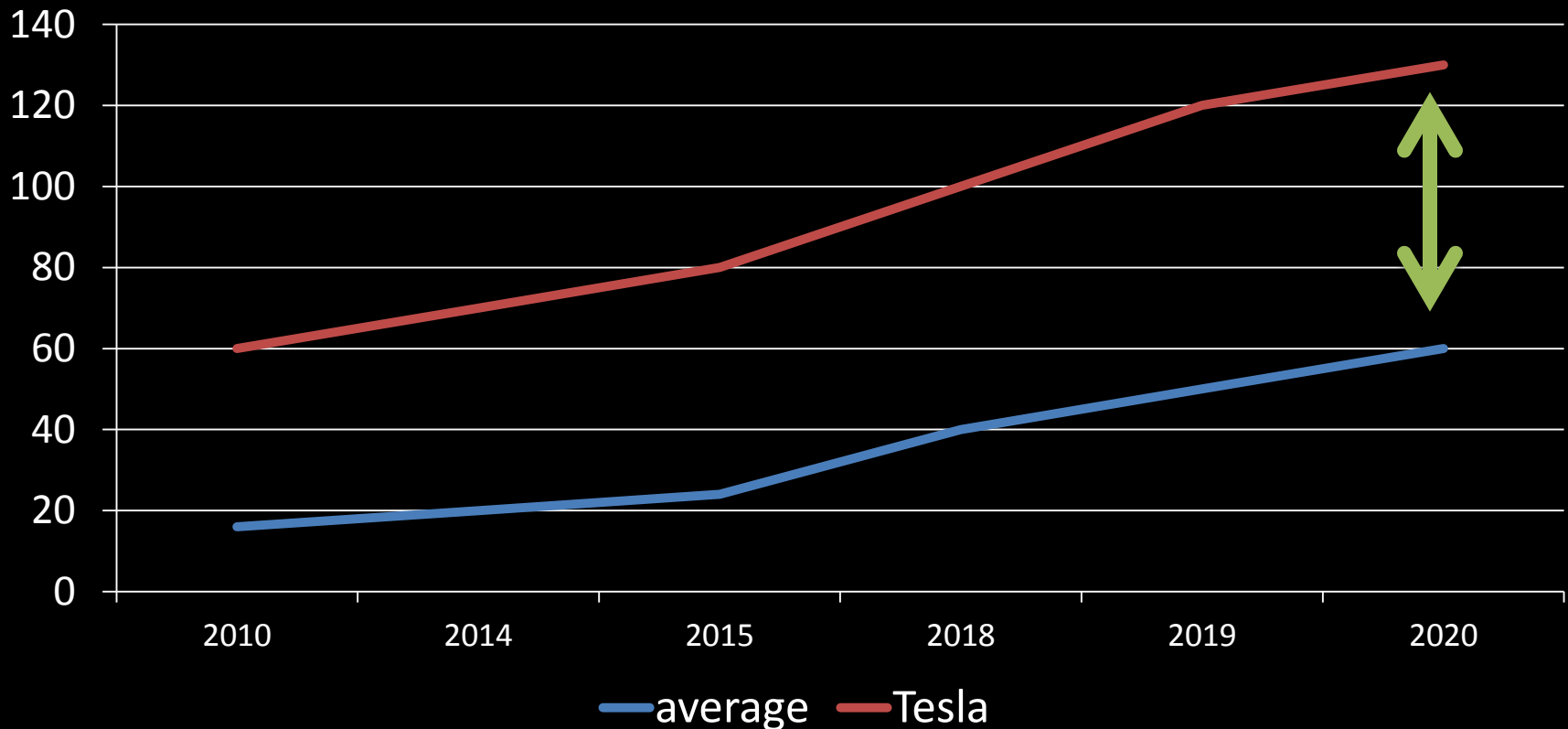
EVs enjoy a Double dynamic: Increase in ENERGY DENSITY & decrease of COST



Source: IEA Global EV Outlook 2016

Less costs => More capacity / car =>
less range anxiety

Evolution of the size of the battery in kWh per car



After 2020 = Cost reduction will normally used to reduce the cost of the EVs

Switching from
« range anxiety »
to
« charging anxiety »

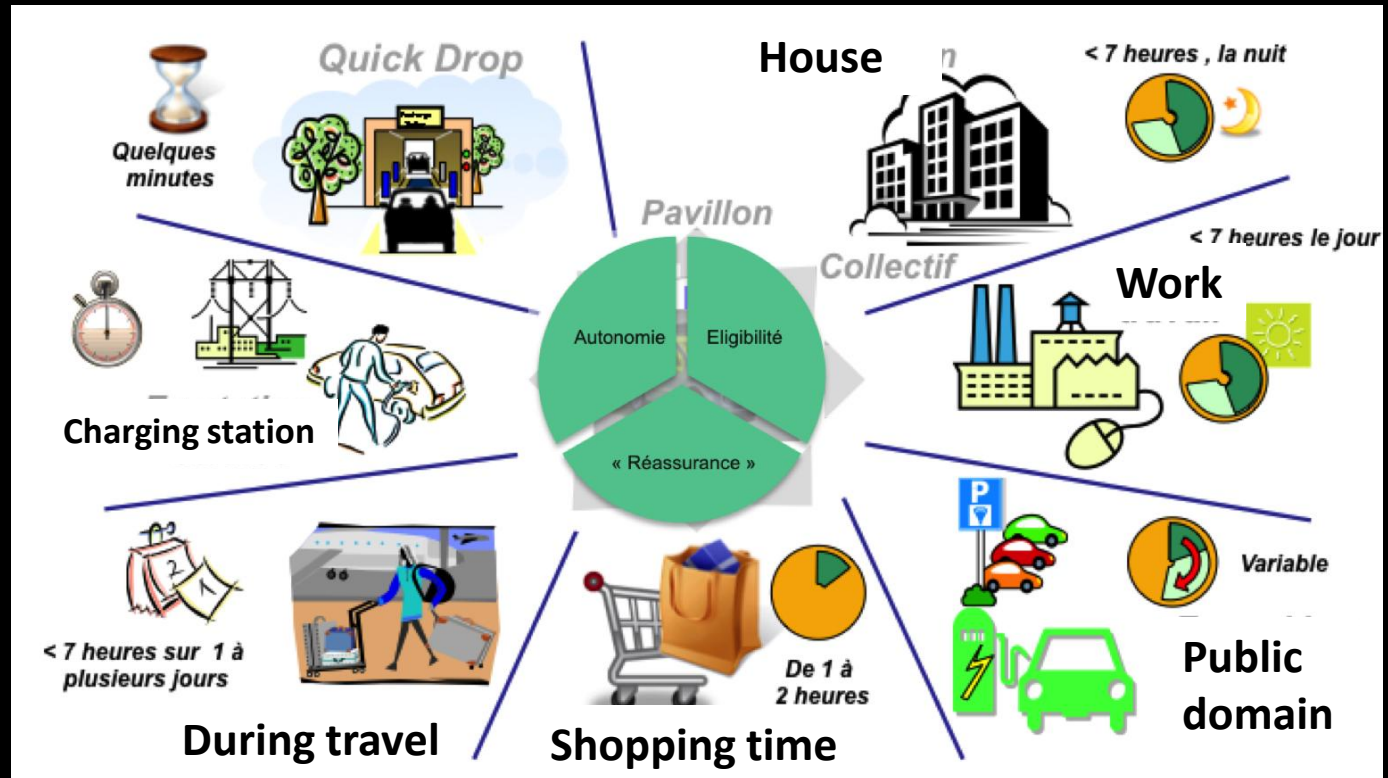
Where and when I can charge?

MAIS NON, PRUNELLE,
PAS D'ACCUMULATEURS,
JE L'AI SIMPLEMENT BRANCHÉE
SUR LA PRISE DE
MA SAUVE DE BAIN...

???



