



V2G DEVELOPMENTS IN THE UK

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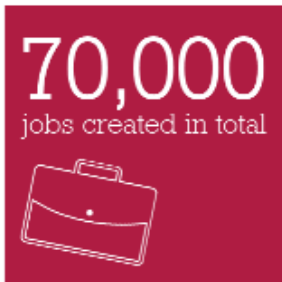
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OUTLINE

- Innovate UK
- Drivers for V2G developments in the UK
- The Innovate UK V2G programme
- Key learnings
- Measuring the impact one year on
- Conclusions

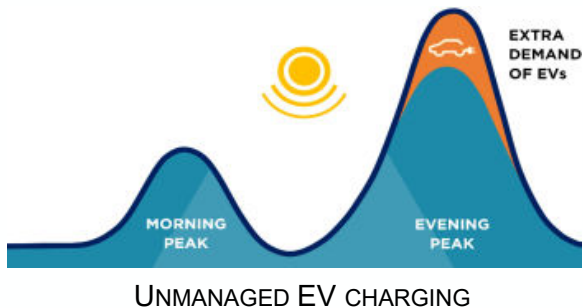
INNOVATE UK

Innovate UK drives **productivity**
and growth by supporting
 businesses to realise the potential
 of new technologies, develop ideas
 and **make them a commercial**
success



V2G OPTIMIZES THE UTILIZATION OF EXPENSIVE ASSETS – THE EV BATTERIES

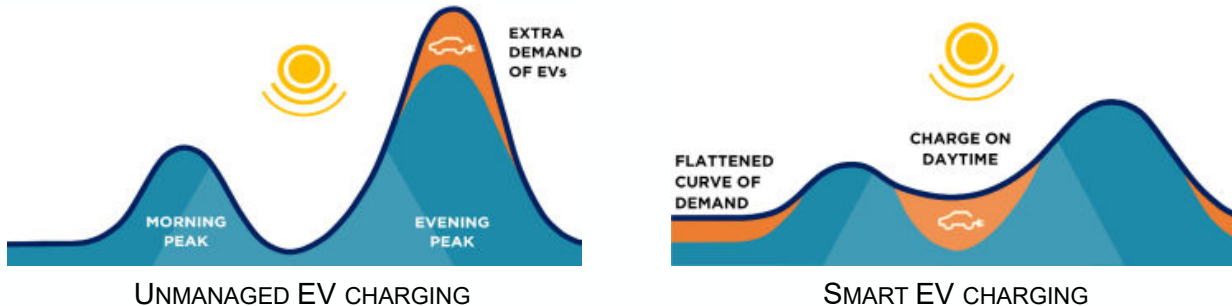
Vehicle to Grid (V2G) includes all technologies and systems that achieve a more tight integration of EVs with the Power Grid:



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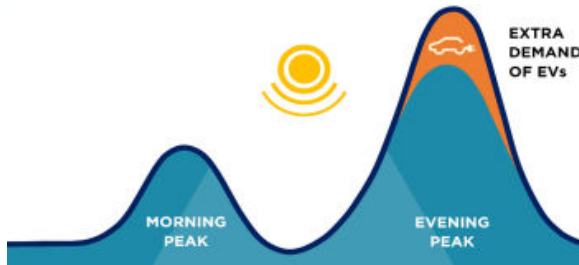
- EVs act as **controllable loads**, to smooth demand peaks



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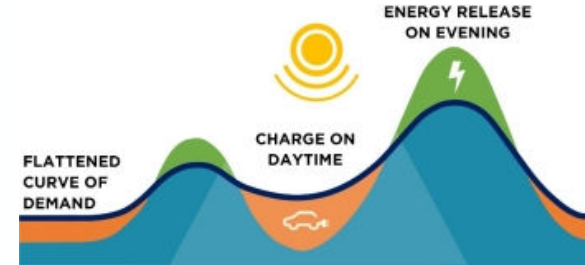
- EVs act as **controllable loads**, to smooth demand peaks
- EVs can act as **distributed storage**, providing energy back to the Grid
- EV drivers earn **rewards** in exchange for grid services



UNMANAGED EV CHARGING



SMART EV CHARGING

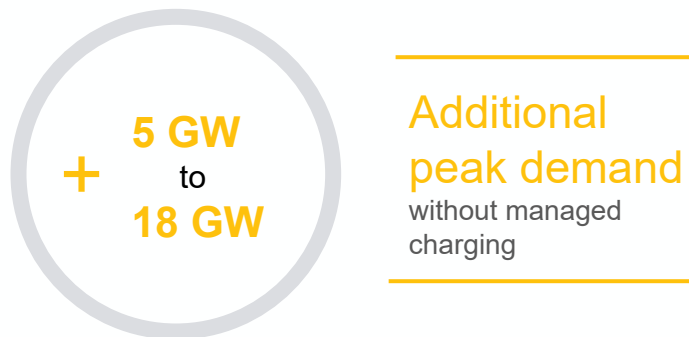


VEHICLE-TO-GRID

THE NEED FOR VEHICLE-GRID INTEGRATION IN THE UK

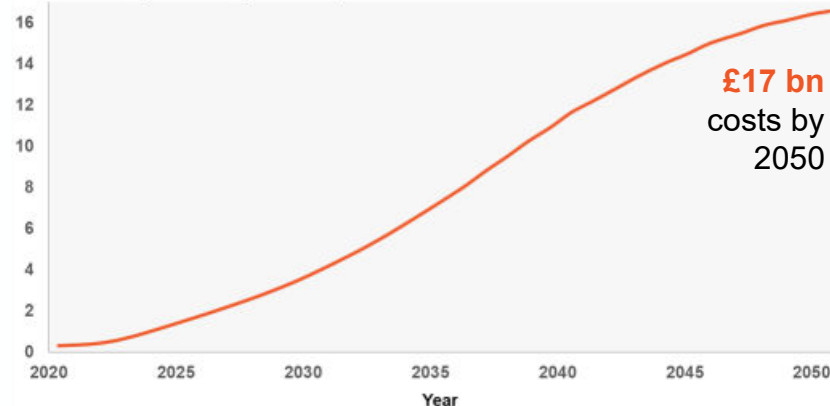


[Source: Bloomberg New Energy Finance Electric Vehicles Outlook 2017]



[Source: National Grid Future Energy Scenarios 2017]

Cumulative network reinforcement costs in UK (£bn)
[Source: Energies Technologies Institute]



