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Large scale EV charging in all parking spaces; how to accelerate the electric disruption

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Summary

The EV market share is reaching 10% of all vehicles in some city areas. To respond to this growth, we have designed a cabling system allowing for the availability of EV charging at all parking spaces. After two years of deployments, we look at the requirements and how we respond to these, as well as findings, experiences, and learnings. In particular, we see a major acceleration of EV adaptation in buildings where we have installed our system, with estimates as much as 50% of EVs within the next 5 years in corporate environment.

Keywords: charging, optimization, smart, business model, infrastructure

1 Introduction

The EV market share is reaching 10% in some city areas. As approximately half of the people live in apartment buildings, being able to charge EVs in an apartment building parking area is creating a "chicken or the egg" problem for EV adaptation.

To respond to this growth, we developed a solution where a cabling system covering all parking spaces is initially installed in office and apartment buildings. After the cabling is present, EV charging stations can be installed by demand and according to the actual requirements of each individual EV driver.

We presented the concept in EVS 30 in Stuttgart, Germany in 2017, "Resource Efficient EV Charging Infrastructure in Real Estate Environment", thus we will not go into similar detail in the implementation, but mostly focus on the actual results of our deployments, adaptation by users, and other changes in the real estate EV charging markets since 2017.

2 Real Estate Requirements

EV charging in real estate has a number of market-specific requirements. When we started in 2014, we interviewed and discussed with a large number of real estate companies and professionals, and worked out a solution to all the challenges we found. The following list covers the most important requirements and how we address them.

Table 1: Real estate requirements

Requirement	How the requirement is addressed
Investment cost must be low to allow sufficient capacity and EV charging stations to be installed	Parking Energy installs cabling first and only brings in charging stations when they are needed. This will cut the

in all parking spaces in the foreseeable future, without a hassle and constant renovations.	initial investment to a fraction, often from around 1/5th to 1/10th. As the charging stations are in our case typically paid by the tenant or rented, there is no charging station investment cost to the property.
Process costs need to be low, and large real estate owners prefer to outsource services.	Parking Energy provides all maintenance, support, and billing of charging stations and electricity as a turn-key service based on a monthly fee charged from the tenant.
Cost of EV charging must be low, as tenants will consider EV charging as a must-have feature and an expensive system will lower the attractiveness of the property.	Parking Energy designed the system and its components for scalability and for keeping the electricity cost as close to the general electricity price as possible. Parking Energy also offers low power, low cost EV charging stations as an option, while providing higher power charging stations to those who have a real need for such equipment. By making our system open and vendor-independent, we lower the cost of EV charging stations and can provide various charging stations to cover everyone's needs.
Cost of maintenance of EV charging must be low.	The Parking Energy cabling includes quick connectors which allow the installation of new units, replacing a faulty unit, and upgrades in 1-2 minutes by the building maintenance personnel instead of requiring an electrician.
Ease of use is important as any support needed by the charging system is costly.	The Parking Energy system has a plug-and-charge functionality that makes using EV charging as easy as plugging into any socket. Parking Energy provides easy-to-use mobile and web apps for EV drivers.
The system should be able to work within the energy and power limits of the property to avoid expensive electrical upgrades as long as possible.	Parking Energy has an extensive load and energy management which is incorporated in the charging stations and optimized by the cloud-based back office system.
Multi-stakeholder issues in apartment buildings set requirements of equal treating of all apartment owners and make decision-making slow and complex.	Parking Energy takes care of the processes, both in the installation phase and afterwards.
The system must be future-proof, as the installation of a large EV charging system is a long-term investment and the expected payback time can be long.	The Parking Energy cabling system is technology-neutral, it has no active components, and the components that are continuously developing and evolving are located in the charging stations installed by demand and which are easy to upgrade.
The system must be vendor and technology neutral, as property owners do not want to get stuck in a single vendor trap.	The Parking Energy system is technology-neutral and a true multivendor environment, allowing competition for services and multisourcing of all components. Multiple

	vendors and operators are already deploying the systems, creating a competitive ecosystem.
The EV charging system needs to be smart to lower the costs of energy and be smart grid aware. The EV charging system needs to be able to talk to the building electrical system, to avoid the need to upgrade the electrical system, to avoid peak loads which may incur power fees, and to utilize a possible renewable energy installation.	The Parking Energy system is smart and can optimize according to smart grid and smart building requirements. At all power levels, from 16 A 1-phase Schuko to medium power 3x32 A units, Parking Energy charging stations are smart.
The system needs to meet regulatory requirements, such as the EU Directive on the Energy Performance of Buildings (EC, 2016a), which sets requirements related to EV charging in new and renovated buildings.	Our system goes past the EPBD, offering much more than just the minimum EPBD requirements.

