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GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

KEY CONSIDERATIONS IN THE PLANNING OF COMMUNITY ELECTRIC VEHICLE (EV) CHARGING INFRASTRUCTURE STATIONS

Autor: Manuel Barril Rodríguez-Arana
Director: George Gross

Madrid

Junio 2022

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Key Considerations in The Planning of Community Electric Vehicle (*EV*) Charging Infrastructure Stations

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Fdo.: Manuel Barril Rodríguez -Arana Fecha: 01/06/2022

Autorizada la entrega del proyecto

EL DIRECTOR DEL PROYECTO

Fdo.: George Gross Fecha: 01/06/2022

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STATIONS

Author: Barril Rodríguez-Arana, Manuel.

Supervisor: Gross,George.

Collaborating Entity: University of Illinois at Urbana-Champaign

EXECUTIVE SUMMARY OF THE PROJECT

The proposed report aims to analyze the key to the establishment of community *EV* charging infrastructure stations and the possible scope and nature of such facilities. The principal premise is to extend the notion of community renewable energy and storage projects for the purpose of providing charging services to the members of the communities where the specific community has no available services. The investigation will explore the type of services that can be provided and the associated strategic and economic considerations for such services. In addition, we plan to investigate the modalities to ensure that all the charging electricity is carbon free and to explore renewable energy resources available. The project of planning a community electric vehicle charging infrastructure (*EVCI)* station requires to study the pertinent considerations in order to be able to absorb a growing demand of the *EV* user population in future years. *EVCI* stations are being supported by local governments that offer certain incentive programs and the rebate. One of the great attractions of the project is that it presents possible solutions to issues such as the *EV* charging schedule or the charging system.

Keywords: *EV* community charging infrastructure, CO_2 emissions

1. Introduction

The world of transportation currently undergoes a transformation to electric mobility, also known as e-mobility, away from dependence on fossil fuels. E-mobility is a term that encompasses the total or partial use of electricity in the operation of means of transport. When we talk about electrification of transportation, *EVs* come to mind, but other means such as bicycles, boats, buses, and others are also included.

EVs have appeared in the transportation landscape as an effective solution. They present great benefits in terms of effectiveness and stability towards the electric grid, in the environmental aspect as it is a key element for the reduction of CO_2 and in economic terms. This transition requires an *EVCI* to support the demand growth expected from *EVs*. Forecasts for 2030 are that there would be around 130 million *EVs* [1] in circulation and it is estimated that this would cost an investment of around $150 billion [2] to achieve the necessary *EVCI*. The current infrastructure lacks a fundamental development in the private sector in terms of the *EVCI* stations in communities where there is no personal space to charge the *EVs* because there is no parking space included in the household. We find this in many communities such as multi-unit dwellings (*MUDs*) or apartment buildings. There are countries like *CN* and the *UK* where this type of community is very recurrent and where there is an urgent need to address this issue. In these places the *EVCI* stations are being neglected due to the described barrier. With careful and effective planning, it is possible to develop an *EVCI* station in communities that do not have houses with in-home parking. This report discusses the planning considerations for the project of installing and managing a community *EVCI* station where the homeowner's association (*HOAs*) or property managers of the community are the ones in charge of the facilities.

2. The Key Requirements for the Community *EVCI* Station

To plan and implement a project it is essential to understand the user of the product. For the purpose of this report, it is the *EV* users of the communities, that are part of the project, who use the charger installation daily. These users have requirements and perspectives that need to be addressed by the project manager or *HOAs*. Table 1 summarizes the user factors that this report considers when developing the key requirements that the community *EVCI* stations must meet to satisfy the user.

Table 1. Key factors considered in the specification of community *EVCI* stations user requirements.

key user requirements factors
carbon footprint
driving range

number of EV chargers
charging time
s.o.h of the EV battery
distance to home
costs

In order to carry out an effective and coherent planning, it is essential to understand the business requirements of this project. To begin with, the people in charge of the community *EVCI* stations are the *HOAs* and property managers. They have the power to make the relevant decisions regarding the operation and facilities of the community. Table 2 summarizes the factors that this report considers when developing the key business requirements that the community *EVCI* station's needs.

Table 2. Key factors considered in the specification of community *EVCI* stations business requirements.

key business requirements factors
comprehension of EV users
scalability
cost allocation
carbon footprint
policy incentives and rebates
EV education
costs

Aligned with the user and business requirements we study the more technical ones. These refer to the aspects related to the electric vehicle supply equipment (*EVSE*), the connection to the grid and the efficiency and health of the *EV* battery. It is a key piece as it is the tool that benefits both users and *HOAs* and property managers. Table 3 summarizes the factors that this report considers when developing the key technical requirements that the community *EVCI* station's needs.

Table 3. Key factors considered in the specification of community *EVCI* stations technical requirements.

key technical requirements factors
type of charger
metering
safety
carbon footprint
battery storage system
connection to the grid
EV education

These requirements are specified and discussed to establish a clear basis for an intelligent and efficient community *EVCI* stations project planning. This report has focused on three essential requirements. First, the requirements of the *EV*-owning members of the community are defined, as they are the ones who mostly use this new facility. These requirements are focused on user comfort and to facilitate their transition to *EVs*. Second, a study of the requirements of the *HOAs* and property managers that carry out the project and address issues such as the comprehension of users' needs and trends, economy of scale in terms of electricity utility, cost-allocation that includes policy incentives and rebate programs, and user education. Third and finally, the technical requirements of the *EVSE* that have been focused on the objective that the community *EVCI* stations complies to take care of the environment, the *EV* batteries and that it works efficiently.

3. Key Strategic Considerations for Planning the Community *EVCI* Station

It is essential that *HOAs* and property managers understand if there is a necessity of implementation of an *EVCI* stations in their communities. The best way is to get to know the members of the households and see their *EV* trends. Not only does it help them understand if a project of this magnitude is necessary, but it also gives them information on how to develop it. We can obtain information on whether they plan to own or currently have an *EV* or information as important as their behavior in terms of time to use their vehicle. Therefore, in this report we give some guidelines on how to approach this issue.

When it comes to a project like the *EVCI* stations of a community, planning is critical. One of the most important aspects is the location of the charging station. In private homes that have their own parking is simple to install an *EV* charger. But when we talk about a set of communities that do not have so the facilities in terms of parking and that the installation depends on *HOAs* and property managers we see the need of a more thorough study. The characteristics that the chosen location should have been summarized in user convenience, safety, and accessibility.

The community *EVCI* stations project for the communities needs an *EVSE* that meets all the requirements proposed. This mainly refers to the user requirements and, above all, to the *EV* charging behavior of the *EV* users. Furthermore, the requirement of technical safety of the equipment with respect to the user has to be addressed.

The demand for *EVs* increases over time and seems to be gradual in nature. This allows electric grids time to increase electricity supply and upgrade existing distribution systems. These increases have already been experienced when refrigeration devices such as air conditioners, cooking devices such as ovens or microwaves, entertainment devices such as televisions and washing machines were introduced into homes. This process starts with certain regions that have greater facilities and incentives that cause a local increase that may have a negative effect on the local electricity grid. *HOAs* and property managers must address this situation with intelligent load management. This requires taking care of the *EV* charging schedules in the community *EVCI* station, add a battery storage system, or use renewable energy resources of electricity.

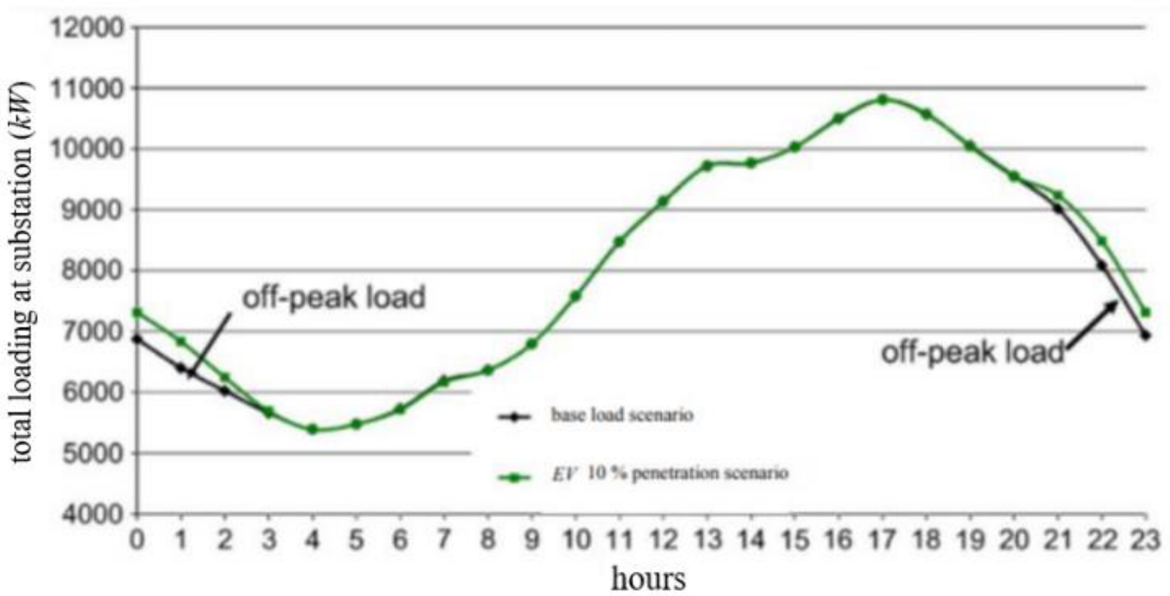

Figure 1. *EV* demand with a 10 % penetration added smartly to the base load scenario [3].

