
LUT
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Recurring “record-breaking” trend

- In 2021, EV sales doubled to a new record of yearly 6.6 million, whereas back in 2012, only 120 000 electric cars were sold worldwide. In 2021, more than that many were sold each week.
- **Nearly 10% of global car sales were electric in 2021**, four times the market share in 2019.

- In 2022, 2 million EVs were sold only in the first quarter, up 75% from the same period in 2021. **About 14% of the sales were electric**.
- This brought the total number of electric cars on the world’s roads today to about 16.5 million, triple the amount of 2018.

- Expert EV sales prediction for 2030: **157 million globally**
- Same prediction for 2040: **745 million globally**

iea

BEV (light shade) PHEV (dark shade) Electric car sales share

DRIVE2X

We have a big problem! Or is it?

"If most of the passenger vehicles sold from 2040 onwards were electric, more than 1 billion EVs could be on the road by 2050"

"In 2050, around 14 TWh of EV batteries would be available to provide grid services"

IRENA International Renewable Energy Agency

iea

DRIVE2X

EV growth as "double-edged sword"

BAU PATH

2ZERO PATH

FORTHCOMING MASS EV DEPLOYMENT (inevitable)

Uncontrolled, Basic, and V1G charging

(UNIDIRECTIONAL)

Extra burden on energy system
****LIABILITY****

Systems-optimized
"smart charging"
(**V2X**: V2G, V2B, V2H)

(ADVANCED/BIDIRECTIONAL)

EV charging flexibility
****OPPORTUNITY****

DriVe2X

DELIVERING RENEWAL AND INNOVATION TO MASS VEHICLE ELECTRIFICATION ENABLED BY V2X TECHNOLOGIES

The DriVe2X project

Gonçalo Mendes, LUT

EEM23 V2X Special Session

Funded by EU HEU R&I
Grant No. 101056934

LUT, Lappeenranta, Finland
8 June 2023

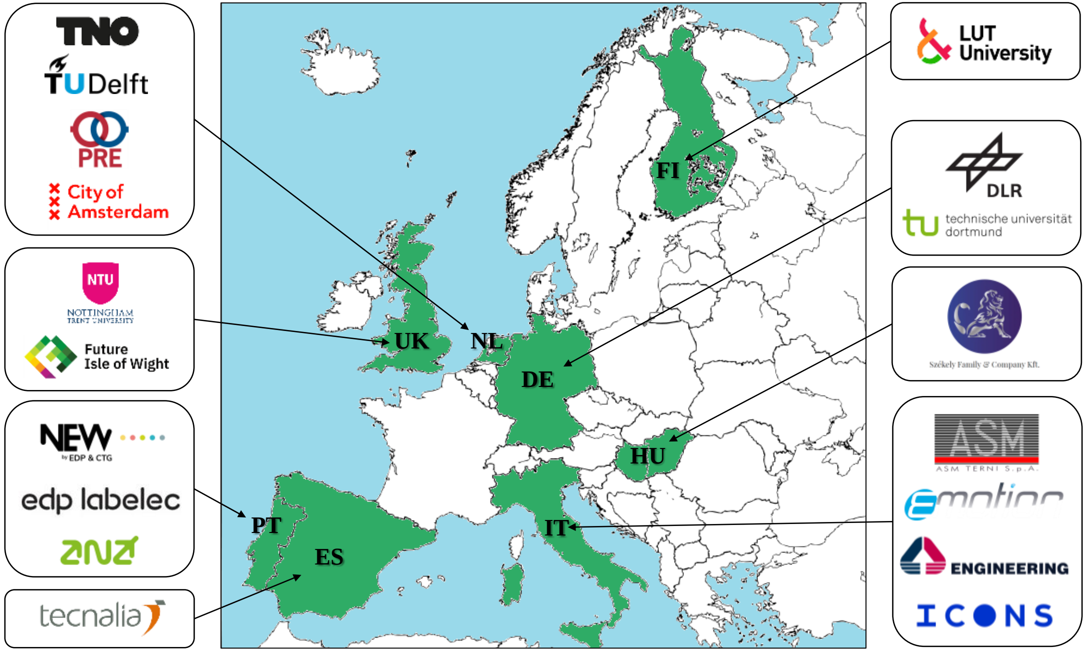
DRIVE2X

DELIVERING RENEWAL AND INNOVATION TO MASS VEHICLE ELECTRIFICATION ENABLED BY V2X TECHNOLOGIES

- **Call topic**: HORIZON-CL5-2021-D5-01-03 — System approach to achieve optimised Smart EV Charging and V2G flexibility in mass-deployment conditions (2ZERO)
- **Type**: Research and Innovation action

- **Coordinator entity**: LUT University
- **Overall budget**: 10.5 Million Euros
- **Duration**: 4 years (Jan 2023 to Dec 26)

The DriVe2X project consortium



ELECTRICITY DISTRIBUTION & POWER SYSTEMS ANALYSIS
(NEW, DUT, ASM, TUDO)

ELECTRIC MOBILITY
(DUT, PRE, EMOT)

ELECTRICITY MARKETS INNOVATION
(TNTU, LUT)

DATA SCIENCE & ANALYTICS
(DLR, ENG)

SOCIAL SCIENCES & HUMANITIES
(TNO)

ENERGY SYSTEMS ASSESSMENT & MODELING
(TEC)

18 partners from 8 European countries. More specifically, 4 universities, 3 public research institutes, 1 corporate research institute, 5 commercial enterprises, 1 non-profit, and 3 civil-society representatives.

DRIVE2X

DriVe2X's objectives

To develop new knowledge, tools, models, and technologies to cope with a V2X-based mass EV deployment future for Europe

Objective 1

To consolidate the understanding of V2X concepts and technologies and help frame among society its future role in European smart cities

Objective 2

To address V2X user experience and behavioural challenges and build operational and economic trade-offs under different charging scenarios

Objective 3

To design and demonstrate a user-centric local V2X marketplace levering its flexible energy potential in parking lots, homes, and public charging stations

Objective 4

To develop and demonstrate novel user-inspired V2X solutions and charging technologies suitable to a mass EV deployment future

Objective 5

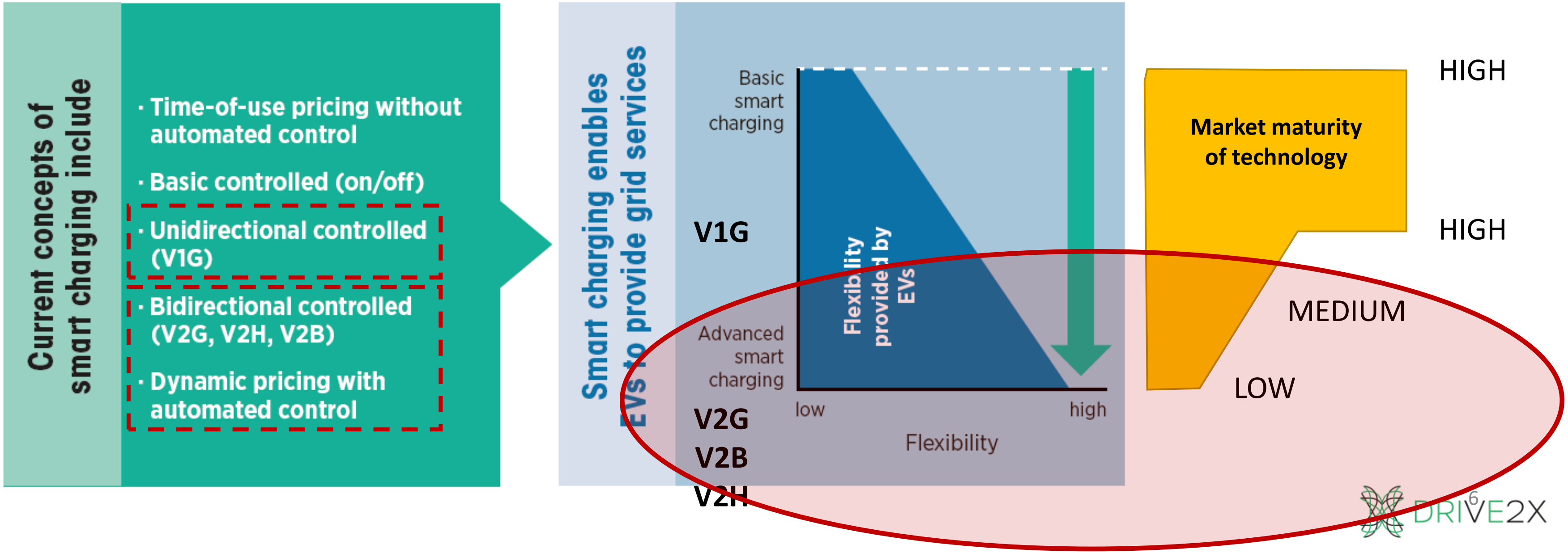
To assess the impacts from mass deployment of V2X technologies on the distribution grids, on the energy markets, and the energy system as a whole

Objective 6

To support the furthering of V2X open research and market scale-up, thus facilitating deployment of roll-out programmes in smart cities across Europe

The opportunity in V2X

The greatest **flexibility potential** linked to smart charging lies with bidirectional approaches, which are also the **least market-mature**



