ACES (Across Continents Electric vehicle Services) project

scaling up the system integration

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Center for Electric Power and Energy

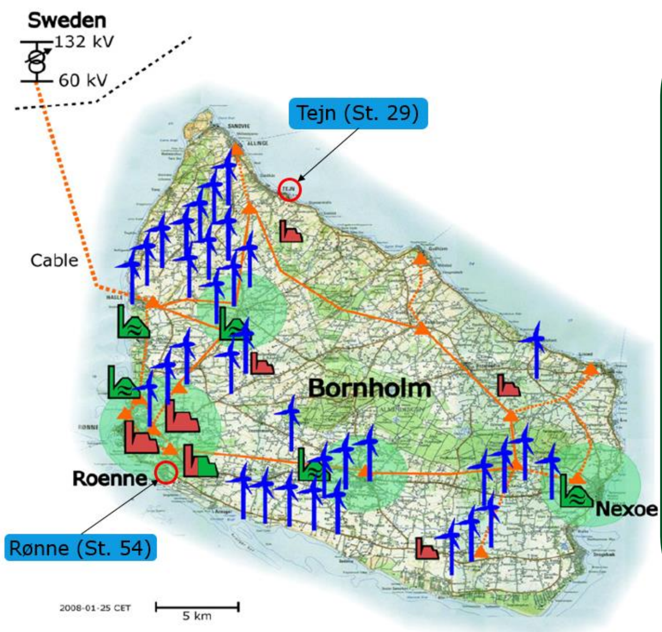
DTU Risø Campus

Outline

- **About the ACES project**
- **Investigated research areas**
- **The overall methodological approach**
- **The speakers and the topics in the session – quick overview**
- **Overall conclusions and the way forward**

The ACES project

Across Continents Electric vehicles Services



Budget: 10 MDKK (=1.4 M€)

Public grant (EUDP): 55 %

Equivalent person-months:

130 over 3y (04/17-03/20)

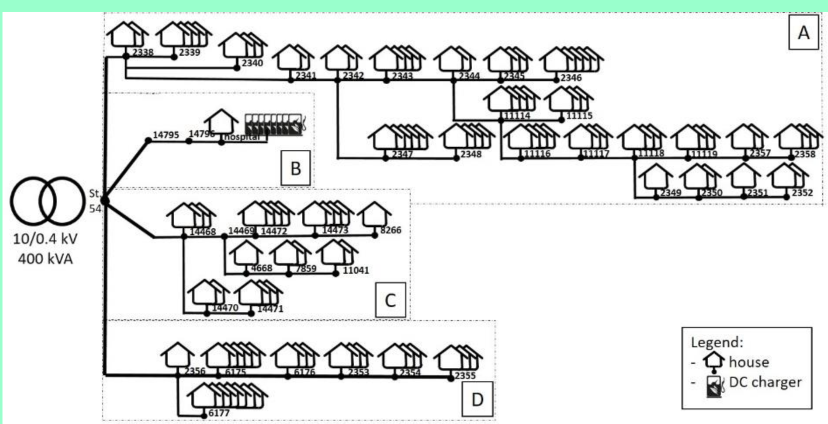
Public chargers and EVs used in the demo:

