
ENERGINET
Vehicle Grid Integration Research
September 2022
RETHINKING ENERGY

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EXECUTIVE SUMMARY

The charging network for the fast-growing fleet of EVs can trigger disruptions in energy supply, or could be a balancing factor if we implement smart, social & responsible charging

Sustainable Energy Transition meets Mobility Transition

The transition to 100% renewable energy and EV fleets creates significant challenges for the electricity grids

THE KEY TRENDS

1. The number of EVs (including hybrids) expected to grow from 150.000 to 760.000 by 2030. At the current speed, Denmark will possibly even reach 1 -1.5 million EVs.
2. Denmark has expressed an ambition for 100% renewable energy by 2030.
3. The electricity grids cannot facilitate growth with the current charging infrastructure. Extending the grid in time is impossible.

The car batteries can be a stabilizing force in the grid

With EVs gaining market share, EV charging can be a huge threat or part of the solution

HOW WE CAN ADAPT

1. If we redesign the way we charge EVs we can create benefits for all stakeholders.
2. Technologies and business models are available and have been tested in more than 100 projects around the world.
3. A national system design is required to prevent disruptions and to create grid stabilization.

We need to design & realize the system to avoid blackouts

We propose to urgently design a National Responsible Charging System and organize for rapid implementation

POSSIBLE NEXT STEPS

1. Most urgently, we propose a high paced system design project in co-creation with all key stakeholders.
2. Energinet can start the identification of enabling technology solutions and run tests in Denmark.
3. Energinet and partners can initiate a joint implementation program with global leading tech players.

THE RESEARCH QUESTION

Energinet is looking for systems and solutions within the EV charging domain that can help shape the direction towards vehicle and grid integration for increased grid stability

WHY

- How can we integrate e-mobility and the grid for more stability?
- What could Energinet's role be in designing a smarter charging system?
- What would it cost us if we do not innovate and have to expand the grid?

WHAT

- What are relevant technologies for smart & bidirectional charging?
- What are common business model drivers currently being tested or used?
- What is happening globally in terms of trials and implementation of V2G?

HOW

- Research insights from a market developments and cost perspective
- Deepdive into 10 promising technologies and 4 (pilot) projects
- Potential system design based on desk research and expert interviews

GLOSSARY OF KEY TERMS

An overview of key terms and abbreviations in alphabetical order

Aggregator	A company that manages the operation of sources of flexibility (e.g. EV fleets) in order to deliver energy services and, in doing so, exploit the economic value of flexibility.
Bidirectional charging	Two-way charging (meaning charge and discharge)
BRP	Balance responsible parties (BRPs) are ecosystem players (energy generators, energy suppliers or consumers) taking responsibility for balancing supply and demand within their own portfolio.
BSP	Balancing Service Providers (BSPs) are market participants (e.g. aggregators) which provide balancing services (energy, capacity or both) to the DSO and/or TSO
CPO	A charge point operator (CPO) installs and maintains charge stations so EV users can charge their vehicle
DSO	Distribution System Operators (DSO), are responsible for managing and maintaining the distribution network, from the generation sources to the households/businesses
e-MSP	An e-mobility service provider (e-MSP) offers charging services to EV drivers, typically including access to multiple charging stations (via app/card), roaming, and analytics.
ENTSO-E	ENTSO-E, the European Network of Transmission System Operators for Electricity, represents 39 European electricity transmission system operators (TSOs)
EV	Electric Vehicle (or electric car)
IRENA	The International Renewable Energy Agency (IRENA) is an intergovernmental organization mandated to facilitate cooperation, advance knowledge, and promote the adoption and sustainable use of renewable energy.
Linear charging	The traditional way of charging that is currently dominant around the world: EVs connect to the grid through a charging point and instantly start charging their batteries, regardless of current capacity and demand
RES	Renewable Energy Sources (RES) refers to energy produce from natural processes (e.g. wind, solar)
Smart charging	Terminology currently used to describe more intelligent charging solutions that are being tested, including delaying charging and limiting the speed of charging to lower the load of the grid
Social & Responsible charging	The driver allows his car to become part of the local or, where it will receive, store and –when needed– deliver energy to other players in the grid, while ensuring a sufficient charge within the time-frame specified by the driver
Time-of-use tariffs (TOU)	A time of use tariff (TOU) is a type of time-based billing where the price for electricity can change depending on the time of the day (static, dynamic or a combination)
TSO	A Transmission System Operator (TSO) is an organisation responsible for reliable transportation of energy (or gas) on a national level
V2G	“Vehicle-to-grid”, a technology that enables that allows car batteries to give back to the power grid
V2H	Vehicle-to-home (V2H) entails using the energy from your EV’s battery to power your house or business
V2X	Vehicle-to-everything refers to passing information from an EV to any entity (e.g. vehicles, pedestrians)
VGI	“Vehicle-grid-integration” refers to the many ways in which a vehicle can provide benefits or services to the grid, to society, the EV driver by optimizing EV interaction with the grid
VRE	Variable Renewable Energy (VRE) sources produce energy intermittently instead of on demand. VREs include solar, wind, hydro and tidal power.

RETHINKING ENERGY

RESEARCH INSIGHTS

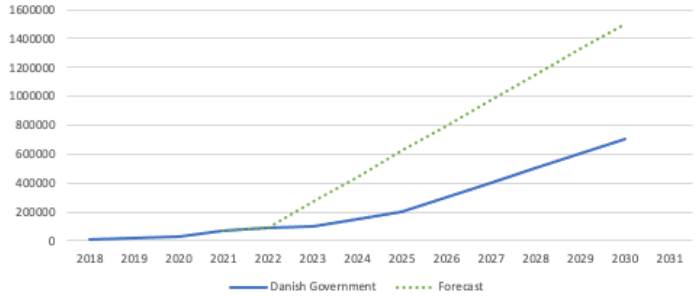
Research based on Danish market trends. To be aligned with international trends in further international alignment.

RESEARCH INSIGHTS: MARKET DEVELOPMENTS

With the rise of e-mobility and the boost in renewable energy production, the pressure on the electrical grid and therefore the potential of EV and grid integration through V2G has grown

DEVELOPMENTS IN E-MOBILITY

The expected uptake of EVs may cause a destabalizing impact on the grid if charging remains unmanaged

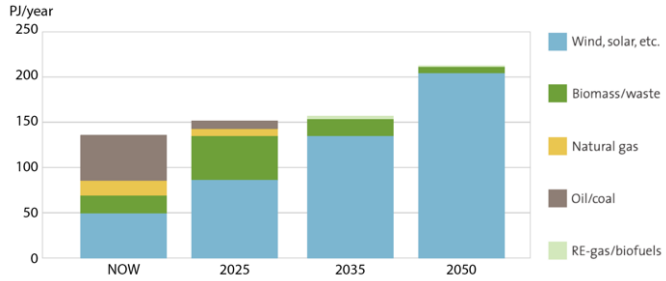


GROWTH AND RISKS

1. **EV uptake:** The Danish government has set a goal of having **760,000** electric cars by 2030. If EV sales continue at their current rate, they could even reach **1 to 1.5 million** units in 2030.
2. **Grid risks**: "unmanaged charging", millions of EVs attempting to charge simultaneously, can have a destabilizing impact – leading to voltage drops, voltage fluctuations and power losses.

DEVELOPMENTS IN RENEWABLE ENERGY

The current electrical grid is already under strain and will not be able to support Denmark's transtion to 100% renewable energy by 2030.

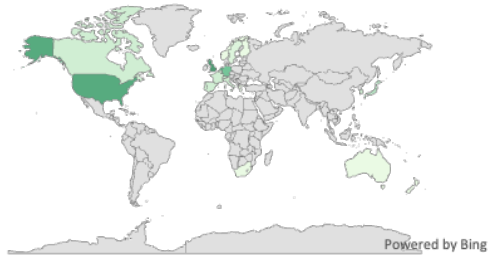


GROWTH AND RISKS

1. **Production:** By 2030 Denmark's entire electricity system will transition to a 100% renewable supply. In fact, by 2040, a threefold growth in solar and wind power generation capacity is projected.
2. **Risks:** Variations in the generation of solar or wind energy and the demand or supply in a specific location can cause grid instabilities and waste of renewable electricity production (leading to fossil fuel use).

DEVELOPMENTS IN BIDIRECTIONAL CHARGING

While bidirectional charging has attracted a lot of attention globally, widespread commercial acceptance has not yet been attained.



POTENTIAL SOLUTION

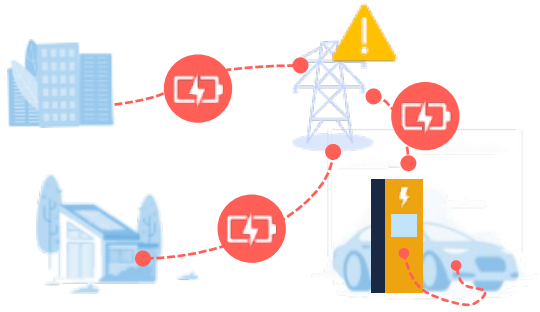
1. **Growing Interest:** VGI and V2G are being promoted by international institutions (e.g. IRENA, ENTSO-E) and many governmental organizations (e.g. Innovate UK) for their ability to stabilize the electrical grid, limit grid expansion and optimize for RES.
2. **Current adoption:** Despite its potential, bidirectional charging is still being tested, with a growing number of projects and few commercial implementations.

THE COST OF NOT ACTING – ON AN INTERGRATED NATIONAL LEVEL

If we fail to implement smart, social & responsible charging as a standard, we risk power outages and we will need costly and labour-intense grid expansion on DSO and TSO levels

COSTS OF LOCAL POWER OUTAGES

With current linear charging and the expected growth numbers, most experts expect local and regional disruptions may occur, with significant direct and indirect costs



BLACK-OUT COST ASPECTS

1. **Direct costs:** The direct costs of disrupted power supply include loss of productivity, loss of perishable goods, potential loss of companies leaving to locations with energy supply security.
2. **Indirect costs**: When power supply is not guaranteed, citizens and companies may need to invest in own local safety measures to minimize the potential impact for themselves.

COST OF GRID EXTENSION

Upgrading the electricity grids to facilitate linear charging will require at least 16 Billion DKK in the next 7 years

GRID EXTENSION COSTS

1. **Materials:** Grid extension requires expensive and more and more scarce materials.
2. **Machines:** The physical installation requires smart new machinery beyond the current fleets.
3. **Labour:** A majority of total grid extension costs are the labour costs.
   The scarcity of qualified engineers comes on top of this cost aspect (see next column)

LABOR ASPECT OF GRID EXTENSION

Availability of sufficient Technical & Engineering talent may well be the major shortage that would need to solved

LABOR CHALLENGES

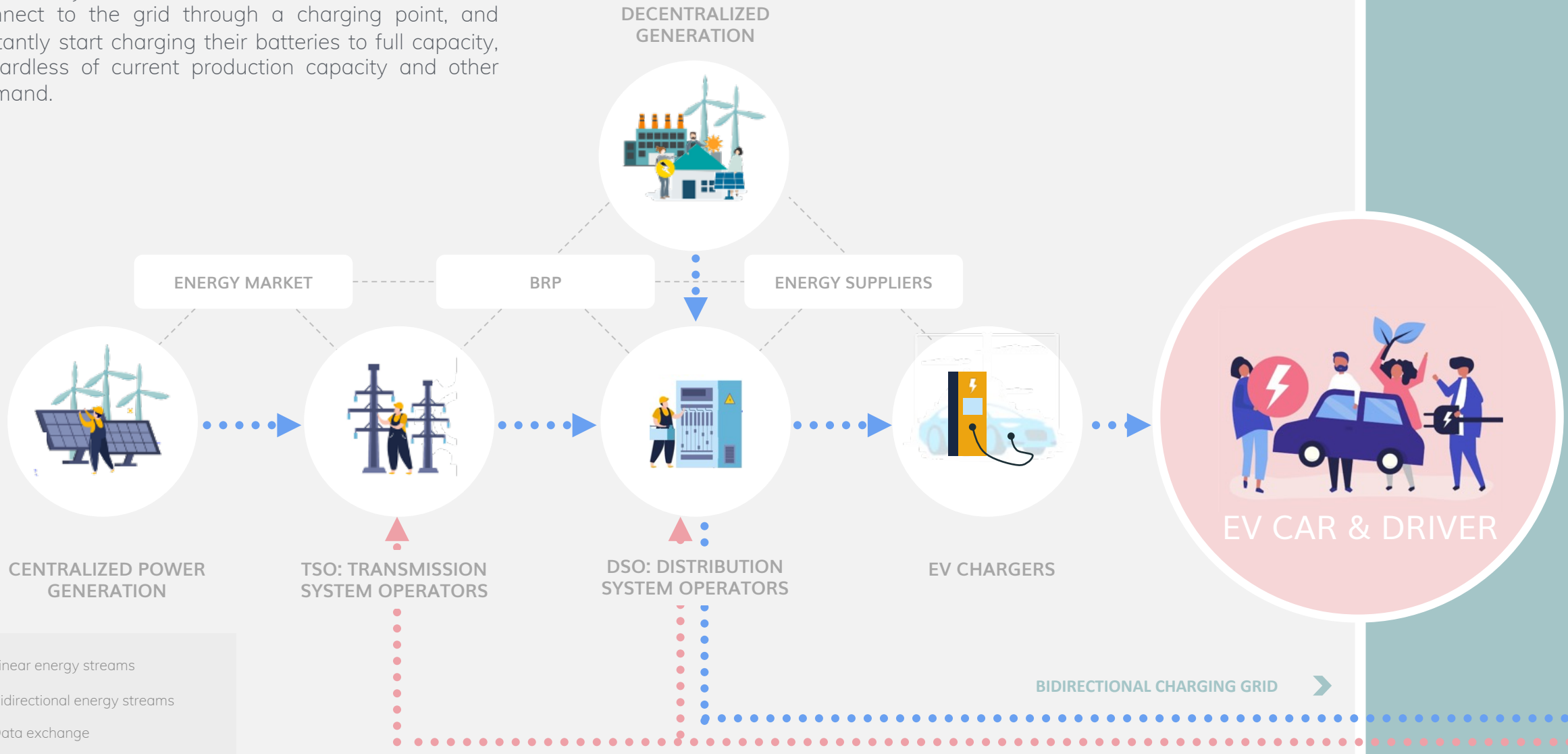
1. **Available qualified people:** Green Power Denmark expects that 29.000 workers yearly until 2030 to upgrade the grids if we do not use the stabilizing capacity of EVs. It will be hard to find enough qualified people.
2. **Costs of qualified people:** Training and paying this workforce is very expensive.
3. **Competing for qualified people with other industries:** We risk to claim scarce technical & engineering talent – competing with other sectors.

RETHINKING ENERGY

SYSTEM DESIGN

LINEAR CHARGING

Linear charging is the traditional way of charging that is currently dominant around the world: EV cars connect to the grid through a charging point, and instantly start charging their batteries to full capacity, regardless of current production capacity and other demand.



SOCIAL & RESPONSIBLE CHARGING

When social & responsible charging is activated, the driver allows his car to become part of its own microgrid, the local grid and/or the national grid, where it will receive, store and –when needed– deliver energy to other players, while ensuring a sufficient charge within the time-frame specified by the driver. Just few percent of balancing capacity per battery can be enough to stabilize the entire national grid.

