Field Experience: Vehicle to Grids in US and Europe

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Electromobility: Challenging issues

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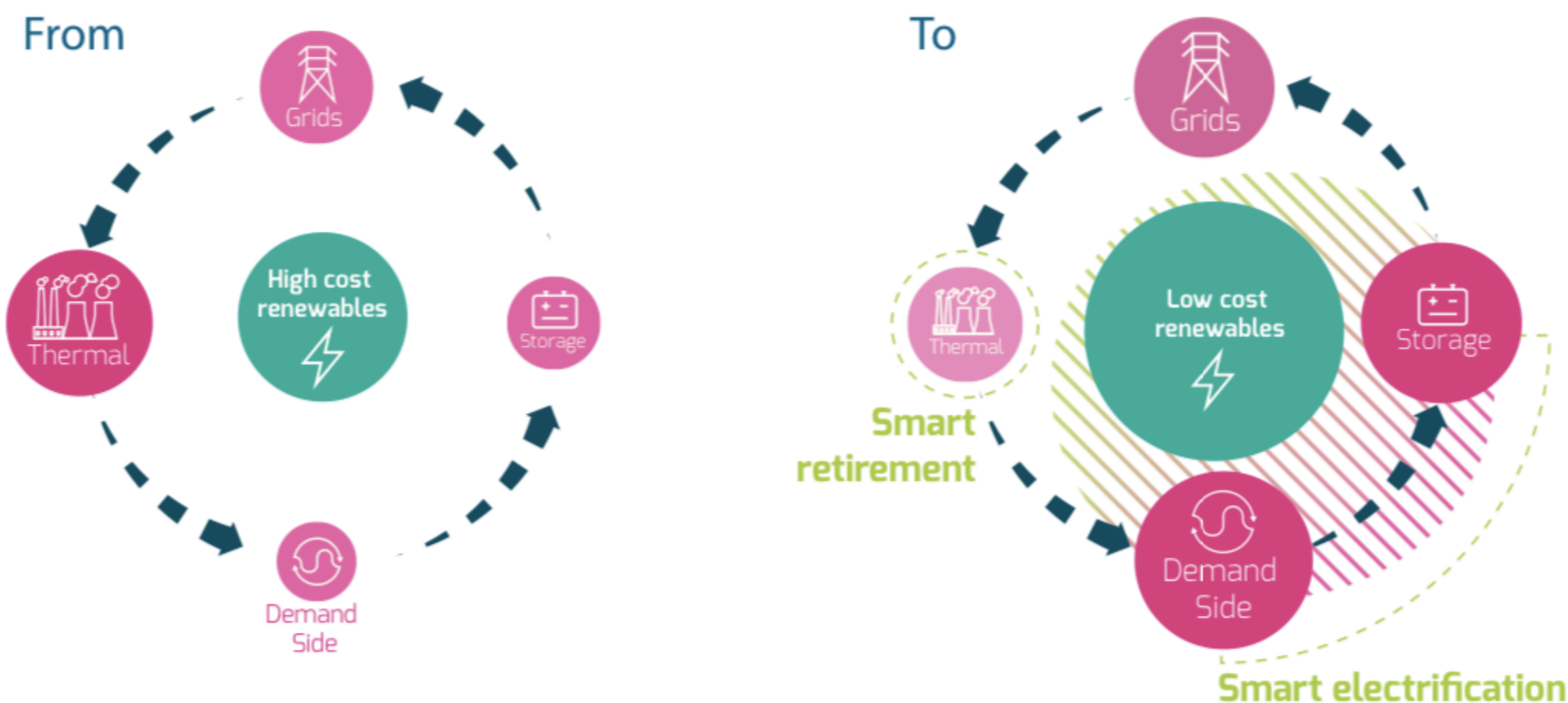
Outline

- Why are we developing e-storage?
- Development from concept to implementation
- US R&D, technology development
- Early commercial projects by Nuvve
- Technical solutions
- Policy and regulatory issues

Cheap Renewables → Storage, DSM

Figure 27: A new way of thinking about power system balancing



from: "Cleaner, Cheaper, Smarter", Energy Union Choices, November 2017, Figure 27
http://www.energyunionchoices.eu/wp-content/uploads/2017/11/AB_EUC_Report_Nov_2017_web_v1.pdf