3 Overview of Parking Energy Concept

We have separated cabling from EV charging stations to make EV charging fit into the property owners' mindset. The cabling is a typical long-term building infrastructure improvement, similar to building a new roof, renovating elevators, or other long-term upgrades, spanning 30 to 40 years. An EV charging station is a moving target, both because of unclear visibility of the coming demand, and because of varying user requirements and developing technology.

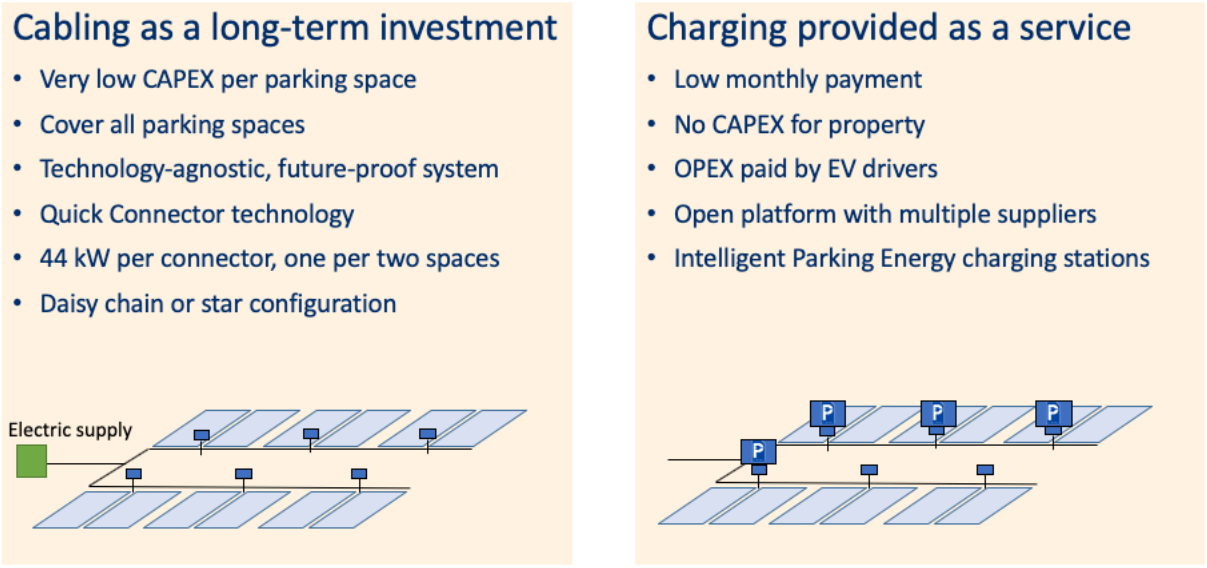

Figure 1: Separating CAPEX (cabling system) and OPEX (EV charging stations).

As an example, in Finland, the tax system strongly drives towards plug-in hybrids instead of full electrics, resulting in a relatively small average battery size that the users prefer to charge from low-cost Schuko charging stations. When fully electric vehicles become more popular, we simply replace Schuko charging stations with Type 2 units, the whole operation taking a few minutes.

As there is a large variation and relatively low demand for electricity in overnight and office EV charging, we can use the cost-effective daisy chain cabling configuration instead of the star configuration. This further lowers the initial investment for the property owner, with a typical saving being from 60% to 70% compared to star cabling.

Any two parking spaces are served by one Quick Connector, further making the cabling simpler to install. Each connector is capable of 44 kW, allowing two 22 kW charging ports without a load management between them, or in the future, up to a 44-kW DC quick charger.

Figure 2: All parking spaces equipped with Quick Connector cabling; one connector for every two parking spaces, offering up to 44 kW.

The Parking Energy cabling system has turned out to be a popular and cost-effective solution compared to a traditional installation of charging stations. The quick connector system allows the charging stations to be installed without electrical work in less than 2 minutes. In practice, this is better than having the charging stations in place from the start, as with Quick Connectors, the type of charging station can be selected to meet the requirements of each individual parking space user, and such charging stations are cheaper and easier to maintain.

Figure 6: Plug-and-play charging station, from 3.7 kW to 22 kW.