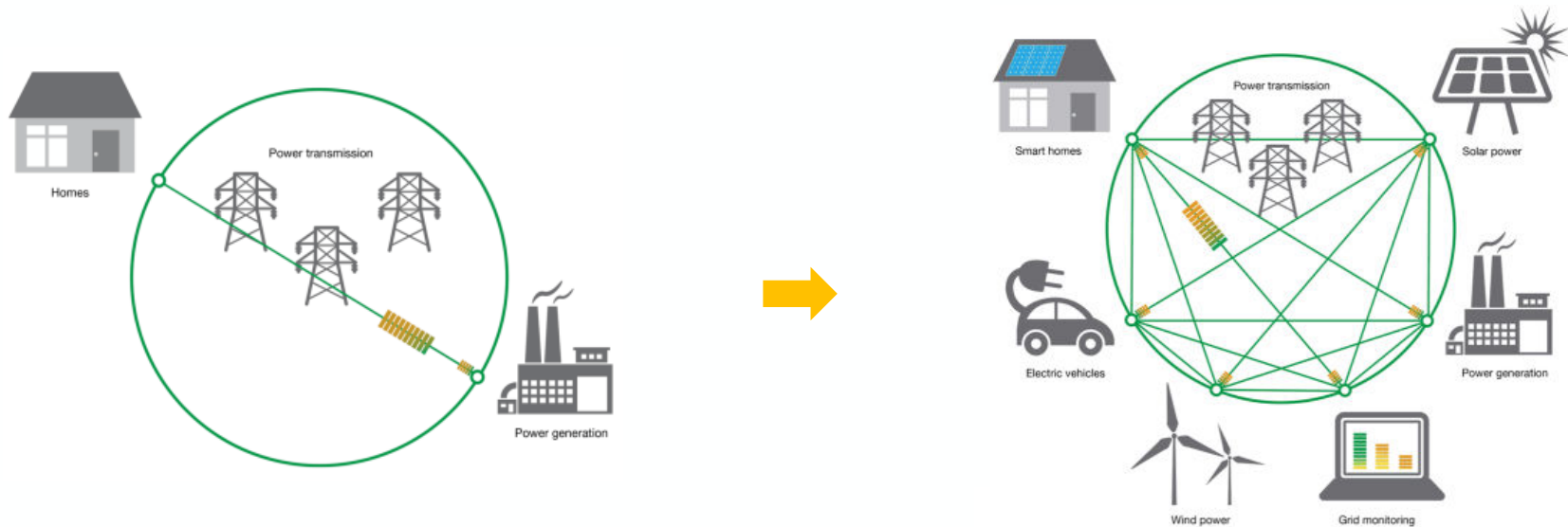
AN OPEN ENERGY SYSTEM ALLOWS V2G TO THRIVE

An Electricity System ready to adapt to new consumers and generators, and business models is necessary for V2G to be viable

- Local Generation
- Electrification of heat
- Time of usage tariffs
- Aggregators and Smart Energy Services
- Open and simplified flexibility markets
- Distribution Network Operators (**DNOs**) ▶
Distribution System Operators (**DSOs**)



THE TRANSFORMATION OF THE UK ELECTRICITY ECOSYSTEM



From a *vertically integrated Power System*:

- Demand easily predictable
- Electricity flow from Power Stations to electricity consumers
- Centralized control

To a *Smart Grid*

- All elements are connected and able to interact with each other
- User can provide energy to the grid
- Generation, Transmission, Distribution and Energy Usage & Storage are optimized across all actors

WHAT IS NEEDED TO MAKE V2G A COMMERCIAL PROPOSITION?

Transportation and Energy sectors converge: effective V2G implementation still requires work on

- Uptake of EVs in the UK market
- Demonstration of reliable business cases for V2G in UK
- Development of affordable hardware
- Development of aggregation platforms
- Evaluation of long term battery life for combined transport and V2G use cases
- User engagement – EV owners need to ‘buy-in’ the V2G technology and operations

THE INNOVATE UK V2G PROGRAMME

Innovate UK V2G competition awarded **£30m** in 3 key areas:



Feasibility Studies

Collaborative R&D

Real-world demo

- Uptake of EVs in the UK market

- Demonstration of reliable business cases for V2G in UK



8 projects explore feasibility of **innovative business models and applications** for V2G

- Development of affordable hardware
- Development of aggregation platforms



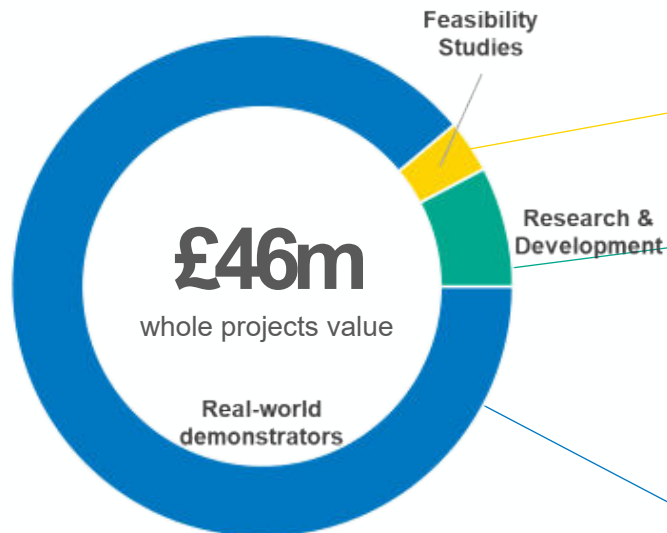
4 projects will develop **V2G HW and aggregation platforms** in the UK, creating an integrated V2G supply chain

- Evaluation of long term battery life for combined transport and V2G use cases
- User engagement – EV owners need to ‘buy-in’ the V2G technology and operations



8 projects will trial more than **2700 vehicles** in V2G operation, covering different customer types, geographical areas and customer propositions

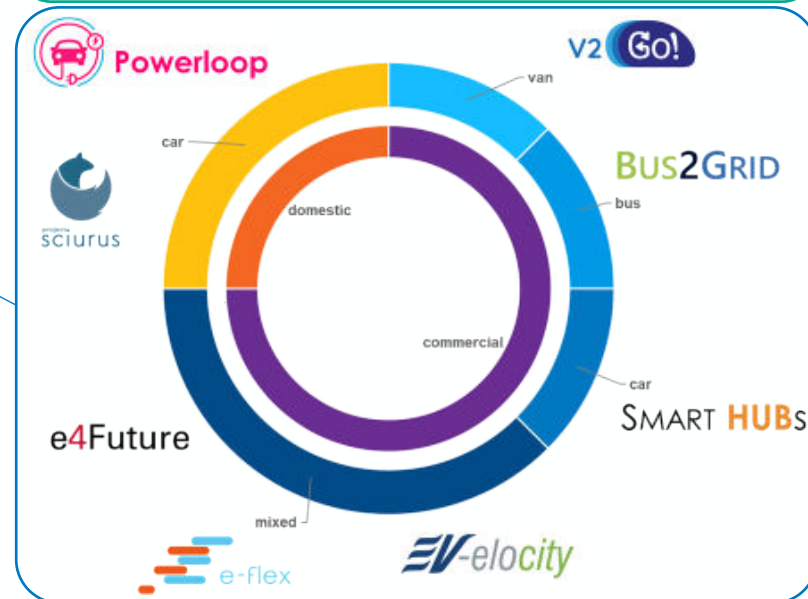
CURRENT PROGRAMME STATUS



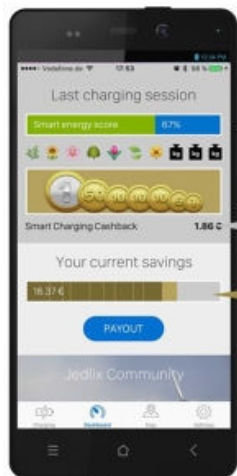
- All Feasibility studies completed by June 2019
- Demonstrator projects finalizing HW certification and site recruitment
- First V2G installations started in Dec 2018

■ Projects on: V2G business models, blockchain for V2G, V2X analytics platform, V2H developments

■ Projects on: onboard charger development, V2G in on-street applications, gamification for V2G



