IEA PVPS

# PV-Powered Electric Vehicle Charging Stations

## Preliminary Requirements and Feasibility Conditions

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December 2021

Technology Collaboration Programme
by iea

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# Trends in PV-powered charging stations development

The PV-powered charging stations (PVCS) development is based either on a PV plant or on a microgrid*, both cases grid-connected or off-grid.

**Microgrid: PV plant, storage, loads, power management*

Although not many PV installations are able to fully meet the energy needs of EVs, and the charging of EVs is dependent on the public grid, the number of projects are rapidly increasing.

| Infrastructures designed mainly for charging EVs | | | | |
|---|---|---|---|---|
| | | | Infrastructure | Comments |
| On-grid | With storage | Car parking shade | MDT-TEX smart PV shelter (Germany, 2018) | ✓ Possibility of shifting the charging without constraining EV users<br>✓ Reduction of the load on the grid during peak hours<br>x Power grid dependency: the storage systems are charged from the power grid<br>x Installations remain insufficient for full charging |
| | | | SECAR E-Port (Austria, 2018) | |
| | | | V3 Superchargers (Las Vegas, United States, 2019) | |
| | | | Car parking shade project (Aix-Marseille-Provence, France, 2020) | |
| Off-grid | With storage | Car parking shade | Electric bus charging (Queensland, Australia, 2020) | ✓ Grid independent and 100% sustainable<br>x Low stationary storage capacity compared to the EV battery capacity<br>x Installations remain insufficient for full charging |
| | | | EV ARC™, Beam Global, San Diego, United States, 2020) | |
| | Without storage | Car parking shade | SEVO Sunstation (United States, 2019) | ✓ 100% renewable energy<br>✓ No utility bill<br>✓ Real-time energy use analytics |
| | | | Fastned | ✓ 100% renewable energy<br>✓ Fast charger: Up to 300 km of autonomy in 15 minutes |

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# Trends in PV-powered charging stations development

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**Microgrid: PV plant, storage, loads, power management*

Although not many PV installations are able to fully meet the energy needs of EVs, and the charging of EVs is dependent on the public grid, the number of projects are rapidly increasing.

| Infrastructures designed mainly for supplying buildings, but EV charging may be developed | | | | |
|---|---|---|---|---|
| | | | Infrastructure | Comments |
| On-grid | With storage | Car parking shade | Self-consumption PV, GÉMO store (Trignac, France, 2019) | ✓ Reduction of the electricity bill<br>✓ Self-consumption<br>✓ Electricity can be sold where PV production is high<br>x Despite the size, low number of charging terminals |
| | | Building roof | PV self-consumption project (Madagascar, 2018) | |
| | Without storage | Car parking shade | PV power plant (Nouméa-La Tontouta International Airport, New Caledonia, 2021) | ✓ Redistribution of energy to power grid<br>✓ Self-consumption<br>x No smart consumption to optimize energy use<br>x Despite the size, low number of charging terminals |
| | | Building roof | PV rooftop plant for a Robinson shopping mall (Thailand, 2018) | |
| Off-grid | Without storage | Car parking shade | PV power plant (Saint Aignan de Grandlieu, France, 2020) | |

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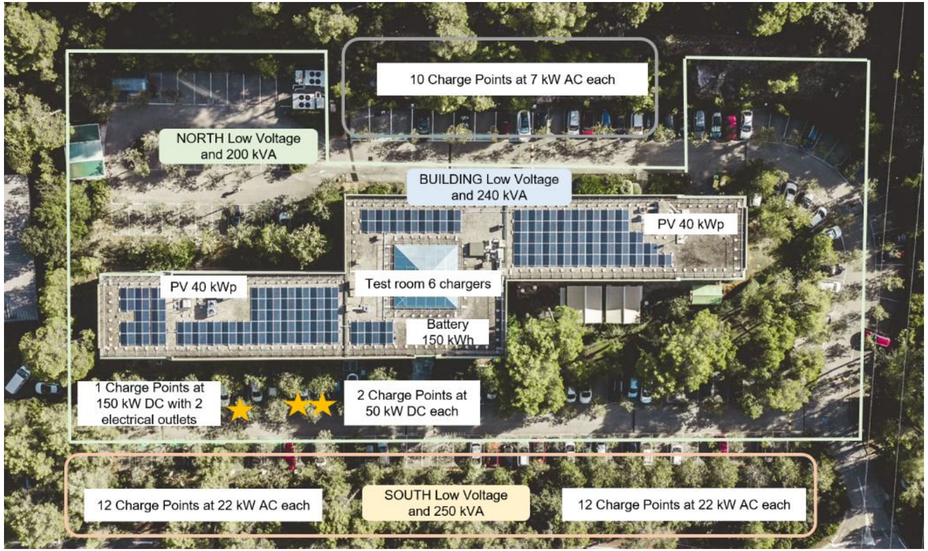
# Case study on PV-powered charging station: France

