

Electromobility: Taking stock Looking head

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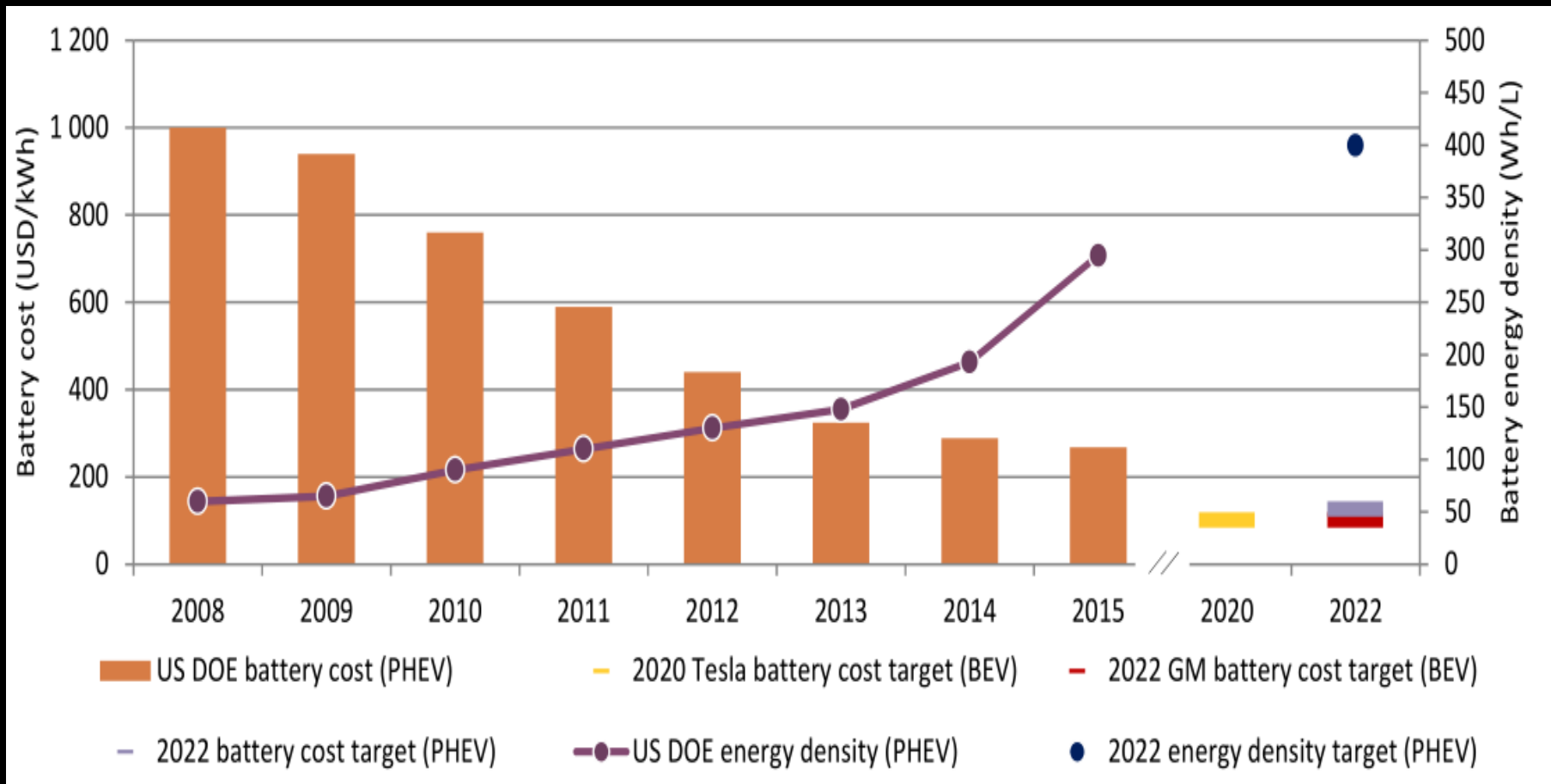
Motivations (1)

- 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

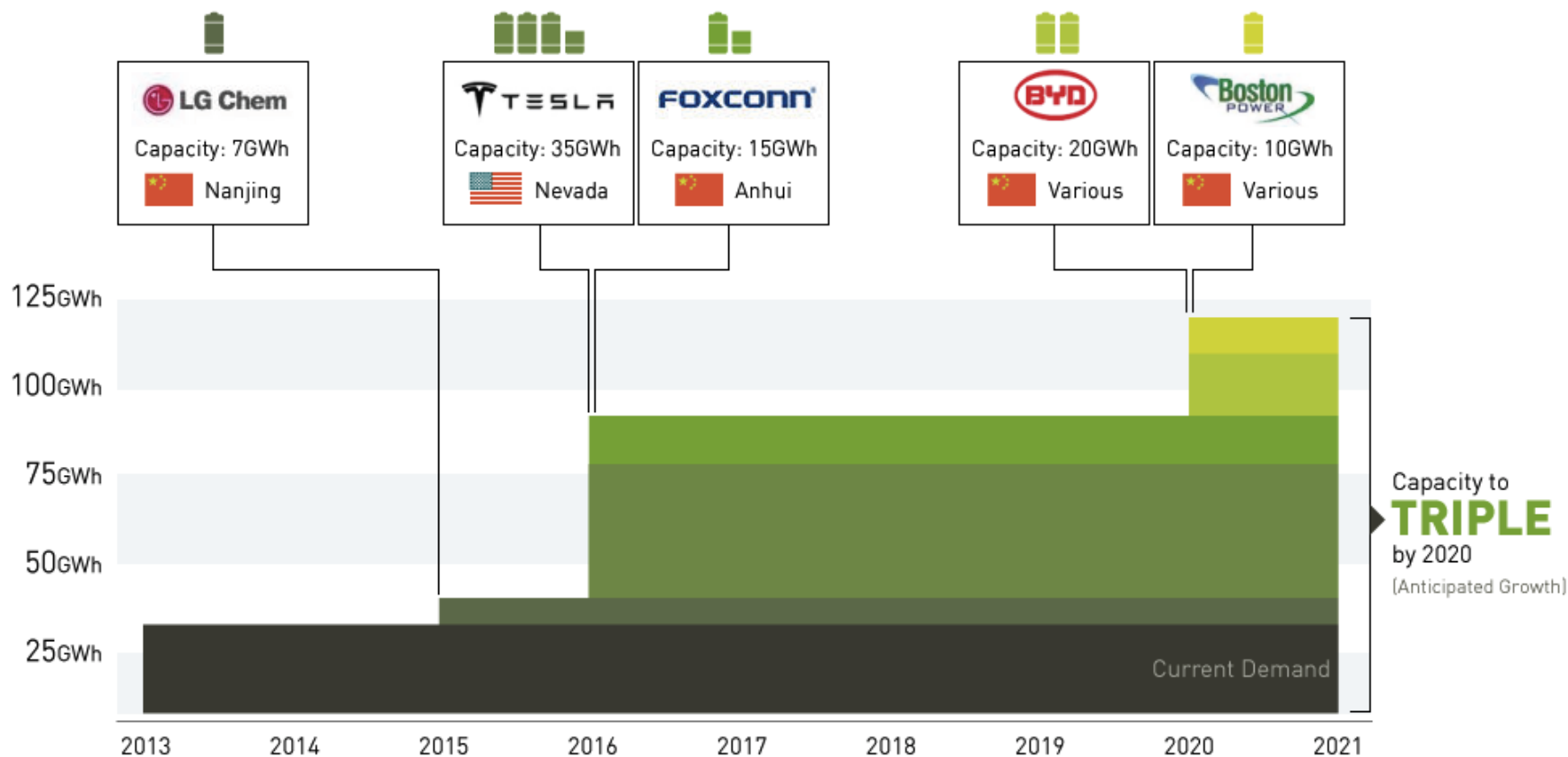
Motivation (3) Evs enjoy a Double dynamic: Increase in ENERGY DENSITY & decrease of COST



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



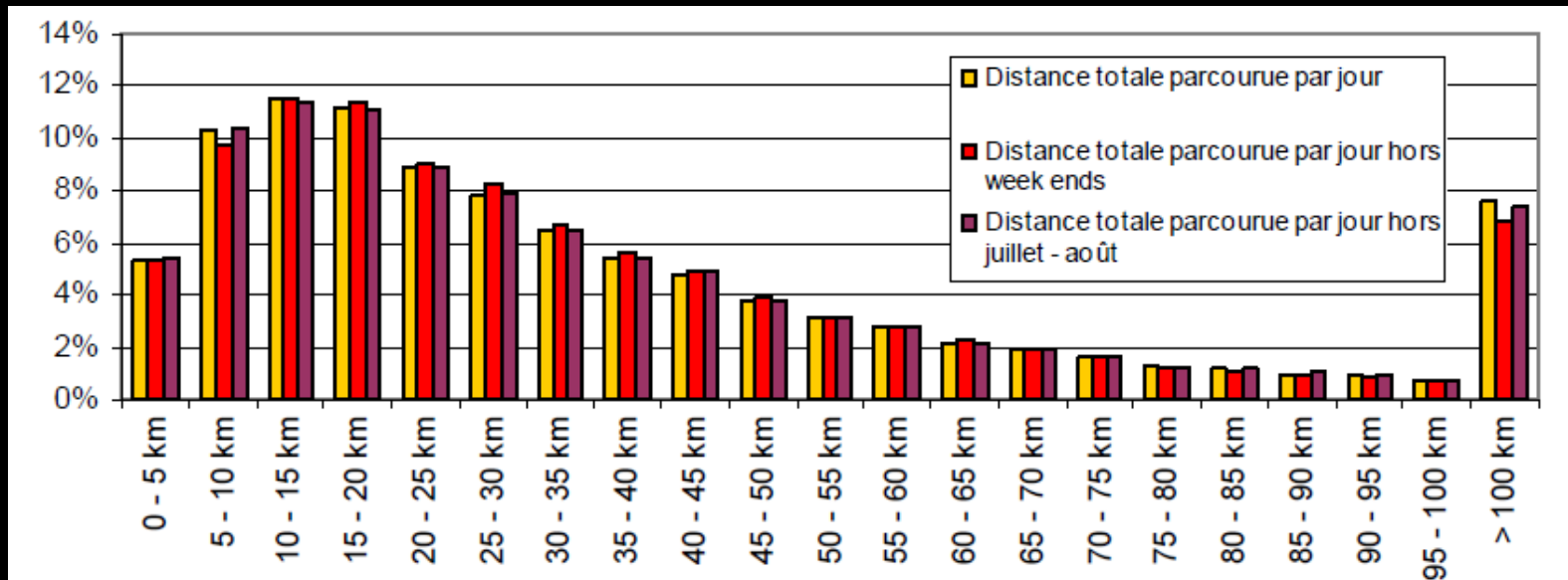
*Benchmark estimates, not all data disclosed by companies **Instant planned capacity stated for graphical purposes, slower ramp up expected

Data by:



Motivations (4)

Distribution of the Thermal car uses per day in France

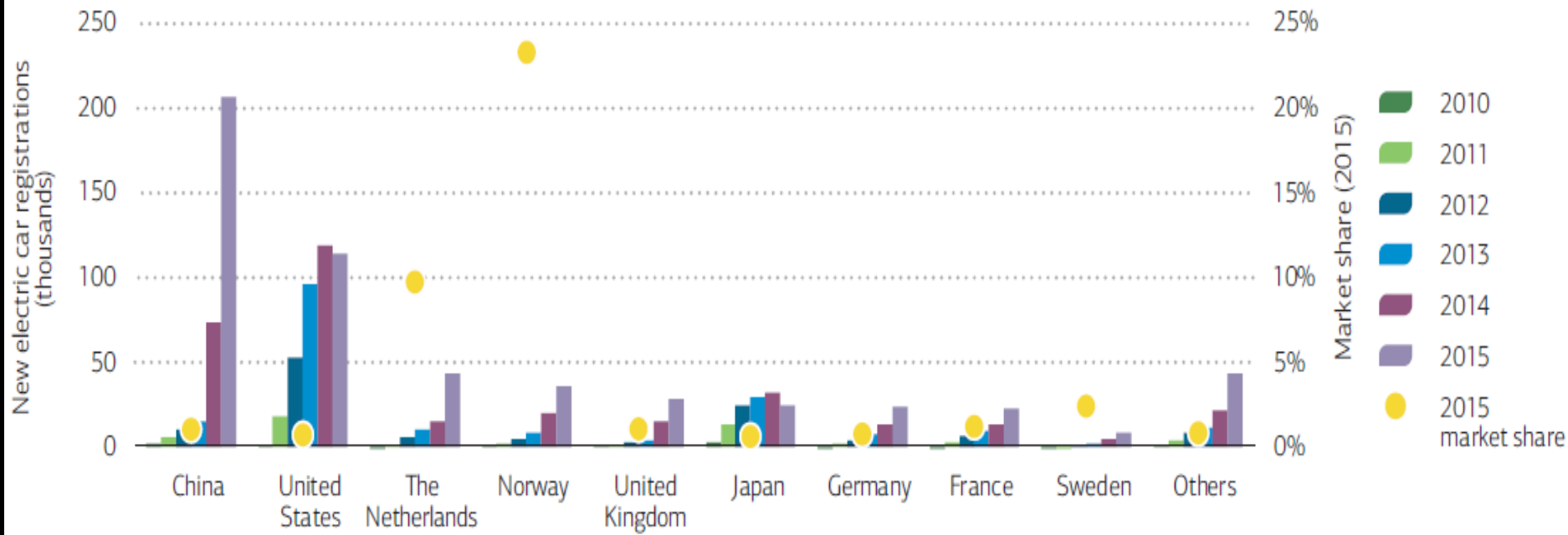


80% trips < 60km → Mean = 12 km → 24 km/Day

Motivation (5)

The year 2015 saw the global threshold of 1 million electric cars¹ on the road exceeded, closing at 1.26 million. In 2014, only about half of today's electric car stock existed. In 2005, electric cars were still measured in hundreds. 2015 also saw more than 200 million electric two wheelers on the road, and 170 000 buses, primarily in China.