Minimum charging infrastructures allows to start equipment



7 logical options to charge but 95% of the charging is made at home
but a lot seems to be needed elsewhere to secure the EV buyer

Business models and Data to “explore” for infrastructure charging deployment

Place	Home	Work	Fast charge	Tesla Supercharger Charging stations	Ionity Charging stations
Characteristics					
Power	3-7 kW	3-22kW	22-50 kW	50-150 kW	350 kW
Time to charge	8-24h	1-3h	40 min 200km	30 min 400km	20 min 500 km
Usages	Commuting trips	Commuting trips	All usages	All usages	All usages
Investment cost per charger	200-500€	500-3k€	15k€-25k€	35-60k€	?
Cost of recharge	2-3€/100 km	4€	5 -7€	10-15€	50-80€

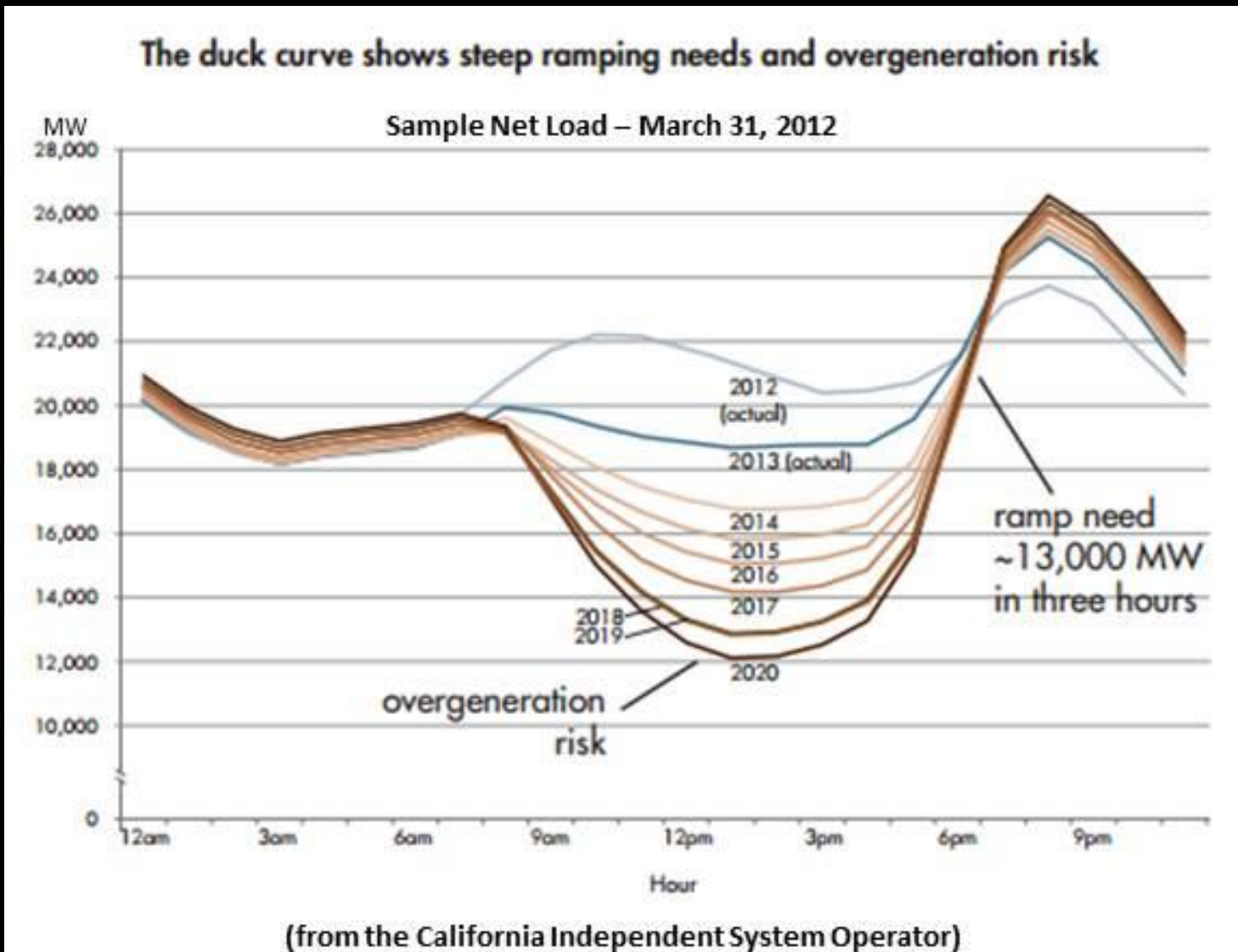
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Why is it promising for TSO?

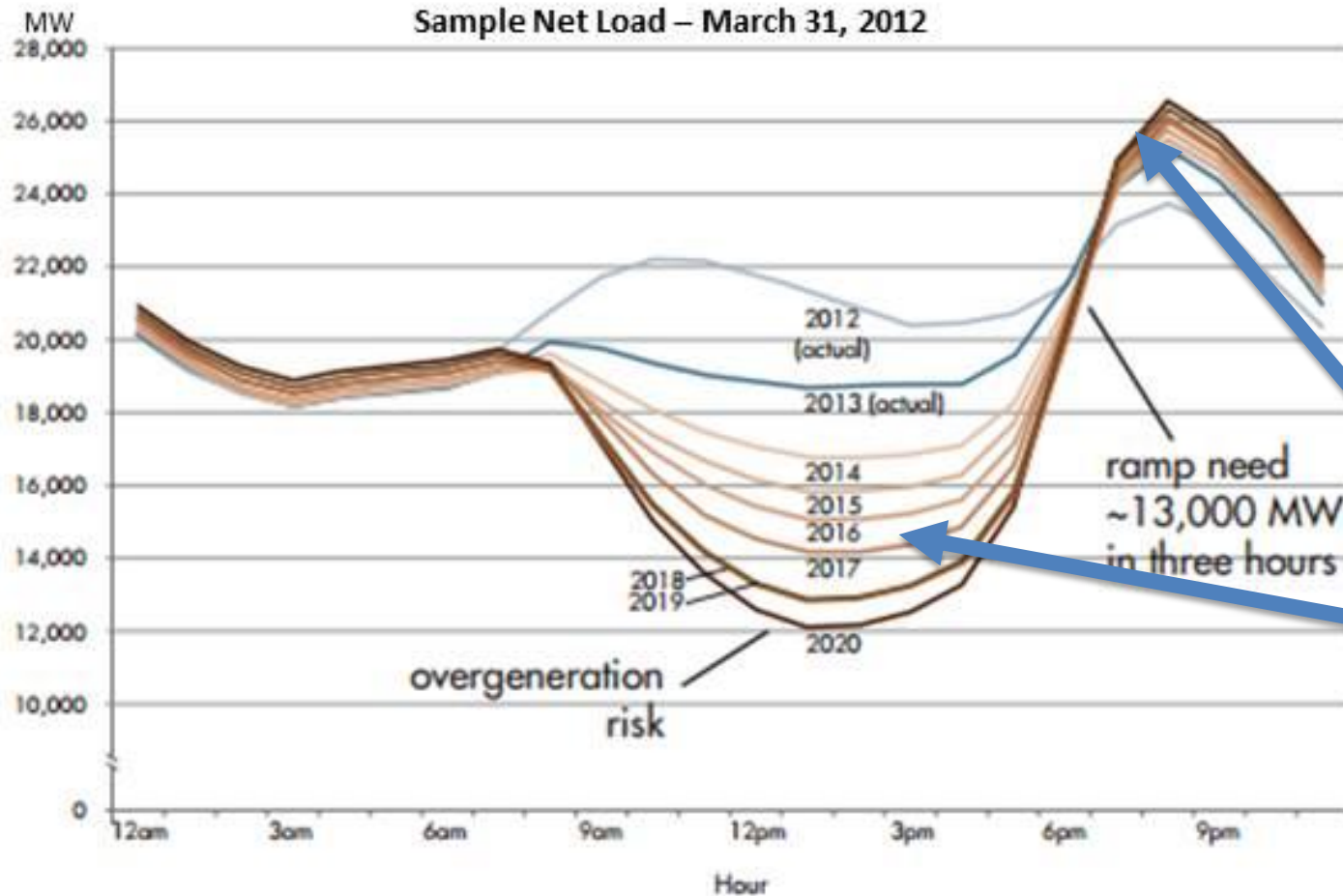


More PV => more Duck issues



EV killing duck curve?