Figure 1 shows the change that occurs if the 10 % penetration caused by *EV* charging is added to the base load scenario but distributed between 21:00 and 1:00 [3]. This causes the increase in demand to be mitigated by the distribution of the load over a longer time range. Most importantly, this increase coincides with the off-peak load on the local grid, which ensures that there are no problems for the grid. There are other added benefits to seek off-peak, such as lower electricity prices due to lower demand.

This report offers a possible charging system that addresses charging flexibility in terms of schedule, adaptability to the growth of demand for *EVs* and efficiency in terms of the procedure of charge. This charging system is studied as two parts that work to achieve compliance with these requirements. On the one hand, there is the option to add chargers with a larger number of ports but to include an intelligent control management system. On the other hand, an application software that manages the moments in which each user charges his *EV*.

The general public is uninformed about *EVs* and their potential benefits. This is one of society's main problem, but it can be fixed within the community. For this project to succeed, *HOAs* and property managers need to raise awareness of *EVs* among all members of the community and have educational initiatives on this topic so that the community *EVCI* stations makes sense in that community. A team with expertise in *EVs* and knowledge of the entire project of the community *EVCI* station should held office hours. Initiatives such as webinars, educational emails or letters to homes explaining the community *EVCI* stations have a very positive impact. In this section, we mainly focus on targeting the education of community *EV* users.

The following safety recommendations [4] should be included by the *HOAs* and property managers in the community *EVCI* stations guidelines for the user:

- follow manufacturer's guidelines when charging your vehicle;
- place all components of the charging device out of the reach of children when not in use;
- signs of excessive wear may indicate possible damage to the charger;
- never use an electric vehicle charger with obvious signs of damage; and,
- cover the electrical outlet of the electric vehicle charging station to prevent water from entering.

4. Key Economic Considerations for Planning the Community *EVCI* Station

This project has to meet the requirements set out in the report. But especially one of the major barriers to *EV* adoption is the cost involved. In this section, of the report guidelines are given to help the *HOAs* and property managers must take into account the economic considerations needed for the project. There needs to be a budget that ensures that the cost paid for the community *EVCI* stations by the *EV* user in the community is not too high. This is achieved with a coherent and efficient planning aided by the guidelines given in this section. The project must be supported by a clear business model that fits the needs of the community. In addition, a cost allocation that makes sense with the chosen business model and that also encourages *EV* adoption in the community. Over time, communities around the world consider having *EVCI* stations and it is essential to try to get neighboring communities to join to carry out the project together. This is beneficial as it favors the scalability of the project and generates synergies. Due to the current situation where internal combustion (*ICE)* vehicles predominate over *EVs*. Local governments around the world offer incentives and rebates programs to encourage adoption that *HOAs* and property managers should try to take advantage of.

To study and analyze the economic considerations in this section we understand the costs that *EVCI* stations entails for the community. These costs are grouped into fixed costs and recurrent costs which can be seen in Tables 5 and 6. In this report fixed costs refer to the investment in capital or fixed assets made by a company to acquire, maintain or improve the community *EVCI* stations. In this report recurrent costs refer to the expenses required for the operation of the community *EVCI* stations.

Table 5. Fixed costs factors involved in the community *EVCI* stations.

fixed costs
EVSE
labor associated with installation
signage
application software
parking acquisition
certification costs

Table 6. Recurrent costs factors involved in the community *EVCI* stations.

recurrent costs
electricity utility
maintenance
parking rental

This project requires a large investment and careful planning to bring it to fruition. There is one aspect that is fundamental to achieve that the project goes ahead addressing the requirements of adoption to a demand growth and to have a low cost. These requirements are solved with a project that presents scalability. Scalability is defined in this case as the ability of the community *EVCI* stations to adapt and respond to the increasing demand in the community of *EVs*. The global perspective of growth of *EVs* in the world is about 24.3 *%* for 2021 – 2028 period [5]. This means that the household members of the community progressively acquire an *EV* over the years and the community *EVCI* stations must be scalable to be able to absorb this demand. The *HOAs* and property managers in order to make the project scalable, they must benefit from economies of scale and make the project modular in nature.

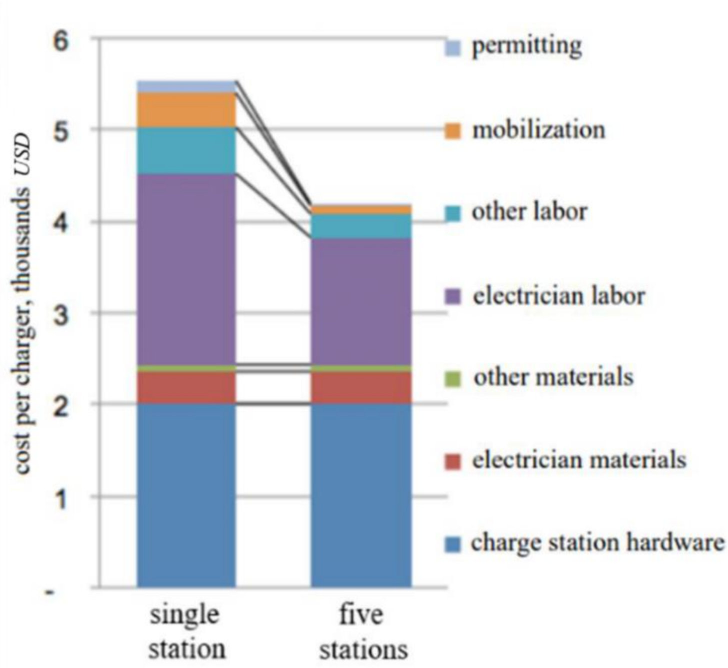

Figure 2. Cost comparison of single station versus five stations [6].

It is key that the community interested in an *EVCI* station seek support from other communities and do the project together. The more communities involved, the more they can benefit from economies of scale and reduce fixed and recurrent costs since better prices are obtained and the cost is distributed among more people. This can be clearly seen in the Figure 2 [6].

In the report all the costs involved in an *EVCI* station in a community are discussed. These costs compared to those of an *ICE* vehicle are much higher. This is due to the fact that the gas stations infrastructure for these vehicles is already in place and there is no clear infrastructure for EVs. In this situation, if we want to achieve this overtake of the number of *EVs* with respect to *ICE* vehicles, governments have begun to develop a program of incentive policies and rebates to encourage this inclusion. *HOAs* and property managers should focus on taking advantage of these incentives to carry out the community *EVCI* stations project.

These policies are a tool to be used in the economic planning of the project. They are mostly offered by *OECD* countries and are focused on the following support:

- economic incentives by local governments in relation to the required *EVSE* of new recharging networks to be included in the *EVCI;*

- the availability of financial resources, such as loans on attractive terms, made available by local governments;
- to streamline and to bundle of the certificates required for the use of users; and,
- the facilitation of the necessary access permits to integrate the community *EVCI* stations into local grids.

For the economic considerations, it is essential that *HOAs* and property managers have a clear business model. This helps future decisions to be made because there is a clear objective. Depending on the objective of the project, the economic outlook can be one or another. On the one hand, the project, as already explained, has the participating communities and their representatives such as *HOAs* and property managers who are in charge of the project and who have to carry out the business model. On the other hand, there are the community members who are the users of the community *EVCI* stations.

For the economic considerations, it is essential that *HOAs* and property managers have a clear business model. This helps future decisions to be made because there is a clear objective. Depending on the objective of the project, the economic outlook can be one or another. On the one hand, the project, as already explained, has the participating communities and their representatives such as *HOAs* and property managers who are in charge of the project and who have to carry out the business model. On the other hand, there are the community members who are the users of the community *EVCI* stations. All this is included in the business model that *HOAs* and property managers have to carry out. As analyzed in the report, the objectives of this model must be aligned with those of the *EV* users and not penalize them with high prices. The objective is to offer a community service and that all revenues are reinvested in the project. In addition, technologies such as *V2G* should not be overlooked as they can offer a great opportunity to help finance community *EVCI* stations.

5. Conclusion and Future Opportunities

This report has focused to analyze the different considerations in the planning of a community *EVCI* stations. By studying the user, business and technical needs, a series of essential requirements have resulted that serve as metrics for planning. This list of requirements has been developed and explained so that *HOAs* and property managers read this report and realize the real needs that must be addressed during the project.

Due to the lack of information on community *EVCI* stations projects, the main contribution of the report would be the three main Chapters 2, 3 and 4 where an analysis of considerations for the planning of these projects is developed. It has been divided into two parts, the first one is Chapter 2 to collect the relevant user, business, and technical needs, and then Chapters 3 and 4 where it goes in depth to solve those needs in terms of planning.

The proposed schedule and charging system are one of the major contributions of the report. Because one of the biggest barriers to not developing *EVCI* stations in communities was the problem of the loading schedule and how to do it. By means of charging in zones A and B, proposed by the report, added with the software application and with the new design of electric chargers with double closed circuit and dual-port in each one, it is possible to overcome this barrier.

