Sector coupling: How to integrate electric vehicles in a grid-friendly way?

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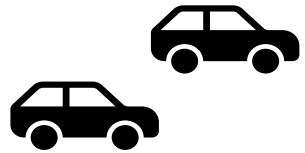
Who of you has already heard about bidirectional charging/ Vehicle-to-Grid (V2G) before?

Who thinks bidirectional charging/Vehicle-to-Grid (V2G) will become mainstream in the future?

Outline

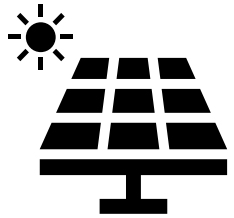
1. **Why is the use phase of EVs important?**
2. **Overview of V2X applications and pilot projects**
3. **Technical, social, and regulatory challenges and uncertainties of V2X**
4. **Implications and outlook: Modeling V2X**



Electric vehicles can be part of both the challenge and the solution.

Challenge for distribution grids

Intermittent Renewables



Electrification

Solution as flexibility provider

Bidirectional Charging

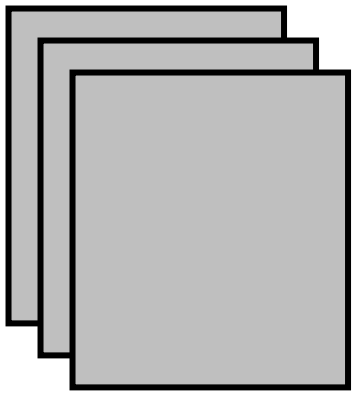
Transmission System Operator

Distribution System Operator

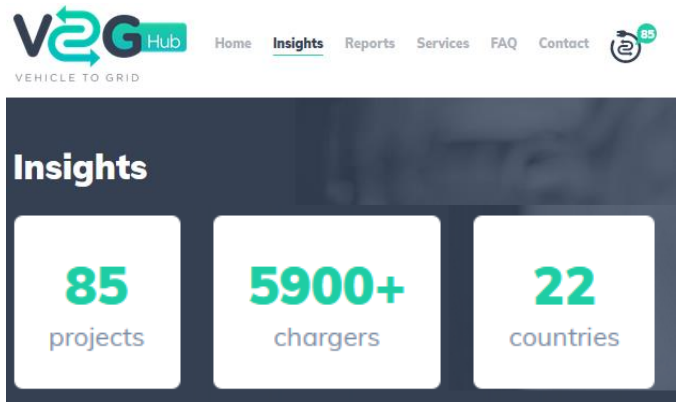
Primary use of EVs remains mobility

How can the increasing share of EVs be beneficially integrated into distribution grids?

