

Grid Applications

Demonstrating how electric vehicles can support our power system.





We Have A Problem: Air Pollution And Climate Change

China



83 million Chinese are expected to die of lung disease in the next 25 years.

India



13 of the 20 most polluted cities in the world *

1.2 million deaths annually due to air pollution in India**

San Francisco (last week)



Paradise, California (Wildfire)



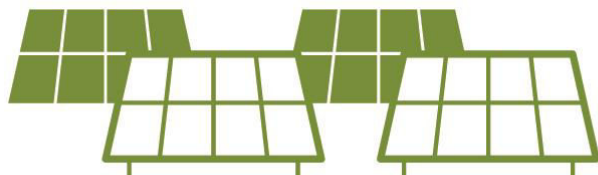
A town of 20,000 wiped out
11,000 structures destroyed
77 people dead; 700+ still missing

*World Health Organization (WHO)

**Greenpeace India Report



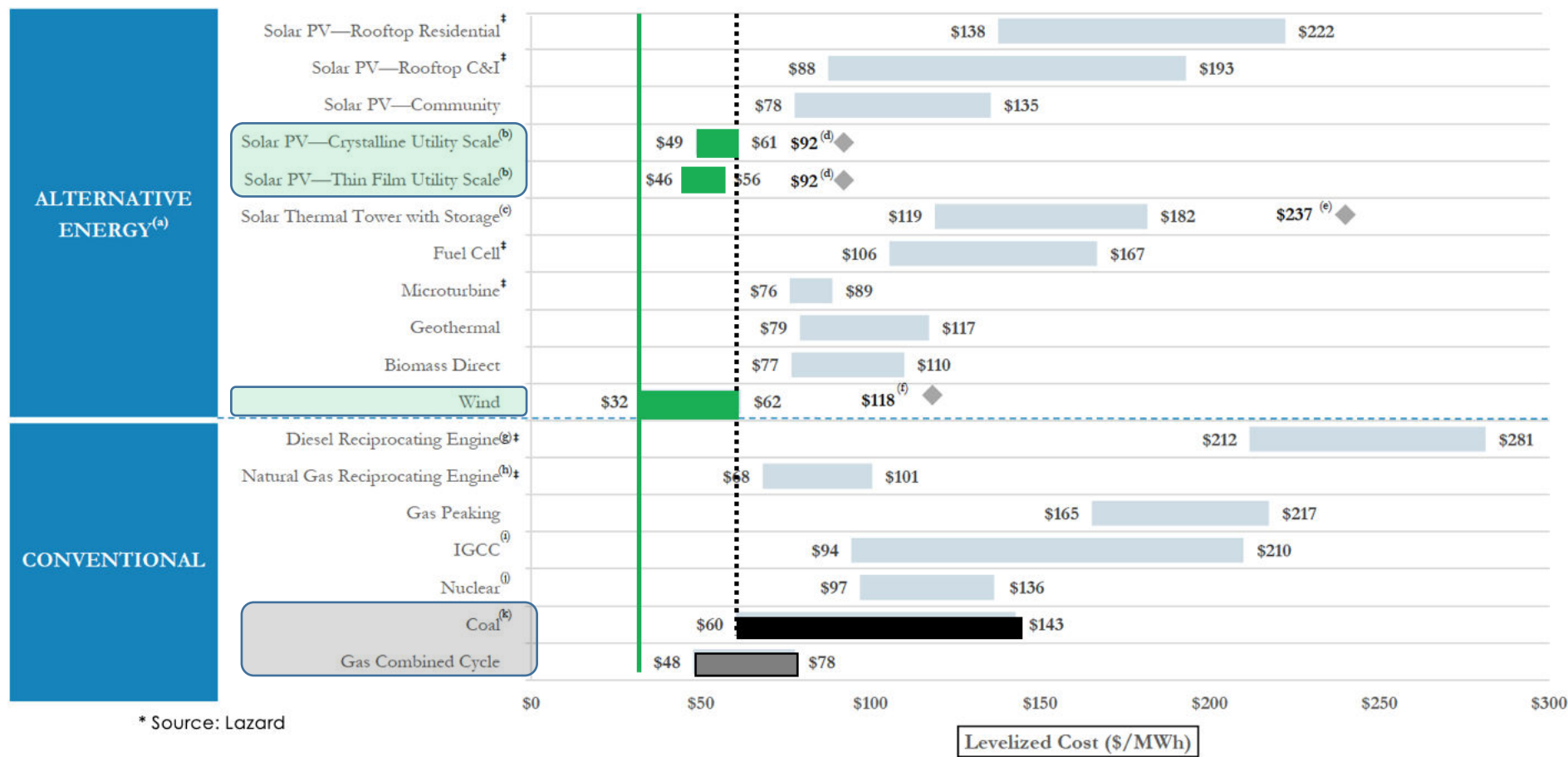
Solution: We Need Renewables And Electric Vehicles





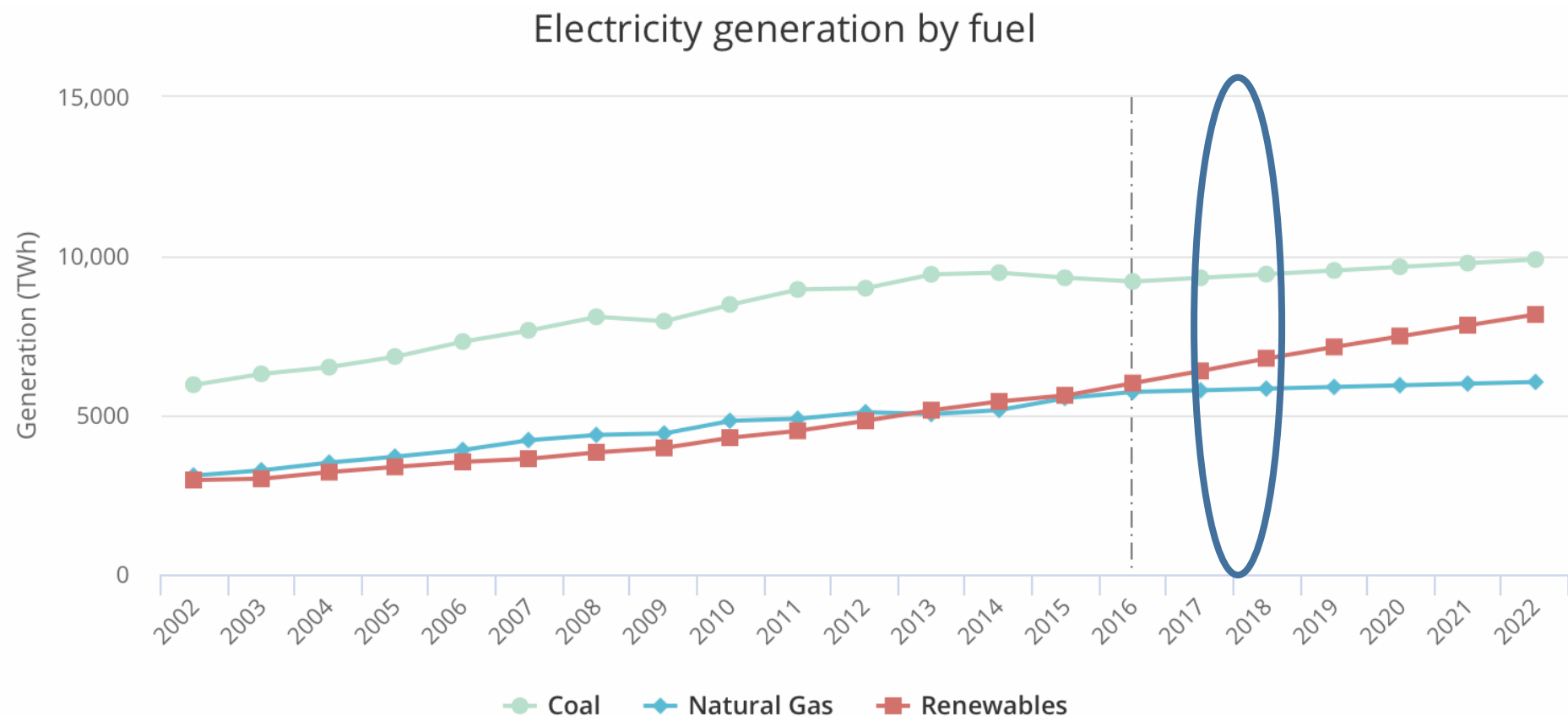
Renewable Is Now Cheaper Than Traditional Power