KEY LEARNINGS: MAKE THE CUSTOMER PROPOSITION EASY



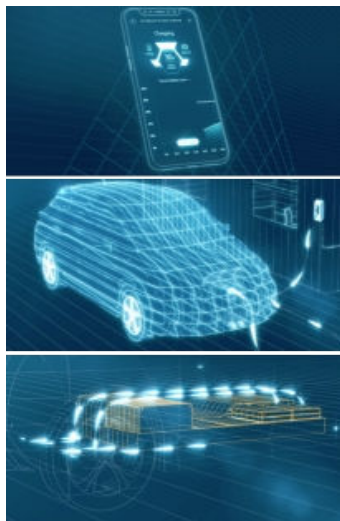
Example of e-drivers daily reward

1.86 €







16.37 €

Example of e-drivers monthly reward

[Source: Jedlix]



The Powerloop bundle has everything you need for a greener future:

-  A lease agreement on a brand-new Nissan Leaf
-  A free Vehicle-to-Grid compatible charger
-  100% renewable electricity for your home
-  Smart meter installed free of charge
-  An app to remotely control your charging
-  Money off your monthly lease if you charge regularly

- Direct customer reward
 - Energy and service payments are treated separately
 - User has full visibility
- “Never pay for mile driven ever again”
 - Energy and service payments are aggregated
 - Limited user intervention needed
- All inclusive monthly payment
 - Easy to understand bundle
 - EV lease agreement requires plug-in for min amount of time

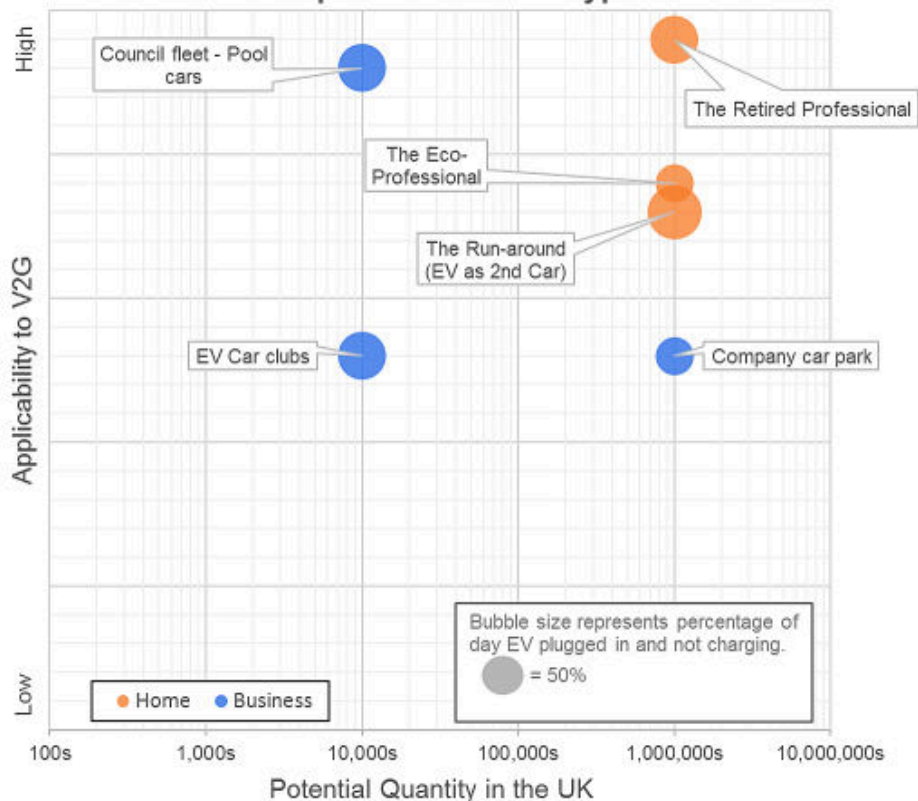
Hands-on

Hands-off



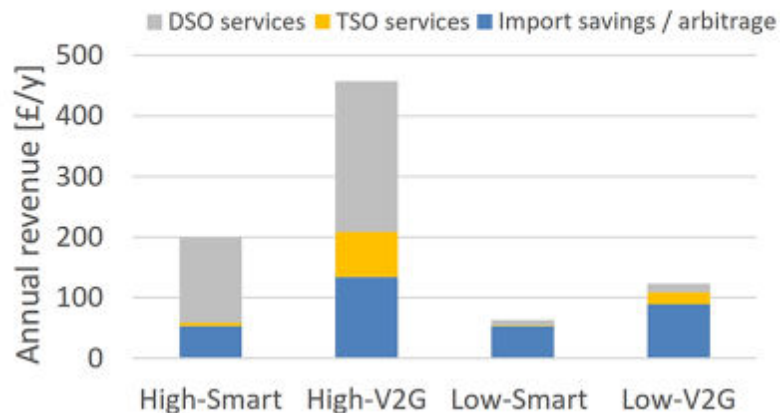
KEY LEARNINGS: V2G BUSINESS CASE WORKS, BUT NOT FOR EVERY TYPE OF USER

Top Customer Archetypes



Revenue stack in 2030

elementenergy



- A key parameter is the **plug-in rate**: increasing it from 28% to 75%, V2G revenues *quadruple*

Sources:

- Cenex, "Understanding the true value of V2G", <https://www.cenex.co.uk/energy/vehicle-to-grid/>
- Element Energy analysis, V2G Britain project

KEY LEARNINGS: V2G BUSINESS CASE WORKS, BUT NOT FOR EVERY TYPE OF USER

Some additional take-aways:

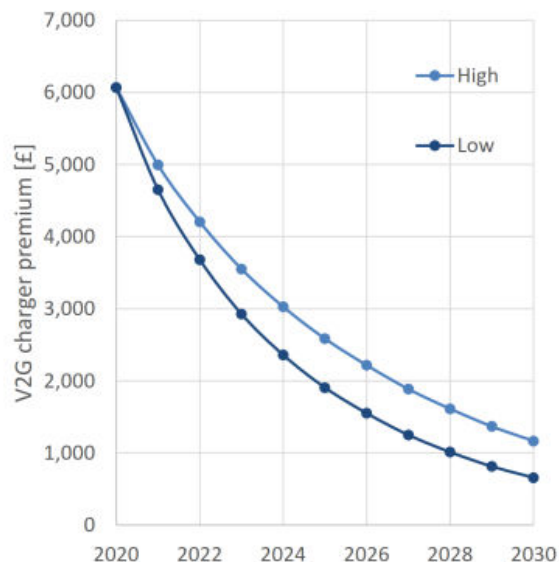
- The distribution network is the area of the grid that will be under more stress, so **DSO services** can have best potential value and fit for V2G. However:
 - DNO to DSO transition ongoing - service *pricing not yet defined*
 - Currently few DSO areas are heavily congested – difficult to build *tomorrow's offering on today's data*
- **Whole-system analysis** suggests V2G-related savings worth £3.5bn/yr by 2040 [Source: Imperial college/OVO, "blueprint for a post carbon society"]
 - Some of the most tangible advantages are *maximisation of renewables utilization*
 - Evident whole system benefits - but not yet clear *who will benefit* from them and *how to quantify* such benefits