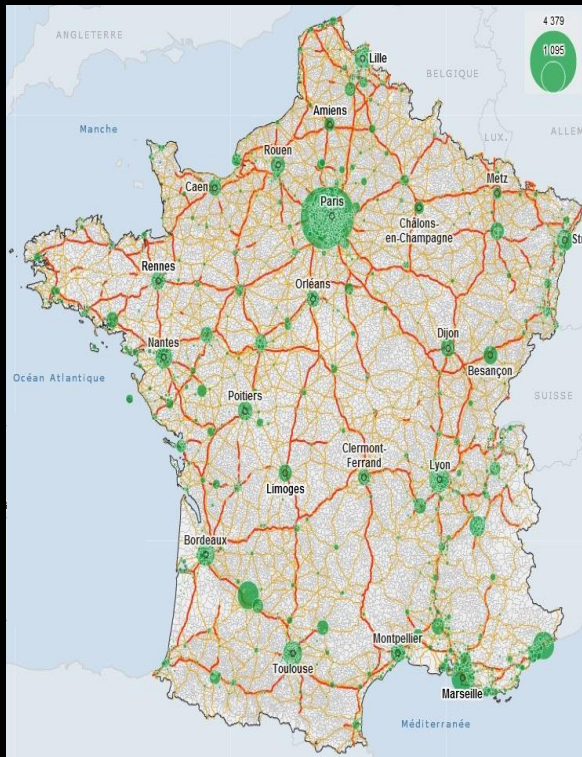
EV sales and market share in a selection of countries and regions, 2015



Key point: The two main electric car markets are China and the United States. Seven countries have reached over 1% EV market share in 2015 (Norway, the Netherlands, Sweden, Denmark, France, China and the United Kingdom).

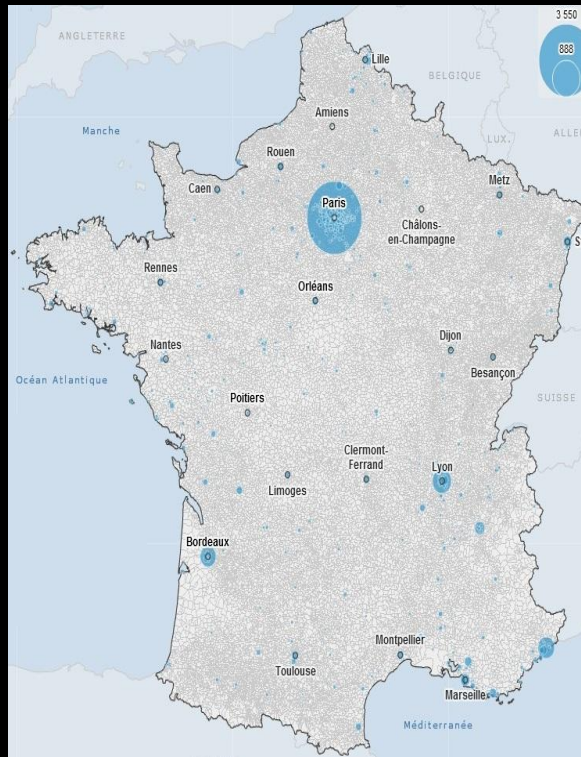
Current deployment in continental France (June 2016)

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



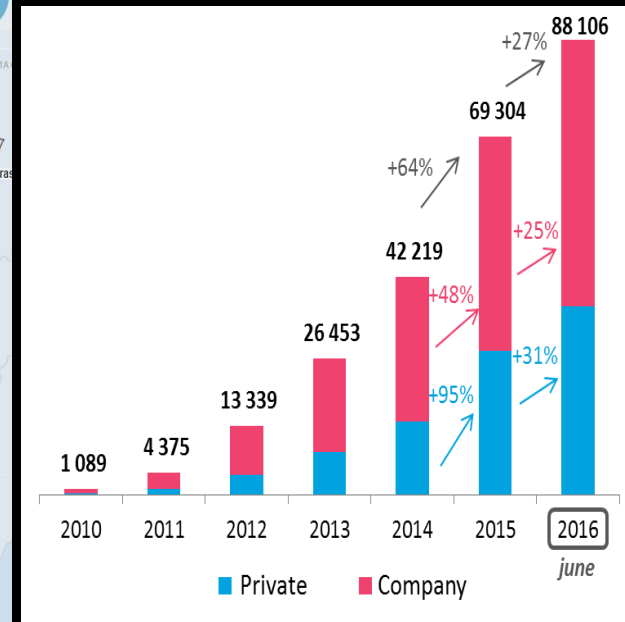
Almost 90 000 vehicles registered in more than 13 000 towns (85% are EV)

- Number of public charging points installed



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

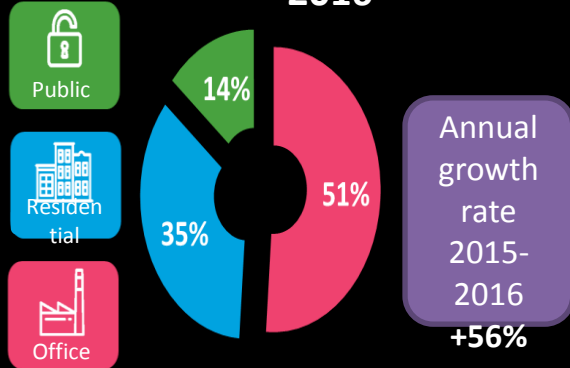
- EV and PHEV: only 0,2% of the total French car fleet... but a sharp growth since 2010



Increase of private owners higher than companies

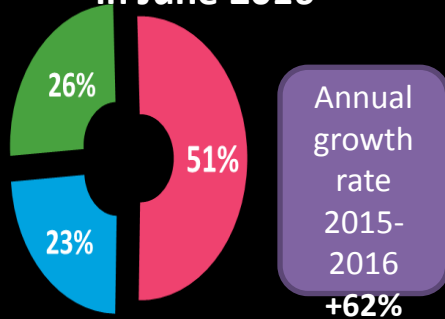
The Energy Transition Law sets an ambitious target of 7 million charging points by 2030, and 1 million by 2020

104 626 charging points in June 2016

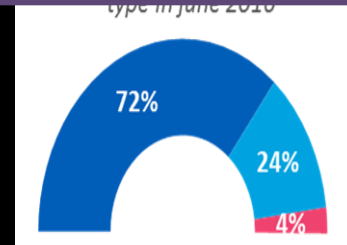


Installed capacity is growing faster than the number of charging points due to the development of quick public charging points

625 MVA of installed capacity in June 2016

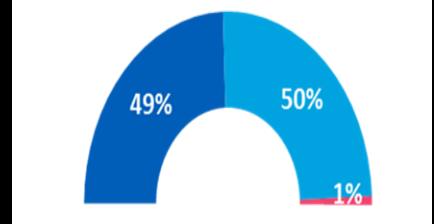


14 509 public points in June 2016



■ Normal charging (up to 7,4 kW)
 ■ Quick charging (22 kW)
 ■ Fast charging (43 kW and more)

55 000 public points in 2020



- 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

THE WASHINGTON POST

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

© 10/10/2016 à 12h51



g Point in

David van der Mark/Flickr

TRENDING



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

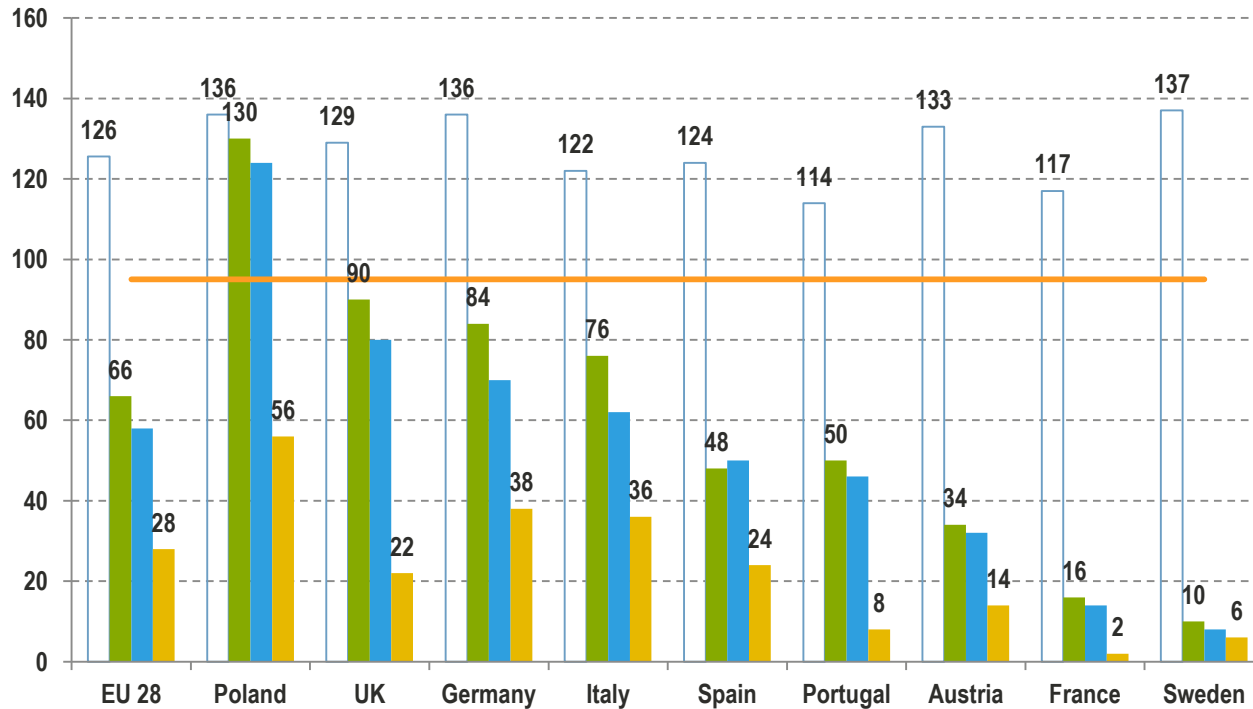
Sales				
Scenario	Powertrain	2020	2025	2030
BIPE Green Constraint	BEV	1 351 434	2 270 912	3 401 518
Bloomberg	BEV	936 455	3 745 819	13 110 368
BIPE Green Constraint	PHEV	1 265 130	4 171 103	8 457 032
Bloomberg	PHEV	1 404 682	4 214 047	7 959 866

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



□ Average of CO₂ of new cars

■ Average of CO₂ EVs (2015)