Unsubsidized Levelized Cost of Energy*





Renewable Is Already Beating Natural Gas Generation

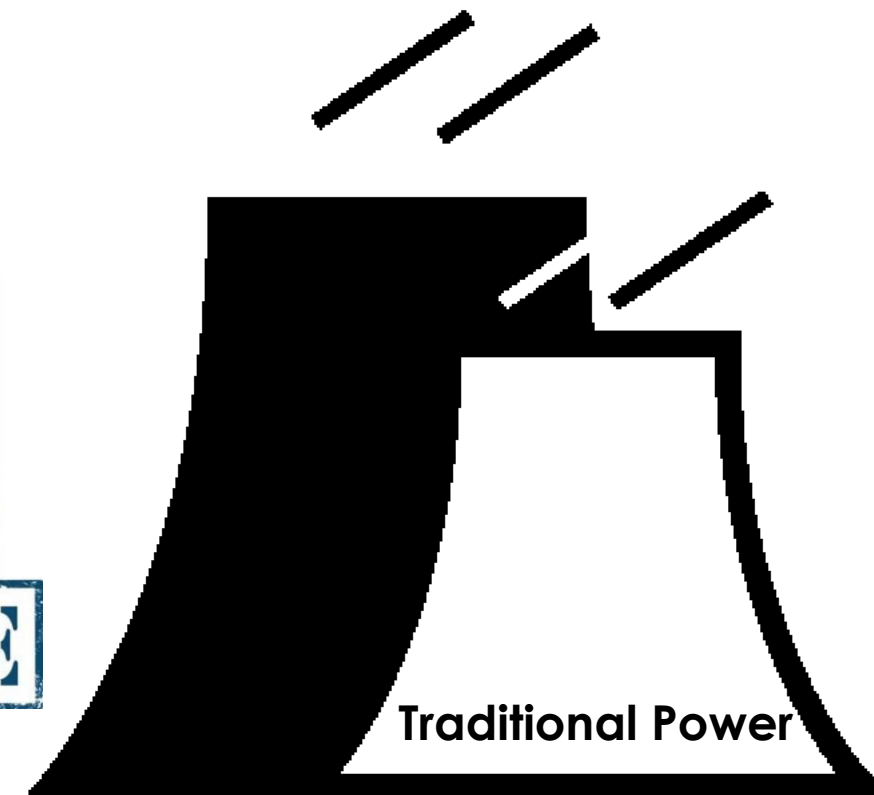
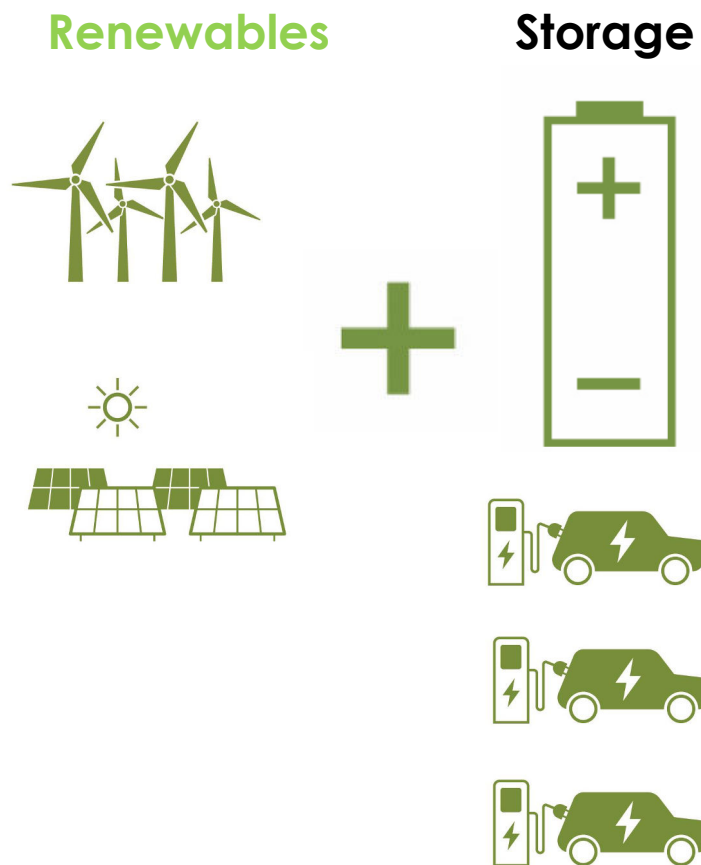
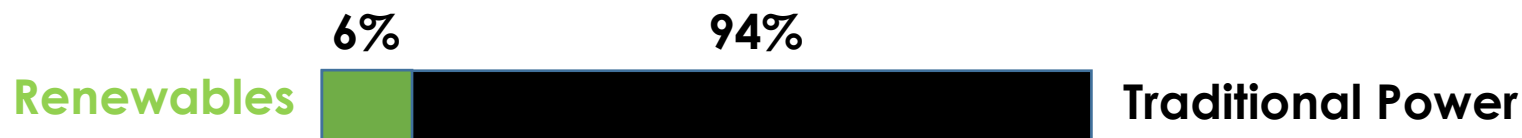


Renewables 2017, IEA

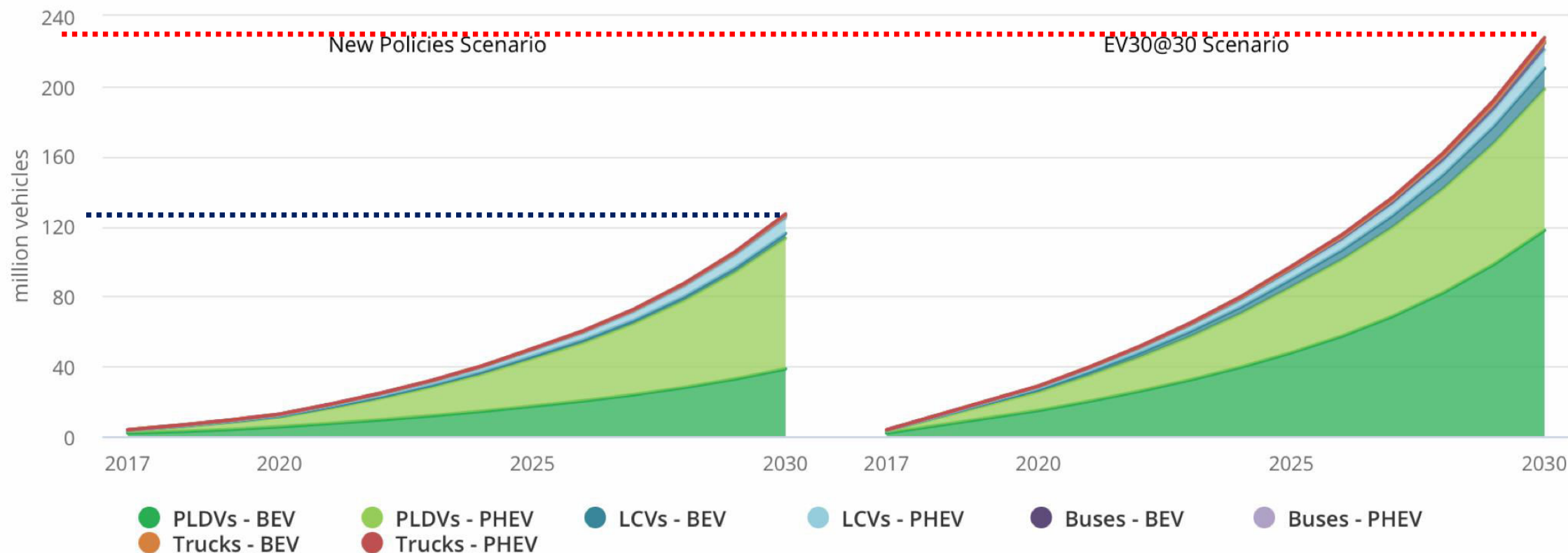




Renewables Need Storage To Replace Traditional Power Plants



Global EV deployment to 2030 by scenario



© OECD/IEA



Car Manufacturers And Countries Are Committed To EV's

Car Manufacturers



Aims for 50% of sales to be "fully electric" by 2025



Believes in an "all-electric" future



To invest €44 billion (\$50 billion) by 2023 to develop electric cars, self-driving vehicles and other new technology.

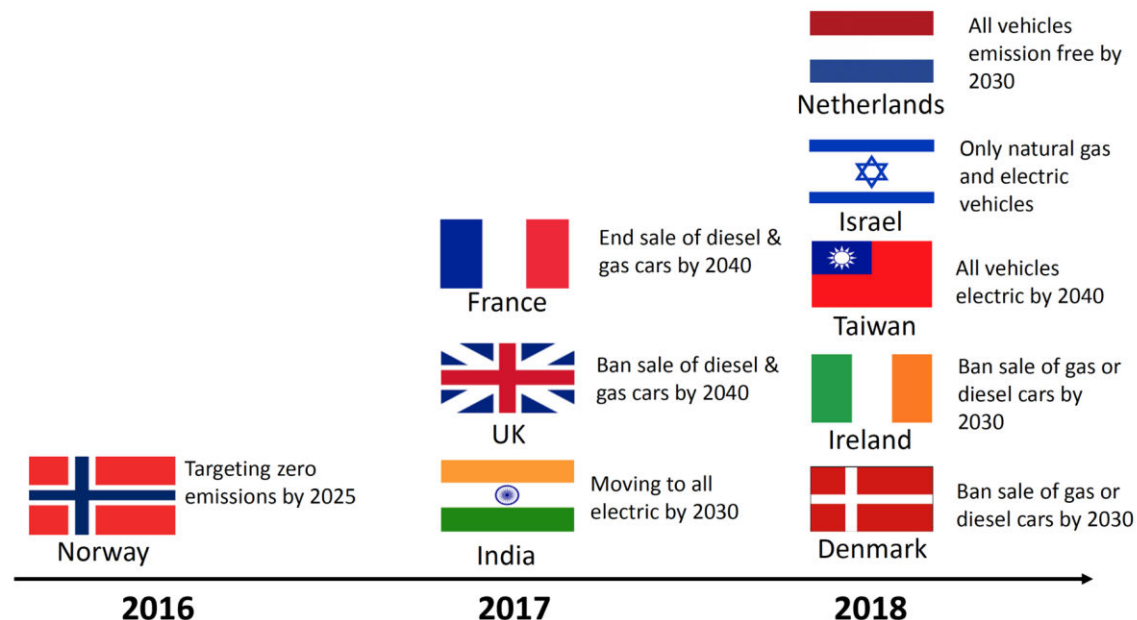


Largest EV manufacturer in the world.
China total sales reached 770,000 units last year
Represents over 50% of global sales