20 Nissan Leaf and env-200

DTU Elektro
Institut for Elektroteknologi

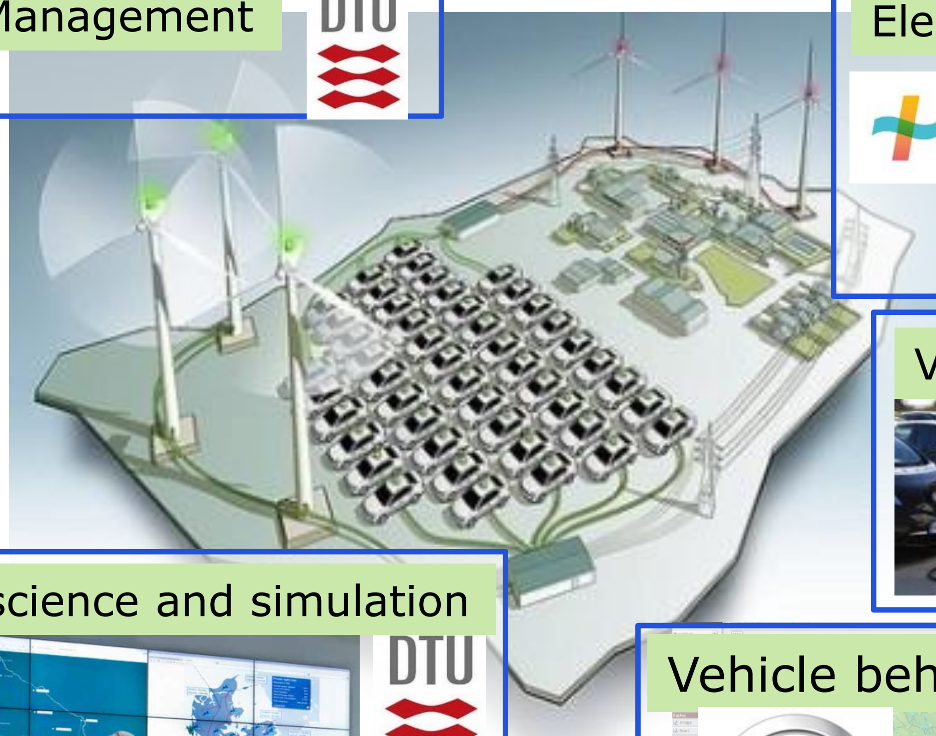
Distribution Feeder in Rønne

- LV grid: 400 V
- 10/0.4 kV 400 kVA distribution transformer
- 4 subfeeders: 110 known load consumptions
- **8 10 kW DC chargers**
- Common district heating



Project overarching objectives

Investigate technical and economic system benefits and impacts by large scale electric vehicles integration in Bornholm, augmented by real usage patterns, grid data and field testing for across continents replicability.



Proj. Management

DTU

Electric grid & energy data

BORNHOLMS ENERGI & FORSYNING

V2G field data

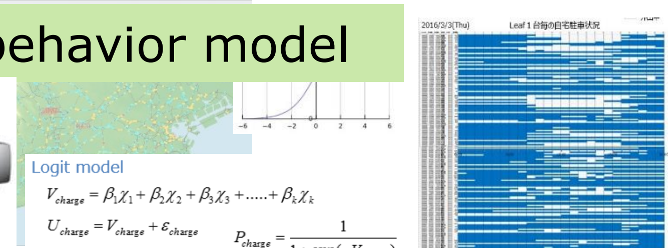
NUVVE

Data science and simulation

DTU

Vehicle behavior model

NISSAN



Logit model

$$V_{charge} = \beta_1\chi_1 + \beta_2\chi_2 + \beta_3\chi_3 + \dots + \beta_k\chi_k$$

$$U_{charge} = V_{charge} + \varepsilon_{charge}$$

$$P_{charge} = \frac{1}{1+\exp(-V_{charge})}$$

The 3 main research areas – some of the research questions

1. DSO vs TSO coordination and grid modelling

- Can a large set of EVs contribute to balance an islanded power system without inducing local grid issues?

2. EV aggregating functions

- Contract phase: for how long, how large, and how fast the aggregated power of EV fleet should be ready on a daily, weekly or monthly basis when contracting with the system operator?

3. Services economic and technical analysis

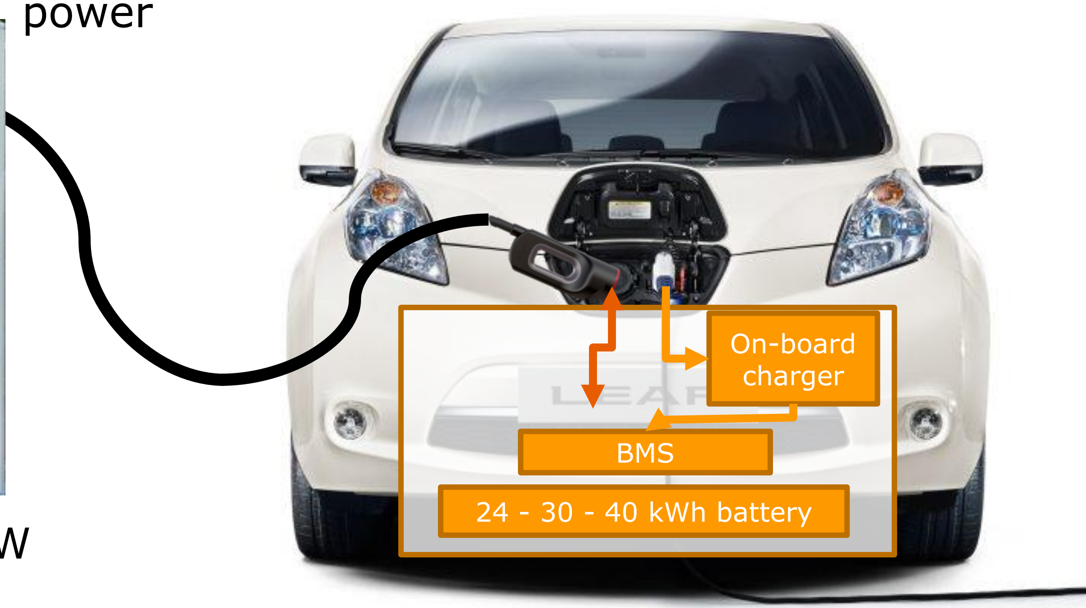
- How much the degradation of the battery, while providing system services, affects the service profitability?
- What is the saturation level of the ancillary service market in term of EV population?