Charge controlling remains necessary to increase PV benefits for EVs charging. Without energy management, the total power demand would be higher than the power capacity of the site. SAP Labs strives to create a microgrid at the Mougins site with software allowing for intelligent communication between the operators and the end-users.

*SAP Labs Mougins, France: software platform*


*SAP Labs Mougins, France: demonstrator site*

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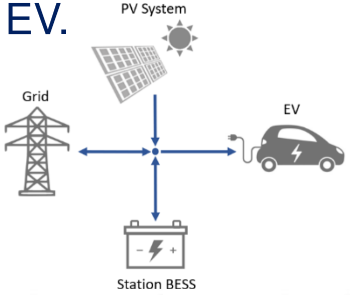
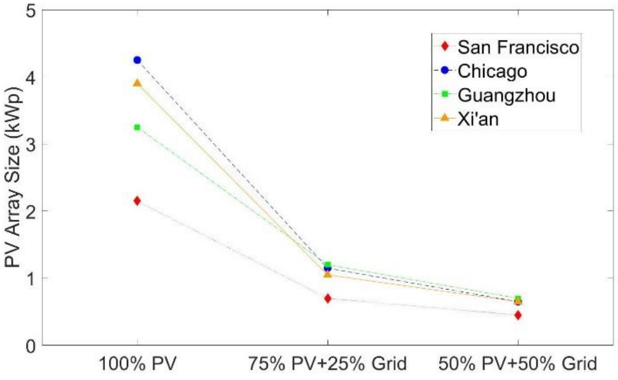
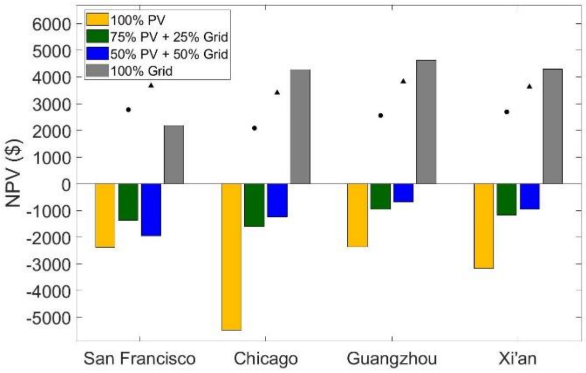
# Requirements, barriers, and solutions for PVCS

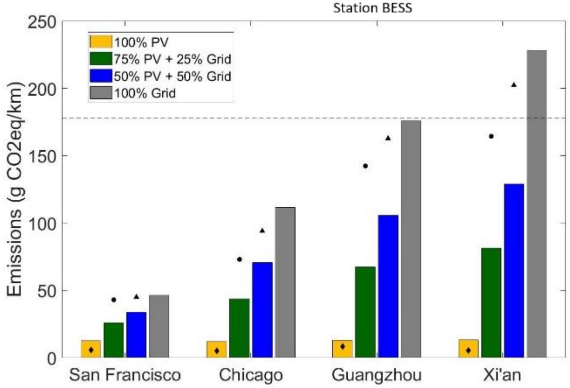
Feasibility assessment of PVCS microgrid based using a simulation model, which estimates the system's energy balance, yearly energy costs, and cumulative CO2 emissions in four scenarios For a microgrid of optimized size, the use of PV systems in all four analysed locations can be a feasible EV charging solution from a technical, financial and environmental perspective in comparison to a gasoline-fueled vehicle and in comparison to a grid-charged EV.