In terms of economics, we find several additional contributions. On the one hand, taking advantage of economies of scale by having several communities agree to join in a common community *EVCI* stations project instead of several separate ones. This allows costs to be reduced considerably and allows this electricity demand to be treated at a company price rather than the private price of a normal household. On the other hand, regarding the possibilities of taking advantage of the community *EVCI* stations and cost reduction we find the use of the time of use (*TOU)* rates since it is observed that the results of price versus other rates are that in the *TOU* rates, we obtain a cost reduction. This is since the demand for *EVs* takes advantage of the off-peak demands where the electricity supply exceeds the electricity demanded.

For all the work of transitioning to electrified transportation to make sense, there must be an increase in demand for *EVs* over the next few years. community *EVCI* stations projects must be a top priority in order for that demand to be absorbed. *RERs*, *EV* education for community members and *V2G* technology are the aspects to be considered in future years and to encourage their development.

The first thing to observe in the future is to achieve a transition to obtain electricity in such a way that there are no CO_2 emissions, and this is achieved through renewable energy resources (*RERs)*. These types of resources are irregular as they depend on natural resources that are not very predictable. In the current scenario, great progress is being made but greater inclusion in the electricity grid is still lacking.

As for the education of community members, it is essential for them to understand that the transition to *EVs* occurs because of the benefits it has for both the user and society. It is a work to be done every year to bring a real change in the way people think. This report serves as a start towards this new panorama of transportation and specifically of *EVCI* stations.

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KEY CONSIDERATIONS IN THE PLANNING OF COMMUNITY ELECTRIC VEHICLE (*EV*) CHARGING INFRASTRUCTURE

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Autor: Barril Rodríguez-Arana, Manuel.

Director: Gross,George.

Entitad Colaboradora: University of Illinois at Urbana-Champaign

RESUMEN EJECUTIVO DEL PROYECTO

El informe propuesto tiene como objetivo analizar las claves para el establecimiento de estaciones comunitarias de infraestructura de recarga de vehículos eléctricos (*VE*) y el posible alcance y naturaleza de dichas instalaciones. La premisa principal es ampliar la noción de proyectos comunitarios de energía renovable y almacenamiento con el fin de proporcionar servicios de recarga a los miembros de las comunidades donde la comunidad específica no tiene servicios disponibles. La investigación explorará el tipo de servicios que pueden proporcionarse y las consideraciones estratégicas y económicas asociadas para tales servicios. Además, tenemos previsto investigar las modalidades para garantizar que toda la electricidad de carga esté libre de emisiones de CO_2 y explorar los recursos energéticos renovables disponibles. El proyecto de planificación de una estación comunitaria de infraestructura de recarga de *VE*s requiere estudiar las consideraciones pertinentes para poder absorber una demanda creciente de la población usuaria de vehículos eléctricos en los próximos años. Las estaciones cuentan con el apoyo de los gobiernos locales que ofrecen ciertos programas de incentivos. Uno de los grandes atractivos del proyecto es que presenta posibles soluciones a cuestiones como el horario de carga del *VE* el sistema de carga.

Palabras clave: infraestructura comunitaria de recarga de *VE*s, emisiones de CO_2

1. Introducción

El mundo del transporte experimenta actualmente una transformación hacia la movilidad eléctrica, también conocida como e-movilidad, alejándose de la dependencia de los combustibles fósiles. La movilidad eléctrica es un término que engloba el uso total o parcial de la electricidad en el funcionamiento de los medios de transporte. Cuando hablamos de electrificación del transporte, nos vienen a la mente los *VE*s, pero también se incluyen otros medios como las bicicletas, los barcos y los autobuses, entre otros.

Los *VEs* han aparecido en el panorama del transporte como una solución eficaz. Presentan grandes beneficios en términos de eficacia y estabilidad frente a la red eléctrica, en el aspecto medioambiental al ser un elemento clave para la reducción del CO_2 y en términos económicos. Esta transición requiere una infraestructura para soportar el crecimiento de la demanda que se espera de los vehículos eléctricos. Las previsiones para 2030 apuntan a que habrá unos 130 millones de *VE*s [1] en circulación y se calcula que esto supondrá una inversión de unos 150,000 millones de dólares [2] para conseguir la infraestructura necesaria. La infraestructura actual carece de un desarrollo fundamental en el sector privado en cuanto a las estaciones de carga de *VEs* en las comunidades donde no hay espacio personal para cargar los *VEs* porque no hay espacio de aparcamiento incluido en el hogar. Esto lo encontramos en muchas comunidades, como en las viviendas múltiples o en los edificios de apartamentos. Hay países como la *CN* y *UK* en los que este tipo de comunidades es muy recurrente y en los que hay una necesidad urgente de abordar esta cuestión. En estos lugares las estaciones de carga están siendo descuidadas debido a la barrera descrita. Con una planificación cuidadosa y eficaz, es posible desarrollar una estación en comunidades que no disponen de viviendas con aparcamiento dentro de la casa. Este informe analiza las consideraciones de planificación para el proyecto de instalación y gestión de una estación comunitaria en la que los administradores de la propiedad son los encargados de las instalaciones.

2. Los Requisitos Clave de la Estación Comunitaria de Carga de *VEs*

Para planificar y poner en marcha un proyecto es esencial entender al usuario del producto. A efectos de este proyecto, se trata de los usuarios de *VEs* de las comunidades, que forman parte del proyecto, que utilizan la instalación de cargadores a diario. Estos usuarios tienen requisitos y perspectivas que deben ser abordados por el director del proyecto o las comunidades de propietarios. La Tabla 1 resume los factores del usuario que este proyecto tiene en cuenta a la hora de desarrollar los requisitos clave que las estaciones de carga de *VEs* de la comunidad deben cumplir para satisfacer al usuario.

Tabla 1. Factores clave considerados en la especificación de los requisitos de los usuarios de las estaciones comunitarias de carga de *VEs*.

factores clave de los requisitos del usuario
huella de carbono
área de manejo
*número de cargadores de VE*s
tiempo de carga
estado de salud de la batería del VE
distancia a casa
costes

Para llevar a cabo una planificación eficaz y coherente, es esencial comprender los requisitos empresariales de este proyecto. Para empezar, los responsables de las estaciones de carga de la comunidad son las asociaciones de propietario. Ellos tienen el poder de tomar las decisiones pertinentes sobre el funcionamiento y las instalaciones de la comunidad. La Tabla 2 resume los factores que este proyecto tiene en cuenta a la hora de desarrollar los requisitos empresariales clave que necesita la estación comunitaria de carga de *VEs*.

Tabla 2. Factores clave considerados en la especificación de los requisitos como empresa de las estaciones comunitarias de carga de *VEs*.

factores clave de requisitos como empresa
comprensión de los usuarios de VEs
escalabilidad
asignación de costes

huella de carbono
políticas de incentivos y reembolsos
educación en vehículos eléctricos
costes

Alineados con los requerimientos del usuario y del negocio estudiamos los más técnicos. Hacen referencia a los aspectos relacionados con los equipos de alimentación del vehículo eléctrico, la conexión a la red y la eficiencia y salud de la batería del *VE*. Es una pieza clave ya que es la herramienta que beneficia tanto a los usuarios como a las comunidades de propietarios. La Tabla 3 resume los factores que este proyecto considera al desarrollar los requisitos técnicos clave que necesita la estación comunitaria.

Tabla 3. Factores clave considerados en la especificación de los requisitos técnicos de las estaciones comunitarias de carga de *VEs*.

factores clave de requisitos técnicos
tipo de cargador
medida
la seguridad
huella de carbono
sistema de almacenamiento de batería
conexión a la red
educación en VEs

Estos requisitos se especifican y discuten con el fin de establecer una base clara para la planificación de un proyecto inteligente y eficiente de estaciones de carga de *VE*s comunitarias. Este proyecto se ha centrado en tres requisitos esenciales. En primer lugar, se definen los requisitos de los miembros de la comunidad que poseen un *VE*, ya que son los que más utilizan esta nueva instalación. Estos requisitos se centran en la comodidad del usuario y en facilitar su transición a los *VE*s. En segundo lugar, se estudian los requisitos de las asociaciones de propietarios que llevan a cabo el proyecto y se abordan cuestiones como la comprensión de las necesidades y tendencias de los usuarios, la economía de escala en términos de utilidad eléctrica, la asignación de costes que incluye los incentivos políticos y los programas de reembolso, y la educación de los usuarios. En tercer y último lugar, los requisitos técnicos del equipamiento que se han centrado en el objetivo de que las estaciones comunitarias de carga de *VE*s cumplan con el cuidado del medio ambiente, las baterías de los *VE*s y que funcionen de forma eficiente.

3. Consideraciones Estratégicas Clave para la Planificación Comunitaria de la Estación de Carga de *VEs*

Es esencial que las asociaciones de propietarios comprendan si es necesario implantar estaciones de *VE*s en sus comunidades. La mejor manera es conocer a los miembros de las viviendas y ver sus tendencias en materia de *VE*s. No sólo les ayuda a entender si es necesario un proyecto de esta magnitud, sino que también les da información sobre cómo desarrollarlo. Podemos obtener información sobre si planean tener o tienen actualmente un *VE* o información tan importante como su comportamiento en cuanto al tiempo de uso de su vehículo. Por ello, en este proyecto damos algunas pautas sobre cómo abordar esta cuestión.