More V2X R&I needed on distribution grids

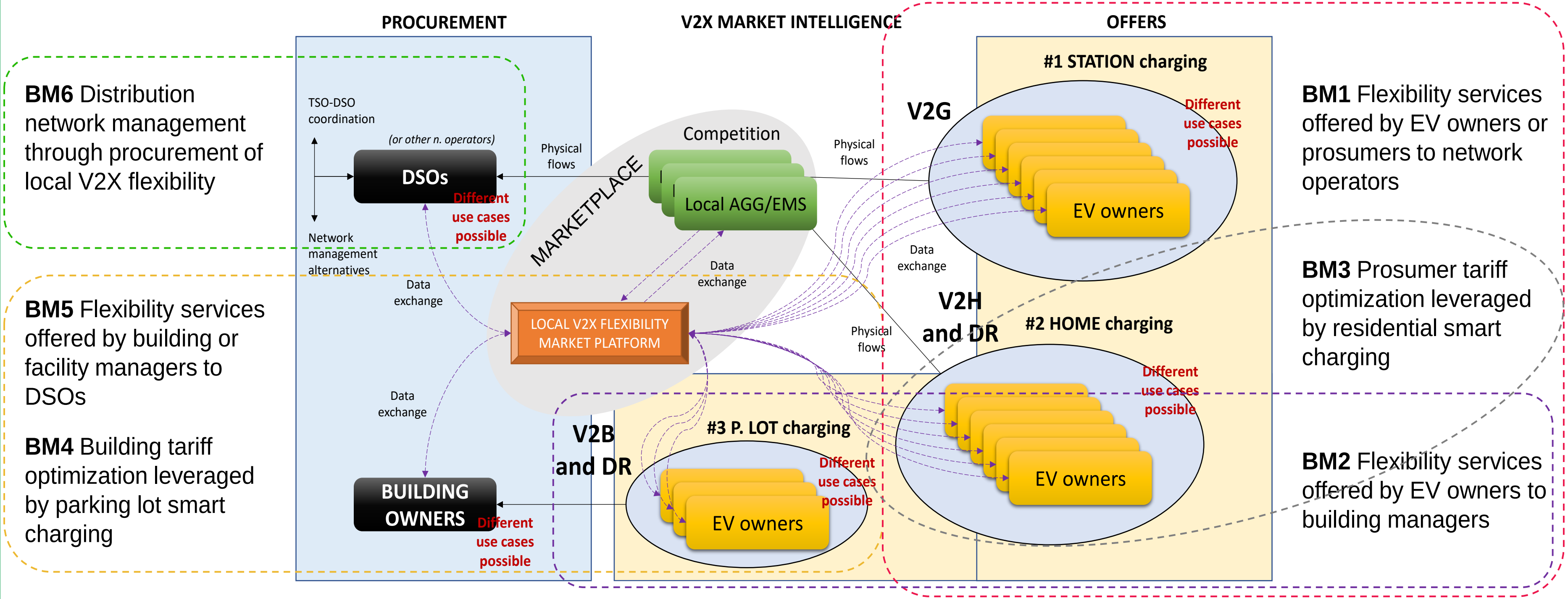
Already >100 projects exploring V2X power system synergies, but only a small fraction have focused on **distribution grid benefits**

SYSTEM FLEXIBILITY		LOCAL FLEXIBILITY	
Wholesale market	Transmission System Operator	Distribution System Operator	Behind-the-meter
• Peak-shaving • Portfolio balancing	• Frequency control • (primary, secondary and tertiary reserve) • Other ancillary services (*e.g.*, voltage management, emergency power during outages)	• Voltage control • Local congestion and capacity management • Local load balancing **V2G** (front-of-the-meter)	• Increasing the rate of Renewable Energy self-consumption • Arbitrage between locally produced electricity and electricity from the grid • Back-up power

V2B
V2H

DRIVE2X

Our system-scale VISION



Unique T&V landscape and multifaceted BMs

Demo 1

NTU

BM2, BM4

Isle of Wight (UK)

Sustainable island energy community facing RES congestion

UC1 – Medium-term V2B charging in hotels as a sustainable means to promote eco-tourism and local economic growth
UC4 – V2G integration in public charging stations for addressing technical grid constraints

Demo 2

NEW by EDP & CTG

BM1, BM2, BM4

City of Maia (PT)

V2B in airports and commercial spaces and public V2G charging

UC2 - Long-term V2B charging with load aggregation in parking lots for dynamic load balancing and BEMS integration
UC4 – V2G integration in public charging stations for addressing technical grid constraints

DriVe 2X marketplace

enabled by user-friendly, lower cost, lower impact bidirectional charging solutions

Demo 3

City of Budapest (HU)

V2H integration with DER & HEMS in prosumer & EV owner homes

Székely Family & Company Llc.

BM1, BM3, BM5

UC3 – V2H integration with HEMS for renewables' integration and tariff optimization in prosumer homes

TNO

Demo 4

City of Amsterdam (NL)

V2B and V2G in extremely congested grid environments

BM1, BM2

UC6 - Peripheral smart renewable energy and mobility hubs for V2G uptake in highly congested urban grids

Demo 5

City of Terni (IT)

V2G integration into highly RES-congested hybrid AC and DC grids

ASM TERNI S.p.A.

BM1

UC4 – V2G integration in public charging stations for addressing technical grid constraints
UC5 – V2G for network stabilization of locally-managed RES-congested grids

DRIVE2X

Four fronts of project AMBITION

01 **V2X flexibility markets**
New AI and ICT tools enabling exploitation of V2X flexibility

02 **V2X charging technology**
Affordable, user-friendly bidirectional chargers

drive2x

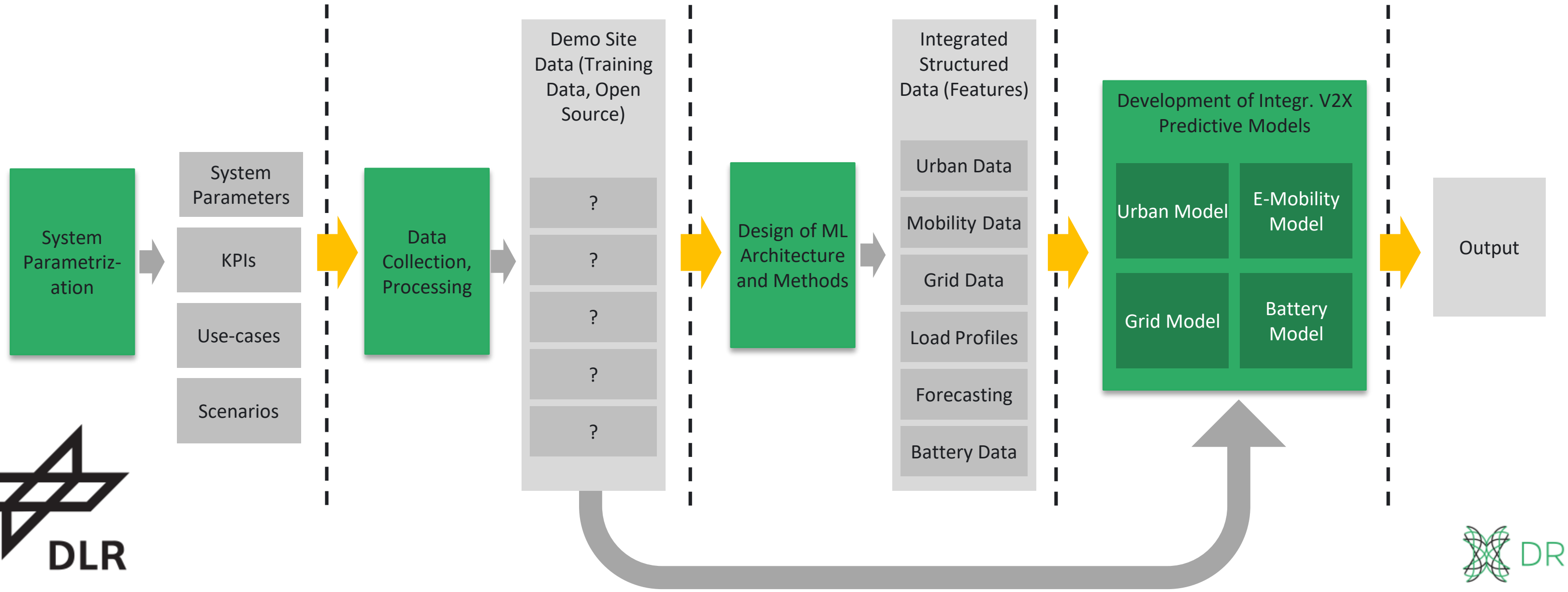
03 **The social side of V2X**
EV user expectations as key success factors of uptake

04 **V2X upscaling studies**
Novel modeling approaches and roll-out frameworks

Optimizing Energy & Mobility through data

01

We will leverage the power of data from distribution grid, driving and electric demand patterns, and mobile batteries, to match location-specific flexibility needs and offers