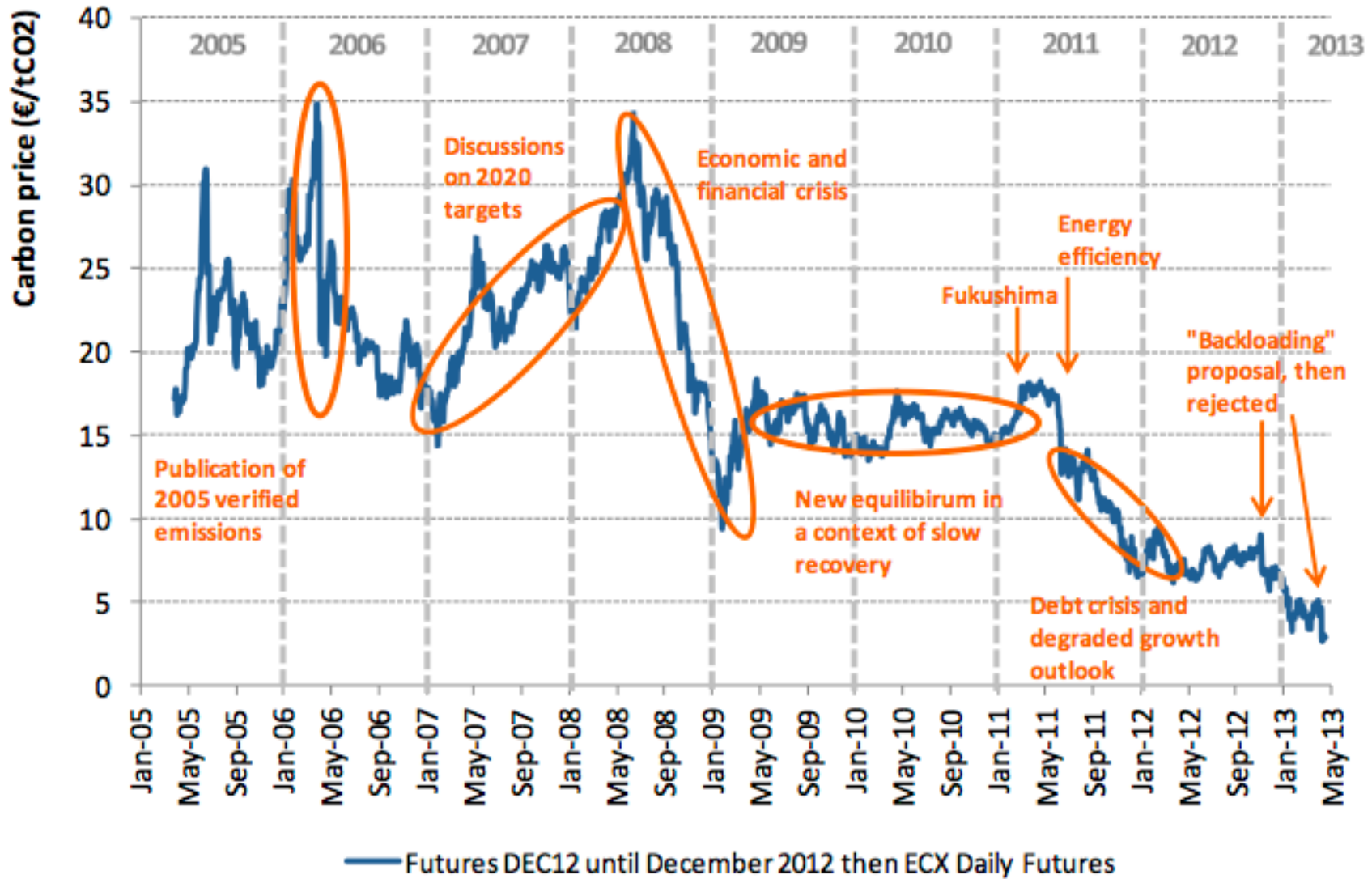
— 2021 Goal 95 gr

■ Average of CO₂ EVs (2010)

■ Average of CO₂ EVs (2035)Ref Scenario 2013

- 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...

What are the actual solutions and the ways forward?

–By Public Policy action

- National base policy
- Local base policy

–By innovations

- Companies driven innovations
- By new research project to value storage flexibility in energy markets

Disclaimer

Only successful 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'AJER

COLONNE DE CHARGE
POUR AUTOMOBILE ELECTRIQUE

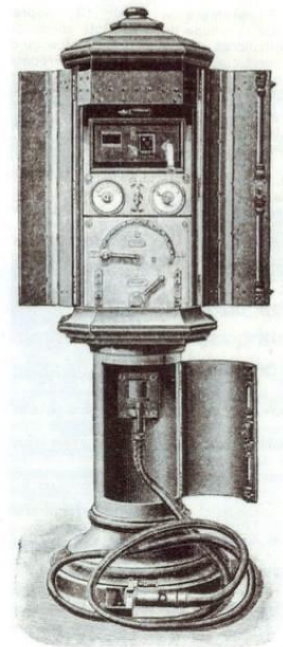
Une voiture se présentant pour charger ses accumulateurs, le préposé ouvre les deux portes du coffret, sort la garniture et la branche sur la voiture (l'autre extrémité restant habituellement branchée sur la partie du fût), met un jeton dans le compteur, ferme les coupe-circuits intérieurs du compteur, 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



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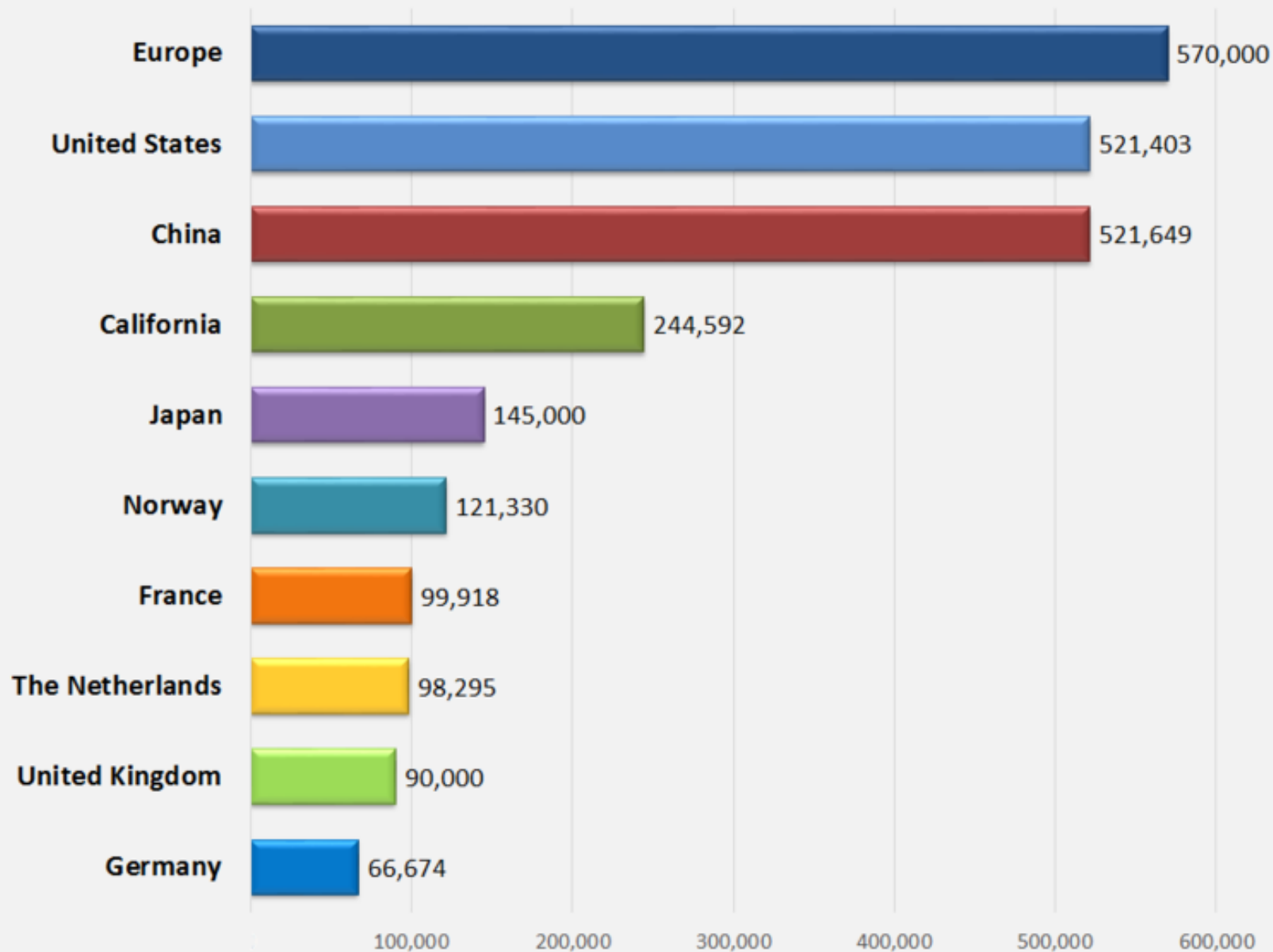
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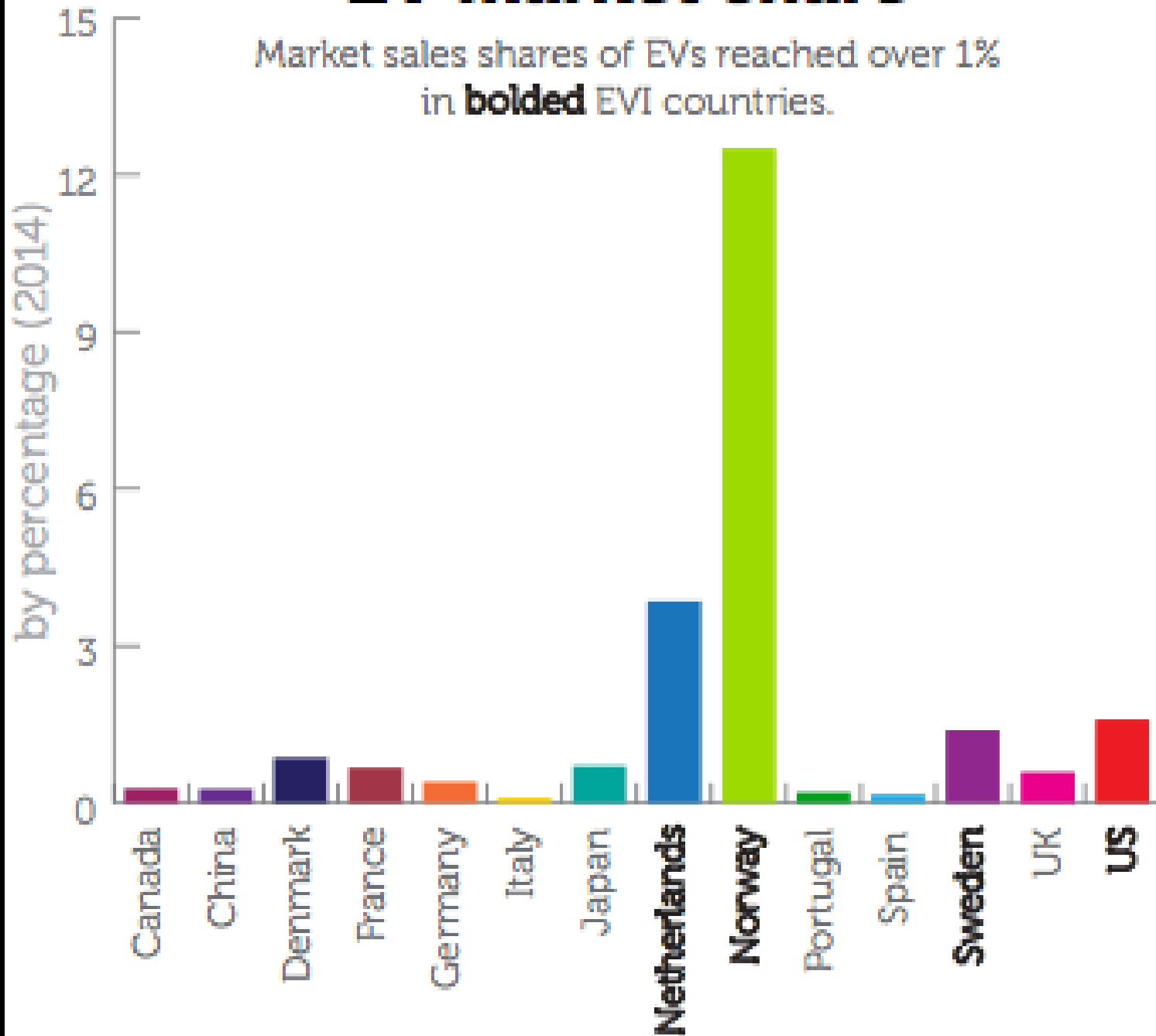
- Companies driven innovations
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Top-selling light-duty plug-in electric vehicle global markets (cumulative sales through September 2016 by country/region)



EV market share

Market sales shares of EVs reached over 1%
in **bolded** EVI countries.