*PVCS based on microgrid*

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# Requirements, barriers, and solutions for PVCS

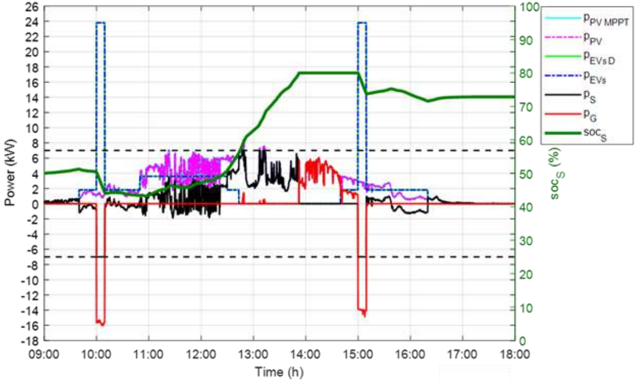
## Preliminary requirements and feasibility conditions for increasing PV benefits for PVCS

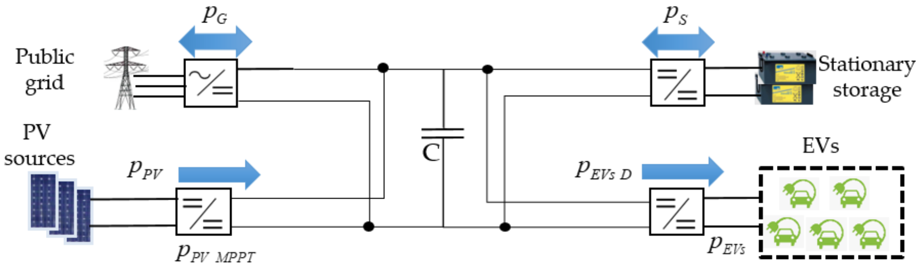
*Slow charging mode*

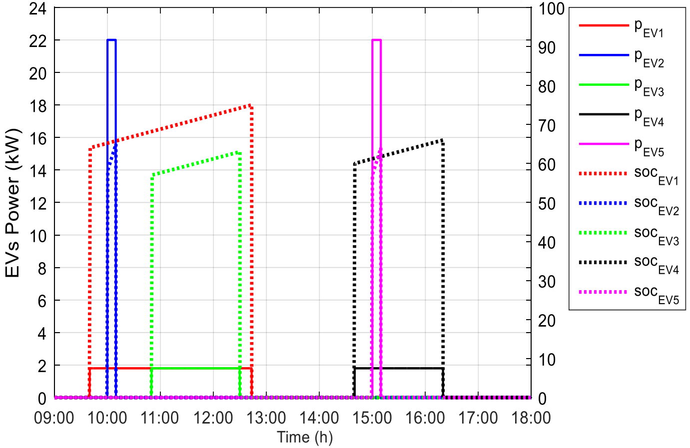
- Charging power of up to 7 kW
- Based on PV and stationary storage energy
- Stationary storage charged only by PV
- Stationary storage of optimized size
- EV battery filling up to 6 kWh on average
- User acceptance for long, slow charging

*Fast charging mode*

- Charging power from 7 kW up to 22 kW
- Based on public grid energy
- Stationary storage power limited at 7 kW
- User acceptance of higher environemental charging costs

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# Requirements, barriers, and solutions for PVCS

Assessment of PV benefits for PVCS: 3-step methodology based on a technical and economic tool for use by local stakeholders to help them determine the preliminary requirements and feasibility conditions for PVCS with a view to optimizing PV benefits.

- PV-powered charging stations including stationary storage and grid connection
- Decision-making model including the PV benefits assessment information
- Technical and economic tool for local stakeholders, allowing to identify the preliminary requirements and feasibility conditions for PV-powered EV charging stations leading to an optimization of PV benefits