KEY LEARNINGS: HW SUPPLY AND COSTS STILL A CONSTRAINT

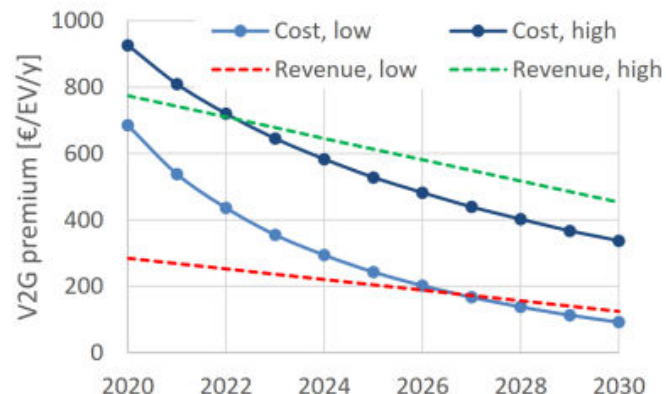
Source: Element Energy analysis, V2G Britain project

Cost-down trajectory for V2G charger



Cost vs revenues 10y lifetime

elementenergy



- Costs based on 7kW charger
- Learning rates based on proxy tech. (high -11% ; low – 15%)

- Need to annualise costs over long life
- Costs include HW, aggregation and battery degradation costs
- Cycle life degradation assuming 4500kWh/year throughput
- High revenues estimated in high-congestion DSO areas

MEASURING THE **IMPACT** ONE YEAR ON

- **Policy** – vehicle-grid integration is central to government initiatives to achieve system-wide benefits of a smarter, more integrated energy system
- **International interest** – favoured by the opportunities offered by an open energy system, the UK has become a centre of activities on vehicle-grid integration
- **Fast-growing supply chain** – multiple EV charger manufacturers developing V2G HW and energy services platforms integrating V2G functionality (both inside and outside Innovate UK projects)
- **V2G commercial customer propositions already available** – Companies like OVO, Octopus and EV8 are setting commercialisation routes and offerings for V2G

FURTHER STIMULATING V2G GROWTH: PUBLICLY AVAILABLE V2G STUDIES

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Cenex Studies

Available at:
<https://www.cenex.co.uk/energy/vehicle-to-grid/>



Independent, not-for-profit, low emission
vehicle and energy for transport experts

V2G Market Study

Answering the preliminary questions for
V2G: What, where and how much?



Independent, not-for-profit, low emission
vehicle and energy for transport experts

EV Charging in Car Parks

A Study of Innovative Solutions to Charging EVs in
Car Parks

Commissioned by Innovate UK



Independent, not-for-profit,
low carbon technology experts

EFES - V2G Data Analysis Summary Report



Everoze & EVConsult V2G Global Roadtrip

Available at: <http://everoze.com/v2g-global-roadtrip/>



Evolving into an
online hub for V2X
projects and activities

www.v2g-hub.com

CONCLUSIONS

- **From problem to solution** – V2G can turn EVs into flexibility resources, generating value for customers, making the Power System more reliable, increasing penetration of renewables
- **A smart energy system** – for V2G to become a commercial proposition catering to a variety of customers, a smart, dynamic and interactive energy system and a responsive regulation framework are needed
- **Innovative business models** – services stacking and understanding market opportunity and value for all actors is key to commercial deployment of V2G
- **A proposition that works for customers** – rolling out V2G commercially hinges in understanding customer behaviours and needs, and find solutions that work for them
- **V2G costs vs revenues** – while HW and implementation costs are still high for V2G, but are rapidly decreasing: V2G can be profitable if applied to the correct setting and user type



Thank You

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Appendix

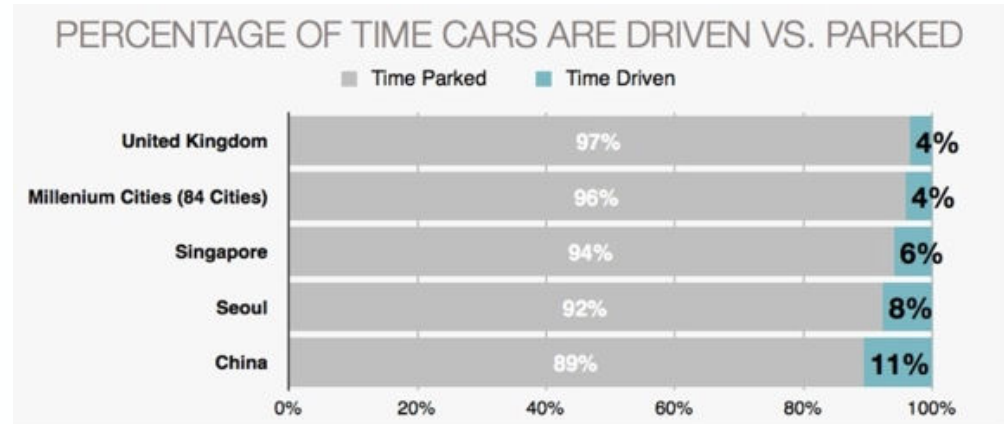
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WHILE USER DEMAND MORE RANGE, VEHICLE USAGE IS DECREASING

- Vehicle usage is decreasing: in UK, car drive for less than **2 trips** a day, with average trip time of 22 minutes

[Source: 2016 National Travel Survey]



Source: Royal Automobile Club

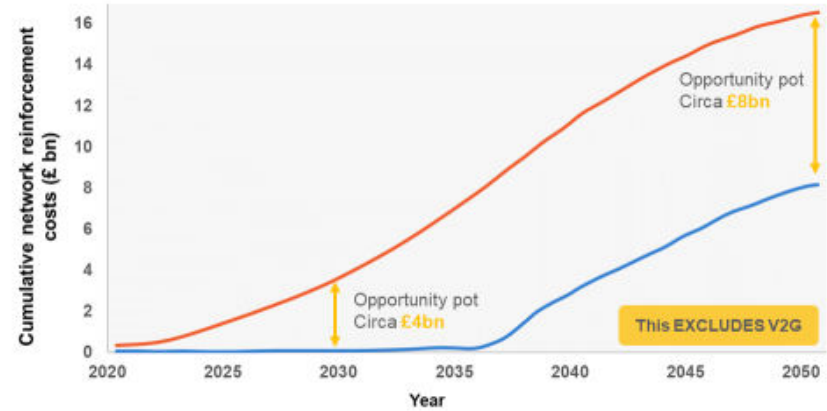
By turning vehicles into distributed energy storage systems, V2G allows to **maximise use of** an otherwise mostly unused **asset**

V2G MARKET VALUE COULD BE WORTH £3.5BN/YR BY 2040

Using EVs as controllable load allows to defer

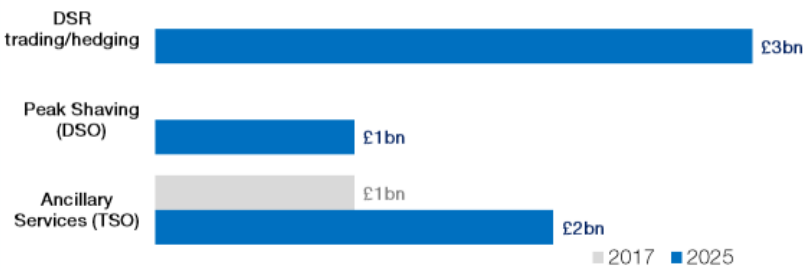
Power System upgrades

- Up to £8 bn cost savings



Value multiplies if EVs act as flexibility source

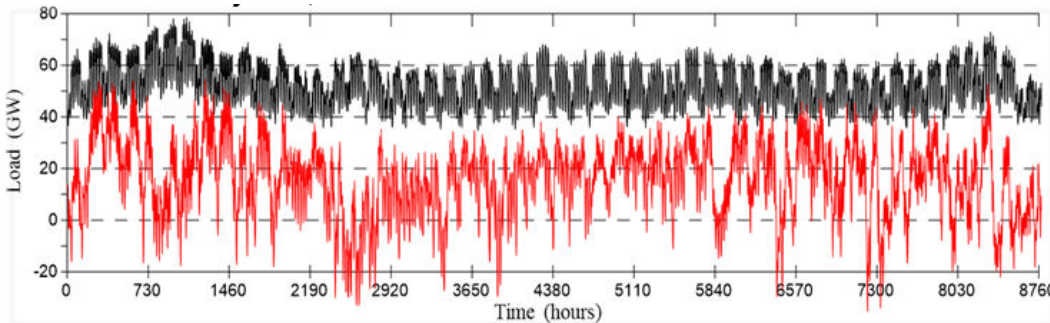
2017 and 2025 (projected) UK flexibility market