Cuando se trata de un proyecto como las estaciones de carga de *VEs* de una comunidad, la planificación es fundamental. Uno de los aspectos más importantes es la ubicación de la estación de recarga. En las casas particulares que tienen su propio aparcamiento es sencillo instalar un cargador de *VE*. Pero cuando hablamos de un conjunto de comunidades que no tienen tantas facilidades en cuanto a aparcamiento y que la instalación depende de las comunidades de propietarios vemos la necesidad de un estudio más exhaustivo. Las características que debe tener la ubicación elegida se resumen en la comodidad del usuario, la seguridad y la accesibilidad.

El proyecto de estaciones de carga de *VE*s comunitarias para las comunidades necesita un equipamiento que cumpla con todos los requisitos propuestos. Esto se refiere principalmente a los requisitos del usuario y, sobre todo, al comportamiento de carga del *VE* de los usuarios. Además, hay que tener en cuenta el requisito de seguridad técnica del equipo con respecto al usuario.

La demanda de *VE*s aumenta con el tiempo y parece ser de naturaleza gradual. Esto da tiempo a las redes eléctricas para aumentar el suministro de electricidad y mejorar los sistemas de distribución existentes. Estos aumentos ya se experimentaron cuando se introdujeron en los hogares dispositivos de refrigeración, como los aparatos de aire acondicionado, de cocina, como los hornos o los microondas, y de entretenimiento, como los televisores y las lavadoras. Este proceso comienza con ciertas regiones que tienen mayores instalaciones e incentivos que provocan un aumento local que puede tener un efecto negativo en la red eléctrica local. Las comunidades de propietarios deben hacer frente a esta situación con una gestión inteligente de la carga. Para ello es necesario cuidar los horarios de carga de los vehículos eléctricos en la estación de carga de *VE*s de la comunidad, añadir un sistema de almacenamiento en batería o utilizar recursos de energía renovable de electricidad.

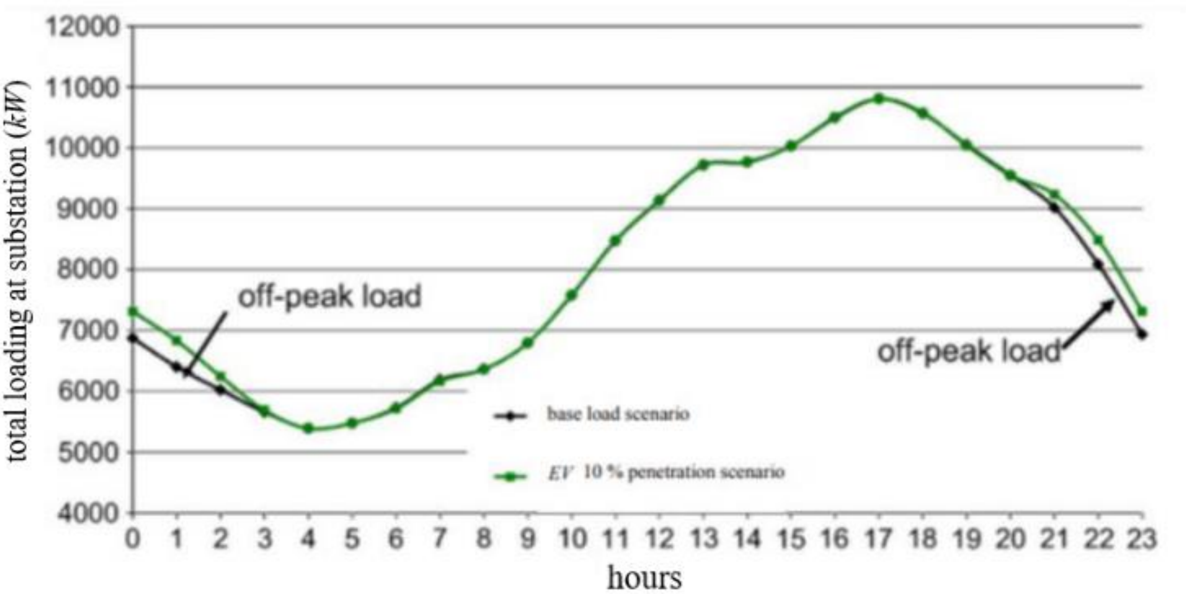

Figura 1. Demanda de *VE*s con una penetración del 10 % añadida de forma inteligente al escenario de carga base [3].

La Figura 1 muestra el cambio que se produce si la penetración del 10 % provocada por la carga de los vehículos eléctricos se añade al escenario de carga base, pero distribuida entre las 21:00 y la 1:00 [3]. Esto hace que el aumento de la demanda se vea mitigado por la distribución de la carga en una franja horaria más larga. Y lo que es más importante, este aumento coincide con la carga fuera de horas punta en la red local, lo que garantiza que no haya problemas para la red. Hay otros beneficios añadidos por buscar la carga fuera de las horas punta, como precios más bajos de la electricidad debido a la menor demanda.

Este proyecto ofrece un posible sistema de recarga que aborda la flexibilidad de la carga en términos de horario, la adaptabilidad al crecimiento de la demanda de *VE* y la eficiencia en términos del procedimiento de carga. Este sistema de recarga se estudia en dos partes que funcionan para lograr el cumplimiento de estos requisitos. Por un lado, existe la opción de añadir cargadores con un mayor número de puertos, pero incluyendo un sistema de gestión de control inteligente. Por otro lado, un software de aplicación que gestione los momentos en los que cada usuario carga su *VE*.

El público en general está desinformado sobre los *VE*s y sus posibles beneficios. Este es uno de los principales problemas de la sociedad, pero se puede solucionar dentro de la comunidad. Para que este proyecto tenga éxito, las comunidades de propietarios deben concienciar a todos los miembros de la comunidad sobre los *VE*s y llevar a cabo iniciativas educativas sobre este tema para que las estaciones comunitarias de *VE*s tengan sentido en esa comunidad. Un equipo experto en VE y conocedor de todo el proyecto de la estación comunitaria de carga de *VE*s debería celebrar horas de oficina. Iniciativas como seminarios web, correos electrónicos educativos o cartas a los hogares explicando las estaciones comunitarias de carga de *VE*s tienen un impacto muy positivo. En esta sección, nos centramos en la educación de los usuarios de vehículos eléctricos comunitarios.

Las siguientes recomendaciones de seguridad [4] deberían ser incluidas por las asociaciones de propietarios en las directrices de las estaciones comunitarias de carga de *VE*s para el usuario:

- siga las directrices del fabricante cuando cargue su vehículo;
- coloque todos los componentes del dispositivo de carga fuera del alcance de los niños cuando no los utilice;
- los signos de desgaste excesivo pueden indicar posibles daños en el cargador
- no utilice nunca un cargador de vehículo eléctrico con signos evidentes de daños; y,
- cubra la toma de corriente de la estación de carga del vehículo eléctrico para evitar la entrada de agua.

4. Consideraciones Económicas Clave para la Planificación de la Estación Comunitaria de Carga de *VEs*

Este proyecto tiene que cumplir los requisitos establecidos en el proyecto. Pero, sobre todo, uno de los principales obstáculos para la adopción del *VE* es el coste que conlleva. En esta sección, del proyecto se dan directrices para ayudar a las comunidades de propietarios deben tener en cuenta las consideraciones económicas necesarias para el proyecto. Es necesario contar con un presupuesto que garantice que el coste pagado por las estaciones comunitarias de *VE* por el usuario en la comunidad no sea demasiado elevado. Esto se consigue con una planificación coherente y eficiente ayudada por las directrices que se dan en esta sección. El proyecto debe apoyarse en un modelo de negocio claro que se ajuste a las necesidades de la comunidad. Además, una asignación de costes que tenga sentido con el modelo de negocio elegido y que también fomente la adopción del *VE* en la comunidad. Con el tiempo, las comunidades de todo el mundo se plantean tener estaciones de carga de VEs y es fundamental intentar que las comunidades vecinas se unan para llevar a cabo el proyecto de forma conjunta. Esto es beneficioso porque favorece la escalabilidad del proyecto y genera sinergias. Debido a la situación actual en la que los vehículos de combustión interna predominan sobre los *VE*s. Los gobiernos locales de todo el mundo ofrecen programas de incentivos y reembolsos para fomentar la adopción que las comunidades de propietarios deberían intentar aprovechar.

Para estudiar y analizar las consideraciones económicas en este apartado se entienden los costes que las estaciones de carga de *VE*s suponen para la comunidad. Estos costes se agrupan en costes fijos y costes recurrentes que se pueden ver en las Tablas 5 y 6. En este proyecto los costes fijos se refieren a la inversión en capital o activos fijos que realiza una empresa para adquirir, mantener o mejorar las estaciones de carga de *VE*s comunitarias. Los costes recurrentes se refieren a los gastos necesarios para el funcionamiento de las estaciones de carga de *VE*s comunitarias.