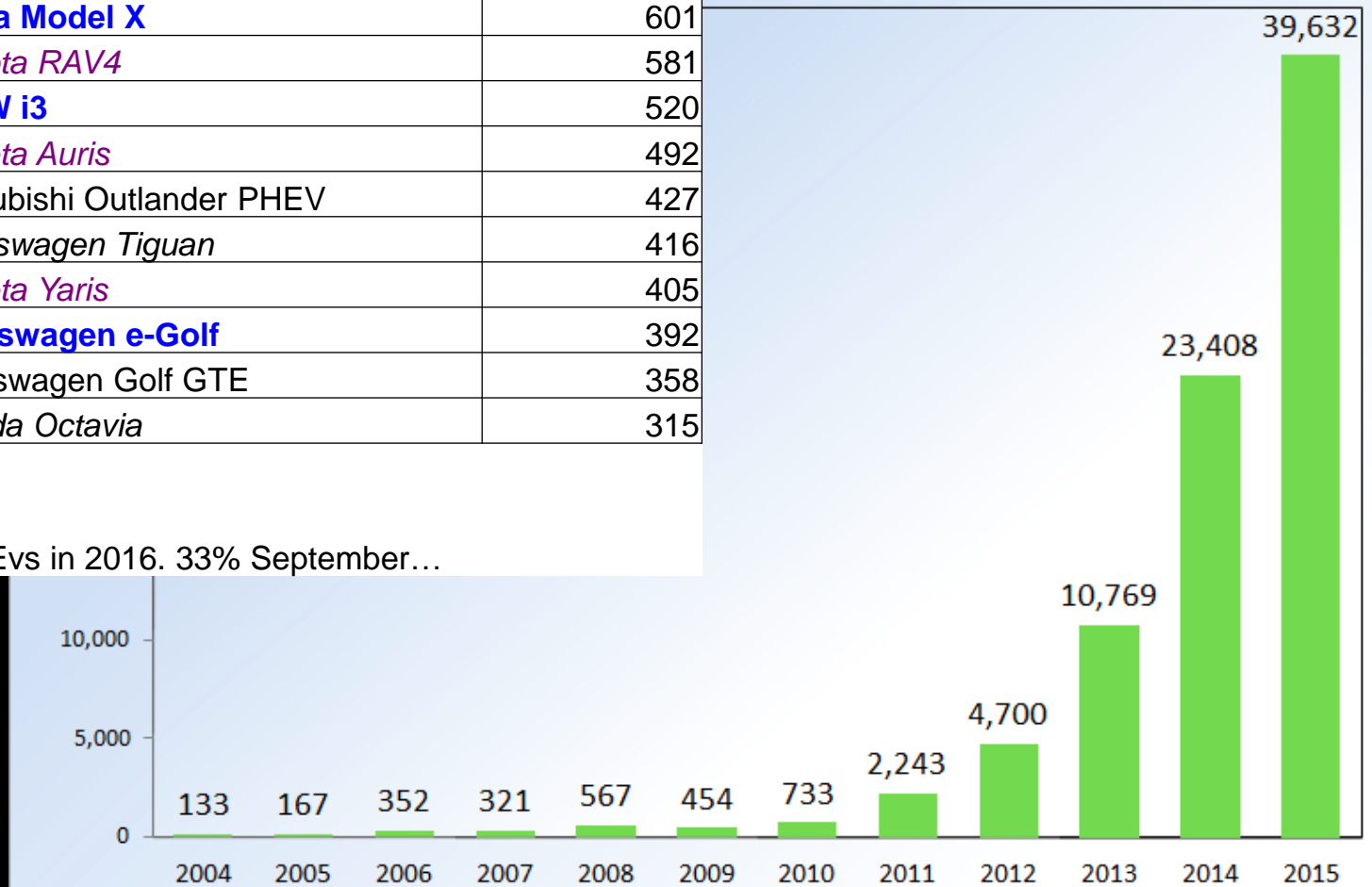


Norway as successful “Public Incentive” model?

Models breakdown by Fuel Source in Norway

PI	Model	Sales
1	Tesla Model X	601
2	<i>Toyota RAV4</i>	581
3	BMW i3	520
4	<i>Toyota Auris</i>	492
5	Mitsubishi Outlander PHEV	427
6	<i>Volkswagen Tiguan</i>	416
7	<i>Toyota Yaris</i>	405
8	Volkswagen e-Golf	392
9	Volkswagen Golf GTE	358
10	<i>Skoda Octavia</i>	315

Electric vehicles in Norway by year (2004-2015)



With 29% share of Evs in 2016. 33% September...

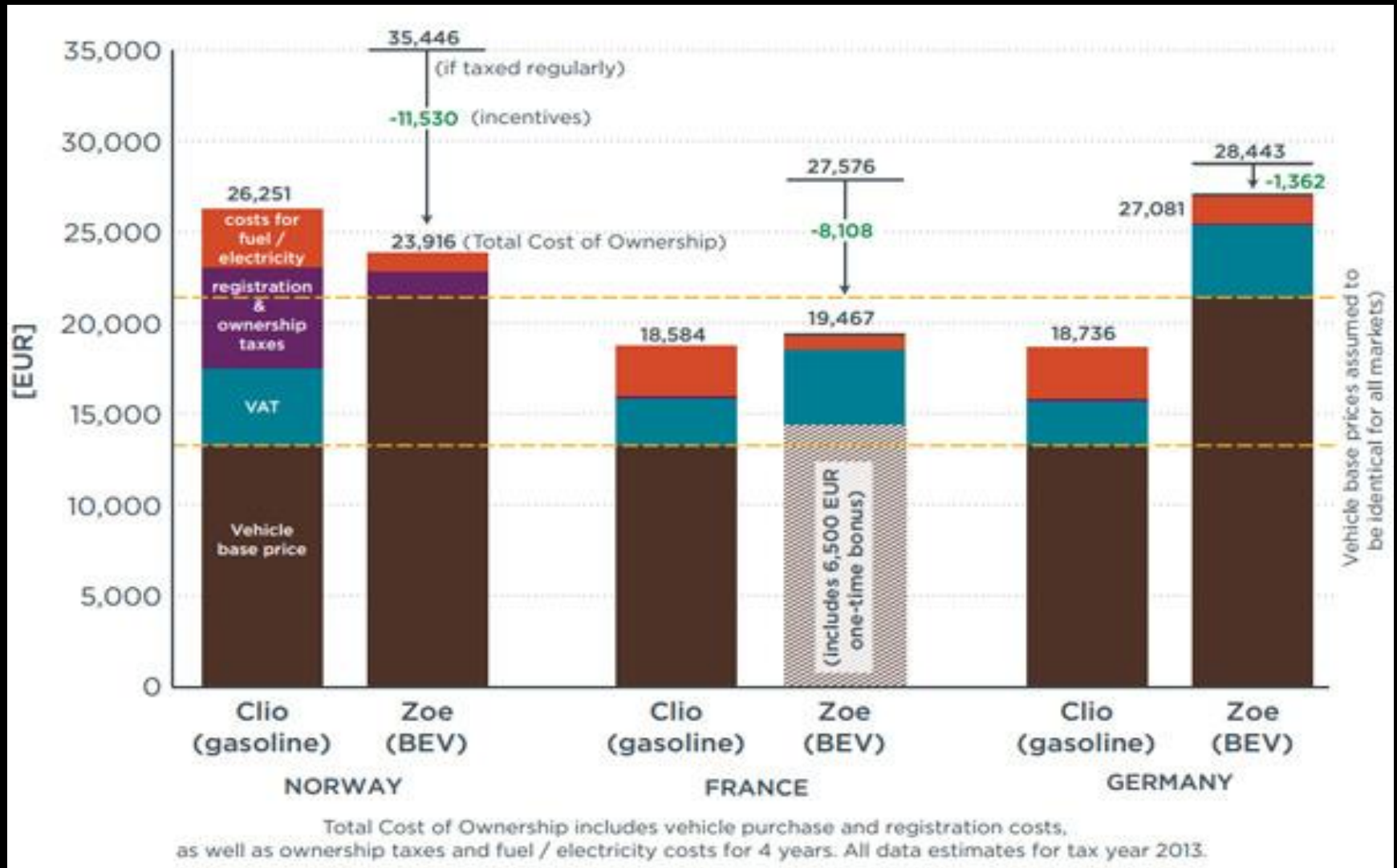
Package of Policies in Norway

1. Action toward demand stimulation
 - VAT tax exemption
 - Highway fees exemption
 - Local tax exemption
 - Access to buses lane in cities
2. Building a safety network of Fast charging at the entry of main cities to secure last miles stress + on highways critical points
3. No action toward offer: no Norwegian EV manufacturers.

Limits of the Norwegian Model

- Cost of the public support
 - Implicit valuation of pollution reduction, infrastructure building, health value, social innovation... are very high.
- The design of the demand side policy is biased in favour of expensive cars because the help is in % of the car price.

But it works even for smaller cars by effectively reducing the TOC



Limits of the Norwegian Model

- Cost of the public support
 - Implicit valuation of pollution reduction, infrastructure building, health value, social innovation... are very high.
- The design of the demand side policy is biased in favour of expensive cars.
- How reproducible it can be by other countries?
- What policy after 2018?
- Ending Thermal Cars in 2030...

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- **Local base policy**

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Car sharing of EVs for « local urban » model ?

- A way to mitigate the TCO constraints => renting the asset (thermal and Electric cars)
- More than 1000 cities around the world are using Car sharing solutions to reduce urban congestions
- and few of them with EVs Fleets to reduce pollution
 - local public experiments with a clear successful business model: Bolloré Autolib.



Driving forces

- Economically and politically:
 - Local Urban Emission limits (climate protection / Urban Citizen claims), expansion of fluctuating RE and consistent user financing.
- Behaviourally:
 - ‘permanently online’, pragmatic multimodality (‘using instead of possessing’) and the erosion of status of possession (+ ‘possessing instead of using’)

The parisian exemple

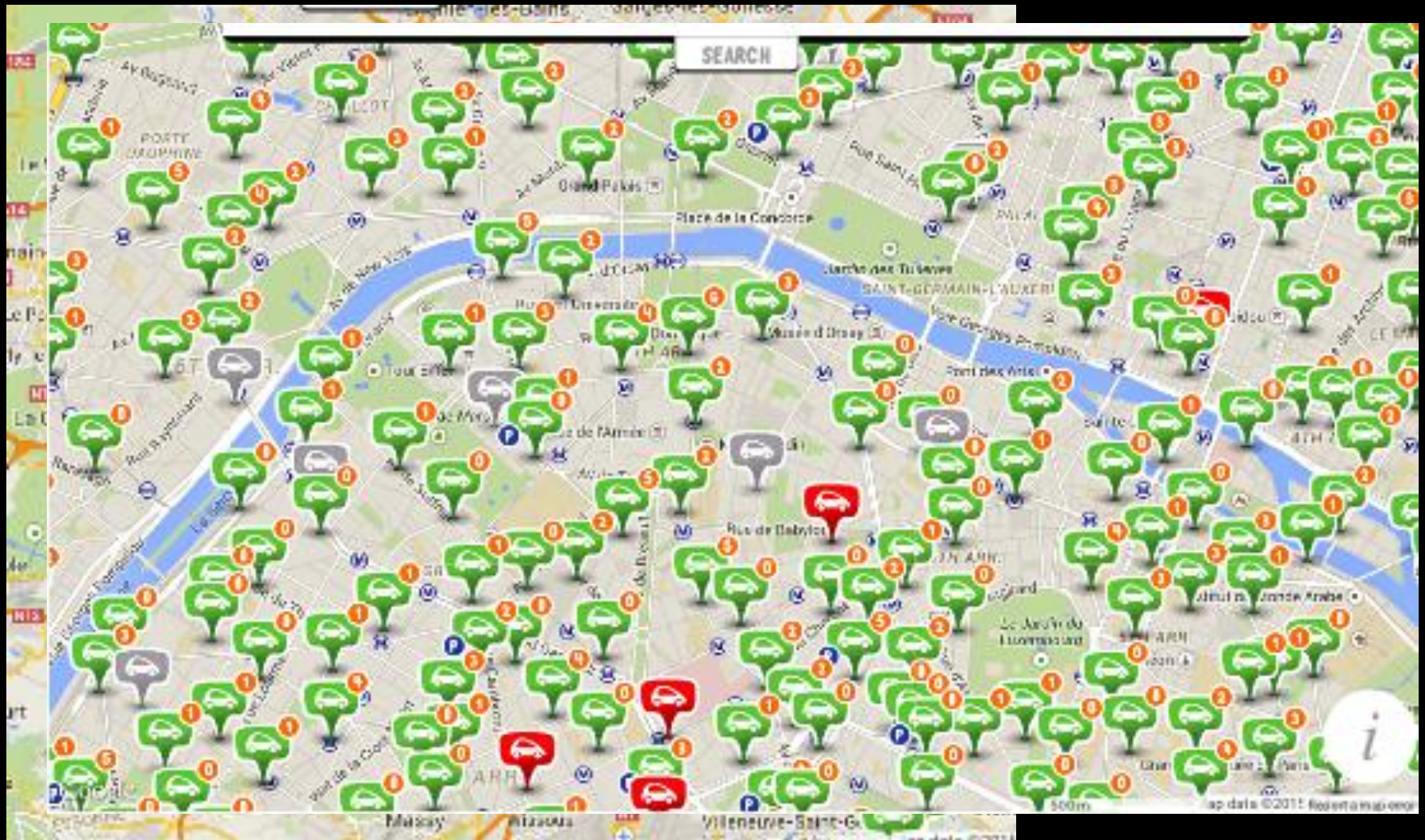
Economic organisation

- Public private partnership 2011 for 180 M€:
 - Bolloré invest in the all integrated service from Battery design, car, to IT system
 - Local public authorities invest in charging stations (1 station – 4-7 plugs => 50k€)
 - Secure the investment of Bolloré in case of losses.
 - Initial goal was to be profitable in 2018 with 80 000 customers.
 - 2013: More than 100 000...
 - Show off effect in Paris for EVs.

Infrastructures

- 3 000 EV cars running
- 1 000 charging stations (more than 4 000 low intensity plugs) open 24h/365
- No parking fees / no waste of time looking for a place to park
- Smart App to find and book EV
- No need to return at the initial point
- 120 € for annual fees + 6€ per 30 m of use
- Each car is rented 6-7 times per day => manage problem of over use...

Smart app overview



New business model to overcome TCO?

- New cities are buying Bolloré like solutions
 - Hanzu (China)
 - Minneapolis (USA)
 - London
 - Bordeaux
 - Lyon
 - Turin
 - Los Angeles / Rio de Janeiro... (avec PSA)
- NB: Big data are produced about real mobility practices and a lot of economic analysis will be needed...