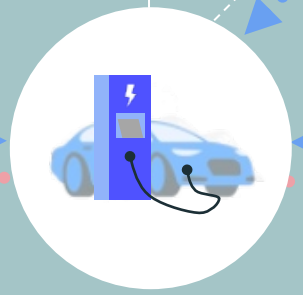
CPO

e-MSP

DECENTRALIZED GENERATION
Decentral production plants, e.g.,
CHP stations, solar, wind

DRIVER APP
Driver specifies max time until full-charge

EV CARS
Offer bi-directional charging to (dis)charge



EV CHARGERS
Can charge and discharge EV batteries on demand

AD HOC MINI GRIDS

SMART HOMES & OFFICES
Balance energy usage to find optimal time & load

AGGREGATOR / BSP

Tracks balance within mini-grids and communicates with DSO and TSO

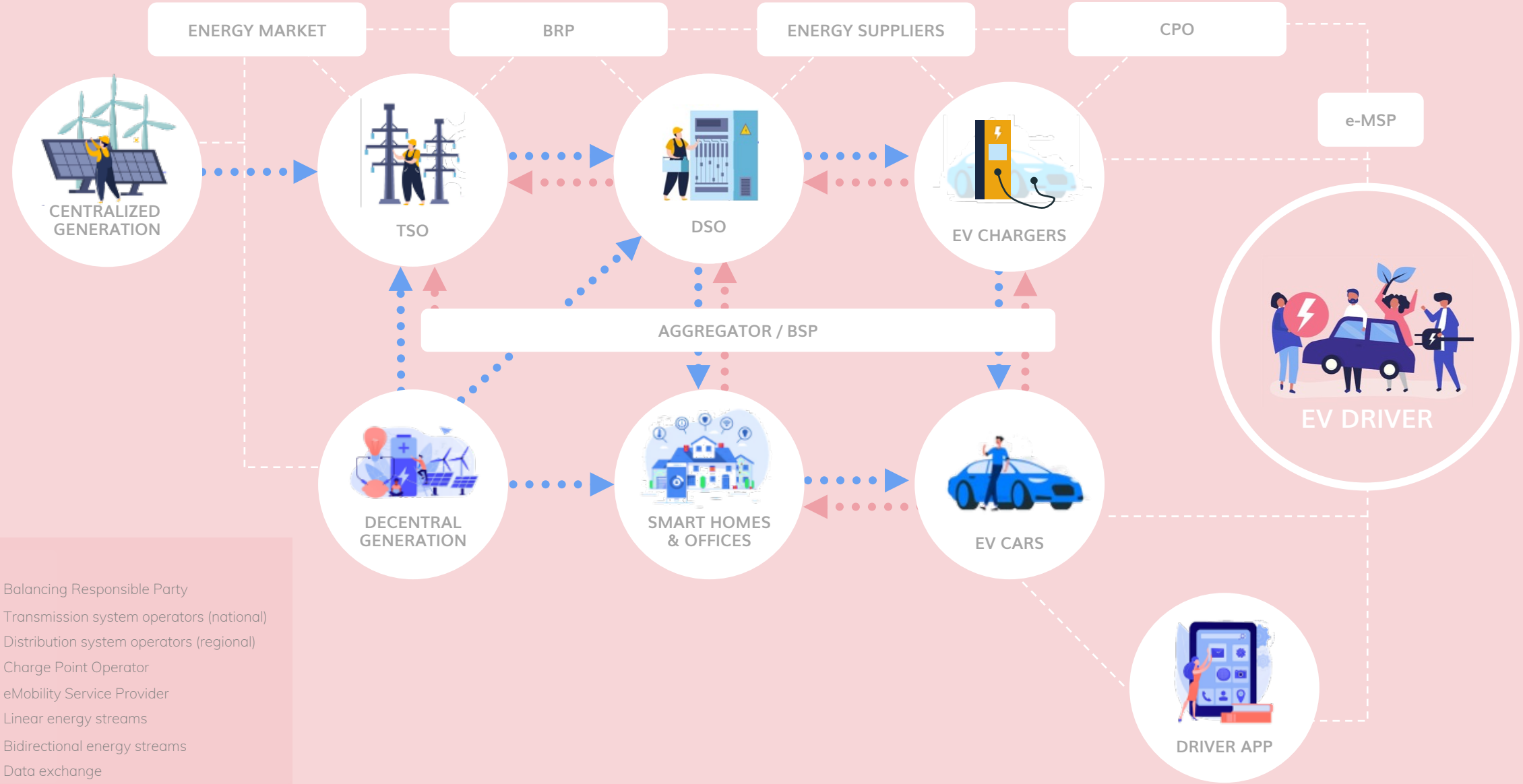
ENERGY GRID

Linear energy streams

Bidirectional energy streams

Data exchange

ENABLING SOCIAL & RESPONSIBLE CHARGING



LEGEND

BRP:	Balancing Responsible Party
TSO:	Transmission system operators (national)
DSO:	Distribution system operators (regional)
CPO:	Charge Point Operator
e-MSP:	eMobility Service Provider
••▶	Linear energy streams
••▶	Bidirectional energy streams
- - -	Data exchange

ENERGINET RETHINKING ENERGY

STAKEHOLDER OVERVIEW – ACTORS & THEIR CHALLENGES

(initial view – based on outside-in analysis. Further research proposed to engage with representatives per stakeholder group)

To be able to implement a social & responsible charging system on a national level, we distinguish the following key stakeholder groups, their roles and key risks/challenges

Stakeholder group	Role within the system	Key risks/challenges
EV users e.g. private, company/sharing fleet	Key Stakeholder. The EV user can be the driver, the owner or the fleet manager; it is the entity who determines how, when and where to charge the EV. We need to incentivize and/or enforce the right behaviour.	It is crucial to understand and satisfy their expectations in terms of the charging process, especially focused on comfort, economic interest, "green focus" and new functionalities around the home and the office.
Manufacturers e.g. cars, batteries, charging stations	Manufacturers are responsible for the essential hardware providing the technical capability to charge and store energy.	Communication towards users regarding the degradation of the battery. This is not a technical challenge, but mainly a social one.
Charging operators e.g. CPOs, eMSPs, Roaming platforms	Charging operators are responsible for facilitating EV charging installation, maintenance, communication and payments.	Hardware: Multidimensional infrastructure planning Software: Data management and privacy
Commercial Energy Markets e.g. BSP, Aggregator, Energy supplier	The link between energy generation and consumers. Activities include buying or selling energy and offering flexibility services.	Coordination of needed energy and flexibility services in a complex decentralized context.
Energy Datahubs e.g. EDSN, DCC, Fingrid Datahub Oy	Energy datahubs collect, store, analyse and exchange data on energy consumption, generation, user behaviour, cars and customers.	All kinds of data-related challenges: availability, safety, privacy, exchange, unbundling of information
EU decision-makers	Responsible for policies and regulations directing current and future use of EVs, renewable energy and infrastructure (e.g. AFID).	Speed of decision making due to/and contradicting interests.
National Government e.g. Department of Energy, Economy	Responsible for setting up the regulatory framework and implementing the market design needed for bidirectional charging.	Avoiding double taxation of electricity. Establishing suitable compensation for service provision. supporting the development of standards.

STAKEHOLDER OVERVIEW – ACTORS & THEIR CHALLENGES

(initial view – based on outside-in analysis. Further research proposed to engage with representatives per stakeholder group)

To be able to implement a social & responsible charging system on a national level, we distinguish the following key stakeholder groups, their roles and key risks/challenges

Stakeholder group	Role within the system	Key risks/challenges
Regional Government e.g. Provinces, Municipalities	A part of the charging points are public and installed on behalf of the local authorities This entity could therefore play an important role in the adoption of smart and responsible charging.	Existing support policies for charging infrastructure create a lock-in for linear charging.
TSO	Responsible for energy supply and grid stabilization a national level. Smart and bidirectional charging services can help to store and manage (renewable) energy and offer ancillary services.	National and international coordination required across multiple stakeholders. Drive the national system design. Enabling data exchange on a national level. AI & Machine Learning technologies to create real time optimization.
DSO	Responsible for the regional transport and distribution of electricity. A DSO can adopt bidirectional and smart charging services as a demand balancing mechanism and load control.	Complexity of implementing & enabling the balancing services with all variables. Multiple DSOs could all be optimizing in their own region, without an eye for the national situation.
Tax Authority	In Denmark the tax authority plays a role in providing tax incentives for EV owners.	Potential complexity in variable incentive schemes. Renewable energy poses challenges to current fuel tax.
Knowledge Institutions	Knowledge exchange is considered to be very important to make an innovation successful. By sharing knowledge and research some issues, e.g. battery degradation, could be resolved.	Research & innovation are focused more on vehicle cost and performances (e. g. ultra-fast charging) than on grid-friendly aspects (e. g. flexibility provision).

STAKEHOLDER OVERVIEW – ACTORS & THEIR VALUE DRIVERS

(initial view – based on outside-in analysis. Further research proposed to engage with representatives per stakeholder group)

To be able to implement a social & responsible charging system on a national level, we distinguish the following key stakeholder groups, their roles and the value if we get this right

Stakeholder group	Role within the system	Value from Responsible Charging
EV users // Society e.g. private, company/sharing fleet	Key Stakeholder. The EV user can be the driver, the owner or the fleet manager; it is the entity who determines how, when and where to charge the EV. We need to incentivize and/or enforce the right behaviour.	Enable Green Transition at minimal costs per user (and avoid disruption of energy supply) – see page 18-21 Convenience: one national standard, without local differences. Enable competition & avoid lock-in as part of design
Car Manufacturers	Car Manufacturers are responsible for the production of EV Cars that are enabled to support bidirectional charging.	Sell more green value into the car. More efficient charging at lower cost per charge. Empower their standards. Make their cars more attractive. Enable the scaling to 1M+, so grow the total revenues.
Charge point Manufacturers	Charge Point Manufacturers are responsible for the essential hardware providing the technical capability to charge and store energy.	Clarity about the national standards - leading to multi-market standards. Accelerating the scaling up to more charge stations. Lower risk.
Charging operators e.g. CPOs, eMSPs, Roaming platforms	Charging operators are responsible for facilitating EV charging installation, maintenance, communication and payments.	One national standard
Commercial Energy Markets e.g. BSP, Aggregator, Energy supplier	The link between energy generation and consumers. Activities include buying or selling energy and offering flexibility services.	Trade energy at real time prices
Energy Datahubs e.g. EDSN, DCC, Fingrid Datahub Oy	Energy datahubs collect, store and analyse data on energy consumption, generation, user behaviour, cars and customers.	Clear direction in how to facilitate the national system and business models.
EU decision-makers	Responsible for policies and regulations directing current and future use of EVs, renewable energy and infrastructure (e.g. AFID).	Denmark can serve as a guiding nation to inform EU policymakers about the art of the possible.

STAKEHOLDER OVERVIEW – ACTORS & THEIR VALUE DRIVERS

(initial view – based on outside-in analysis. Further research proposed to engage with representatives per stakeholder group)

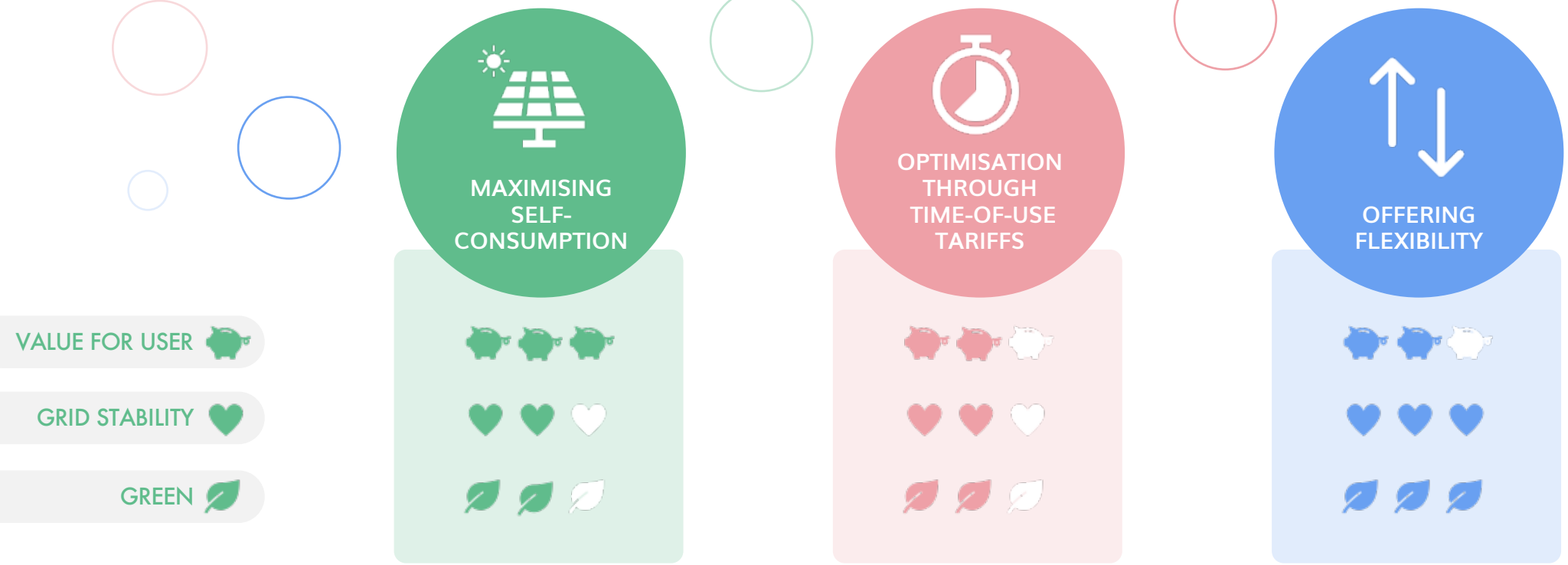
To be able to implement a bidirectional charging system on a national level, we distinguish the following key stakeholder groups , their roles and the value if we get this right

Stakeholder group	Role within the system	Value from Responsible Charging
National Government (Energy & Transportation)	Responsible for setting up the regulatory framework and implementing the market design needed for social responsible charging.	Clear direction for national market. Reach the goals for the green transition, at minimal costs. Differentiate towards other countries as a frontrunner, and have following economical opportunities.
Regional Government e.g. Provinces, Municipalities	A part of the charging points are public and installed on behalf of the local authorities This entity could therefore play an important role in the adoption of smart and responsible charging.	Enable Citizens with convenient services. Enable Green cities by using the balancing services of EVs
TSO	Responsible for energy supply and grid stabilization a national level. Smart and bidirectional charging services can help to store and manage (renewable) energy and offer ancillary services.	Reduced system costs (because of slower charging and balancing services – less chance for downtime). Enable the ambition of 100% green transition Reduced total grid extension Keeping up supply, avoiding brown-outs Reduce the costs for congestion management
DSO	Responsible for the regional transport and distribution of electricity. A DSO can adopt bidirectional and smart charging services as a demand balancing mechanism and load control.	
Renewable Energy Producers	Responsible for producing Renewable Energy at sufficient levels to power Denmark and supply to international markets	Increase value of Green Energy, as excess energy will not be wasted as much, and moments of lower RE generation can be compensated by the balancing services
Tax Authority	In Denmark the tax authority plays a role in providing tax incentives for EV owners.	Easy tax system – based on one national standard. Create Futureproof, generic system.
Knowledge Institutions	Knowledge exchange is considered to be very important to make an innovation successful. By sharing knowledge and research some issues, e.g. battery degradation, could be resolved.	Be involved in global leading system design and applying research insights in the transformation