Investigated AC and DC (V2G) charging/control options for EVs

Grid power ⟷ Battery power

+/- 10 kW

3-phase

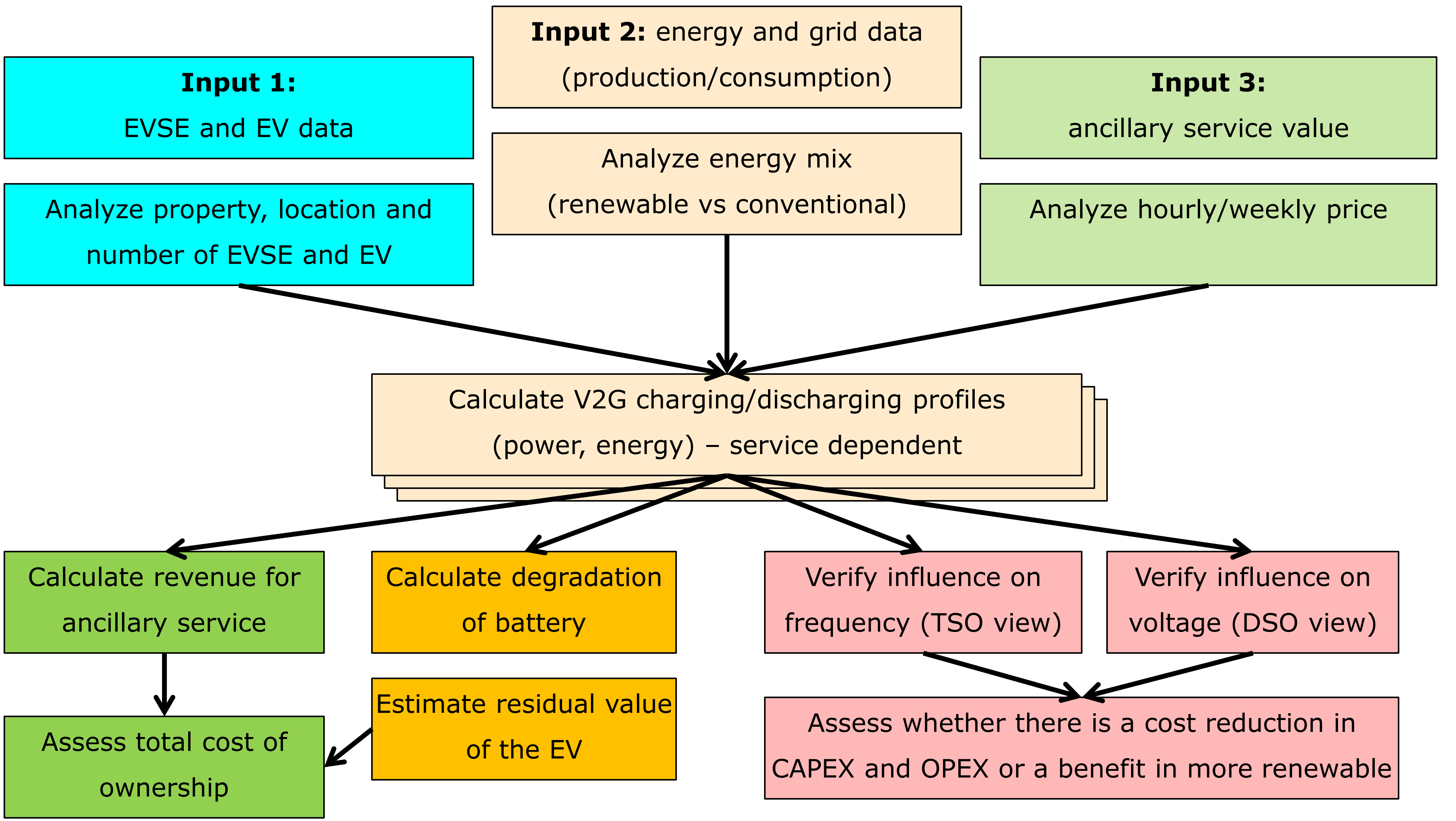


3.7 - 11 - 22 kW

1; 3-phase

- **Charging options considered:**
  - 10 kW DC via external charger bidirectional control
  - 3.7 - 11 - 22 kW AC via internal charger unidirectional control

