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Electric Vehicles Charging Services Perspectives and Challenges

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Abstract. *The year 2023 marked another breakthrough in electromobility. Customers accept electric powertrain; sales of battery electric vehicles and plug-in hybrid vehicles are booming and public charging infrastructure follows the similar pace. However, the leading European independent charging stations operators, despite the significant public funding utilized for financing their expansion activities are still experiencing losses, as a result of their operation. Generally, current research work in area of electric vehicle charging is rather focused on specific and rather technical aspects of charging infrastructure operations, like optimization of charger locations, connection to energy networks and operational excellence. Very few authors are focusing on core business essentials of charging infrastructure operation, in particular on sustainability of their operations. Within this paper author conducted financial analyses of selected charging infrastructure operator in Europe, compared the conclusions with its peers. Furthermore, this paper has an ambition to perform synthesis (after thorough review and analysis of relevant information sources) of different aspects of e-mobility ecosystem to conclude innovative recommendations. The main result of this paper is the recommendation for the charging infrastructure operators to adjust their strategies and respective business models in terms to make a move towards slow charging world, by building and operating Vehicle to Grid equipped infrastructure as a supplement to fast chargers' network. Sooner charging infrastructure operators will develop their competences in Vehicle to Grid world the better, mainly for two reasons. Firstly, it is very probable that Vehicle to Grid market will jump on fast track very soon. Not only from technology point of view, but also from services provided/expected from customers. Secondly, in Vehicle to Grid connected ecosystem lays needed tens or even hundreds of millions EUR opportunities which will be waiting for Electric Vehicle´s owners and any subjects which can facilitate and instrument interconnection between energy network's needs – auxiliary services, storage of electricity, integration of renewable energy sources and traction batteries of Electric Vehicles.*

Keywords: electric vehicles, charging infrastructure, vehicle to grid (V2G), auxiliary services, improvements of charging infrastructure operators business models**,** financial analyses

Introduction

Global EV sales forecasts surpassed 14,1 million units for 2023, and, more importantly, electric vehicles (EVs) accounted for 16% of all new cars sold worldwide. This represents a 3-percentage point increase from the previous year in 2022 and a 8- percentage point increase compared to 2021. It seems that electromobility has started to experience exponential growth as could be clearly seen from Graph 1.

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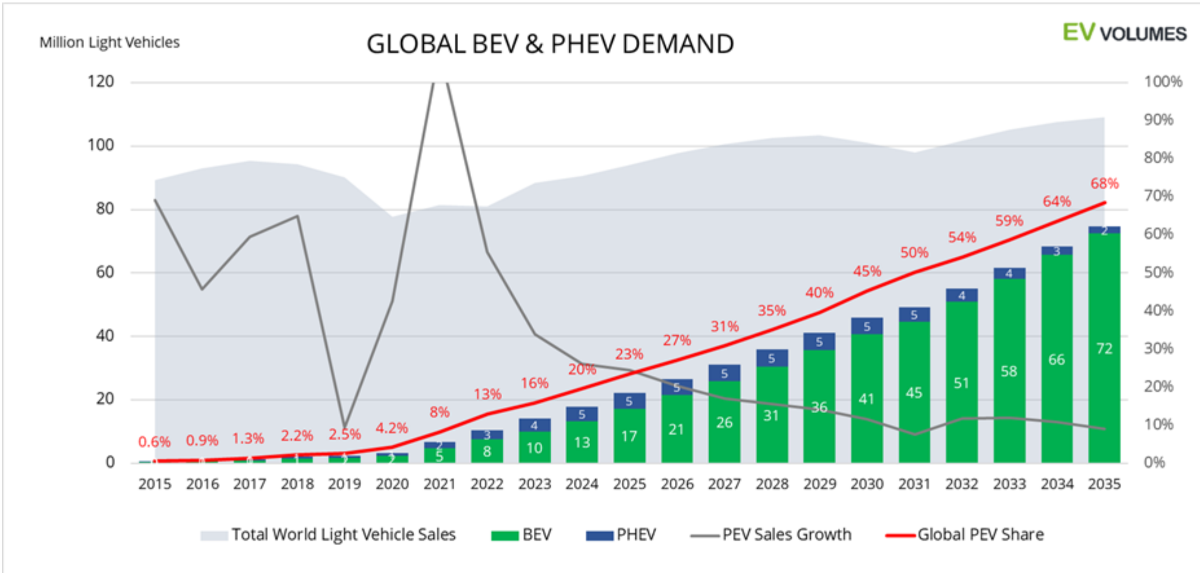


Graph 1. Global BEV & PHEV demand

Source: Neil King, 2023.