Tabla 5. Factores de costes fijos que intervienen en las estaciones de carga de *VE*s.

costes fijos
equipamiento de carga de VEs
mano de obra asociada con la instalación
señalización
software de la aplicación
adquisición de estacionamiento

costes de certificación

Table 6. Factores de costes recurrentes que intervienen en las estaciones de carga de *VE*s.

costes recurrentes
servicio de electricidad
mantenimiento
alquiler de estacionamiento

Este proyecto requiere una gran inversión y una cuidadosa planificación para llevarlo a cabo. Hay un aspecto que es fundamental para conseguir que el proyecto salga adelante atendiendo a los requisitos de adopción a un crecimiento de la demanda y a tener un bajo coste. Estos requisitos se resuelven con un proyecto que presenta escalabilidad. La escalabilidad se define en este caso como la capacidad de las estaciones de carga de *VE*s de adaptarse y responder a la creciente demanda de la comunidad de *VE*s. La perspectiva global de crecimiento de los *VE*s en el mundo es de aproximadamente el 24,3% para el periodo 2021 - 2028 [5]. Esto significa que los miembros de la comunidad adquieren progresivamente un *VE* a lo largo de los años y las estaciones de carga de *VE*s de la comunidad deben ser escalables para poder absorber esta demanda. Para que el proyecto sea escalable, las comunidades de propietarios deben beneficiarse de las economías de escala y hacer que el proyecto sea de carácter modular.

Es clave que la comunidad interesada en una estación de carga de *VE*s busque el apoyo de otras comunidades y haga el proyecto conjuntamente. Cuantas más comunidades participen, más podrán beneficiarse de las economías de escala y reducir los costes fijos y recurrentes, ya que se obtienen mejores precios y el coste se distribuye entre más personas. Esto puede verse claramente en la Figura 2 [6].

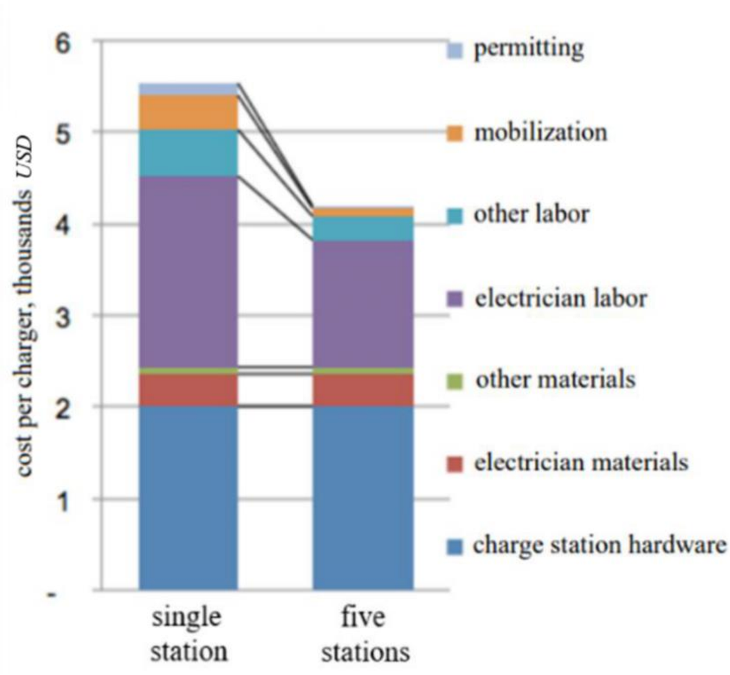

Figura 2. Comparación de costes entre una estación y cinco estaciones [6].

En el proyecto se analizan todos los costes que conlleva una estación de carga de *VE*s en una comunidad. Estos costes comparados con los de un vehículo de combustión interna son mucho más elevados. Esto se debe a que la infraestructura de las gasolineras para estos vehículos ya está en marcha y no hay una infraestructura clara para los *VE*s. En esta situación, si se quiere conseguir esta superación del número de *VE*s respecto a los vehículos de combustión interna, los gobiernos han comenzado a desarrollar un programa de políticas de incentivos y rebajas para fomentar esta inclusión. Las comunidades de propietarios deben centrarse en aprovechar estos incentivos para llevar a cabo el proyecto de estaciones comunitarias de carga de *VE*s.

Estas políticas son una herramienta para utilizar en la planificación económica del proyecto. En su mayoría son ofrecidas por los países de la *OCDE* y se centran en los siguientes apoyos:

- incentivos económicos por parte de los gobiernos locales en relación con el equipamiento necesario de las nuevas redes de recarga que se incluyan en las estaciones de carga de *VE*s;
- la disponibilidad de recursos financieros, como préstamos en condiciones atractivas, puestos a disposición por los gobiernos locales;
- la agilización y agrupación de los certificados requeridos para el uso de los usuarios; y
- la facilitación de los permisos de acceso necesarios para integrar las estaciones

comunitarias de carga de *VE*s en las redes locales.

En cuanto a las consideraciones económicas, es esencial que las comunidades de propietarios tengan un modelo de negocio claro. Esto ayuda a tomar decisiones futuras porque hay un objetivo claro. Dependiendo del objetivo del proyecto, las perspectivas económicas pueden ser unas u otras. Por un lado, el proyecto, como ya se ha explicado, cuenta con las comunidades participantes y sus representantes, como las comunidades de propietarios, que son los encargados del proyecto y los que tienen que llevar a cabo el modelo de negocio. Por otro lado, están los comuneros que son los usuarios de las estaciones de carga de *VE*s.

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5. Conclusión y Oportunidades Futuras

Este proyecto se ha centrado en analizar las diferentes consideraciones en la planificación de una estación comunitaria de carga de *VE*s. Mediante el estudio de las necesidades de los usuarios, de la empresa y de la técnica, se ha obtenido una serie de requisitos esenciales que sirven como métrica para la planificación. Esta lista de requisitos ha sido elaborada y explicada para que las comunidades de propietarios lean este proyecto y se den cuenta de las necesidades reales que deben ser atendidas durante el proyecto.

Debido a la falta de información sobre los proyectos de las estaciones comunitarias de carga de *VE*s, la principal aportación del proyecto serían los tres Capítulos principales 2, 3 y 4 donde se desarrolla un análisis de las consideraciones para la planificación de estos proyectos. Se ha dividido en dos partes, la primera es el Capítulo 2 para recoger las necesidades relevantes de los usuarios, de las empresas y de los técnicos, y luego los Capítulos 3 y 4 donde se profundiza en la solución de esas necesidades en términos de planificación.

La propuesta de calendario y sistema de tarificación es una de las principales aportaciones del proyecto. Porque una de las mayores barreras para no desarrollar las estaciones de carga de *VE*s en las comunidades era el problema del horario de carga y cómo hacerlo. Mediante la carga en zonas A y B, propuesta por el proyecto, añadida con la aplicación de software y con el nuevo diseño de cargadores eléctricos con doble circuito cerrado y doble puerto en cada uno, es posible superar esta barrera.

En términos económicos, encontramos varias aportaciones adicionales. Por un lado, el aprovechamiento de las economías de escala, al acordar que varias comunidades se unan en un proyecto común de estaciones de carga de *VE*s en lugar de varias por separado. Esto permite reducir considerablemente los costes y que esta demanda de electricidad sea tratada a precio de empresa y no a precio privado de un hogar normal. Por otro lado, en cuanto a las posibilidades de aprovechamiento de las estaciones comunitarias de carga de *VE*s y la reducción de costes nos encontramos con el uso de las tarifas de tiempo de uso ya que se observa que los resultados de precio frente a otras tarifas son que en las tarifas de tiempo de uso se obtiene una reducción de costes. Esto se debe a que la demanda de *VE* aprovecha las demandas fuera de horas punta en las que la oferta de electricidad es superior a la demandada.

Para que todo el trabajo de transición hacia el transporte electrificado tenga sentido, debe haber un aumento de la demanda de *VE* en los próximos años. los proyectos de estaciones comunitarias de carga de *VE*s deben ser una prioridad absoluta para que esa demanda sea absorbida. Los recursos de energía renovable, la educación en materia de *VE* para los miembros de la comunidad y la tecnología de vehículo conectado a la red son los aspectos a tener en cuenta en los próximos años y a fomentar su desarrollo.

Lo primero que hay que observar en el futuro es conseguir una transición para obtener electricidad de forma que no haya emisiones de CO_2, y esto se consigue a través de los recursos energéticos renovables. Este tipo de recursos son irregulares ya que dependen de recursos naturales poco predecibles. En el escenario actual se está avanzando mucho, pero aún falta una mayor inclusión en la red eléctrica.

En cuanto a la educación de los miembros de la comunidad, es esencial que entiendan que la transición a los *VE*s se produce por los beneficios que tiene tanto para el usuario como para la sociedad. Es un trabajo que hay que hacer cada año para conseguir un cambio real en la forma de pensar de la gente. Este proyecto sirve como inicio hacia este nuevo panorama del transporte y en concreto de las estaciones de carga de *VE*s.

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KEY CONSIDERATIONS IN THE PLANNING OF COMMUNITY ELECTRIC VEHICLE (*EV*) CHARGING INFRASTRUCTURE STATIONS

By

Manuel Barril Rodriguez Arana

Senior Thesis in Electrical Engineering

University of Illinois at Urbana-Champaign

Advisor: George Gross

June 2022

Abstract

To mitigate the emission of greenhouse gases, the *EV* is considered an efficient alternative to the internal combustion engine vehicle. To maximize the *EV* user and grid benefits, it is necessary to devise an intelligent implementation of the *EV* charging infrastructure. The community charging station will be the ideal charging location for *EV* users. It will be in communities that have households without in-home parking where the *EV* charging infrastructure (*EVCI*). Community members that have no charging options close to their homes have to rely on commercial or public *EVCI*. To be able to charge the *EV* during the hours when the user is at home is a great advantage in terms of convenience.