Overall methodological approach

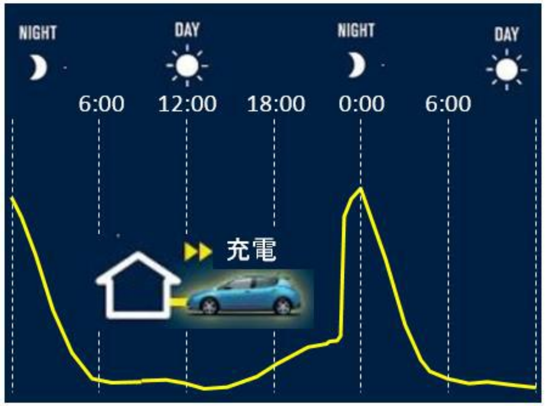


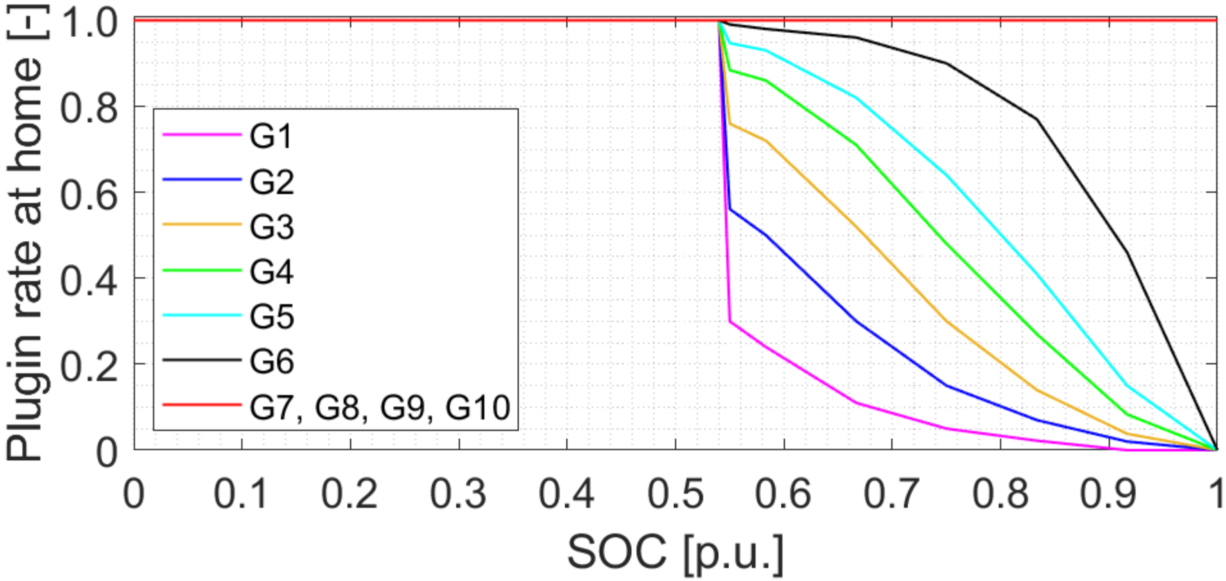
The speakers in the ACES session

- **Driving patterns and charging profiles – lesson learned from Japan**
  - **Kenta Suzuki, NISSAN**
- 100% EVs on the island of Bornholm
  - Hans Henrik Ipsen, BEOF
- Controlling the frequency – scheduling and degradation
  - Andreas Thingvad, DTU
- Managing the distribution grid – what's the limit?
  - Lisa Calearo, DTU
- Stabilizing the islanded Bornholm with V2G chargers
  - Antonio Zecchino, DTU

Driving patterns and charging profiles – lesson learned from Japan

- Information on Japanese EVs driving and charging behaviour made it possible to clearly quanfity how much the evening charging peak would be.
- For each group (G1-G10), knowing the SOC at the end of the day, the plug-in rate at home is defined (no plug-in at work is considered).