| | | Energy system benefit (£bn/yr) | |
|---|---|--------------------------------|------|
| Scenario | | Smart Charger | V2G |
|  | Burning platform (assumes 50% participating vehicles) | 0.1 | 0.15 |
|  | Stepping stone (assumes 50% participating vehicles) | 0.5 | 1.4 |
|  | Future survival (assumes 80% participating vehicles) | 1.1 | 3.5 |

WHY DO WE NEED FLEXIBILITY RESOURCES?

EXAMPLE OF LOAD (black) vs RESIDUAL LOAD VARIATIONS (red) IN SPAIN



- **Obligation to serve:** supply must follow the (variable) demand
- Historically, the variability has been absorbed with controllable sources
- **Renewables** inherently add to the uncertainty, on the supply side too
- Storage (including EVs through V2G) is a **controllable source** that can buffer variability

V2G CAN SATISFY DIFFERENT GRID SERVICES:

STACKING SERVICES MAXIMISES VALUE

| | | | Typical Response Times | Typical Duration of Service | Typical Revenue |
|--------------------|---|--------|--|--|-----------------|
| Frequency Services | Including Frequency Regulation, Restoration and Containment i.e. FFR | + - | 0 – 30 seconds | 30 seconds – 30 mins | €€€€€ |
| Reserve Services | Typically separate positive and negative services i.e. STOR & DTU | + - | 5 – 240 mins (faster response = higher value) | 30 mins to 4 hours | €€ |
| Capacity Markets | Used to ensure sufficient capacity is available to meet system need | + | Up to 4 hours | Potentially unlimited (risk to DSR) | €€€ |
| Behind the Meter | Peak shaving services to avoid high price periods i.e. TRIAD, DUoS, TOU Tariffs | + | N/A | 15 – 120 mins | €€€€ |
| | Increased utilisation of generation | + | N/A | 15 mins – 4 hours | €€ |

V2G IS NOT HEAVILY DETRIMENTAL TO BATTERY LIFE

V2G does not involve bulk energy transfers: only a **small percentage of** battery **State of Charge** is used to support the Grid

Multiple sources suggest V2G does not significantly impact battery life:



Simulation results: V2G high cycle operations only impact 5% battery health over 10 years



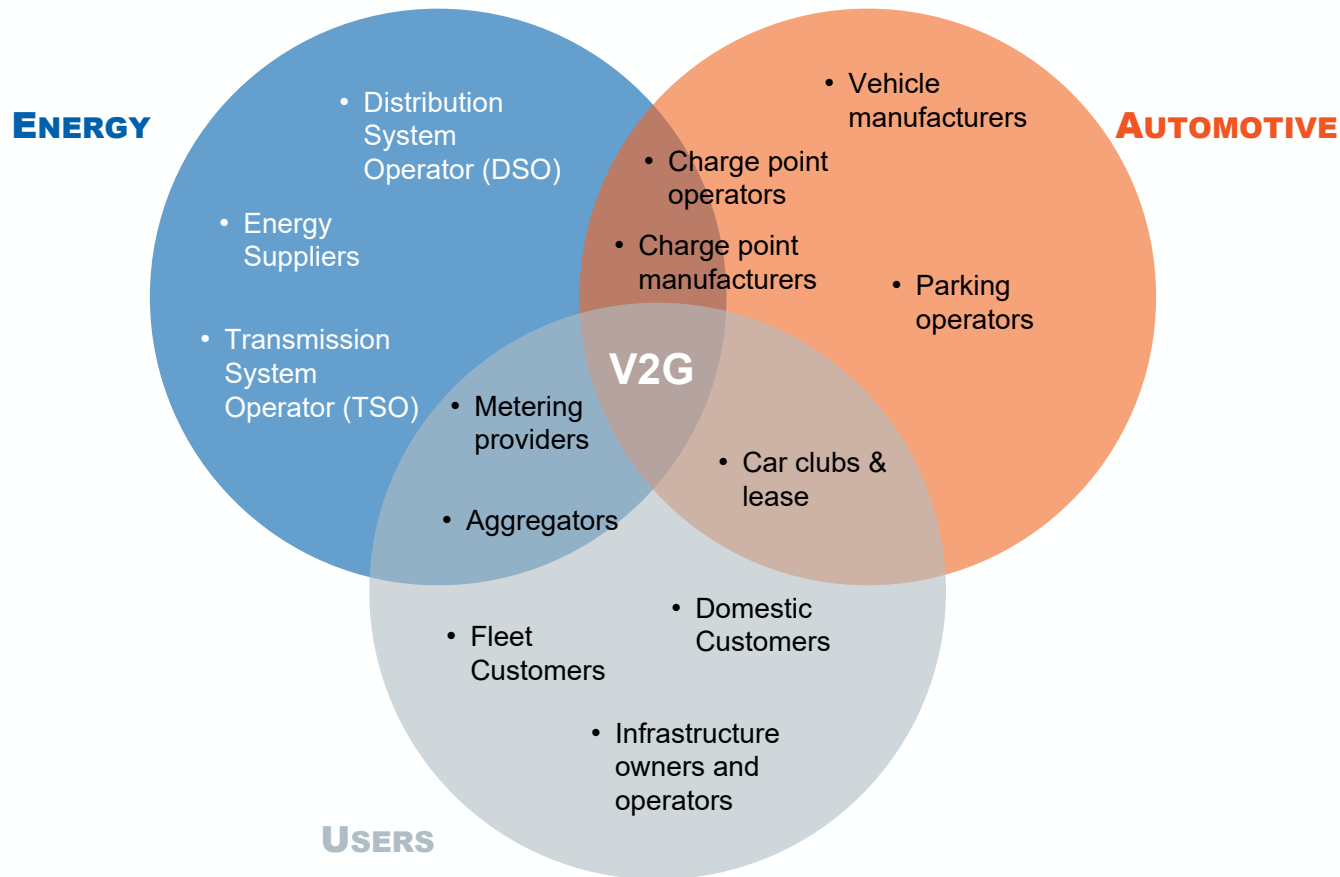
Nissan covers **V2G operations into warranty**: Calendar age more impactful than V2G-related cycles



Warwick university study proves intelligently-managed **V2G** operations can actually **extend battery life**