Note: BEV stands for Battery electric vehicle, PHEV stands for Plugin Hybrid Electric Vehicle, PEV is a subcategory of electric vehicles that includes battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs)

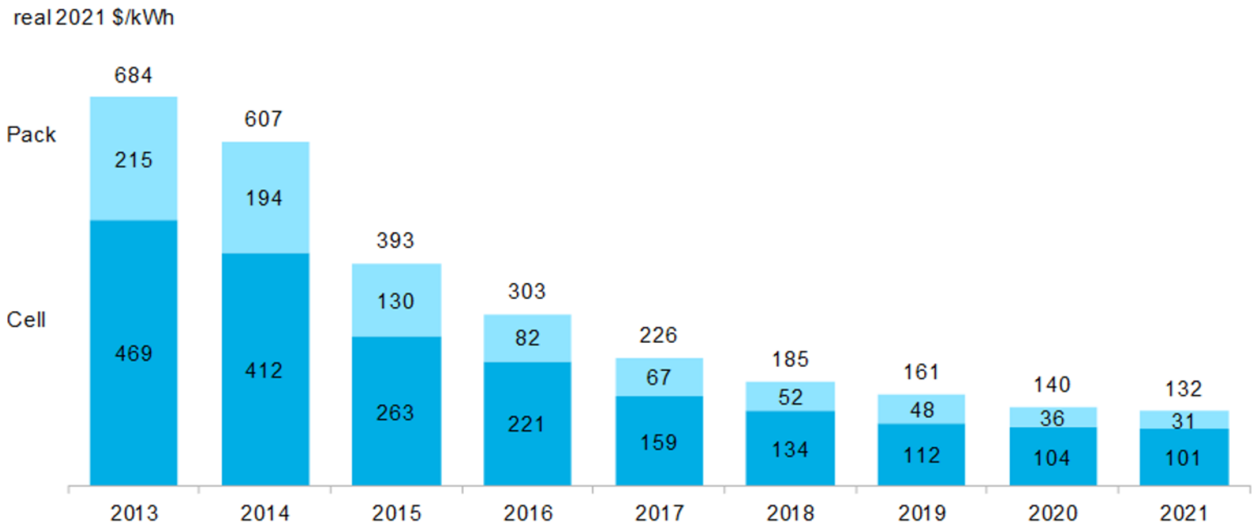
In March 2023, European parliament provisionally agreed the Alternative Fuels Infrastructure Regulation (AFIR) which sets the targets for member states regarding public infrastructure based on the size of the registered fleet, including coverage requirements for transport corridors in Europe. Respective numbers of charging points to be deployed (different for Battery electric vehicles and Plug-in hybrids) are set as a percentage of new registrations, whereas also installed capacity of charging stations is foreseen.

China continues to lead in battery production, with technological advancements primarily focusing on battery chemistry, construction, and increasing energy density. At the same time, the unit cost for stored energy in batteries is decreasing which is the main trigger for further exponential growth of electric vehicles, as can be seen from Graph 2.

The global and European e-mobility market is booming in recent years. The growth of the market is supported by policies adopted by regional, national and European level that impose both targets and serves as background for supporting financial schemes aimed to further expansion of public charging infrastructure.

However, the most profound European independent charging stations operators (or further in text charging infrastructure operators) like Allego, Fastned, GreenWay (despite significant public funding utilised for financing their expansion activities) are still experiencing losses, as the result of their operation.

Current discussions on charging infrastructure operators highlights utilisation rates and margins increase as the levers that will foster the sustainability of their operations. It is difficult to disagree with such opinions, however the basic question that this paper tries to discuss is whether there are realistic perspectives for increase of the utilisation rates and whether there are possibly other levers that might bring additional revenue generation streams for charging infrastructure businesses model.



Graph 2. Volume - weighted average pack and cell price split

Source: BloomberNEF 2023.