Just doing it

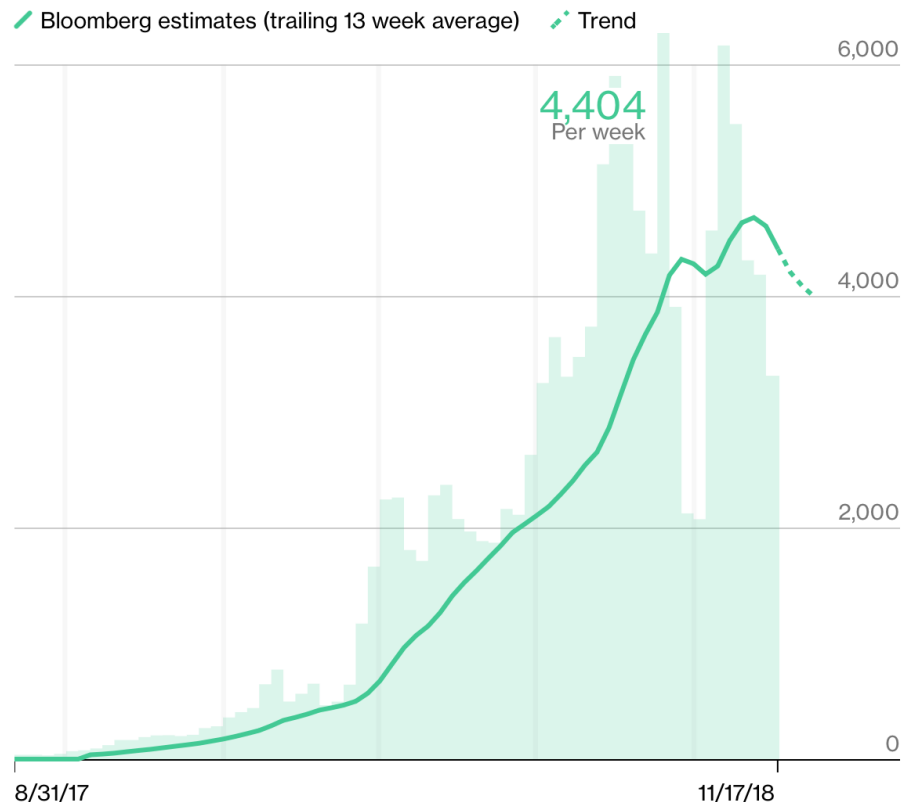
Countries prohibiting gas powered vehicles





... And Something Is Happening

Weekly Model 3 Production Rate

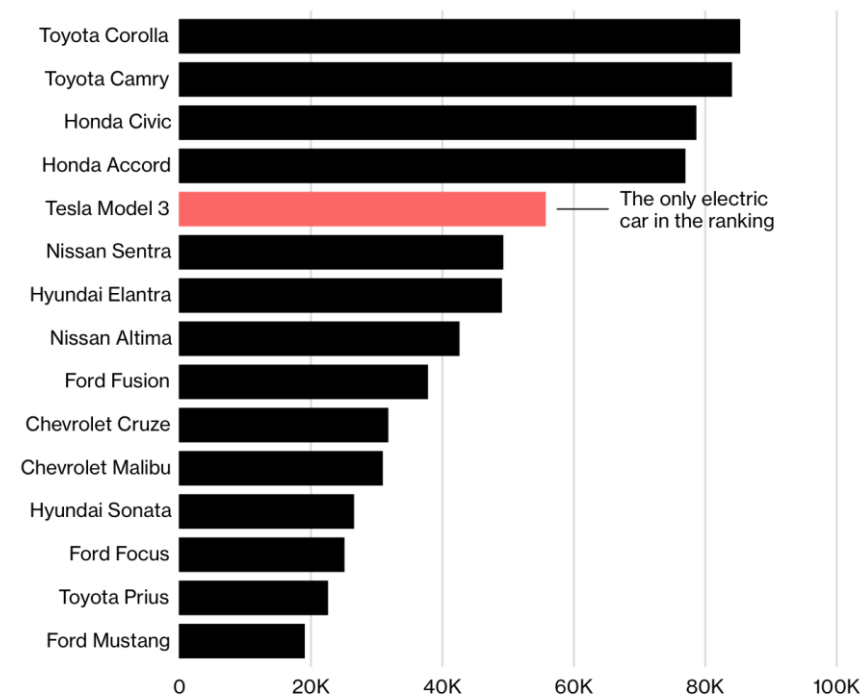


Source: Bloomberg

Tesla Breaks Into America's Top 10

Tesla Breaks Into America's Top 10

The Model 3 electric car ranked among the best-selling sedans of the third quarter



Source: Bloomberg, company filings

Note: Tesla's Model 3 tally includes some deliveries in Canada



Uni-Directional And Bi-Directional Electric Vehicles

Telephone



iPhone



Telephone
Text
Video
E-mail
Camera
Money Vault
.....

Charge



The EV can be used for more than
transportation services (Energy Services)

Charge



Discharge



Definition Of Grid Applications

Grid Applications



Charge Discharge



Behind-the-Meter Applications

Charge



Charge Discharge



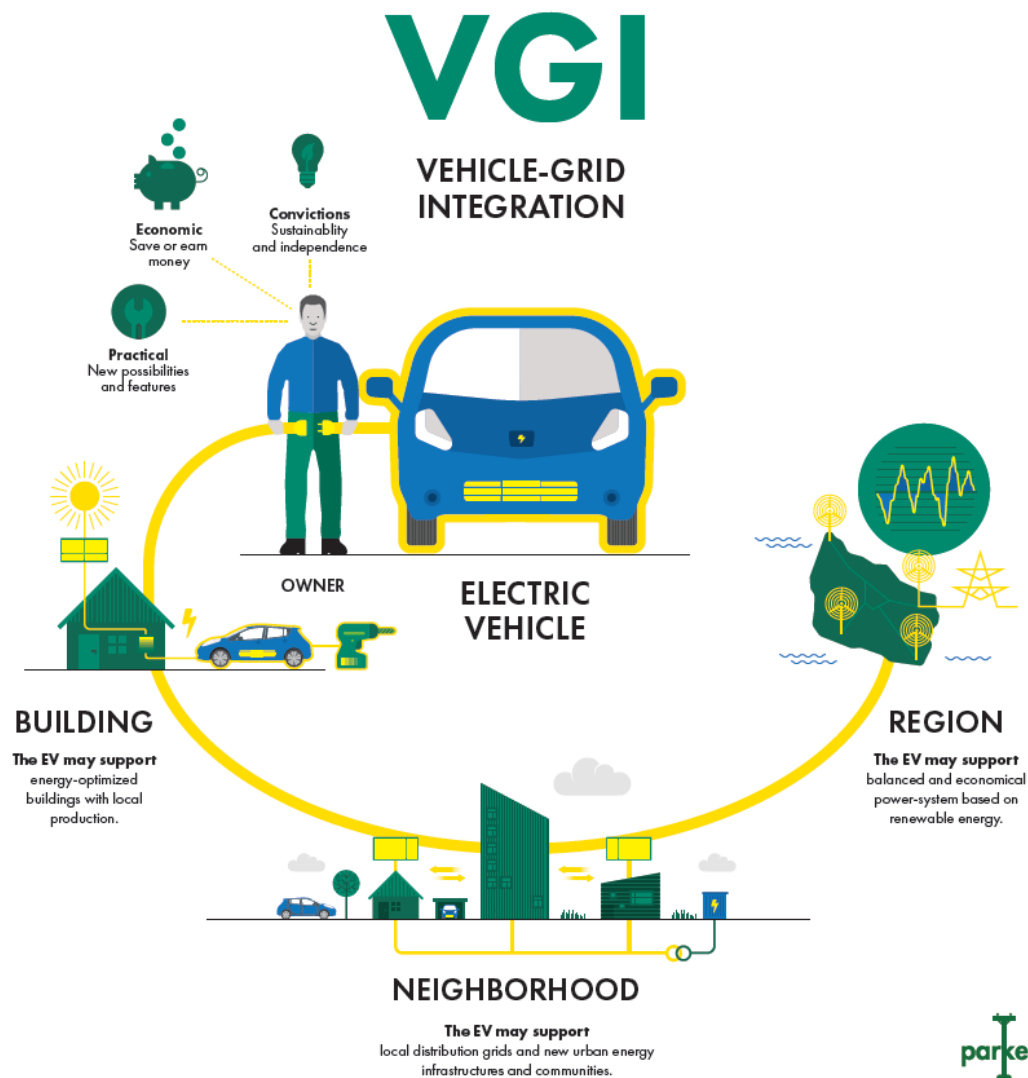
Definition						Evaluation			
Type	Groups	Name	Short description	Behavior	Stakeholders & potential benefits	Value for system	Value for owner	Tech./ standard support	Market/ regulatory support
Power and energy services	System-wide services	Frequency regulation	Keeps the frequency in an interval around 50 Hz	Balancing***	Aggregator/EV Owner: Market earnings TSO: Larger, more competitive market	High	High	Medium/High	High
		Frequency regulation - very fast	Frequency regulation with ramping times and precision that go beyond what traditional generators can provide	Balancing***	Aggregator/EV Owner: Market earnings TSO: New/improved service	High	High	Medium/High	Low
		Secondary regulation	Replaces frequency regulation and restores the frequency to 50 Hz	Balancing***	Aggregator/EV Owner: Market earnings TSO: Larger, more competitive market	Medium	Low	Medium/High	Low
		Tertiary regulation	Replaces secondary regulation and fulfills a higher requirement to energy capacity and delivery timescale	Balancing***	Aggregator/EV Owner: Market earnings TSO: Larger, more competitive market	Low	Low	Low	Low
		Synthetic inertia	Mimics rotational inertia by taking advantage of the fast chemical reaction of batteries	Balancing***	Aggregator/EV Owner: Market earnings TSO: New/improved service	Medium/High	Low	Low	Low
		Adaptive charging	Delays or advances charging in time based on e.g. energy costs or renewable contents	Adaptive*	Aggregator/EV Owner: Energy cost or CO2 savings	High	High	Medium/High	Low
		MORE – Mother of all regulation	Includes all the abovementioned traditional types of regulation in one - assuming a large fleet of EVs.	Balancing*** Energy backup** Adaptive*	Aggregator/EV Owner: Market earnings TSO: New/improved service + Larger, more competitive market	Low	Low	Low	Low
	Distribution grid services	Islanded micro grid and black start	Enables one or a set of EVs to sustain a small power system	Energy backup**	EV owner: Security of supply.	Low	High	Low	Low
		LV network balancing	Mitigates unbalances between phases of LV network	Balancing***	Aggregator/EV Owner: Unknown DSO: New service	Medium	Low	Low	Low
		LV overvoltage management	Mitigates overvoltage of LV feeders	Balancing*** Adaptive*	Aggregator/EV Owner: Unknown DSO: New service	High	Medium	Medium	Medium
		MV-LV transformer and lines overloading	Mitigates overloading of transformers and cables of LV network	Adaptive*	Aggregator/EV Owner: Unknown DSO: New service	High	Medium	Medium	Low
		LV congestion due to fast charging stations	Manages EV fast charging to keep within operational limits of LV network	Adaptive*	Aggregator/EV Owner: Unknown DSO: New service	High	Medium	Medium	Low
ICT Services	User added services	Charging management	Support EV service participation for the EV owner through interface.		Aggregator/EV Owner: Added simplicity for service participation		High	Low	
		Charging flexibility assessment	Estimates whether sufficient charging flexibility exists in order to participate in services.		Aggregator/EV Owner: Knowledge on charging flexibility		High	Low	
		Charging information	Presents the EV user with the information most relevant when controlling (dis)charging of the EV		Aggregator/EV Owner: Improved information service		Low	Medium	
		Vehicle-to-Load	Enables the EV to supply electric energy to the EV user in places where access to the general electric grid is impossible or impractical		EV Owner: New electric energy services		Medium	Medium	