The proposed report aims to analyze the key to the establishment of community *EV* charging infrastructure stations and the possible scope and nature of such facilities. The principal premise is to extend the notion of community renewable energy and storage projects for the purpose of providing charging services to the members of the communities where the specific community has no available services. The investigation will explore the type of services that can be provided and the associated strategic and economic considerations for such services. In addition, we plan to investigate the modalities to ensure that all the charging electricity is carbon free and to explore renewable energy resources available. The project of planning a community *EVCI* station requires to study the pertinent considerations in order to be able to absorb a growing demand of the *EV* user population in future years. *EVCI* stations are being supported by local governments that offer certain incentive programs and the rebate. One of the great attractions of the project is that it presents possible solutions to issues such as the EV charging schedule or the charging system.

The report starts with the necessary requirements of the users, the business part, and finally the technical aspects. These serve as metrics to build an efficient and intelligent community *EV* charging infrastructure station. Moreover, it continues with the planning of the strategical aspects and the economics to meet all the requirements. This systematic process generates a report that can be used by all communities worldwide to start the implementation of a community *EVCI* station. There is a high complexity barrier as everything is still in the development phase especially in terms of the technology surrounding *EVs*. The positive results are that due to the promising future of *EVs*, these facilities following the report's planning can be efficiently carried out.

Acknowledgements

I wanted to thank my advisor Prof. George Gross whose insight and knowledge of the subject guided me in this research. Without his support, encouragement, and patience I would not have been able to enjoy and develop this report.

I would like to express my sincere thanks to Jorge and Felipe with whom we have built a special trust throughout this year abroad.

My final thanks go to my family for always believing in me and for their unconditional support.

Table of Contents

List of figures

List of tables

CHAPTER 1:

INTRODUCTION

Electric vehicles are composed of a battery which allows them to have a certain range of kilometers of autonomy. It is recharged by a charger that provides the necessary electricity. This charger would be the equivalent of a gas station for the internal combustion engine (*ICE*) vehicles. The inherent *EV* characteristics render them noiseless when they are driven and provide an excellent energy efficiency.

The benefits allow its adoption to become a reality in the near-term future. We discuss that for this to happen an infrastructure is needed to support the demand of *EVs*. This is the so-called the *EVCI*, which consists of the *EVCI* stations and the entire distribution system that surrounds them. We then explain why this report is necessary for the development of a community *EVCI* stations around the world and why it sheds light on issues that had not been addressed. In the final steps of this chapter, we discuss the content guide of the report. The analysis and study content of this report is carried out on Chapters 2, 3 and 4, where the essential planning to achieve the desired effective and intelligent community *EVCI* stations are developed.

1.1 EVs deployment

The world of transportation currently undergoes a transformation to electric mobility, also known as e-mobility, away from dependence on fossil fuels. E-mobility is a term that encompasses the total or partial use of electricity in the operation of means of transport. When we talk about electrification of transportation, *EVs* come to mind, but other means such as bicycles, boats, buses, and others are also included.

Figure 1 shows that in terms of inland transport, the most widely used is the passenger vehicle. Approximately 83 % of the Europe population uses this means of transport [1]. Therefore, we felt that the report should study and analyze the relevant considerations for the community *EVCI* stations focusing on providing a service for *EV* users.

This trend towards an electrified world is due to the benefits it offers to consumers, communities, and society in general. These benefits are primarily economic, environmental, and electric grid oriented [2].

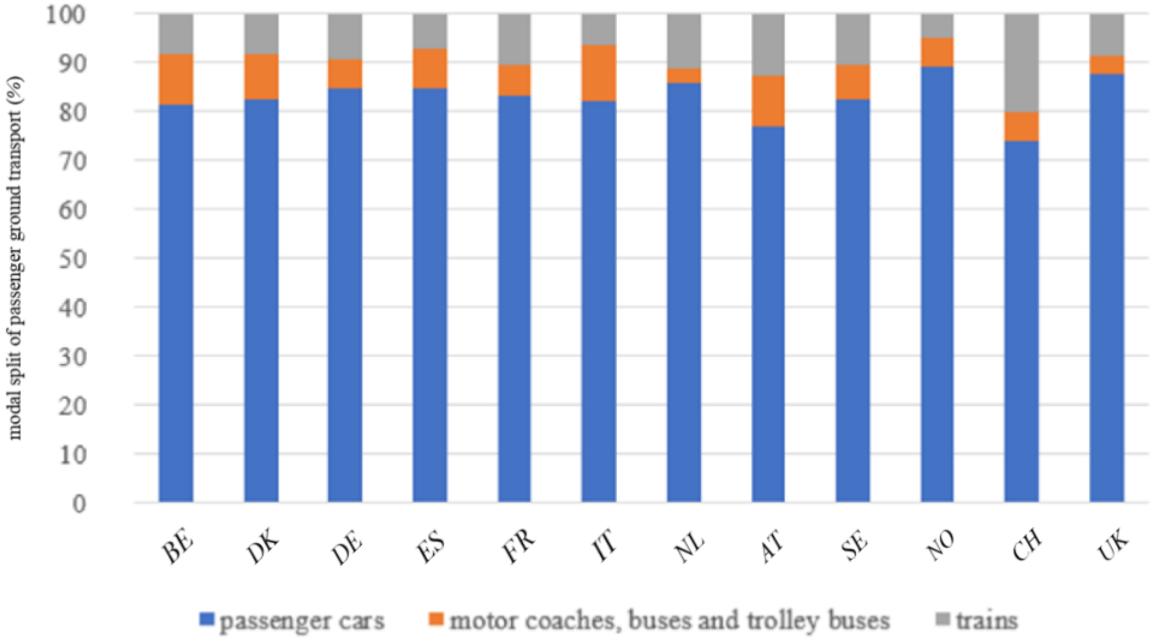

Figure 1. Modal split of passenger ground transport in countries from Europe [1].

In terms of the economics the *EVs* present a great opportunity for both economic development and cost reduction. *EVs* present an increase in electricity consumption, reduce oil imports, and saves money on fuel. All of this increases the gross domestic product (*GDP*) and generate a positive economic development that encourages new jobs related to this innovative technology. In addition, *EVs* bring a reduction in maintenance and refueling costs over the life of the *EVs* compared to *ICE* vehicles. The main barrier would be the large upfront payments required for the installation of an *EVCI* station, but with time and technology improvement these payments should be decreasing.

As for the impact on the electric grid, we find that with the planning proposed in this report *EVs* have a great benefit. This comes in the form of a positive impact of the demand for *EVs* on the grid as they improve efficiency and bring stability to it. *EVs* are characterized as a significant and flexible load introduced to the grid. Efficiency is achieved with the flexibility they present since at times of off-peak load, such as at night, this load allows to absorb the electricity that was not used. Another significant aspect is how they are also able to encourage the use of renewable resources to obtain electricity. Even if it is mostly irregular because it depends on natural resources, since the load of the *EVs* can take care of the moments in which these resources produce a large amount of electricity and there is not enough demand to absorb it. With the addition of this new demand, the inclusion of smart charging is encouraged. The system would understand through data the supply and demand situation and adjust to the needs of both the grid and the customer, promoting a great stability. This could be developed to other electrical demands such as households.

As for the environment, there are several benefits of the transition to *EVs*. Despite that the electricity to charge an EV in many cases is obtained from fossil fuel resources, EVs are still a major reducer of greenhouse gas emissions. For instance, *CN* has had a 20 % reduction in emissions from *EVs* [3]. One of the biggest concerns is the carbon footprint of the battery. It generates CO_2 but with the improvement of the technology this emission could be reduced and become non-existent. Currently the carbon footprint of a standard *EV* battery is between 2 and 3 times less than the amount in 2017 [4]. A major benefit is that after manufactured, *EVs* do not pollute the air they drive through. *ICE* vehicles, on the other hand, continuously increase pollution when they are used.

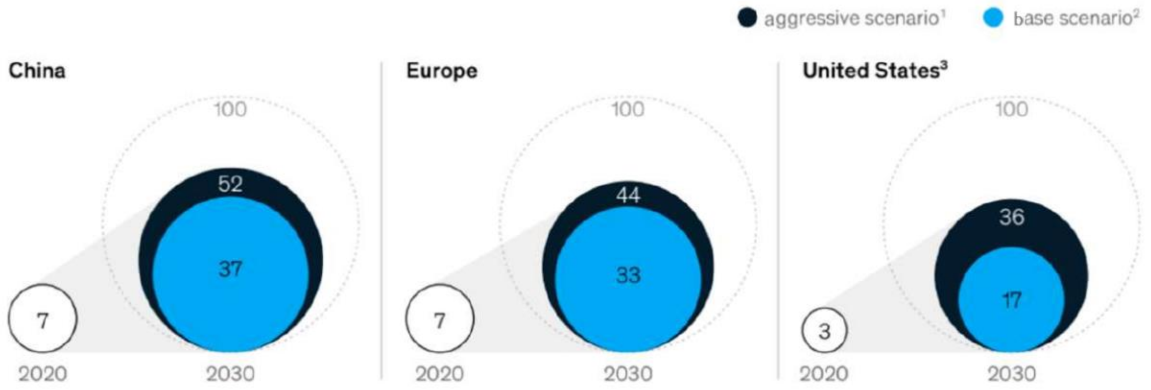

Figure 2. Projected *EV* share of light-vehicle market [5].