Literature review

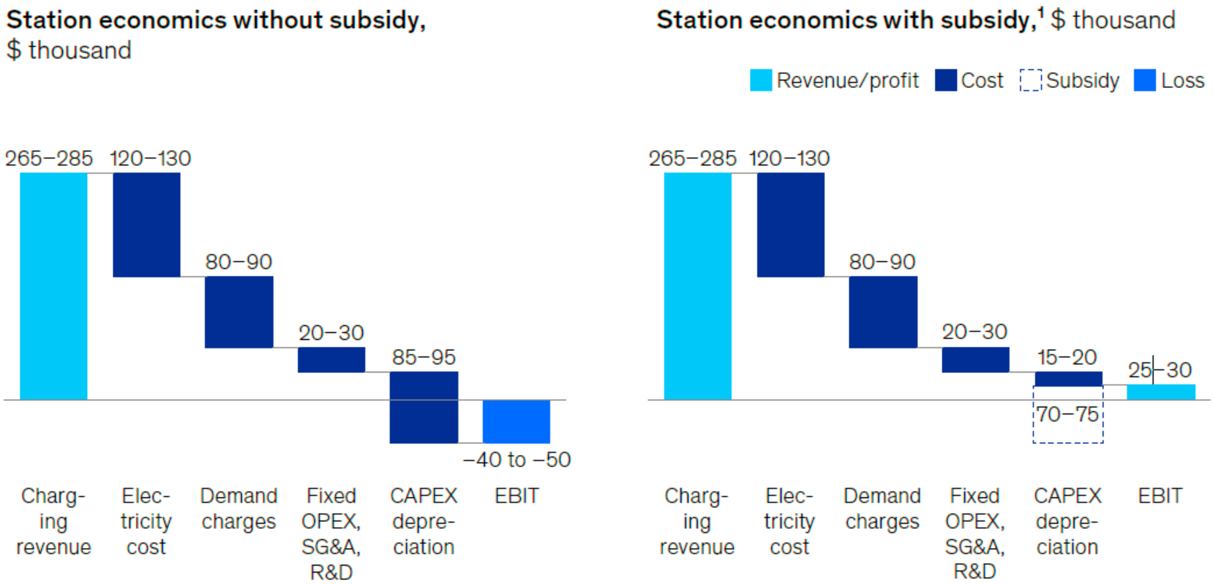
Utilization of charging point

The renowned consulting firm McKinsey&Company anticipates that by the year 2030, approximately every second car sold in the USA will be electric. This projection represents a significant increase compared to the 8% in 2022 and 5% in 2021. (McKinsey&Company by Peter Fröde et al., 2023)

In its model, McKinsey identifies challenges for charging station operators to achieve positive (profitable) results at current and modelled utilization rates. The competition in the market is increasing, and the number of required charging points should directly grow with the increasing number of electric vehicles on the roads.

McKinsey defines a simple calculation for the economics of a charging station operator in subsidized and non-subsidized markets in California, USA. Assuming a 15% utilization rate – equivalent to approximately seven 30-minute charging sessions per day, McKinsey's hypothetical station would generate annual revenue of $265,000 to $285,000 at a rate of $0.45 per kWh. (Prices may vary depending on the time of day). On the cost side, annual expenses were estimated at $220,000 to $250,000 for electricity, distribution fees, fixed operating costs, research and development, and management, sales, and administration costs. Capital expenditure depreciation would amount to $85,000 to $95,000 annually. With these assumptions, the station would incur a loss of approximately $40,000 to $50,000 annually on EBIT (see bellow).

In their model with subsidies, the loss turns into a modest profit. However, it is essential to realize that the sustainability of the charging station operator's business model should not depend on political decisions related to subsidies.



Graph 3. Charging point economy without/with subsidies

Source: McKinsey&Company by Peter Fröde et al., 2023.

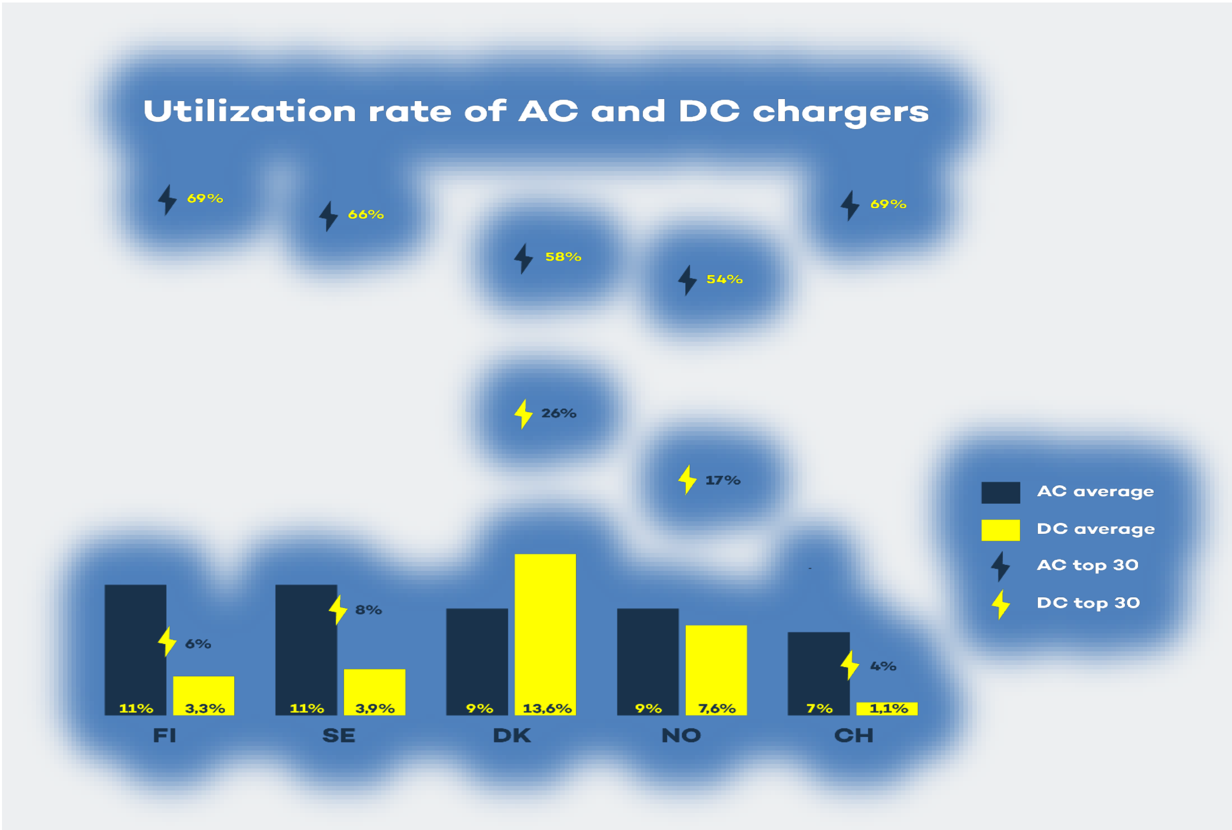
Note1:OPEX stands for operational expenses, SG&A stands for Selling, General & Administration expenses, R&D stands for Research and Development

