

# A Greener Denmark

## Intelligent Integration of Electric Cars in the Danish Grid

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June 26, 2018

Presentation to Folketingets Energi-, Forsynings- og  
Klimaudvalg - June 28th, 2018

## Denmark's Ambitious Energy Plans

“verdens første CO<sub>2</sub>-  
neutrale  
hovedstad i 2025”



June 26, 2018

Vi skal videreføre en ambitiøs og bæredygtig grøn omstilling.

Danmark er et foregangsland inden for grøn omstilling og energieffektivitet. Den position skal vi fastholde, da den også har stor betydning for grøn eksport og danske arbejdspladser. Vores førerposition er skabt over årtier, hvor Danmark har haft et højt ambitionsniveau. Dette skal vi også fastholde, for det skylder vi de kommende generationer.

REGERINGENS POLITIK A-A

### Energi, forsyning og klima



Foto: Colourbox

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# How can Denmark reach it's ambitious green energy goals?

## Reduce CO2 emission



## Reduce pollution in cities



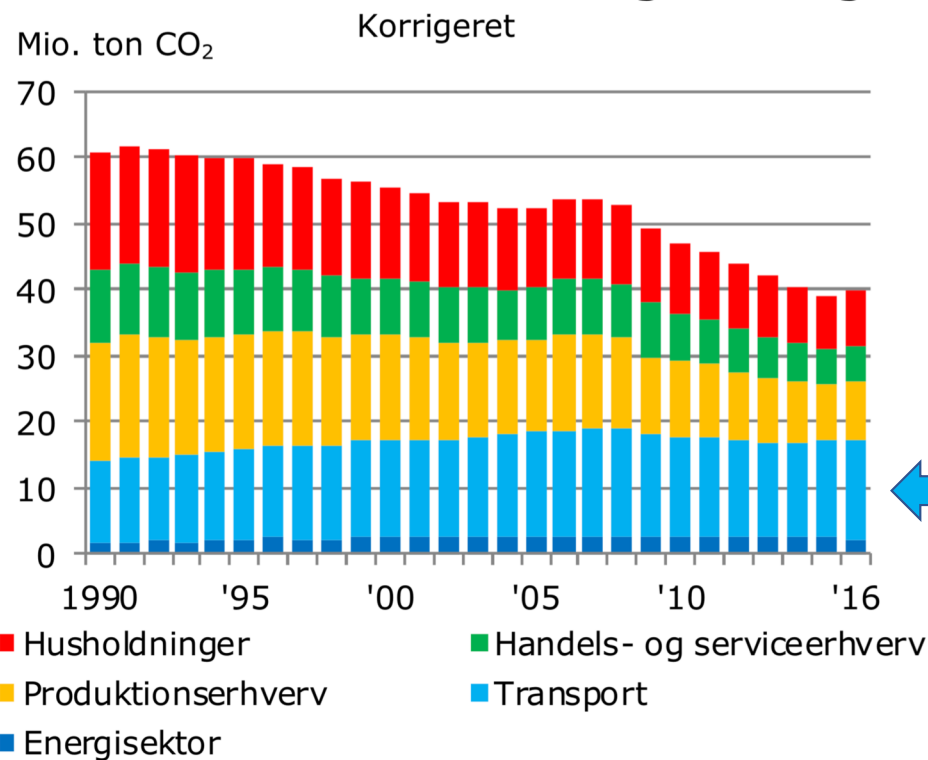
## Better utilization of wind energy



# Electrification of Transport Sector is Required for Deep De-carbonization

Transport Sector is a Major Source of CO<sub>2</sub> Emissions and Pollution in Denmark

## CO<sub>2</sub>-emissioner ved slutforbrug af energi



← **Transport = 37.7% (2016)**

Source: Energistyrelsen 2016 report

# Electric Cars are Key to the Solution

Can EVs be used for other things than driving  
and  
Can we lower the cost of EV ownership?



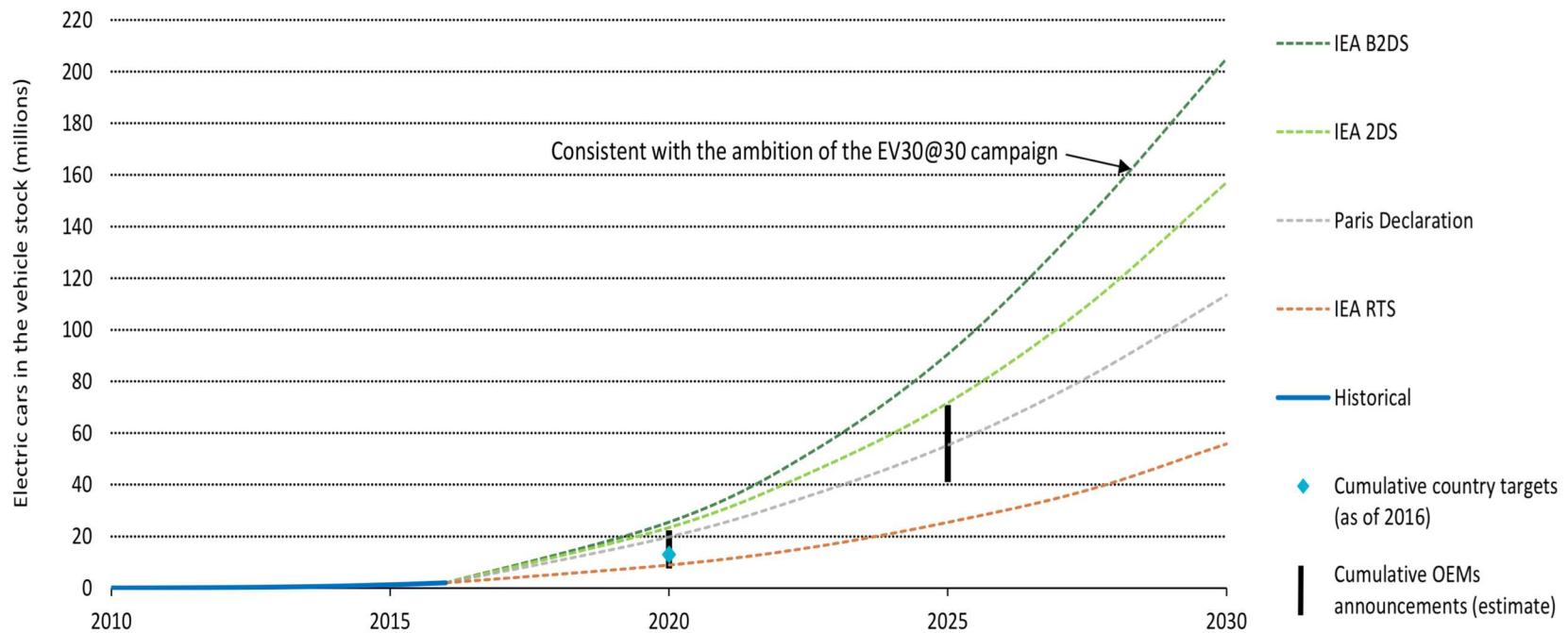
## Today's EV

- 40 – 60 kWh battery
- Uni/Bi-directional power flow
- Used 2 – 3 hours per day for driving
- Stranded asset 21 – 22 hours a day
- Battery already paid for by the owner