4 Key Findings

4.1 Most Drivers Need Less Than 10 kWh of Energy per Day

A large part of all EV charging sessions consume less than 10 kWh. This indicates a typical driving distance around the Finnish average, approximately 50 km/day. While the typical driving distance varies worldwide, 50 km is a good average. In Europe, the daily range is from 40 km to 90 km. As we do not provide DC quick charging, this data set is mostly from daily parking at work or overnight parking at home. It should be noted that the Finnish EV population is weighted towards plug-in hybrids, which may skew the result. However, a large share of those vehicles will run on electricity for most of the time, in particular if the driver has a charging possibility both at work and at home, and many plug-in hybrids can manage typical commuting back and forth with one charge.

One of the learnings is that a small number of drivers tend to use substantially larger amounts of energy. These users fall in varying categories, such as taxi drivers, companies that have acquired one or more Teslas with large batteries for intercity commuting, or salespeople driving long distances. Some drivers have a tendency to plug in only every few days, thus making the per session energy use a slightly misleading measurement. Additional analysis of usage patterns is needed per driver rather than per charging session.

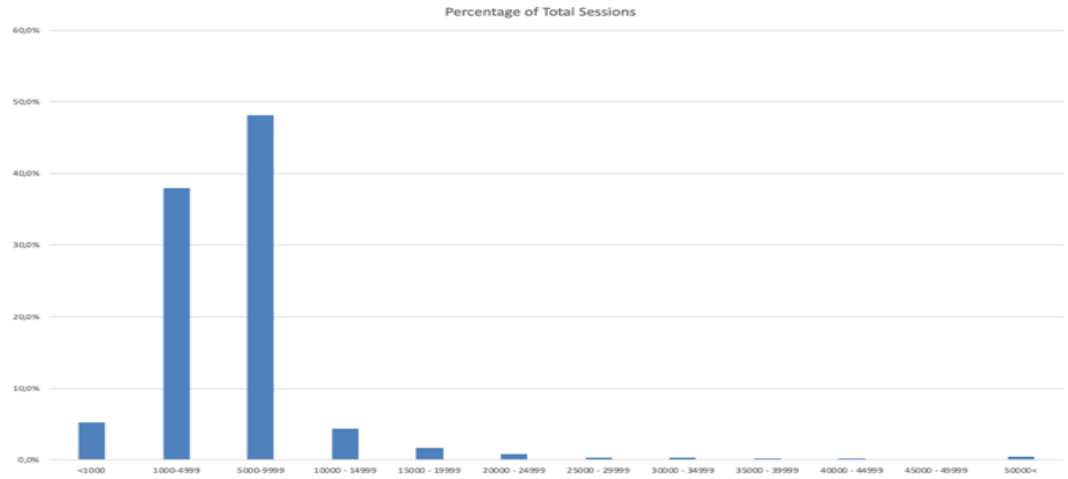

Figure 3: Energy use per charging session relates to the typical driving distance.

4.2 Availability and Cost Beat High Power by a Wide Margin

It is very clear that EV drivers consider low cost and availability more important than getting access to high power charging. Even the high-end cars with large batteries, such as Tesla and the new Hyundai Kona vehicles are often plugged into Schuko outlets without time charges even when a 22-kW unit with a time charge is available right next to it. This is contradictory to the general discussion which focuses on high charging power. One driving factor here is the high cost of the 22-kW charging stations, which forces time charges or higher electricity price. However, other factors are the convenience of a lighter Schuko cable, and in the Parking Energy case, plug-and-charge functionality which is available only for Schuko. An additional complaint about the Type 2 charging stations with a socket is their unreliability and frequent cases where the charging station does not release the cable when needed.

Schuko and Type 2 outlets, no time charges, 20 places	Type 2 outlets, time charge, 4 outlets
	
18 16-A Schuko and two 22-kW Type 2 outlets	Four Type 2 outlets, 3.7-kW and 16.5-kW
Very busy, site upgraded twice since 2017	No upgrades needed, low usage
22-kW outlets see little use and do not have a business case other than completeness of service.	Even less use with Type 2 at 16.5-kW and 3.7-kW power

Figure 4: Two systems right next to each other, lowly Schuko outlets steal the show from the high power 22-kW charging stations.

Parking Energy is installing low-cost Type 2 charging stations with tethered cables to improve the Type 2 charging station usability and to allow lower costs.