Vehicle Grid Integration (VGI)

Unidirectional and Bi-directional



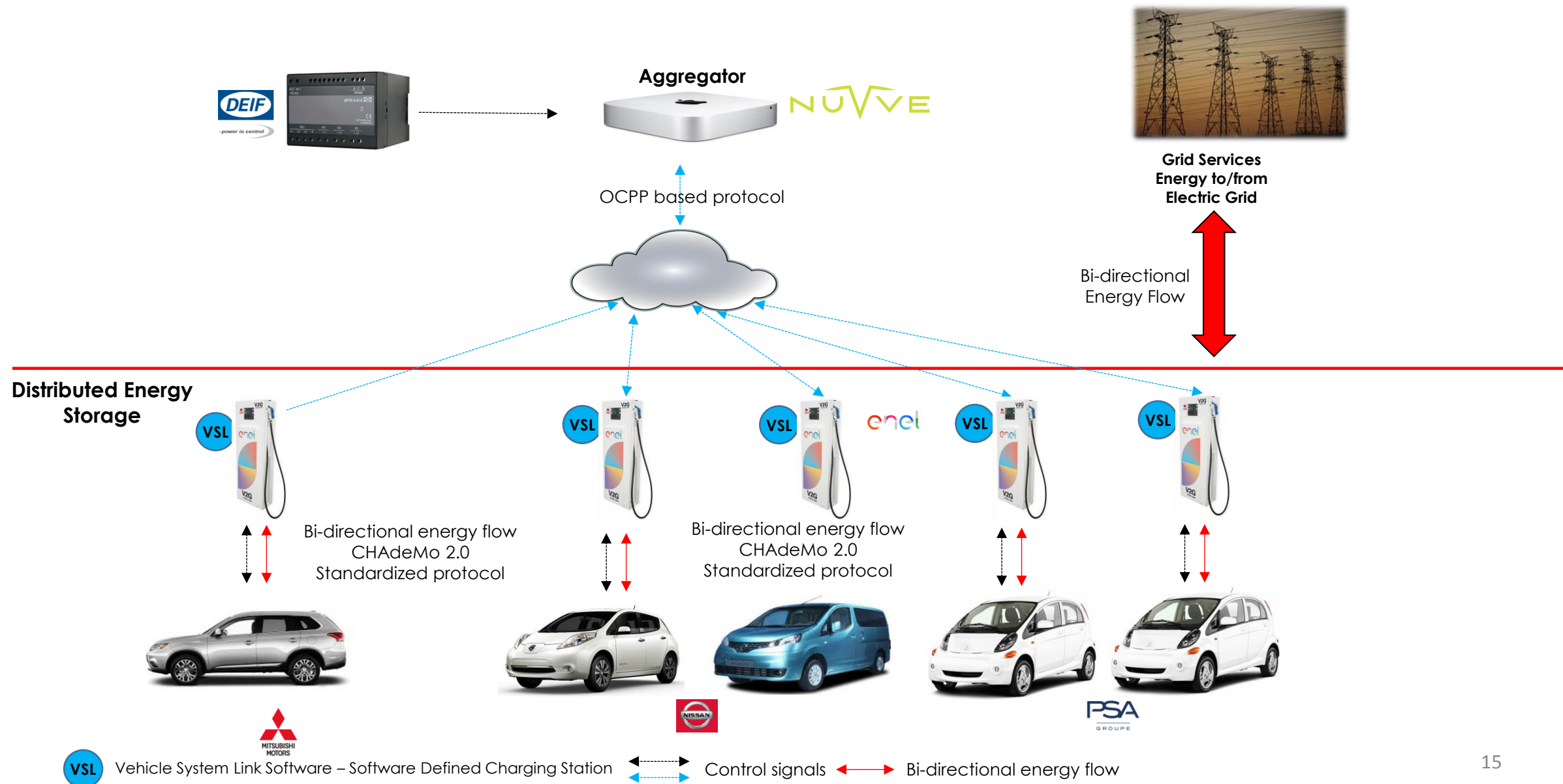


Parker Service Catalog 2.0 - (VGI)

Unidirectional (V1G) and Bi-directional (V2G)

Domain	Categories	Service examples	Short description	EV and EVSE		USER	
Region (Transmission)	Power balancing	Synthetic inertia	Mimic inertia of rotating machines.		-Fast activation -Controllable ramping rate - Bidirectional (V2G)		Availability payment
		Frequency containment	Keep the frequency within a required interval.				
	Neighborhood (Distribution)	Energy balancing	Wholesale energy	Responsiveness to varying energy prices.		(no special performance requirements)	
Regulation			Balancing energy schedules/portfolios.				
Marginal emission			Defer charging based on CO2 cost of marginal consumption.				
Building (behind the meter)	Grid contingencies	Loading issues	Mitigate overloading of transformers and cables in LV network. May also include phase load balancing.		- 4Q / Reactive power capabilities		Savings on connection costs /compensation from utility
		Voltage issues	Mitigate overvoltage and voltage drops in distribution systems.				
	Building (behind the meter)	Energy autonomy	Bilateral trading	Local peer-to-peer trading of energy.		- Bidirectional (V2B)	
Self consumption maximization			Ensure the highest possible utility of locally produced energy.				
Islanded operation		Back-up power	Sustain a small power system temporarily disconnected from the grid.		- Bidirectional (V2B) -Islanding capability		Security of supply /Independence
		Fully off-grid	Sustain a small power system permanently disconnected from the grid.				
Building (behind the meter)	Mobile load serving	Vehicle-to-tool	Provide a mobile power-source for equipment during in-field use.		- Bidirectional (V2L)		Access to mobile power source
		Vehicle-to-Vehicle	Provide energy directly from one vehicle to another.				





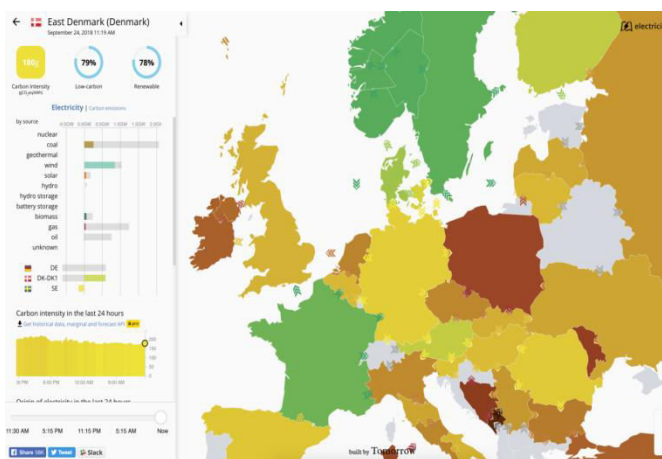
Services Tested In Parker

Service	Description
SYSTEM-WIDE SERVICES	
FCR-N DK2 -Frequency Containment Reserve (ENTSO-E)	Keeps the frequency in an interval around 50 Hz
FCR-N DK2 - Frequency Containment Reserve - very fast	Frequency regulation with ramping times and precision that go beyond what traditional power plants can provide
FCR-D DK2 - Frequency Containment Reserve - Disturbance	Activated when frequency falls under 49.900 Hz. Is active in the interval between 49.000 Hz and 49.500 Hz. Only up-regulation
Primary reserve, DK1 (FCR)	Keeps the frequency in an interval around 50 Hz
aFRR DK1 -Frequency Restoration Reserve (ENTSO-E)	Replaces Frequency Regulation and restores the frequency to 50 Hz
Marginal Emission Factor CO2	Charge the EV to minimize the CO2 emission from power sources
DISTRIBUTION-GRID SERVICES	
Congestion Management	EV is responding to the total feeder current measurement of its respective phase.
Local Voltage Support	Providing local voltage support, and partially mitigating the EV self-induced low voltages.
USER SERVICES	
	Not tested