## But still too expensive

... and they are coming – World EV Market is Growing Fast  
 EV market inflection point in 2020/2021

**Figure 2 • Deployment scenarios for the stock of electric cars to 2030**



Source: IEA  
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## This will require massive investments in the electric grid

- Currently Denmark invests ~DKK 2.2 billion per year in upgrading the electric grid
- To handle large penetration of EVs much larger investments may be needed
- They will increasingly compete for public funding with
  - Education
  - Health care
  - Public pensions
  - Welfare programs

Unless smart V2G solutions are employed - laying the groundwork now

# But Many EVs leads to congestion in grid

The grid was designed for consumption and not for charging cars

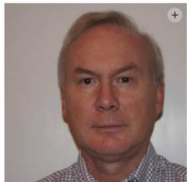
Average household consumption  
Average person consumption

4,900 kWh/year  
1,600 kWh/year

An EV driving 40 km/day

**3,650 kWh/year**

Norway is already experiencing grid congestion

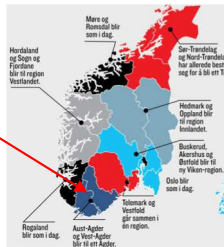


Rolf Eriend Grundt i Agder Energi  
Nett sier kraftige hjemmeladere for elbiler kan gi skjeve spenninger for både den som lader og også naboene.

– Hva må gjøres hvis det blir stadig flere kraftigere ladere hjemme hos folk?

– Da må strømnettet forsterkes med mer høyspentnett og lavspentnett og transformatorer. Bare her i Agder ville det koste

**over åtte milliarder kroner.**



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## Energistyrelsen

Årligt elforbrug i parcelthus		
	140 m <sup>2</sup>	200 m <sup>2</sup>
1 voksen	3.300 kWh	3.700 kWh
2 voksne	4.200 kWh	4.700 kWh
2 voksne og 2 mindre børn	4.900 kWh	5.300 kWh
2 voksne og 2 større børn	5.300 kWh	5.800 kWh



# With V2G Technology EVs Become Part of the Solution

EVs Provides a Large Distributed Storage Resource Paid for by the EV Buyer

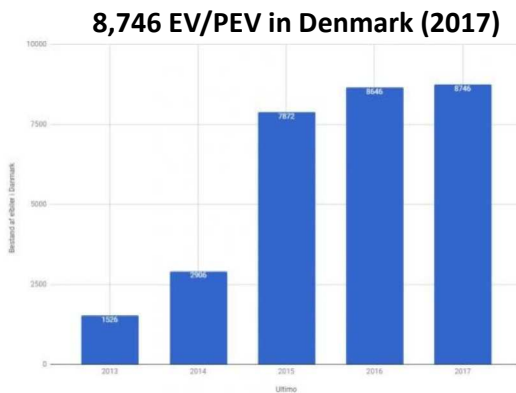
1,000 EVs	@ 40 kWh	40 MWh Energy	2 WT* @2 MW for 10 hours
100,000 EVs	@60 kWh	6,000 MWh Energy	3,000 WT @ 2MW for 10 hours
1,000,000 EVs	@ 60 kWh	60,000 MWh Energy	3,000 WT @ 2MW for 100 hours



# EVs Reduces the CO<sub>2</sub> Emission but must Scale to have a Real Impact

But Denmark has only 8,745 EV/PEV Dec 2017

8,500 EVs would reduce the yearly CO<sub>2</sub> emission\* from Transport with 39,000\* metric tons (~0.23%)!!  
 To reach a reduction of 30% Transportation caused CO<sub>2</sub> 1 Million EVs are required



Sådan har bestanden af elbiler udviklet sig i Danmark siden 2013. (Illustration: Danske Bilimportører)

\* Source: EPA - 1 car average CO<sub>2</sub> emission per year is 4.6 metric tons

\*\* Assuming the EVs would run on renewable energy only

## 1,076 EV/PEV sold in Q1 2018

### Top 5 over mest solgte elbiler og opladningshybridbiler

ELBILER	
	1. kvartal 2018
NISSAN LEAF	101
BMW I3	15
VW E-GOLF	14
TESLA MODEL S	13
TESLA MODEL X	13
ELBILER I ALT	156

OPLADNINGSHYBRIDER	
	1. kvartal 2018
KIA NIRO PHEV	317
VW GOLF GTE	265
KIA OPTIMA PHEV	78
VOLVO XC60 T8	68
VW PASSAT GTE	36
OPLADNINGSHYBRIDER I ALT	764
<b>ELBILER OG OPLADNINGSHYBRIDER</b>	<b>920</b>

Kilde: Bilstatistik.dk

## ... and the Charging Infrastructure must be in Place

A combination of public chargers and work place charger will make it more attractive for the population to acquire EVs.