4.3 EV drivers Love Plug-and-Charge

One of the unique features of the Parking Energy system is true plug-and-charge. As 15118 is not yet widely available, neither in vehicles nor in charging stations, this is currently available only for the Schuko plug. All EV charging service tests by EV blogs in Finland considered Parking Energy the best EV charging service, and all of them quoted the ease of use as one of the reasons for their evaluation. A similar message is coming from the Parking Energy users.

Figure 5: Parking Energy implements plug-and-charge in Schuko outlets by using an NFC ID installed in the Schuko plug. The Schuko socket has an NFC reader which detects the NFC for identification. The same technology is used for other traditional plugs and sockets.

5 Separating Cabling from Charging Stations

The cabling of the parking area is a long-term investment. Cabling will not wear out, and it has a long, at least 30 to 50 year lifespan, so it is comparable to any long-term investment in the property, such as a new roof, renovating elevators, or renovating outer walls. In terms of investment decision, this is business as usual in the real estate industry.

The EV charging stations are a moving target, with lifespans of as low as a few years in public use, with technologies and customer needs changing as the market progresses. This makes EV charging as a whole a difficult concept for the real estate owners, as typically such short-term investments are a burden to the tenants.

One key decision for us was that we need to separate the cabling system from the EV charging station infrastructure.

Table 3: Comparison between cabling and EV charging stations

	Cabling	EV charging station
Lifespan	30-50 years	5 years
Technology complexity	Low	High
Cost structure	Large overhead, low cost per parking space	Cost is mostly linear to the number of parking spaces equipped

Who should pay for the investment	Property	EV driver
Fits into the real estate owners' mindset	Yes	No
Cost	300-700 EUR/parking space, inversely proportional to the number of parking spaces	To buy, a few hundred euros; service, 15-40 EUR/month

In new building projects, installing the cabling system and quick connectors during the initial construction can create substantial savings. Thus, increasingly, new properties are built with cabling already pre-installed.

6 Examples of Installations

Examples of parking spaces with the Parking Energy cabling system

Figure 7: A large office building in Helsinki, Finland, 238 parking.

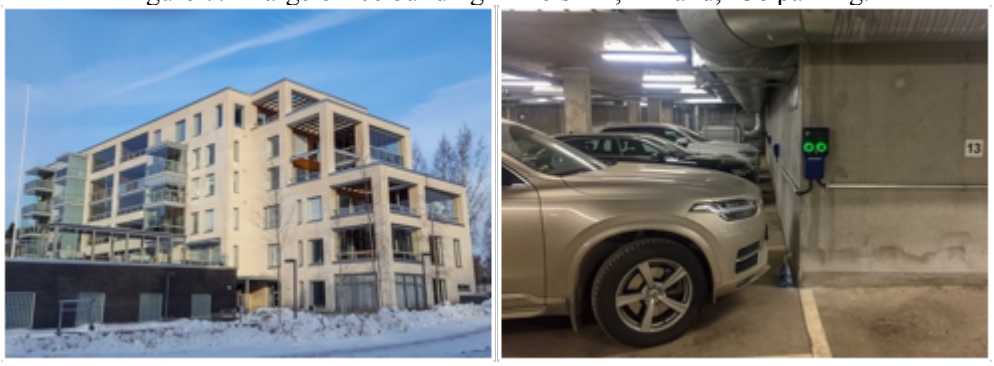

Figure 8: Residential building in Espoo, Finland, 32 parking spaces.

Figure 9: A large apartment block in Helsinki, Finland, 170 Parking spaces.

7 Experiences, Learnings and Specifications

7.1 Cost per Parking Space

The table includes various sites installed, and their respective cost per parking space. The office buildings saw more commonly a partial install, where the electrical infrastructure was upgraded for being ready for a full install but not all cables were installed for all parking spaces. In the large parking garages, where the installation only covers a small percentage of the parking spaces, the electrical panels and base infrastructure upgrades are a substantial part of the cost. However, installation costs for additional parking spaces in these prepared sites will be lower as the base infrastructure is already there and electrical planning has been done.

Table 4: Cost per parking space various installed buildings

Number of parking spaces	Cost per parking space €	Building type
243	370	Office, full installation
12	792	Office, partial installation (10%)
24	854	Office, partial installation (10%)
24	1900	Office, partial installation (5%), complex garage over multiple garage floors
86	465	Apartment building, full installation
84	524	Apartment building, full installation
32	625	Apartment building, full installation
28	839	Apartment building, full installation

7.2 Optimizing Costs

The Parking Energy cabling system is cost-effective to install, in particular when implemented in a large scale. The cost reduction is due to a number of factors:

1. installing the cabling and connector system with a daisy chain topology.
2. using standardized components.
3. separating the long-term cabling investment from the rapidly evolving charging stations .
4. installing charging stations on demand and according to the actual needs of the users.
5. lower total overhead as the cabling is installed as a single project.