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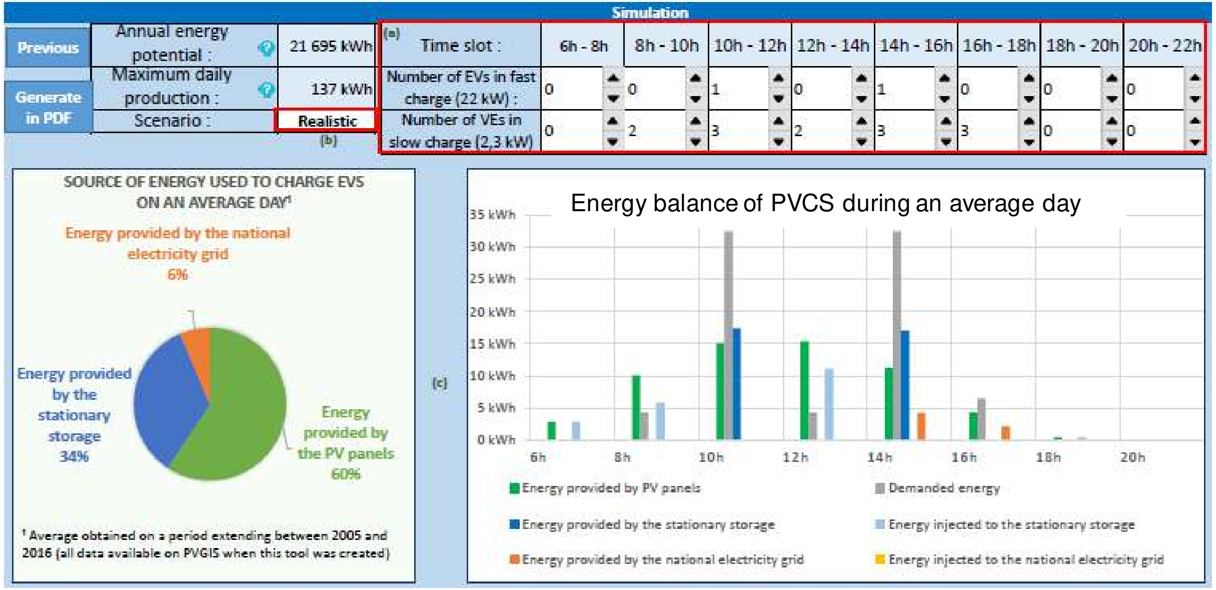
# Requirements, barriers, and solutions for PVCS

Assessment of PV benefits for PVCS: 3-step methodology based on a technical and economic tool for use by local stakeholders to help them determine the preliminary requirements and feasibility conditions for PVCS with a view to optimizing PV benefits.

*The design methodology included the use of an algorithm, resulting, phase by phase, in the constitution of the techno-economic tool with an easy-to-use interface.*