Work place charging

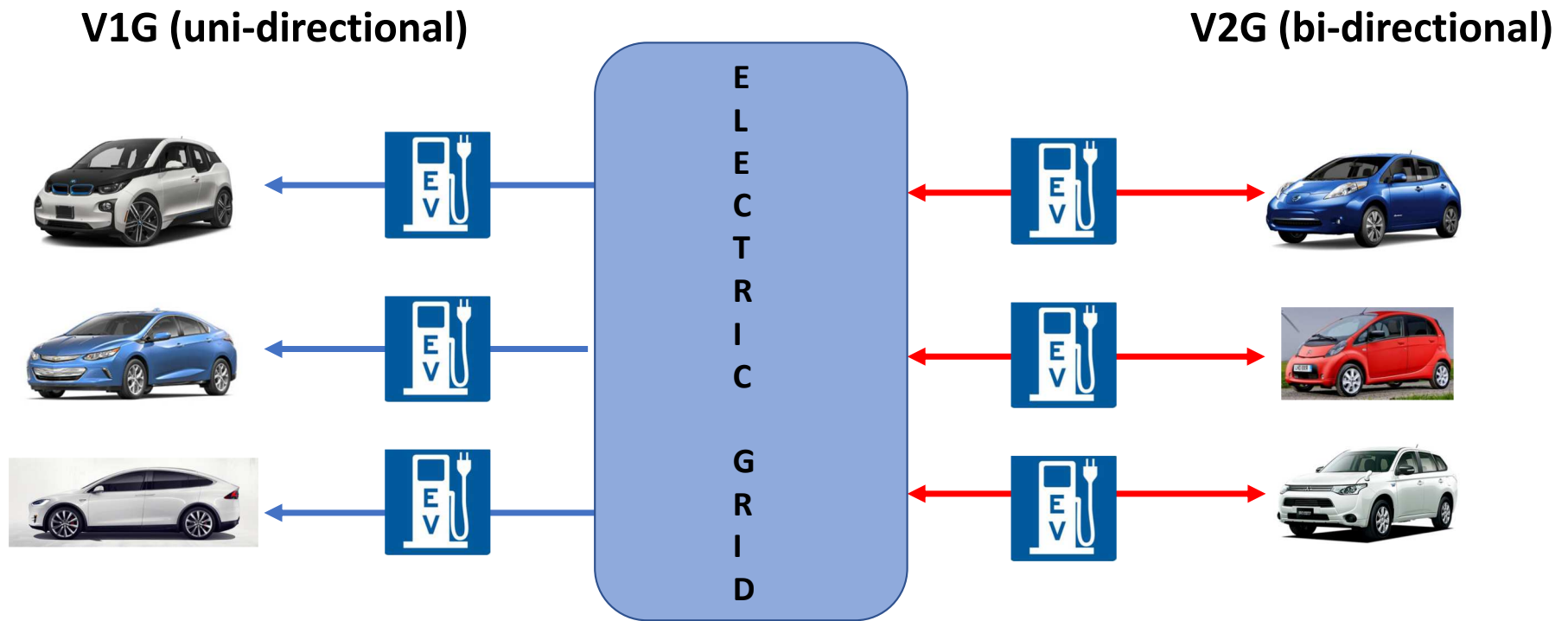


Public charging



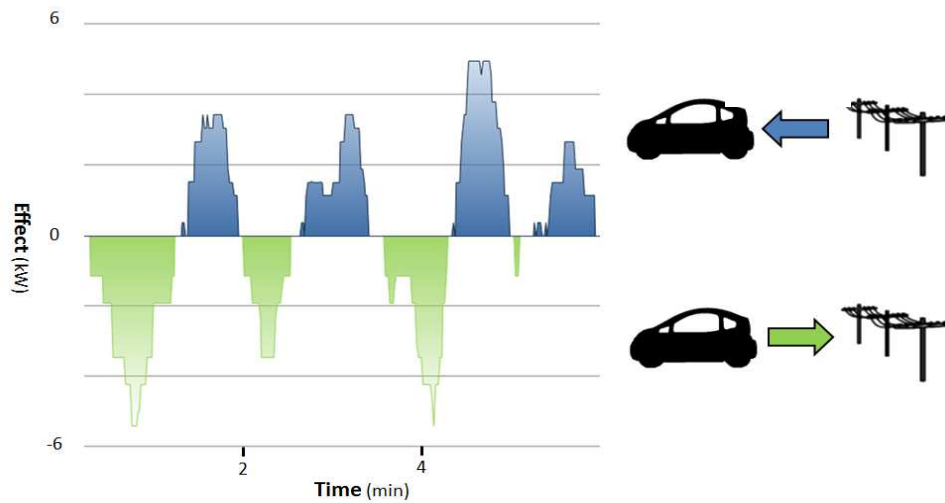
# Introducing Vehicle-to-Grid Concept (V2G)

Operating in harmony with the electric grid



# What is Vehicle-to-Grid (V2G)?

The EV functions as a large distributed energy storage that supports the electric grid



### Charging

When the grid has excess energy it stores it in the EV batteries

### Discharging

When the grid has too little energy the EVs returns the energy to the grid

The grid is for solar  
as  
The EV is for the grid

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## Barriers for V2G Solutions

### Danish tax laws

The V2G solutions helps the grid when it has excess energy to allow the grid to store energy in the EV batteries.

- When the grid needs energy the EVs can return the stored energy to the grid.
- The grid uses the aggregated EVs as a storage.

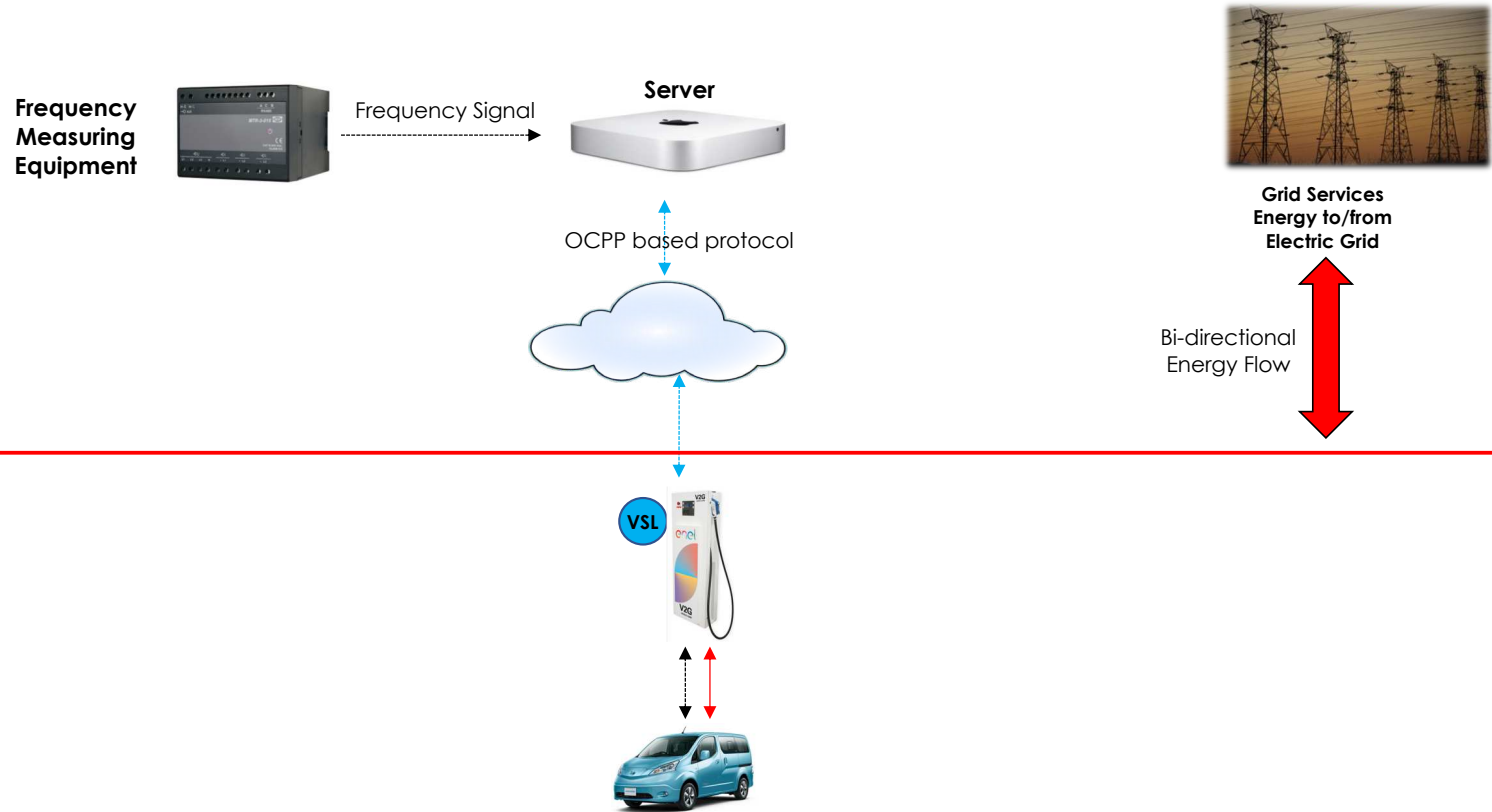
Since the V2G solution helps the grid they should not be “punished” with taxes and fees for providing a solution.

Current Danish tax laws treats energy that is stored in the EV and the same energy that is returned to the grid differently.

This leads to V2G solutions only being marginally profitable and not attractive for companies providing the solution.

The tax law should be changed to treat the energy for storage and the energy returned to the grid the same. I.e. only taxes and fees on net energy should be applied.