Note 2: Analysis assumes 4 direct current fast charging (DCFC) 150KW chargers at each station; 15% utilization, 80% charger efficiency, price of ~$0.45/kWh. Costs assume wholesale electricity at $0.20/kWh with a $20/kW demand charge (75% concurrence, ~$250/month per charger for maintenance, ~$95,000 per charger for the charging hardware and installation excluding grid and site equipment, 5% SG&A / R&D, 15% discount rate. Analysis assumes ~80% of the capital cost is covered by a subsidy.

McKinsey introduces an interesting assumption and recommendations in its model. The 15% utilization rate corresponds to an average of 7 charging sessions per day across the entire charging station network, each lasting 30 minutes, throughout the year. The recommendation for improving business profitability is to increase utilization to achieve a 20% utilization rate, which would lead to profitability even without subsidies. (Three other, perhaps less surprising, recommendations aim to increase the selling price for services and reduce variable operating costs, supplemented by recommendation of achieving additional revenues per charger through other services, such as advertising.)

Compared to the modelled utilization, the current average utilization rate of fast-charging networks in the USA is around 7.2% annually, with the best month reaching approximately 13%. The current annual average is, therefore, more than 50% lower than the modelled value, and without subsidies, charging station operators are still generating losses. (McKinsey Centre for Future Mobility Sean Kane et al., 2021)

The Scandinavian countries have maintained a leading position in the electromobility sector in the European context for quite some time, especially Norway (In December 2022, 80% of newly registered vehicles were electric in Norway). So, what is the utilization rate of charging networks in Europe, specifically in the Scandinavian states? According to Virta, which has been collecting relevant data on charging station utilization since 2013 (this company sells systems for charging station management), the utilization rate of charging stations in 2020 was as follows:



Graph 4. Utilization rates of AC and DC chargers at selected European markets

Source: Virta, 2023.

Among AC chargers, both private and public charging stations are included. The current most developed market in Norway achieves an average utilization rate of charging stations at only 7.6%.Average arithmetic DC utilization rate for selected European markets is 7,4%, which is comparable to 7,2% as indicated by McKinsey for USA.

If we prospect the evolution scenarios by IEA both on electric vehicles (EVs) and public charging points as presented by International Energy Agency (IEA) in its recent Global EV Outlook 2023 (see the Table 1. bellow), we find that there might be optimally increase in range from 27% to 46% in ratio EV/ Public charging points. (based on the assumption, that only 50% of increase ratio EVs/Public charging point will transform to increase of utilisation rate of DC charging stations). Even in full reflection in utilisation rates, results do not meet the 20% utilisation rates as modelled by McKinsey company which should lead (in combination with other optimisation measures) to profitable operations.

Table 1. Perspective evolution of ratio EV/Public charging points

Scenario	Year	EVs (in thousands)	Public charging points (in thousands)	Evs/Public charging points	Percentual increase (year to year)
	2019	1300	175	7,43	
	2025	14000	1300	10,77	45,0
low	2030	33000	2900	11,38	5,7
high	2030	40000	2900	13,79	21,2

Source: Author´s own research based on data from Global EV Outlook2023.