Inherent Storage

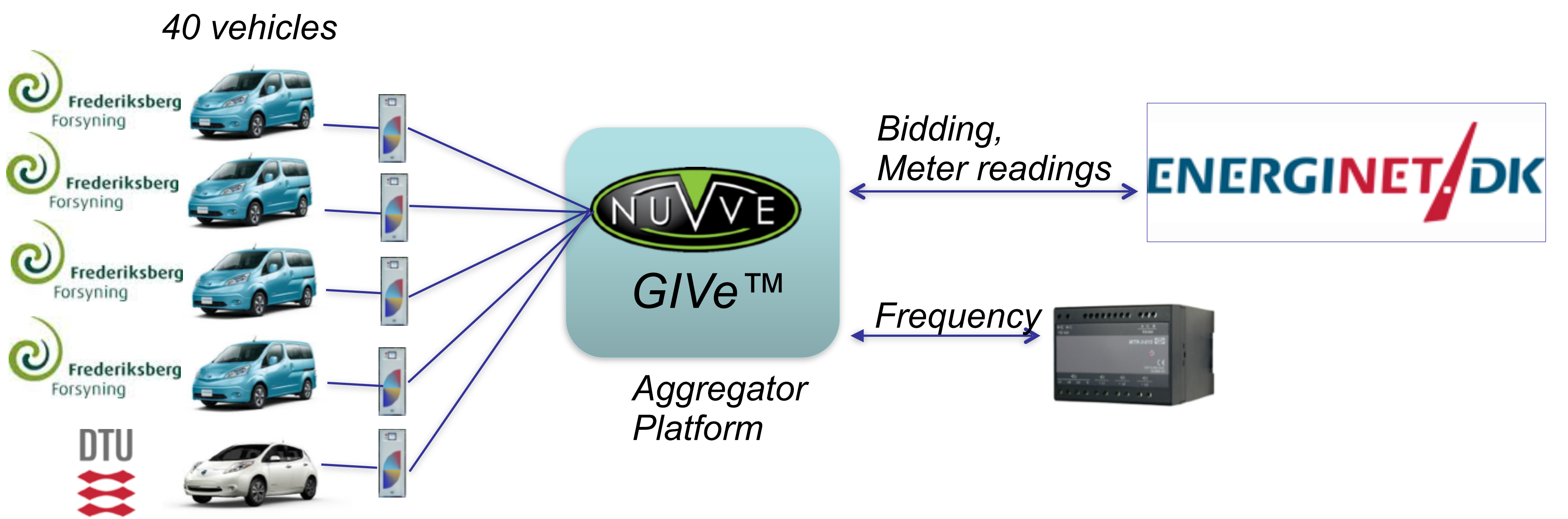
- Electric storage is already built in to many devices, more so with every passing year
  - Mobile devices; laptop computing
  - Backup emergency lighting
  - Computer backup
- Major problems
  - Storage in the range of 5 Wh to 100 Wh
  - Either: Wh is too small (mobile devices) or time needed is unknown (emergency power)
- EV solution: large battery & predictable use schedule
- Storage in building heat, may be very cost-effective but

Idea: Use inherent storage in EVs

- Use batteries and chargers in EVs for grid storage, and participate in electric markets…
  - Create a second use when the car is parked (average 23 h/day)
  - Controlled charge from, and discharge to, the grid, based on TSO/DSO need
- A payment or other benefit to the EV owner, thus lowering TCO

Architecture

- GIVe platform aggregates cars in different locations (DTU, Frederiksberg Forsyning, Nissan, within DK2)