DLR

DRIVE2X

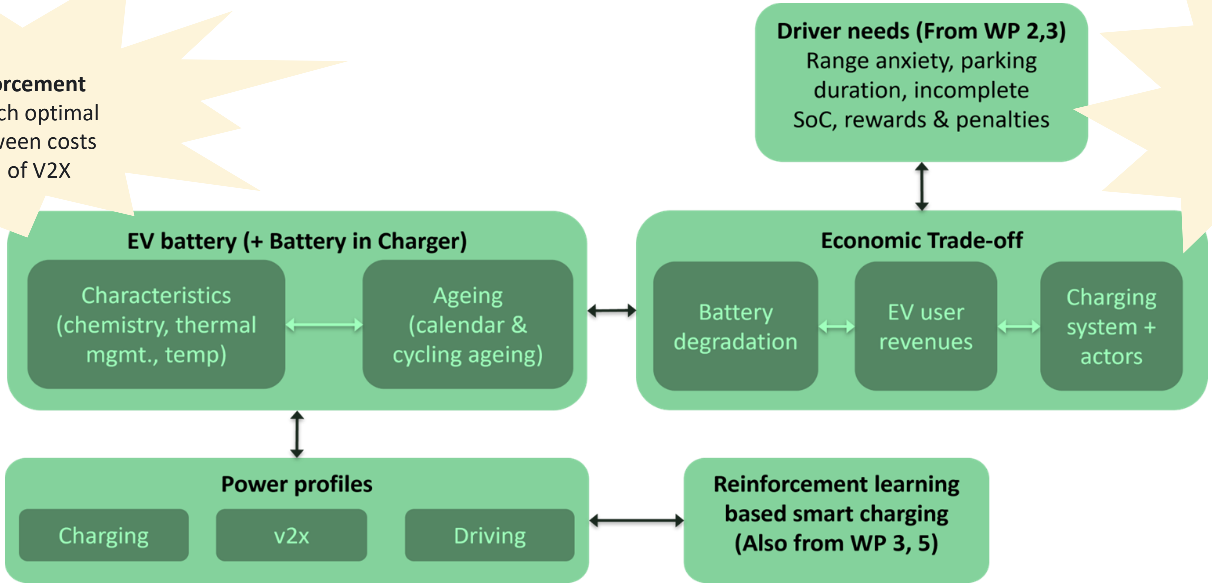
Reducing EV battery ageing in 25%

01

We are testing the impact of different thermal management strategies in calendar and cycling ageing for 1^{st} and 2^{nd} life battery chemistries

We use **reinforcement learning** to reach optimal trade-offs between costs and benefits of V2X

We adopt **high-fidelity digital twins** to assess EV battery degradation



TU Delft
Delft University of Technology

DRIVE2X

Bidirectional EV charging technology

02

Current bidirectional charging solutions are characterized by:

- High cost and low efficiency
- Lack of integration with other resources and systems
- Not yet designed for facilitating customer experience

In order to overcome these challenges and to demonstrate feasibility, DriVe2X will develop two V2X charger prototypes capable of interfacing with other local resources, alongside the DSO flexibility market.

- A 6kW single-phase, solar integrated direct DC charger with local storage and end TRL 7, destined at V2H applications (**x10**)
- A three-phase AC/DC 15kW unit with end TRL 7 for V2B/V2G (**x30**)

PRE

DRIVE2X

Redefining "SMART" mobility

03

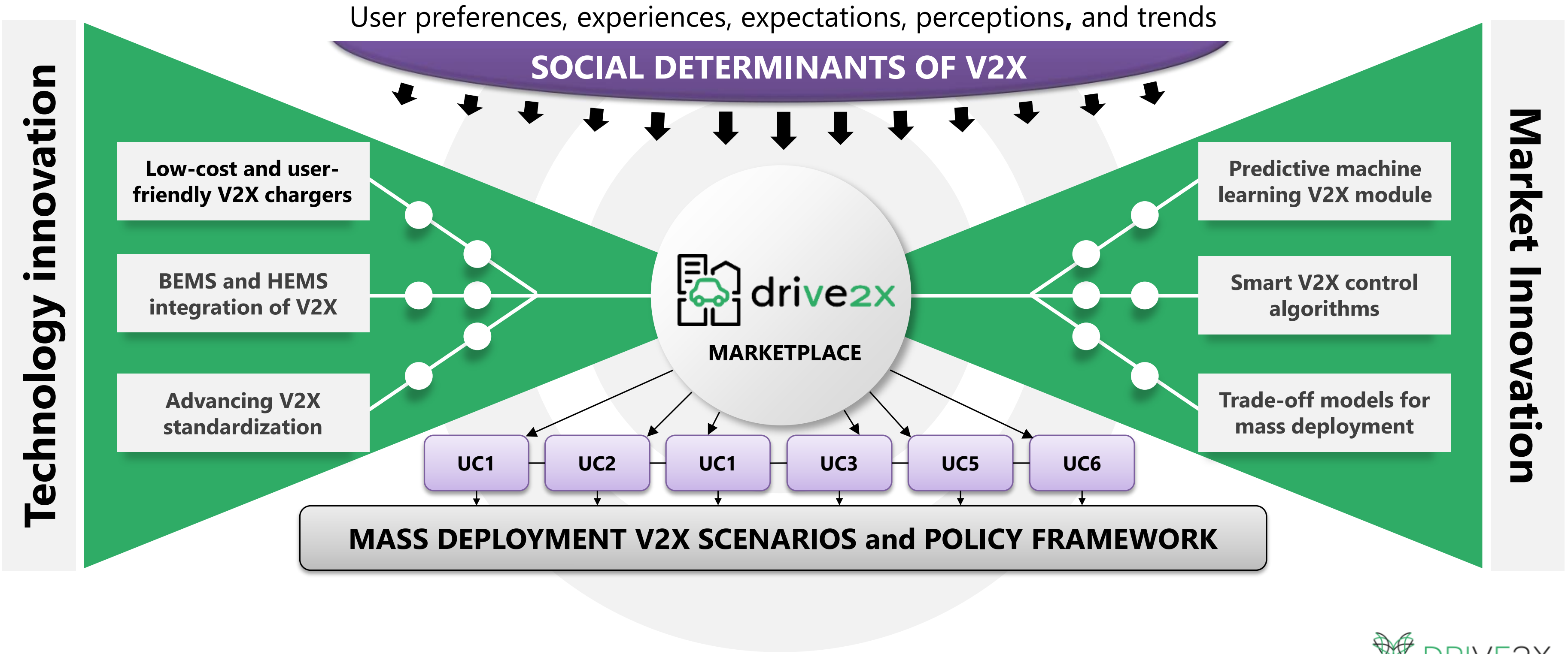
"Smart charging means adapting the charging cycle of EVs to both the conditions of the power system and the needs of vehicle users."

VIRTA.

DRIVE2X

“Socially-inspired” solution design

03



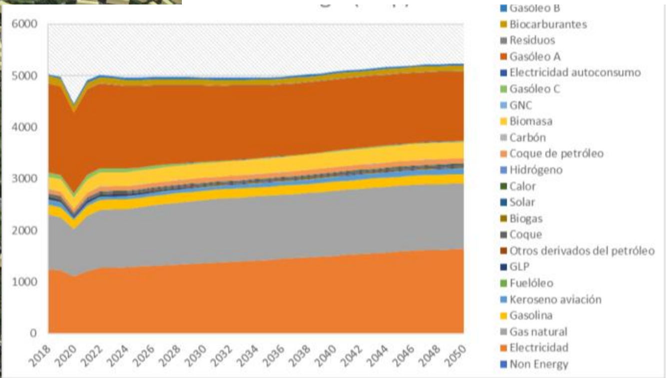
DRIVE2X

City strategies from geo-ref models

04

Urban layers

Scenario analyses



tecnalia Inspiring Business

DRIVE2X

Supporting V2X roll-out in SMART CITIES

04

V2X and **Battery** technologies deployment: Twin transition evolution over time horizon 2035