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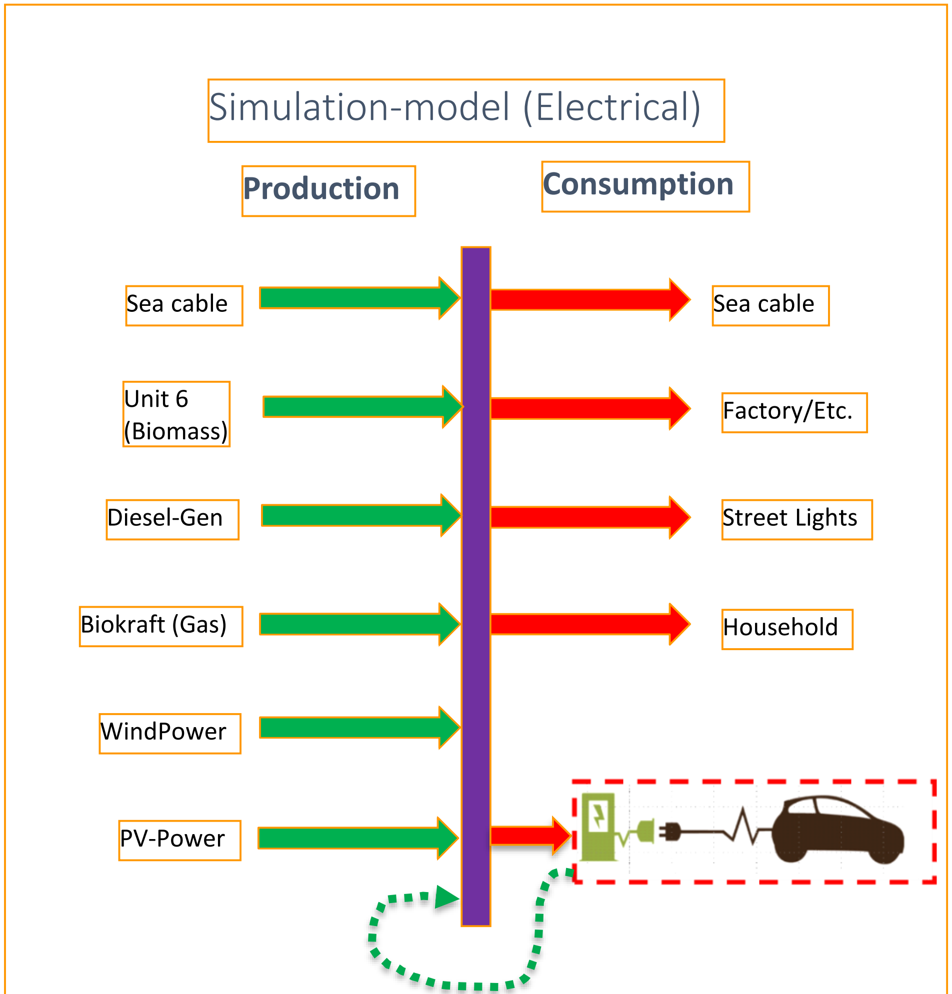
100% EVs on the island of Bornholm



- How would Bornholm power system react to a population of 17500 EVs?
- V2G used as source of revenue on the energy market.
- We assumed 11 user classes with different driving/charging characteristics.

Profile #	#1	
Type	Production	
Charge rule	9=V2G	
#EVs	2,500	
Capacity [kWh]	40	
Charging rate [kW]	3.6	
Discharging rate [kW]	3.6	
Charge loss [pct.]	10	
Discharge loss [pct.]	10	
Km/kWh .	5	
Behavior	Daily	Weekend
Plug out [time]	06:00	10:00
Plug out σ [min]	30	120
Plug in [time]	15:30	16:00
Plug in σ [min]	30	240
Km/trip	35	38

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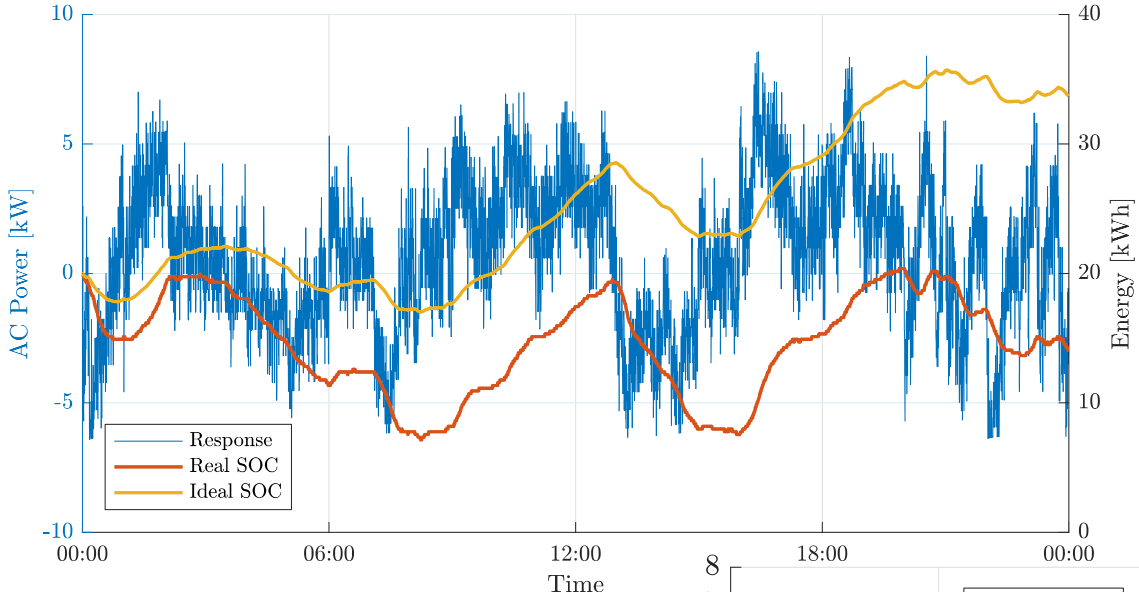
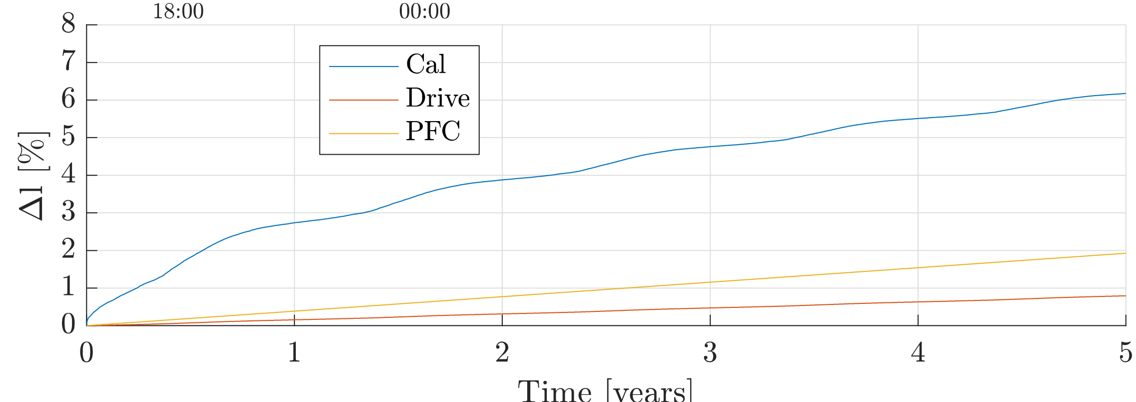
Controlling the frequency – scheduling and degradation