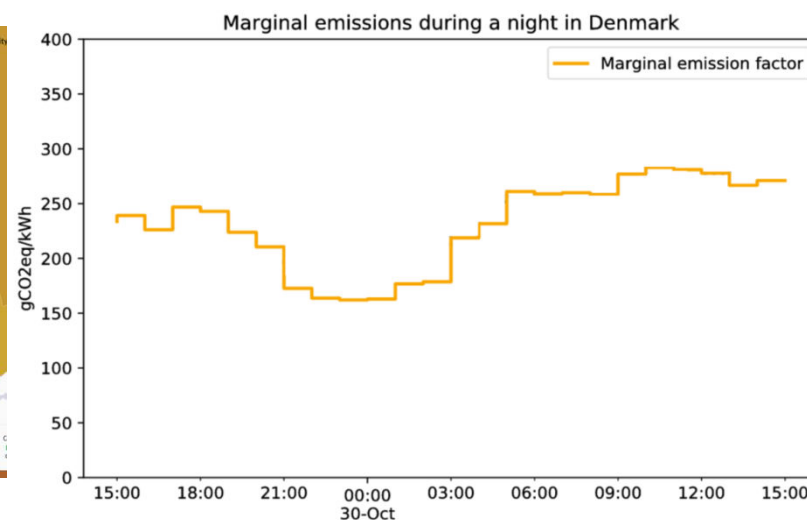


Marginal CO2 Emission Factor

A service that seek to support low-emission energy production by postponing charging to hours with the lowest marginal emission (gCO₂/kWh)



Tomorrow



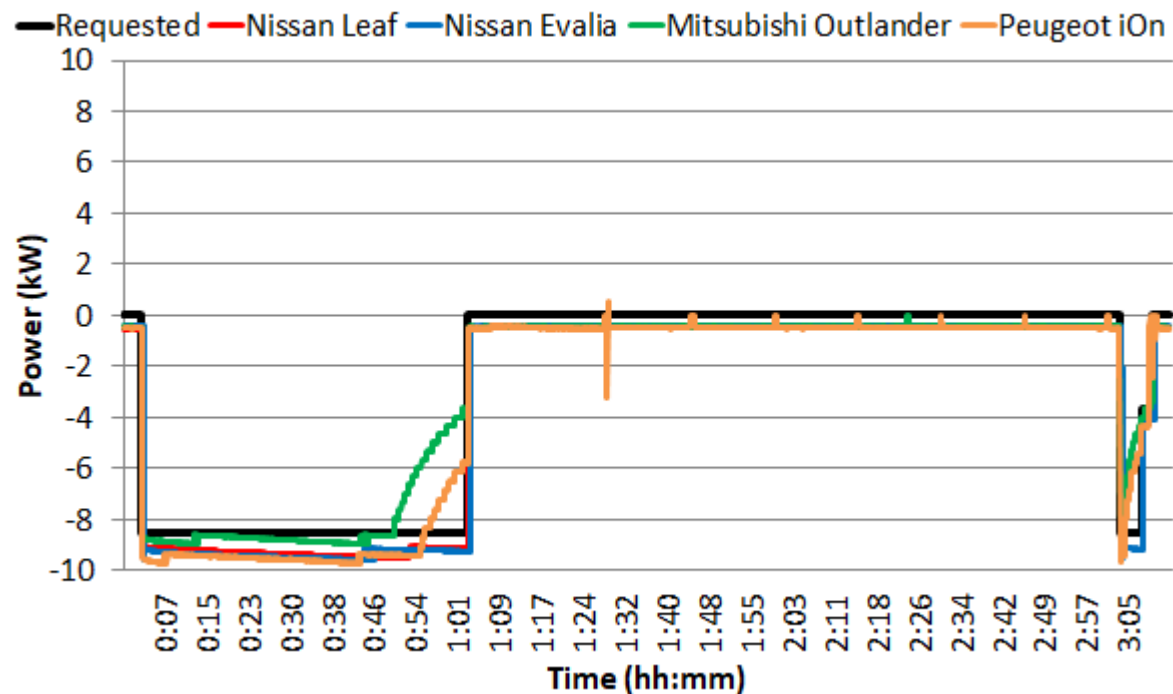
The service does not depend on V2G and does not have high requirements to activation time (informally: smart charging)

<https://www.electricitymap.org>

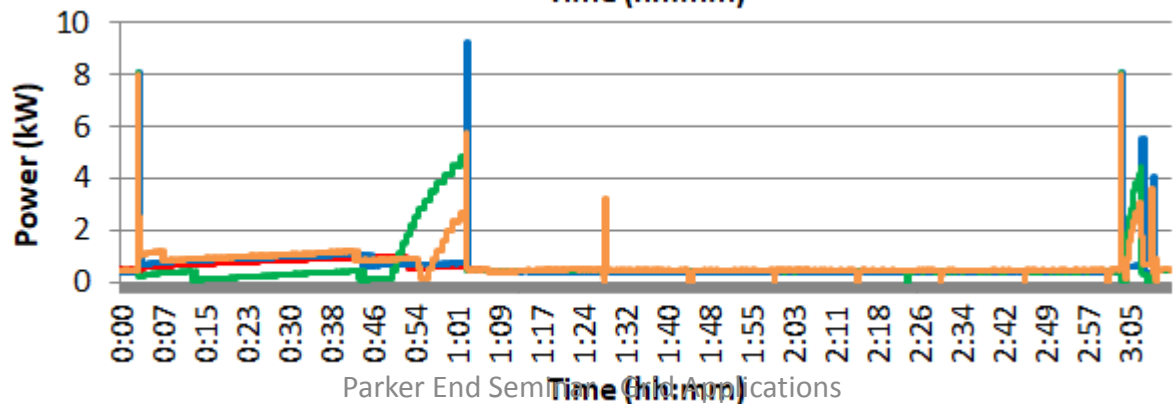


Service – Marginal Emission Factor

Requested
and
provided
power

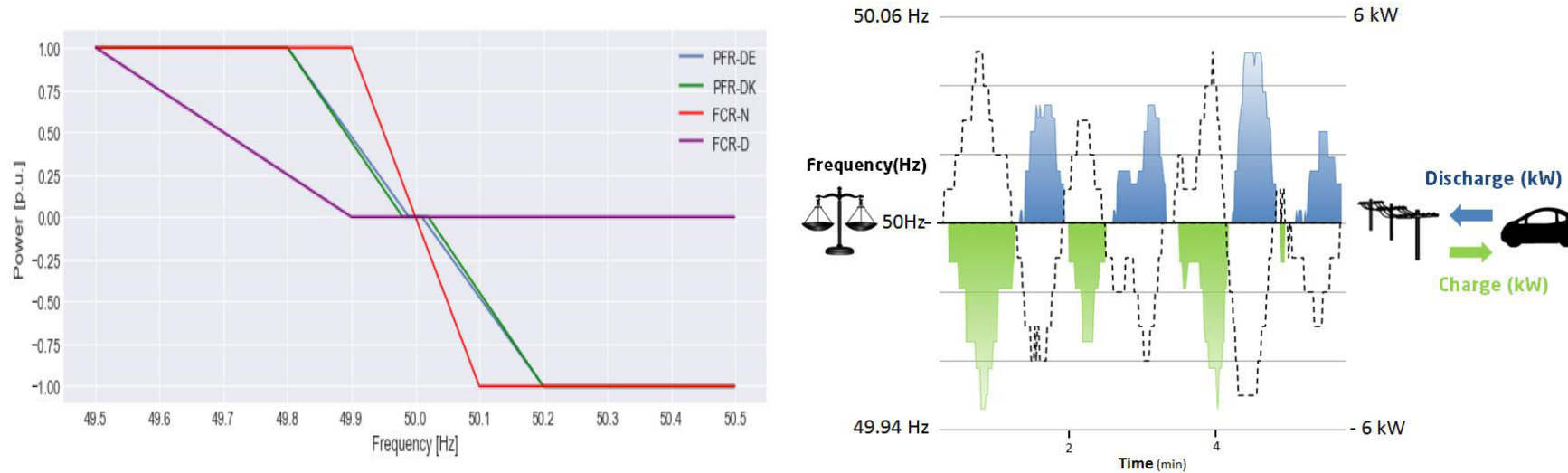


Absolute
difference



Frequency Containment

An ancillary service that support the system balance by providing a fast response to deviations in system frequency according to a predefined droop function



May utilize V2G and requires a fast power response (150 sec down to 5 sec depending on the specific product provided)