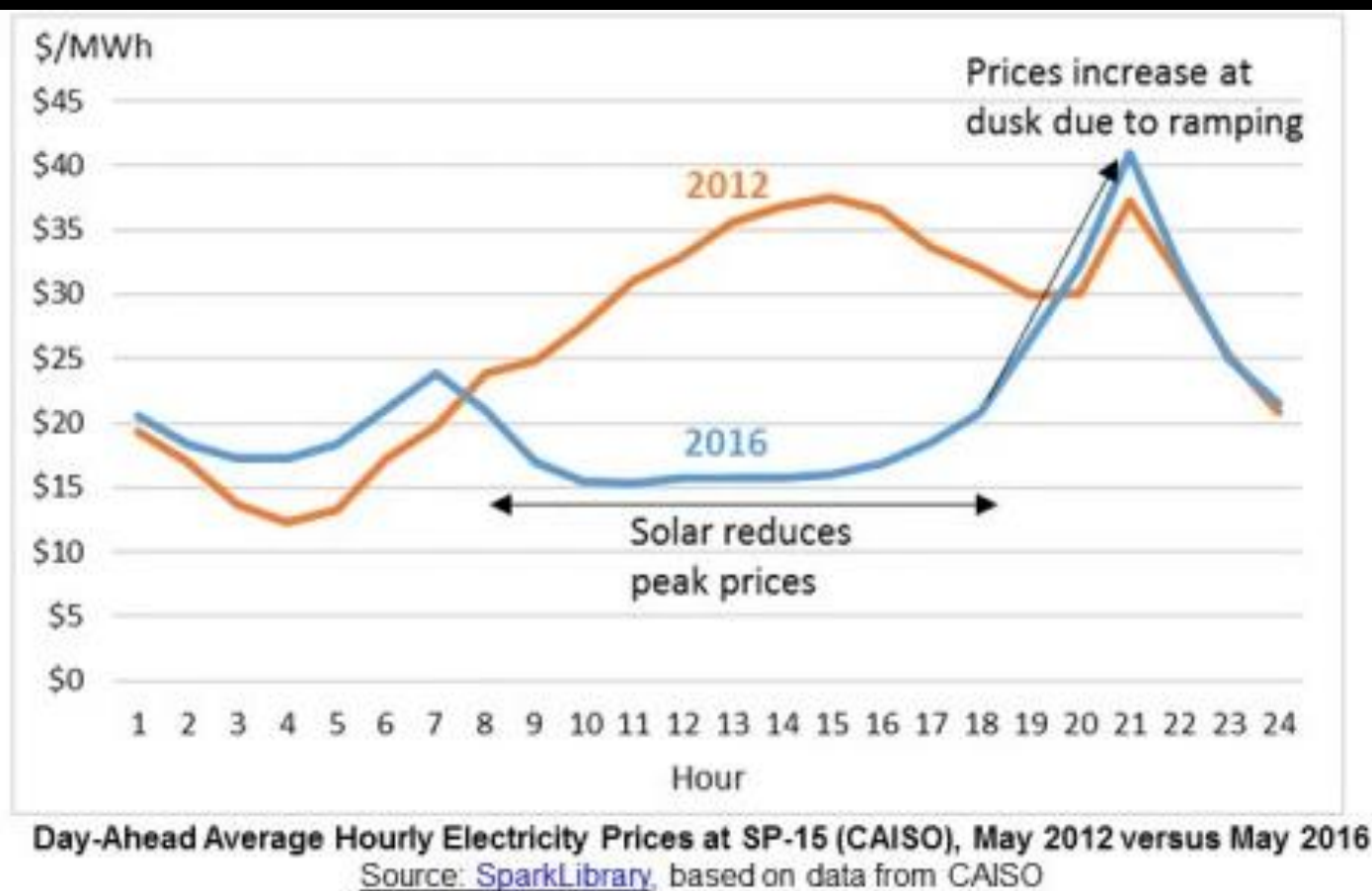
The duck curve shows steep ramping needs and overgeneration risk



(from the California Independent System Operator)



Revenue issue also...