- How to reliably bid into the frequency market having a limited storage capacity?
- Considering also a “far from ideal” V2G charger with losses and unpredictable frequency patterns, do we need to spare some capacity for adjustments?



- Can we quantify the weight of frequency provision in term of battery degradation compared to driving and calendar?



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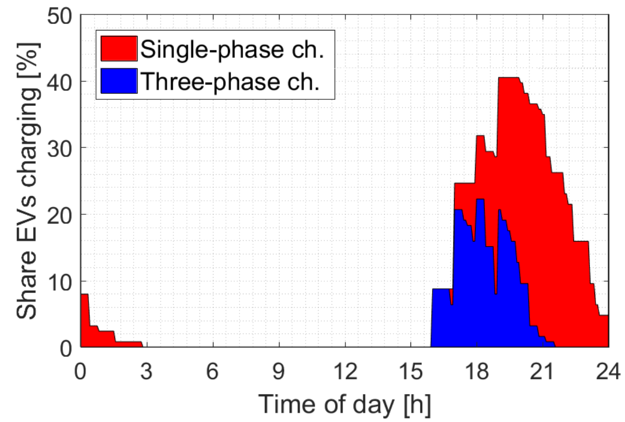
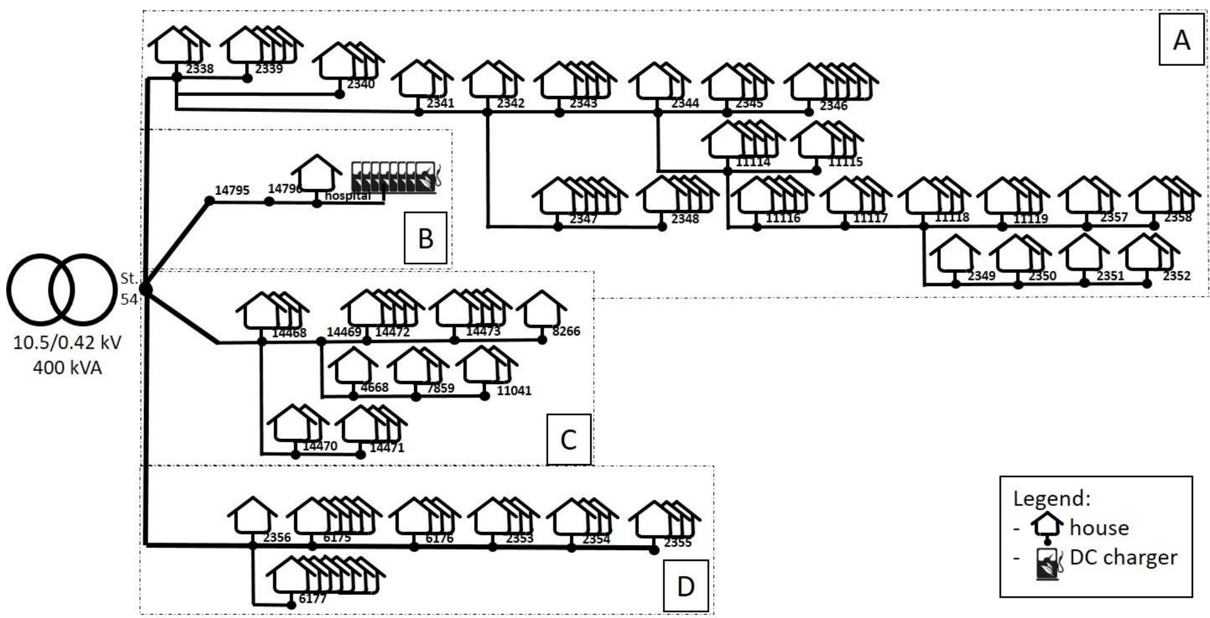
Managing the distribution grid – what's the limit?