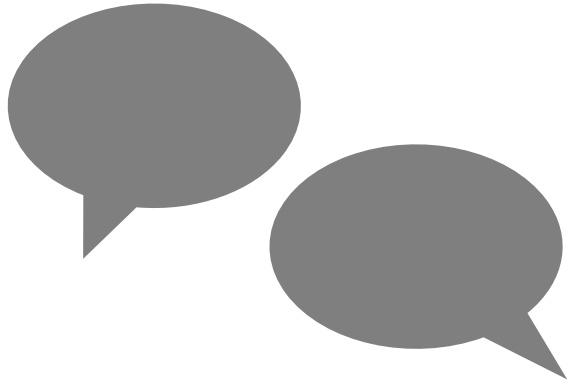
1. Analysis of V2G literature



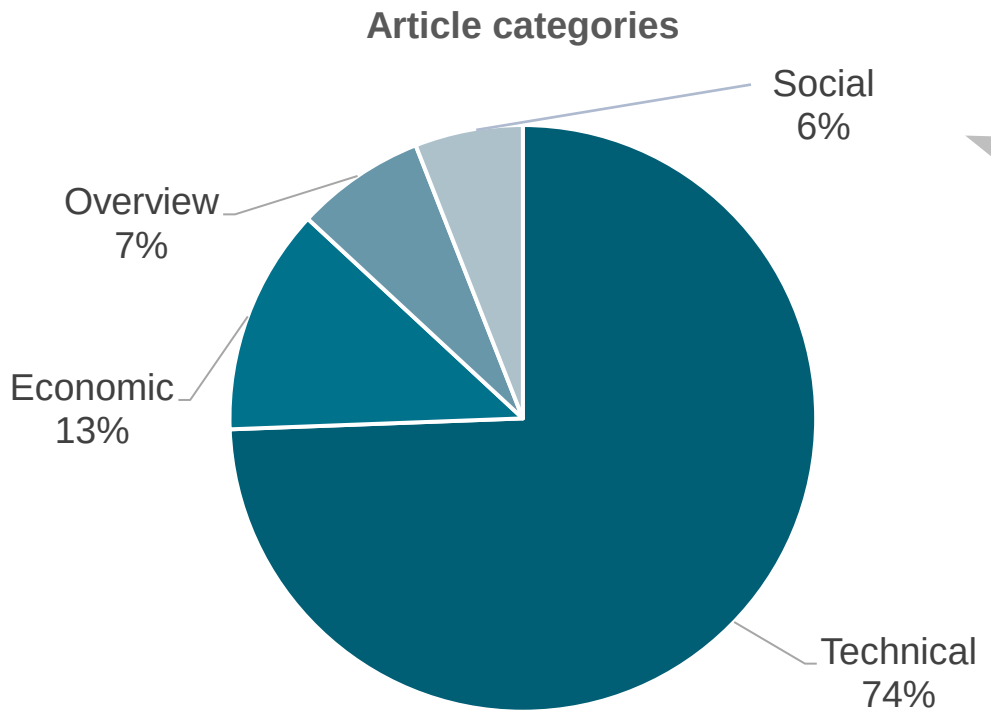
2. Analysis of online V2G database



3. Interviews

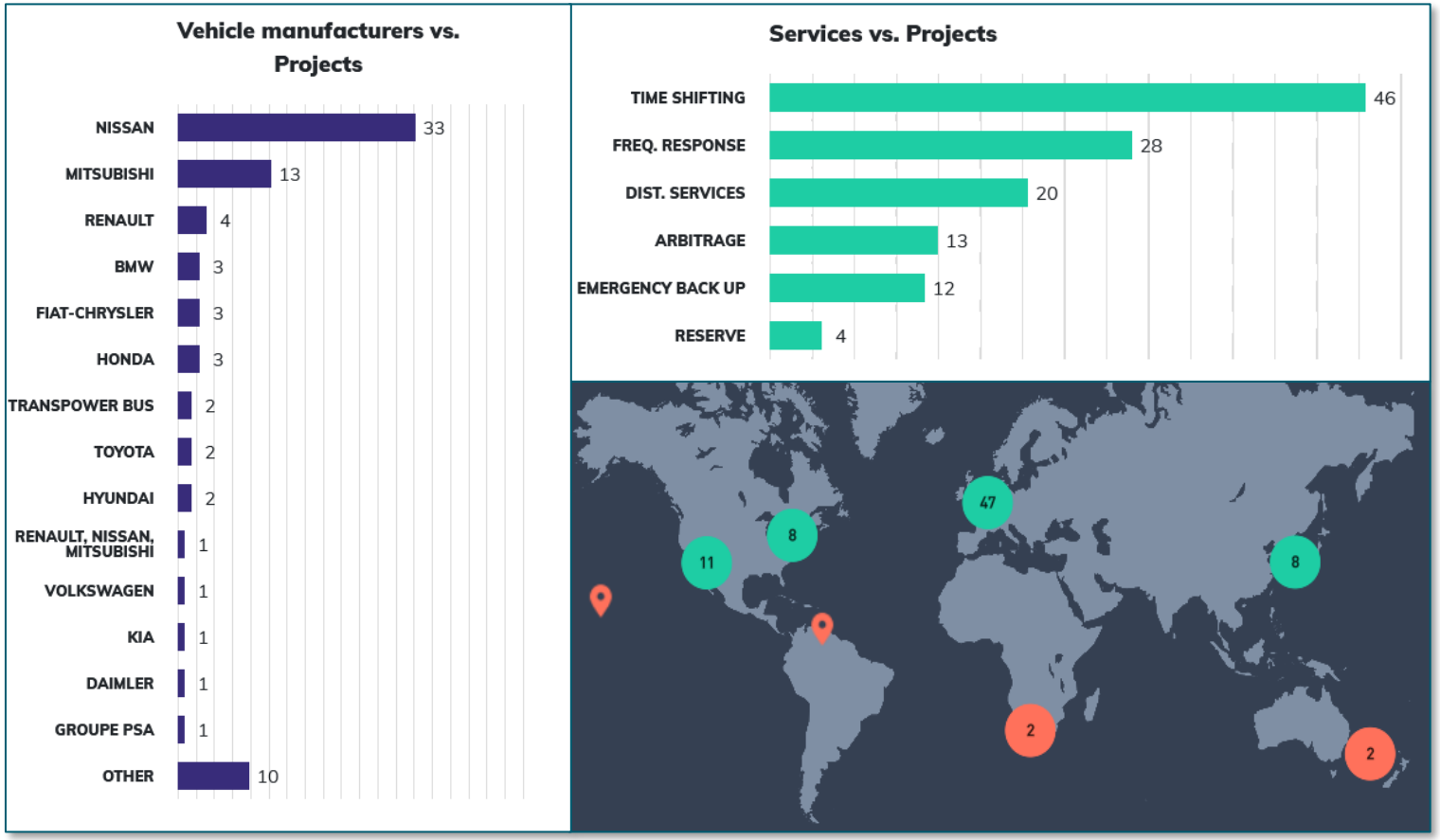


Current literature focuses on technical aspects of V2X technology.