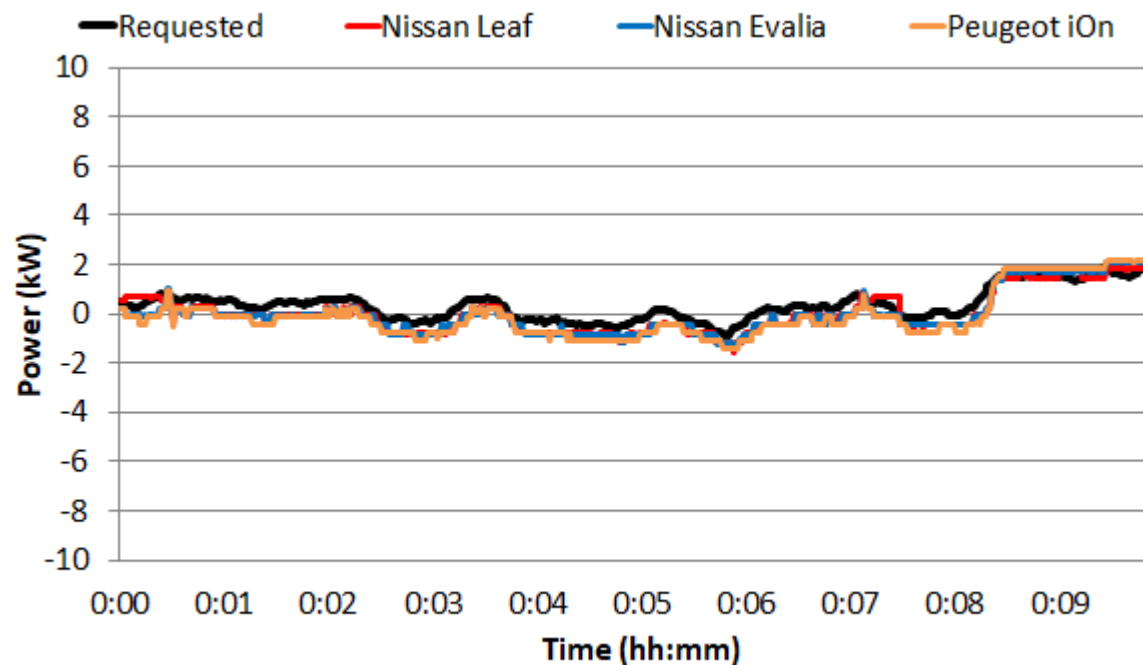




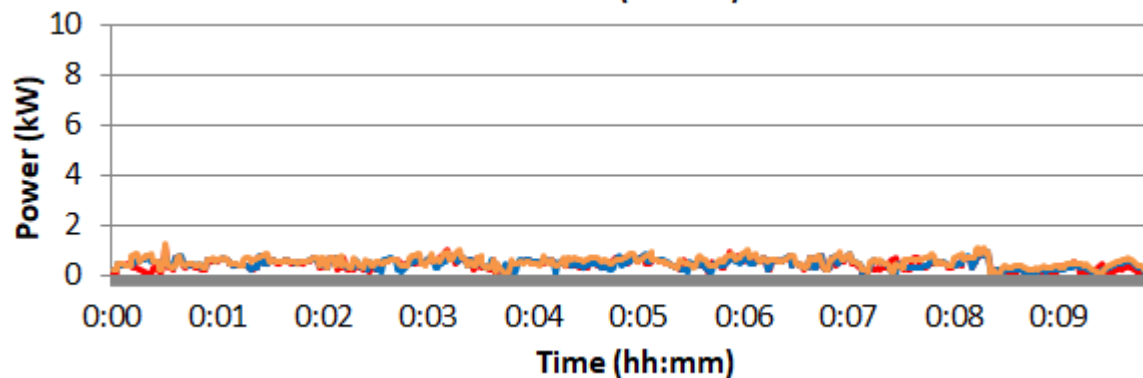
Cross-Brand Test Frequency Containment 1