Limits of the EV car sharing experiments

- Only a “small” fleet of EVs are actually running
 - 2011 : 1000 cars
 - 2013 : 2000 cars
 - 2015 : 3000 cars
 - 2016: 3800 cars
- Not all cities around Paris have participated
 - Policy bias / Costs
 - Side effect on suburb housing prices would be a nice work to do...
- What is the minimum population density in a given environment to « worth the cost »?
 - In other words : => some economic studies can be made here...

Conclusion for Public policy design

- We have 2 interesting cases but a lot of innovation / creativity to define the optimal public policy (EU / Nation / Local)
 - Charging network decision?
 - What is the optimal ratio: plug/car ?
 - Level of involvement of public actors?
 - Innovative actions still need to be made and analyzed
 - France Coupling of demand subsidy (6 300 € + 2700 if you destroy an old diesel car)...
 - Germany : zero subsidy and a nice counter example benchmark...

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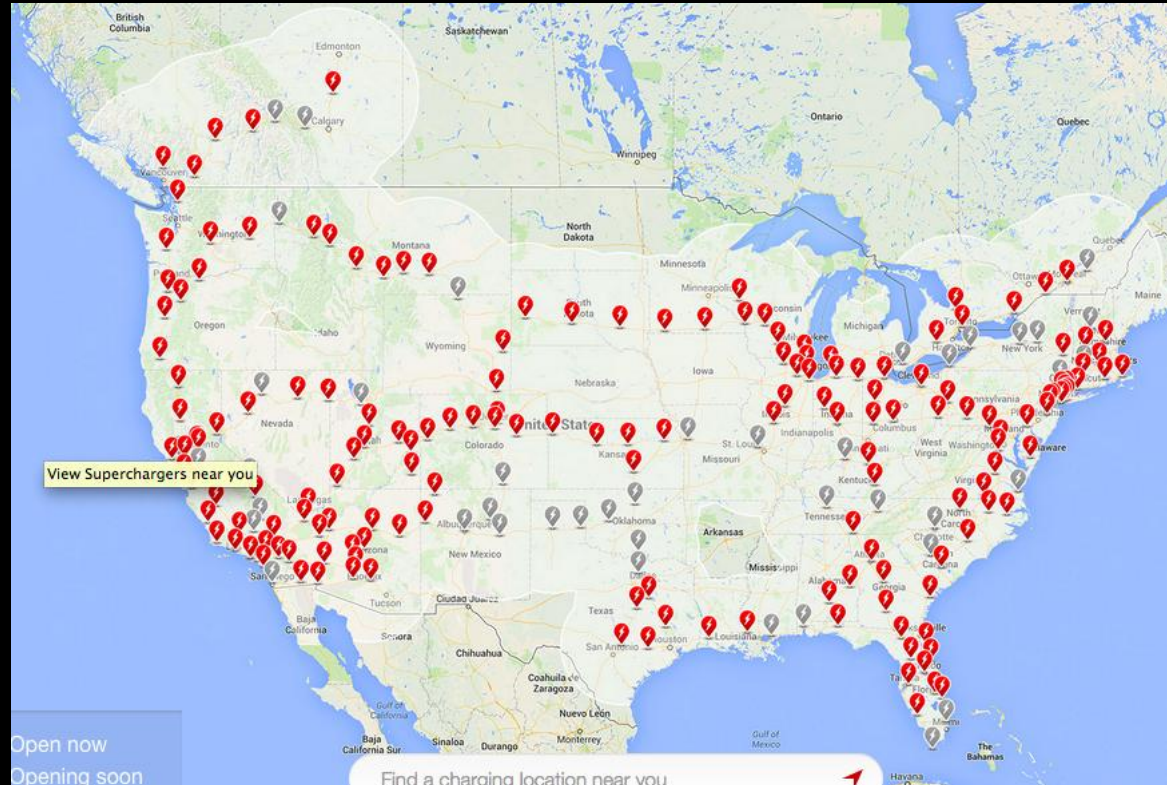
–By innovations

- **Companies driven innovations**
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Tesla as the successful “Apple cars”

- The last start up since Ford in US Car industry : 2004
- Luxury high performance EV:
 - Make a expensive full electric car with XXL battery (85kW)
 - Rely on “**slow Moore's law.**” Processor doubling in power every 18 month, batteries doubled in power every 10 years.
 - Model S, the sports sedan released in 2013, earned the distinction of Motor Trend Car of the Year
 - In US market Model S outsold the Mercedes Benz S Class, the BMW 7 Series, and every other large luxury sedan in 2013.
 - Model 3 SUV presales and sales start October 2016

Superchargers today (120kW) for 30 m charging for 170 miles for free (+ wifi)



IT – Car-merging services



The limits of the TESLA model?

- Manufacturing Millions / Thousands?
- Setting the worldwide « superchargers » standard for XXL batteries is a challenge
 - How to cooperate with DSO / TSO to install needed superchargers in all places?
- Response of large classical cars manufacturers
 - BMW / Audi... Toyota...
- New “Tesla vision” : PV + EV + Home Storage

What are the actual solutions and the ways forward?

–By Public Policy action

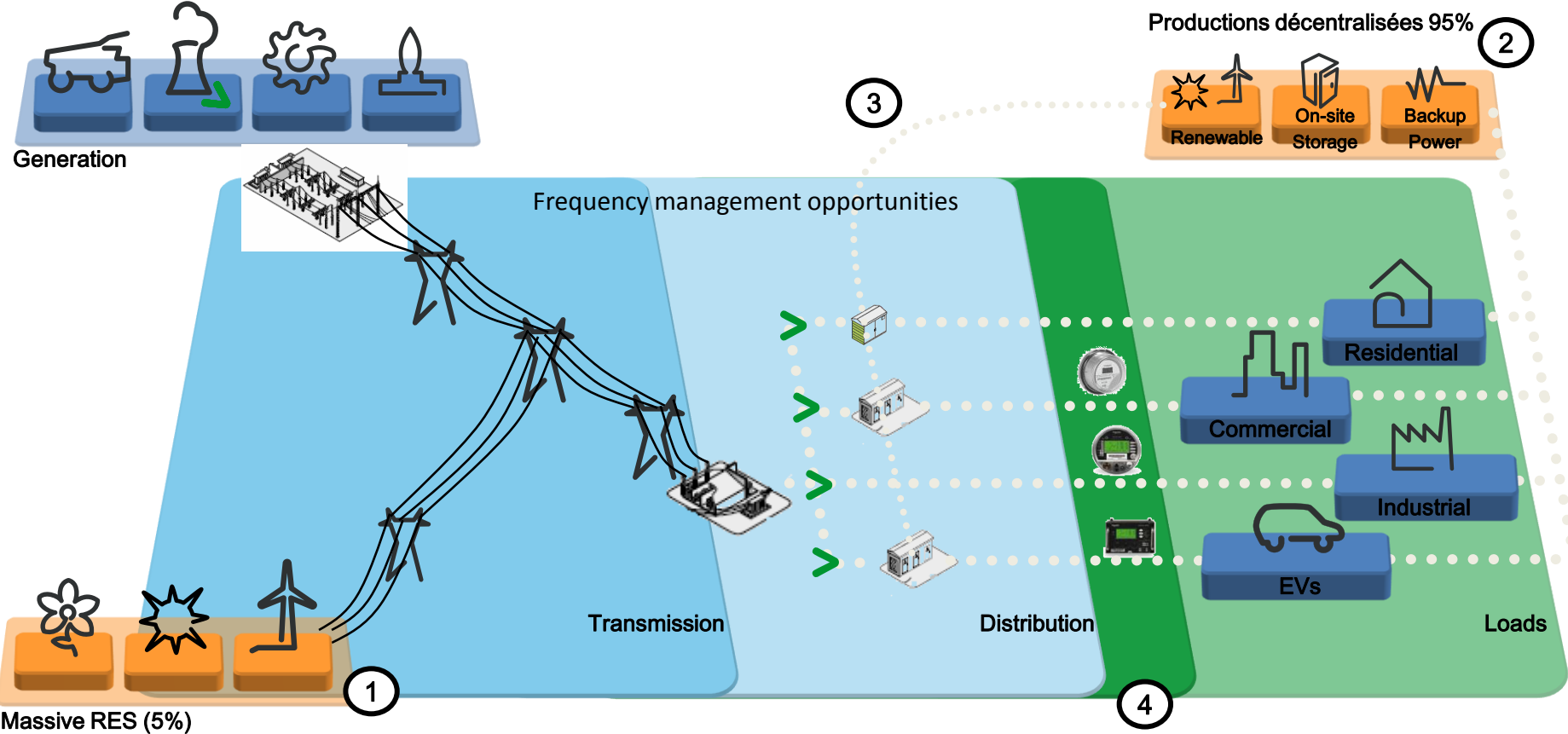
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Why do we need more flexibility
in electrical systems?

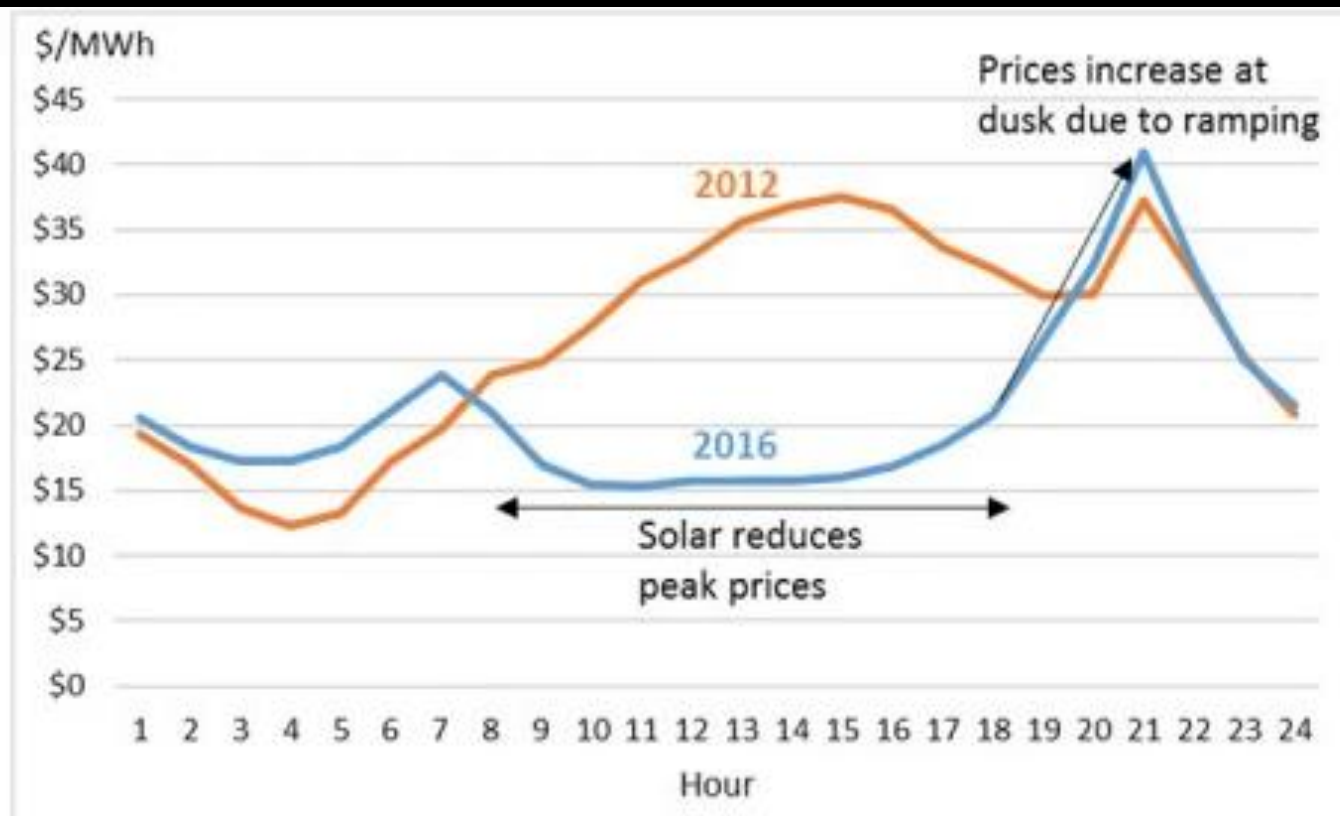
From Old days to EV smart grids issues



Voltage issues and management opportunities



More PV => more Duck issues



Day-Ahead Average Hourly Electricity Prices at SP-15 (CAISO), May 2012 versus May 2016