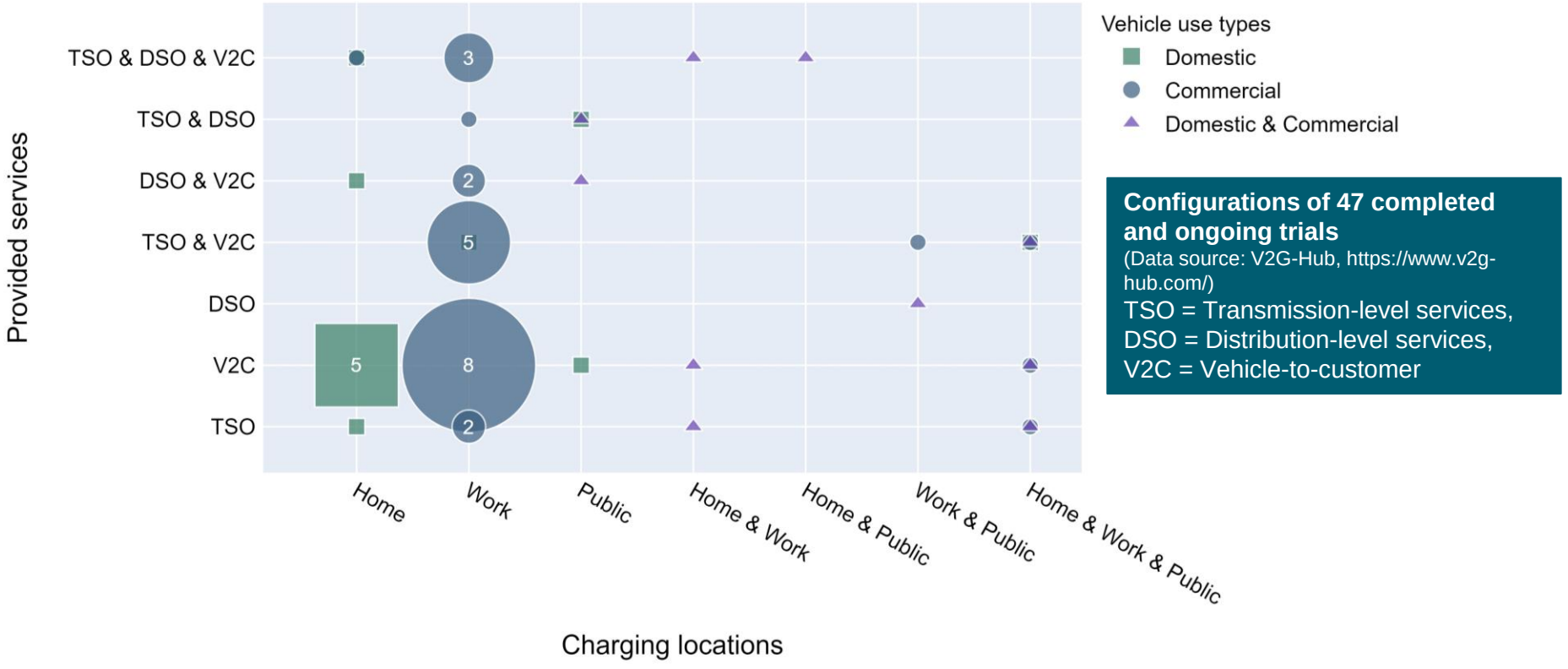


"We can't assume that V2G will be wonderful if we can't make customers to behave in a way that enables V2G" [UK, EV infrastructure lead]

More than 80 V2X pilot projects worldwide test several different services.