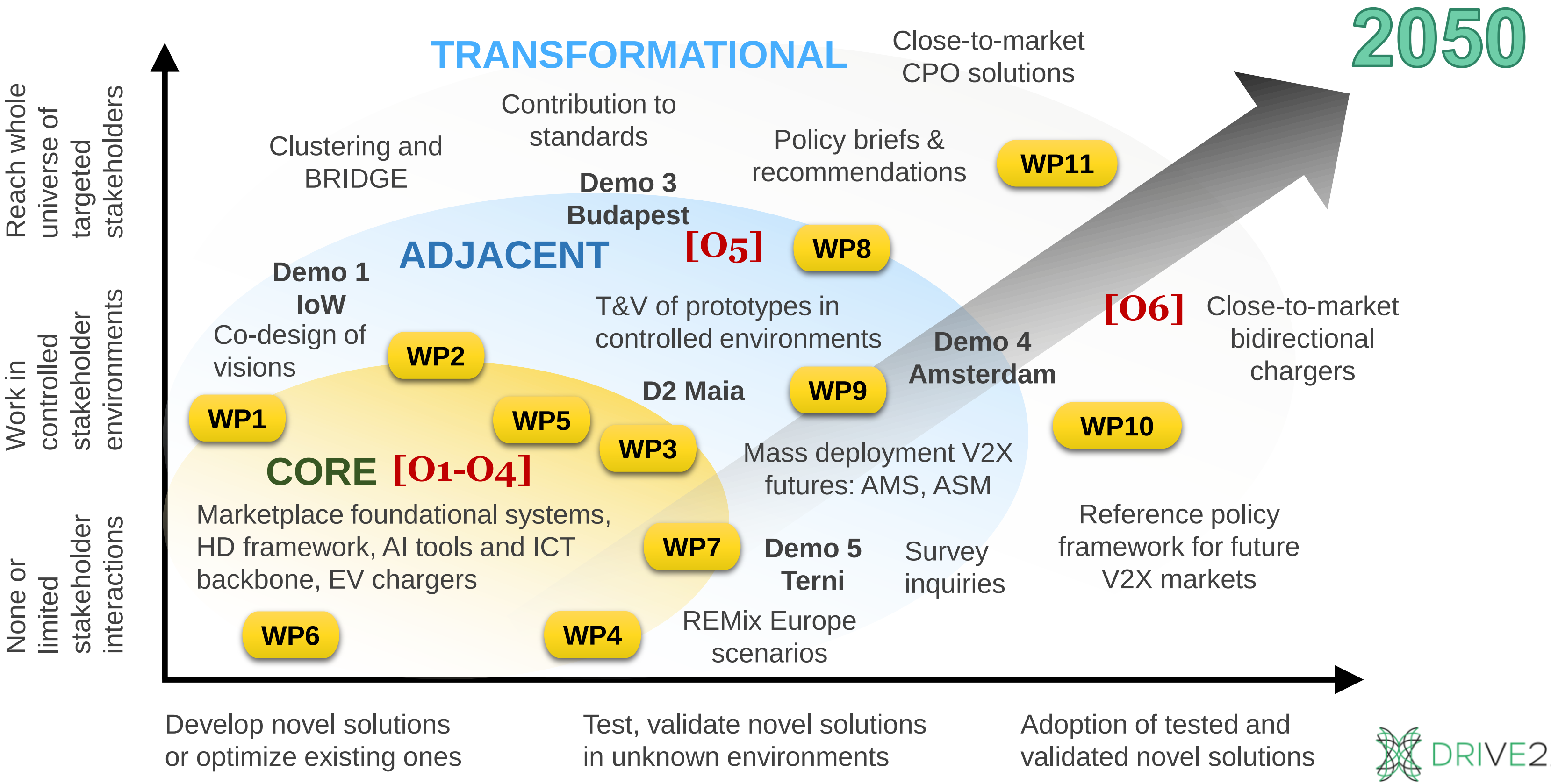
Transitions structuration stages 2035

Reference policy framework for structuration and evolution of future V2X markets over the next 5-10 years

Marginal evolution	Moderated evolution	Change in full swing
Ideation **V2X** twin **battery** tech	Leading Cities/MS adopt V2X	Full legitimisation across sectors
Primary Knowledge accumulation	Specialised knowledge in education	Broad deployment of pilot projects
Pockets lobbying groups	Increased participation across sectors	Lobbying groups coopted in mainstream
Institutional validation	V2X Sectoral policy roadmap in EU	V2X in sectoral policy in MS
New managerial approaches	New business models for mobility	City & Industrial contract agreements
Policy multi-lateral support	More cities adopt smart V2X principles	Issues of tracking products monitoring process
Early Investment pilots, IPR	Islands of change	Investment level and islands, V2X and new Batteries equal footing
Early adopters/policy	Alignment of new business models	V2X expands to whole value chains
Early upscaling/regulation	Dominant standards markets'alignment support diffusion of V2X products	V2X/Battery Markets in full swing

Will help city planners, policy makers and businesses in locating and assessing the advance of their initiatives in a long-term transition landscape

DriVe2X: A comprehensive innovation view



DRIVE2X

DRIVE2X

Thank you!


LUT
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International Conference on the EUROPEAN ENERGY MARKET

EEM23 – 19th

6.–8. June 2023 | Lappeenranta, Finland

Special Session on V2X Visions

EV4EU – V2X scenarios and vision

Hugo Morais

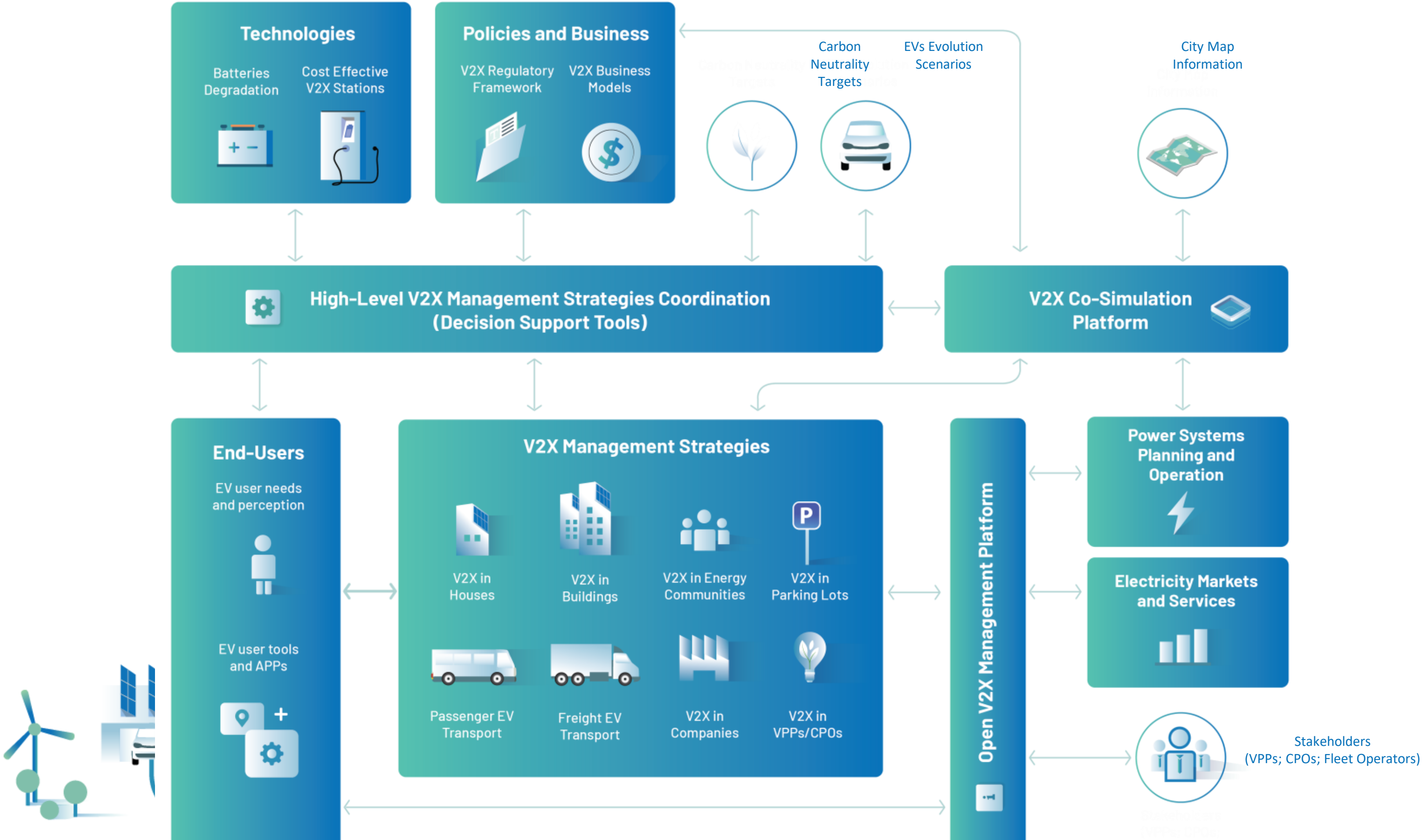
2023 / 06 / 08

hugo.morais@tecnico.ulisboa.pt

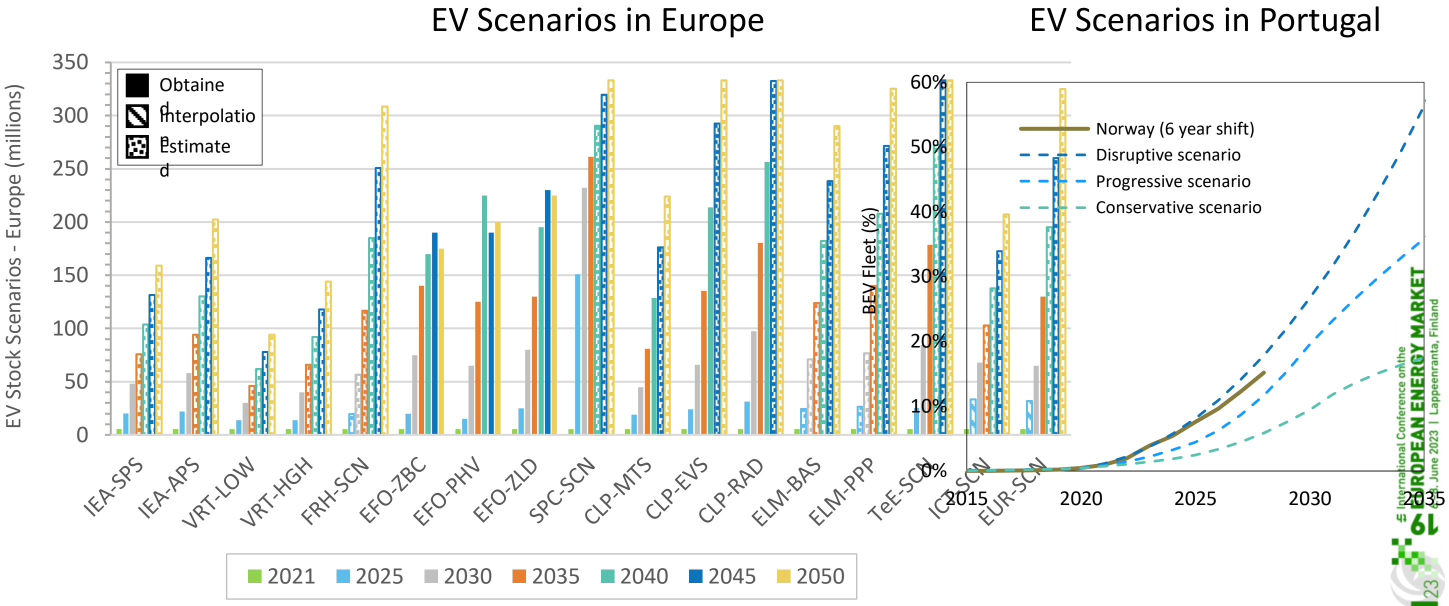
EV4EU – Consortium

International Conference on the EUROPEAN ENERGY MARKET
6.–8. June 2023 | Lappeenranta, Finland
EEM23
ev4eu

