
NUVVE
We Make Electric Vehicles Greener
... and less expensive
TRITON RIDES
8CZE838

# Presentation Outline

- Overview of Nuvve
- What value can V2G deliver behind-the-meter?
- Scenarios and Optimisation
- Results
- Discussion & Conclusion

# Nuvve – Global Commercial V2G Specialist

- The world's only platform enabling profitable deployment of EV fleets globally
- Working on V2G since 1996
  - University of Delaware Prof. Kempton spin off – patented technology
- Headquarters in San Diego, CA, USA
- Offices in Copenhagen, London, Paris, Newark (DE, USA)
- World's most experienced:
  - Only V2G firm to complete TSO/DNO qualification in multiple countries
  - Operating on 5 continents
  - Over 3.5 million hours kW of commercial V2G operation (by end 2018)
- Scaling through partnerships, e.g. EDF using Nuvve for all e-mobility
- Corporate investors
  - EDF Renewable
  - Toyota Tsusho

EDF

TOYOTA TSUSHO

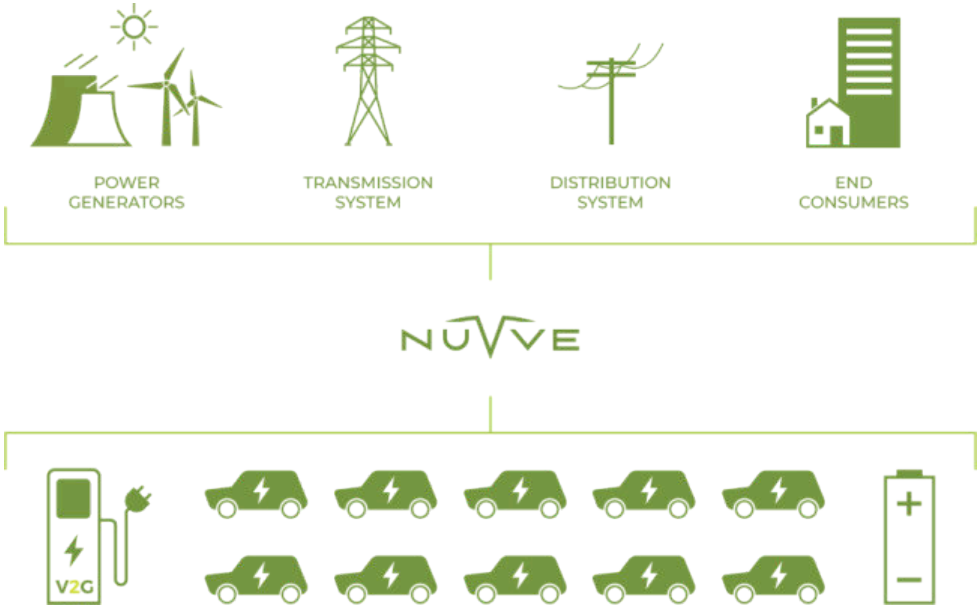


NUVVE

# Nuvve GIVe™ Platform

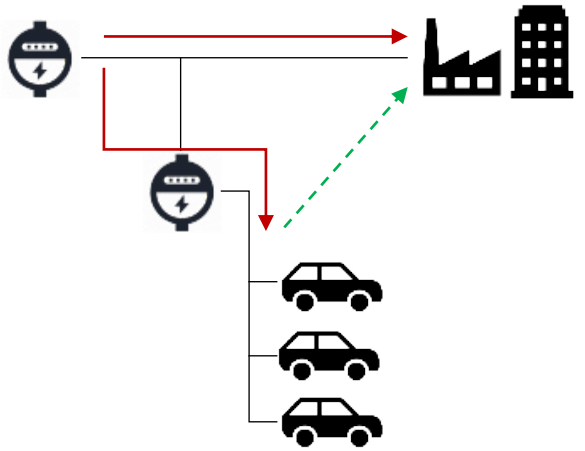
## Aggregation Platform

- Enables second by second control on EV batteries that can match the fluctuation of the grid
- Provides the grid with varying, aggregate energy flows according to the needs of the grid



# Research questions

- Nuvve has demonstrated revenues on the order of €1,500/EV/year in frequency regulation markets (PJM, DK2)
- In certain jurisdictions, the value of V2G is mainly in savings on energy bill “behind-the-meter”
- The objective of this article is to quantify the range of value of behind-the-meter savings



# V2G Services in Buildings - Typology

Behind-the-meter value from V2G can be defined in three broad types of services :

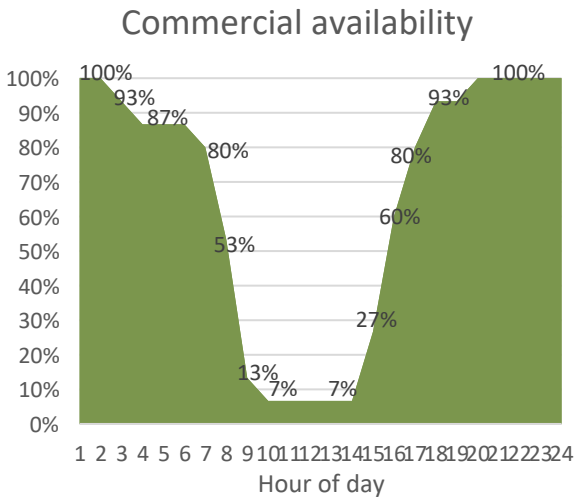
- **Demand Response**
  - Responding to events of national peak demand by reducing site load
  - Tariffs usually in $/kW-year
- **Time-of-Use (TOU)**
  - Optimising the variable (non-fixed) components of energy prices:
    - Energy (spot) prices
    - Distribution use of system charges
    - Capacity market supplier charges
  - Tariffs and charges applied in $/kWh
- **Demand Charge Management**
  - Mitigating a site's maximum demand
  - Tariffs usually in $/kW-month