MAKING V2G A COMMERCIAL PROPOSITION: DELIVERING VALUE TO ALL ACTORS



EMPOWERED CUSTOMERS PARTICIPATE IN V2G VOLUNTARILY

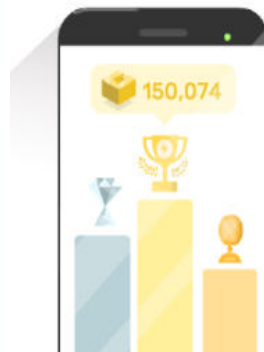
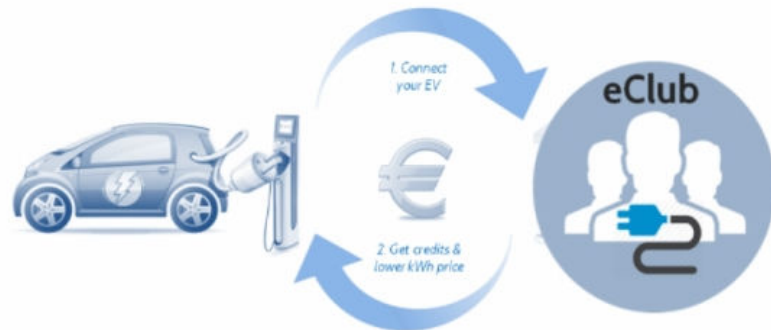
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- **Choice, not obligation** – Participation in V2G programmes must be voluntary
- **Reward** – V2G business models need to find a way to compensate EV drivers
- **Engaged users** – customers will join V2G schemes if they see clear advantages and no disruption to use of EVs for transport

KEEPING **USERS ENGAGED** IS KEY TO **SUCCESSFUL V2G DEPLOYMENT**

- **Compensation is not necessarily monetary**
 - Green credits, air miles, free charging can move customers to use V2G systems [ref: ENGIE V2G Consumer Research project]
- **Gamification** – User engagement is typically high during first adoption, then tends to fade: interactive and game-based systems keep engagement alive



Points System

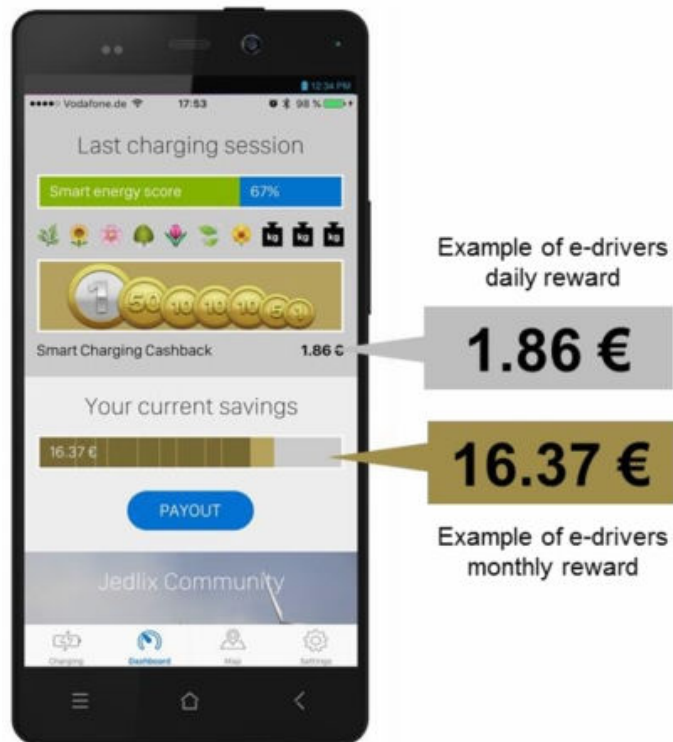
Players are rewarded with points for their progress. They can track their carbon impact which has been offset by their actions.

Leagues and Prizes

Players can compete with each other as individuals or in teams, for example "Nissan Leaf drivers vs BMW i3 drivers." Players can win real prizes. For example "win 5 free Electric Highway charges."

APPROACHES TO V2G CUSTOMER PROPOSITIONS:

DIRECT CUSTOMER REWARD



- More **immediate model**: revenue of energy and power trading are passed on to customers
- Aggregators take a **fee** from the revenues for the service providers (acting as energy brokers)
- Requires **traceability** of energy and revenues up to national/local market
- More indicated for **advanced users** who want direct control

APPROACHES TO V2G CUSTOMER PROPOSITIONS: ALL INCLUSIVE MONTHLY PAYMENTS

Car Lease

Insurance

Breakdown cover

Tyres

Service, Maintenance &
Repairs



Home Electricity Tariff (incl. EV charging)

V2G operations

V2G Charger

APPROACHES TO V2G CUSTOMER PROPOSITIONS:

“NEVER PAY TO DRIVE AGAIN”

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1. Tell us when you need to use your car and your chosen minimum charge level, via the app.



2. Plug your car in to your charger whenever you're at home.

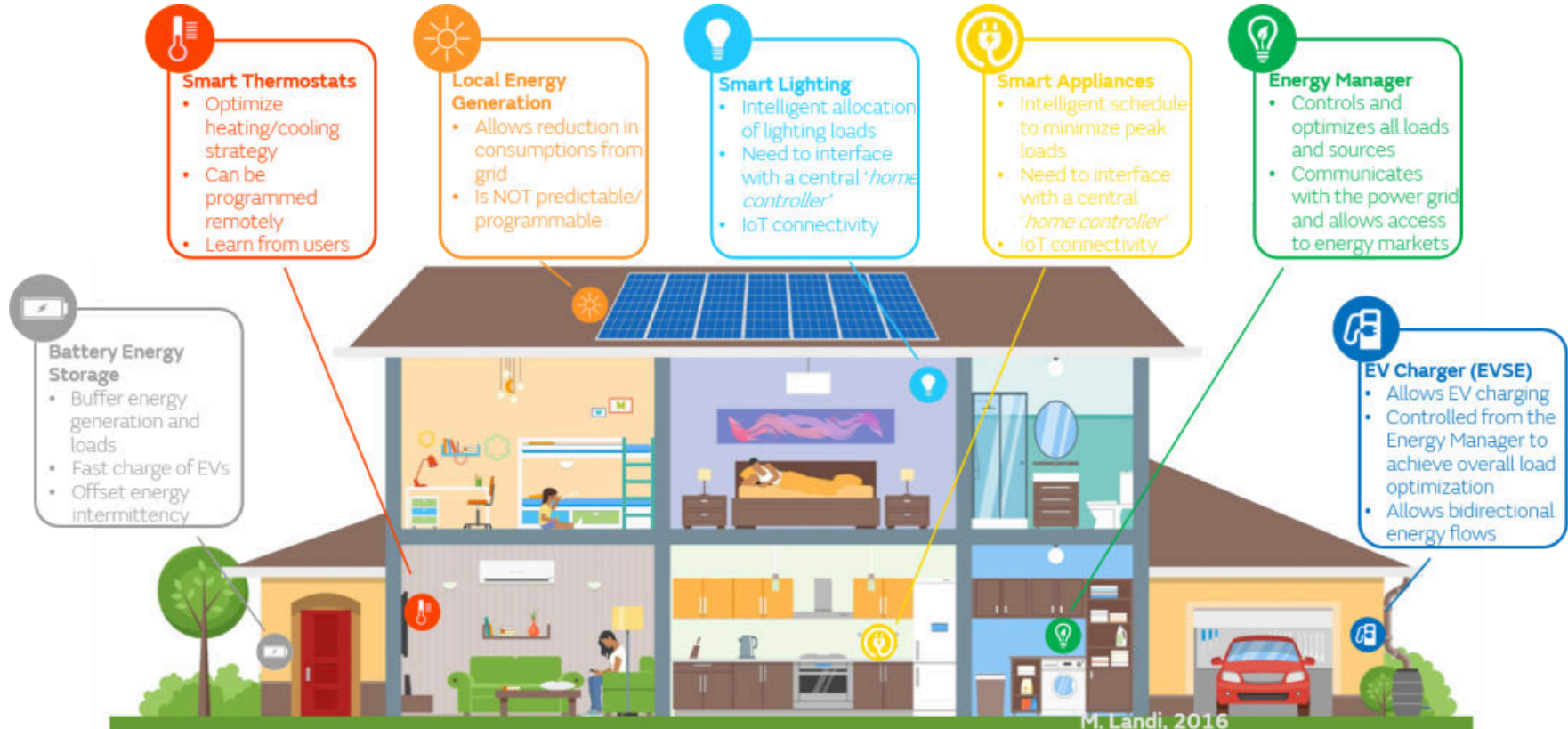


3. We'll charge your car when demand on the grid is low, and export when demand is high (working around the charging schedule you've set in the app)