BUSINESS MODEL DRIVERS FOR THE EV DRIVER

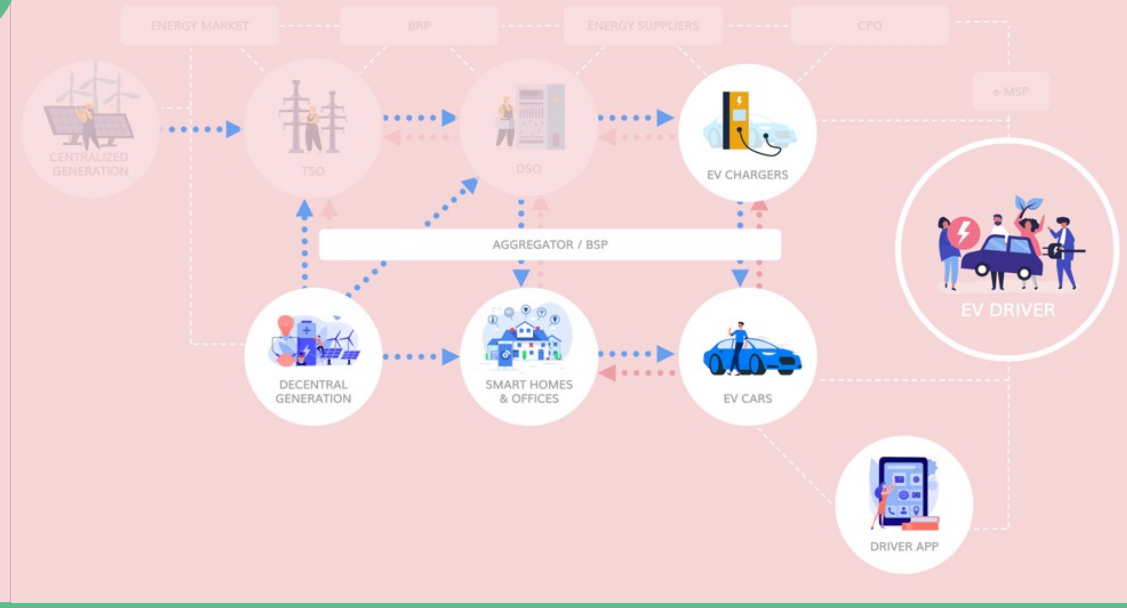
Drivers / triggers: We have identified three main **business model drivers** for social charging: **1)** Maximising self-consumption, **2)** Optimisation through time-of-use tariffs, **3)** Offering flexibility services. See next three pages for explanation per driver.

Value creation: These business model drivers can influence the behaviour of people and provide to them the **value** of: **A)** Charging on lower tariffs (when green energy supply is high), **B)** grid stability (near the house and in the neighbourhood), **C)** maximizing their green energy adoption



1) MAXIMISING SELF-CONSUMPTION & BE SELF SUPPORTING

The EV driver can aim to maximize the use of their own green energy production into the car batteries, to prevent having to deliver to the grid at low or no fee. On top of that, in other countries like the USA the Car Battery is promoted as a stabilizer for the home grid in case of local black-outs, with capacity to deliver a few days of electricity supply to the own house.



Bidirectional charging can aid in the self-consumption of nearby renewable energy sources. If there are solar panels on the building, any extra energy that is created (i.e., energy that is not needed by the building) can be used to recharge an electric vehicle. The EV can then be discharged to assist in meeting the building demand at times when the solar power is reduced.

Related cases and findings

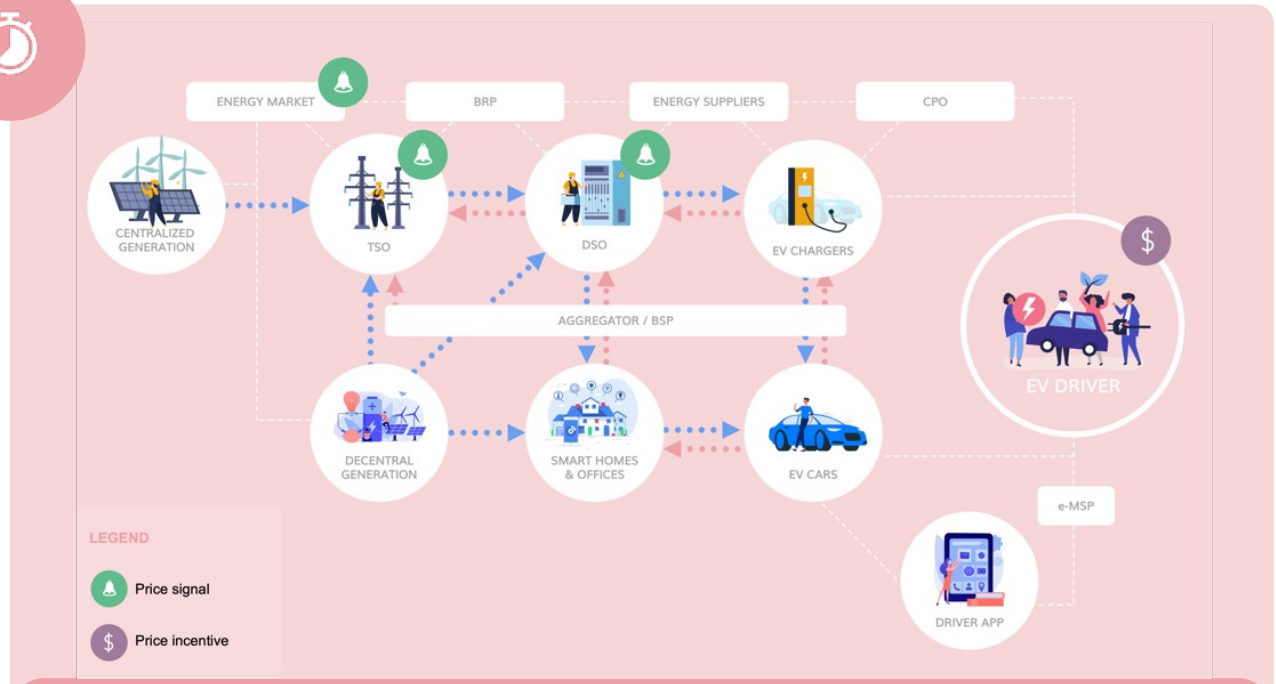
The energy crisis and associated price increases could speed the adoption of V2H as consumers try to maximize their own energy use and safeguard themselves from rising electricity costs.
The contribution from incorporating solar power into the V2H setup would be sufficient to save around €800 a year per household on electricity, depending on the exact price per kWh of a specific tariff.

The usage of V2H is anticipated to increase substantially as consumers strive to maximize their own energy use and prepare for potential disruptions.
Aiming to enhance its customers' energy independence, Ford, for instance, is the first automaker to enable customers to use their truck battery to power their houses when the grid goes down.

By optimizing the usage of renewable energy during off-peak hours, bidirectional charging has the potential to lower a household's or company's carbon footprint.
By using neighbouring or privately owned renewable energy sources to store energy in EVs during off-peak hours, EV owners can later use this green energy to power their building.

2) OPTIMISATION THROUGH TIME-OF-USE TARIFFS

When charging smarter the EV driver can benefit from lower costs of energy when they allow for charging to start when green energy production is high, and optimize their green footprint.



Time-of-Use, often known as ToU, aims to reduce the demand for EV charging during peak hours by implementing static and/or dynamic price differences for consumers. The price signals are time-varying, as their name suggests, and are based either on the power system balance or on short-term wholesale market price signals (such as day-ahead or intraday price signals).

Related cases and findings

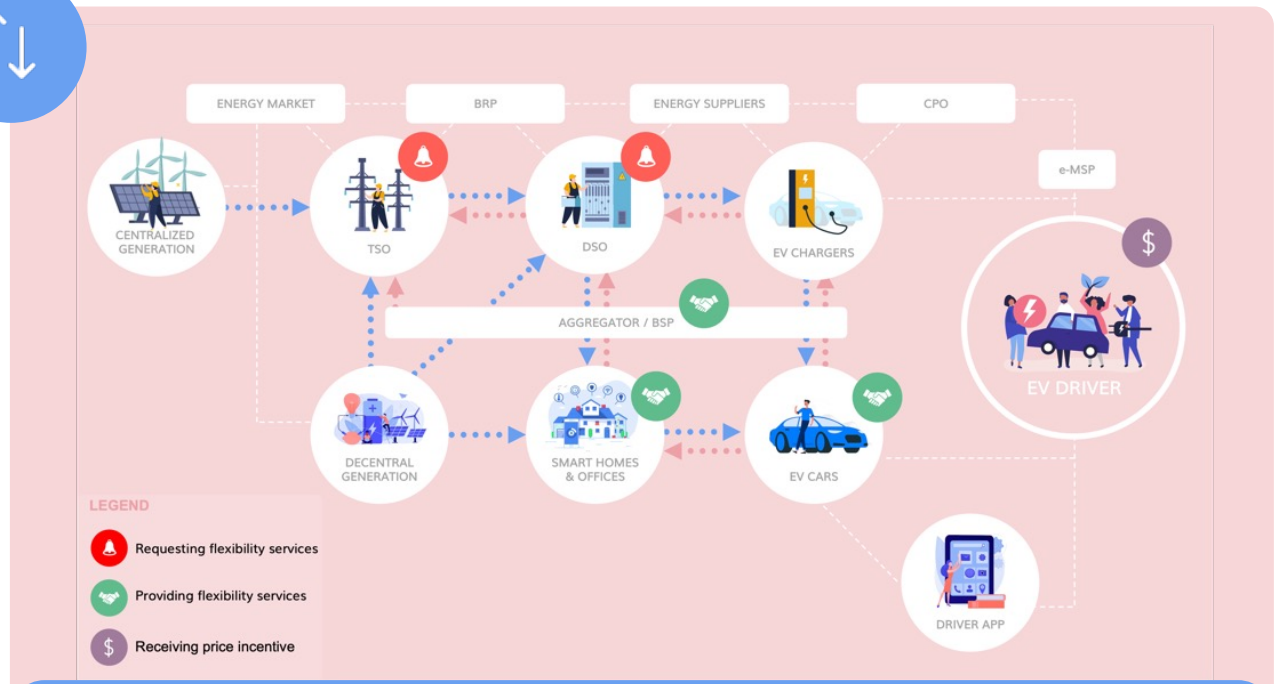
With a ToU tariff structure, EV drivers can voluntarily limit or delay their electricity consumption (either automatically or manually) to lower their energy costs.
E.ON Energy UK and Ev.energy launched 'Next Drive', a virtual time-of-use rate that is added onto any of E.ON's flat rate tariffs. EV drivers are saving an average of £267/year by charging off-peak through the app.

The implementation of ToU by EV drivers guarantees that EV charging occurs when it will have the least negative effects on the grid, thereby preventing an overload.
The ability to direct or delay charging could improve system stability and reduce the need for costly grid upgrades.

ToU tariff programs can change demand to match with periods of high renewable energy production and decrease use during periods of low generation. ToU may significantly lessen the need to restrict VRE resources. With real-time pricing, even short-term changes in renewable energy generation may be balanced with demand.

3) OFFERING FLEXIBILITY SERVICES

If the car owner allows their car battery to be utilized temporarily in times of energy shortage in the grid, they can be paid a fee for the energy they deliver to the grid on those moments



Energy from various nearby sources is locally stored, optimized, and supplied to the system via aggregators. By taking an active part in grid balancing and the larger energy transition, EV owners can gain from selling the excess electricity through an aggregator.
As a participant in the market, the aggregator can help stabilize the electrical grid.

Related cases and findings

By leaving cars plugged in when not in use and supplying the grid during peak hours, EV owners are able to save on their electricity bill.
In a three-year study, Project Sciurus (page 38) deployed 330 bidirectional chargers in homes throughout the UK. The study concluded that members may save up to £725 a year on electricity expenses.

Local, regional, or national energy needs can be balanced and resolved via V2G. As a result, EVs can recharge during off-peak hours and contribute to the grid during peak hours, when there is a greater need for electricity. By participating in frequency control markets, V2G-enabled EVs will guarantee stability of the grid and network operators' costs will go down.

By temporarily storing excess renewable energy sources into the EV batteries and releasing the energy when needed, EV batteries play an important role in maximising the use of renewable energy sources. Additionally, research by E.ON and Imperial College London states that by lowering overall CO^2 emissions from the power system, V2G enabled EV fleets can have a considerable negative carbon footprint.

RETHINKING ENERGY

TECHNOLOGIES

GLOBAL TECH SOLUTIONS LANDSCAPE

The global tech solution landscape visualizes a snapshot of the global (emerging) tech players that provide solutions to enable bidirectional charging services

RETHINKING ENERGY

GLOBAL V2G TECHNOLOGY SOLUTIONS LANDSCAPE

ENERGINET

V2G ENABLED HARDWARES

EV BIDIRECTIONAL CHARGERS

sun2wheel, JET CHARGE, blink, UUGreenPower, emporia, solarMD, CORITECH SERVICES, AMPERE ENERGY, revel, smappee, CHARGECORE, evolt, ovo energy, EVTEC, endesa, SIEMENS

BIDIRECTIONAL CHARGING ENABLED AUTOMOTIVE BRANDS

TOYOTA, PORSCHE, NISSAN, TESLA, VW, PROTERRA, gogoro, Highland, SONO MOTORS, Electric VEHICLE, HYUNDAI, Ford, LUCID

FACTORIES/SUPPLIERS

HITACHI, V2G EVSE Limited, SINENG, YAZAKI, AC PROPULSION, ninedot energy, DENSO, EVTEC

V2G ENABLED SOFTWARES

DATA ANALYSIS & INSIGHTS

LADE, HIVE POWER, ICEPCO, Origami, Grid Edge, driivz

CHARGING PATTERN OPTIMIZING

ampcontrol, FUERGY, MOEV, moixa, KALUZA, enel x

V2G CONNECTIVITY

VECTOR, EVBOX, GreenFlux, OBEE POWER, CORINEX

FULL SOLUTIONS

V2G ENABLED SOFTWARE AND HARDWARE

wallbox, Switch, newmotion, THE MOBILITY HOUSE, IoTecha, nrg, FERMATA ENERGY, VIRTA, EDF, NUVVE