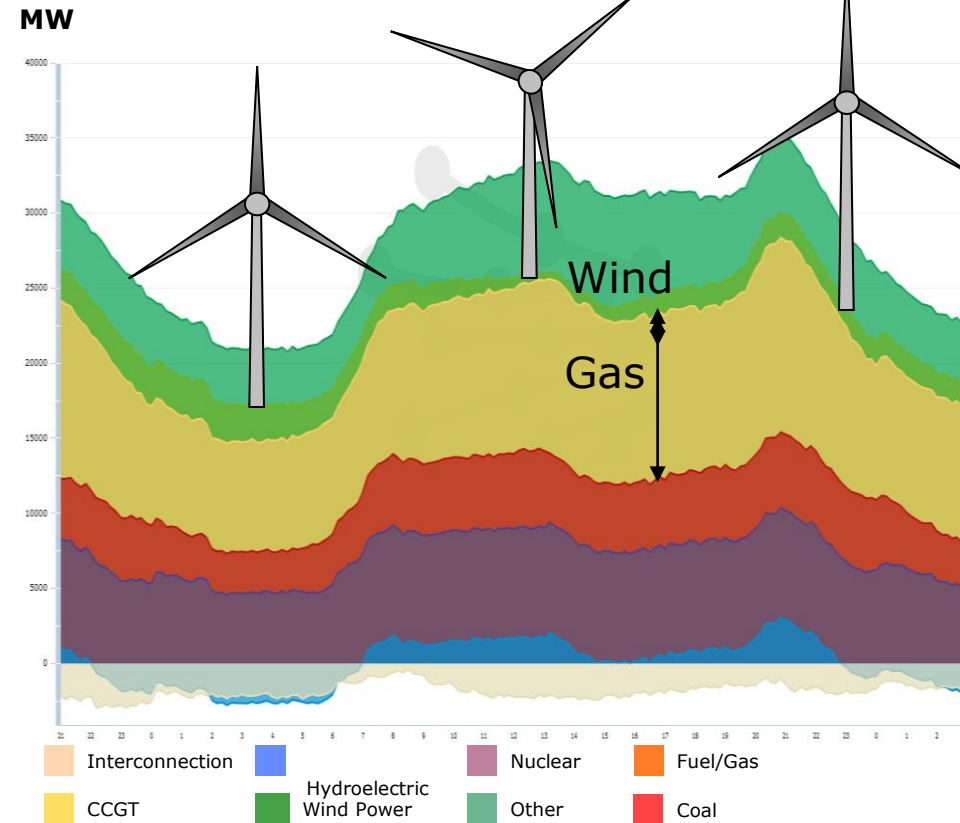


More wind => more flexibility required

The Spanish case

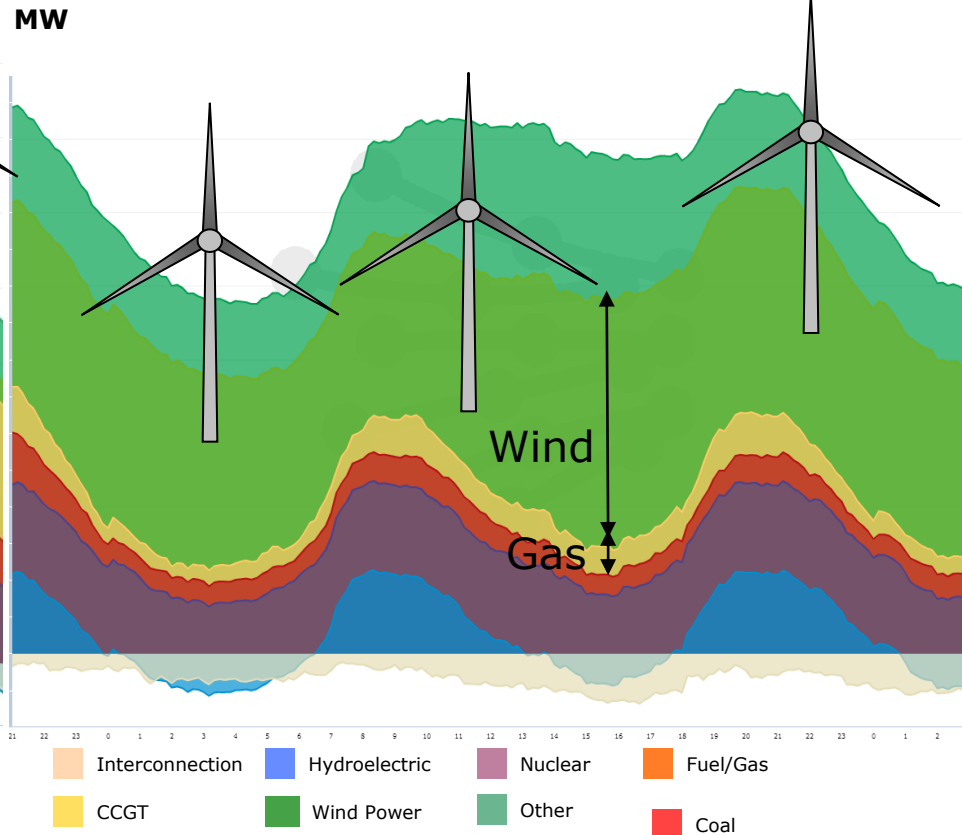
30-september-2010

Wind 1%
17:45h



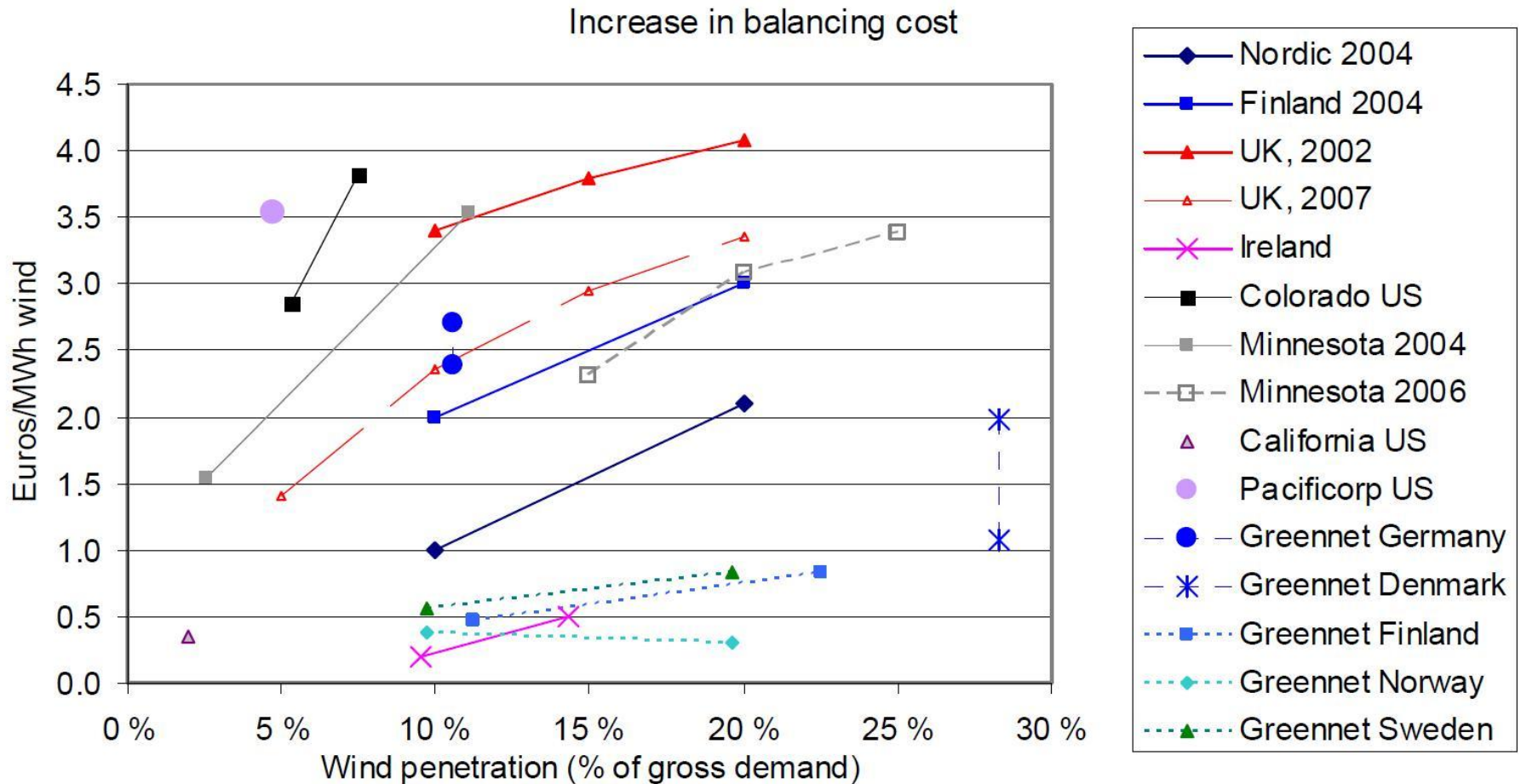
6-Februray-2013

Wind 66.5%
15:50h



Source REE, ENAGAS

More wind => more costly flexibility required



Problem... Rules are inadapted



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Barriers to entry in frequency-regulation services markets: Review of the status quo and options for improvements



Olivier Borne^{a,1}, Klaas Korte^b, Yannick Perez^{c,d,*,1}, Marc Petit^{a,1}, Alexandra Purkus^b

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^b Department of Economics, Helm holtz Centre for Environmental Research – UFZ, Permoserstr. 15, 04318 Leipzig, Germany

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Energy Policy 119 (2018) 140–148



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Market integration or bids granularity to enhance flexibility provision by batteries of electric vehicles



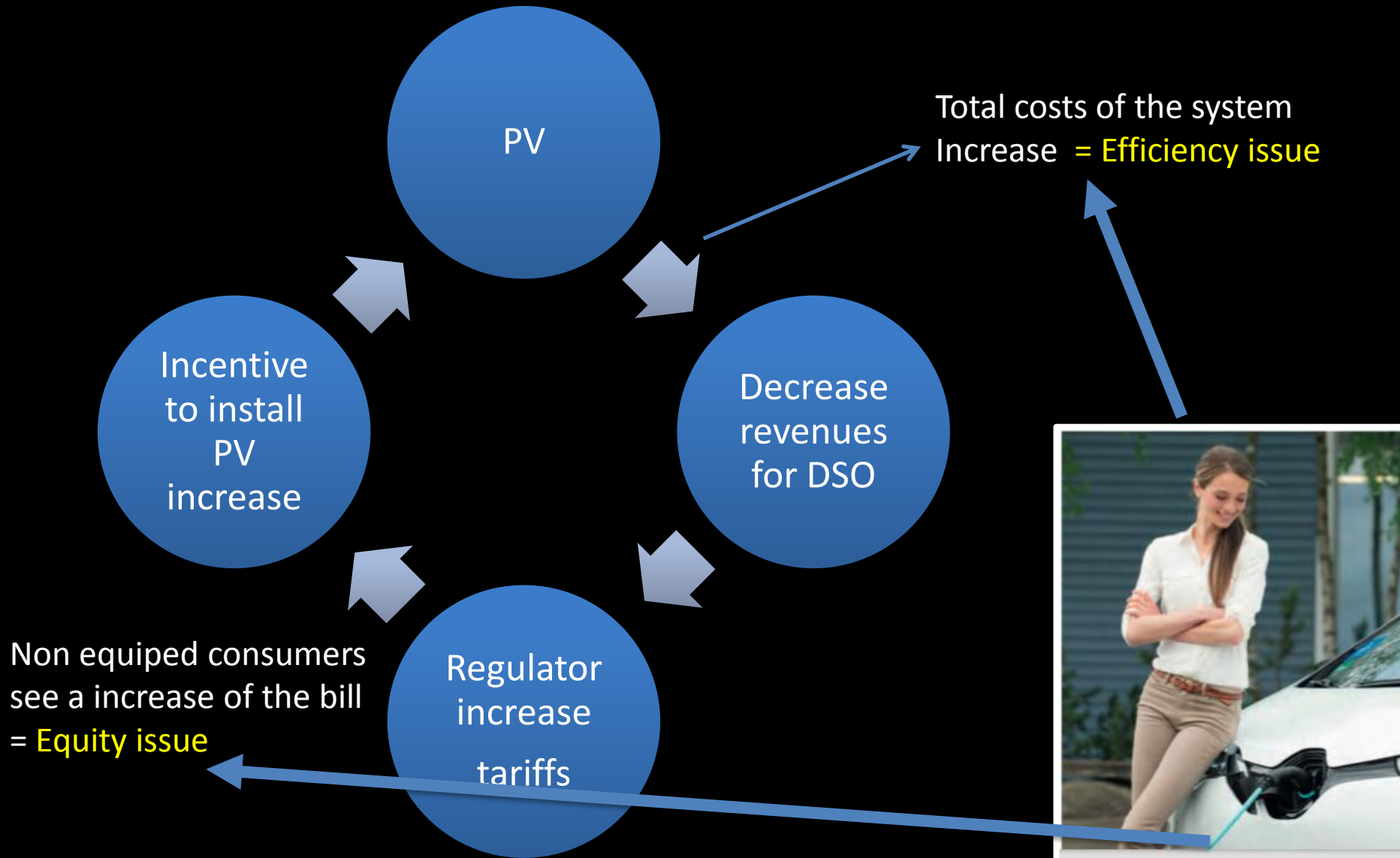
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^a GeePs, CNRS UMR 8507 CentraleSupélec, UPSud and UPMC, 91192 Gif-sur-Yvette, France

^b RITM Université Paris-Sud, and LGI, CentraleSupélec, 91192 Gif-sur-Yvette, France

Why is it promising for DSO?