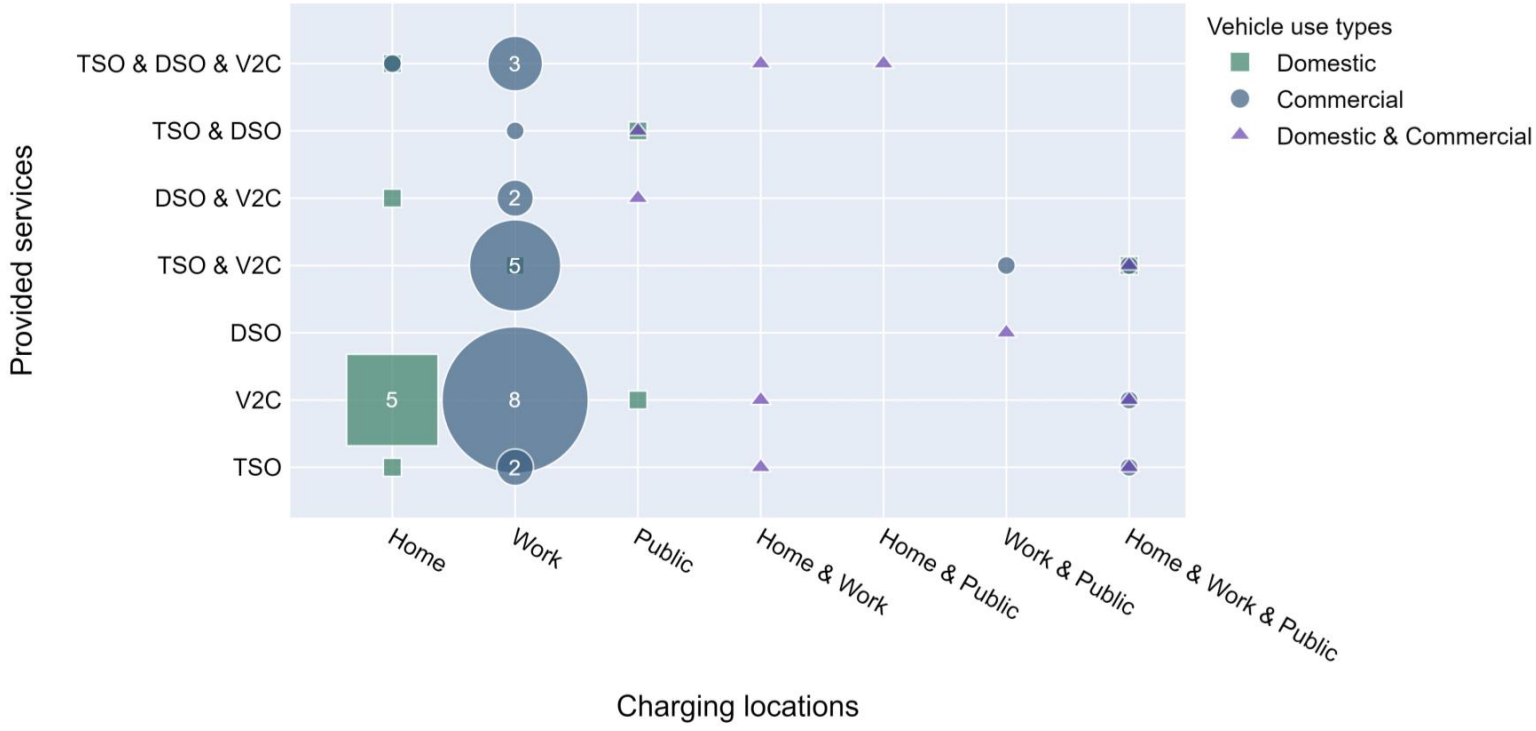
V2X implementations: Pilot projects focus on workplace charging, TSO and V2C services, and commercial fleets.



Configurations of 47 completed and ongoing trials
(Data source: V2G-Hub, https://www.v2g-hub.com/)
TSO = Transmission-level services,
DSO = Distribution-level services,
V2C = Vehicle-to-customer

Gschwendtner, C. et al. (2021), Vehicle-to-X (V2X) implementation: An overview of predominate trial configurations and technical, social and regulatory challenges, *Renewable and Sustainable Energy Reviews*, Vol. 145, https://doi.org/10.1016/j.rser.2021.110977

Charging locations with long dwell-times allowing for centralized approaches are most frequently tested.