ENERGY TRACEABILITY & VERIFICATION

ENERGY TRADING

origin, energy web

EV IDENTIFICATION

here, JOTTUN

VERIFICATION

commsignia, AUTOCRYPT

DATA SOLUTIONS PROVIDING INSIGHTS TO STAKEHOLDERS

BlockLab, Circulor, reengen

CHARGING STANDARD PROMOTION

OCPP

Open Charge Alliance, Elaad nl

ISO 15118-21

ISO, V2G Clarity

CHAdeMO

CHAdeMO

OpenADR

openADR ALLIANCE

CCS

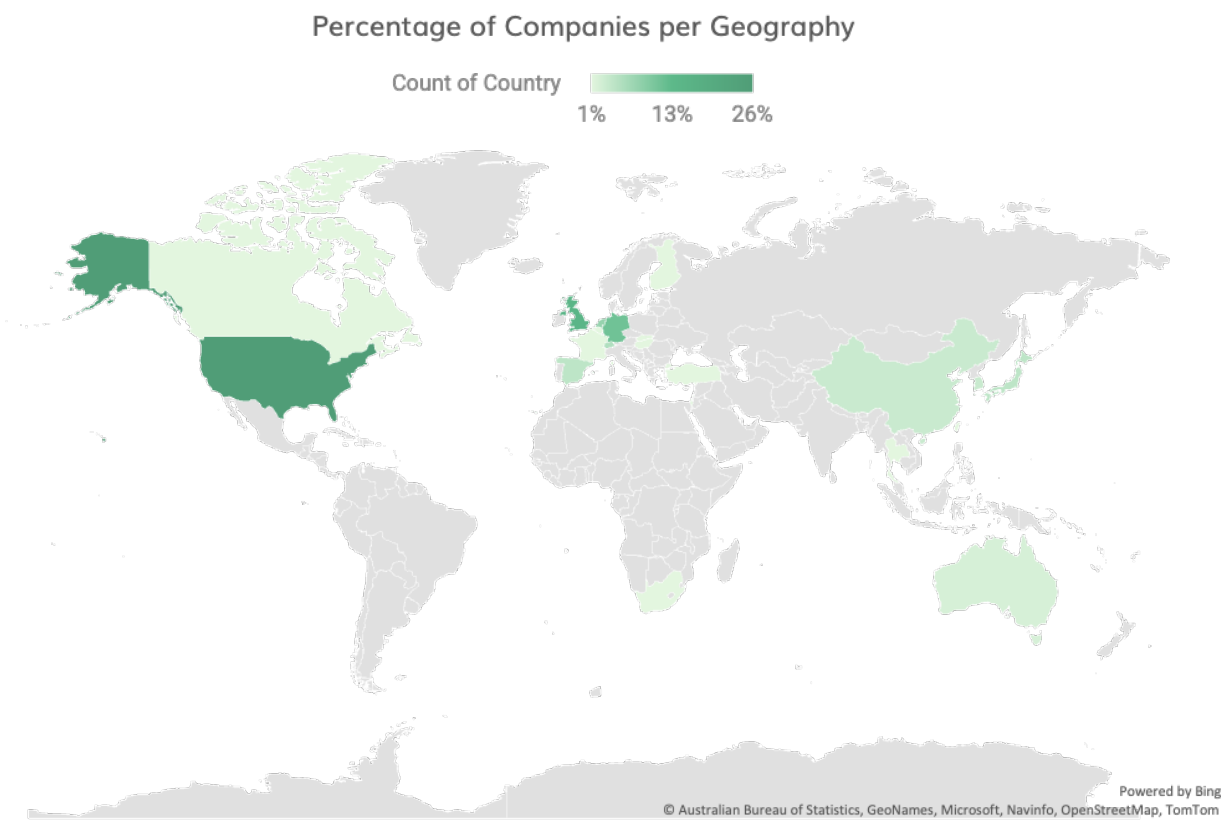
CHARIN

UI CONTROLLER APPS & REWARDS

ev.energy, lightsourceLabs, EcoG, JEDLIX, GREEN ENERGY WALLET

GLOBAL TECH SOLUTION LANDSCAPE

The largest portion of V2G solutions is currently being developed in the US, followed by the UK, Germany and The Netherlands respectively.



Based on our findings and expert interviews we conclude that most V2G solutions are currently being developed in the United States. This might be explained by the EV batteries potential to secure electricity supply in times of grid instabilities and potential outages. See the example of Ford (page 23) for an example tech solution in this domain.

According to experts and academic literature concentrating on the technical implementation of V2G, recent studies and insights from trials show that the technical performance of smart and bidirectional charging has been validated. The hurdle for scaled implementation appears to be in the commercial and regulatory side.

(Bidirectional) EV chargers ought to become increasingly accessible and affordable over the next years as the necessary infrastructure is developed and their use spreads. Customers of EVs must be convinced, though, that frequent charging and discharging won't hasten the aging of their batteries.

THE DEEPDIVES

We selected a few emerging tech companies active in the V2G domain to bring to life different aspects of the enabling technology infrastructure that will be required to enable social charging

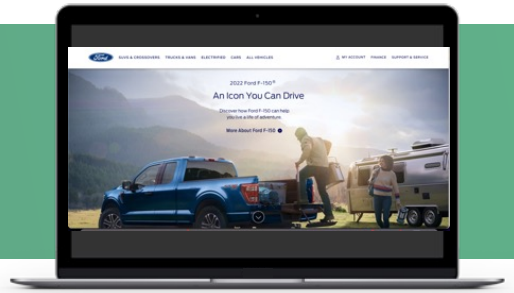
RETHINKING ENERGY

DEEPDIVE SHORTLIST

HARDWARES	HARDWARES	HARDWARES	SOFTWARES	SOFTWARES
Ford	sun2wheel	gogoro	ampcontrol	GreenFlux Smart charging
1903 · 10K+ · USA	2020 · 7 · LU	2011 · 876 · TW	2018 · 18 · USA	2011 · 84 · NL
GLOBAL CHARGING STANDARD PROMOTION	**FULL SOLUTIONS**	**FULL SOLUTIONS**	**ENERGY TRACEABILITY & VERIFICATION**	**UI CONTROLLER APPS & REWARDS**
OPEN CHARGE ALLIANCE	NUVVE	wallbox	AUTOCRYPT	ev.energy
2013 · 9 · NL	1903 · 78 · USA	2015 · 989 · EES	2019 · 76 · KR	2018 · 55 · UK

ENERGINET RETHINKING ENERGY

TECHNOLOGY SOLUTION SNAPSHOT

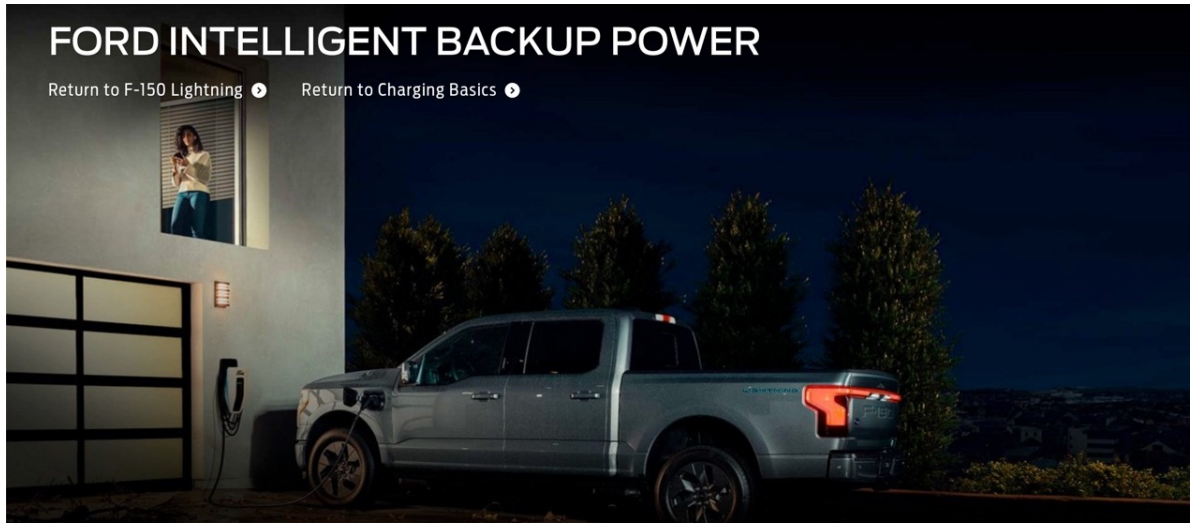


COMPANY	SCOPE	COMPANY DETAILS	PROJECTS AND CASE STUDIES
Ford		1903 · USA · undisclosed · 10K+ · ford.com	• Ford F-150 Lightning (2021)

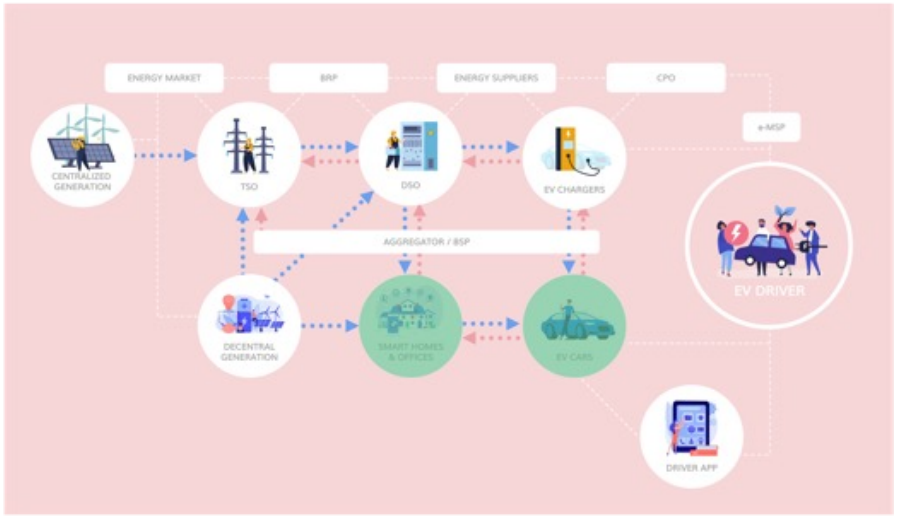
Ford Motor Company manufactures or distributes automobiles. Ford's new F-150 model, the F-150 Lightning, is built to provide houses with power if there is a blackout. When connected to Ford's Charge Station Pro, your truck will immediately start powering your home. Depending on the rationing of your usage, the battery can power your home for three to ten days.

- F-150 Lightning with available Ford Intelligent Backup Power can provide power and security during an electrical outage – the first electric truck in the U.S. to offer this capability.

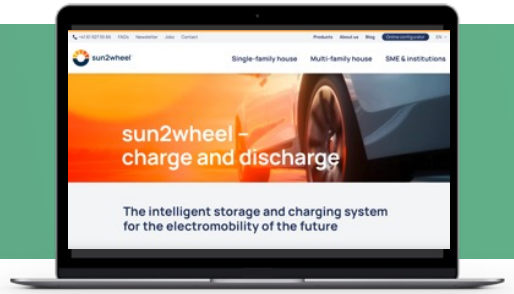
PRODUCT VISUALISATION



ECOSYSTEM FIT



TECHNOLOGY SOLUTION SNAPSHOT



COMPANY

sun2wheel

SCOPE

COMPANY DETAILS

2020

LU

undisclosed

7

sun2wheel..com

PROJECTS AND CASE STUDIES

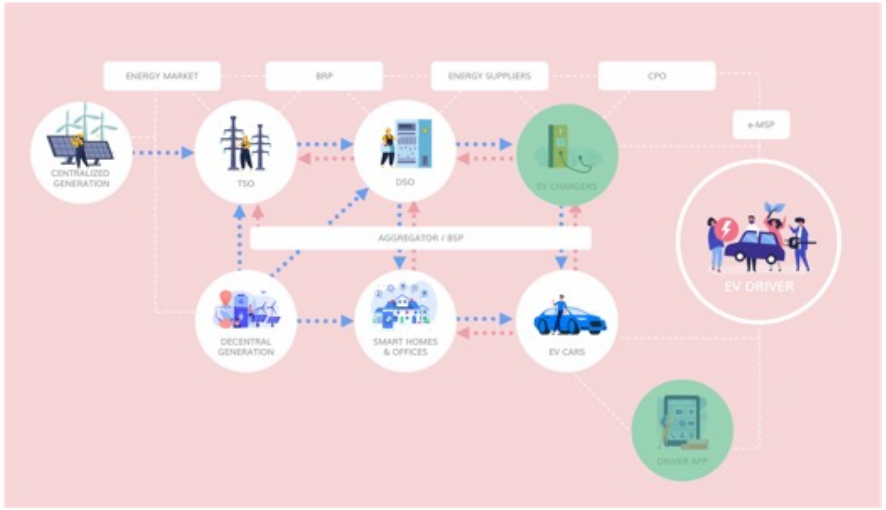
- V2X Suisse (CH) | 2021- ongoing
- EV FLEX (CH) | 2021 - ongoing

The start-up sun2wheel's goal is to establish bidirectional charging (V2H/V2G) as a standard and to offer smart charging and storage solutions. They designed an intelligent charging and storage system (V2X) that can be used to optimize the entire energy consumption of private households, apartment buildings, or SMEs by integrating electromobility.
In a next step, services for stabilizing the power grid will also be enabled.

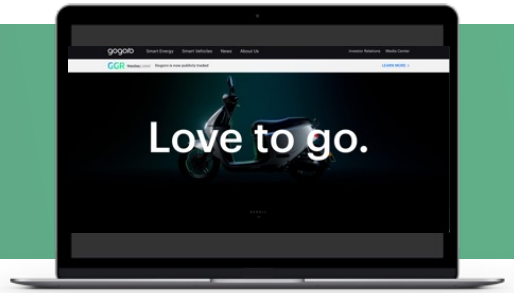
- ⊕ Offering multiple V2G charger options which can be connected and combined in the Sun2Wheel V2G controller App
- ⊕ Involved in multiple promising V2X pilots
- ⊗ Not commercially available or proven yet

PRODUCT VISUALISATION

ECOSYSTEM FIT



TECHNOLOGY SOLUTION SNAPSHOT

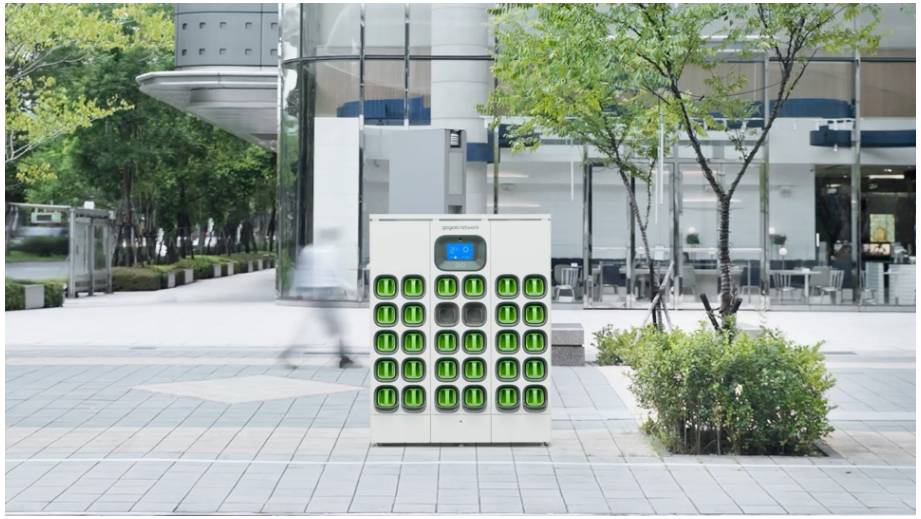


COMPANY	SCOPE	COMPANY DETAILS	PROJECTS AND CASE STUDIES
gogoro		2011 · TW · 775 MM · 876 · gogoro.com.io	• V2G Battery Swapping (TW) | 2021

Gogoro is an electric scooter maker. With a mission to deliver consumer innovations that will improve how the world's most populated cities distribute and utilize energy, the company is enabling the transformation of megacities into smart cities. Gogoro is working toward a better future by putting power in the hands of everyone - to move us all forward, faster.