Source: [SparkLibrary](#), based on data from CAISO

More wind => more flexibility required

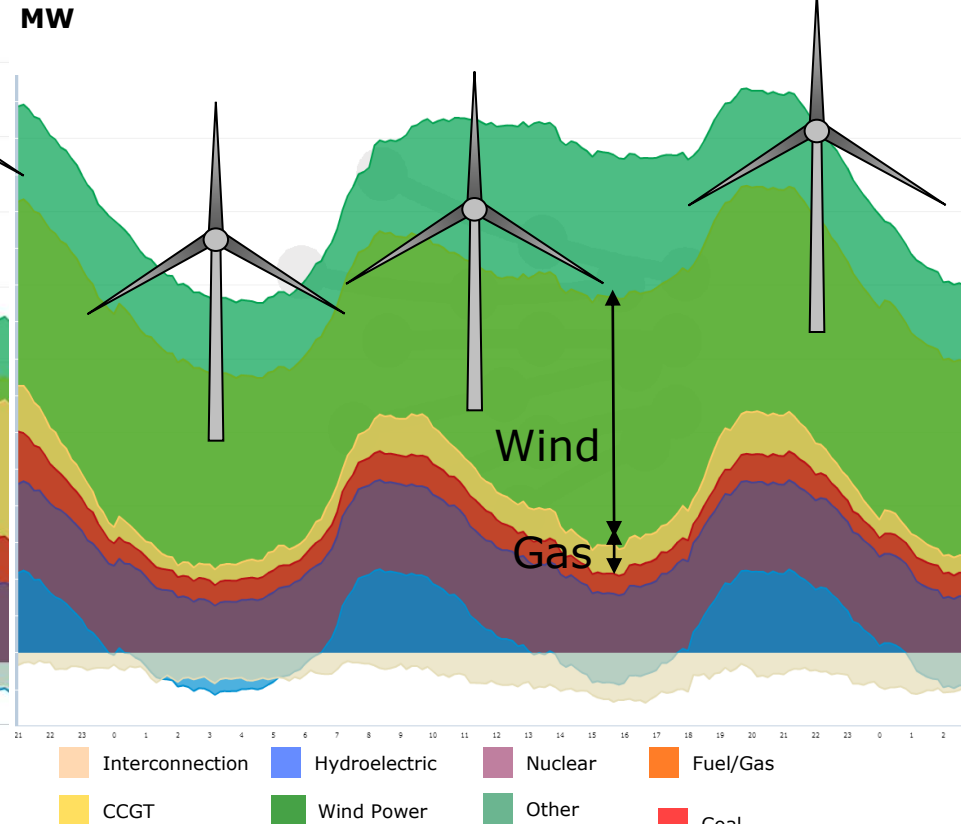
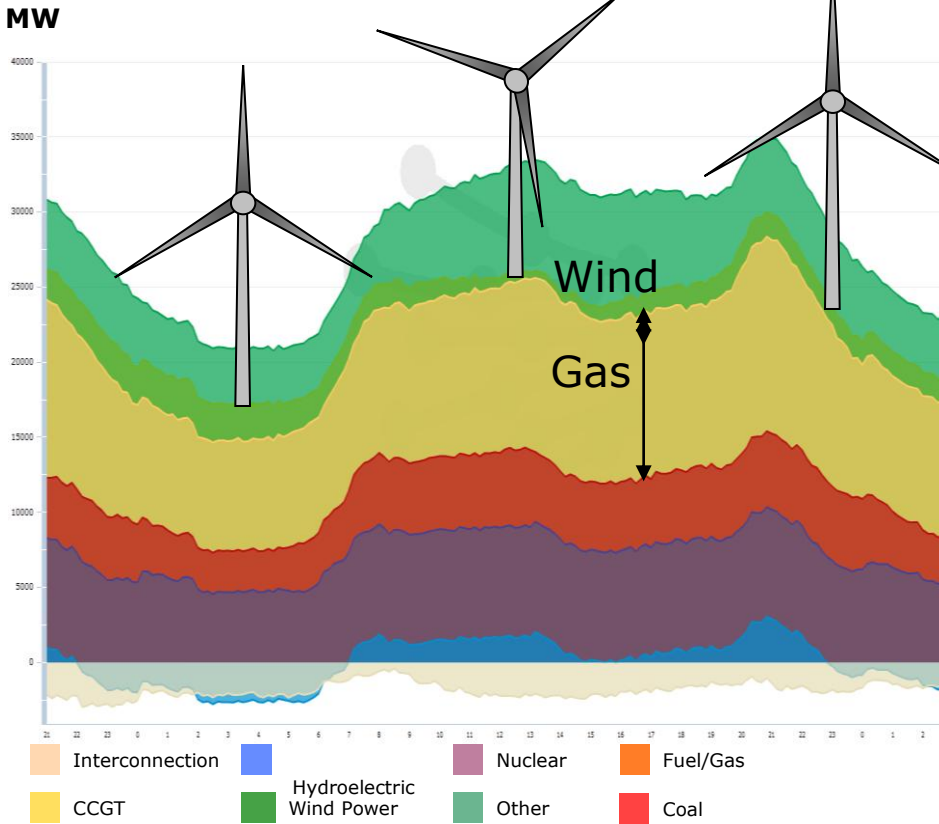
The Spanish case

30-september-2010

Wind 1%
17:45h

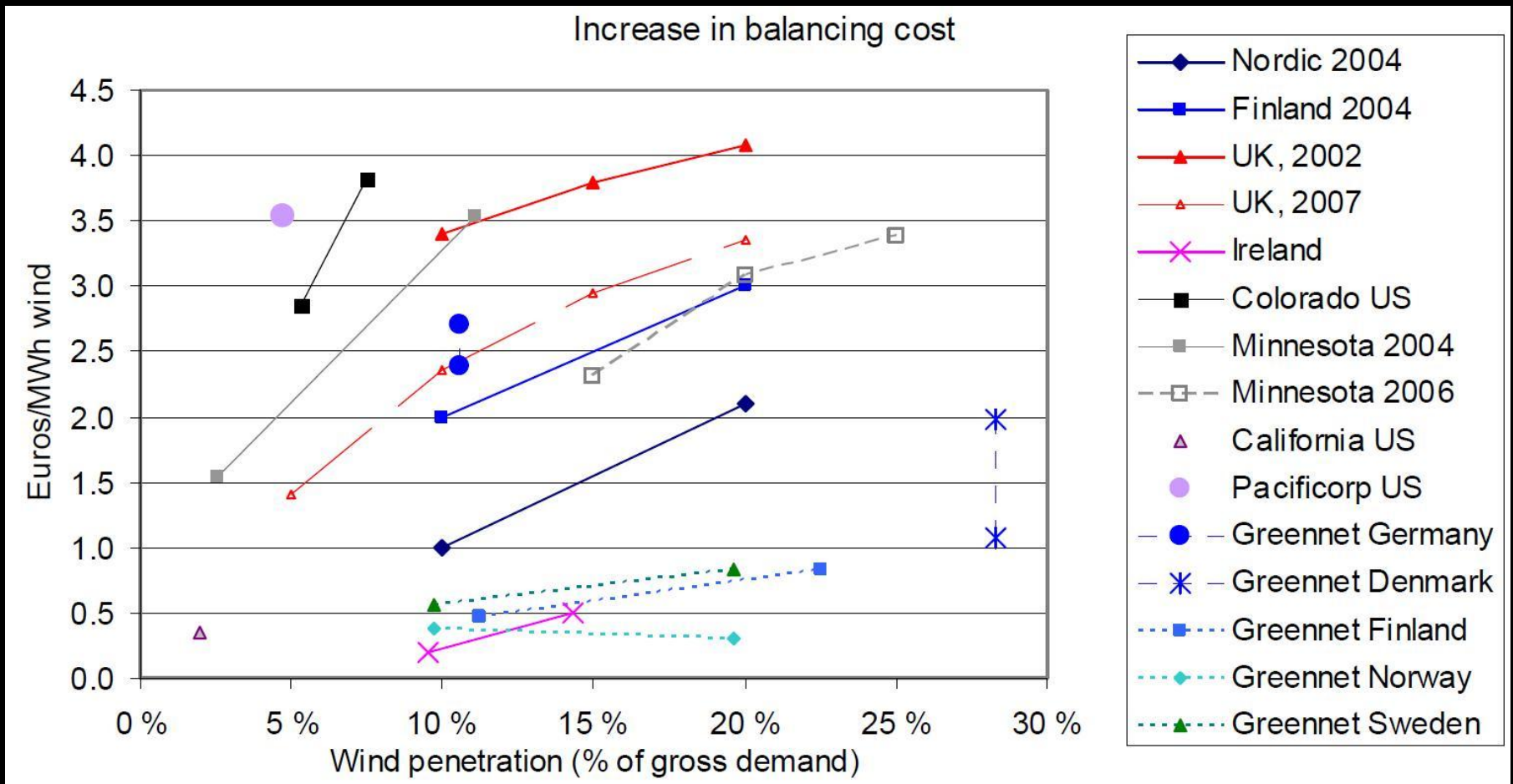
6-Februray-2013

Wind 66.5%
15:50h



Source REE, ENAGAS

More wind => more costly flexibility required



Flexibility by market coordination

PJM as a “Grid services” future?

- Traditional natural monopoly regulation:
 - All services provided by long term contracts
 - Fixed price for the length of the contract with the national minister or regulator
 - Example in France, regulated tariffs for:
 - T/D
 - Energy
 - Reserves
 - Renewables
- No Room for EV !

PJM as a “Grid services” future?

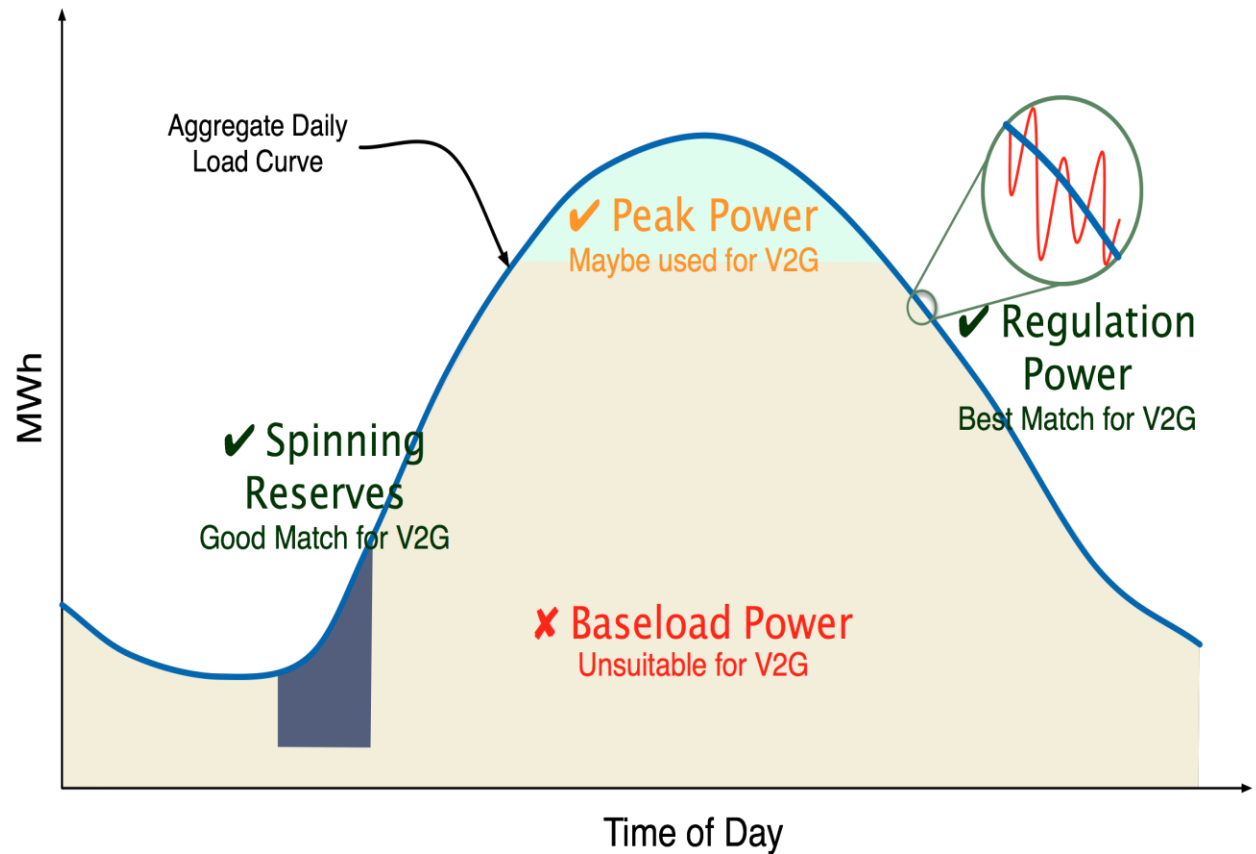
- Traditional natural monopoly regulation without markets
 - All services provided by long term contracts
 - Fixed price for the length of the contract with the national minister or regulator
 - Exemple in France, regulated tariffs for:
 - T/D
 - Energy
 - Reserves
 - Renewables
- No Room for EV !
- Using markets to provide Grid services in liberalized electricity systems:
 - Introduction of markets for:
 - Energy (MWh)
 - Capacity (MW)
 - Transmission Rights
 - Reserve Markets
 - Demand response
 - ...
- But Rules need to be recrafted accordingly !

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 coordinate disperse storage unit as flexible ressources?