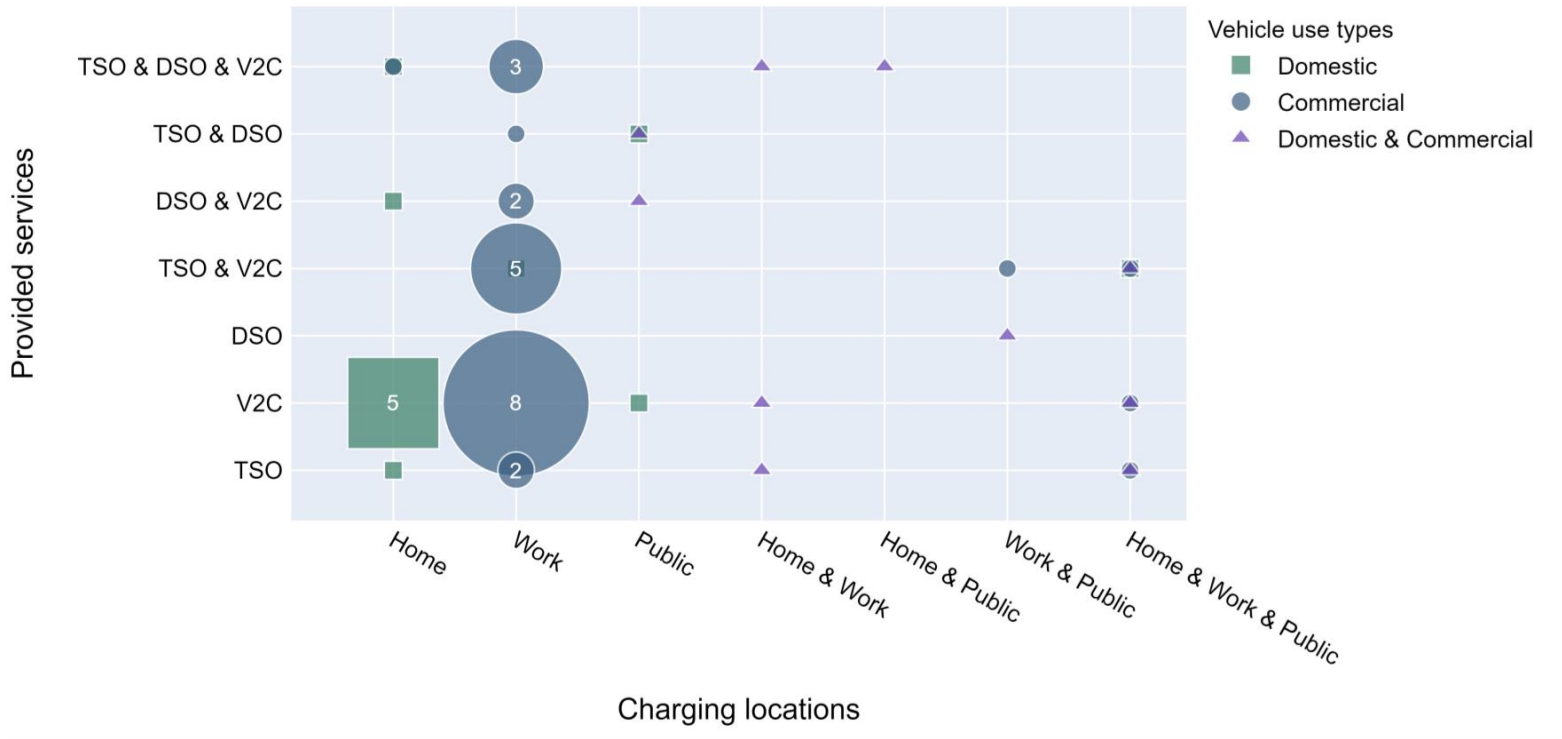
Charging locations

- Different charging locations are important to **diversify** electricity demand in **time and space** to reduce adverse impacts on distribution grids.

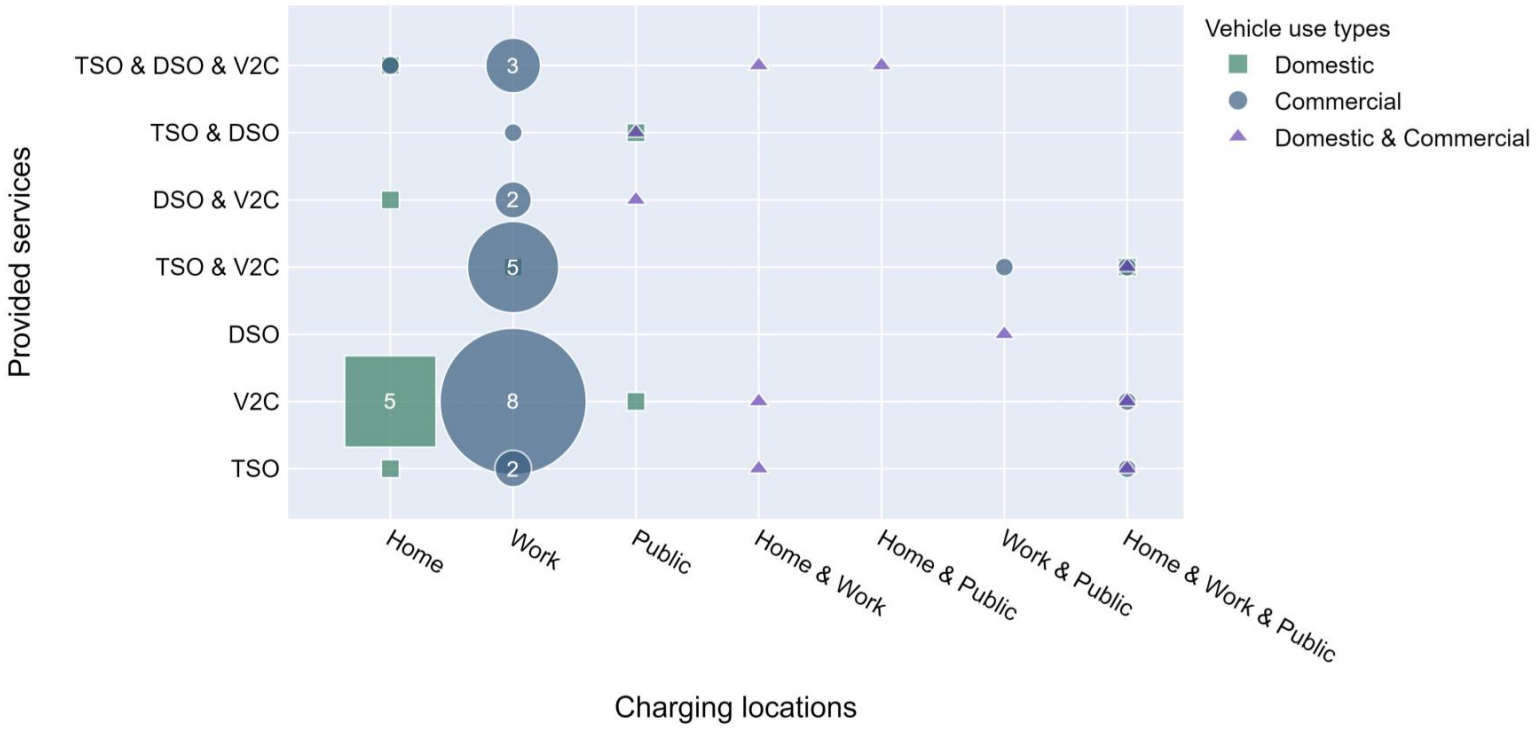
Stacking of services reduces risks but their interdependence is uncertain.