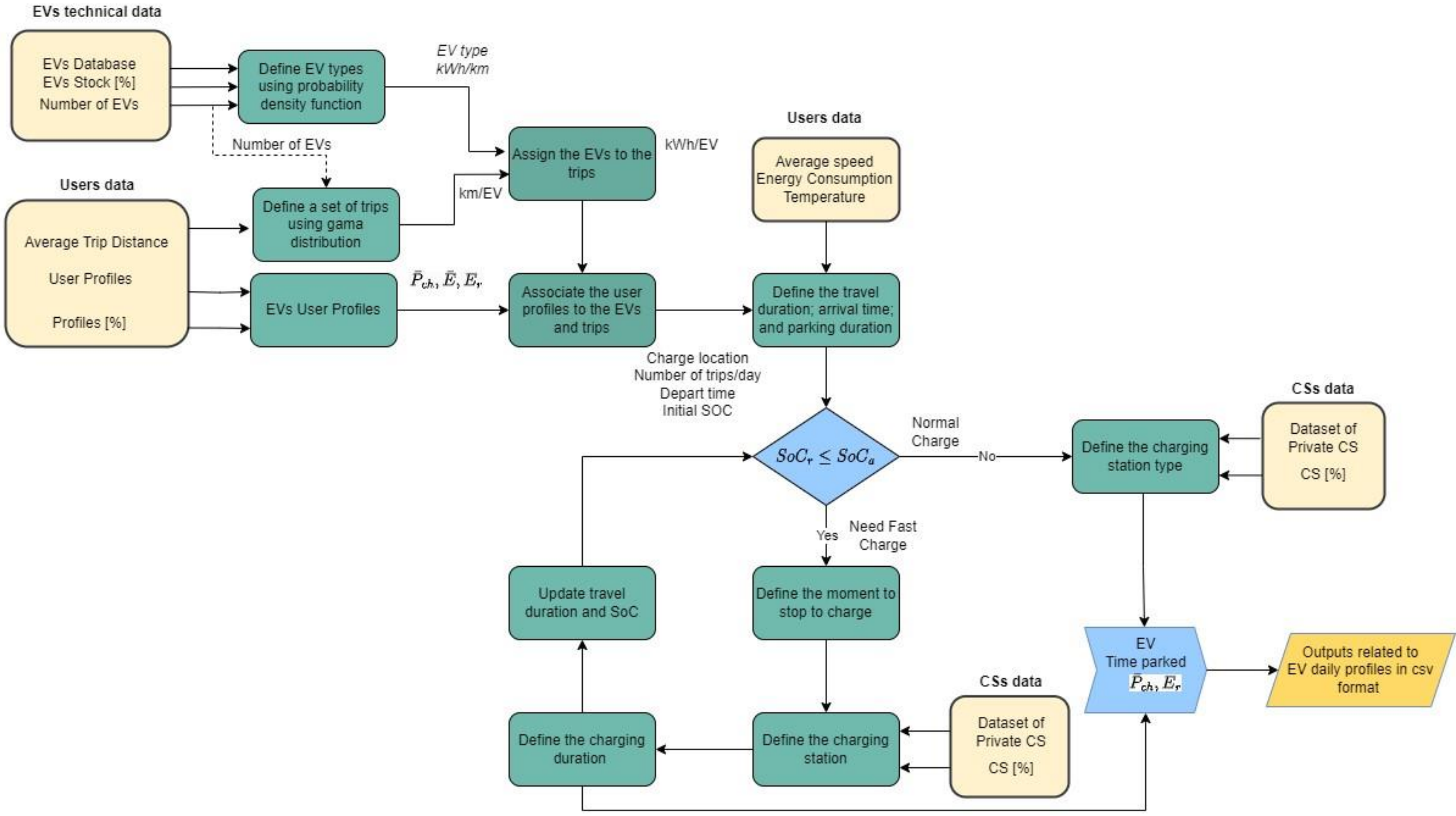
EV4EU – Concept



EV4EU – EVs Evolution Scenarios

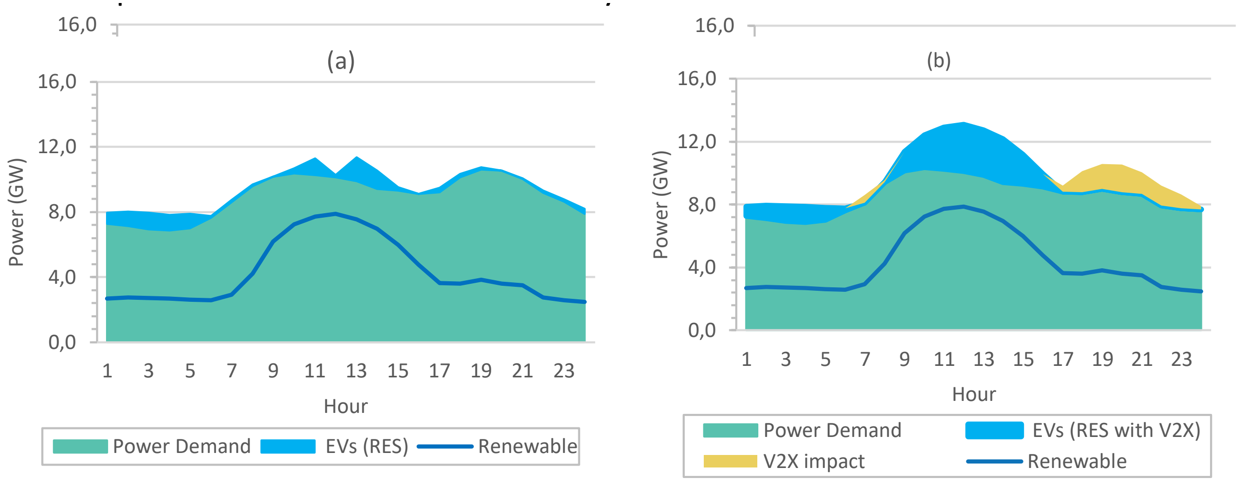


EV4EU – EVs Impact in Energy Systems



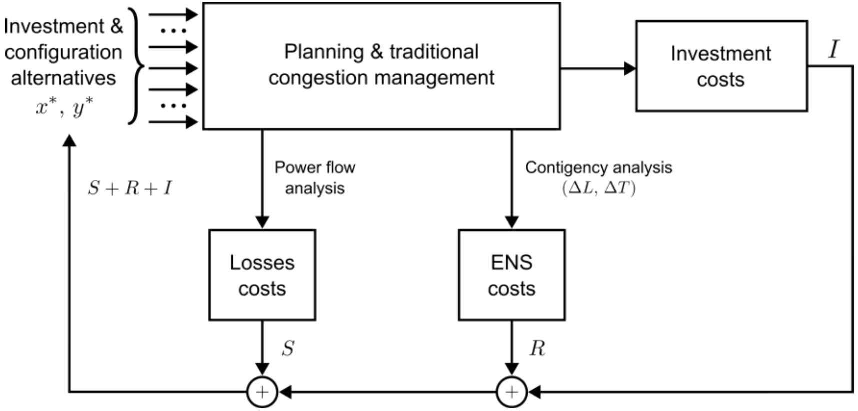
EV4EU – EVs Impact in Energy Systems

Impact of EV / RES coordination in Greek System in 2050

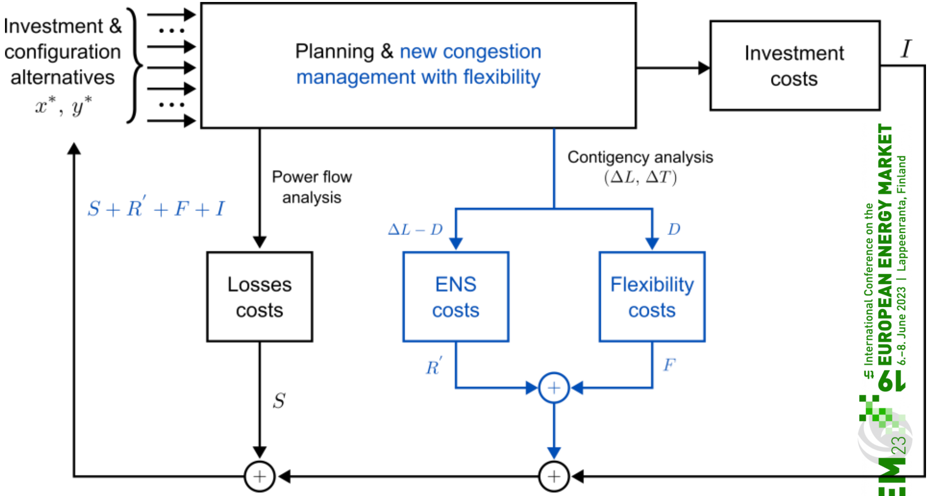


EV4EU – Modeling EVs flexibility in distribution system planning

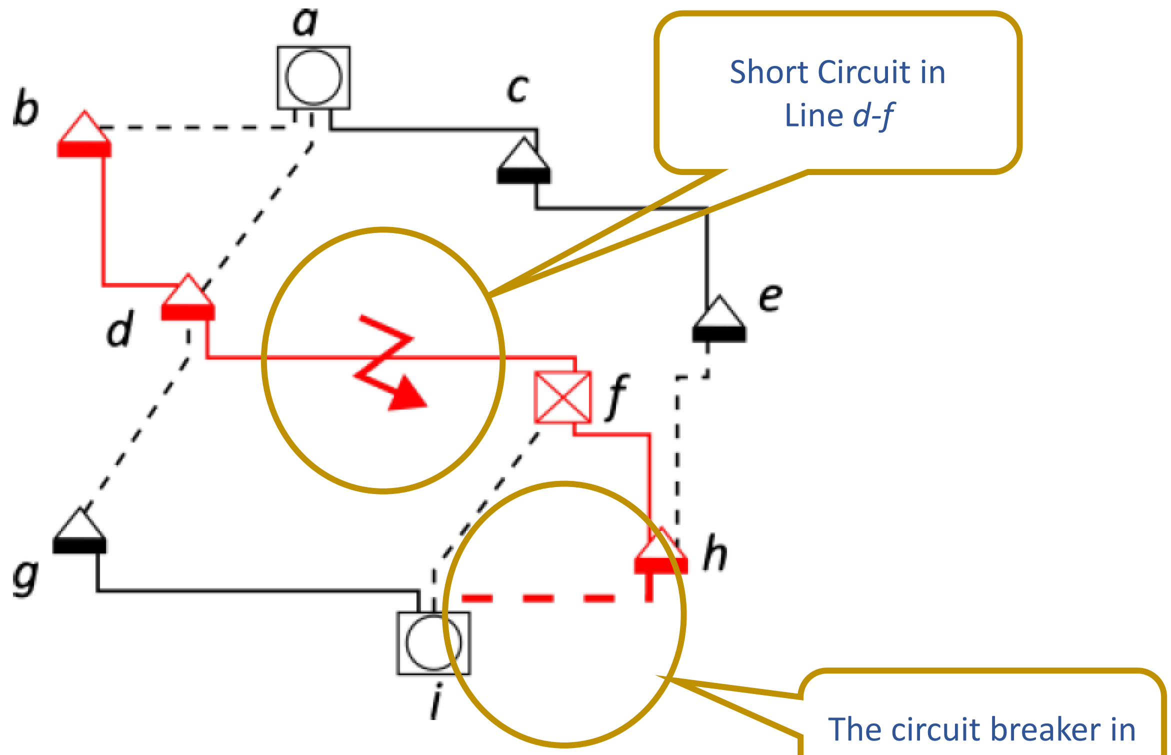
OPTION 1
Low Flexibility Availability



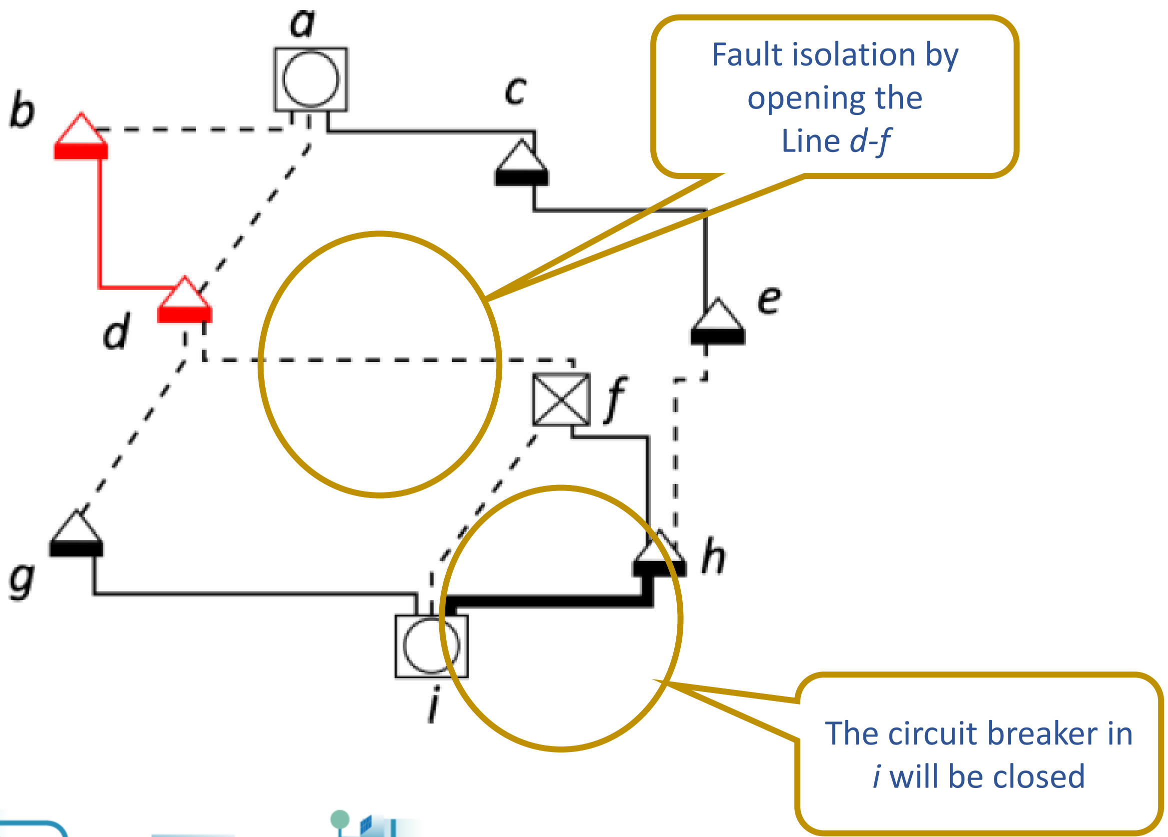
OPTION 2
High Flexibility Availability