EV solving « Death Spiral » for DSO revenues?



Network tariffs need to be
redesigned for
decentralised storage solutions

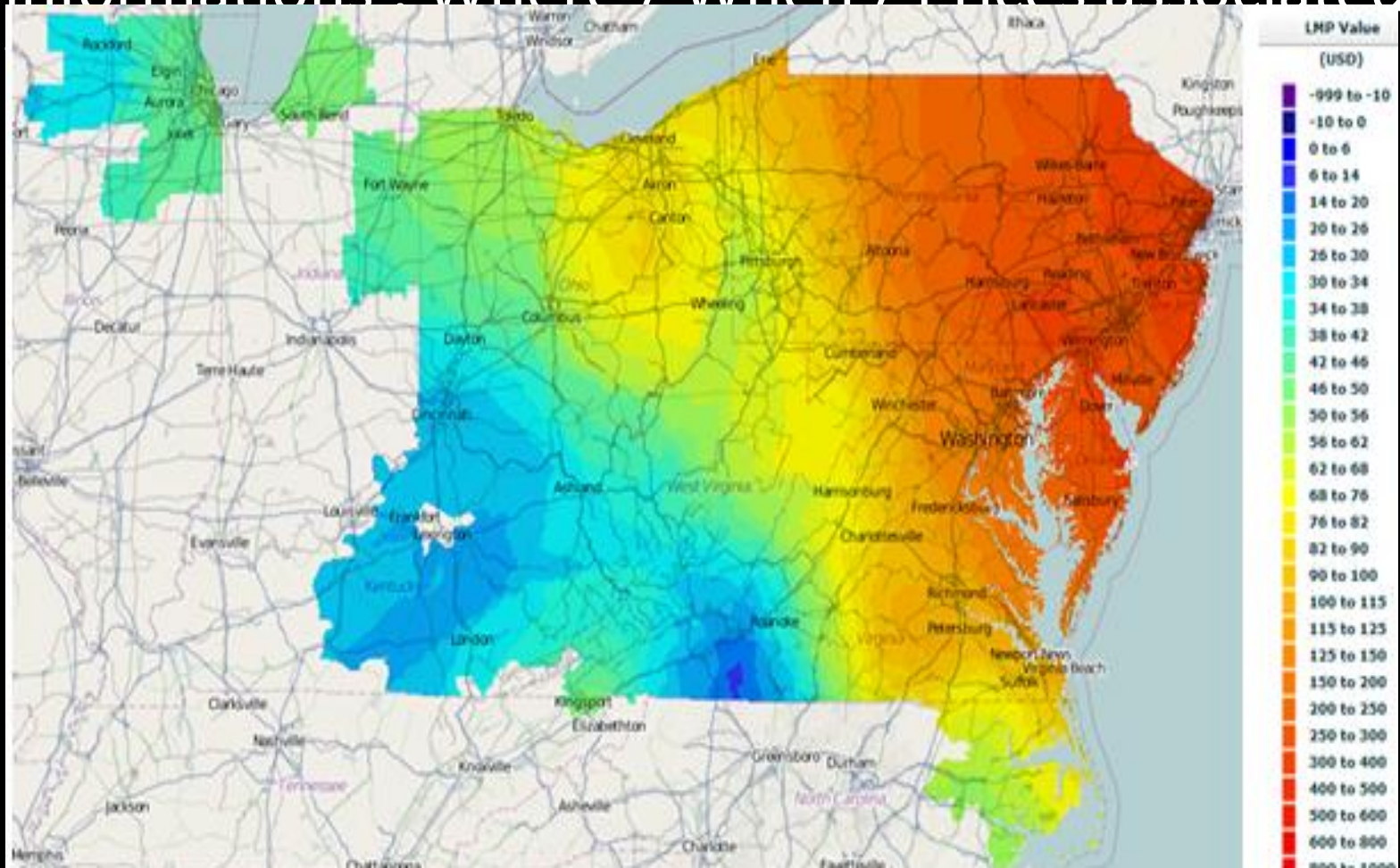
But how?

Decentralised – time consistent- market based – transparent - solution for charging-discharging

- Decentralized = price signals per node per time: 3 informations : Where / When / Prices associated for charging and discharging

Decentralised – time consistent- market based – transparent - solution for charging-discharging

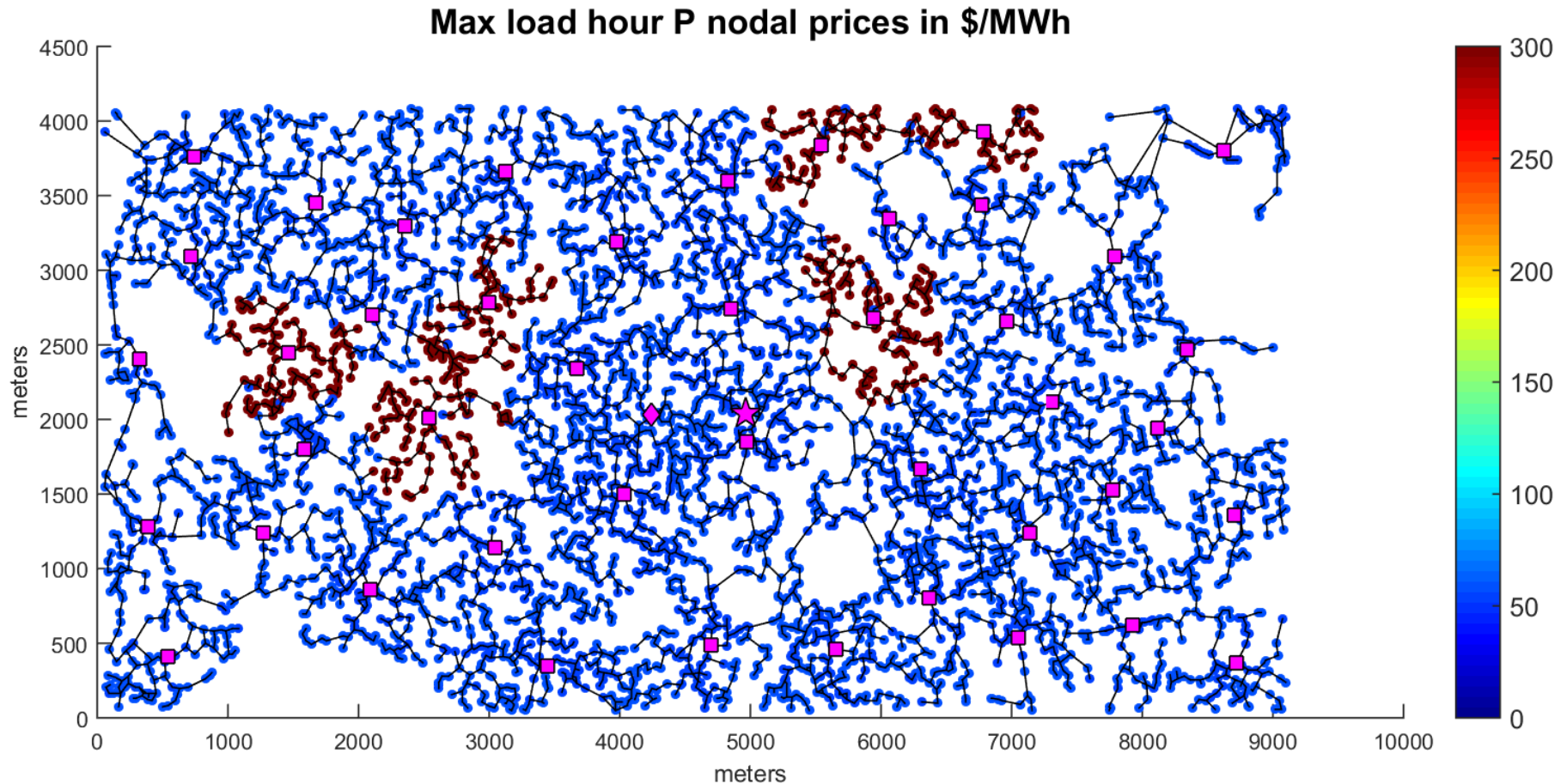
- Decentralized = price signals per node per time: 3 informations : Where / When / Prices associated