Bidirectional charging

Bidirectional charging refers to an advanced charging system for electric vehicles capable of bidirectional power flow. This involves a relatively complex process of converting alternating current (AC) to direct current (DC), as opposed to conventional unidirectional chargers for electric vehicles that utilize AC. Typically, in conventional setups, AC is converted to DC within the vehicle to charge the traction battery. In contrast, bidirectional chargers facilitate both the charging and discharging of the electric vehicle's traction battery. In the discharging mode, the electric vehicle serves as a source of electrical power.

Due to their sophisticated design, bidirectional chargers are more expensive than conventional electric vehicle chargers. This increased cost is attributed to the advanced electronics for energy conversion and energy flow control to and from the vehicle.

Usage of Bidirectional Charging

There is plenty of information on pilot programs, existing commercial services and projects that in some extent deal with bidirectional charging in form of V2G or V2H. Regulation of the extent of this paper do not allows to provide substantial overview, author has decided rather to synthetize the information to a nutshell description of bidirectional charging ecosystem. Just to mention a few, authors reviewed outcomes of companies active in this area among others Nuvve, Virta, databases of position documents and reports available at evmarktetsreports.com and cleanenergyreviews.com

Bidirectional chargers can be employed for two main applications. The first and most discussed is Vehicle-to-Grid (V2G), designed for sending or exporting energy back to the electric grid during periods of high demand. When thousands of vehicles with V2G technology are connected and activated, it has the potential to revolutionize electricity storage and production on a massive scale. Electric vehicles (EVs) have integrated large and powerful batteries, so the combined power of thousands of vehicles with V2G can be substantial. It's worth noting that V2X is a term sometimes used to describe all three variations mentioned below.

1. Vehicle-to-Grid (V2G) – EV exports energy to support the electric grid.
2. Vehicle-to-Home (V2H) – EV energy is used to power homes or businesses.
3. Vehicle-to-Load (V2L) – EVs can power appliances or charge other EVs. (*V2L does not require bidirectional chargers for operation.)

The second use of bidirectional EV chargers is for Vehicle-to-Home (V2H). As the name suggests, V2H allows using an EV as a home battery system to store excess solar energy and power your home. For instance, a typical home battery system like the Tesla Powerwall has a capacity of 13.5 kWh, while the average electric vehicle has a capacity of 65 kWh, equivalent to nearly five Tesla Powerwalls. With such a large battery capacity, a fully charged EV can support an average household for several consecutive days or much longer, especially in combination with a solar power system on the roof.

For Charging Infrastructure Operator capable of delaying charging, modulating power (primarily reducing), stopping charging, and, if needed technology integrated into the vehicle, controlling the reverse flow of electricity (with related adjustments in the charging infrastructure), conditions are created for providing ancillary services to Energy System Operators. Further explanations of ancillary services will be provided later in the text. The Charging Infrastructure Operator can offer additional value to its customers through V2G services only if electric vehicles are connected to V2G-compatible charging infrastructure. Logically, the key prerequisite is the duration of the connection, as a vehicle connected during, for example, fast or ultra-fast charging for 15 to 45 minutes is too short a time frame to provide support services or other V2G opportunities. Therefore, for V2G functionalities, it is significantly more advantageous if the Charging Infrastructure Operator can control the charging/discharging process, which takes place over a longer period (several hours), or when the electric vehicle is not in use for mobility purposes and is typically parked at home (in a garage or parking space), at the owner's workplace, or any place where the electric vehicle is parked for an extended period.

In these cases, "slow" (low-power) AC charging or low-power DC charging (e.g., 22 kW) is used to charge the electric vehicle. Therefore, it is important to realize that the Charging Infrastructure Operator needs to have control over the charging process, which primarily takes place in households, workplaces, and wherever electric vehicles are parked for an extended period if it wants to provide V2G services.

Prerequisites for a competitively priced offer for Energy System Operators primarily stem from the fact that someone (EV owner) has already paid for the core technology to provide smart charging (e.g., auxiliary services), hence the most valuable battery in the electric vehicle is already paid by EV owner. The necessary condition is that the Charging Infrastructure Operator can control the charging/discharging process when the vehicle is connected to the charging station and that the charging stations, their control systems, power electronics, and measurement are adapted for bidirectional energy flow. So, if we have an electric vehicle with V2G functionalities, the price of the traction battery is already included in the cost of the electric vehicle.

Therefore, to provide V2G functions and obtain relevant benefits, the electric vehicle owner needs to invest relatively lower resources compared to entities that will compete for the same services in terms of price (like traditional auxiliary service providers). In addition to the V2G charging station, its connection to the internal or external distribution system, communication costs (internet access), costs of wear and tear on the traction battery (for reasons other than using it for mobility), costs to ensure market access, the owner of the electric vehicle with V2G functionality has covered a significant majority of the costs needed to provide services in the context of V2G and possibly gain relevant associated benefits.