Distribution Systems Planning with EVs

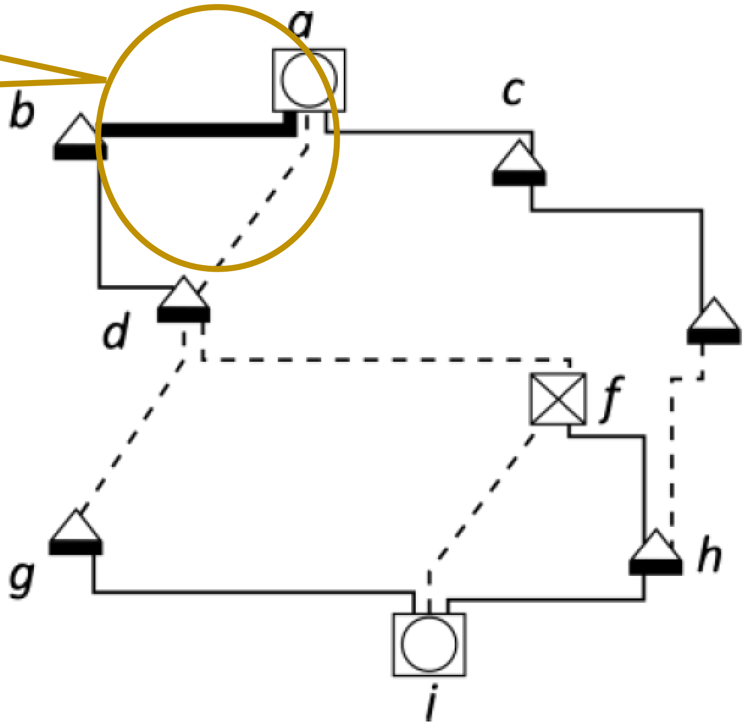


Distribution Systems Planning with EVs

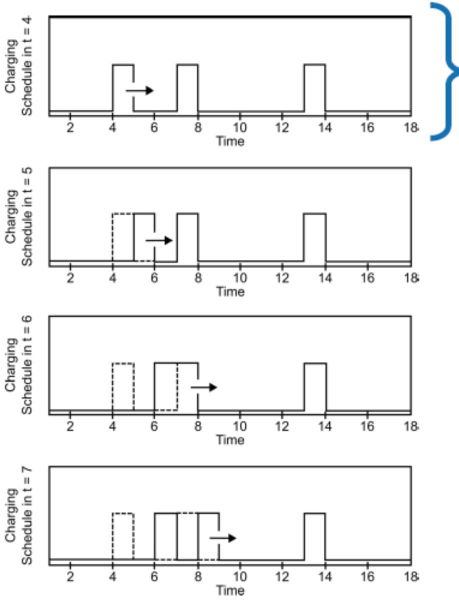


Distribution Systems Planning with EVs

Service Restoration to PS *b* and *d*



Distribution Systems Planning with EVs



- Load shifting flexibility is represented in the lattice by the empty positions ahead of each occupied position

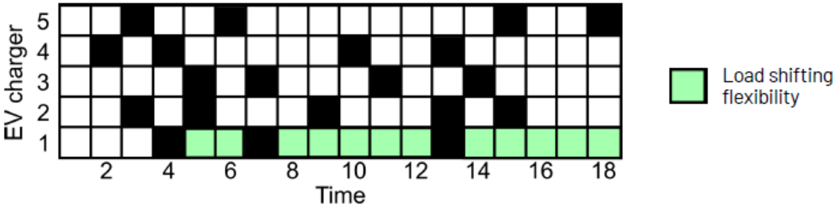


Figure 6 - Two-dimensional lattice of cells representing the original charging schedules of 5 EV chargers.