Provided services

- Regulation could pose **spatial or temporal restrictions** on aggregators' service provision to achieve synergies between local and transmission needs.
- **Combination of different services** can increase overall revenue of a portfolio.
- **Impact of V2C** on the flexibility requirements of distribution grids is uncertain.



Different driving profiles of different vehicle use types can decrease uncertainties related to social behavior.



Vehicle use types

- Domestic vehicles: **higher availability but lower predictability** compared to commercial vehicles.
- Both commercial fleets and domestic vehicles can support service provision at the TSO and DSO-level.
- Combining different vehicle use types **decreases uncertainty** resulting from driving patterns and plug-in behavior.

What technical, social, and regulatory challenges for V2X can you think of?

Overview of technical, social, and regulatory challenges for V2X implementation

	Technical challenges	Social challenges	Regulatory challenges
Common evaluations	• **Battery degradation** is rather a social challenge	• Implementation of **decentralized charging**	• Market participation of **small providers**
Different evaluations	• Distribution **grid reinforcement deferral and mitigation**	• **Plug-in behavior** • **Future mobility**	• Hesitation of DSOs toward **smart solutions**
Knowledge gaps	• **Future flexibility** supply and demand	• Participation in V2X and **potential incentives**	• **Markets, tariffs, auctions or tenders** at the DSO level

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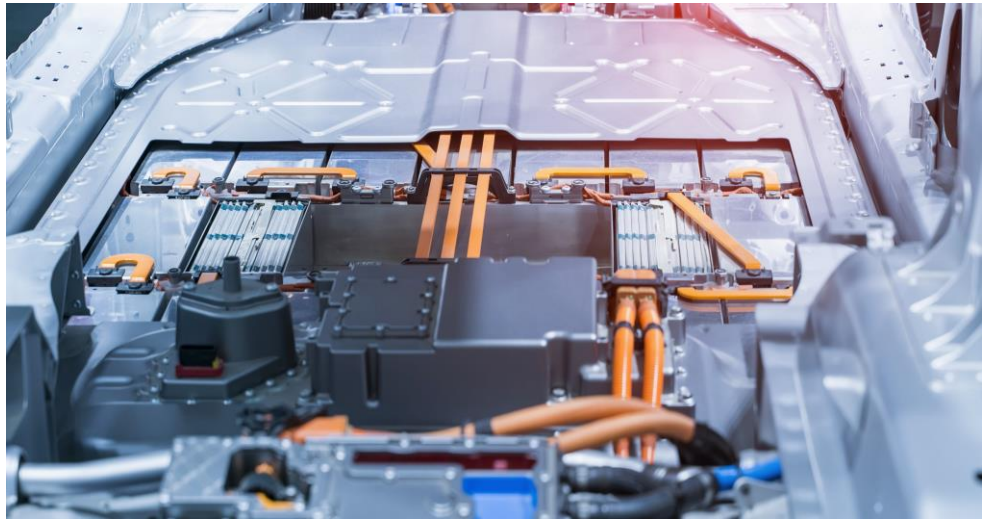
Battery degradation is primarily a social challenge but not enough data is available yet.

Conditions influencing battery degradation:

- Temperature
- Driving behavior
- Type of provided services
- ➡ More long-term data required for various combinations of conditions