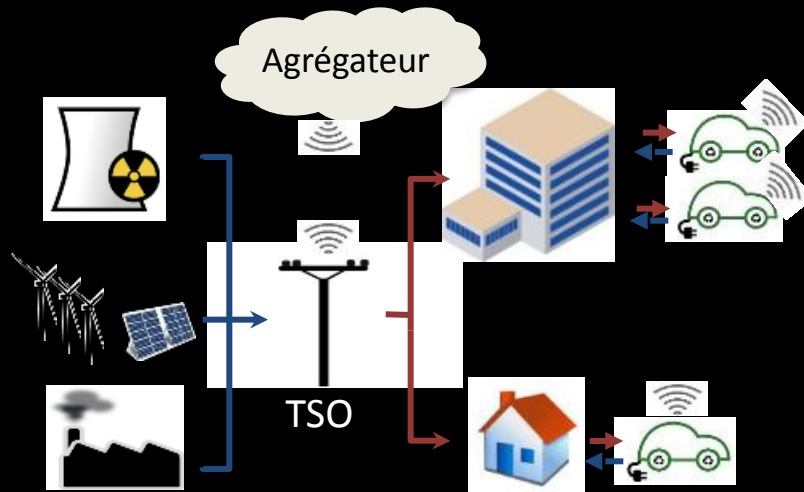
Combination of data

1+2+3

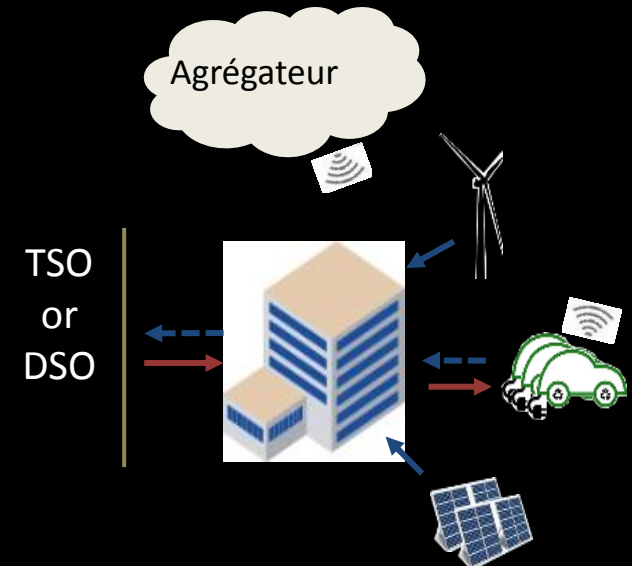
Into new algorithms (to be tested)
to deliver « market like products to be traded on
energy markets »

Input 1: Definition of EV resources provision

Vehicle-to-grid



Vehicle-to-building



Input 2: Definition of EV Trips & needs

1. Commuting Privately owned Fleet

- You go to work and return home: very predictable and easy to capture.

2. Collective fleet

1. used in a coordinated way

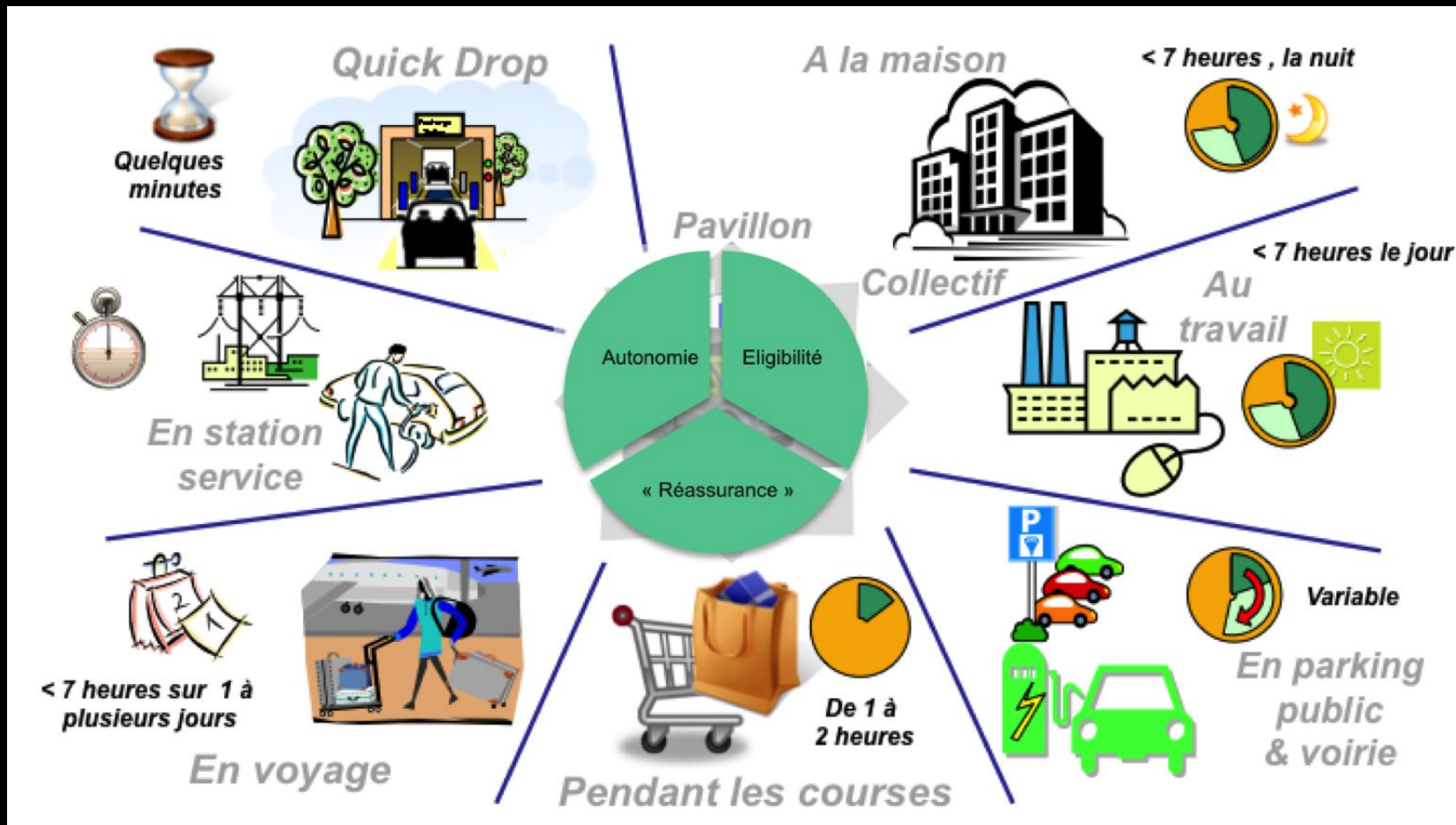
- Postal / delivery services fleet / Last mile delivery

2. used in a uncoordinated way

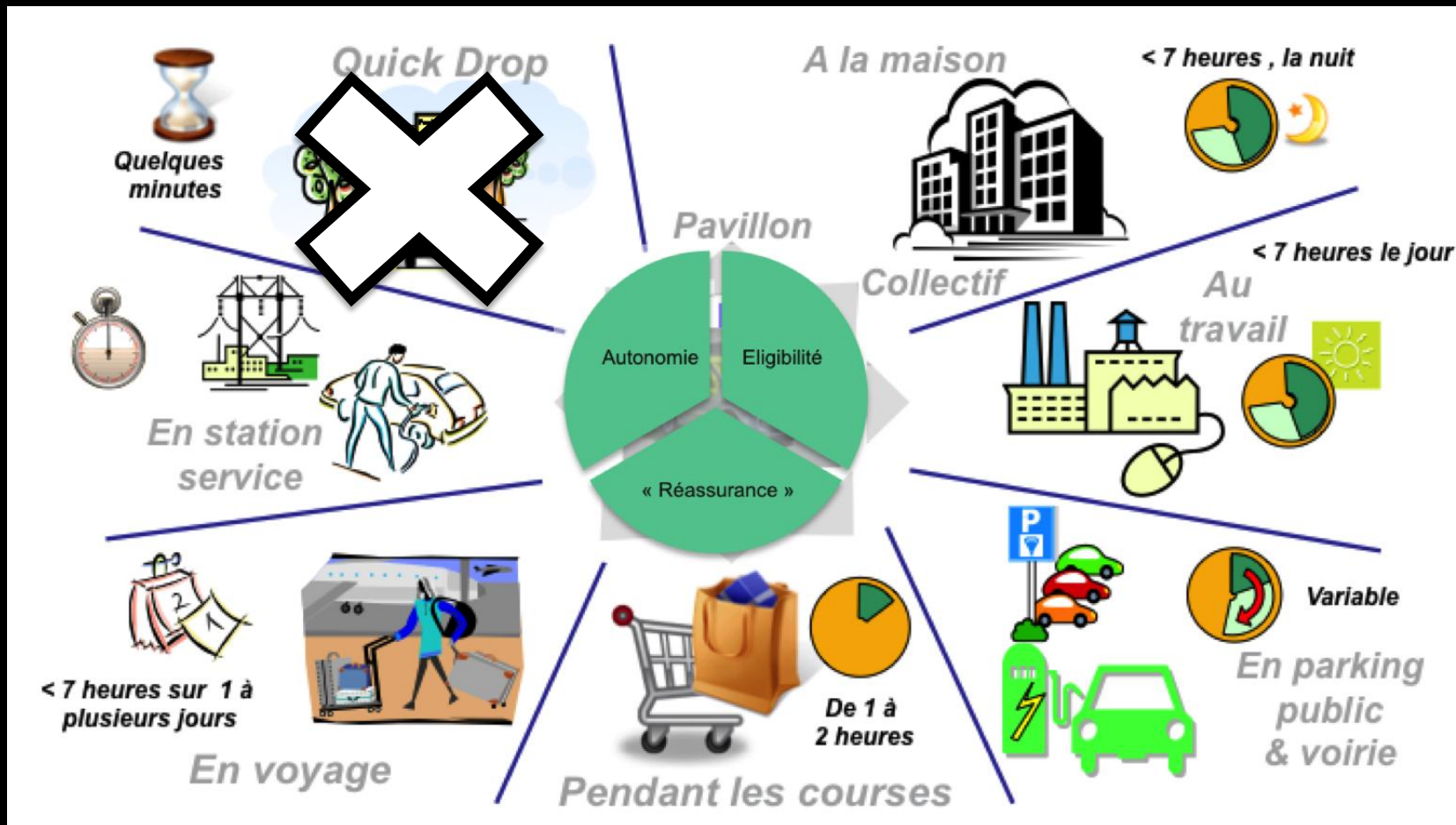
- Companies cars given to staff
- Renting cars companies

=> Trip definitions: when, how long, risk...

Input 3: design of Charging infrastructure



Input 3: design of Charging infrastructure



Strategies for charging : +/-

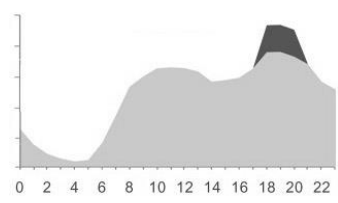
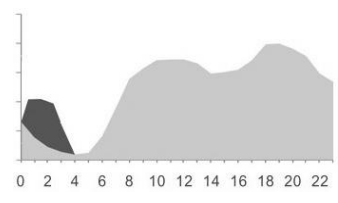
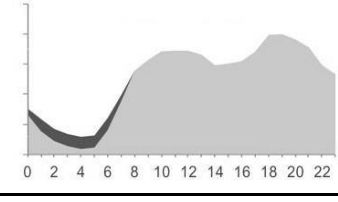
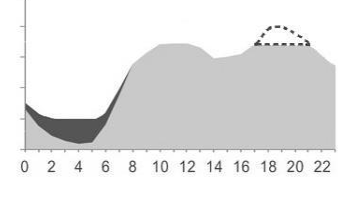
		Advantages	Drawbacks
Dumb Charging		<ul style="list-style-type: none"> ✓ Easy implementation ✓ User friendly 	<ul style="list-style-type: none"> ✗ Overload of transformers and lines ✗ Voltage deviations ✗ Peak power increase ✗ Increase of electricity CO₂ intensity ✗ Electricity cost increase ✗ Needs to reinforce the grid
Off-peak Charging		<ul style="list-style-type: none"> ✓ Easy implementation ✓ Demand profile flattened ✓ Better integration of wind energy at off-peak hours ✓ Delay in grid investments 	<ul style="list-style-type: none"> ✗ Imbalances due to rapid increase of power consumed by PEVs ✗ Possible overload of transformers and lines ✗ Possible voltage deviations ✗ Willingness of the customer required
Smart Charging (Valley filling)		<ul style="list-style-type: none"> ✓ Ancillary services provision ✓ Demand profile flattened ✓ Better integration of wind energy at off-peak hours ✓ Delay in grid investments 	<ul style="list-style-type: none"> ✗ Complex implementation ✗ ICT technologies required ✗ Willingness of the customer required
Smart Charging (Peak saving)		<ul style="list-style-type: none"> ✓ Ancillary services provision ✓ Peak power reduction ✓ Optimal integration of intermittent RES ✓ Reduction of electricity CO₂ intensity ✓ Less investments in network reinforcements 	<ul style="list-style-type: none"> ✗ Very complex implementation ✗ ICT technologies required ✗ Willingness of the customer required ✗ Premature degradation of batteries resulting of using V2G ✗ Energy losses in grid-battery-grid transmissions

Figure 3.16. Advantages and drawbacks of different strategies for PEVs integration

Combination of inputs and maths to create “bundle of valuable flexible resources” for the energy markets

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 - ...