Continental Europe Regional group

Requested
and
provided
power



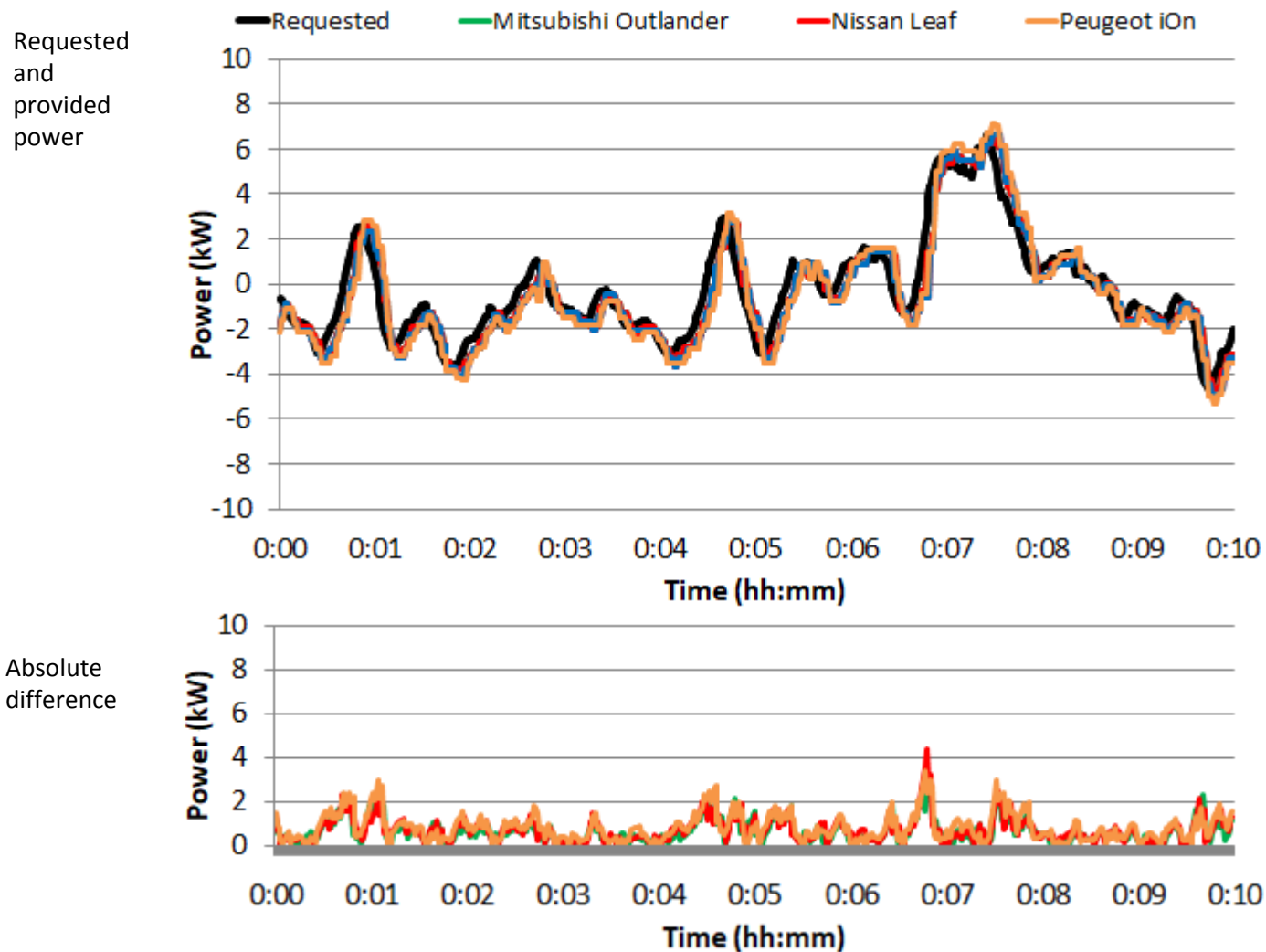
Absolute
difference





Cross-Brand Test Frequency Containment 2

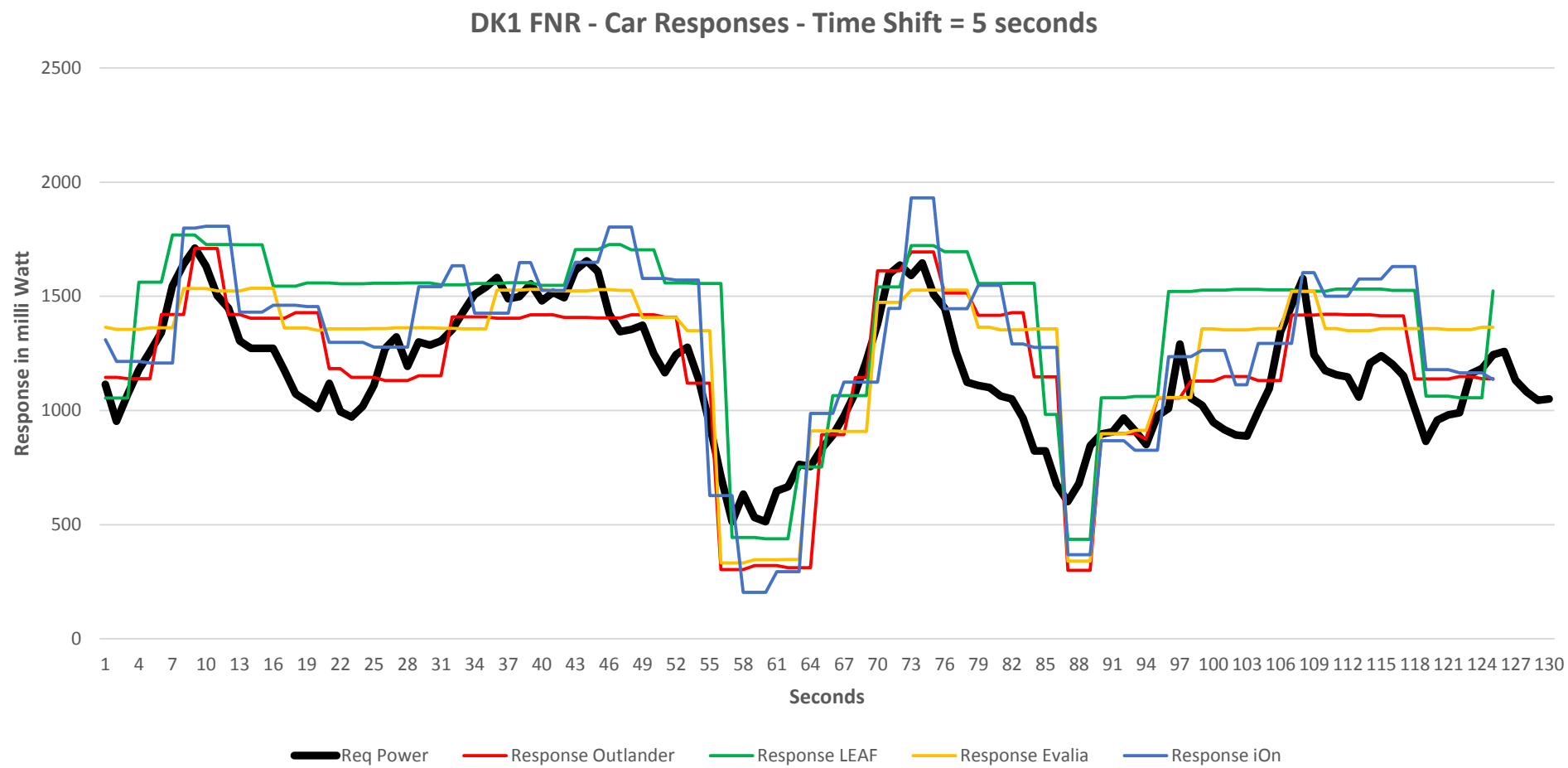
Nordic Regional group





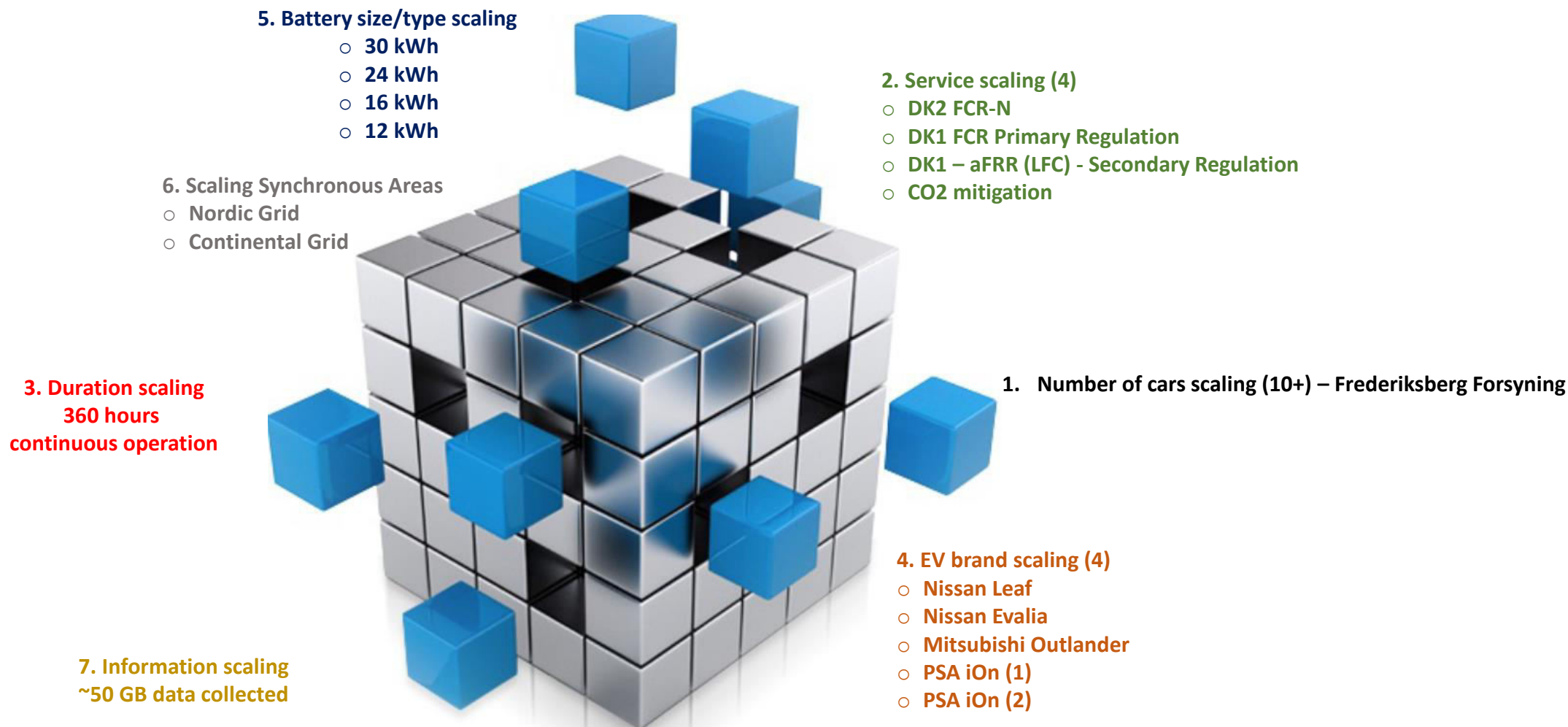
Cross-Brand Test Frequency Containment 2 (zoomed)

Nordic Regional group





Parker Has Demonstrated Scaling In Different Dimensions



Business Cases – Calculated Values

FCR-D DK2 Service – 14 hours per weekday and 48 hours in weekends @9.25 kW

DK2		
Period	FCR-D DK2 Price/MWh-h	Projected Yearly Revenue per car
Jan 01 - Dec 31, 2017	€7.45	€422.85
Jan 01 - Oct 2, 2018	€19.56	€811.29

FNR DK1 Service – 14 hours per weekday and 48 hours in weekends @ 9.25 kW

DK1				
Period	FCR-UP DK1 Price/MWh-h	FCR-DOWN DK1 Price/MWh-h	COMBINED DK1 Price/MWh-h	Projected Yearly Revenue per car
Jan 01 - Dec 31, 2017	€23.75	€1.51	€25.26	€1,549.95
Jan 01 - Oct 2, 2018	€30.16	€1.54	€31.70	€1,314.82





Frederiksberg Forsyning - Worlds First Fully Commercial V2G Hub



- Utility company – domestic gas, tap water, district heating and sewage
- Approximately 100.000 Residents
- Part of greater Copenhagen

- 10x Nissan eNV200 electric Vans
- 10x ENEL V2G units (bidirectional 10 kW)
- Used mainly for maintenance and service tasks.
- Driving usage hours = Work day 07:00 – 16:00
- Frequency Regulation 16:00 – 06:00 weekdays; 2X 24 hours weekends

Participants:

Customer



**Aggregator
Project Leader**



Cars



Charging Stations



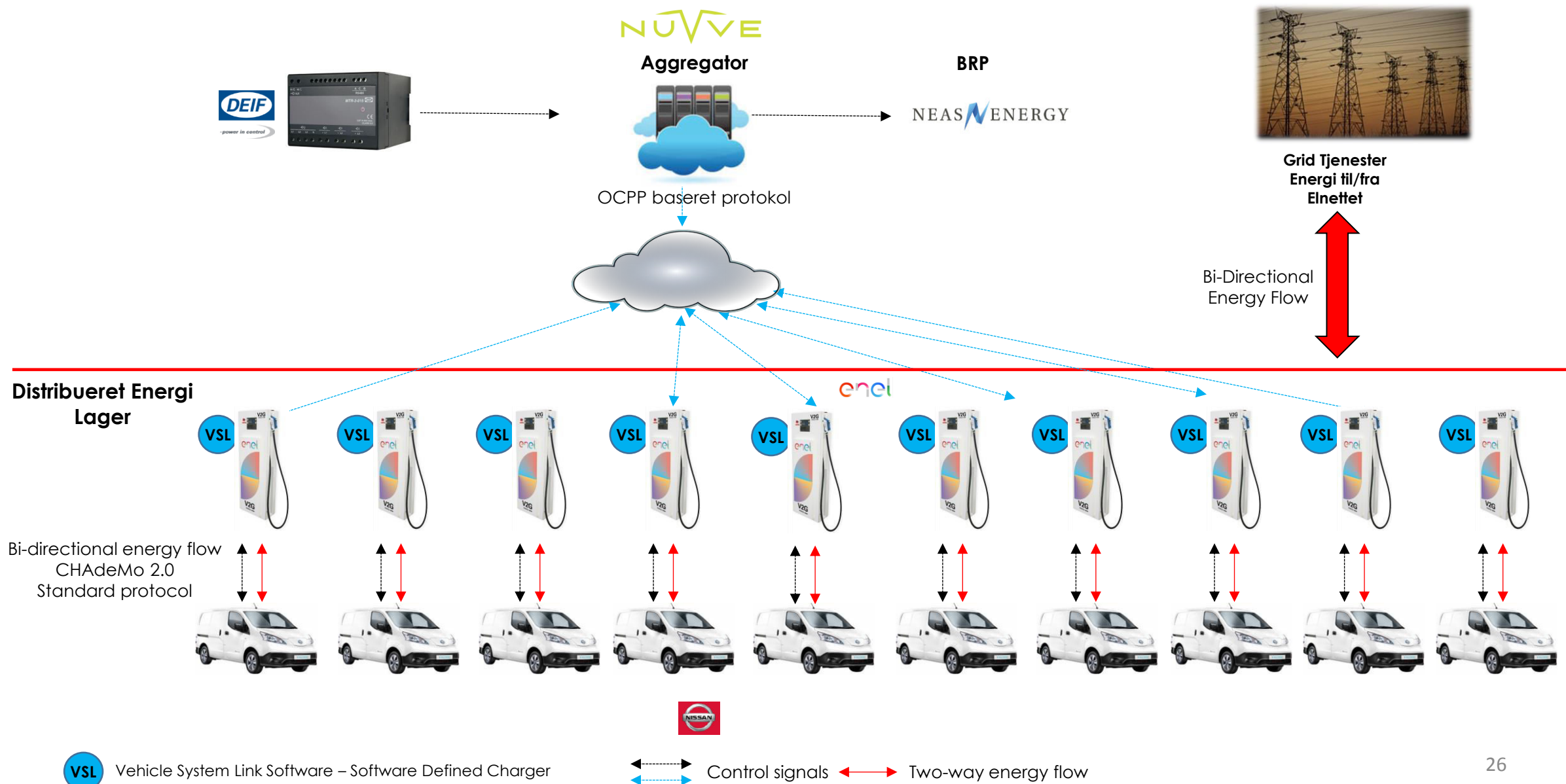
BRP



TSO

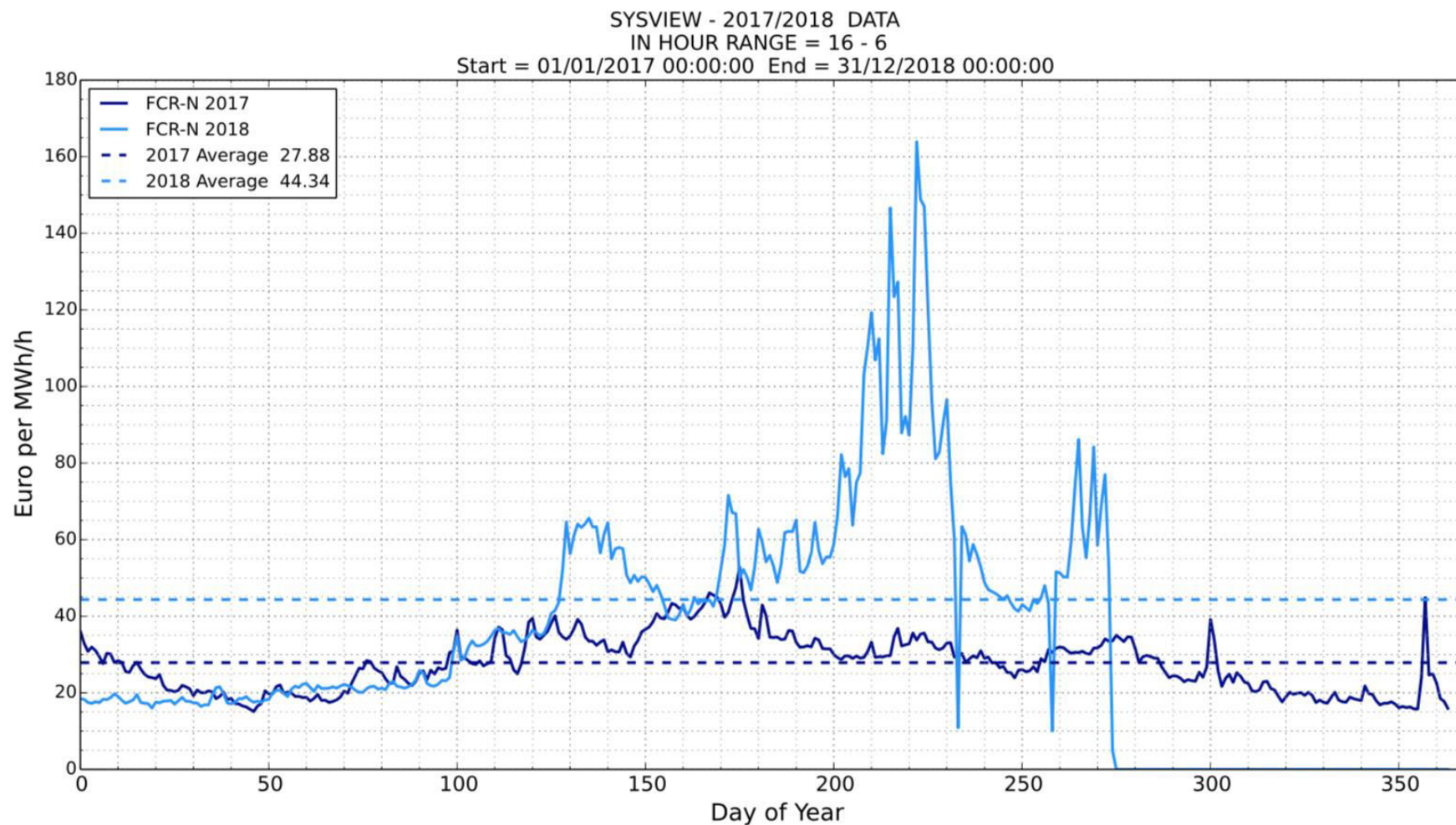


Frederiksberg Forsyning (FF) Configuration

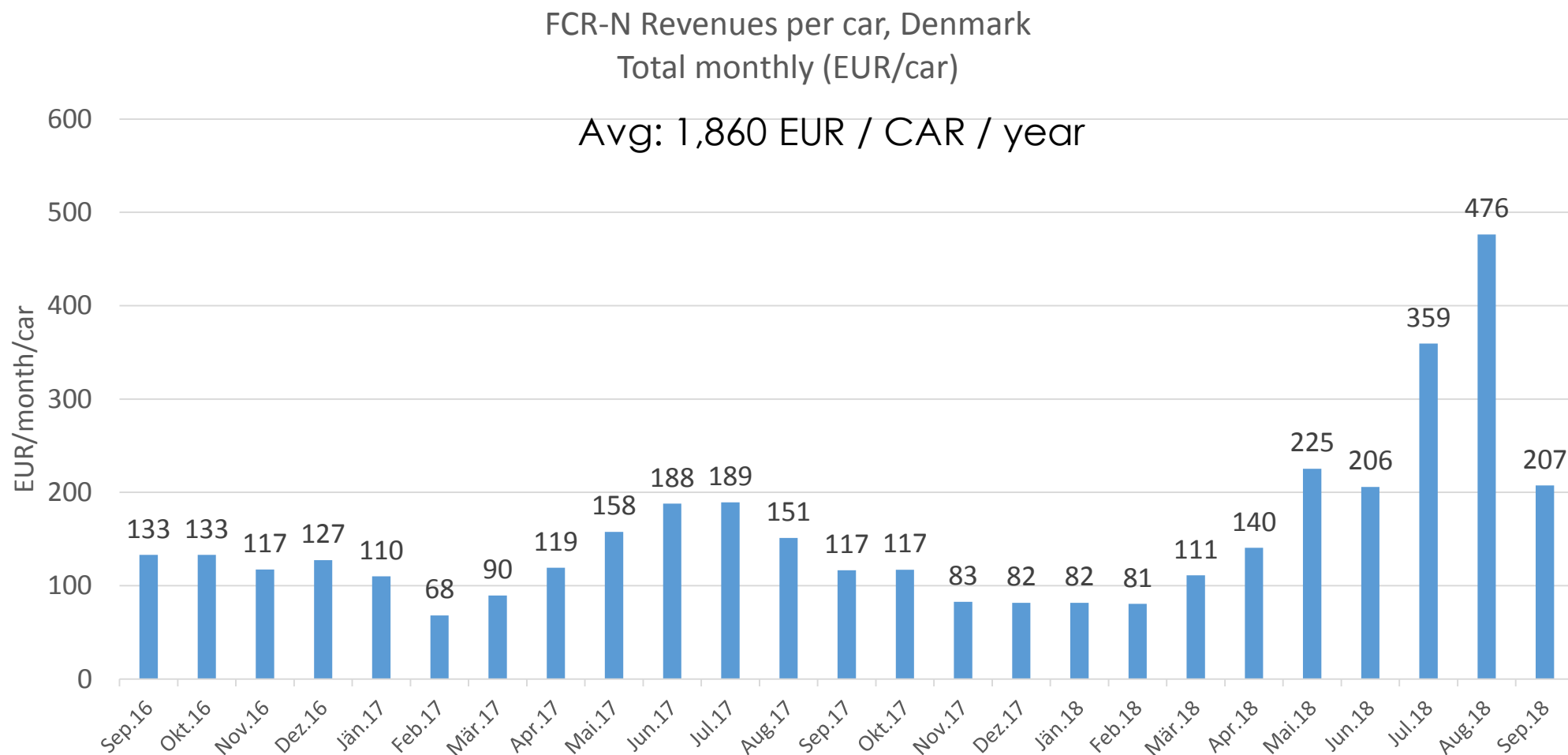


DK2 FCR-N Availability Payments 2017 – 2018

Prices varies from year to year and within year



Frederiksberg Forsyning - FCR-N Revenues Per Car Bid



Frederiksberg Forsyning - FCR-N DK2 Revenues 2017 – 2018

DK2 14 hours per weekday and 48 hours in weekends @9.25 kW		
Period	FCR-N DK2 Price/MWh-h	Projected Yearly Revenue per car
Jan 01 - Dec 31, 2017	€27.88	€1,582.41
Jan 01 - Oct 2, 2018	€44.34	€1,839.09



Barriers – Most Are In Process Of Being Addressed*

TECHNICAL

- TWO-WAY ENERGY LOSS
- LONG DURATION FREQUENCY BIAS
- POTENTIAL BATTERY DEGRADATION

MARKET

- MARKET MODELS FOR AGGREGATORS

REGULATORY

- SETTLEMENT METERS
- PRE-QUALIFICATION

TARIFFS AND TAXATION

- ENERGY TARIFFS AND TAXATION

INTERNATIONAL STANDARDS

- OCPP AND IEC 15118

* Except taxation – Net Billing or Net Metering





SUMMARY – The V2G Solution Is Scalable

1. Number of aggregated EVs
2. Multiple grid services
3. Multiple OEM brands
4. Two TSO regions
5. Multiple Battery Sizes
6. Duration





SUMMARY – The FF V2G Solution Work And Is Profitable

1. Technology works and is reliable
2. There is a market
3. Business cases can be made
4. Customer accepts the solution





World's First Commercial V2G Operation - Denmark

10

Nissan e-NV-2001 V2G EVs at Frederiksberg Forsyning

100

Hours of V2G commercial operation per EV per week

13,000

Hours of V2G commercial operation since September 6, 2016 for one EV

130,000

Hours of V2G commercial operations for 10 X Nissan e-NV200

130,000

kWh returned to the grid = 21 one family houses consumption per year

130,000

kg CO2 emission saved

€1,860/Year

average per car/year, market participation revenue generated