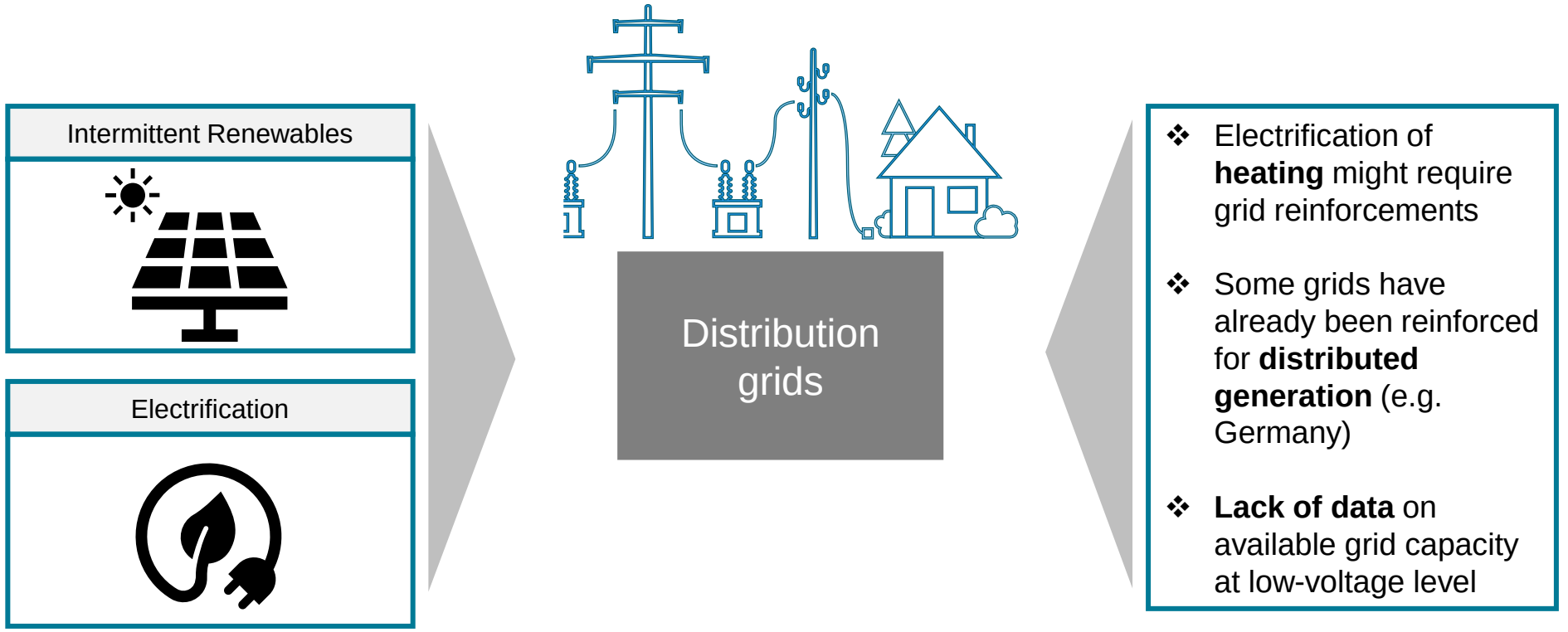
Optimized charging strategy considers:

- Battery aging costs for prevailing conditions
- Current state of charge (SOC)
- Wholesale market price signal
- Potential grid price signals



Transparent information and related warranties required

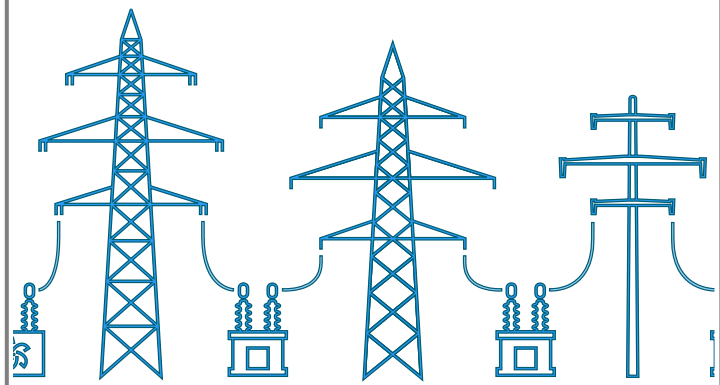
While V2X can defer distribution grid reinforcement, its mitigation depends on many local factors and is highly uncertain.



Frequency service markets might be saturated in the future while flexibility supply and demand at distribution level is uncertain.

Transmission level

- Frequency services mainly provide **short-term revenues** due to market saturation.
- Once V2G infrastructure **costs decrease**, other typically less lucrative markets, such as **secondary and tertiary reserve** markets, become more attractive



Distribution level

- If **reinforcement is unavoidable**, the value of V2X services decreases
- Other technologies **compete** with V2X, e.g. demand response with heat pumps or stationary batteries
- Balance of flexibility demand and supply **uncertain**.

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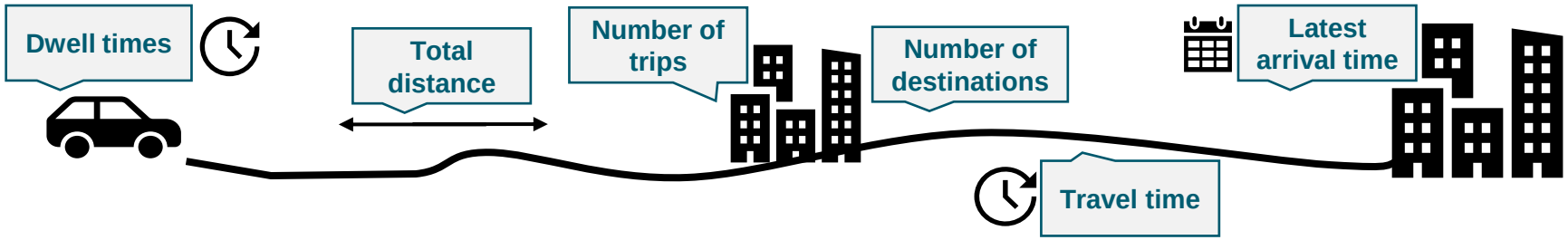
Availability and predictability of V2X services depend on respective vehicle use types.