# How does V2G work?



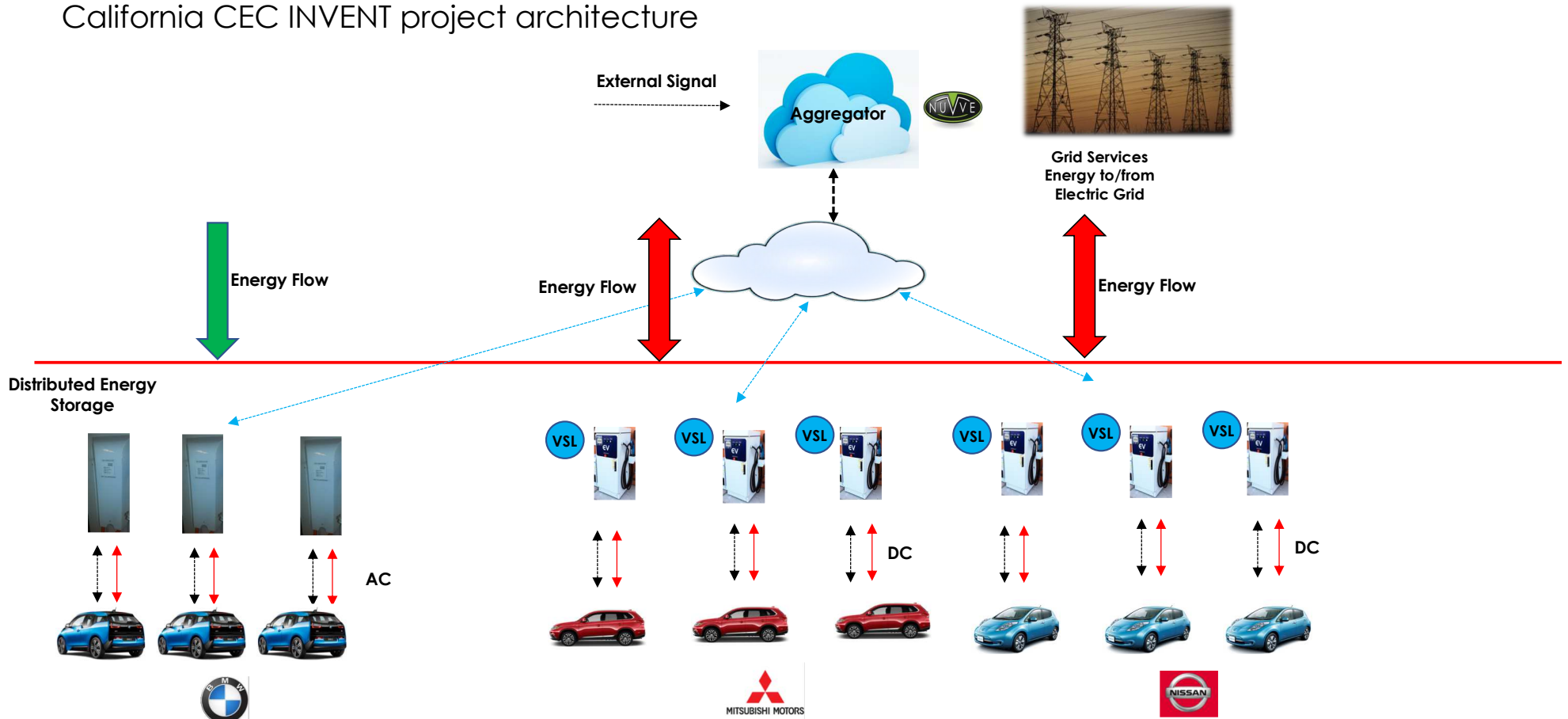
**VSL** Vehicle System Link Software – Software Defined Charging Station

Control signals     Bi-directional energy flow  
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# Aggregation of Many Cars to a Virtual Power Plant (VPP)

## California CEC INVENT project architecture





# Vehicle-to-Grid - How it all started - The Eureka Moment in 1996

Dr. Kempton University of Delaware (CTO of Nuvve) paper on using EVs for storage of energy



Pergamon

*Transp Res -D*, Vol. 2, No. 3, pp. 157-175, 1997  
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## ELECTRIC VEHICLES AS A NEW POWER SOURCE FOR ELECTRIC UTILITIES

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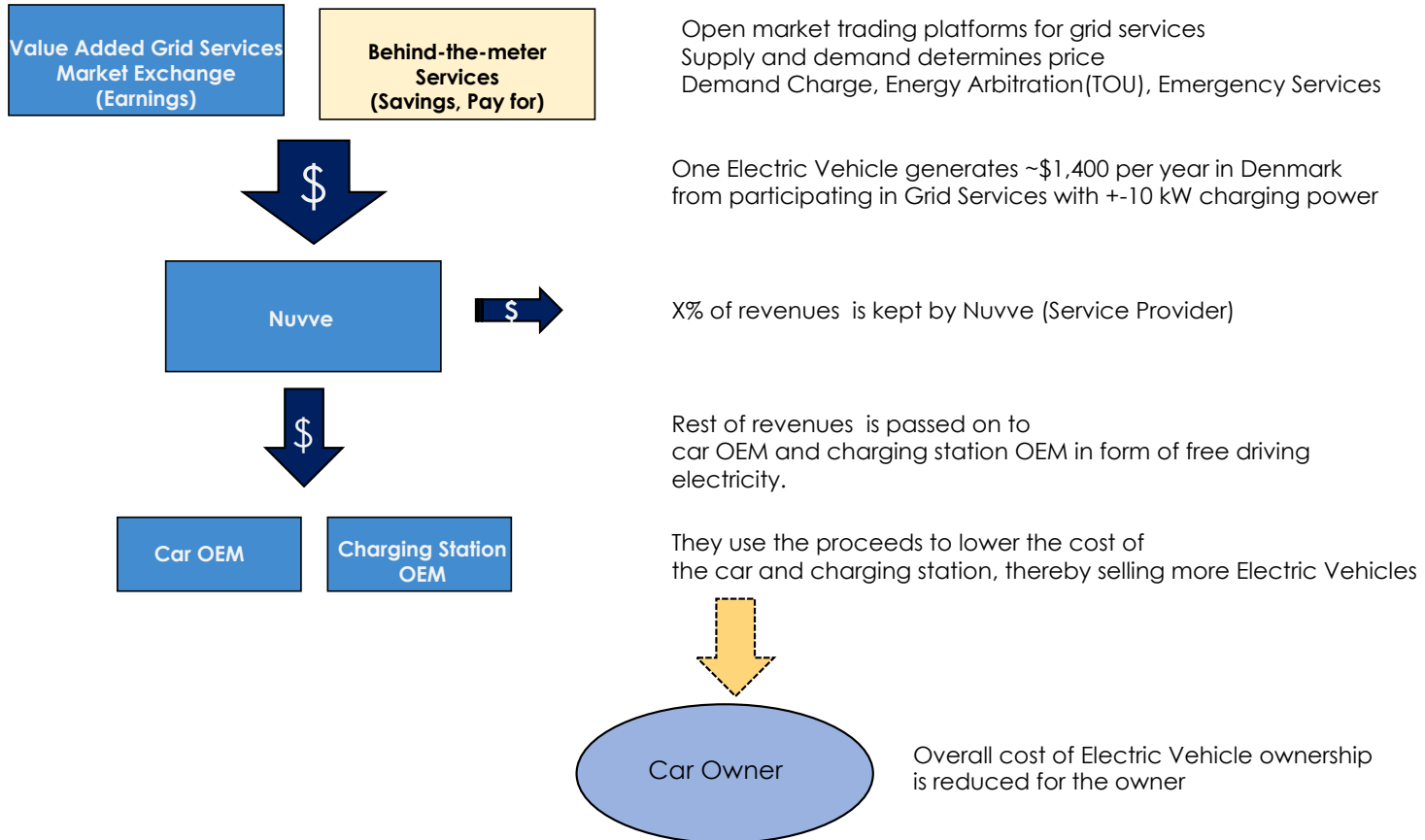
*(Received 26 August 1996; accepted 18 December 1996)*