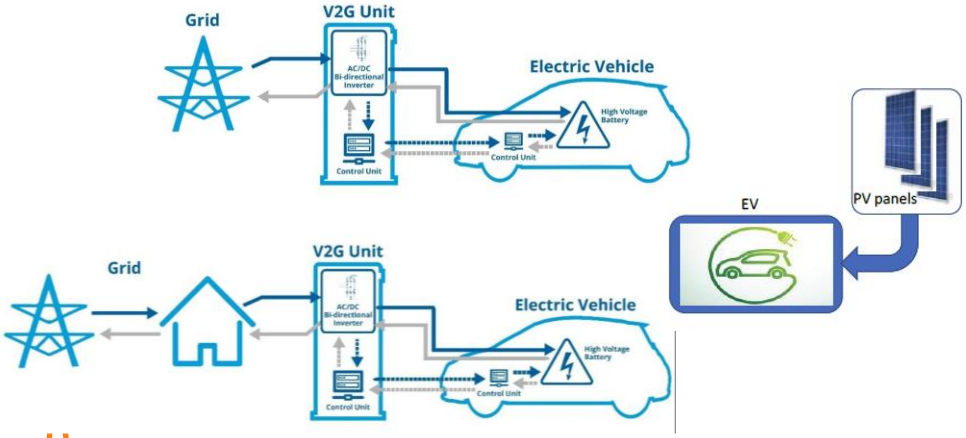


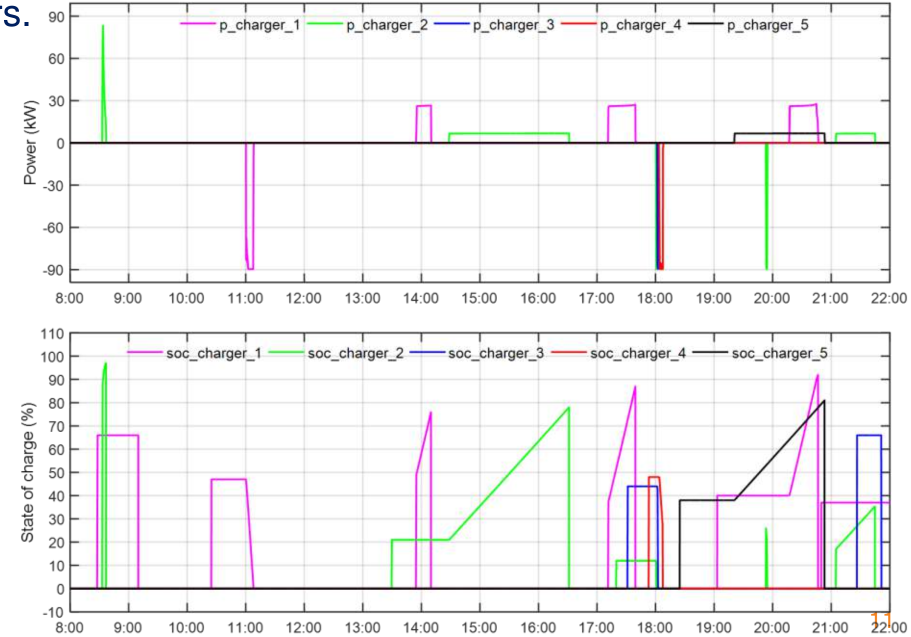

*Next step: integrate $CO_2$ emissions and the total cost of energy, (over the lifespan)*

# Trends in V2G / V2H services and impact of PVCS

PVCS would provide an environmental benefit in the operation of V2G / V2H services, although V2G / V2H systems are not yet ready for industrial-scale use, as a number of difficulties remaining to be overcome and requiring solutions.
A successful implementation of V2G / V2H will depend on the growth of the EV fleet.

Power management strategy with integrated V2G reduces the peak pressure on the public grid while meeting the needs of users.

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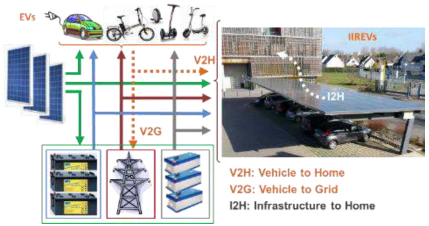
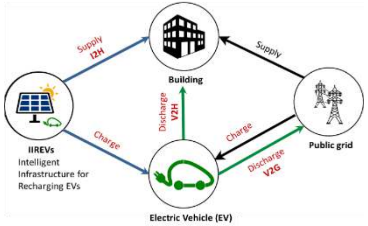
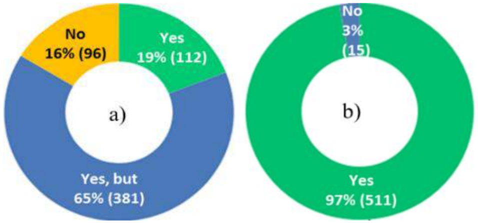
# Societal impact and acceptance of PVCS and V2X

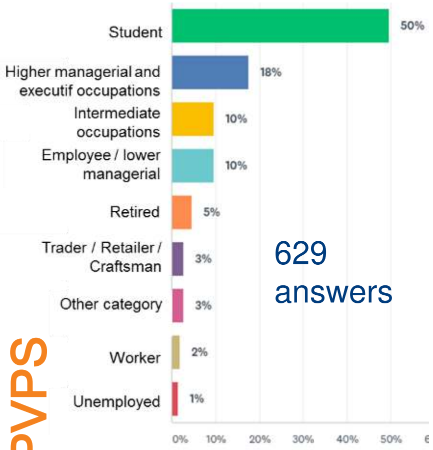
Case study in France based on a survey on the social acceptance of PVCS and new services: the results indicate that PVCS is socially acceptable to a large majority, although some aspects such as location, business model, and design require careful consideration.