- 2400 sites throughout Taiwan,
- Listed on the stock exchange
- Expanding to other regions like Israel

PRODUCT VISUALISATION



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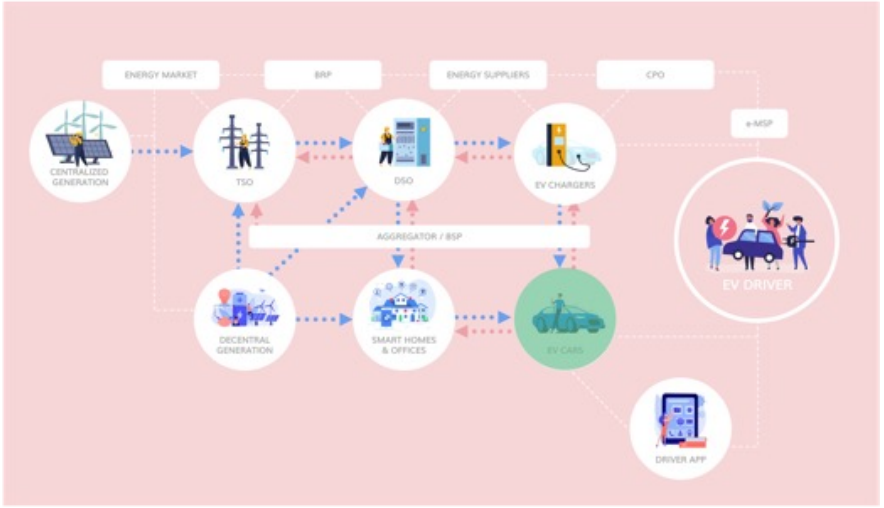
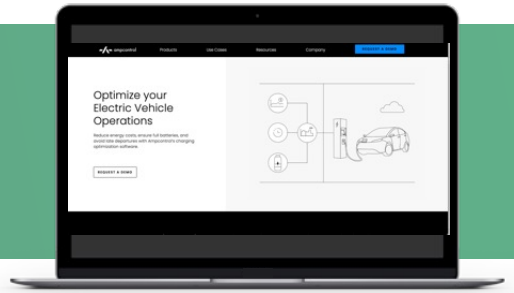


TECHNOLOGY SOLUTION SNAPSHOT



COMPANY

ampcontrol

SCOPE

COMPANY DETAILS

2018

USA

1.1 MM

18

ampcontrol.io

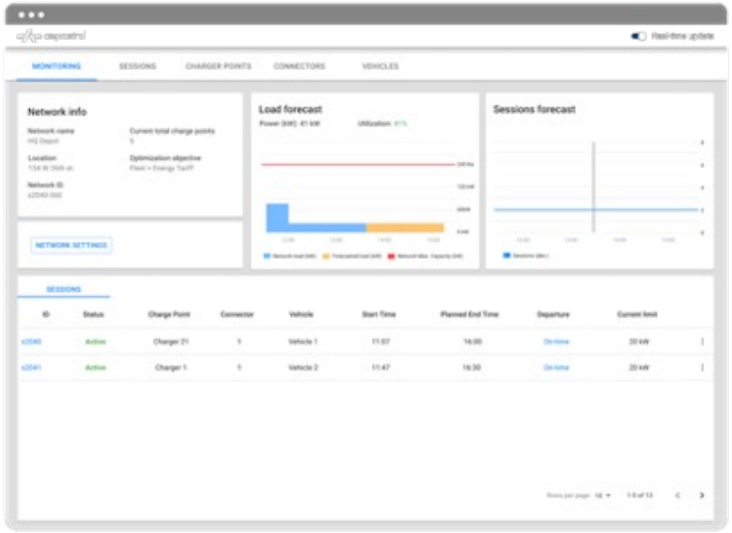
PROJECTS AND CASE STUDIES

- Revel (USA) | 2022

With intelligent technology for charging point operators (CPOs), fleet managers and vehicle manufacturers, Ampcontrol is dedicated to helping the world build a safe and reliable EV charging infrastructure. We specialize in cutting-edge smart charging systems. These are integrated AI-powered software solutions enabling automatic and optimized bidirectional charging. Ampcontrol's software discharges the vehicles at the right time without causing late departure or high battery usage.

- Ampcontrol implemented their system for Revel's (public) fast charging hub in North America (25 DC chargers). Ampcontrol managed to reduce demand charges with 45%.
- Scalability not proven

PRODUCT VISUALISATION



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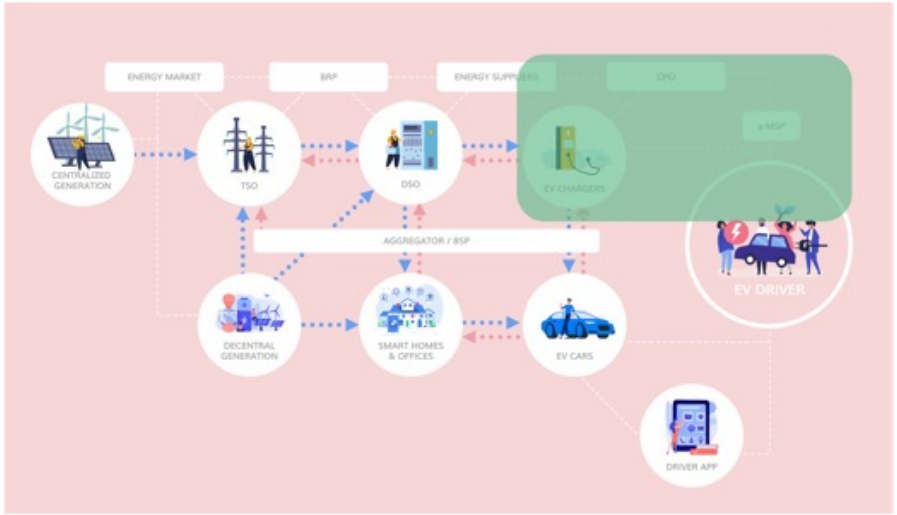
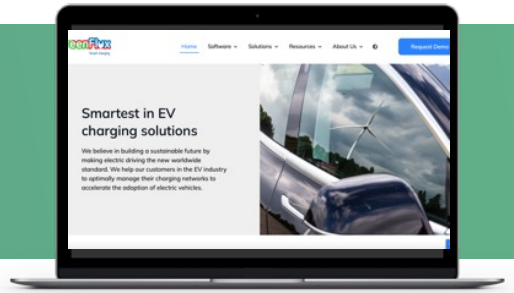


TECHNOLOGY SOLUTION SNAPSHOT

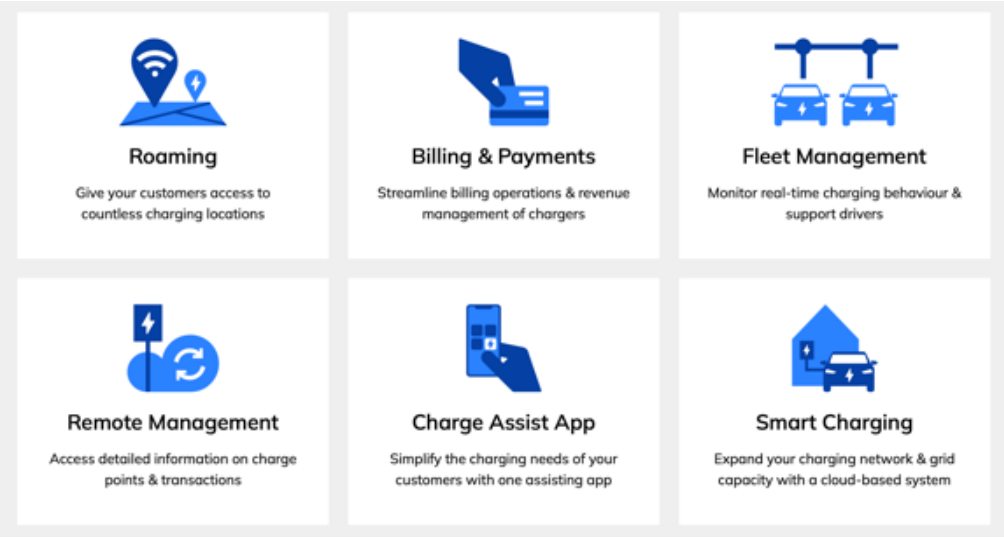


COMPANY	SCOPE	COMPANY DETAILS		PROJECS AND CASE STUDIES
GreenFlux Smart charging		2011	84	• Eneco (NL) | 2021
		NL	greenflux.com	
		12.9 MM		

GreenFlux supports energy companies, network operators and parties in the automotive industry to remotely manage charge stations, process transactions and adjust the charging process to the capacity of the electricity grid and (local) energy generation. We offer a cloud-based platform, combining technology and easy solutions for managing infrastructures of charge points via open protocols and systems, allowing every charge point to connect to the platform.

- The backend platform supports all current and legacy versions of OCPP and can perform any required integrations and customisations for protocols.
- GreenFlux is active in +21 countries with an ecosystem of more than 28,000 connected charge points.

PRODUCT VISUALISATION



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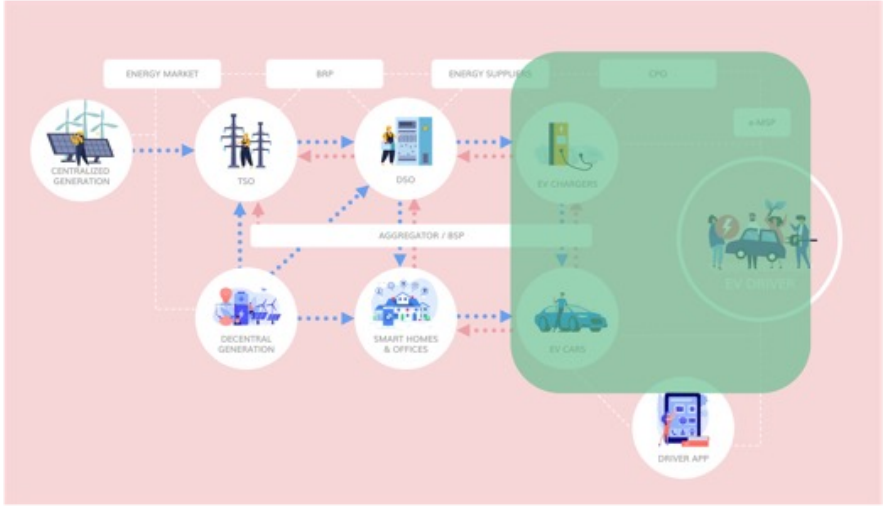
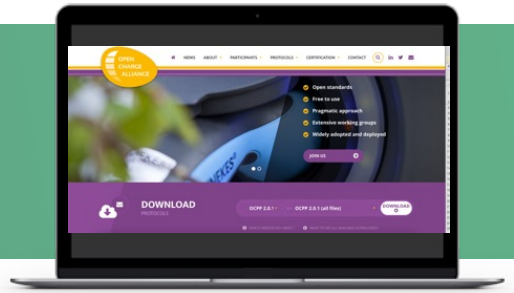


TECHNOLOGY SOLUTION SNAPSHOT



COMPANY

OPEN CHARGE ALLIANCE

SCOPE

COMPANY DETAILS

2013

NL

Unfunded

9

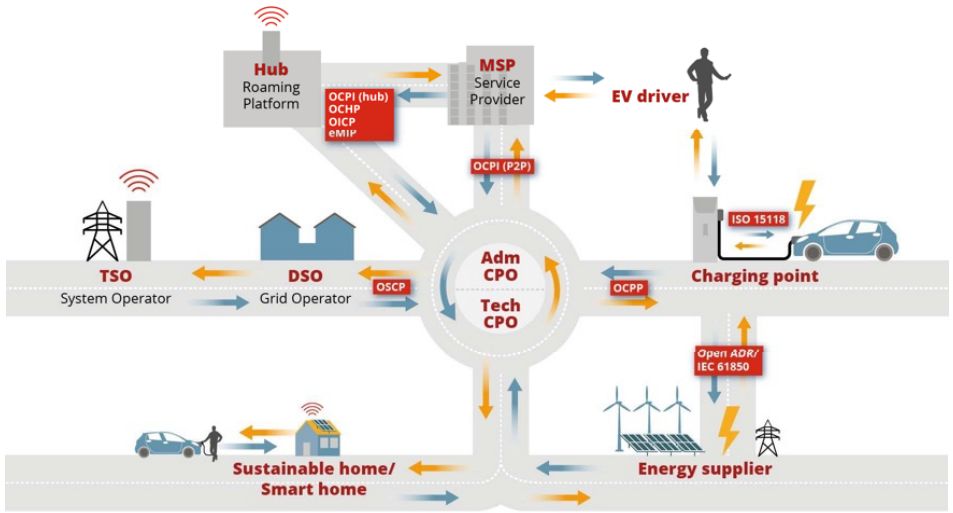
opencharge alliance.org

PROJECTS AND CASE STUDIES

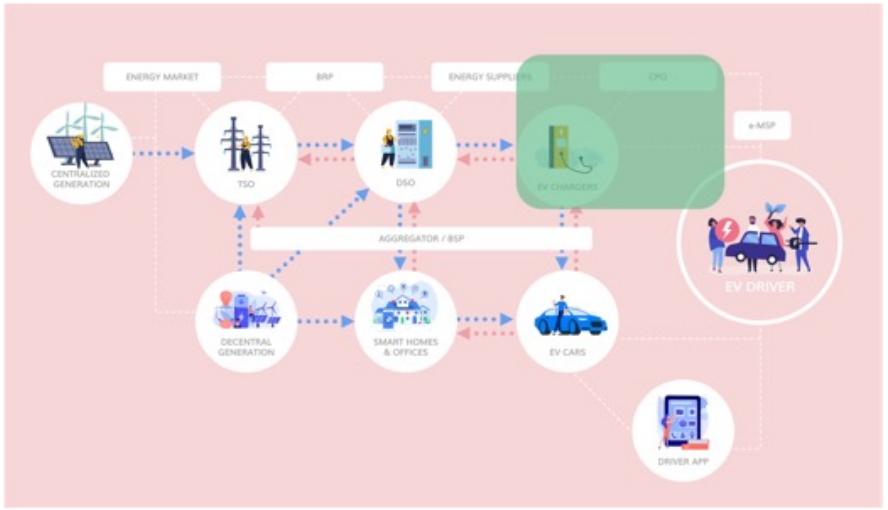
The Open Charge Alliance (OCA) is a global consortium of public and private electric vehicle infrastructure leaders that have come together to promote open standards through the adoption of the Open Charge Point Protocol (OCPP) and the Open Smart Charging Protocol (OSCP). OCPP is the accepted protocol of choice in 50 countries and over 10,000 charging stations, providing accessibility, compliance and uniform communications between charging stations and management systems.

- With OCCP, no one gets stuck to one vendor, and in cases of a price increase by the vendors, even financial troubles or bankruptcy, there is a freedom to switch vendors even while using the same charging station.