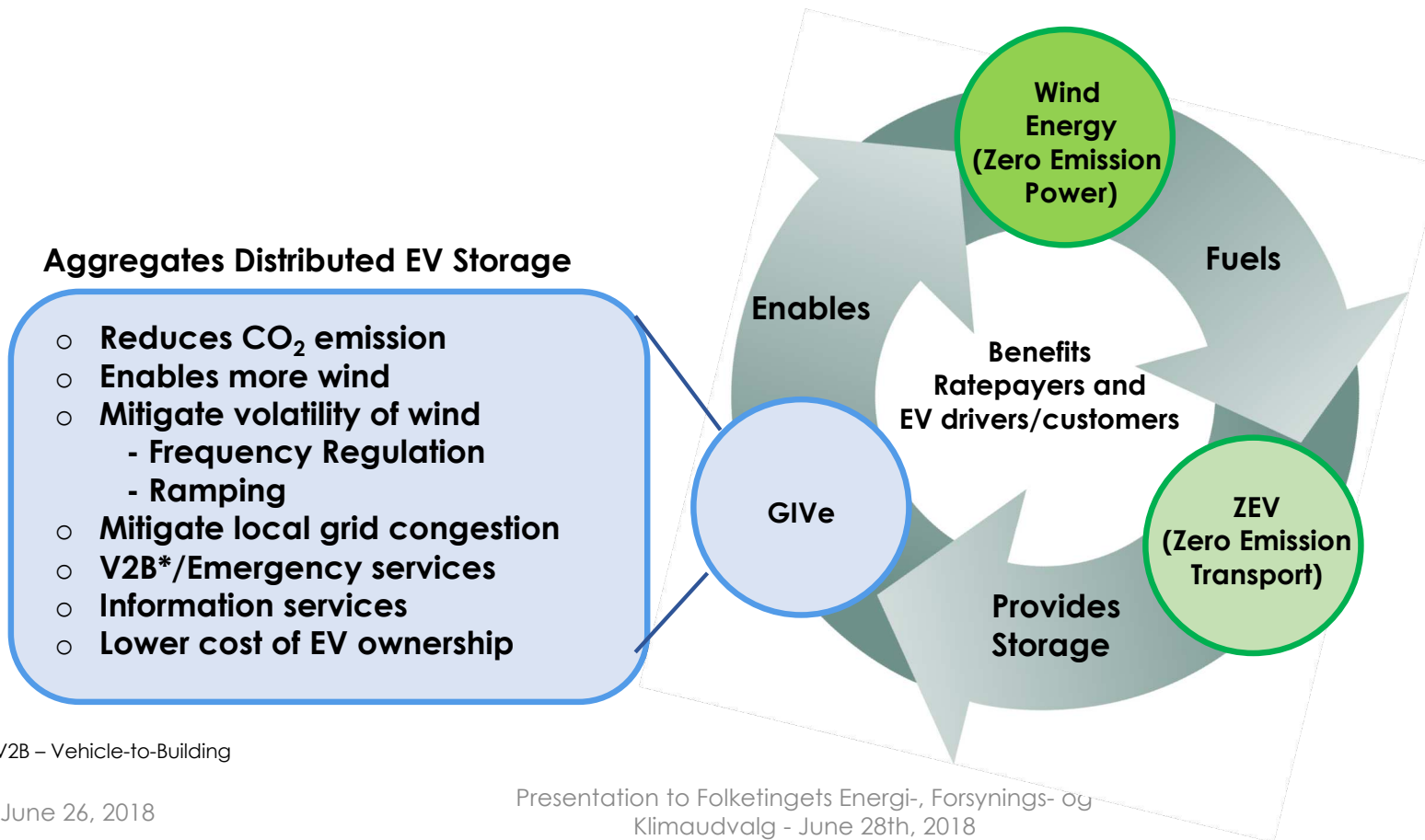


Dr. Kempton - 2009

# The Value Chain – Lowering Cost of EV Ownership

An example





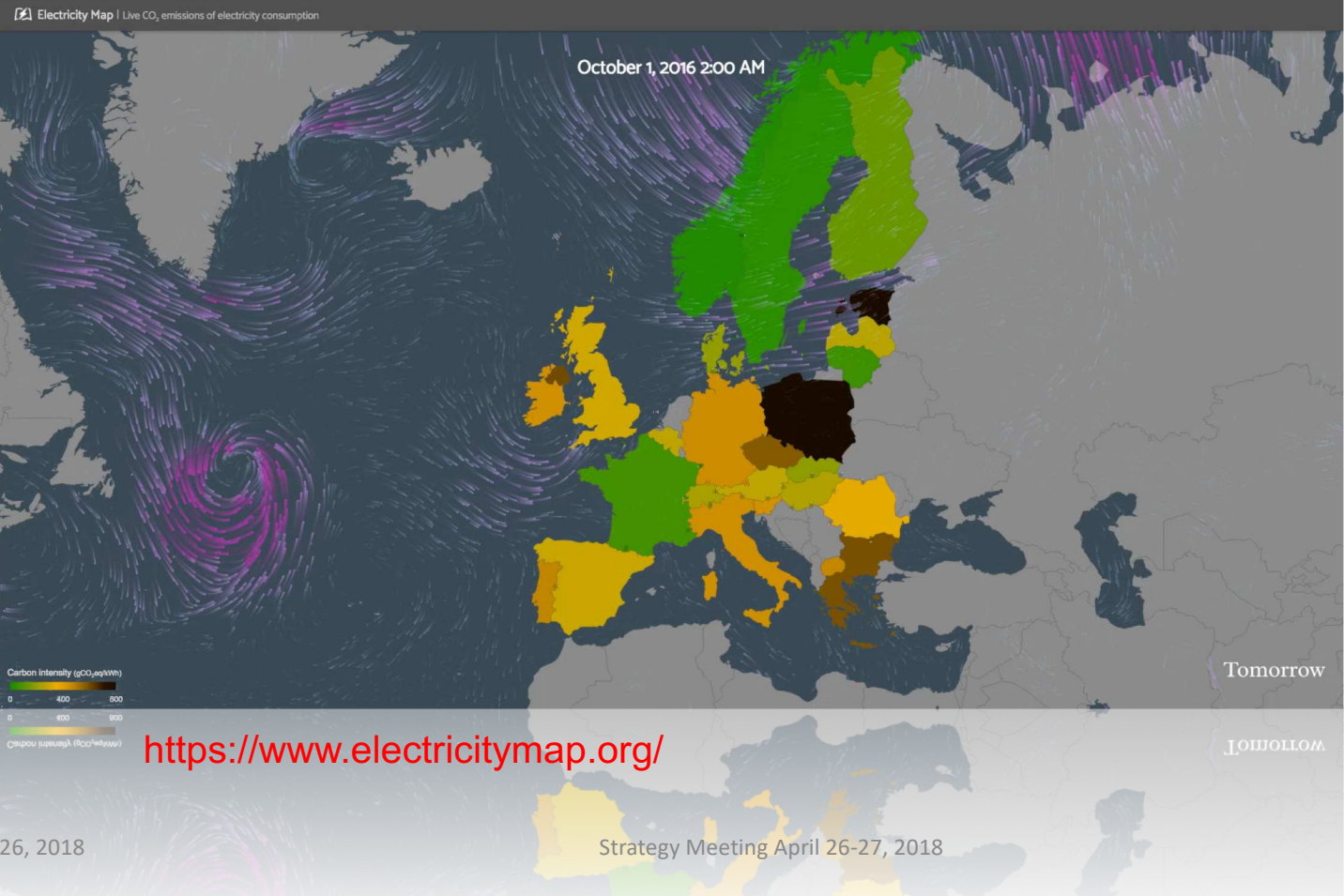
\* V2B – Vehicle-to-Building

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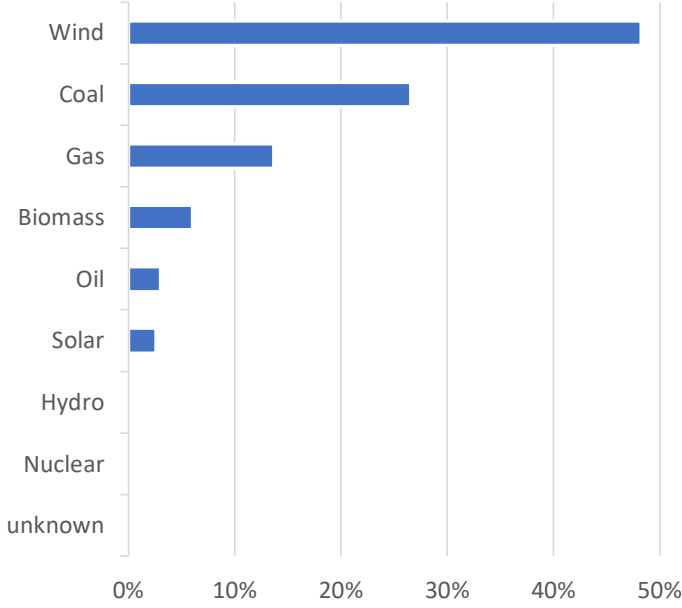
# CO<sub>2</sub> Emission Avoidance becomes ever more important

Nuvve working with the Danish startup Tomorrow

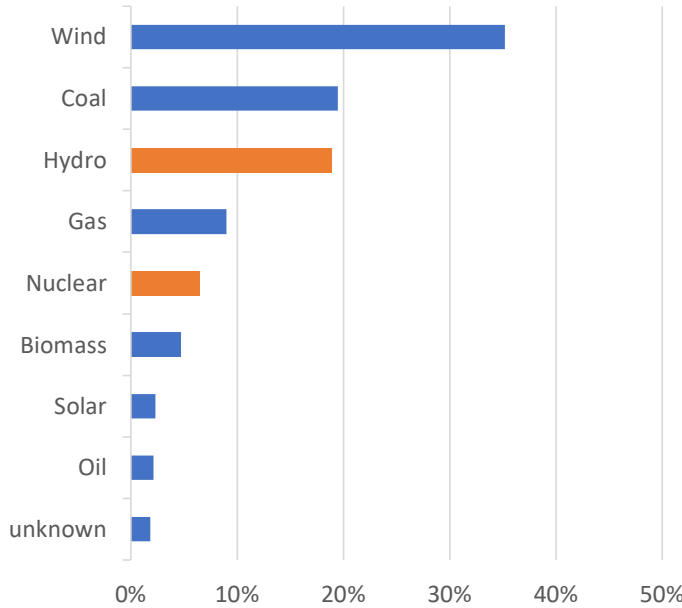