To keep the component counts low, 16 mm^2 cable is standardized, and 63 A fuses are used to a varying number of parking spaces, depending on the usage pattern of the places. For the electrical contractors, this allows making larger orders with better prices.

The daisy chain or bus topology is a major cost saving when compared to the star topology.

Table 5: Cost comparison for electrical topologies.

Installation topology	Copper used	Cost of installation, materials and work
Star	Average length of 55 m of 5x10 mm2 cable, 100 cables, 2300 kg of copper	31,000 EUR
Star + daisy chain topology	Average length of 92 m of 5x16 mm2 cable, 6 cables, 500 kg of copper	10,000 EUR

7.3 Power Requirements

An average car will travel 40-90 km/day, and thus the amount of energy needed is low on average, between 5 and 20 kWh per day. When charging is carried out overnight, there are more than 10 hours available for charging, and thus the average power is between 1 kW and 2 kW per car. For office parking spaces, slightly more power is needed, between 2 kW and 4 kW. Parking Energy uses the following power guidance, which is adjusted to local circumstances when necessary.

Table 6: Power requirements depending on the building type

	Power reservation per parking space	Notes
Office property, employees	3 kW to 5 kW	200 km to 300 km during the working day
Office property, guest parking	11 kW to 22 kW	100 km to 200 km during a meeting
Apartment building	2 kW to 3 kW	200 overnight

Apartment buildings in suburbs further away from city centers tend to require more energy because of longer average daily driving distances than apartment buildings in city centers. In city centers, commutes are shorter, and the availability of public transport, shared cars, bicycles, and possibility for walking often decrease the need for driving a car or owning one in the first place.

7.4 Electrical Infrastructure of Building

Adding EV charging to an existing building may require upgrading the electrical system. As this can be very expensive, it is more cost-effective to be carried out in the context of another renovation; thus it is worth pushing such an upgrade to a later stage. When installing an EV charging system, it often makes sense to build the cabling system in the parking area and initially use what is available in the building, and use load management, and further, possible in-building battery and solar installation to gain time for the upgrade. Parking Energy follows the load levels and gives the property management a heads-up early enough to allow preparing for the possible electrical system or electrical connection upgrade.

There are several factors that should be considered when installing or upgrading the electrical panels:

1. Assume that electricity will be needed in all parking spaces.
2. Use average power estimates and take local circumstances into account. Double the energy need for the local driving distance and divide it by the typical parking time.
3. Use 63 A or 80 A fuses and use load management to share the capacity in the fuse groups.
4. 16 mm^2 copper cable is the most cost-effective way to implement cabling in the parking area, while still reasonably easy to install.
5. Allow for 20% to 30% of spare fuses for possible upgrades or unexpected energy use growth or specific needs of professional users, such as taxi drivers.
6. Install a local distribution panel centrally in the parking area, as it can be fed with a longer aluminium cable from the main board, or directly from the substation.
7. It is often cheaper to install ground cables without tubing than install tubing or cable ways and then install the cables later. In Finland, we have 1.5 M electrical outlets in parking spaces installed during the last 50 years, and a large majority of them have been installed with ground cables without tubing.

8 Cabling Systems Accelerating EV Adoption

The most valuable result from covering all the parking spaces is that we are seeing a substantial increase in EV adoption in buildings where the cabling system has been installed.

In cases where we have installed the system in large office buildings, we see changes in company car policies and fleets replaced with plug-in vehicles, which would not happen without the availability of easy and cost-effective EV charging.

We conducted a survey with the tenants of the first large office building where our system was installed, 8 months after the initial installation. The results were even better than we expected. Both large tenants who responded estimated that in 5 years, half of their company car fleet will be plug-in hybrids. The third tenant who moved in after the survey, ordered 18 charging stations within a few weeks of moving in.

After 1.5 years of the initial cabling system installation, 13% of the parking spaces already have EV charging.

This accelerated effect does not seem to happen in buildings where just a few EV charging stations are installed, as using them tends to be priced according to the high installation cost making them unattractive to EV drivers. Too few charging stations seem to create resistance to EVs rather than accelerate the EV market.