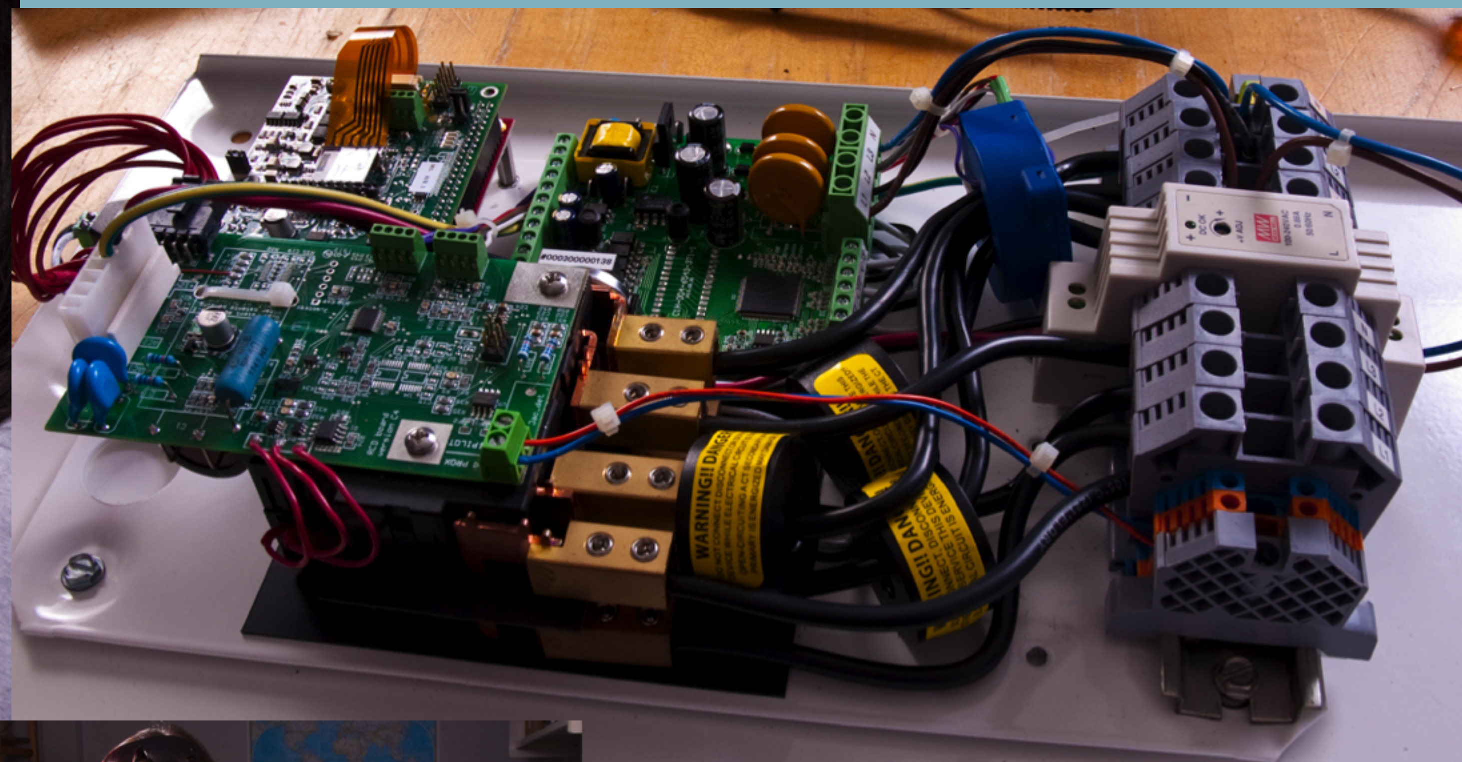


US R&D and Demo projects

- From one EV dispatched by TSO, to an aggregated fleet
- Intelligence in EV, in EVSE, and in central server
  - Agent-based computing, each entity manages it's own priorities
- 2011- 2017, move from university R&D projects to commercial license to Nuvve Corp

MiniE fleet at U Delaware

Development of 1ϕ and 3ϕ AC EVSEs



1ϕ 19 kW
3ϕ 42-133kW

Heavy vehicles, Nuvve Pilot in California

California Projects And Roll-Out

Bus integration

EPC on-board bidirectional charger integrated with motor drive. about 25 kW at 208V, or 50-70 kW at 480V

First US projects, lessons (1)

- Economic: EVs very cost effective; easier to participate with competitive TSO markets
- Technical: EVs very high performance for fast-response grid services
- Computing design: Agent-based, with high data flow EV-EVSE-GIVe aggregator is highly effective (but a lot of work to achieve all functions)
- Design of charger: Bidirectional charger on board w/ AC EVSE is much cheaper than off-board charger (e.g. $600 versus $5K - $15K added cost)

First US projects, lessons (2)

- Regulatory: EVSE is a “power plant”; TSO qualification and registration clumsy
  - Power plant registers once after 3-year build
  - We’d like to incrementally register 10+ units per day
- Safety standards, IEEE-1547 & UL-1741 not well suited to “roaming inverters”
  - Off-board charger regulatory like solar inverter
  - For on-board chargers, we supported development of automative standard SAE J3072

First US projects, lessons (3)

- Metering, one possible solution:
  - kWh metering by standard DSO meter for whole building
  - kW/time metering in charging station (mass produced product, certified, low cost)
- PJM, can register either as “demand resource” or “small generator” — but neither is a good fit, increasing difficulty & cost of PJM registration

Commercial Operations by Nuvve

Partners Around The World

Customers

Car OEM

Utilities

Infrastructure

Universities

Others

Diverse TSO Projects

- eVgo, U Delaware, BMW R&D in US with TSO PJM Interconnection - *Nuvve now re-registering for commercial expansion*
- Nuvve, DTU, Nissan, PSA, Enel - project in Denmark, TSO energinet.dk - *Commercial trial*
- Nuvve & New Motion project in Netherlands, with TSO TennenT - Pre-c*ommercial trial*
- Nuvve, Nissan, Enel, in England and Wales with TSO National Grid - *Awaiting interconnection*
- PSA, Nuvve, & others "GridMotion" in France with Direct Energie - Ramping up for pre-commercial test

Denmark Fleets

DENMARK V2G installations

AFA JCDECAUX fleet in Copenhagen

UK's first V2G installation in Nissan Technical Center in Cranfield + Newcastle University

Commercial lessons

- Pre-commercial and commercial GIV already is operating, with more launching
- Technology is commercially ramping up, with some growing pains
- Charging + backfeeding value is ~13x that of controlled charging (Thingvad et al, 2016), but more difficult to permit and interconnect.
- Subsidies not needed, can be self-supporting in well-selected markets, today best is TSOs with good payments for reserves
- Many policy barriers remain

Lessons: Policy Barriers (1)

- Many ENTSO-E countries require constant bid for 7 days! Bid granularity of 4 hours.
  - Should allow bids by hour or 1/2 hour.
- Returned energy should cancel consumption
  - Now: demand tax to incentivize energy efficiency & production tax to put solar on parity with other generation
  - Now: Network charges blind to actual network load, e.g. controlled charging or discharging for grid needs can reduce load on network

Lessons: Policy Barriers (2)

- Sub-meters not allowed in some jurisdictions, some require second DSO meter — very high cost!
    - Should allow sub-meter on EV charging
- Interconnection not designed for EVs especially with mobile inverters — SAE J3072 now available but not yet recognized by electric industry

END

More information:

www.udel.edu/V2G

www.nuvve.com

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