Cross-border electricity exchanges explain the difference between electricity produced in Denmark and electricity consumed by the Danish

Origin of electricity **produced**  
(2017, Denmark)



Origin of electricity **consumed**  
(2017, Denmark)



Source: data.electricitymap.org

tmrow.com

# How to Make the EV Owner Aware of where his EV electricity come from Example



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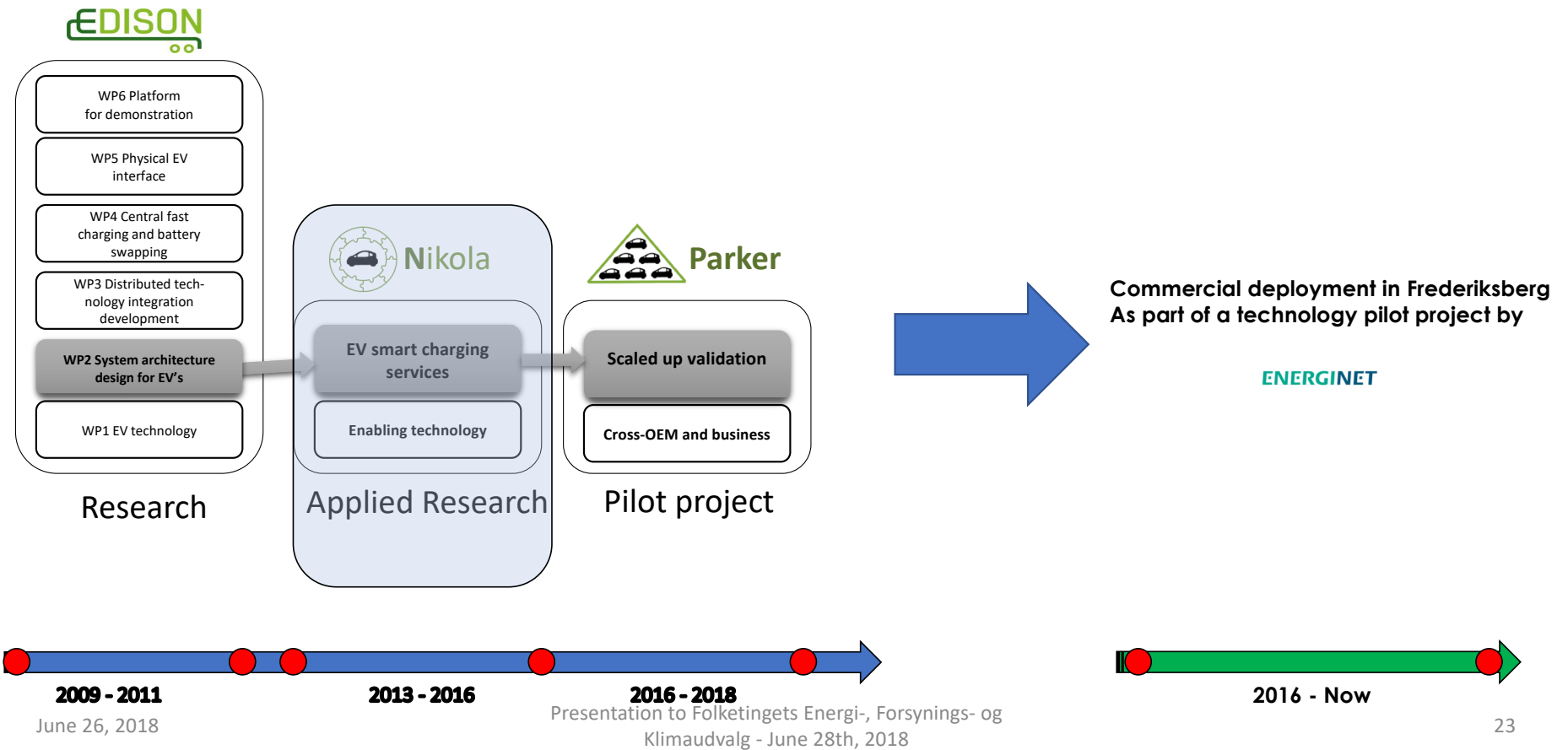