Methodology

With regards to research methodology that was applied within this paper, author decided to use financial analyses of selected subject, in particular application of standard financial relative metrics based on latest available published company (selected) financial statements. Furthermore, review and analysis of relevant literature and available online resources served as a basis for concluding the most important outcomes by applying synthesis, thus integrating different aspects of e-mobility ecosystem. Author also used comparation techniques and application of simple mathematical algebra to present opinions and conclusions.

The nature of this paper is rather systematic. Ambitions was to highlight shortcomings in present charging industry in Europe, and at the same time to find out possible solutions for the industry as such, considering latest technological advancements and existing market design of energy markets. Despite combining national and European perspective, sometimes supplemented by global perspectives, author believes that recommendations and conclusions are of the universal nature and their validity will not be hindered by local specificities.

Results and discussions

Financial situation of leading Charging Infrastructure Operators in Europe

Those of charging infrastructure operators, that experienced going public through IPO (initial public offerings) in the past suffered from significant value drops, where lack of profitability over midterm periods could be easily attributed with. The situation is best displayed by historical stock prices evolutions for Allego and Fastned companies (see below). If any reader looks to the financial results of major charging infrastructure operator, many of them might be close to the bankruptcy according to standard methodology of financial analysis.

Graph 5. Historical stock prices of leading Charging infrastructure operators (Allego, Fastned)

Source: Google.com/Finance 2024.

For the demonstration of above mentioned I have chosen as an example three leading European charging infrastructure operators: Fastned, Allego and GreenWay. Fastned and Allego are listed companies, GreenWay is privately owned. Fastned and Allego are operating in Western European region (mainly Benelux area and Germany), GreenWay is leading Charging infrastructure operator in Central Europe (Poland, Slovakia, Croatia). For Fastned and Allego author depicts the evolution of share prices over available period, GreenWay financial statements were analysed, using publicly available financial statements for last 6 years.

Financial Analyses of GreenWay Infrastructure

Bellow is the summary of selected indicators of financial position and performance of GreenWay company together with description of methodology applied and comments to the outcomes.

Table 2. Financial analyses results of GreenWay Infrastructure

Year	Value Added (000)	Gross Margin %	ROA %	Working Capital (000)	Altman´s index	Index 05
2017	105	18.52	-3.66	-1055	0.25	0.71
2018	-607	-170.85	-13.53	-1812	-0.54	-0.47
2019	-707	-172.99	-19.37	567	-0.43	0.07
2020	-486	-83.67	-16.41	308	-0.59	-0.41
2021	-752	-82.85	-39.37	-941	-1.43	-1.43
2022	-1385	-99.29	-48.42	-988	-1.55	-1.97

Source: Authors' own research.

Value Added

Value added represents the difference between revenues plus own performance and direct costs of procured goods, purchase of materials, energy, and services. From the value added, the company further covers personnel costs, other operating expenses, and financial costs. Value added is calculated as follows:

Value Added = (Sales Revenue+Sales of Own Products and Services+ Changes in Internal Inventory+Activation)−(Cost of Goods Sold+Material, Energy, and Other NonInventory Consumables + Inventory Adjustments+Services)

We can clearly see that Value Added is continuously depleting in its value over years which impose high risk of cash shortage, difficulty to raise debt financing and fulfillment of its obligations. Moreover, from generated revenues company would have problems (if not receiving continuously injections of capital) to pay its employees and other operating expenses.

EBITDA

EBITDA expresses the operational performance of the company. EBITDA is calculated as follows in this case:

EBITDA=Operating Result of Business Activities+Depreciation−Sales Revenue from LongTerm Intangible Assets and LongTerm Material Assets and Materials+Adjustments to Inventory+(−Adjustments to Inventory)+(−Adjustments to Fixed Assets and Intangible Assets)+(−Adjustments to Receivables)

EBITDA has dropped for GreenWay Infrastructure, by 32,9% compared to previous year and its value for the year 2022 was – 2 318 485 EUR. Operational performance is worsening, which hypothetically might be acceptable (under normal course of business) only if company has significantly invested recently mainly in its human resource and competences empowerment in order to satisfy expansion of its activities, which should result into significantly rising revenues in the near future.

Gross Margin

Gross margin is a financial profitability indicator calculated as the ratio of created value added to the total revenue of the company. Gross margin is calculated as follows:

Gross Margin=Value Added/Total Revenue×100

This indicator expresses the percentage of revenue that remains with the company in the form of added value (or gross profit) after deducting direct costs of procured goods, purchase of materials, energy, and services. From the gross profit, the company further covers personnel costs, other operating expenses, and financial costs.