- Considering realistic driving/charging behaviour, what's the expected loading impact on two representative distribution grids assuming a 100% EV scenario?
- If reinforcement is necessary, what would be a fair value for a load deferring?





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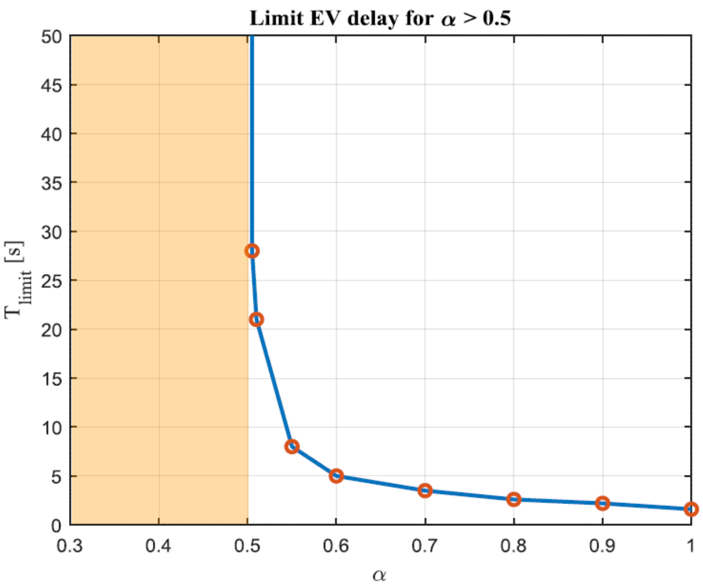
Stabilizing the islanded Bornholm with V2G chargers

- If we supply frequency reserve with a large contribution of EVs, is it possible to keep the system stable? What's the maximum response time we can accept?
- The consolidated practice on the island is to disconnect all renewables non-controllable and limit wind turbines output. Can EVs increase help to have them online?

$$\alpha = \frac{P_{res\_EV}}{P_{res\_tot}}$$



Time's up Mattia!

Key conclusions achieved so far

- **Driving behaviour and charging probability**
  - EV drivers won't charge every day and not altogether
  - At Japanese level, 16% EVs (2030) could reduce 7 TWh of renewable curtailment
- **Equivalent storage and energy based service**
  - 100% EVs on Bornholm (=17500) can lead to and equivalent storage of 700 MWh, though mostly available at night.
  - Individual revenue by speculating on the energy market equal to 168 DKK/year (=23€/y), up to 336 DKK/y (=45 €/y) by using 3.7 kW charging.
- **Frequency based services and degradation**
  - Bidding into the frequency market can be very remunerative, up to 10000 DKK/y (=1400 €/y), but the need for extra equipment (V2G charger), cost of losses and need to fulfil bid requirements can reduce the profit. Unidirectional modulation for frequency requires less hardware but revenue is limited, 450 DKK/y (60 €/y).
  - Early simulations show that frequency regulation has limited impact on degradation, though further experimental investigations are needed.