PRODUCT VISUALISATION



ECOSYSTEM FIT



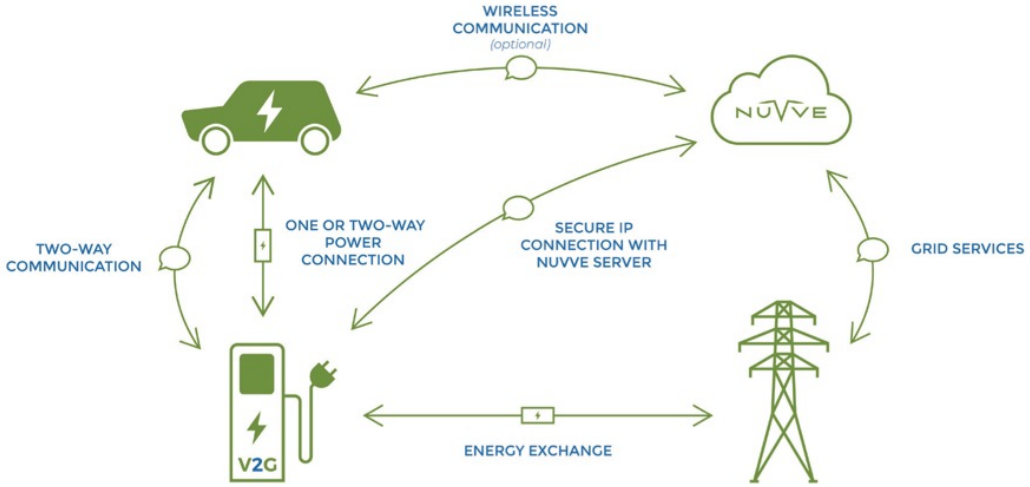
TECHNOLOGY SOLUTION SNAPSHOT

COMPANY	SCOPE	COMPANY DETAILS		PROJECS AND CASE STUDIES
NUVVE		2010 USA $ 18MM	78 nuvve.com	• EVVE (FR) | 2022 - ongoing • E-Flex (UK) | 2018 - ongoing • Parker (DK) | 2016- 2018

Nuvve is accelerating the electrification of transportation through its proprietary vehicle-to-grid (V2G) technology. Its mission is to lower the cost of electric vehicle ownership while supporting the integration of renewable energy sources, including solar and wind. We offer AC and DC charging station options and NUVVE's Grid Integrated Platform (GIVe™). Our cloud-connected application ensures that every vehicle on the platform has enough charge for the next trip before calculating how much capacity is available to sell back to the grid.

- Experienced player: Over 10+ years of V2G deployments across 5 continents, including multiple successful projects in Denmark
- Proven technology: Experience operating 10K+ EVs at once
- Japanese TSO approved Nuvve and partners to provide ancillary power and stabilizing services to the grid

PRODUCT VISUALISATION



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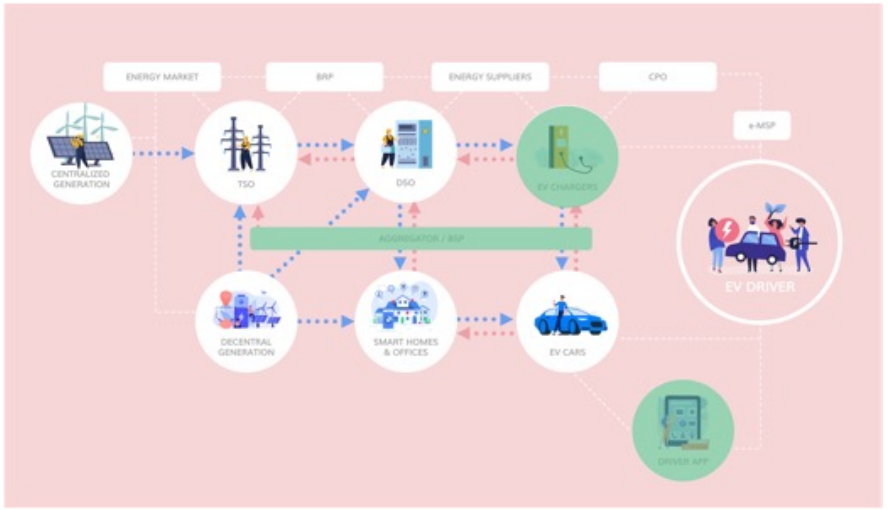
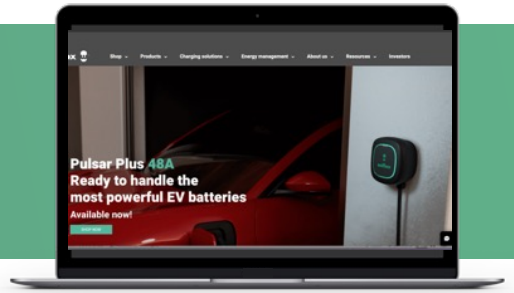


TECHNOLOGY SOLUTION SNAPSHOT



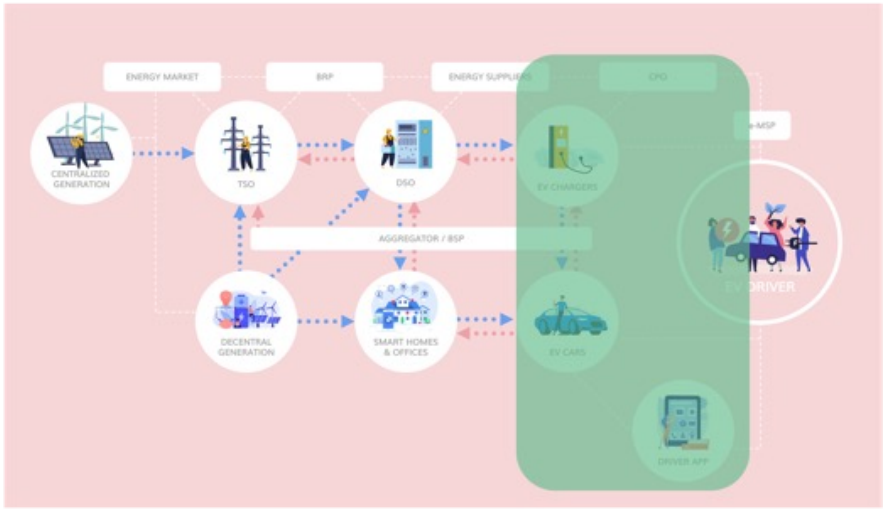
COMPANY	SCOPE	COMPANY DETAILS	PROJECTS AND CASE STUDIES
wallbox		2015 · ES · 167 MM · 989 · wallbox.com	• Nuvve Partnership (ES) | 2021 – ongoing • Electric Nation (UK) | 2020 - 2021 • E-Flex (UK) | 2018 - ongoing

Wallbox is a global company, dedicated to changing the way the world uses energy in the electric vehicle industry. Wallbox creates smart charging systems that manage the communication between vehicle, grid, building and charger. Wallbox offers a portfolio of charging and energy management solutions for residential and semi-public use in more than 60 countries, and soon will begin commercializing public charging solutions as well. Retail price Wallbox Quasar: $4000 - $6000.

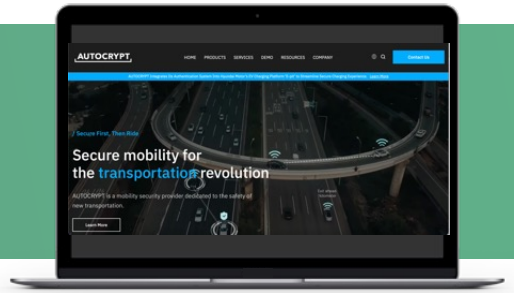
- ⊕ Wallbox Quasar is considered the first and best two-way DC charger for homes – winner of multiple CES awards
- ⊗ Companies like Sono Motors, Ford etc are currently launching chargers that are much more affordable. Ford's V2H charger has a retail price of around $1,500

PRODUCT VISUALISATION

ECOSYSTEM FIT



TECHNOLOGY SOLUTION SNAPSHOT

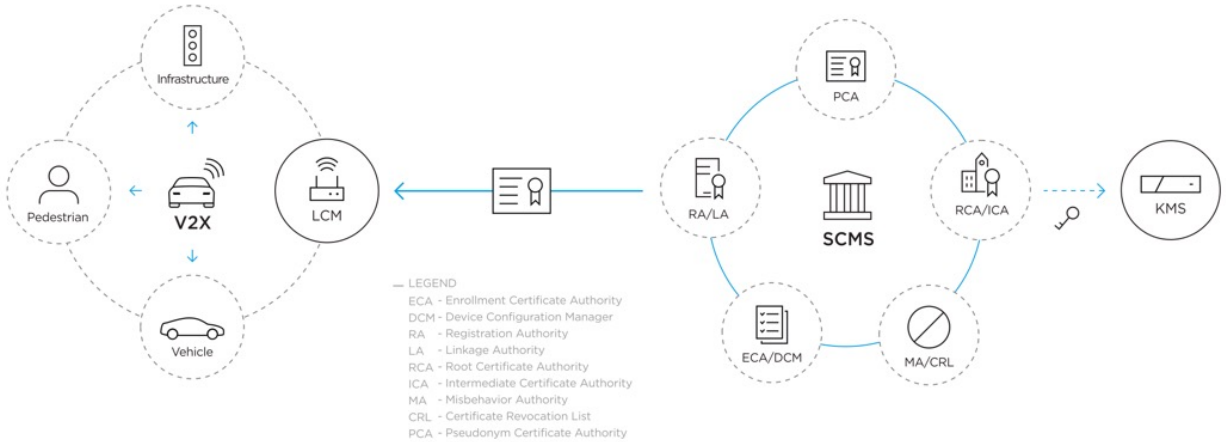


COMPANY	SCOPE	COMPANY DETAILS	PROJECTS AND CASE STUDIES
AUTOCRYPT		2019 KR 66 MM 76 autocrypt.io	• Many C-ITS and V2X security certification system projects across South Korea

AUTOCRYPT secures the rapidly-evolving framework of smart mobility from start to finish. AutoCrypt V2X is an authentication and encryption system for V2X communications. It consists of an SDK (software development kit) that can be embedded into the V2X connectivity units of vehicles (onboard units) and infrastructure (roadside units), ensuring that the basic safety messages (BSM) transmitted between these participants are safely encrypted and two-way authenticated.

- Autocrypt is the first company in the Asia-Pacific region to have developed a V2X SCMS that complies with the standards
- Selected as “Automotive Security (IoT)” Gold Winner by Cybersecurity Excellence Awards

PRODUCT VISUALISATION



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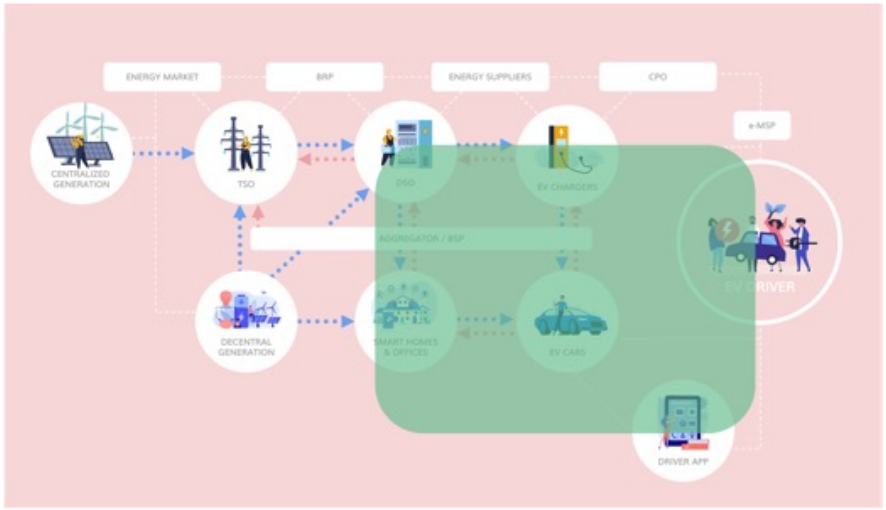
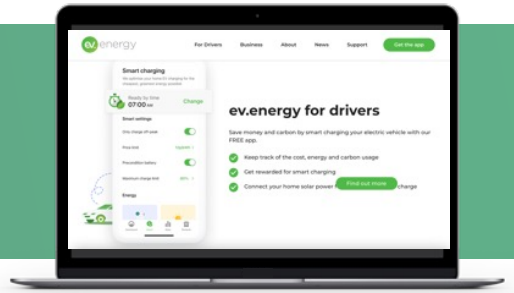


TECHNOLOGY SOLUTION SNAPSHOT



COMPANY

ev.energy

SCOPE

COMPANY DETAILS

2018
UK
13.5 MM
55
ev.energy

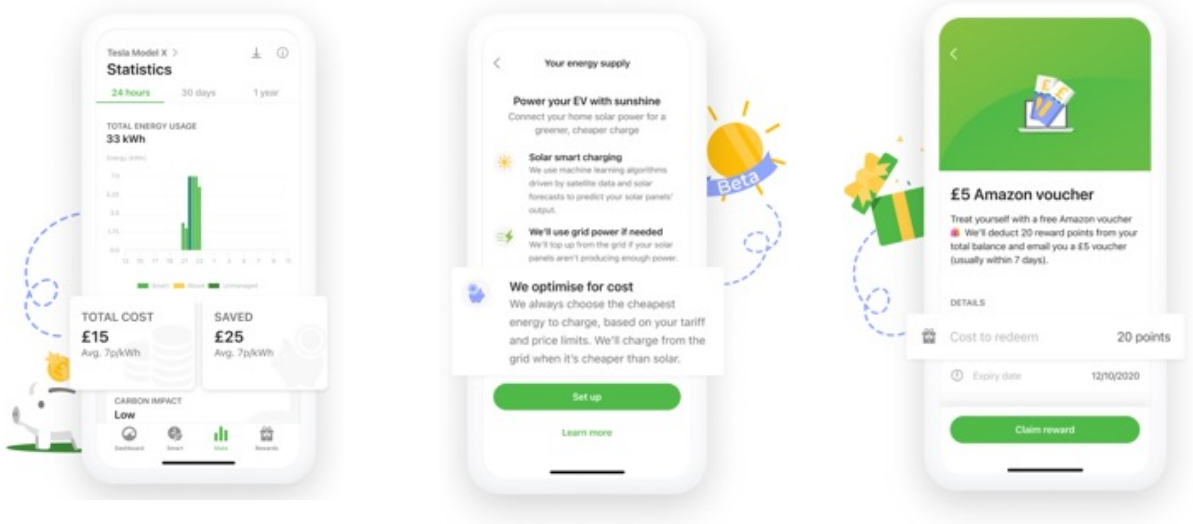
PROJECTS AND CASE STUDIES

- E.ON Next Drive (UK) | 2021

Ev.energy is a smart charging software platform for electric vehicles, to reduce carbon emissions and costs. Ev.energy offers a Smart Charging App allowing to control and optimize EV charging. The app can be used either as a mobile app or connected with vehicle systems through API. Key functionalities: (1) allow customers to charge with off-peak rates, (2) ease grid pressure and reward customers for demand response participation (3) empower customers to take full control of their charging.

- Experience working with TSOs like National Grid (UK)
- Demonstrated commercial success: E.ON Energy UK and Ev.energy launched 'Next Drive', a virtual time-of-use rate that is added onto any of E.ON's flat rate tariffs. EV drivers are saving an average of £267/year by charging off-peak through the app.