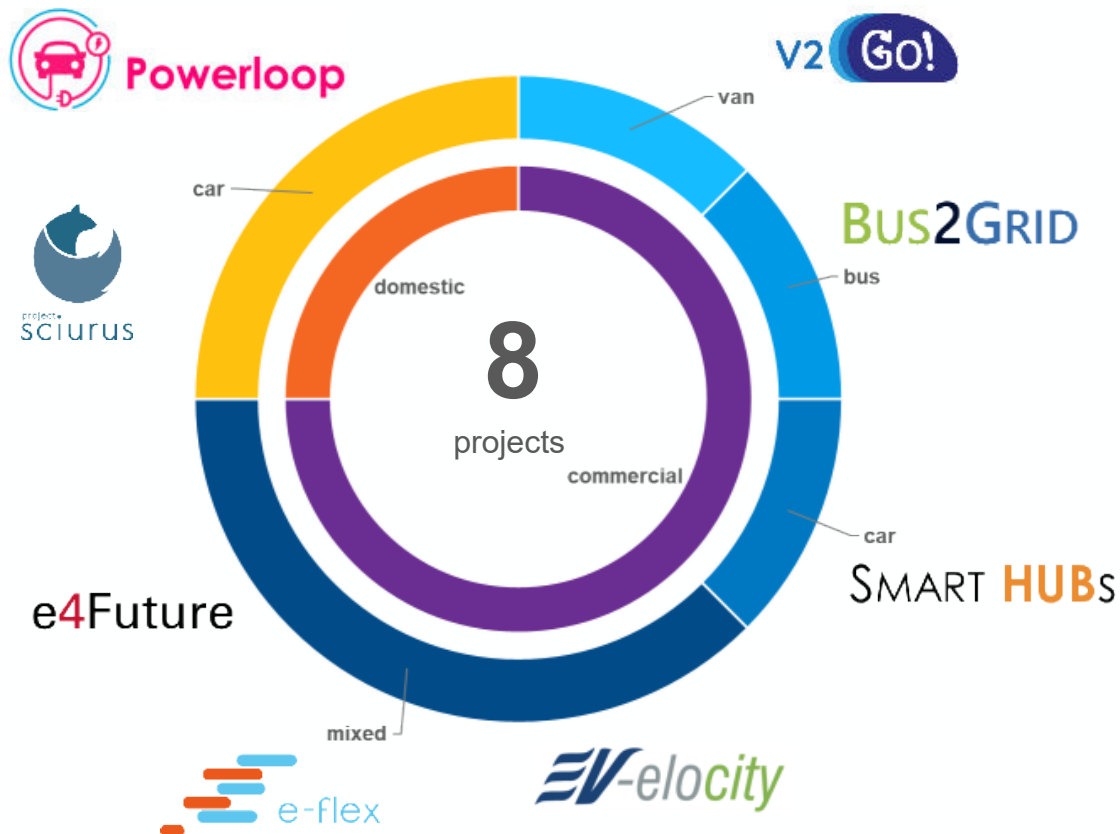


4. Anything exported that your house doesn't use, we'll sell back to the grid. You'll see the money you've saved on your monthly statement.

APPROACHES TO V2G CUSTOMER PROPOSITIONS: VEHICLE-TO-HOME (V2H) AND -BUILDING (V2B)

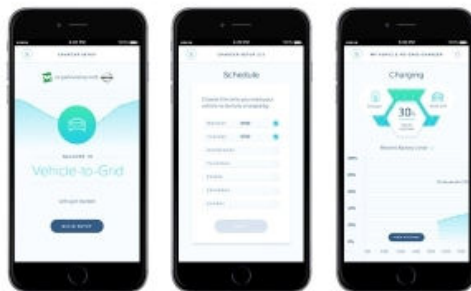


A WORLD-LEADING RANGE OF V2G PROJECTS



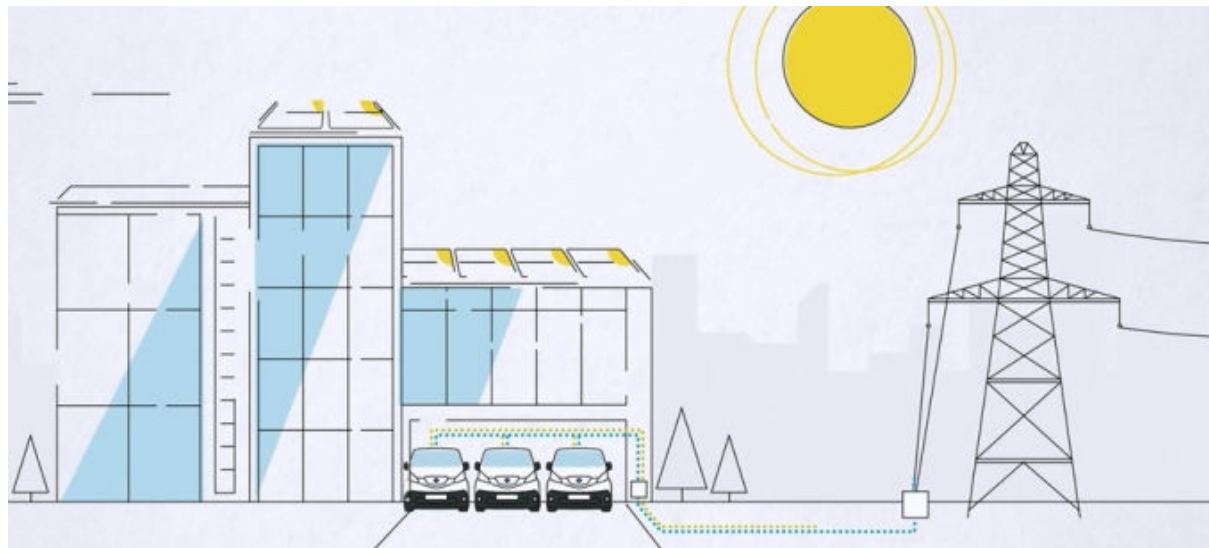
V2G PROJECTS: SCIRIUS

- **1000** V2G chargepoints installed for residential customers
- Low-cost domestic charger developed as part of project
- 'Never pay for mile driven again' customer proposition



V2G PROJECTS: E4FUTURE

- Deploying **1000** V2G chargers to business customers in different areas
- Quantification of whole system benefits and impact of V2G
- Stacking of services and tailoring to customer needs