Negative trend of negative gross margins over the analyzed period indicates the company would have serious difficulties to sustain positive cash situation. Without continuous rounds of equity financing, sustainable operation would not be possible. Negative gross margins questions pricing policies applied and extent of investments into the assets, which are underutilized. It also shows the vulnerability of the business over the external factors like energy prices evolutions.

Return on Assets (ROA)

The return on assets (ROA) indicator expresses the ratio of net profit after tax to the total value of assets. It provides a percentage representation of the net profit that the company generated from one EUR of assets. It indicates how effectively the company uses its assets to generate profit. ROA is calculated as follows:

ROA=Net Profit After Tax/Assets×100

Despite significant negative trend of ROA over last six years, positive conclusion could be raised. Company´s asset base is expanding, thus providing opportunity for the future revenues to be generated. Obviously, ROA will turn to be positive only in case company will reach net profit.

Working Capital

Working capital, also known as net working capital, represents the difference between the current assets of the company and its short-term liabilities. Working capital is an indicator of the company's liquidity, operational efficiency, and short-term financial health. Working capital is calculated as follows:

Working Capital=(Short-Term Receivables+Inventories+Financial Accounts+Short-Term Financial Assets+Active Time Resolutions)−(Short-Term Liabilities+Short-Term Financial Assistance+Short-Term Bank Loans+Passive Time Resolutions)

Results of working capital (despite showing positive figures in 2019,2020) also indicate negative trend. Those suppliers that perform financial checks over their customers might impose more strict payment conditions over the company supplies. Again, without timely managed rounds of fresh equity, company would not be able to survive cash shortages.

Altman's Index:

Altman's Index is the most used predictive bankruptcy model. Altman's model is generally being used to assess the efficiency and profitability of investment projects.

Z=0.717×Net Working Capital+0.847×Retained Earnings from Past Periods+3.107×EBITDA+0.420×Net Fixed Assets+0.998×Total Assets

The results of Altman´s index computation reflects high risk of the bankruptcy for GreenWay, as the results are in the worst possible range.

Index 05:

Index 05, a Czech predictive model for evaluating the financial health of a company, can predict with a certain probability whether there is a risk of financial problems for the business in the future. This model was developed by reflecting the business environment of Czech companies. Due to the proximity of location, legislation, it achieves a high level of accuracy and is suitable for use in Slovak conditions.

Index 05=0.13×Total Capital+0.04×EBITDA to Net Worth+3.97×EBITDA to Total Capital+0.21×Net Sales+0.09×Operating Activity Indicators of Short-Term Financial Stability Index

Comparable to Altman´s Index result, also these results indicate that company could experience serious financial problems. Under standard provisions, company is not eligible for debt financing and without having short perspective on turnout of financial performance fundamentals (operating revenues and their relation to incurred costs), there is a high risk of bankruptcy.

To conclude, all the indicators shows that GreenWay is having serious financial problems for longer period of time. The only possible explanation of why it has not bankrupted yet lays in the trust of its owners/investors that finance the company operation and expansion. Trust may be based on the belief that existing and projected expansion of the market will dramatically change the profitability of company´s operations and from longer perspective they will recover losses incurred in the past. The longer times goes on, the harder will be to persuade investors to believe in positive outlook.

Opportunities and challenges of Vehicle to Grid ecosystem

Large batteries in EVs, in the case of an electric vehicle connected to a bidirectional charging station and simultaneously supporting V2G functionality, enables the storage of electric energy generated from renewable sources, thereby promoting the development of renewable resources.

In case that electric energy is produced from renewable sources and stored in the traction battery of an electric vehicle with Vehicle to Grid (V2G) functionalities, the electric vehicle (its battery) can become the exclusive source of electric energy for powering households upon arrival at home during peak consumption times (morning and evening). Aside from cost-effectiveness regarding electricity prices, the V2G-enabled electric vehicle model serving as a source of electric energy for households during peak hours significantly contributes to the stability of the electrical power systems.

Demand response (DSR), or consumption management based on, for example, price motivations, is an important complementary functionality that leverages the ability of electric energy consumers to control their consumption. Yule-Bennett (2022) states that by using the traction battery of an electric vehicle in V2G mode as an energy storage and local source during energy shortages, the ability of consumers to respond to price motivations will be optimized.

Bidirectional charging and discharging of many electric vehicles supported by both domestic and public networks, allowing charging and discharging based on remote control along with built-in optimization functionalities. Enough installed renewable energy capacity combined with emissions free stable (baseload) sources, expanded demand response, strengthened connections between transmission systems, and resolved V2G details will make the electric vehicle a key component of the energy system, enabling distributed production of electric energy from renewable sources and cheaper electric energy for consumers.