# Optimisation model

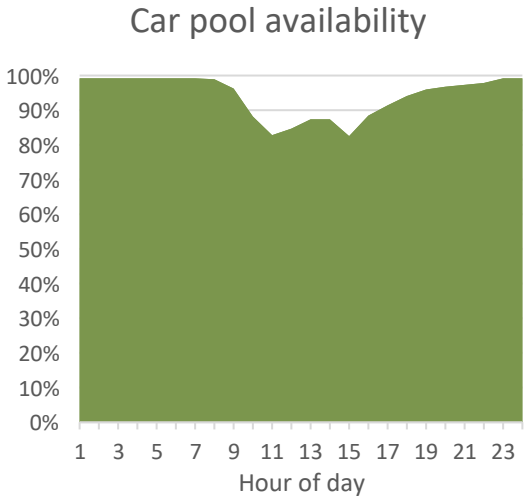
- 9 scenarios
- Solve for minimum cost of energy >> Find the hourly optimal charge and discharge rate of the V2G capable EV
- Key parameters influencing value behind-the-meter from V2G are:
  - Vehicle use patterns: plug-in times, energy consumed on daily trips, plug-in durations
  - Building demand profiles
  - Electricity price structure
  - EVSE power rating (9.25kW)
  - EVSE Efficiency (81%)
  - Battery size (24 kWh)

# Vehicle use patterns

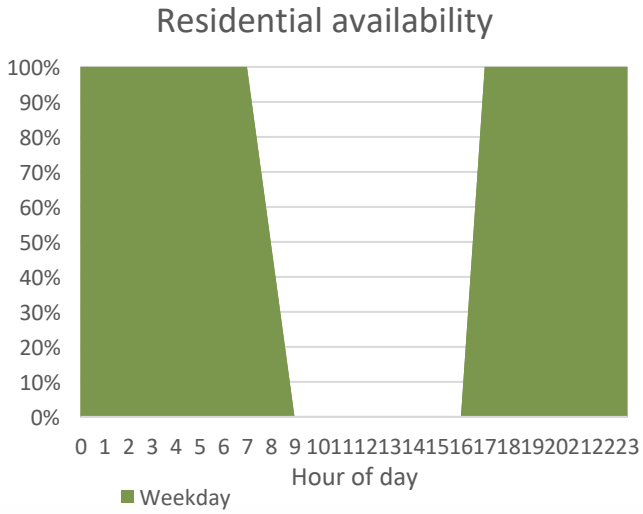
## Scenarios 1: Commercial EV fleet - Low availability



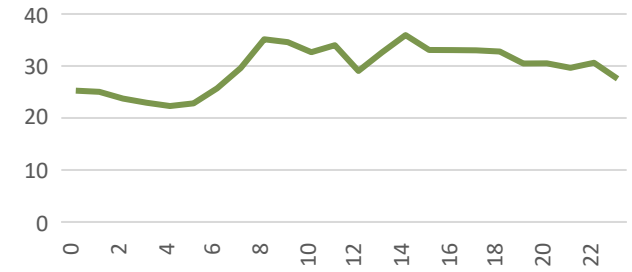

## Scenarios 2: EV Car pool High availability



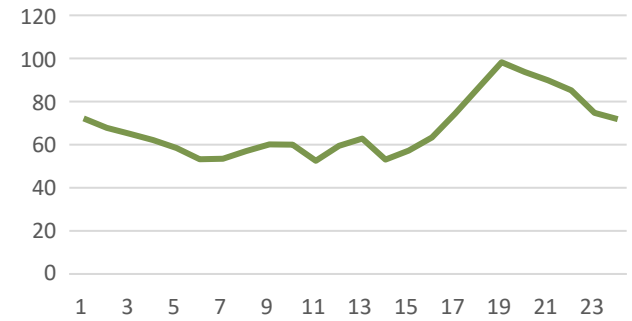

## Scenarios 3: EV Residential Medium availability



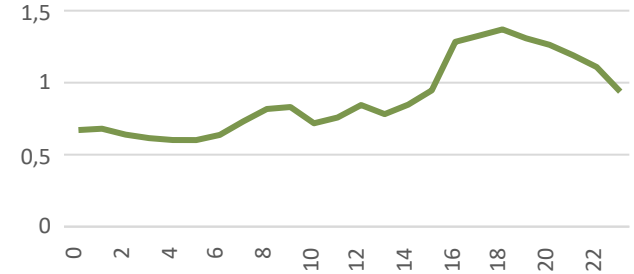
UK 1 Commercial building load (kW)



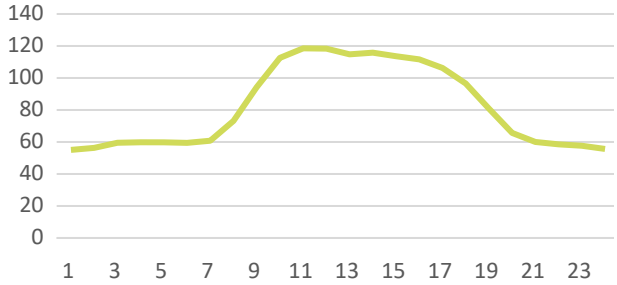

UK 2 Industrial building Load (kW)



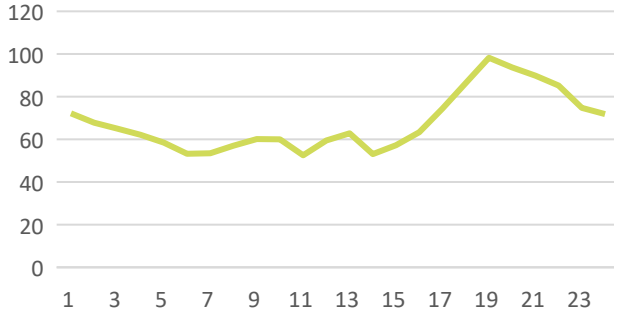

UK 3 Residential building load (kW)



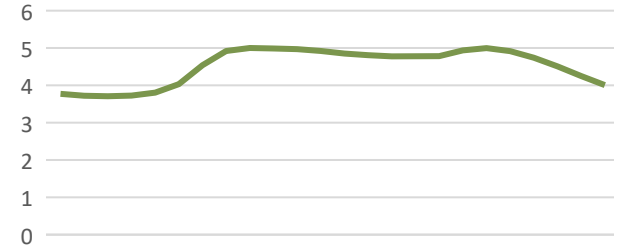

SE 1: Sweden municipal building Load (kW)