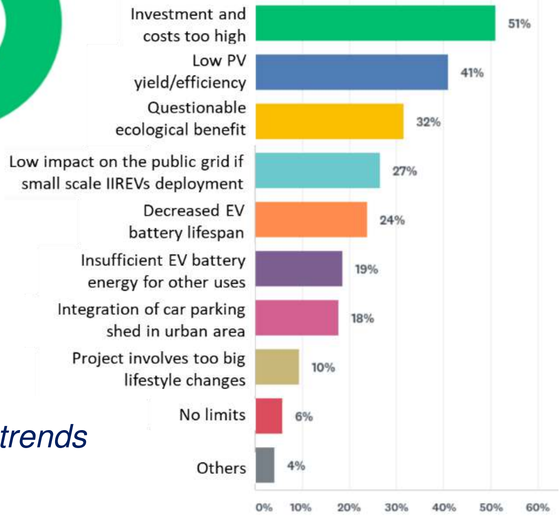




*General trend to the discharge acceptance (a);*
*General trend to the recharge of EVs by PV panels (b)*




629 answers


*PVCS project limits general trends*

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# Societal impact and acceptance of PVCS and V2X

Design of new innovative conceptual PV applications for electric mobility systems
PVCS design is a relevant topic for user acceptance of PVCS as well as for communicating to users their function and their focus on sustainability,
However, space constraints regarding PV cells, modules or arrays were hardly observed.



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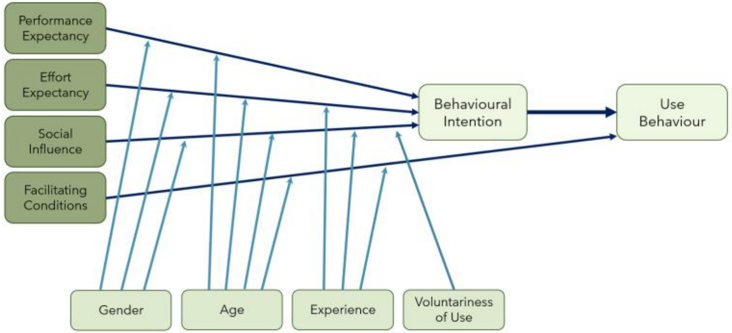
# Societal impact and acceptance of PVCS and V2X

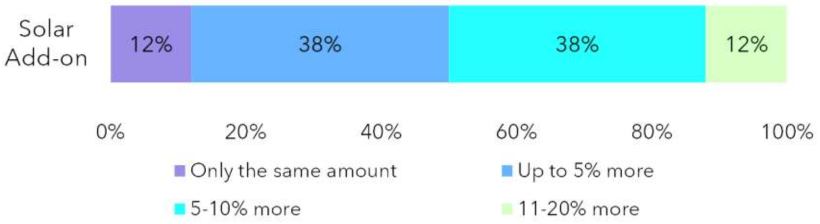
Significant difference in EV ownership between respondents with residential PV and respondents without it, indicating a positive relationship between the use of solar energy at home and an interest in electric transport

Complexity of decision-making processes for transport use and car ownership.

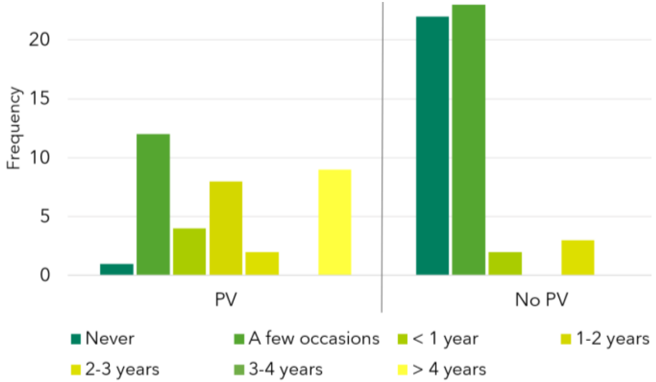



| User Variable | UTAUT Component [16] |
|---|---|
| General | |
| Previous experience with PV and EVs | Experience |
| Pro-environmental attitudes | Social Influence<br>Facilitating Conditions |
| Adoption of PV and EVs by peers | Social Influence |
| Future intention to purchase or lease a vehicle | Behavioural Intention |
| Socio-economic and demographic variables | Gender<br>Age<br>Facilitating Conditions |
| PV-powered mobility applications | |
| General perception and willingness to adopt | Voluntariness of Use |
| Evaluation of specific attributes (e.g. sustainability, cost, appearance) | Performance Expectancy<br>Effort Expectancy |

*EV drivers' willingness to pay an additional cost for a 'solar' version of their vehicle*




*Experience with EV use among respondents with and without a residential PV system*