Strategy Meeting April 26-27, 2018



# DTU is a world leader in V2G Research

ForskEl has financed and paved the way for world's first V2G commercial deployment at Frederiksberg, Denmark



# Frederiksberg Forsyning - World's first Commercial V2G Operation

Operating since September 6, 2016

**10**

**Nissan e-NV-2001 V2G EVs at Frederiksberg Forsyning**

**100**

**Hours of V2G commercial operation per EV per week**

**10,000**

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

**100,000**

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

**100,000**

**kWh returned energy to the grid = 16 one family houses consumption in DK/year**

**100,000**

**kg CO2 emission saved**

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# Nuvve Services

## Region



- Frequency Regulation
- Demand Response

## Community



- Fast charging
- Demand Charge Reduction (Peak Shaving)
- Energy Shifting (TOU)
- Emergency services
- Minimal CO<sub>2</sub> charging

## Home



- Fast charging
- Energy Shifting (TOU)
- Emergency services
- PV Integration/Energy optimization
- Minimal CO<sub>2</sub> emission charging

# V2G Projects World Wide - Nuvve V2G Projects



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## Case Study California: Ambitious Goals Like Denmark's

**Senate bill 350 – Clean Energy and Pollution Act of 2015** (Statues of 2015) requires among others that the amount electricity generated and sold to retail customers from eligible renewable energy resources be increased by 50% by December 31, 2030.

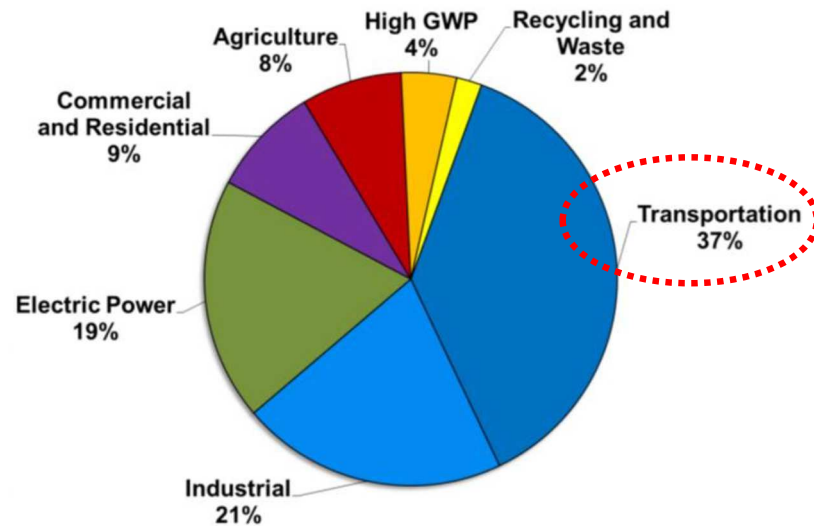
**Executive Order B-16-2012** - Governor Brown has set a target of reaching 1.5 million ZEVs on California roadways by 2025.

**CPUC Decision 13-10-040, “Decision Adopting Energy Storage Procurement Framework and Design Program”** policies and mechanisms for energy storage procurement were established with achieving a target of 1,325 megawatts of energy storage by 2020.

# Electrification of Transport Sector is Required for Deep De-carbonization

California CO<sub>2</sub> from Transport sector almost same as in Denmark

Figure 4. 2015 GHG Emissions by Sector\*

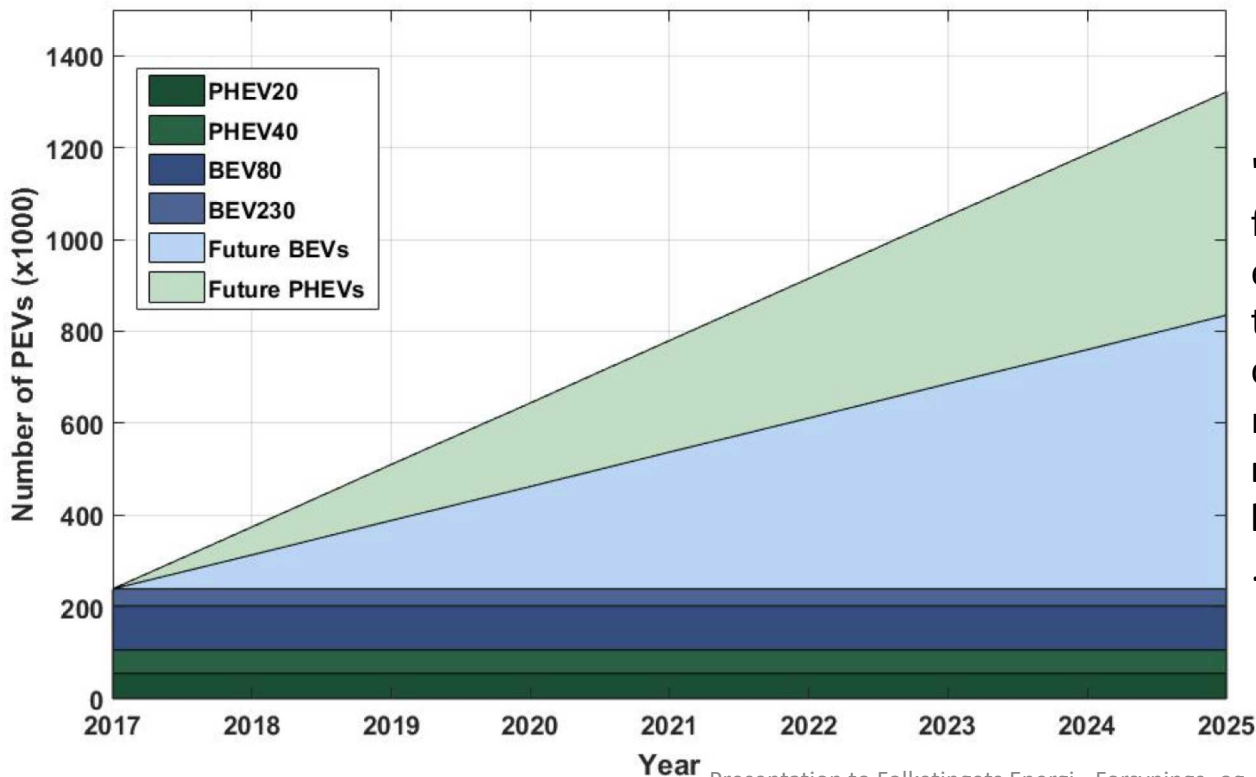


Source: EPA - Total Emissions in 2016 = 6,511 [Million Metric Tons of CO<sub>2</sub> equivalent](#)