Imperial College
London

nationalgrid



UK
Power
Networks
Delivering your electricity

e.on

NORTHERN
POWERGRID

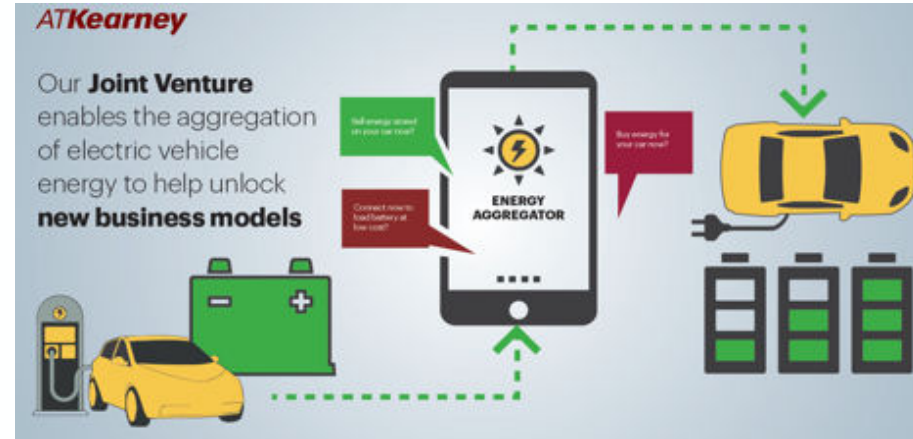
V2G PROJECTS: EFLEX

- **200** V2G-enabled vehicles from heterogeneous fleets with different duty cycles
- Analysis of both fixed and real-time scheduling
- Investigation of market design and operation with focus on safety and security



V2G PROJECTS: **VELOCITY**

- 100-110 V2G units installed over 3 years
- Assessment tool to evaluate V2G opportunity, and EV management platform
- Joint venture (EV8) for solution commercialisation created as a result of the project



ATKearney

HONDA
The Power of Dreams



The University of
Nottingham



FORWARD
UTILITY

WVG
Innovative Solutions



Nottingham
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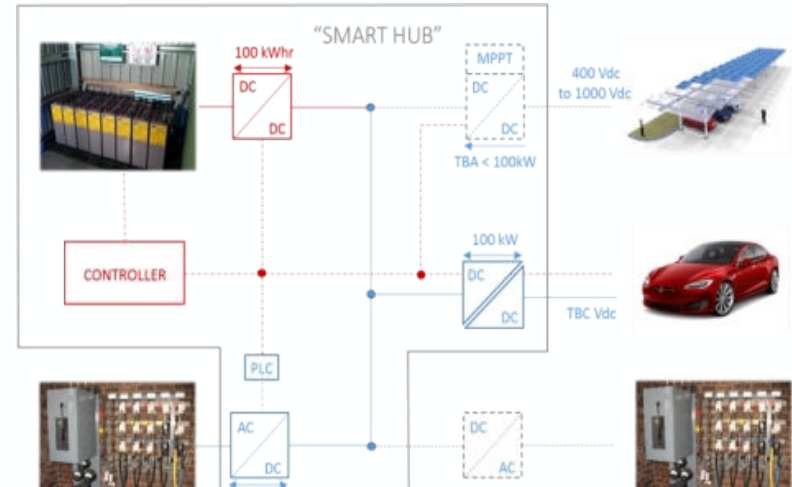
ecar
A Europcar Company

brixworth
TECHNOLOGY

V2G PROJECTS: SMARTHUBS II



- **Smart Hubs:** Solar carport + local storage + V2G charging (with local DC microgrid)



V2G PROJECTS: POWERLOOP

- **135** domestic V2G installations
- Powerloop V2G Leasing Bundle:
 - lease agreement of a new **Nissan Leaf**
 - V2G charger
 - 100% renewable energy from Octopus
 - smart meter
 - Charge control smartphone App



octopus
energy

octopus
electric vehicles

open energi
UK Power
Networks
Delivering your electricity

NAVIGANT



Charge Point
Intelligent eTransport Solutions

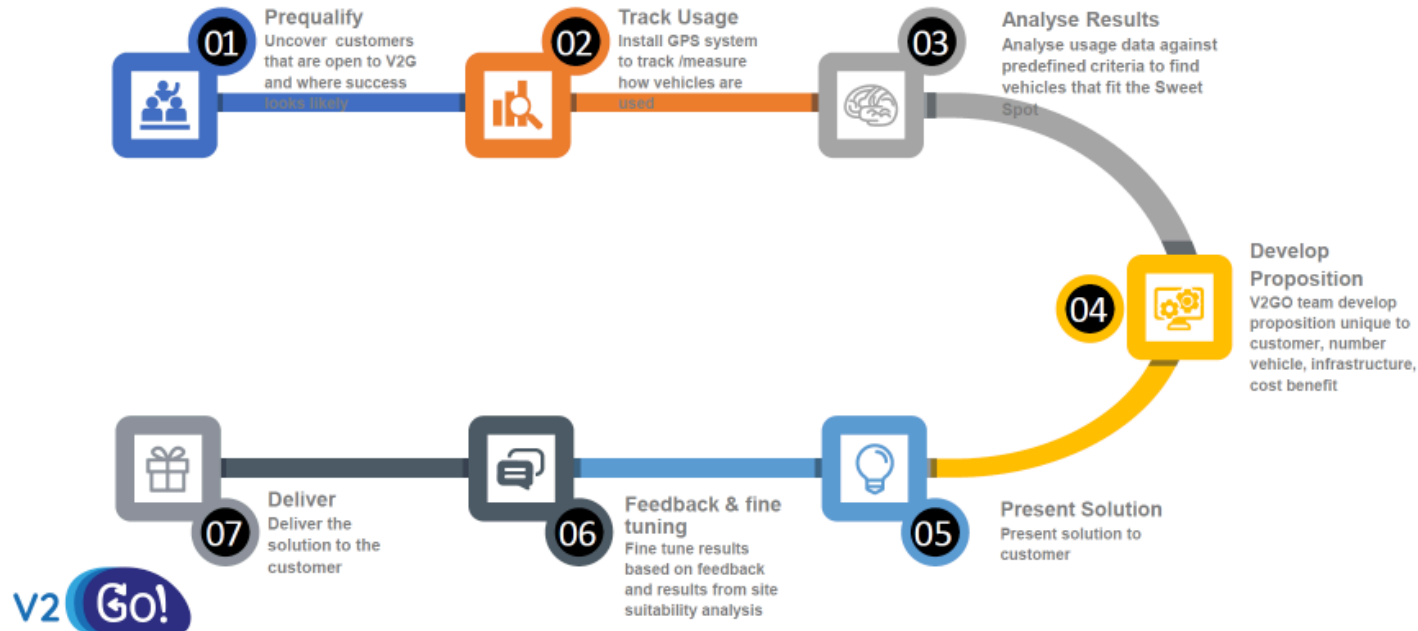
energy
saving
trust

V2G PROJECTS: V2GO



THE VIRTUAL FORGE®

*ARRIVAL



V2G PROJECTS: BUS2GRID



Software and
technology
validation at
BYD test
centre

Over 30 e-
buses
enabled for
bidirectional
charging and
V2G service
provision to
TSO and
DSO

A
comprehensiv
e aggregation
service for
V2G assets

Trials of new
DNO
services and
dispatch
arrangement
s

Business
Models and
technical
case studies
to address
V2G market
entry
barriers