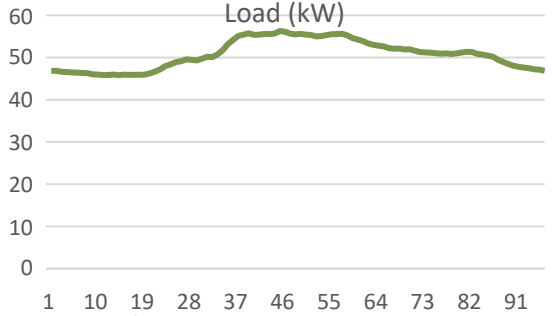

SE 2: Sweden Industrial profile building Load (kW)



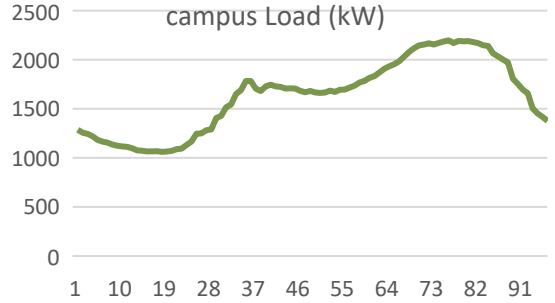

SE 3: Sweden residential profile building Load (kW)



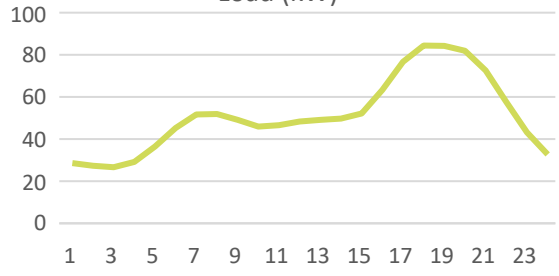

California CA 1 University building Load (kW)



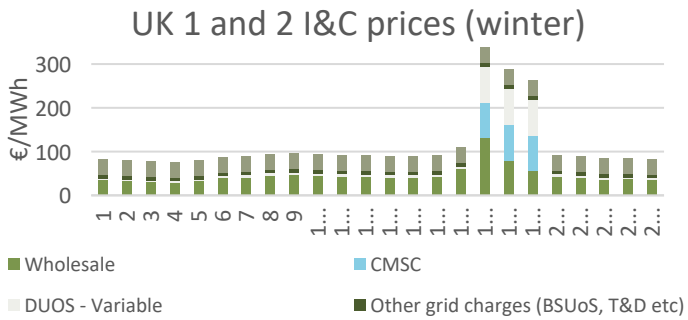

California CA 2 University entire campus Load (kW)




California CA 3 Residential Building Load (kW)

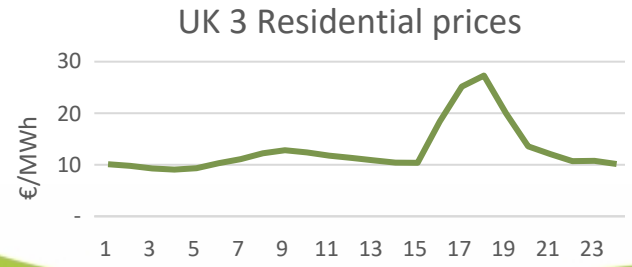


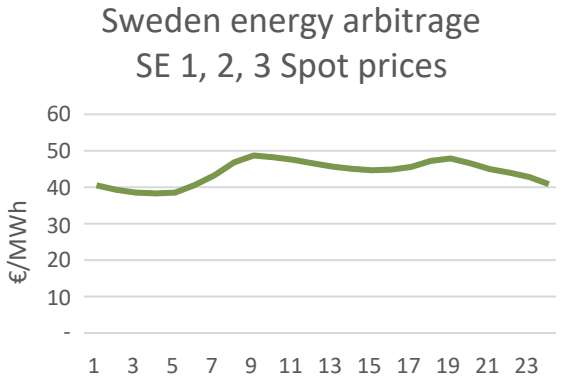
# Prices in UK, Sweden and California




+ For UK I&C UK 1 and 2:

"Triad" charge: 45 £/kW-year (52 €/kW-year)




+

For Sweden I&C SE 1 and 2:

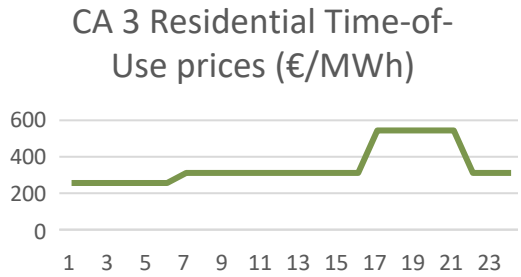
Demand charge: 110 SEK/kW-month (10€/kW-month)

For California I&C CA 1 and 2:

Demand charge: 13.2 $/kW-month (11.7 €/kW-month) N/C peak

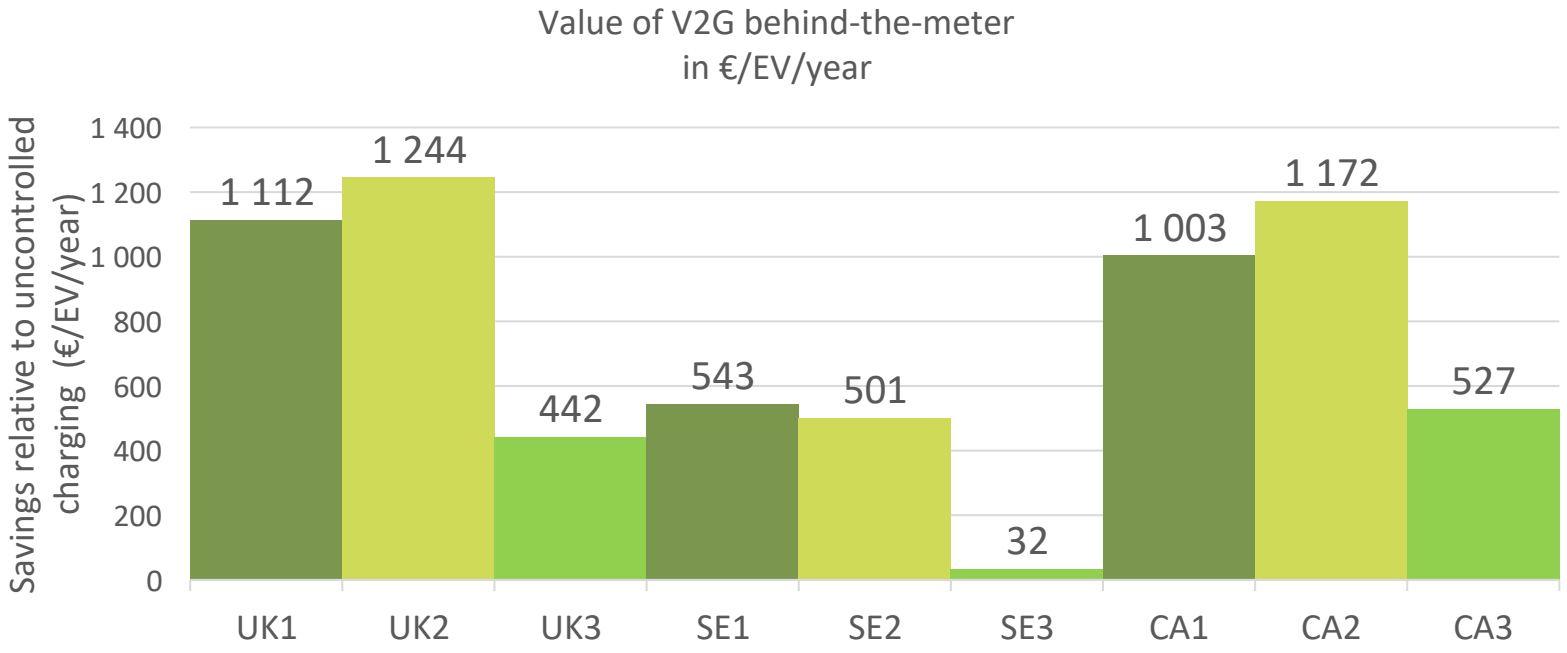
+2.5 $/kW-month (2.2 €/kW-month) summer peak