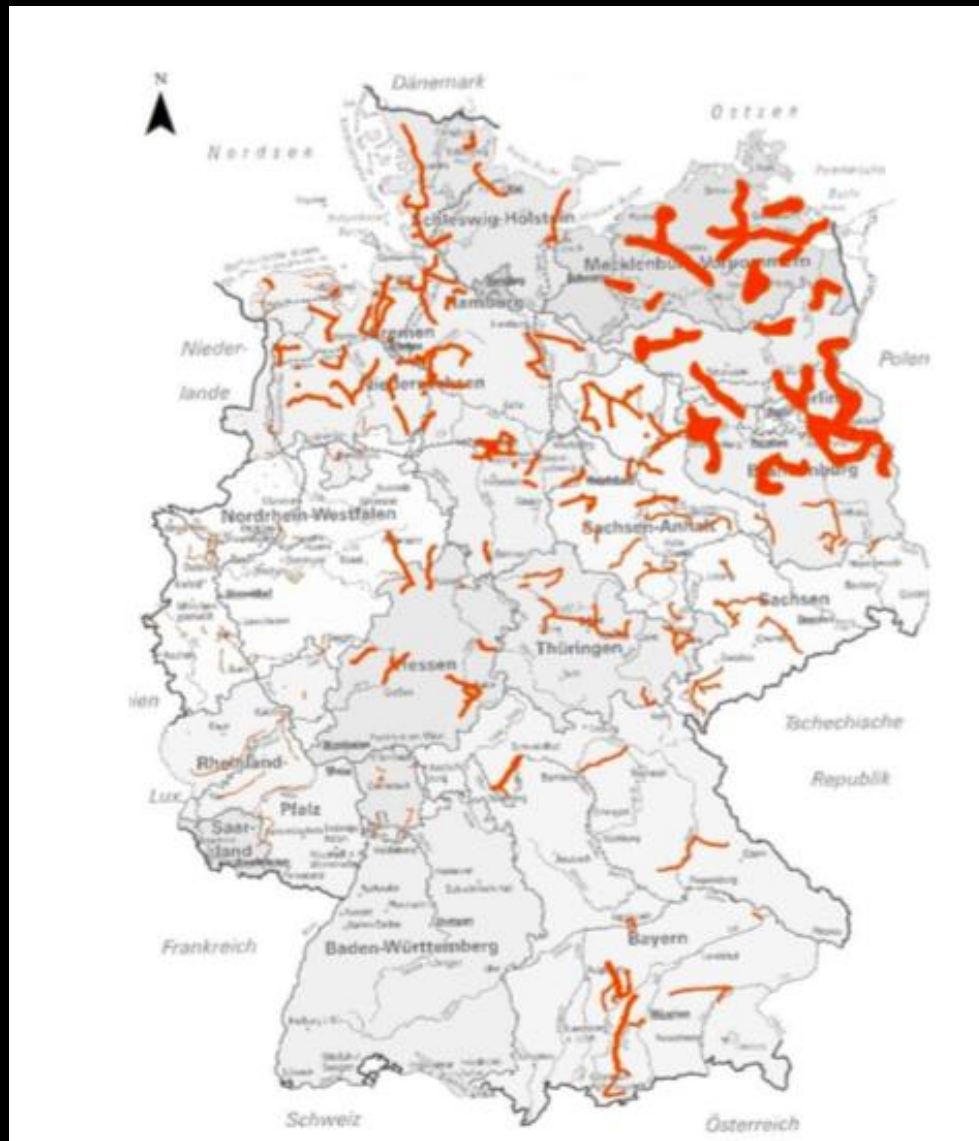
Decentralised – time consistent- market based – transparent solution for charging-discharging

- Decentralized = price signals per node :
 - 3 informations :
 - Where
 - When
 - Prices associated for
 - Charging
 - Discharging
 - Per services offered

Simulation results for PJM



German example of DSO's issues





MITe*i*
MIT Energy Initiative

UTILITY OF THE FUTURE

An MIT Energy Initiative response
to an industry in transition

In collaboration with IIT-Comillas



Outline of the presentation

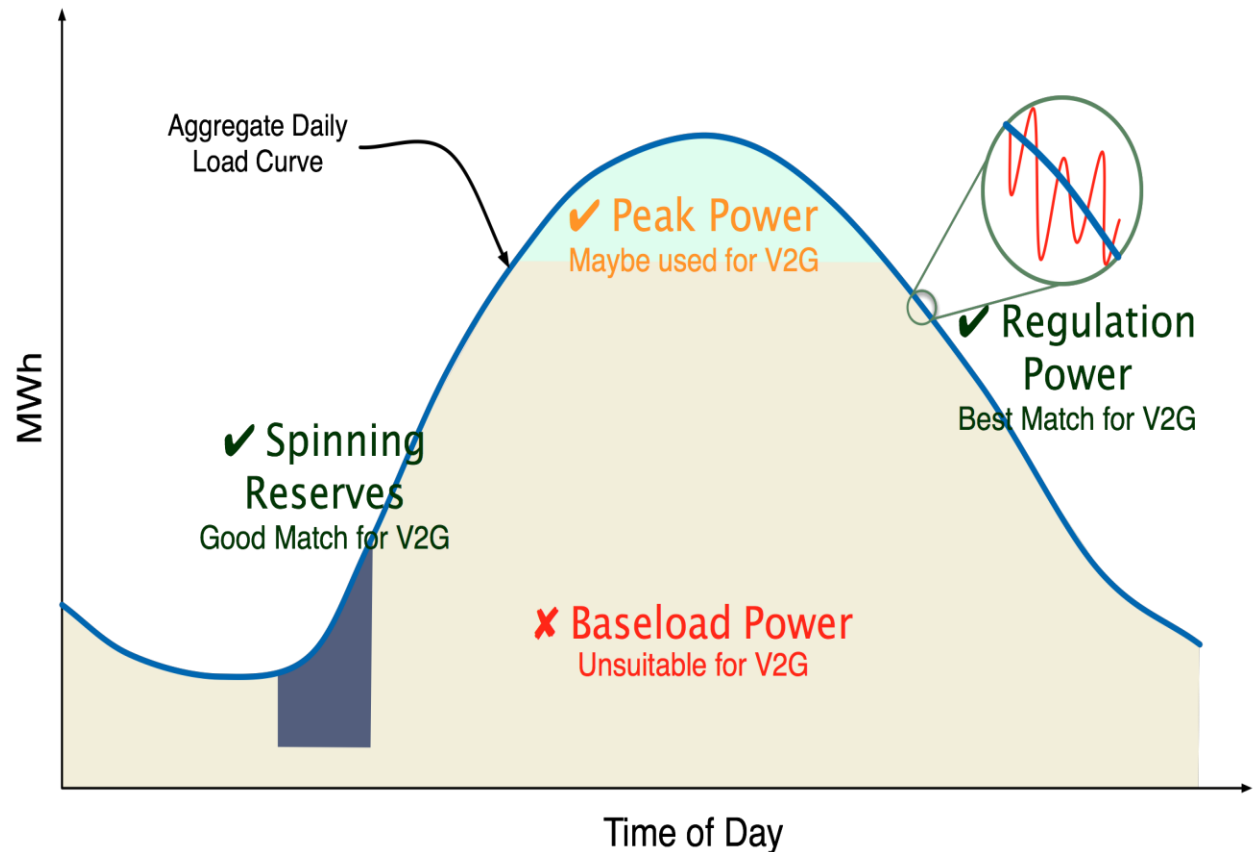
- Why Electromobility is starting?
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EV fleet for one Market or for Markets?

Which possible markets?