It is all these benefits that favor an increase in the adoption of EVs. This adoption for *CN*, Europe, and the *US* is expected to be in 2030 around a 37 %, 33 % and 17 % of the market share of vehicles respectively [5].

1.2 The charging infrastructure for *EVs*

In order to have the expected demand for *EVs* in the next years, it is necessary to have an infrastructure that can support it. *EV* users must be convinced that there are enough charging points so that it does not become an inconvenience at the time of purchase or use. To describe this infrastructure, we use the acronym *EVCI*, which encompasses all aspects of the infrastructure needed to provide electricity for charging *EVs*. It consists of a network of charging stations called *EVCI* stations, which in turn divides this infrastructure into three parts. The first part is the infrastructure needed between the stations where the electricity is created and the meter where we find the distribution structure that supplies the electricity to the user. In this case there is a transformer before the meter in charge of providing the necessary voltage to charge the *EVs*. The second part is the infrastructure from the meter to the charger which includes all the wiring and circuits that connect the meter to the charger. The third part consists of the charger itself which is different depending on the voltage necessities of the *EVs*.

The problem with the *EVCI* is that it is not yet developed, and it is currently in an expansion phase. *EV* users are not fully confident that they have enough charging points, so governments incentivize the rise in demand for *EVs* by public funded charging stations. On the other hand, the private sector realizes that they can create a profitable business model by supplying an *EV* charging service. Therefore, in the *EVCI* both the private and the public sector coexist to create an *EVCI* network that can support and encourage this transition to *EVs*.

An important advantage over the gas stations for *ICE* vehicles is that electricity has greater accessibility as it arrives to each household. On the other hand, gasoline cannot be supplied to the household itself making the infrastructure fail in convenience. The *EVCI* should take advantage of this, and the private sector involved with communities and private houses should install charging points. This is where the report brings great value and lay the groundwork for developing *EVCI* stations at the community level where there is a huge gap in development.

1.3 Motivation and nature of contributions of this report

EVs have appeared in the transportation landscape as an effective solution. They present great benefits in terms of effectiveness and stability towards the electric grid, in the environmental aspect as it is a key element for the reduction of CO_2 and in economic terms. This transition requires an *EVCI* to support the demand growth expected from *EVs*. Forecasts for 2030 are that there would be around 130 million *EVs* [6] in circulation and it is estimated that this would cost an investment of around $150 billion [7] to achieve the necessary *EVCI*. The current infrastructure lacks a fundamental development in the private sector in terms of the *EVCI* stations in communities where there is no personal space to charge the *EVs* because there is no parking space included in the household. We find this in many communities such as multi-unit dwellings (*MUDs*) or apartment buildings. There are countries like *CN* and the *UK* where this type of community is very recurrent and where there is an urgent need to address this issue. In these places the *EVCI* stations are being neglected due to the described barrier. With careful and effective planning, it is possible to develop an *EVCI* station in communities that do not have houses with in-home parking. This report discusses the planning considerations for the project of installing and managing a community *EVCI* station where the homeowner's association (HOAs) or property managers of the community are the ones in charge of the facilities.

One of the contributions of this report is to provide the metrics to achieve an effective and intelligent community *EVCI* stations. These metrics are the essential requirements in the user, business, and technical aspects. When *HOAs* and property managers start their community *EVCI* stations project they should focus and check if these requirements are met, as they are the essence and the reason for the project.

The second most important contribution of the report is the usefulness of the guidelines given in planning considerations. It is designed to meet the requirements as metrics. All the considerations that *HOAs* and property managers must follow in the strategic and economic aspects are included in the report.

The third key point where the report adds value is in the proposed schedule and charging system. It encompasses charging in two zones, one fast and one slower, and an application software system to be able to withstand the numerous load requests by *EV* users. This system allows us to have great flexibility and adaptability that are essential to be able to make the community *EVCI* stations absorb the demand growth of users that are in the communities.

1.4 Outline of the remainder of this report

This report stems from the lack of development of the community *EVCI* stations in the world due to their barriers to entry. It is a fundamental piece in the *EVCI* since the development of *EVs* depends on the speed of including them into the households. In Chapter 2 we perform an analysis of the possible requirements necessary as a metric to develop a planning that seeks efficiency and intelligence in the community *EVCI* stations. These requirements are categorized into user, business, and technical requirements. Chapter 2 is fundamental and necessary for the development of the next chapters.

Chapter 3 addresses the requirements of Chapter 2 by analyzing aspects such as the comprehension of community *EV* users forecasts and trends, localization, technical aspects of the *EVSE*, network connection to the grid, schedule charging system or community member education. The section of the potential schedule and charging system provides a solution to one of the key barriers to *EV* chargers in communities without in-home parking which is an intelligent charging schedule system with two parking zones which are explained in depth in Section 3.5. Chapter 4 analyzes the economic considerations required for the community *EVCI* stations. The fixed and variable costs of the community *EVCI* stations are broken down. Furthermore, we look at the opportunities offered by scalability and government incentive programs. Moreover, Chapter 4 provides considerations of the possible business model that could work with the community *EVCI* stations. Chapter 5 concludes the report with the general conclusions and add the future guidelines that could be taken.

1.5 Concluding remarks

In this introductory chapter we have given the main thread to the report. The adoption of *EVs* seems imminent and in the next few years they could have a very important market share in the automotive sector. The need for an *EVCI* that can support this new demand is essential, and it must be based on private *EVCI*, both with personal household *EVCI* stations and community *EVCI* stations in locations where there is no in-home approval, as they are the backbone of the infrastructure. Community *EVCI* stations projects must take a step forward and be developed with an effective and intelligent planning. For proper planning, user, business, and technical requirements should be the foundation for decision making as they serve as metrics for a future project evaluation.

CHAPTER 2:

THE KEY REQUIREMENTS FOR THE COMMUNITY *EVCI* STATION

To achieve the electric transition in the field of passenger transport and especially automobiles as stipulated by the countries that form the Organization for Economic Co-operation and Development (*OECD*) citizens need to be encouraged to switch from *ICE* vehicles to *EVs*. This development must be carried out especially in communities of *MUDs* or apartments in buildings so that the household members have a place near home to charge their *EVs*. We must first understand what requirements need to be addressed in order to plan and implement the project to install and manage an *EVCI* station in a community where there is no in-home parking. We distinguish in this report three fundamental parts: users, business, and technical aspects. The users refer in this report to the members of the community who own an *EV* and use the implemented *EVCI* station. In the business area, we include all the requirements of the entity in charge of the project, in this case, that entity is the community and the *HOAs* and property managers of that community are the ones responsible for the facilities in the community. When we talk about technical requirements, we refer to the aspects that are fundamental for the development of the project. In this chapter, we study the key requirements and simplify the system into one that is efficient and intelligent.

2.1 Nature and scope of the *EV* users' requirements

To plan and implement a project it is essential to understand the user of the product. For the purpose of this report, it is the *EV* users of the communities, that are part of the project, who use the charger installation daily. These users have requirements and perspectives that need to be addressed by the project manager or *HOAs*. Table 1 summarizes the user factors that this report considers when developing the key requirements that the community *EVCI* stations must meet to satisfy the user.

The demand from the charging station must be met in the cleanest possible way. Since *EVs* were introduced to the world, we have seen how they have achieved transportation with no CO_2 emissions. It is one of the attractions for people to buy these vehicles. The problem comes as while charging the *EV* we get that electricity from an energy source that produces greenhouse gasses (*GHG*). It would be a contradiction to install the charging station for electric vehicles and fuel them with electricity that has a great amount of *GHG* pollution. More than 40 % of energy-related CO_2 emissions are as a result of the use of fossil fuels for electricity generation [8]. All electricity generation technologies emit *GHG* at some point in their life cycle [8]. The best options to mitigate this impact would be to obtain electricity through nuclear fission and renewable energies [8]. Even so, the impact would not be zero since these sources indirectly emit CO_2. For example, with the construction of any power plant we get CO_2 emissions. In Figure 3 we can observe how coal, biomass and coal are the most contaminant sources.

Table 2. Key factors considered in the specification of community *EVCI* stations user requirements.

key user requirements factors
carbon footprint
driving range
number of EV chargers
charging time
s.o.h of the EV battery
distance to home
costs

In Figure 3 it can be seen which the energy resources are used to obtain electricity that most favor the emission of CO_2. It is essential that the *EVCI* station of the community relies on energy resources with low CO_2 emissions like wind, nuclear, geothermal, solar or hydropower.

Community members need their vehicles to get from one place to another during the day. The proposed *EVCI* station for the community is required to give them the necessary driving range so that they can go about their day before they run out of battery power. We use as a benchmark for this report the daily average distance traveled per vehicle obtained from the data of [9], [10], [11], [12], [13] and [14]. These data results from samples of the *US, CA, DE, SE,* and *CN*. We suppose in this report these geographic locations to be the significant representation in terms of *EVs* adoption.