+0.5 $/kW-month (0.5 €/kW-month) winter peak



# Results

# Key Results


Value of V2G behind-the-meter
in €/EV/year
Savings relative to uncontrolled charging (€/EV/year)
1 400
1 200
1 000
800
600
400
200
0
1 112
1 244
442
543
501
32
1 003
1 172
527
UK1
UK2
UK3
SE1
SE2
SE3
CA1
CA2
CA3

# Results Table

| *€/EV/year* | UK1 | UK2 | UK3 | SE1 | SE2 | SE3 | CA1 | CA2 | CA3 |
|---|---|---|---|---|---|---|---|---|---|
| V2G service description | TOU & Demand response | TOU & Demand response | TOU | Demand charge & TOU | Demand charge & TOU | TOU (excl. taxes and tariffs) | Demand charge | Demand charge | TOU |
| EV plug-in profile | Commercial | Car pool | Residential | Commercial | Car pool | Residential | Commercial | Car pool | Residential |
| Cost of uncontrolled EV charging | 292 | 102 | 630 | 1,521 | 1,339 | 192 | 1,518 | 39,087 | 1,247 |
| Cost of Smart Charging | 167 | 51 | 306 | 1,433 | 1,268 | 169 | 860 | 39,087 | 891 |
| Cost of V2G optimised | (820) | (1,142) | 187 | 978 | 838 | 160 | 515 | 37,915 | 720 |
| **Value of V2G** | 1,112 | 1,244 | 442 | 543 | 501 | 32 | 1,003 | 1,172 | 527 |
| **Value of V1G** | 125 | 52 | 323 | 89 | 71 | 23 | 658 | - | 356 |



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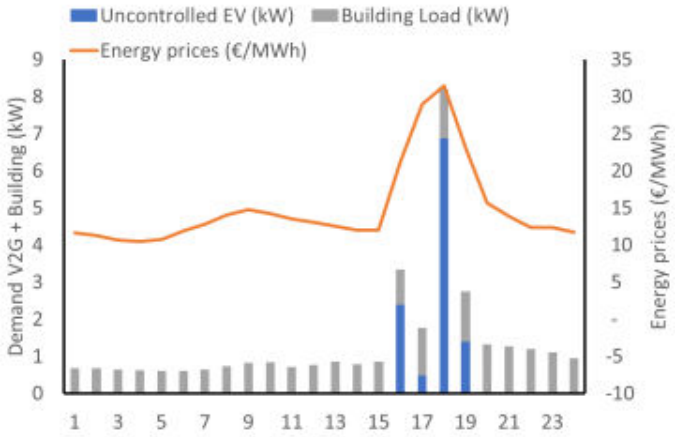
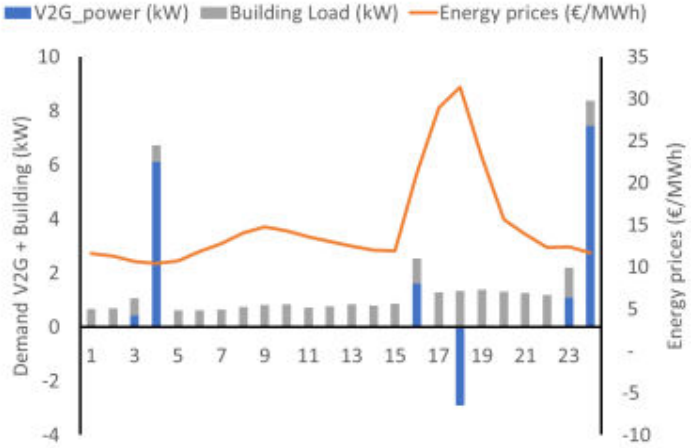
# Findings 1

Smart charging better for residential

# Case UK 3 (Residential, UK)

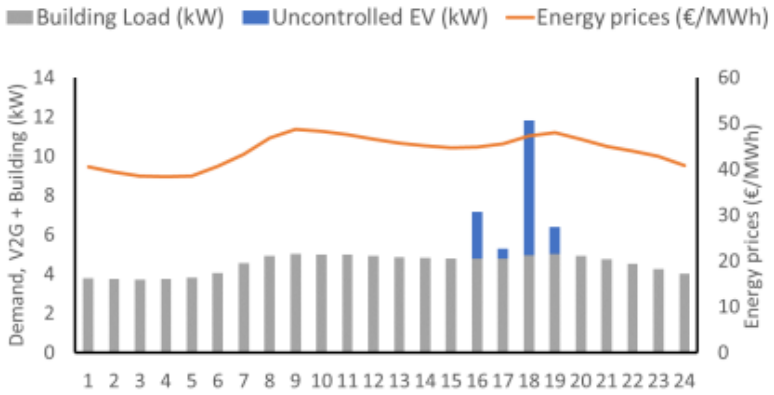
- **In the residential cases, smart charging alone offered c. 68-73% of the benefits of V2G**