How to characterize flexibility?

- Load charging density, d (sole parameter)

$$d = \frac{\#\text{ occupied cells}}{\#\text{ total cells}}$$

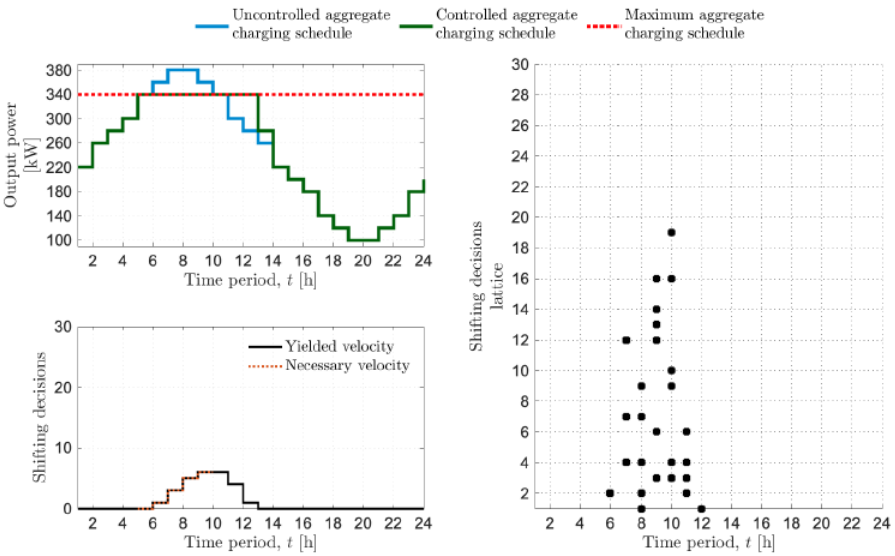
How to control the aggregate load in each time t ? → Shifting charging particles

- $v(t)$ - Load particle shifting velocity (number of shift per time period) at time t

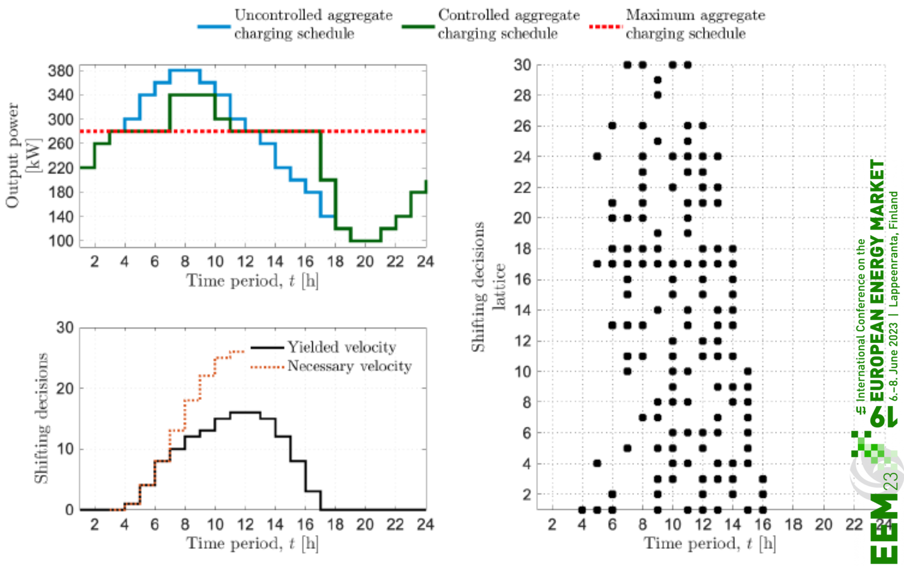
$$v(t) = \sum_{n=1}^{N} v_n(t), \qquad v_n \in \{0,1\}, n = 1, \dots, N$$

Distribution Systems Planning with EVs

Example 1: $\Delta T \Delta L < (\Delta T \Delta L)^{lim}$



Example 2: $\Delta T \Delta L > (\Delta T \Delta L)^{lim}$



For more Information

https://ev4eu.eu/

- Deliverable 1.1 – Electric Road Mobility Evolution Scenarios. **DOWNLOAD PDF**
- Deliverable 1.2 – Impact of V2X in energy and power systems. **DOWNLOAD PDF**
- Deliverable 4.1 – Distribution Network Planning Strategies considering V2X Flexibilities. (Available soon)

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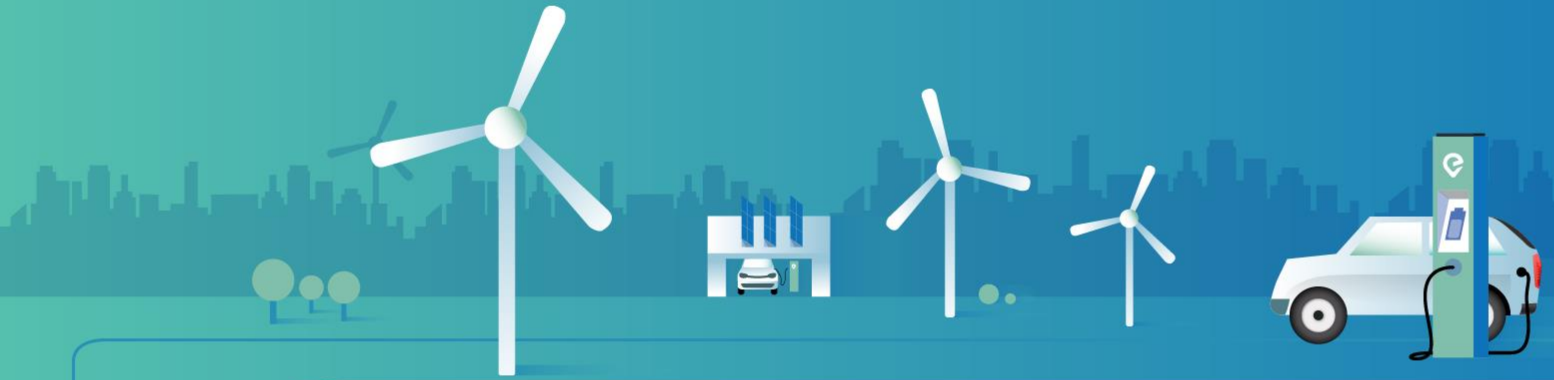

Hugo Morais
2023 / 06 / 08

Funded by
the European Union

Funded by European Union´s Horizon Europe research and innovation programme under grant agreement no. 101056765.
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SCALE

What is SCALE

- **SCALE (Smart Charging Alignment for Europe)** is a three-year Horizon Europe project that aims at preparing EU cities for mass deployment of electric vehicles and the accompanying smart charging infrastructure.

Preparing smart charging concepts for upscaling to mass-market-level

Innovating in Vehicle-to-Everything solutions

Deploying user-centric approaches

Advancing interoperable, standardized and open smart charging networks

Maximizing use of renewable electricity and reducing needs for grid reinforcement

his project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101056874.

SCALE

Demonstrations

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European Union's Horizon Europe
research and innovation programme
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SCALE

Partners

OEMs

E-mobility fleet & software

Research & knowledge institutes

Cities & associations

DSOs & TSOs

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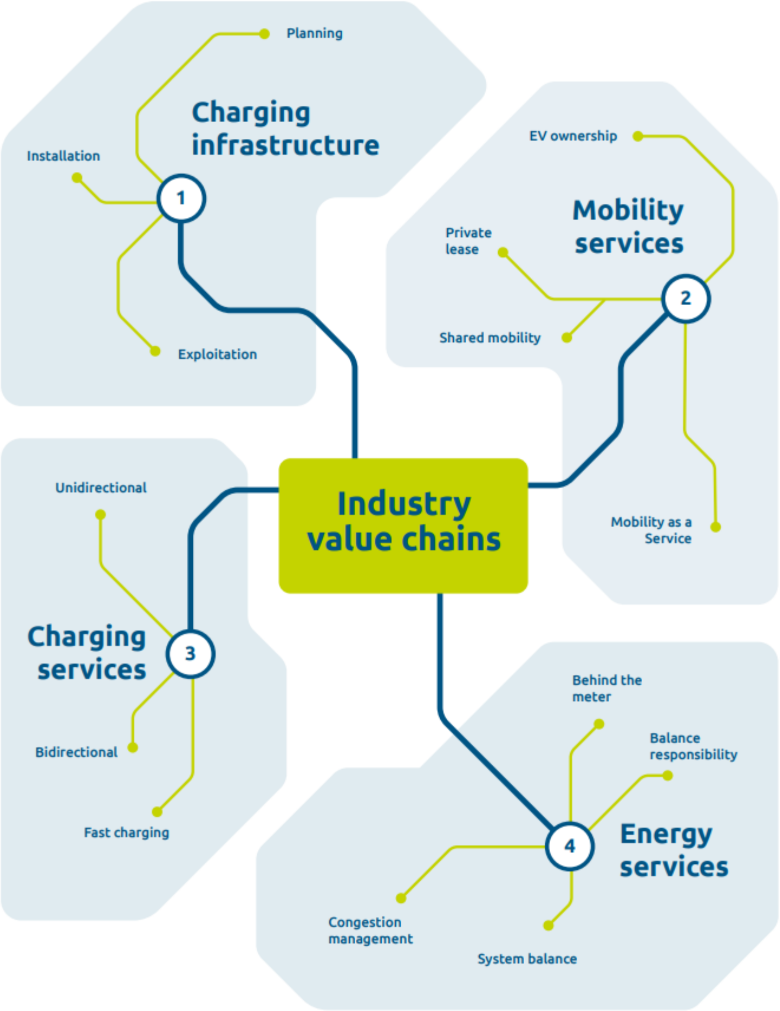
SCALE



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Different grid code; similarities!