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# Key recommandations

- PV-powered infrastructures for EV charging require stationary storage in both configurations grid-connected and off-grid
- Charge / discharge controlling, optimization, PV production forecasting, and intelligent communication between the operators and the end-users remain necessary to increase PV benefits
- Main requirements and feasibility conditions for increasing PV benefits are:
  - Daily charge instead weekly charge
  - Charging power of up to 7 kW
  - Based on PV and stationary storage energy
  - Stationary storage charged only by PV
  - Stationary storage of optimized size
  - Stationary storage power limited at 7 kW (for both fast and slow charging mode)
  - EV battery filling up to 6 kWh on average, especially during the less sunny periods
  - User acceptance for long and slow charging
- Technical and economic optimization of PVCS under local meta-conditions (site, weather conditions, user profile, etc.) and over the lifespan is strongly recommended to make full direct use of the PV energy
- Assessment of PV benefits over the lifespan prior to setting up PVCS allows a faster massification of infrastructures
- Power management well-conceived strategies with integrated V2G reduces the peak pressure on the public grid while meeting the needs of users, and provide an environmental benefit in the operation of V2G / V2H services
- Societal impact and social acceptance, as well as aesthetic design aspects, of PVCS and new services associated have to be considered and undertaken as preliminary studies
- Complexity of decision-making processes must lead to design methodologies and tools allowing stakeholders to act quickly and increase the PVCS market

# Main issues for effectively implementation and use

- Lack of understanding on the advantages and disadvantages of slow charging versus fast charging from the stakeholders' perspectives
- Charging points have been deployed without the necessary planning due to insufficient insights on user behavioral, driving patterns, and solar potential, thus not fully optimized
- Charging energy distribution unknown leading to hide the PV benefits
- Underdeveloped user experience for different PVCS solutions and multiple use-case scenarios leading to a lack of standardization in user interfaces
- Lack of proven models for the user experience to make optimal decisions in selecting charging points and improving their overall trip planning
- Lack of necessary data for optimal planning infrastructure due to uncertainty over fast charging as an alternative for mass low power charging
- No clear evidence on influence of bidirectional charging (V2G / V2H) on the life of EV battery and power electronics
- Lack of strategies that take battery aging into account
- Lack of tools, services and strategies to reach total V2G / V2H flexibility and fully optimized wider PVCS infrastructure (value chain)
- Lack of business models and business process implementation and optimization tools to increase PV benefits
- Non-optimal use of the current slow/medium power charging solutions
- Lack of recognized optimal charging strategies in various scenarios, e.g. public (including on-road and covered parking), private (residential and office buildings), in cities, for light and heavy-duty vehicles

# The way forward

PV-powered charging stations (PVCS) may offer significant benefits to drivers and an important contribution to the energy transition. Their massive implementation will require technical and sizing optimisation of the system, including stationary storage and grid connection, but also change of the vehicle use and driver behavior. Long parking time for EVs, short driving distance (around 45 km), and slow charging mode are the most realistic requirements and feasibility conditions for increasing PV benefits for PVCS. In addition, the EV charge controlling allowing intelligent communication between the operators and the end-users, based on powerful algorithms, remains necessary to increase PV benefits for EVs charging.

PVCS have the potential to further decrease the CO2 emissions impact of electrified transport and accelerate the adoption of EV overall due to decreased dependence on the public grid. In order to effectively implement the PVCS, techno-economic and environmental approaches including a life cycle analyze will be important for assessing the role and benefits of PV electricity for EV charging infrastructures.

As a concept of bridge technology to V2G / V2H services, it will be possible to consider that PVCS, including a well-designed power management strategy, would provide an environmental benefit in these services, although V2G / V2H systems are not yet ready for industrial-scale use.

The questions of how to directly use and manage PV electricity for different types of PVCS, driving profiles and locations with different solar irradiance, and how to integrate PVCS components with keeping mechanical and physical reliability and safety including standardisation will be important for all kinds of PVCS.

Regarding the social acceptance of PVCS and V2G / V2H services, the results indicate that PVCS is socially acceptable to a large majority, although some aspects such as location, business model, and design require careful consideration. PVCS design is a relevant topic for user acceptance of new forms of PVCS as well as for communicating to users their function and their focus on sustainability. It will be important to identify factors that potential users of PVCS perceive as benefits or barriers, as well as their impact, and to explore a wide variety of possible designs, knowing that in this early phase of innovation the potential range of designs has not yet fully crystalized.

# Thank you

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