PRODUCT VISUALISATION



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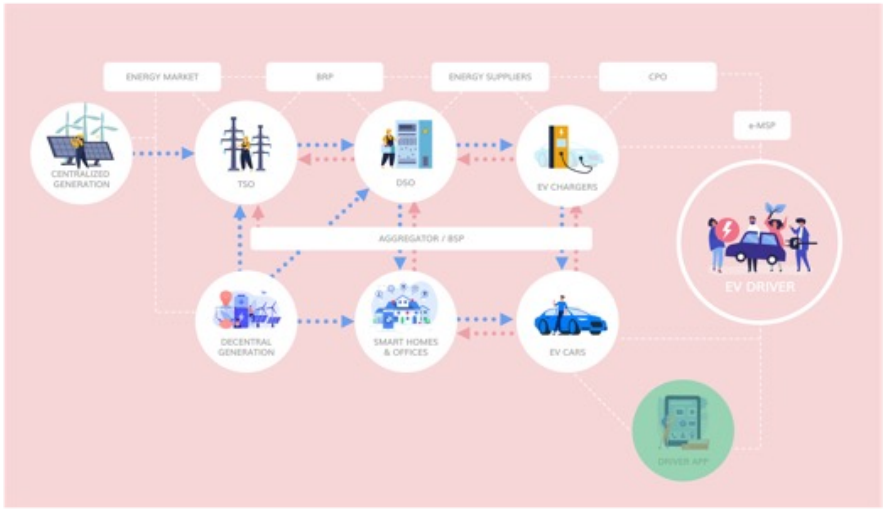
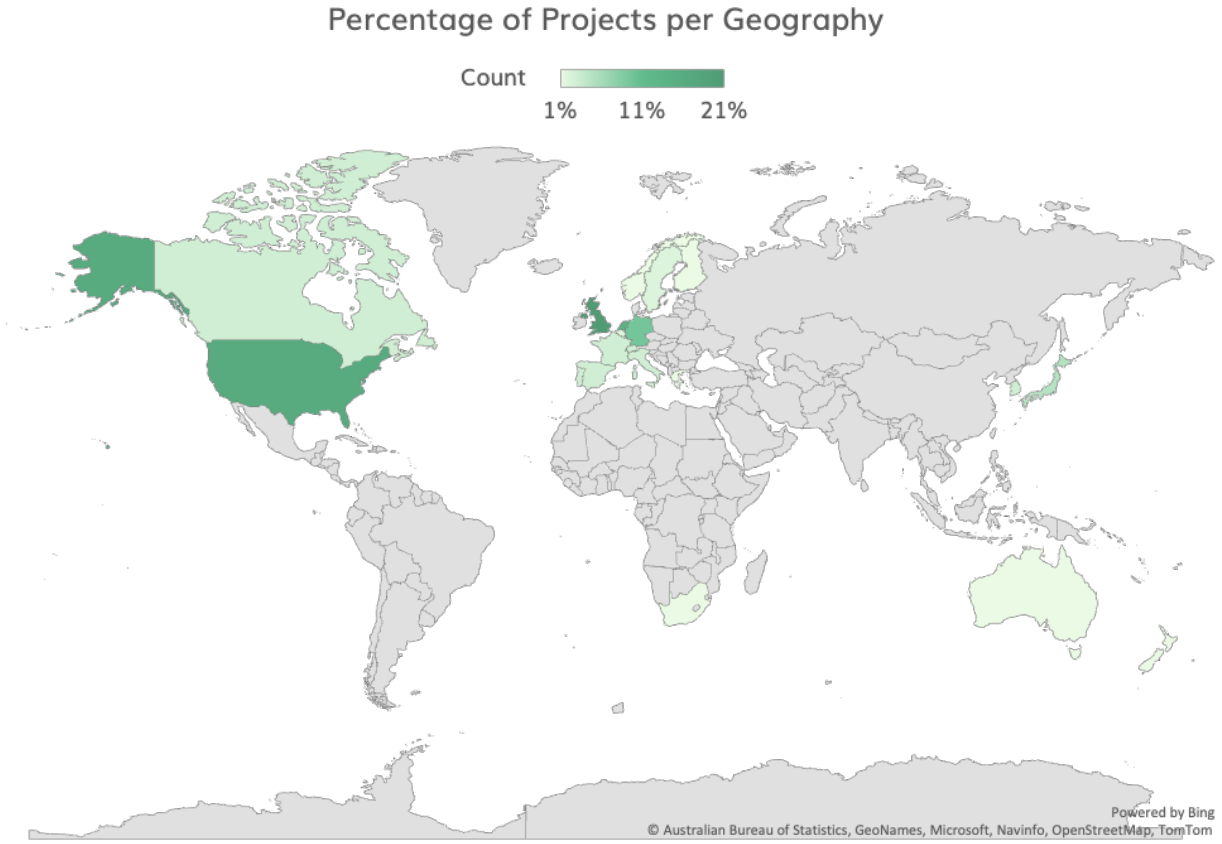


RETHINKING ENERGY

PROJECT DEEPDIVES

GLOBAL V2G PROJECTS LANDSCAPE

The largest portion of past and current V2G projects is situated in the UK, followed by the US, the Netherlands and Germany. Not one country has designed and implemented on national scale.



There are more than 100 bidirectional charging trials worldwide, most of which take place in Europe and the United States in collaboration with grid providers and electric vehicle and charger manufacturers.

The electricity grid fluctuates, especially in the UK as it is not connected to the mainland. Experts suggest that's why there is more interest and funding from the government to push trials and gain experience with systems that can support the grid.

According to experts, past trials have proved that there are no significant barriers from a technical point of view. Obstacles holding back large-scale implementation are suggested to be the regulatory framework and commercial models.

No countries have designed and implemented a national system and national policies enabling and stimulating Social Charging practices yet.

PROJECT DEEPDIVES

Out of 100+ global bidirectional charging projects, we picked a few examples which could be interesting for Energinet based on their scale, focus areas partners and business models

PROJECT SHORTLIST

EVVE

Project led by EDF aiming to form a virtual battery with a capacity of 8.36 MW across Europe by 2024.

ABB's hardware integrated with DREEV (Nuvve) software will enable EV drivers to charge at the most optimal time and export surplus power back to the grid - generating up to €240/EV/year

2022 800 FR

V2X Suisse

Project led by cars-sharing provider Mobility including 50 Honda EVs testing bidirectional charging on a national scale.

Mobility's car-sharing fleet can feed up to 60 megawatts of power back into the grid. This electrical regulating power will help stabilise the grid and avoid, reduce or delay expensive grid expansions

2022 50 CH

Sciurus

Project Sciurus is one of the largest domestic vehicle-to-grid trials in the world - having operated 300 bidirectional chargers for home use.

The V2G units were able to create between £230 and £300 of value / year. When combined with flexibility services this could grow to £500 / year

2018 300 UK

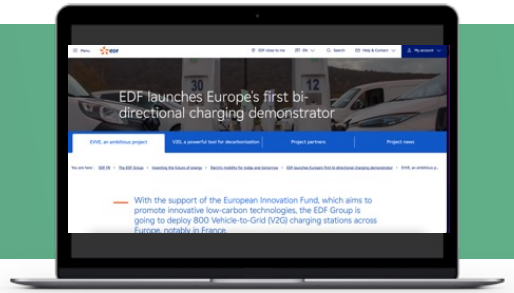
Bidirectional Loadmanagement - BDL

Project BDL connects 9 ecosystem players (including the TSO) to pilot bidirectional charging using 50 BMW's.

BDL will for the first time connect electric vehicles, charging infrastructure, and the energy grid in a holistic solution generating benefits under real life conditions using V2G technology

2021 50 DE

PROJECT SNAPSHOT



PROJECT

EDF

PROJECT DETAILS

2022 - 2024

FR

800 chargers

edf.fr/evve

KEY PARTNERS

DREEV (EDF & Nuvve), Nuvve, ABB, Izivia

European Innovation Fund

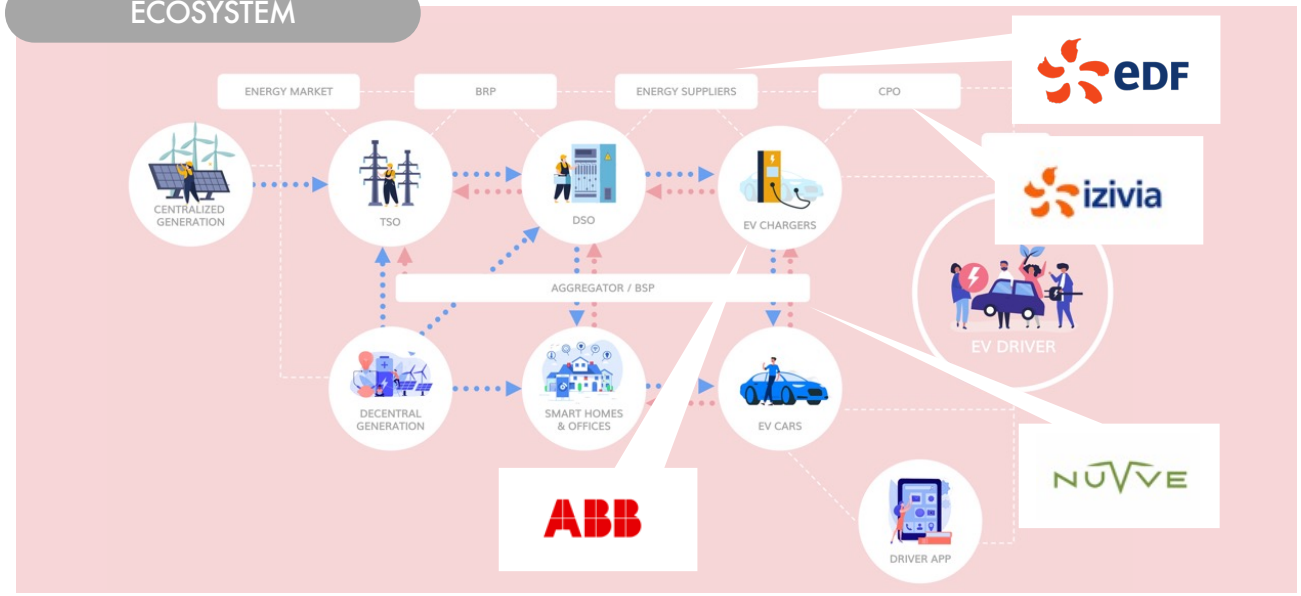
DESCRIPTION

EVVE is a Europe-wide project, led by the EDF Group and its subsidiary Dreev. Its ambition is to deploy and aggregate around 800 bi-directional charging stations across Europe to form a virtual battery with a capacity of 8.36 MW, which will draw its energy from hundreds of compatible electric vehicles. This project is subsidised by the European Innovation Fund, and will benefit companies and local authorities that wish to electrify their vehicle fleet.

KEY OBJECTIVES

- install 800 bi-directional charging stations by the end of 2024
- aim to extend the functionalities of V2G to prepare for its development on a larger scale
- optimise economic performance of V2G
- increase the reduction in volume of CO_2

ECOSYSTEM



BUSINESS MODEL

Maximising self-consumption

Optimisation through time-of-use tariffs

Offering flexibility services

EVVE offers companies and local authorities a hard & software package including chargers, management platform, mobile app, charging card and technical assistance. ABB's hardware integrated with DREEV (Nuvve) software will enable EV drivers to charge at the most optimal time and export surplus power back to the grid. Users generate up to €240/EV/year or 15,000 km of electric fuel EV/year.

ENERGINET RETHINKING ENERGY

PROJECT SNAPSHOT

PROJECT

V2X Suisse

PROJECT DETAILS

2022 - 2023

CH

50

mobility.ch/v2x

KEY PARTNERS

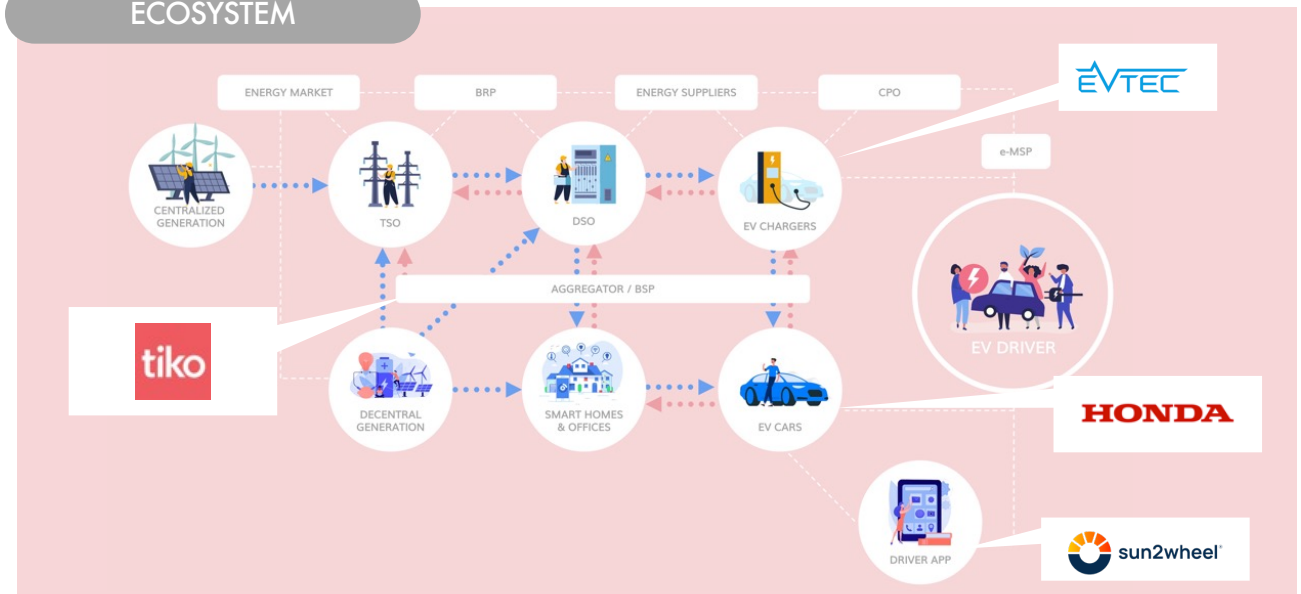
Mobility, Honda, sun2wheel, EVTEC, tiko, Novatlantis, ETH Zürich

Swiss Federal Office of Energy (SFOE)

DESCRIPTION

From September 2022, 50 Honda EVs will be available at 40 Mobility stations across Switzerland for one year. For the first time, mass-produced electric vehicles with bidirectional charging will be available for use across the country for day-to-day journeys. So far, (1) there has never been a comparable test with 50 vehicles – other projects are smaller, (2) we are the first to test across the whole country and (3) we are the first to include multiple user groups: grid regulation, local energy providers and consumers.