	Plug-in availability	Plug-in predictability
Commercial fleets	Different patterns depending on company type	High predictability due to fixed schedules
Domestic vehicles	96% of the time not used for mobility purposes New EV drivers: range anxiety	Lower predictability Individual driving patterns quite predictable, but every individual has their own regularity
School buses and car parks at airports	High availability as parked for 80-85% of the year or several weeks	High predictability
Car sharing vehicles	Lower availability for V2X of about 30%	Rather high predictability (depending on booking system)
Autonomous vehicles	Depending on ownership model	Depending on ownership model/booking system

Heterogeneity of driving and (dis)charging behaviour affects availability and reliability of V2X services.

Driving behaviour

Short distances (21%)	Low and early car use (16%)	Long distances (7%)	Commuter (20%)	Exceptionally high car use (1%)	No car use (36%)



Charging behaviour

Charging cost	Fast/normal charging	Dwell time	Distance/time to next charging opportunity	Distance to home	Initial State of Charge

Overview of technical, social, and regulatory challenges for V2X implementation

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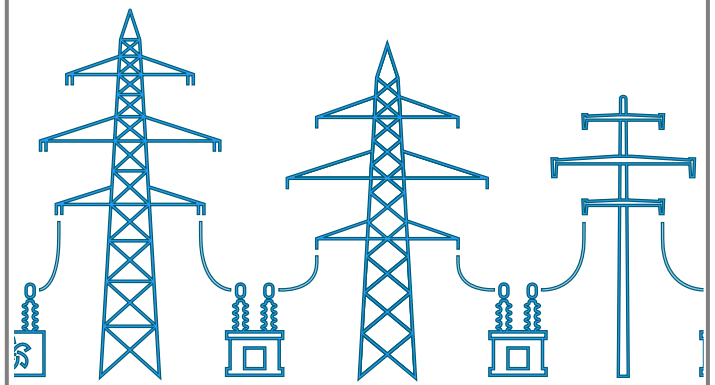
Regulatory changes are required at both transmission and distribution level to enable V2X services.

Transmission level

- **High thresholds** for market participation in MW
- Long **sale cycles**
- Measurements and **verification** requirements designed for large assets



Distribution level

- Currently **no defined services** at DSO level
- DSO market still evolving; **local markets** at different levels are in discussion
- Different **tariffs or aggregators** might replace the need for a DSO market

V2X could provide services to the electricity system but many uncertainties remain.

EV integration

- **EV use phase matters** for synergies of sector coupling.
- **Bidirectional charging** could support the integration of EVs into the electricity system.

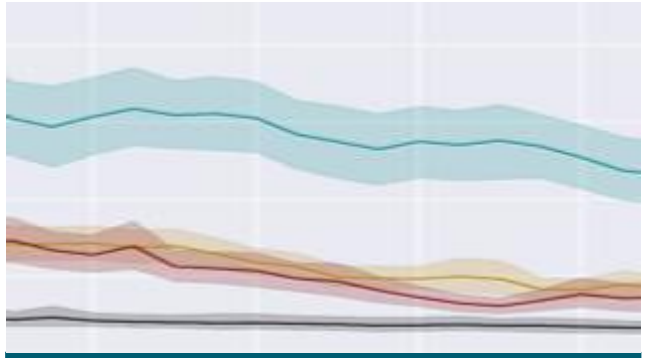
V2X implementation

- V2X pilot projects show only **little variety in the combinations** of charging locations, provided services, and vehicle use types although **risks decrease** with variations.
- **Technical, social, and regulatory challenges** remain.

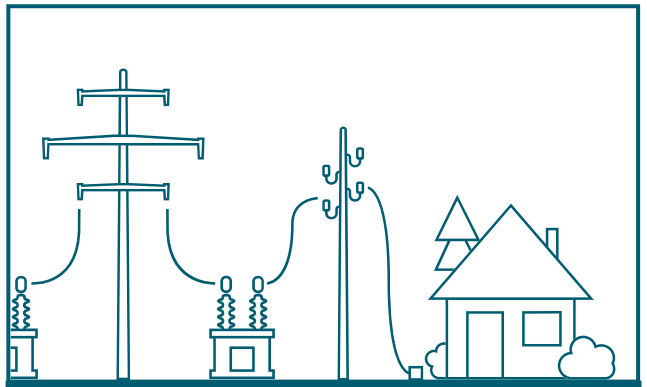
Implications

- **Availability and reliability** of V2X services depend on heterogeneous driving and (dis)charging behavior.
- Differentiating **incentives** for increased **plug-in** rates and **controlled charging** strategies between different EV users could facilitate flexibility provision.

Outlook



Generating EV load profiles based on mobility behavior



Modeling the impact of current and new loads on distribution grids

- **Future scenarios**: EV and V2X uptake and future mobility behavior
- **Impact of incentives** for different EV users on their flexibility provision
- Interactions of **different technologies** providing flexibility services

Thank you for your attention and I am looking forward to the discussion!

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References

Images

[1] Title picture, EV battery by © [xiaoliangge] / Adobe Stock

[2] V2G Hub Database | V2G around the world, https://www.v2g-hub.com/insights (Accessed: 17 May 2021)

[3] Swiss grid, https://www.swissgrid.ch/en/home/operation/power-grid/grid-levels.html (Accessed: 17 May 2021)