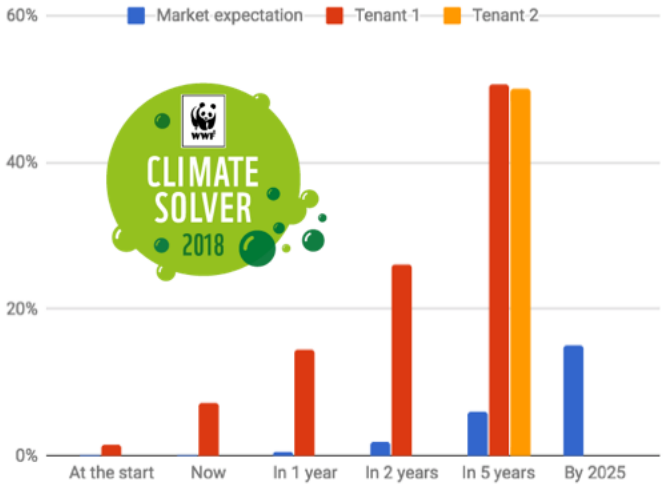

Figure 10: Accelerated EV adoption in an office building

Table 7: Comparing One-by-one installation and cabling system installation

	One by one installation	Cabling for all parking spaces
Cost	By the time 10-15% of places are equipped with charging station, the whole garage would be been cabled for everyone.	10 times more parking spaces for same cost, and charging stations are more cost effective to buy and maintain, and available as service.
Bureaucracy	To get EV charging, permit from property management is needed	Process is in place already
Time to get the EV charging station	From weeks to 1-2 years	1 day
Increased value of property	Just for one	The whole building
Neighbour relations	Jealousy, fights regarding decisions in the management	Equal service for everyone
Legal	No requirements to do anything currently. Property owner or	Legal contracts are already in place.

	housing co-op can block installing charging stations.	

Parking Energy received the "Climate Solver" award from WWF in 2018 for its high potential in reducing greenhouse gases by accelerating electric mobility.

8.1 Profitability to All Parties

The Parking Energy business model is based on creating an ecosystem which adds to profitability of all ecosystem members. The benefits include reducing the installation and maintenance costs, creating larger open market, having the possibility to use the latest technologies, creating less disruption in the parking area, and simplifying the processes for the property owners and users. Property owners will enjoy higher rents, and EV drivers benefit from increased availability and lower cost.

9 Regulation and Incentives

9.1 EPBD

The European Union Energy Performance of Buildings Directive (EPBD) sets requirements for preparing EV charging in new buildings and buildings undergoing major renovations. The directive is not very ambitious, as it only requires tubing for the later installation of EV charging cabling, and due to the previously mentioned cost-efficiency factors this is not enough. The EPBD also failed to incorporate the electrical panel capacity requirements, which may lead into situations where brand new buildings need electrical system upgrades at opening.

9.2 Cabling Infrastructure Incentives

New incentives are appearing in many countries to encourage installations of EV charging in real estate. One of the best success stories in Finland has been the incentive for apartment buildings by The Housing Finance and Development Centre of Finland, ARA. ARA provides a 35% subsidy for up to 90,000 euros per housing cooperative, or up to 200,000 euros for larger rental apartment building owners. This incentive has been wildly successful, and one of the reasons is that it is focused on the problem, the long-term cabling, rather than adding individual charging stations.

9.3 Cities and Municipalities

Municipalities usually control building code, and can effect EV charging station requirements in the building permitting process. In this early phase, the focus has not been on the cabling, but on the charging stations, sometimes leading to suboptimal installations. However, we are slowly seeing progress here as well.

9.4 Forcing Legislation

In some countries, such as Norway, the currently leading country in the EV market share, there are plans or existing legislation that force building owners to install EV charging even when just one apartment owner needs it. This is being widely discussed, and similar legislative efforts are ongoing in multiple markets, including the European Union.

References

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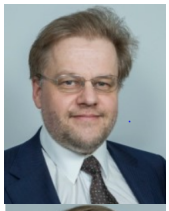
Authors



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Markku Peräniitty received the Masters degree in Electrical Engineering from Tampere University of Technology. Markku has a long track record in the energy industry and information technology. His career covers management of a wide variety of projects including business and technology development, strategy, process management and R&D. He led previously a Project Management Office of an extensive smart metering project and headed IT for a Pan-Nordic business unit of a listed company. Markku is Director, Market Development at Parking Energy.