# Case Study California: 1.5 million PEV by 2025//5.0 million by 2030

Goal requires massive scaling and incentives for Electric Vehicles

Figure ES.1: Shares of PEVs Input for the Default Scenario, 2017-2025



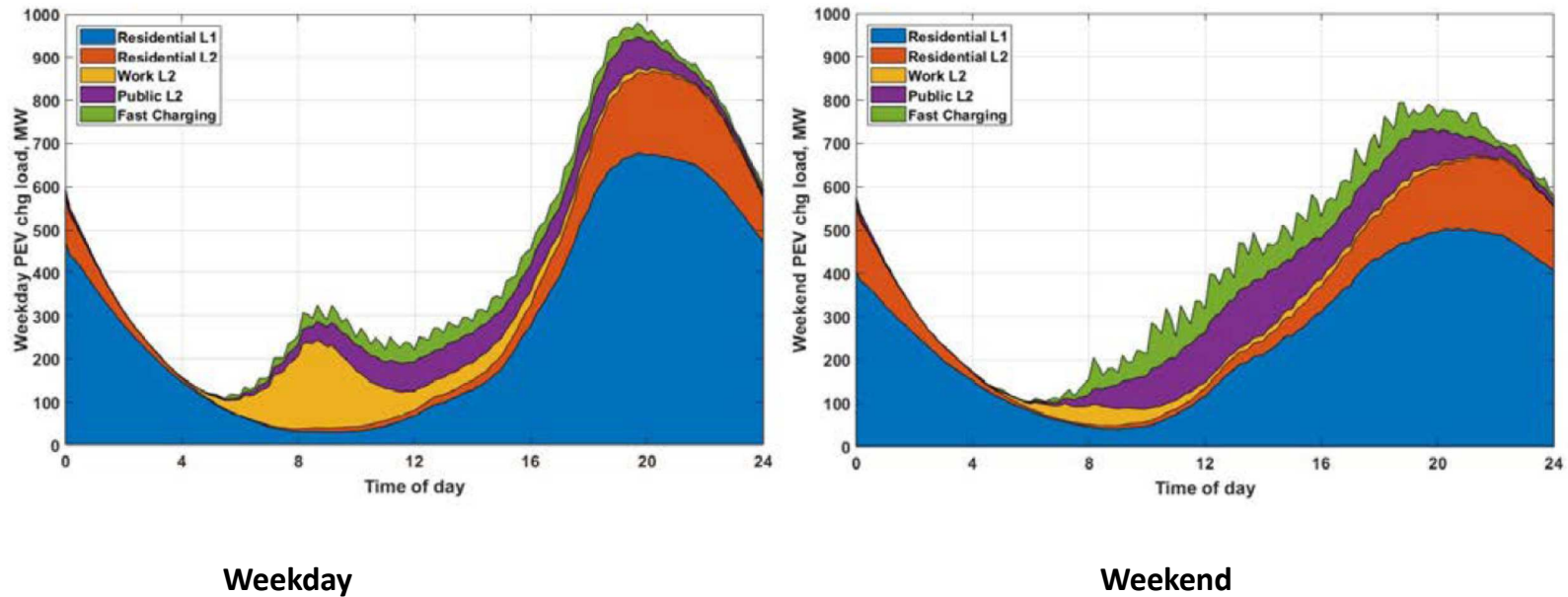
"The goal is to make our neighborhoods and farms healthier, our vehicles cleaner -- zero emission the sooner the better -- and all our technologies increasingly lowering their carbon output.," he said in the speech. "To meet our ambitious goals, **we will need five million zero-emission vehicles on the road by 2030.**"

... Gov. Jerry Brown, 2018 State-of-the-State

# 1.5 million PEVs need 1.5 GWh Electricity and 5 X More Chargers

## From Duck Curve to Dragon Curve

**Figure ES.2: PEV Charging Load Profiles in 2025**



# The California Duck Curve – 2020 Ramping 13,000 MW in 3 hours

The scaling must be massive

Equivalent to ...

**13 Nuclear power plants**



**4,300 Wind turbines**



**1,300,000 EVs**



Action: California has a goal of 1,500,000 Zero Emission Vehicles (ZEV) on the roads by 2025  
 Today June 2018 there are 400,000 ZEVs on California's roads.  
 2017 sales: 96,000; Annual growth rate: 29%

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## Proposal (1) – Kick-start the market

- Provide funds in “Energiforliget” to incentivize the installation of 3,500 new technology chargers
- Start in major cities will immediately reduce pollution in the cities
- Promote both public chargers as well as work place chargers
- Lower barriers for introduction of aggregated V2G EV solutions (only taxes and fees on net energy)

This will signal to the market that Denmark is serious about reducing transport generated CO2 emission.  
And will serve as a catalyst to bring private funding into the market for EVs and EV infrastructure.



## Proposal (2) – Kick-start the market

- Ensure that budget is allocated for V2G and V2G-Ready chargers:

2019	500 chargers
2020	1,000 chargers
2021	2,000 chargers

- Subsidy per V2G charger\*                      DKK 15,000
- Total cost    DKK 52 Million

\* For the charger and/or the installation costs

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## Benefits

This will allow Denmark to:

1. Accelerate CO<sub>2</sub> reductions according with the Climate Accord
2. Accelerate reduction in pollution in Copenhagen, Aarhus and other major cities
3. Reduce CO<sub>2</sub> emission by using more of the wind energy
4. Help make wind solution be more economical and potentially reduce subsidies

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## Summary

This initiative will additionally give Denmark a strong international position in green el technologies and digital energy solutions.

Denmark will be in a strong position to contribute to world-wide technological energy solutions.

It will make Denmark a center for a number of international projects and give Danish companies the possibility to contribute and export.

It will create high tech jobs in Denmark and further strengthen DTU's leadership.

Examples are:

- Tomorrow (example of a Danish company with CO<sub>2</sub> reduction information technology)
- The Danish Parker project <http://parker-project.com>



**Denmark a World Leader in Wind Energy**

**now**

**Become the Leader in Smart EV Energy Solutions**



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## Who are we?

- Nuvve is a San Diego, US based startup founded in 2010 with European HQ in Frederiksberg, DK
- Our mission is to integrate electric vehicles into the grid for the benefits of society, EV owners, the OEMs and the grid operators
- Our technology is based on University of Delaware research and Nuvve has acquired the IPs for the technology
- We are involved in projects in Europe, US, Japan and Africa
- We have launched the world's first V2G commercial operation in Denmark September 6, 2016

[www.nuvve.com](http://www.nuvve.com)