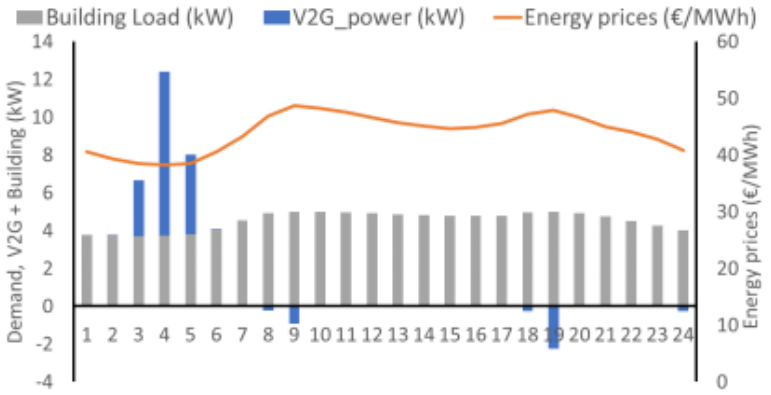



| | |
|---|---|
| **Value of V2G** | 442 |
| **Value of V1G** | 323 |

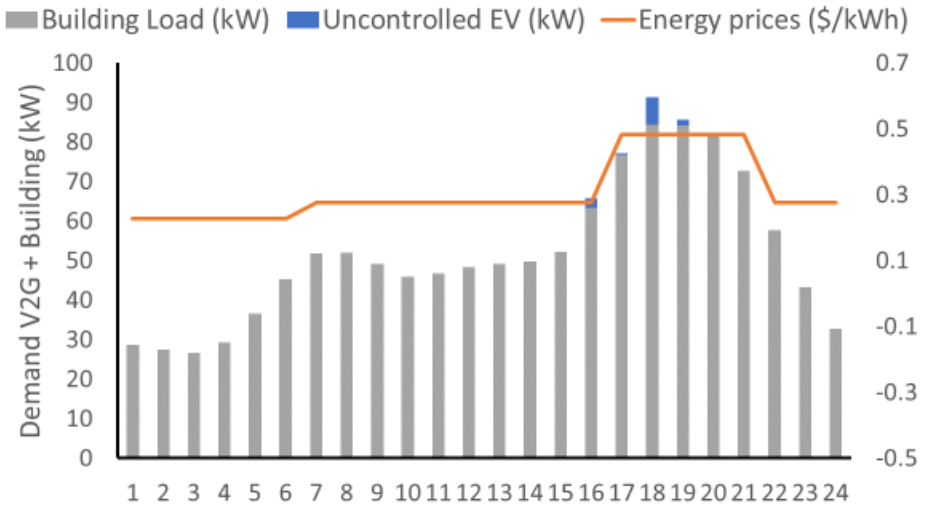
# Case SE 3 (Residential, Sweden)