Key conclusions achieved so far

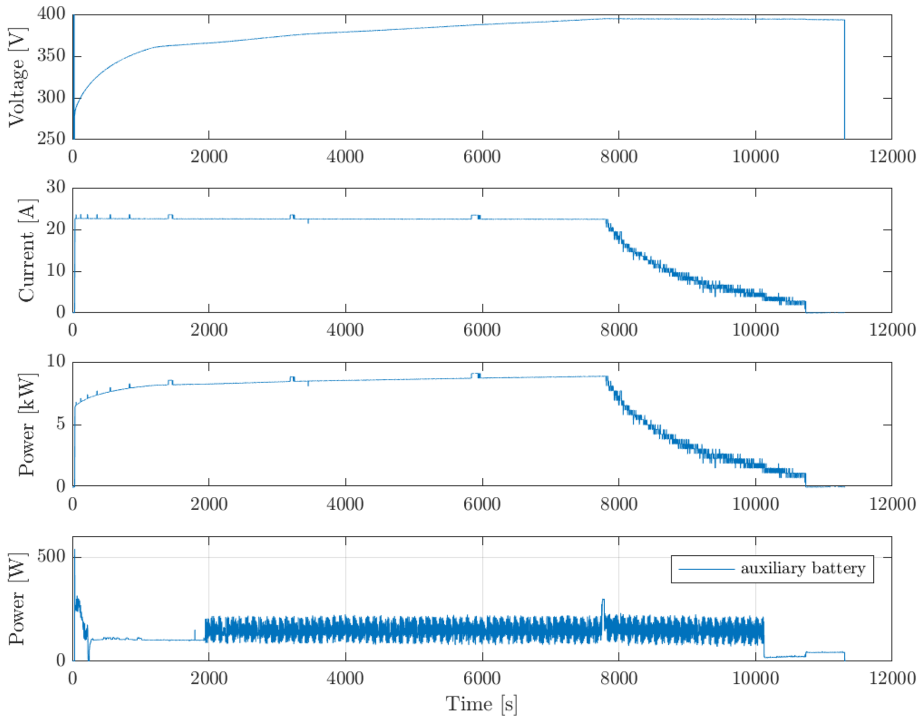
- **Distribution grid services and congestions**
  - Concurrent charging when considering large population of EVs (100% case) will be 40% for a 3.7 kW level and 20% for a 11 kW → the average distribution grid in DK would be able to handle 50% of EVs without any criticality, though safety margins are reduced (problems may arise if EVs are not equally distributed on the phases)
  - Perspective revenue for providing local services via unidirectional charging modulation between 77 DKK/y (10 €/y) and 150 DKK/y (=20 €/y) per customer.
- **System stability and need for speed of response**
  - A generic power system (2H=7 s and conventional prime movers) would be able to accept a primary reserve up to 50% from EVs with no particular problems.
  - Considering the grid layout and, specifically, Bornholm's plant characteristics, 7 s is a critical response time (the faster the better). However if the amount of EVs is limited, it can (already now) positively support the integration of renewables.

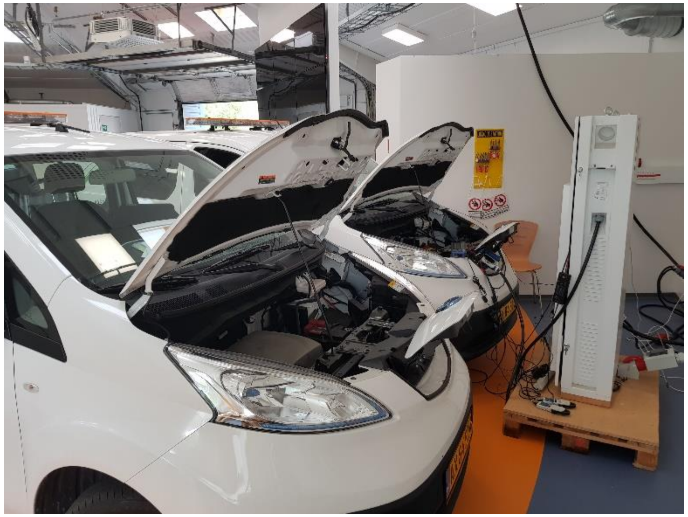
…and the way forward till the end of the project

2 key areas

Assessing the battery degradation while providing different grid services

- **How will the battery really degrade because of grid services?**
- **How much compared to normal ageing and driving?**





The Ultimate Demo – Island islanded

- **50 chargers (10 kW each) with 50 EVs providing +/- 500 kW of regulating reserve.**

- Can we help increasing the amount of wind/renewables during islanded situations?

- How to transfer the lesson learned to other (larger) power systems?

Final considerations: getting 1 million EVs on the road in DK – any issue?

From an energy perspective

- 1 EV drives in DK 45 km/day (= 16425 km/y) → 9 kWh/day (= 3285 kWh/y)
  - 1 million EVs (40% of all vehicles in DK) → 3.3 TWh (= 3285 kWh*1E6)
    - ➢ **2017 electricity consumption: 34 TWh → + 10% increase**

From a power perspective

- The aggregated population, considering driving/charging behaviour, would bring a coincidence factor of 40% (hp no charging at work) with charging power 3.7 kW
  - 1 million EVs → 1.5 GW (= 3.7 kW*40%*1E6)
    - ➢ **2017 peak consumption: 6.1 GW → +25% increase**

Both system and local wise it can be handled (though local problems may arise on particularly weak feeders).

Yet, this represent a great storage opportunity, assuming each EV has 50 kWh,

1 million EVs 50 GWh to be used on a daily basis for multiple services.

→ As reference, DK daily electrical consumption is 9.3 GWh (=34 TWh/365 d)

STAY TUNED!

CHECK THE RESULTS IN THE WEBSITE

www.aces-bornholm.eu