ECOSYSTEM



KEY OBJECTIVES

- exploring V2G's potential of grid stabilization and self-consumption from solar chargers
- Investigate the business potential of bidirectional charging electric vehicles in Switzerland.
- test the competition between the potential flexibility buyers (Swissgrid, grid operators, and self-consumption associations)

BUSINESS MODEL

Maximising self-consumption

Optimisation through time-of-use tariffs

Offering flexibility services

Starting Q3 this year, the potential of V2G for grid stabilization maximizing self-consumption is going to be tested under real circumstances through the Mobility car-sharing app. Mobility's car-sharing fleet can feed up to 60 megawatts of power back into the grid. This electrical regulating power will help stabilise the grid and avoid, reduce or delay expensive grid expansions

ENERGINET RETHINKING ENERGY

PROJECT SNAPSHOT

PROJECT

Sciurus

PROJECT DETAILS

2018 - 2021

UK

300 chargers

ovo.com/v2g

KEY PARTNERS

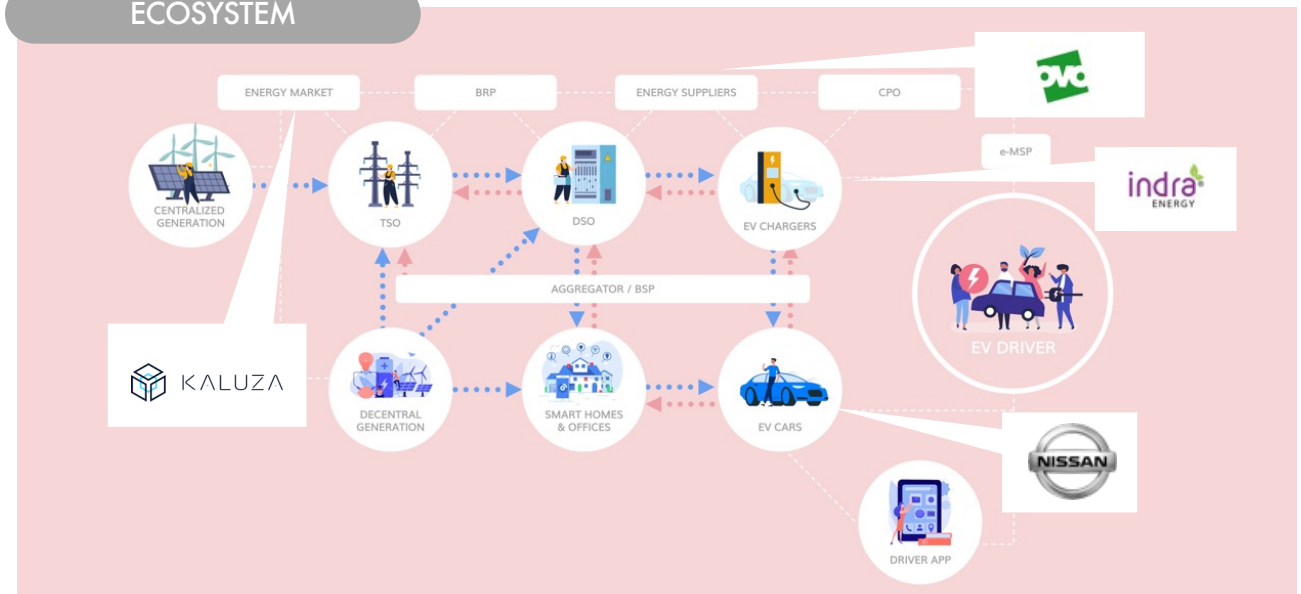
OVO Energy, INDRA, Kaluza, Cenex, Nissan

Innovate UK

DESCRIPTION

The OVO Energy V2G Project (Project Sciurus) is one of the largest domestic vehicle-to-grid trials in the world. OVO Energy provided Nissan EV drivers with V2G hardware made by Indra, and installed it in their homes. Kaluza Flex platform responds to real-time schedules - optimising EV charging based on customer needs, energy wholesale and balancing markets. Customers are paid for their exports to the grid, enabling many of them to drive their EV effectively for free as a result of using their V2G charger.

ECOSYSTEM



KEY DELIVERABLES

- Gather sufficient data from the project in order to determine the optimum business models for exploitation.
- Develop and evidence capability of a smart grid platform aggregating and controlling at least 300 V2G chargers,
- Develop at least 300 6kWh bi-directional chargers capable of providing vehicle-to-grid services.

BUSINESS MODEL

Maximising self-consumption

Optimisation through time-of-use tariffs

Offering flexibility services

Consumers participating in the trial were provided the chargers at no cost. During the project, customers save money off their energy bills by buying energy when prices are low and will make a profit by selling surplus energy back to the grid – transforming homes into mini power stations. The V2G units were able to create between £230 and £300 of value / year through the spot electricity market via the Kaluza platform. When combined with flexibility services this could grow to £500 / year

ENERGINET RETHINKING ENERGY

PROJECT SNAPSHOT

PROJECT

PROJECT DETAILS

2021

DE

50 EVs

bdl-projekt.de

KEY PARTNERS

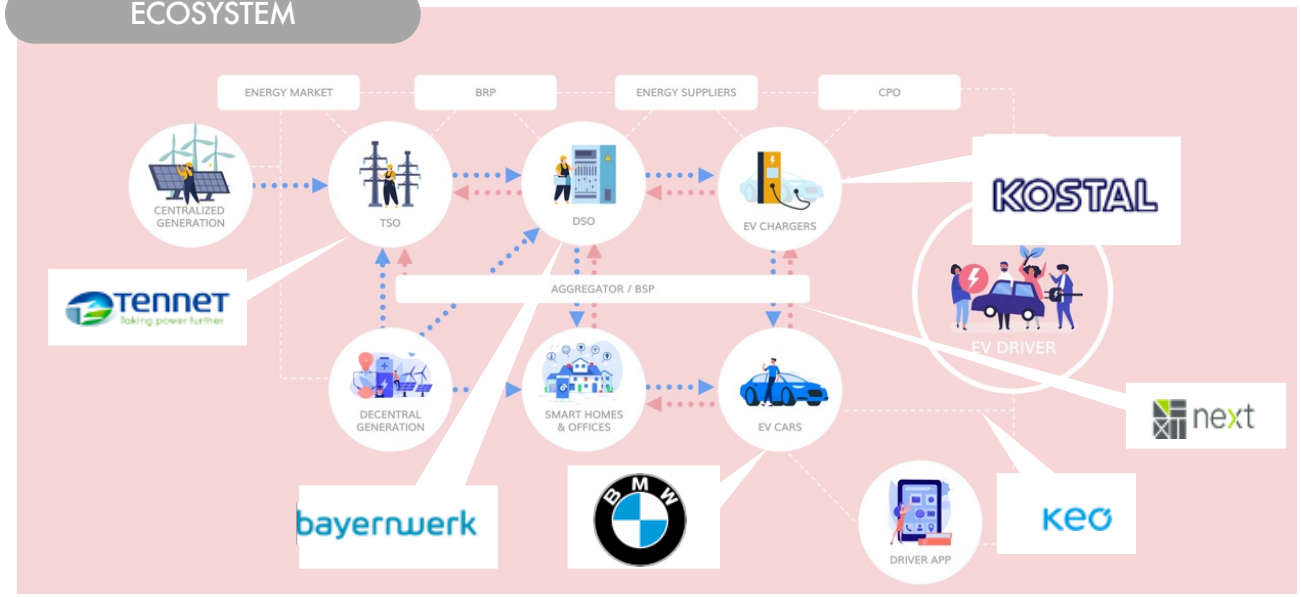
BMW, Kostal, Bayernwerk, TenneT, KEO, Next Kraftwerke, Ffe Ffe, KIT, Universität Passau

German Federal Ministry of Economy and Energy

DESCRIPTION

Project BDL connects partners from the automotive and energy sectors as well as from science. They develop and pilot technical solutions to make e-mobility more comfortable and cost efficient also reducing the carbon footprint. The interdisciplinary project will for the first time connect electric vehicles, charging infrastructure, and the energy grid in a holistic solution generating benefits under real life conditions using bidirectional charging technology, i.e. by feeding energy back from the vehicle into the house or the local grid.

ECOSYSTEM



KEY OBJECTIVES

- Use cases for the system-serving use of flexibilities
- Regulatory check for feasibility of uses cases
- Economic implementation of technological solution for the use case
- Demonstration of customer value as well as system service
- Proof of economic and CO2 advantage

BUSINESS MODEL

Maximising self-consumption

Optimisation through time-of-use tariffs

Offering flexibility services

The first part of the BDL project focuses on private customers and maximizing their self-consumption through solar PV and intra-day trading. A total of 7,771 kWh were charged in the self-consumption optimization use case, of which 36% could be covered by PV electricity. A total of 3,524 kWh were discharged again.
Regarding intraday-trading, a total of 14,473 kWh were charged in the use case and 8,693 kWh were unloaded in order to sell them profitably on the intraday market.

RETHINKING ENERGY

IT WON'T HAPPEN BY ITSELF...

CONCLUSION & NEXT STEPS

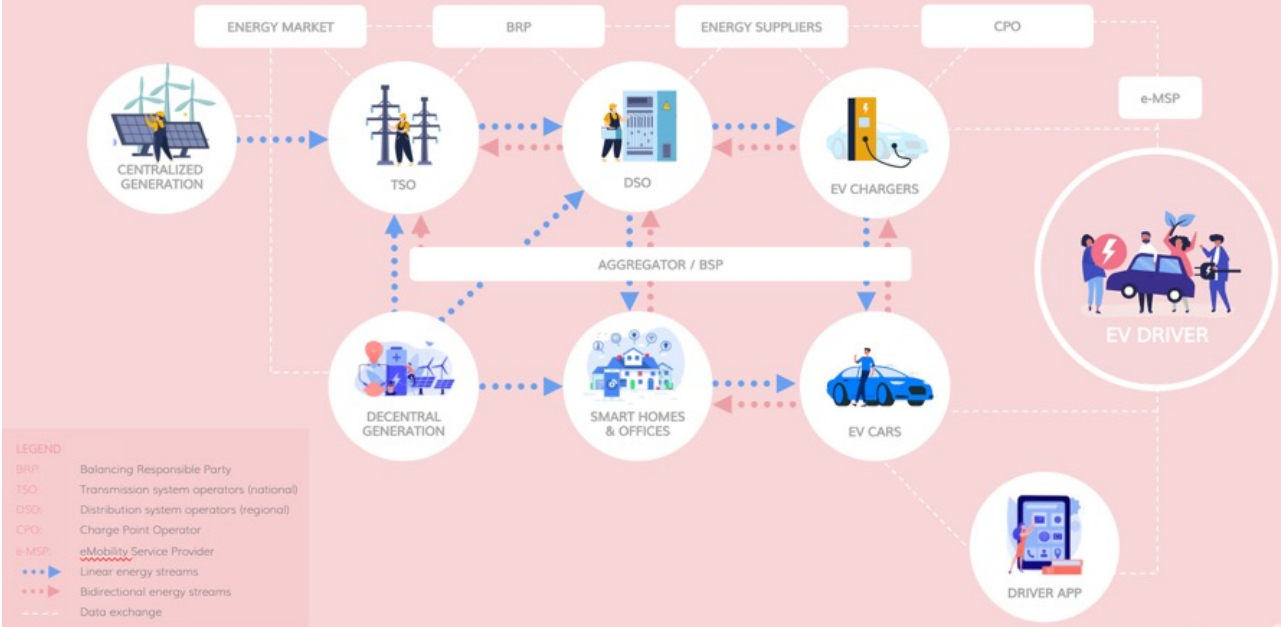
NEXT STEPS: URGENT NEED FOR SYSTEM DESIGN

There is an urgent need to provide direction for the future national system design, and to develop the policy frameworks and the technology foundations to direct and enable the transition towards smart, social & responsible charging.

A System Design is needed to direct and enable the responsible & social charging models

1. Agree on roles & responsibilities for key actors for the different aspects of system & market development
2. Develop the policies to enforce the new models
3. Design, implement and run the technology systems that are needed to facilitate the bi-directional charging models
4. Design, implement and run the financial market drivers including energy market and tax systems

ENABLING SOCIAL & RESPONSIBLE CHARGING



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PROPOSED NEXT STEPS – INTERNATIONAL ALIGNMENT

We propose to align with international TSO peers about their directions and planning for system design to guide the national direction and allow for efficient alignment across borders.

INTERNATIONAL STAKEHOLDER ANALYSIS

Perform detailed stakeholder analysis to identify the key challenges and opportunities per country, to prepare for the co-creation of system design national and/or international level

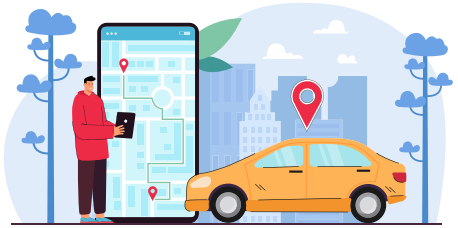
- Identify stakeholders in TSO's and other entities
- Conduct stakeholder interviews
- Report out with stakeholder interest overview

INTERNATIONAL POLICY ANALYSIS

International alignment project to understand the perspectives and the planning for system change per country, including the direction for policy development and financial systems

- Engage with selected TSO's & stakeholders
- Conduct interviews and exchanges
- Report out with European perspectives

TECHNOLOGY EXPLORATION



Explore European perspectives about the key enabling technologies that enable the Smart Charging model, to provide direction for the design and implementation of the enabling system

- Define key technology area's
- Identify leading tech solutions
- Potentially – conduct joint technology pilots

International alignment can provide direction, inform decisionmaking, and potentially create room for international optimization

ENERGINET

RETHINKING ENERGY

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RESOURCES – SELECTION OF ARTICLES, REPORTS & EXPERT INTERVIEWS

Name	Company / Author(s)	Year	Website/Download Link
IEA Denmark Country Profile	International Energy Agency	2022	Link
Stock of Motor Vehicles	Statistics Denmark	2022	Link
Energy Concept 2030 – Summary	Energinet	2015	Link
Long Term Development Plan for the Power Grid	Energinet	2022	Link
Er elnettet klar til elbilerne? (Is the power grid ready for the electric cars?)	Dansk Energi	2019	Link
Forsyning til tiden (Supply in time)	Green Power Denmark	2022	Link
Vehicle-to-Everything (V2X) in the Netherlands	Netherlands Enterprise Agency	2019	Link
Vehicle-to-X (V2X) implementation: An overview of predominate trial configurations and technical, social and regulatory challenges	ETH Zürich / Gschwendtner et al.	2021	Link
Electric Vehicle Integration into Power Grids (Position Paper)	the European Network of Transmission System Operators for Eletricity (ENTSO-E)	2021	Link
Innovation Outlook: Smart Charging for Electric Vehicles	International Renewable Energy Agency (IRENA)	2019	Link
The Next eMobility Architecture	evRoaming4eu / The Emobility Communication & Information System Structure (ECISS) Project	2020	Link
Market model 3.0: The Electricity Market as the Key to a Climate Neutral Society	Danish Energy Agency	2021	Link
The Drive Towards A Low-Carbon Grid (Whitepaper)	Nissan, E.ON Drive and Imperial College London	2021	Link
The Parker Project – Final Report – Appendices	Parker Project / Peter Bach Andersen et al.	2019	Link
Commercial Viability of V2G: Project Sciurus White Paper	Project Sciurus / Cenex	2021	Link
A Fresh Look at V2G Value Propositions	Cenex	2020	Link
Bidirectional Charging Management - A highly interconnected system	Xaver Pfab, Frank Burghardt, Wolfgang Duschl	2022	Link
Bidirectional Charging Management - Insights and Evaluation of the Field Trial	Adrian Ostermann	2022	Link
Interview with Bjoern Christensen	Former CSO at Nuvve	2022	
Interview with Peter Bach Anderson	Senior scientific Researcher at the Technical University of Denmark (DTU)	2022	
Interview with Panagiotis Andrianesis & Scott Englander	Co-founders FLxDER	2022	