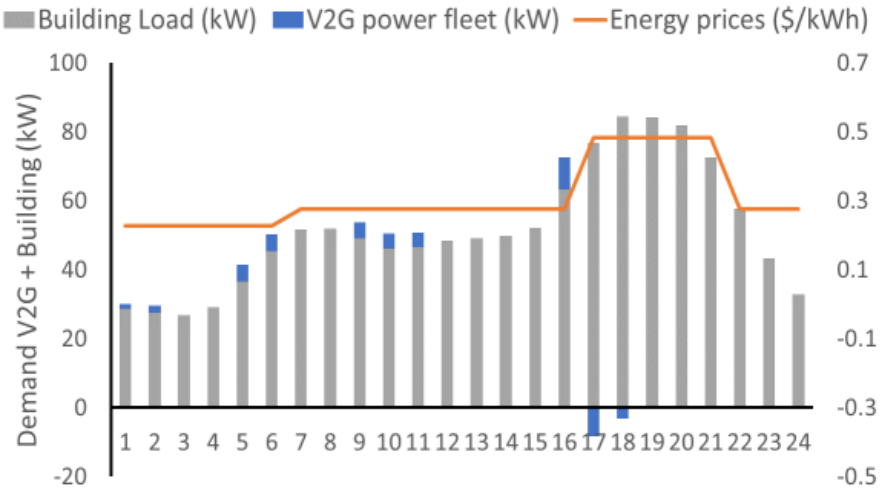



| | |
|---|---|
| **Value of V2G** | 32 |
| **Value of V1G** | 23 |

# Case CA 3 (Residential, California)



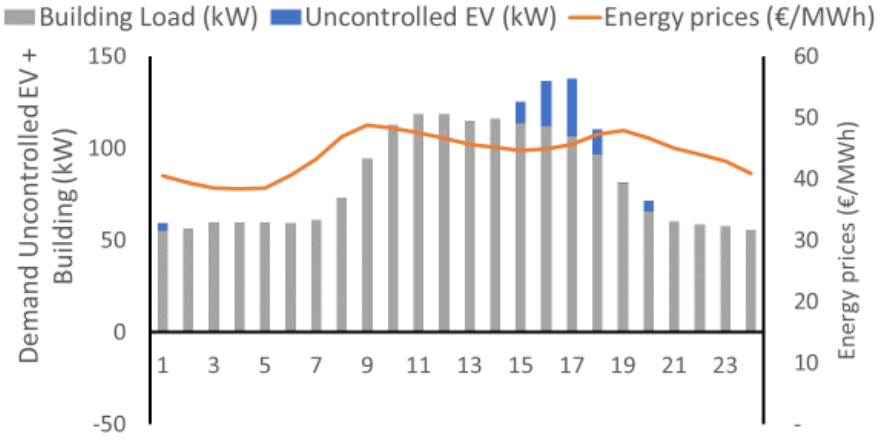

| | |
|---|---|
| **Value of V2G** | 527 |
| **Value of V1G** | 356 |

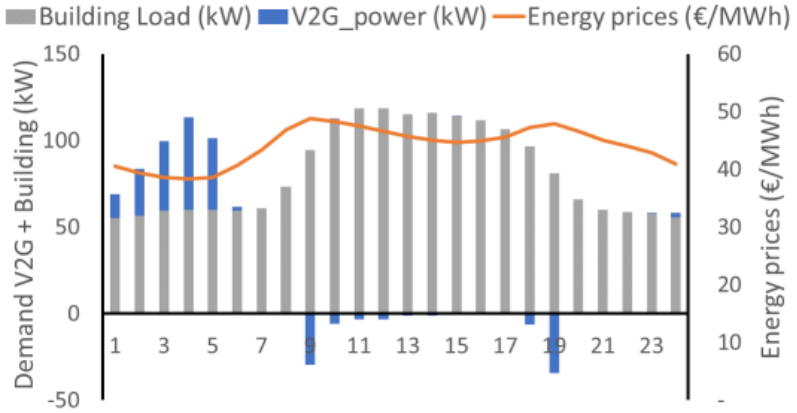
# Findings 2

Building load shape impact

# Case SE 1 (Fleet, Sweden)

- **Where the main value of V2G is in reducing a building's demand charge, the more concentrated the demand peaks, the more value V2G can deliver**




| | |
|---|---|
| **Value of V2G** | 543 |
| **Value of V1G** | 89 |



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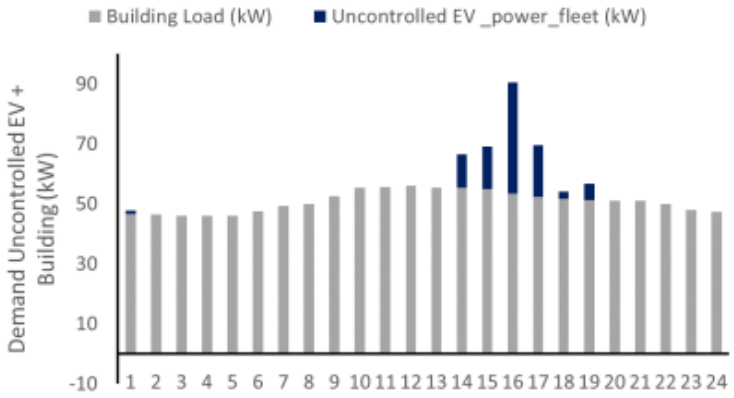
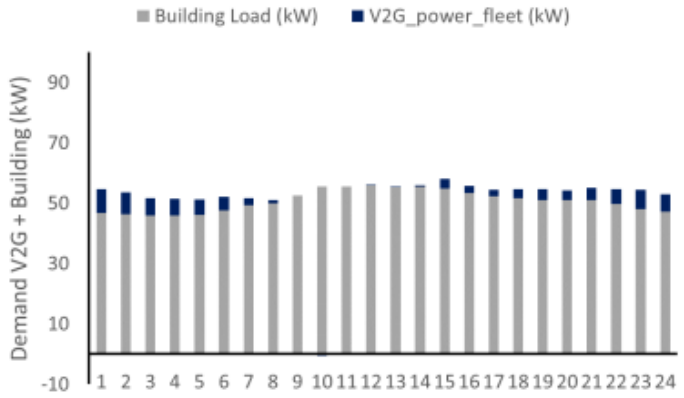
# Case CA 1 (Fleet, California)

- **When the building load is relatively flat, smart charging or V1G can achieve most of the benefits for demand charge management**




| | |
|---|---|
| **Value of V2G** | 1,003 |
| **Value of V1G** | 658 |

# Discussion

# Conclusions / Key findings

1. V2G delivers savings behind-the-meter of between **400-1,200 €/EV/year** in the UK, **30-500 €/EV/year** in Sweden, and **500-1,200€/EV/year** in California
2. **Residential users**: In the residential cases, smart charging alone offered c. 68-73% of the benefits of V2G.
3. **Building load shape**: For demand charge management, the more concentrated the demand peaks, and better ability to forecast, the more value V2G can deliver