Case Studies

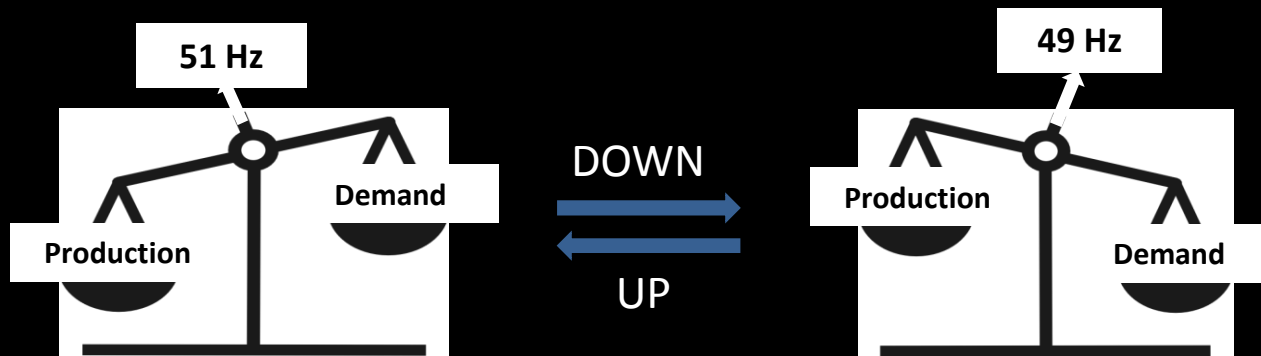
Frequency Regulation market revenue

Revenue from grid services for EV



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 (Nicc), 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)

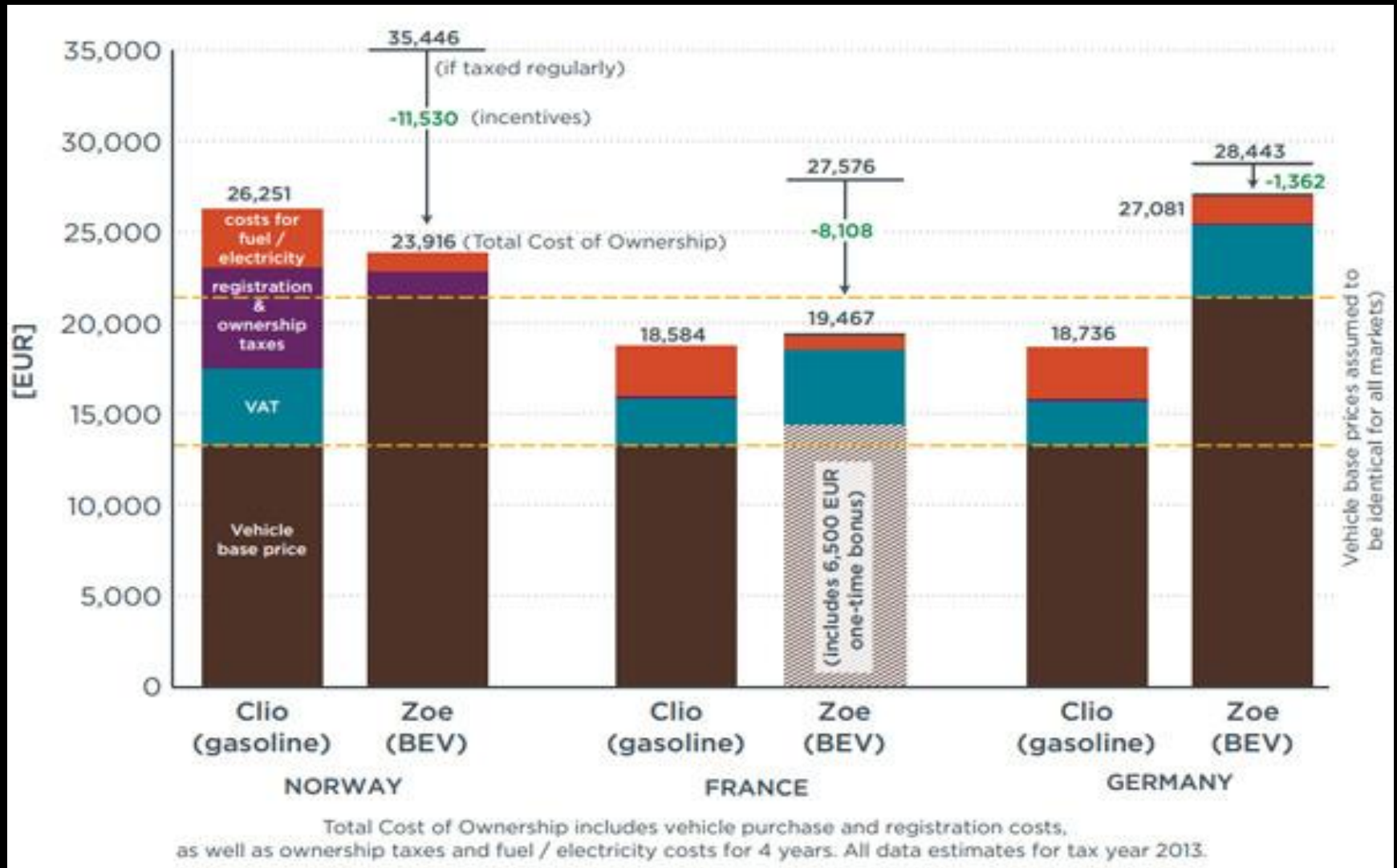
Frequency remunerations for EV : PJM real case / France exploration

**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

A very nice contribution to TCO



Flexibility solution by contrats

Contractual solutions for VtoH

- Objectives of the House manager
 - Minimizing energy cost over time
 - Maximizing auto consumption of local renewable energies if incentives are aligned
 - Distribution grid services provision (optional)
- Sharing potential benefits with the consumers



Japan

- Nissan and Mitsubishi Motors are taking a lead in commercialization, products already in the market.
- V2H field demonstration test programs have been conducted in

History of V2H Products and standards



CHΛdeMO

CY2011

2012

2013

2014

2015

2016

★ (3/11 earth quake and tsunami)

★ 8/2 Nissan V2H demo



★ 4/27 Mitsubishi Power box

★ Nichicon L2H
"EV power station"



3000 V2H units are in service in Japan

????



★ L2H ver2

★ Mitsubishi-electric.

★ Endesa V2G

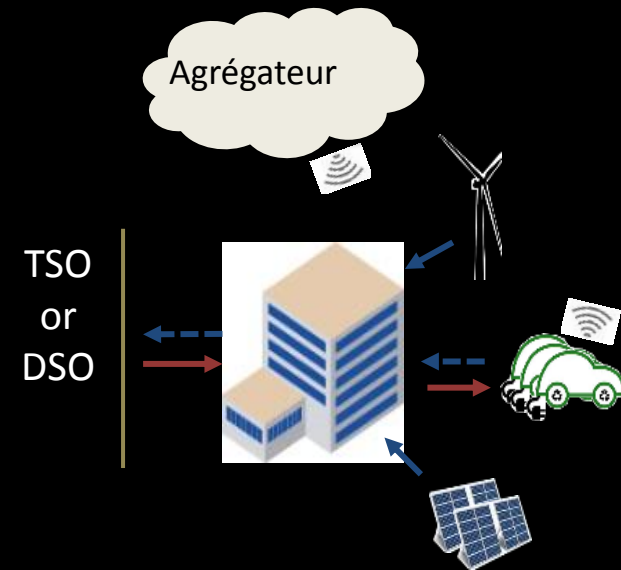
products



Contractual solutions for VtoB

- Objectives of the site manager
 - Minimizing energy cost over time
 - Maximizing auto consumption of local renewable energies
 - Minimizing the peak demand toward networks
 - Limiting the investments in networks reinforcements
- Sharing potential benefits with the consumers / networks managers

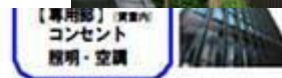
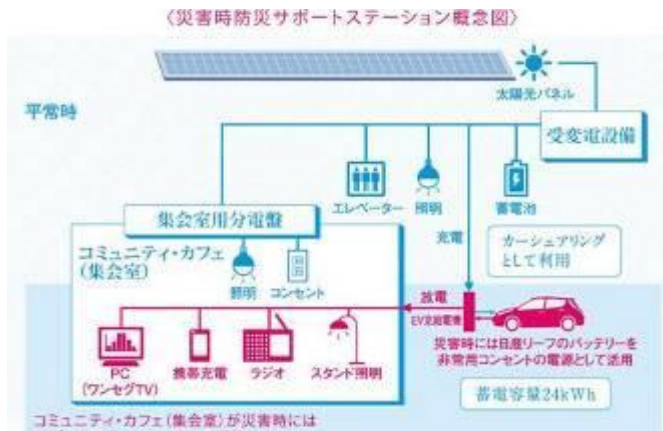
Vehicle-to-building



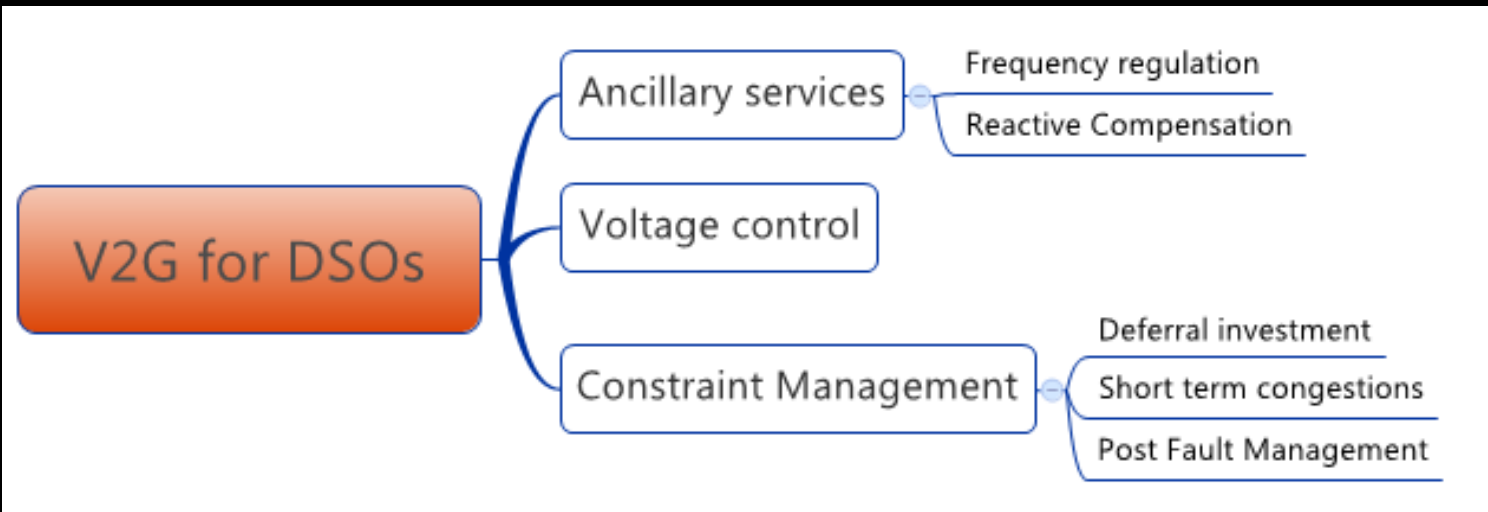
Japan exemple

Park homes OKURAYAMA, apartment complex with V2H and shared EV -2011 NOV

- Shared area of apartment complex is backedup in emergency. EV supplies power for TV, radio, lightings and mobile phone charge for ten days.
- EV is car-shared by the residents in daily use.



Contractual solution with the Distribution Service Operator (DSO)



If V2G avoids investments, at least the value of V2G has to equal CAPEX and OPEX of the avoided reinforcement.

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

Conclusion on innovations by companies and Spin-off

- Tesla is the promoter of a disruptive innovation from PV to storage (EV or home or building base)
- A lot of studies have to be made to promote new business models based on energy markets /contractual potentials.

Conclusions

4 incomplete solutions!

Predicting the future of EV is hard

If you were asked in the 1980s about having a camera in your phone...

what would you have imagined?





Selected Literature

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- Donada Carole and Perez Yannick 2016, *Introduction to the special issue about « Electromobility at the crossroads »*. **International Journal of Automotive Technology and Management**, Vol 16, N°1, pp 1-15, 2016.
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- Codani Paul, Petit Marc and Perez Yannick, 2015, *Participation of an Electric Vehicle fleet to primary frequency control in France*, **International Journal of Electric and Hybrid Vehicles**, Vol 7, N°3, pp 233-249.
- Kempton Willett, Perez Yannick, and Petit Marc, 2014, *Public Policy Strategies for Electric Vehicles and for Vehicle to Grid Power*. **Revue d'Economie Industrielle**. N° 148, pp 263-291.