Challenges

Despite the long-standing discussion on V2G, this technology is more of a future prospect. Apart from the absence of electric vehicle models supporting V2G technology and the insufficient deployment of V2G charging stations, the technological challenge also lies in the unresolved question of communication protocols and connectors (the ChaDeMo connector has been compatible with V2G applications for several years, but the dominant CCS standard in Europe announces compatibility with V2G functionality in 2025).

Among electric vehicles readily available in the market, the Nissan brand (in its Leaf and e-NV 200 models), along with Mitsubishi, offers V2G functionality already since 2013. Ford presented its solution, and several dominant players like VW, PSA, and Toyota, Tesla, Hyndai and Kia are currently planning V2G functionalities in their electric vehicles.

Similarly, the regulatory environment needs to address many issues related to safety and compliance with energy system regulation. V2G technologies are perceived as sources of electric energy and, for instance, must be able to cease supplying electric energy to the grid in the event of technical issues on the grid.

Rapid implementation of V2G is also hindered by the lack of standardization of communication protocols and connectors. This issue is relatively complex, as it involves safety issues and managing electric energy flows during battery discharge into the system. Only in 2020 did the first charging hardware pass certification, demonstrating compliance with the UL9741 standard in the USA, which sets conditions for charging devices for electric vehicles in bidirectional charging/discharging mode. The new international ISO standard 15118-2 defines the communication interface between electric vehicles with V2G functionality and the corresponding charging infrastructure.

Conclusion

New entrants are stepping into charging market, public charging infrastructure is growing in line with new EV´s registrations (or should be at least when finally approved) according to Alternative Fuel Infrastructure Directive but profound public discussion on how to improve viability of charging infrastructure operators is at its beginning. According to author´s opinion, public financing might be a good tool to accompany market transformation (like a shift from fossil fuel burning to zero emissions transportation), but based on the condition that sustainable business operation might evolve over predetermined period or fulfilment of key market indicators. For some subjects, even after decade of loss generations, positive perspectives are subject to future positive utilisations and margins evolutions projections only.

From the perspective of auxiliary services or applications where an electric vehicle could be utilized for purposes other than mobility functions (in its interaction towards energy networks), I anticipate that EVs will find the most significant use in the following areas:

Frequency Regulation: The technical compatibility for a rapid response from the electric vehicle to the operator's signal to charge/discharge makes it well-suited for frequency regulation.

Additionally, Nuvve corp. (2021) states that relatively small power requirement (on the order of megawatts or tens of megawatts) for charging and discharging, and for very short durations (on the order of minutes), is crucial for frequency regulation and matches with EV´s abilities.

Peak Load Management/Deviation Balancing: By managing the intake and supply to the grid through charging and discharging, electric vehicles can prevent deviations within the balance group, avoiding penalties. Controlling the current values during charging and discharging, along with delaying these processes (shifting them to a later time), aids in peak load management and deviation avoidance.

Operational Reserves: In the event of a source outage, controlled discharging can serve as an agreed-upon operational reserve for supplying energy to energy systems within specified limits.

These applications showcase the versatility of electric vehicles in providing ancillary services to the electrical grid, beyond their primary function of transportation. Their ability to respond quickly to signals and contribute to grid stability makes them valuable assets in the management and optimization of the electrical power networks.

Is charging infrastructure operation sustainable also without public subsidies (in forms of grants, convertible debts) in long term?

Due to increased competition, governmental obligations related to alternative fuel infrastructure expansion (thus providing further public funding) and positive perception of capital managers, it is very probable that parallel to the boost of EV´s registration, charging infrastructure will also have parallel rising effect.

Even, based on the recent projections, it is not unrealistic, that utilisation rates of EV´s charging assets will not improve sufficiently to achieve sustainable operation (profit generation) in long term perspective.

Therefore, charging infrastructure operators should seek for alternative sources of income. The V2G seems to be very promising option. Vehicle to Grid (V2G) technology, communication standards is gaining momentum recently. In coming two to three years, major EV manufacturers (according to their announcements) should bring their popular EV models equipped with V2G functionalities on the market, supplementing thus "beardy" promoters of V2G like Nissan and Mitsubishi. (Nissan Leaf is V2G compliant from 2013).

Complementary energy system transformation is also gaining momentum. Due to energy prices shock waves, which European consumers could experience from 2022 and in line with EU Green deal strategy and Fit for 55 policies, energy sector experience drastic changes which will continue onwards. Distributed energy resources, mainly renewable energy (solar and wind) are widely deployed across continents. Demand response, flexibility, aggregators, prosumers, battery storage systems, smart grids, strengthening of interconnections, emissions reductions, all this and more are elements of ongoing energy systems transformation.

So, there is a great fit between energy system transformation and transition to electric mobility. Bidirectional charging represents great opportunity to speed up these processes and provide interesting business solutions not only for charging infrastructure operators.

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