# Thank you

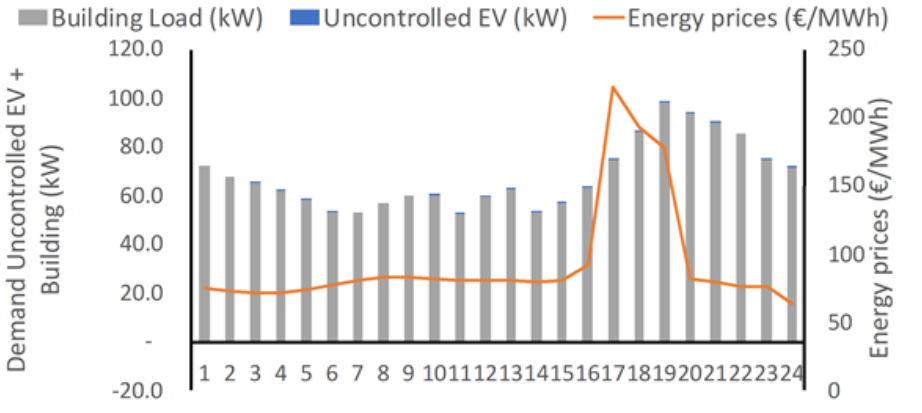
Contact: Claire@nuvve.com

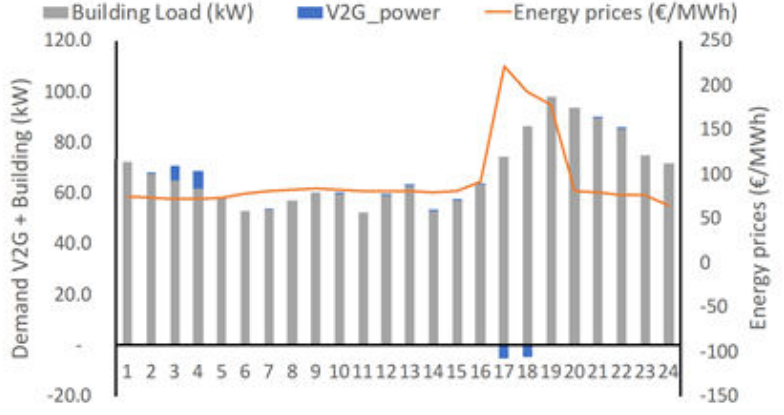
# Scenarios - Summary

| | Scenario | Vehicle use pattern | Building load | Electricity prices |
|---|---|---|---|---|
| **UK** | UK 1 | Commercial fleet historical data | Hourly historical demand data from a commercial fleet depot | Published Industrial and Commercial 2019 tariffs for Triads [17] and DUoS [18] (London) |
| | UK 2 | Car-pool fleet historical data | Generic hourly demand profile for a medium commercial building | Same as above |
| | UK 3 | Residential simulated profile | Generic hourly demand profile for a detached home residential | Octopus EV Agile time-of-use retail tariff (London) [19] |
| **Sweden** | SE 1 | Commercial fleet (same as UK1) | Hourly historical office building demand and solar generation data from a municipality | Wholesale energy prices from NordPool 2017-2018 and distribution network grid tariff for peak demand for 2019 published in [20] |
| | SE 2 | Car-pool fleet (same as UK2) | Example hourly demand profile for a medium commercial building (taken from UK) | Same as above |
| | SE 3 | Residential simulated (same as UK3) | Example hourly demand profile for a detached home residential (taken from UK) | Wholesale energy prices from NordPool 2017-2018 |
| **California** | CA 1 | Commercial fleet (same as UK1) | University campus building in California | UCSD Demand charge scheme @ 13.24$/kW + 2.54/0.54 $/kW (summer/winter) |
| | CA 2 | Car-pool fleet (same as UK2) | University campus in California | Same as above |
| | CA 3 | Residential simulated (same as UK3) | Example hourly demand profile for mid-rise appartment [15] | Retail “TOU 2 tariff” San Diego Gas & Electric |

# Case UK 2 (Car pool, UK)

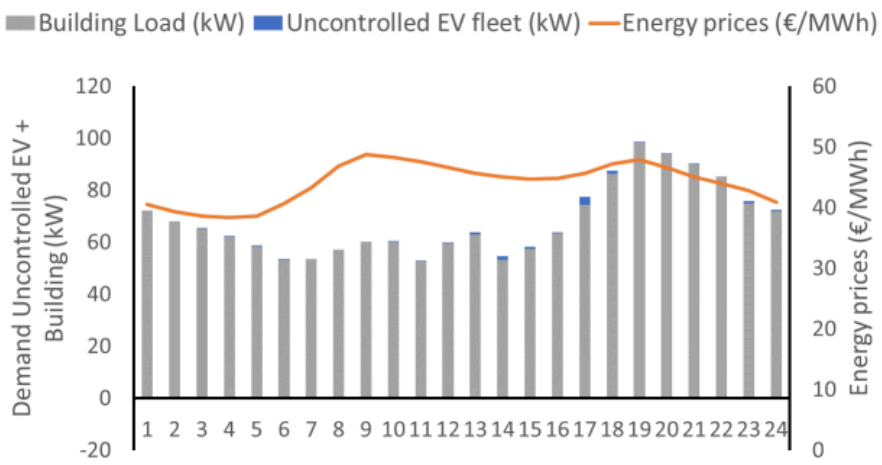
- **When vehicles are not driven much, V2G delivers high value by enabling "energy trading"**

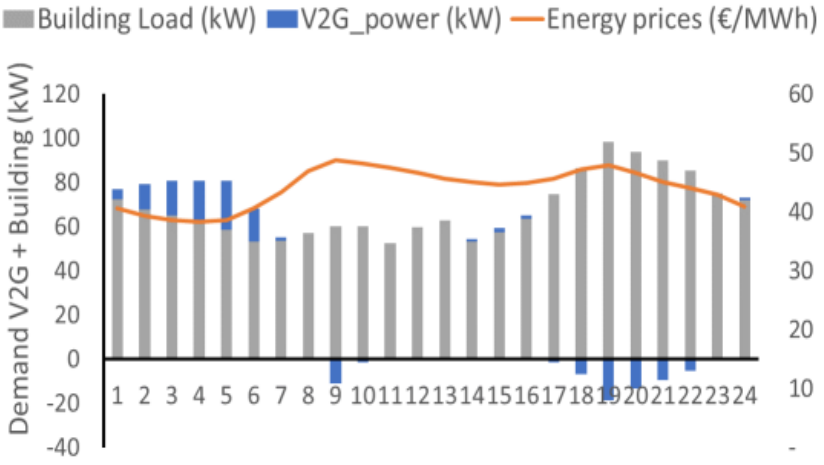



| | |
|---|---|
| **Value of V2G** | 1,244 |
| **Value of V1G** | 52 |

# Case SE 2 (Car pool, Sweden)

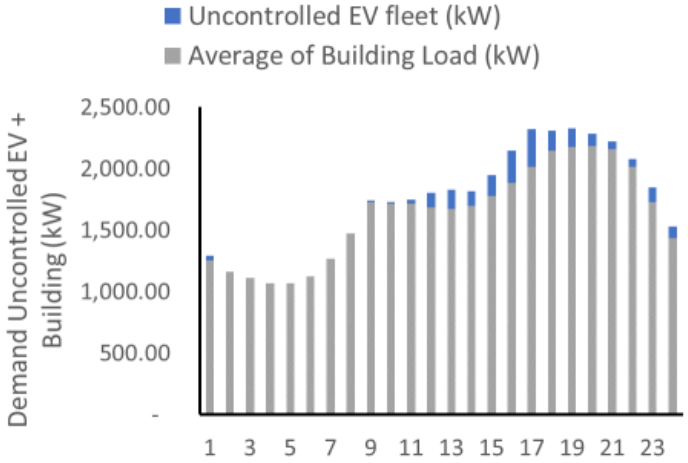


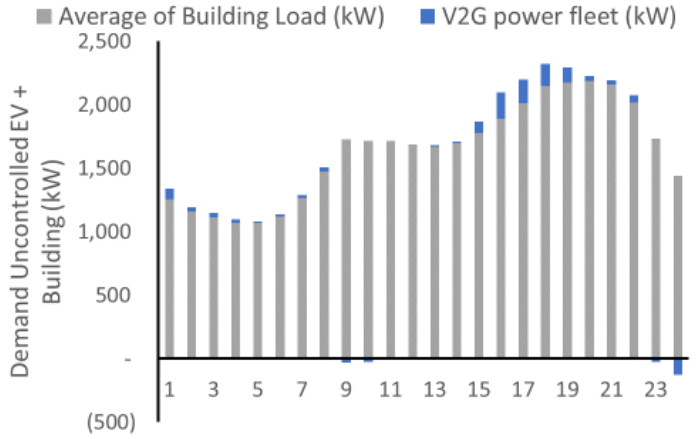




| | |
|---|---|
| **Value of V2G** | 501 |
| **Value of V1G** | 71 |

# Case CA 2 (Car pool, California)

- **With perfect forecasting, when building demand peaks are occasional, V2G can deliver much higher value than V1G**
- **When the charging load does not coincide with building peak, smart charging delivers no value at all whereas V2G enables peak load reduction**