Profitable markets for EVs:

- little amount of energy, quick responsiveness
- remuneration based on availability and not utilization

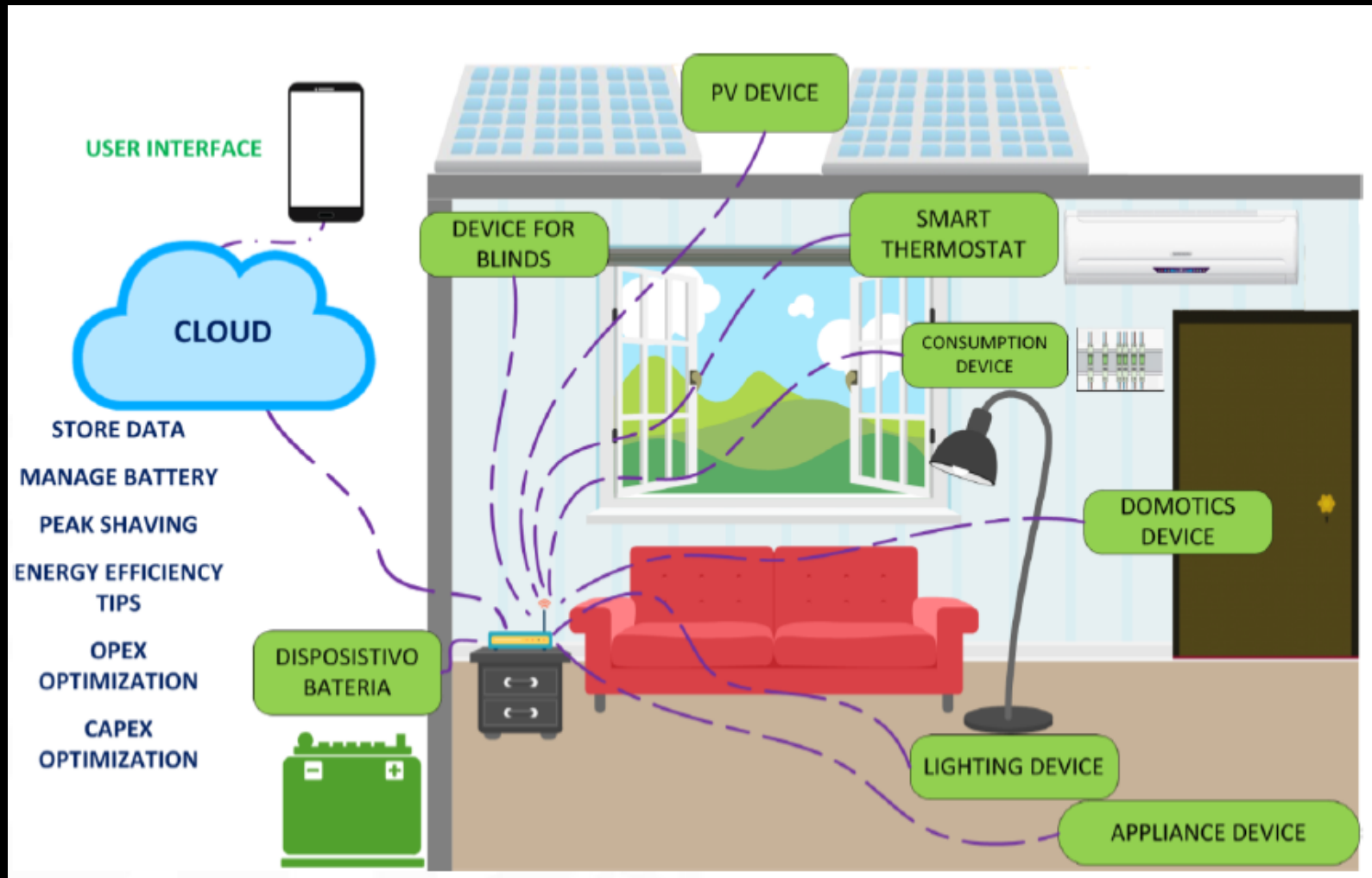


How to create “bundle of valuable flexible resources” for the energy markets => Aggregator

Times	MW or MWh	Services on market base if exist
Second	MW	<ul style="list-style-type: none"> - Frequency regulation - Voltage regulation - Quality of delivery
Hour	MW Or MWh	<ul style="list-style-type: none"> - Terciary reserve market - Demand respons - Balancing services - Congestion management - Intraday-market - Coupling With RES - ...
Block orders	MWh	<ul style="list-style-type: none"> - Day head market - Effacement - Time of Use - Coupling with RES - ...

For one client?

EVs reduce opex of Building / house by savings Connexion charge (W) and Consumption (Wh)



Empowering consumers

Off grid, cutting taxes, networks charges...

9OCT2012 press-released
27APR2012 sales-stared

1.5kW V2L
PowerBox

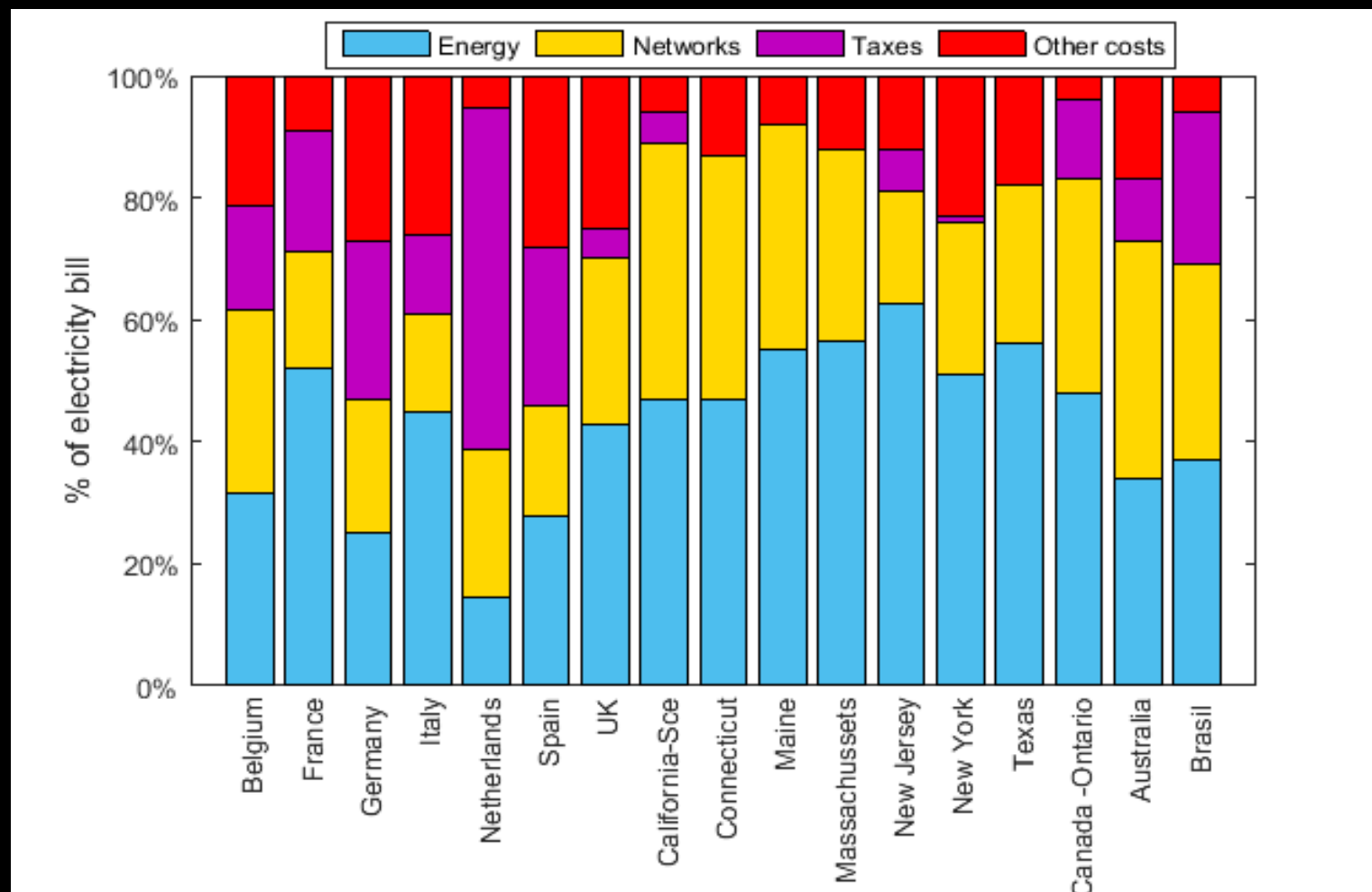


30MAY2012 press-released
**SEP2012 sales-stared

6kW V2H
EV power station



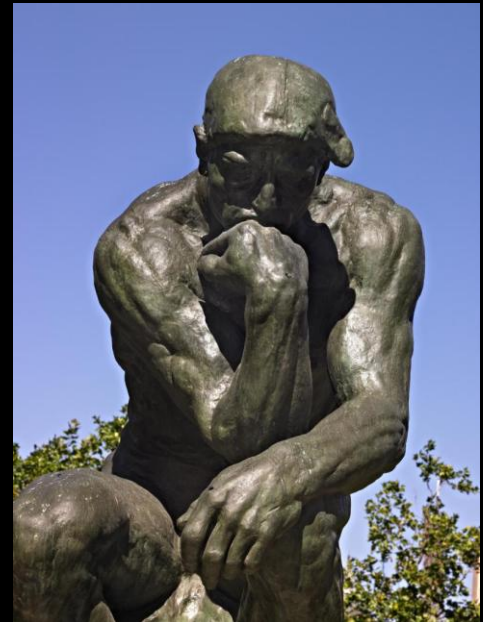
Energy-Networks-taxes-other “costs” => looking for savings with “Behind the meter solutions”



Breakdown of residential electricity bills in different jurisdictions in 2014-2015

Conclusions

Who EVs are going to help?