- Adjust your behavior according to the grid frequency and voltage
- Listen to a stop signal if things go wrong
- Continue operation despite grid disturbance, if everybody stops, a cascade effect makes things worse
- Detect if the grid is down, do not feed back into the grid when it is down, and when the grid restores, reconnect with care

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SCALE

Standardisation

Issues

- Missing incentive for consumption behind the meter
- Price transparency will improve participation in Smart Charging initiatives
- Roll out a Smart Charging infrastructure with optimum capacity
- Offer regional grid operators the opportunity to make flexibility agreements
- Improve financial incentives
- Double energy tax
- Unclear who determines the use of the battery of the EV
- Hardware requirements
- Efficiency
- Cyber security
- Fully test electric cars before they plug into the grid
- Open standards
- Embed data required for Smart Charging and V2G

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V2x Alliance

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SCALE

Thank you!

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Appendix

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Missing incentive for consumption behind the meter

- EV drivers who own a house with rooftop solar panels lack in some member states a financial stimulation make full use of self-generated renewable electricity, in combination with the storage capacity from their EV's to manage their own (peak) demand for electricity.
- In other European countries, the use of Feed-in tariffs promotes optimization of own consumption behind the meter.
- Patchwork of regulation is suboptimal

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Price transparency will improve participation in Smart Charging initiatives

- At the moment the structure of the underlying costs of electric driving is often unclear.
- The e-driver pays a contribution to the energy supplier (home charging) or to the Electric Mobility Service Provider (public charging), depending on the charging location but only sees this afterwards.
- As a result, e-drivers are unaware of costs made at a specific time.
- Lease drivers who often only use public charging points often have even less insights into their costs as the leasing company is responsible for payment.
- Greater transparency for e-drivers about the current costs of electric driving will ensure that they can better assess the financial benefit of a Smart Charging initiative beyond the meter.

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Roll out a Smart Charging infrastructure with optimum capacity

- By connecting the charging station to the grid with the largest possible capacity connection, we can create maximum flexibility for Smart Charging.
- An electric car can be charged faster at times when this is desirable if there is greater capacity.
- Faster charging reduces the grid load at peak hours, provided that the correct Smart Charging regime is linked to this.
- Unfortunately, a higher capacity connection is more expensive than a lighter one. This is partly due to the difference in capacity that has to be reserved in the grid to meet the peak load.
- If grid operators can combine Smart Charging signals with the capacity rates that they are allowed to charge, then the e-driver will receive a much 'faster' charging station and we can use the electric car even better to request power when desirable .

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Offer regional grid operators the opportunity to make flexibility agreements

- Take advantage of the abundant grid capacity, make smart charging mandatory in tenders
- By charging EVs at smart moments, for example at night or in the weekend, we can optimally use available grid capacity.
- Without Smart Charging, the further growth of electric driving will lead to greater peaks in power demand, while at the same time charging electric cars with Smart Charging offers a great deal of flexibility for managing the grid and for the use of solar and wind energy as it is produced.
- Options for making specific agreements for the use of Smart Charging to prevent peak overloads (congestion management) are currently limited legally, outside approved experimental conditions.

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Improve financial incentives

- In most countries, EV-drivers currently pay a flat rate for their electricity consumption or have a day/ night rate.

- Smart Charging offers the opportunity to better align their electricity consumption with the availability of (sustainable) electricity by charging at times ‘cheap’ electricity is available. And if V2G is applied, it will be possible to resupply energy at a different time.

- Flexible rates for electricity use can provide a price incentive to better match consumption with supply. In practice, this is only currently applied on a small scale. Central governments, municipalities and provinces could pass on this incentive to e-drivers via tenders for the charging infrastructure. Cheaper charging when electricity prices are low.

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Double energy tax for V=G

- Every time an EV is charged again after discharging, it appears that energy tax has to be paid on the charged kWh.
- Double energy taxes are mainly a result of the lack of a definition of storage, as charging and discharging are defined as consumption and supply, respectively.
- A structural and harmonized solution would be to implement a European tax regulation stating that bi-directional charging qualifies as storage. In that way, it should not trigger energy tax. This can be implemented via (preferably) the Energy Tax Directive.

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Unclear who determines the use of the battery of the EV

- Under current regulations, nowhere can it be found that the e-driver is the one who gives permission for the use of his electric car and under which conditions (time of departure, minimum battery capacity, et cetera.).
- Moreover, exceptions may be needed. For example, preventing local grid overload is more important than other factors, as currently we have few alternatives and we need to ensure grid reliability.

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SCALE

Hardware requirements

- Hardware (settings) are often country-specific (like PV inverters)
- A charging station has a fixed location while an EV can visit multiple locations / countries.
- These safety requirements should be aligned on national, or even better, European level.

- A first set of technical requirements for Smart Charging Ready (in the Netherlands) is being prepared with all stakeholders and is expected to be published in Q1 2021

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Efficiency

- The business case of V2G and its potential to provide grid services is heavily dependent on the round-trip efficiency.
- There is a wide range of efficiency values used in V2G modelling studies:
  - different dates,
  - current rates
  - average states of charge
- Charging at lower ambient temperatures and lower current rates had a statistically significant adverse effect on the round-trip efficiency. Efficiency at high and low state of charge was found to be marginally lower than around medium state of charges.
- Regulation regarding standards on minimal efficiency is needed from a consumer- and system protection perspective.

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Cyber security on devices

- A future-proof design with enough computational power and memory resources to be able to handle future algorithms and protocols, and firmware updates.
- The cryptographic algorithms and protocols of todays are well known and considered secure. However, it could be that a vulnerability is found which requires to switch to a different algorithm. The requirements, to follow the latest security advices, should be part of the requirements or regulation regarding roll out of charging infrastructure.
- Communication to and from the device(s) should be secured by encryption and digital signatures, for example by TLS.
- Resilience and system hardening. Charging stations should have unused interfaces disabled, and maintenance interfaces secured. The charging station should not crash when malicious messages are sent; the infrastructure should be able to detect a different format and handle it accordingly.

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Cyber security on the public key infrastructure

- Develop a transparent, trusted, safe, simple, fast, cost-efficient and legal PKI that supports the level playing field in e-mobility.
- There is a need for an open standard and a level playing field between different regions and sectors.
- A neutral and independent referee in case of disputes.
- Therefore there is a role for an European Authority to oversee the governance of the PKI.

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Cyber security, protecting the e-driver and the grid

- As electric cars and Smart Charging become a crucial part of the electricity system, the exchange of data and measurements must also be safe and reliable.
- The system has to be completely secure to prevent access by unauthorized parties via hacks.
- The need for better (cyber) security matches consumer desires for an open market with freedom of choice in combination with a seamless service. The charging infrastructure needs to be defined by the regulator as a critical infrastructure.
- Tenders for public charging points need to commit to the cyber security requirements set.

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Fully test electric cars before they plug into the grid

1. Currently, European type approval of electric cars is conducted by the certifying authorities, in particular with regards to vehicle safety.
2. Additional tests are performed on a voluntary basis, for example interoperability (being able to charge on all charging points), power quality (grid pollution) and Smart Charging (monitoring of control signals).
3. Every new electric car should be tested on all these aspects, not just on road safety.
4. Action is needed in the short term. The electric cars, vans, trucks and buses that are now being made and are being launched on the market will be on the road for many years to come. Currently, the average lifespan of a passenger car is around sixteen years.

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Ensure open access and the use of open standards

- In a successful Smart Charging ecosystem, all kinds of devices can ‘talk’ to each other regardless of type or brand. Solar panels, home energy management systems, charging points for electric cars and back offices must all be able to communicate with each other problem-free.
- By using open standards a worldwide roll-out is possible and we can prevent lock-ins and further develop the system.
- This can be reinforced by requiring the use of open protocols in tenders for the new charging infrastructure.

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Embed data required for Smart Charging and V2G

1. Information on the state of charge (size of battery and the extent to which it is charged), the time of departure (or the time the consumer needs the battery to be fully charged), the type of electric car, the charging speeds (threshold values for the minimum and maximum power for charging) and e-driver preferences (for example, minimum range that must be available) is needed.
2. At present, access to this data (in particular the state of charge) has not yet been arranged and laid down in a technical standard.
3. Specific bilateral agreements must be made with car manufacturers to unlock the state of charge.

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Conclusion

- Existing legislation and regulation in this field are inadequate to cope with the emergence of electric cars and locally generated sustainable electricity.

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Thanks!

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