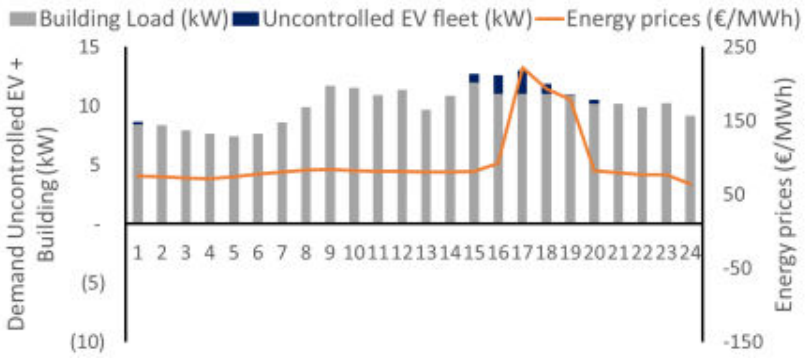


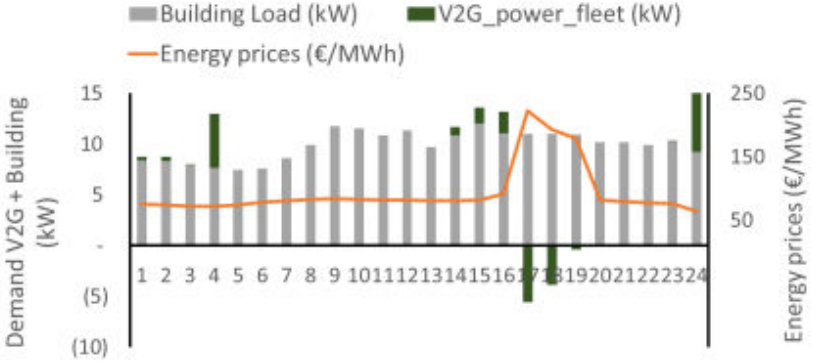




| | |
|---|---|
| **Value of V2G** | 1,172 |
| **Value of V1G** | 0 |

# Case UK 1 (Fleet, UK)

- **Fixed time-of-use tariffs as in the UK create incentives to displace peaks rather than eliminate them**




| | |
|---|---|
| **Value of V2G** | 1,112 |
| **Value of V1G** | 125 |

# Building demand profiles

Combination of sources from actual customer data and generic sources:

- **UK**
  - Last mile distribution fleet warehouse (Commercial fleet/UK1)
  - Generic demand profile data from Imperial College London for industrial and Residential (Car pool fleet/UK2, Residential/UK3)
- **Sweden**
  - Municipality (Commercial fleet/SE1)
  - Same as UK Industrial (SE2)
  - ENTSOE generic demand profile (Residential/SE3)
- **California**
  - University campus data (single building CA1, entire campus CA2)
  - Open EI generic demand profile data residential (Residential/CA3)

# Optimisation model

- Pyomo toolbox
- Solve for minimum cost of energy for vehicles based on the set of constraints on charger power and efficiency, vehicle battery size and SOC conservation, vehicle hourly availability, vehicle trip requirements, and building hourly demand
- Find the hourly optimal charge and discharge rate of the V2G capable EV
- Big M method (general disjunctive programming) used for energy losses

# How does V2G with E-flex benefit you?

By using Nuvve's optimization software you could save up to

**£900* per EV per year**

by participating in V2G.

**Offer Includes**

- **Free** bidirectional 10 kW charger(s)
- Annual **maintenance** of charger
- **Final charger installation** including delivery to site, mounting, connection, and commissioning
- **24/7** Customer support
- Fleet monitoring **dashboard**
- Charge scheduling & trip booking app

* Savings relative to uncontrolled charging. Savings materialise on customer energy bills and may vary with energy tariff, fleet utilization patterns, time plugged in, vehicle type. Contact e-flex for a custom quote see what V2G can do for your fleet.

e-flex

# Findings 3

Pricing policy: Peak

# Findings 4

Business case for electric car clubs

# E-Flex – Innovate UK

E-Flex is a scaled demonstration of **200 V2G charging stations** in the greater London area combining variable duty cycles and vehicle types to expand understanding of how whole-system benefits in a larger metropolitan city.

Cisco (Lead)
Nuvve
Greater London Authority
Transport for London
E-Car Club LTD
Imperial College London
Cenex

## Key Goals:

- Examine the system value of V2G in a high-density city
- Understand whole-system benefits of V2G
- Identify business models that provide end-to-end value for all participants - realizable market with multiple demand/supply participants.
- Install and operate 200 stations in greater London area

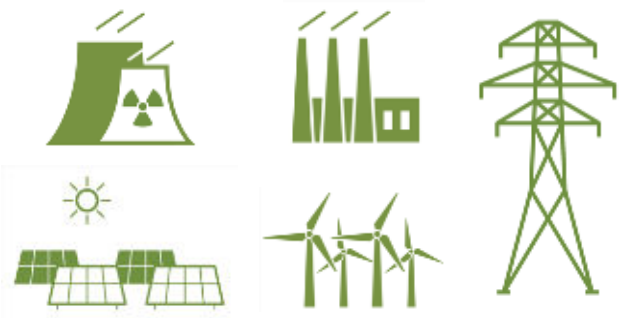
# Our Mission

To lower the cost of electric vehicle (EV) ownership while supporting the integration of renewable energy sources including solar and wind.

***The global Digital Energy Platform for Connected EVs***

# V2G Markets

## Transmission System



*Frequency regulation, voltage control*

## Distribution System

*Transformer upgrade deferral, congestion management*

## Behind the Meter

*Peak shaving, tariff optimisation, arbitrage, emergency back-up*



NUVVE

# Limitations

- The analyses present the highest values achievable
- We assume perfect forecasting (e.g. no demand response event missed)
- Analysis does not factor in any externalities or costs other than energy costs
- The definition of baseline has a greater influence on estimations of smart charging benefits than V2G