Energy Markets / grids / Behind the meter
uses?

Depends on Market design decisions...

1. Energy market for EV: Need to change the rules
 2. Vehicle to Transmission grid : Need to change the rules
 3. Vehicle to Distribution grid : Need to change the rules
-
1. Vehicle to buildings = VtoB : Out of regulators scope
 2. Vehicle to Home = VtoH : Out of regulators scope
 3. Vehicle to Load = VtoL: Out of regulators scope

Selected Literature

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- Hoarau Quentin and Perez Yannick, 2018, *Interactions Between Electric Mobility And Photovoltaic Generation: A Review*, **RSER** 94 (2018) 510–522.
- Rodríguez Brito Maria Gracia, Ramírez-Díaz Alfredo Jesús, Ramos-Real Francisco J., Perez Yannick, 2018, *Psychosocial traits characterizing EV adopters' profiles: The case of Tenerife (Canary Islands)*, **Sustainability** 2018, 10, 2053.
- Borne Olivier, Yannick Perez and Marc Petit 2018, *Market integration or bids granularity to enhance flexibility provision by batteries of Electric Vehicles*, **Energy Policy**, Volume 119, August 2018, Pages 140–148.
- Borne Olivier, Korte Klaas, Perez Yannick, Petit Marc and Purkus Alexandra 2018, *Barriers to entry in Frequency-Regulation Services Markets: Review of the status quo and options for improvements*, **RSER**. Volume 81, Part 1, January 2018, Pages 605–614.
- Codani Paul, Perez Yannick and Petit Marc 2016, *Financial Shortfall for Electric Vehicles: economic impacts of Transmission System Operators market designs*, **Energy**, Volume 113, pp 422-431.
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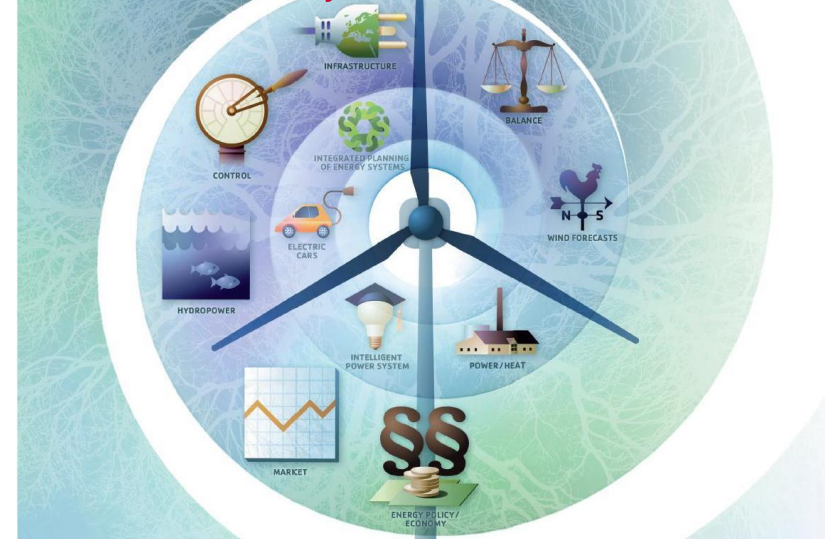
Case Studies

Frequency Regulation market revenue

Revenue from grid services for EV

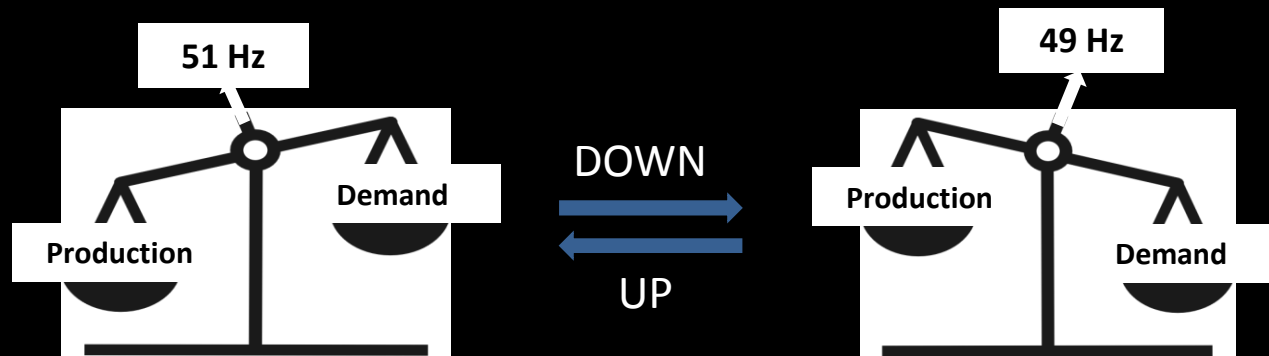


Pilot project for emerging technologies in the ancillary services markets



EV as frequency control resources

- Why do we need a steady frequency?
 - material performances
 - risk of saturation for devices with magnetic circuits
- Who is responsible?
 - TSOs
- How?
 - Balancing production and demand at each moment



In other countries, values are function of market design-fleet characteristics and charging points capacities

Sources	Analyzed region	Participated market	Net Profit €/Month/Vehicle	Regulation power	Battery/ Vehicle constraints
Kempton and Tomic 2005	USA	Regulation up and down	112-165	10-15 kW	Electric drive vehicles
Tomic and Kempton 2007	USA, Four different control areas	Regulation down (Th!nk City) Regulation down and up (Toyota RAV4)	4.3 – 43 (Th!nk City) 6 – 64 (Toyota RAV4)	6.6 kW	100 Th!nk City vehicles (Nid) ,252 Toyota RAV4 (NiMH)
Larsen et.al. 2008	Denmark	Secondary and Tertiary control	6 – 160	power: 2 kW, 20 kW, 20 kW	EDV: Capacity: 5 kWh, 5 kWh, 20 kWh,
Camus et.al. 2009	Portugal	Secondary and Tertiary control	18	3.5 kW	Plug-in Hybrid and electric vehicles
Andresson et.al. 2010	Sweden/ Germany	Control energy market	30 – 80 (Germany, coal fired power plants) 19 ; 7 (Sweden, Hydro power plants)	3.5 kW	Plug-in hybrid EV (10 kWh , Maximum depth of discharge 20 %) Charging and discharging efficiency are 94 %.
V2G-Strategies 2011	Austria	Secondary and Tertiary control	7.32 – 63.94	10.5	Electric Vehicles (16 kWh, 24 kWh, 48 kWh)

Frequency remunerations for EV : PJM real case / France exploration

**1500 €/ year and per car
in PJM Zone
for only « frequency
regulation market base
Provision »**

Charging point capacity (kW)		Revenus /VE/ year
Primary	Secondary	
3	0	179,4 €
3	3	310,7 €
3	7	505,7 €
3	22	1346,8 €
7	0	474,5 €
7	3	543,4 €
7	7	780 €
7	22	1448,2 €

Sources: Codani, Petit & Perez 2016

Flexibility provision with EV fleets

- **Not perfectly done yet...**
 - VtoG experiment around the world (US / Denmark...)
 - Majors success with regulation power : mainly frequency control.
- **Expected benefits from coordination :**
 - Costs savings / resources provision
 - Capacity reduction need (Less peak demand investment)
 - RES coupling: less grid stress
 - Demand response resources
- **Main problems to overcome**
 - Rules and Market regulation to adapt for EV Fleets
 - Communication standards (15118 / CHAdeMO...) to clarify
- **Coordination via hybrids are probably part of the solution (spin-offs...)**

Does it worth the cost?

To be added on the « benefit » of ownership

Including the

1. added costs of measurement
2. aggregation services cost
3. Marginal Battery degradation cost