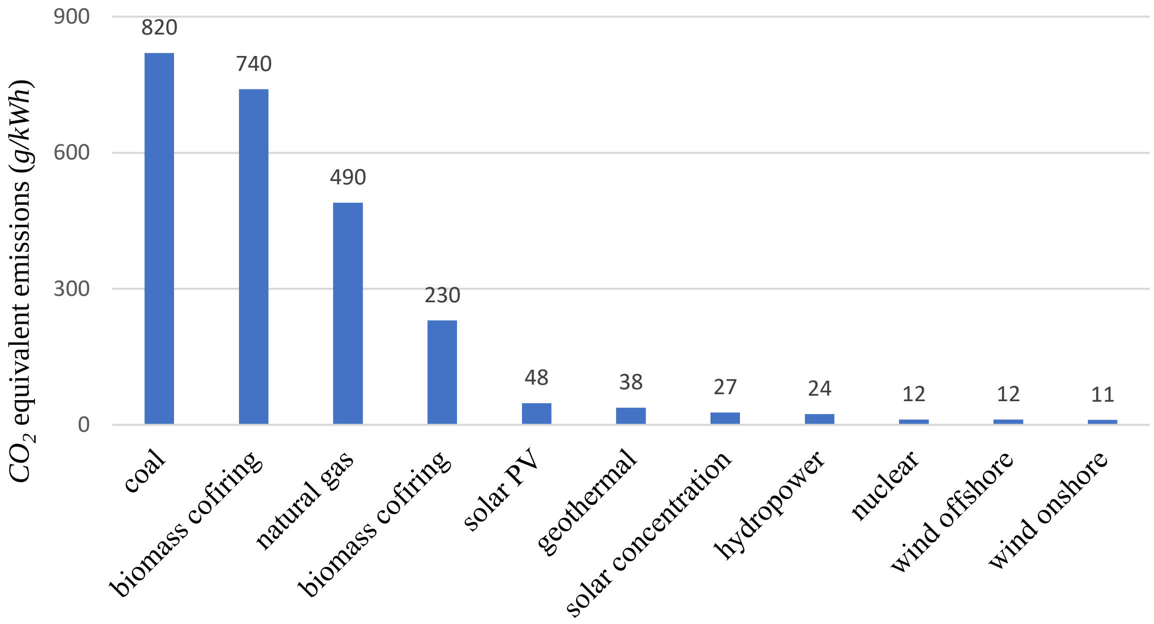

Figure 3. Average life-cycle CO_2 equivalent emissions per energy resource [8].

Table 3. Average daily distance in *km* traveled per vehicle by region.

country	*average daily distance traveled per car in km*
US	60
CA	42
DE	37
UK	29
JP	26
CN	25

In Table 2 we see the different averages of distance traveled per vehicle in diverse countries. This shows an overview of the daily usage required by the user and thus the requirement that the community charging system can provide that driving range. On the one hand in countries like the *US* we can see where there is a higher usage of the car. On the other hand, in other countries such as *CN* and *JP* there are not so many long trips. Therefore, it is key to ensure the driving range anxiety of *EV* users as one of the main requirements that needs to be addressed.

The users of the *EVCI* stations would be the *EV* users' members of the households of the communities associated with the project. Each has their own responsibilities and different places to go. They would normally have a routine but that can change at any time. It is a requirement that there is flexibility in the charging schedule for each user and various studies agree that it is a key attribute [15] and [16]. This means that there needs to be as many charging spots as users want to charge at that time. It is because most people work during the day that the load demand during the weekdays can be predicted. Another case exists on weekends where people's activities are not so predictable, and the load moment is spread over the whole day. Figures 4 and 5 shed light to the distribution of *EV* charging hours during weekdays and weekends [17].

Figures 4 and 5 show how people tend to charge their vehicle during the evening and stop charging in the morning [17]. This means that users require availability of *EV* chargers mainly in those hours of the day, where there is an increase in the demand. In the remainder hours there is no charging problem as there is almost no demand and most chargers of the community *EVCI* stations would be free for use.

Along the same lines as the previous requirement, users want to be able to have flexibility in their charging time and no stress while their *EV* is charging. The plan must consider that when the *EV* of the user is already charged, which happens mostly at nighttime where most people leave their vehicle charging, they cannot be asked to unplug it for another one to come.

Charging when the battery is completely full damages the life of the battery. The user requires the *EVCI* stations to extend the life of the batteries to the maximum because they are the highest priced part of an *EV*. It has a cost per *kWh* for the consumer of between \$245 and \$345 [18]. For example, the average vehicle with a 100 *kWh* battery would cost approximately a total of \$ 29,500. This is a major cost that the user tries to avoid and postpones its replacement until it is totally necessary.

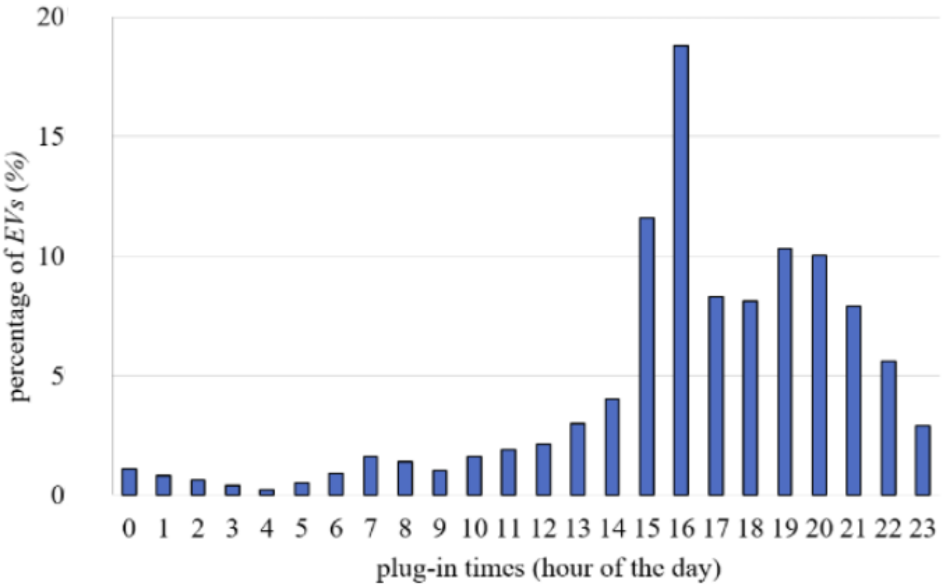

Figure 4. Average daily distribution of *EV* plug-in times during weekdays [17].

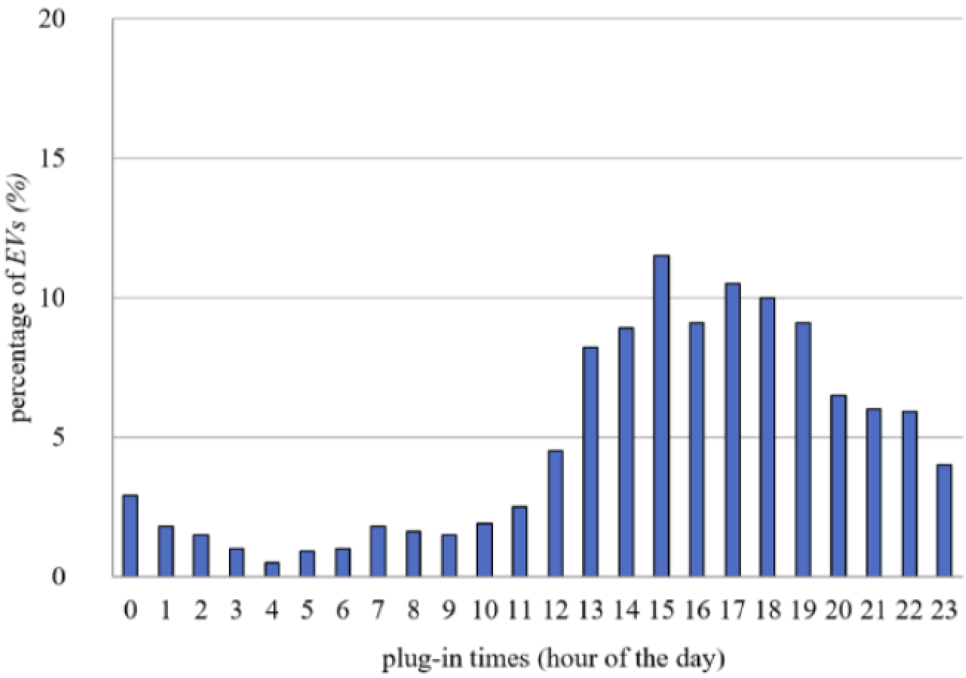

Figure 5. Average daily distribution of *EV* plug-in times during weekends [17].

The location of the *EVCI* stations is an issue that community members are concerned about. On the one hand, it must be close to the houses so that not too much time is lost on the way home from the community *EVCI* stations. On the other hand, it must be big enough to be able to bear the charging infrastructure. This aspect is fundamental because if the location is too far away the project would not make sense, as users want a near home charging alternative. It is essential that it is within the boundaries of the community and at a reasonable distance from all the households. In some regions of the world, indoor locations are needed and in others they could be implemented outdoors. In northern locations where heavy snow is prevalent, it may affect the performance of the community *EVCI* stations and would need to be covered.

However, one of the most important aspects to keep in mind is that users search for the lowest price possible. The current barrier to electric vehicles is the higher price compared to *ICE* vehicles. When people buy an *EV*, they consider that charging the battery does not represent a significant cost as they have already paid a premium over *ICE* vehicles. Because of all the different opportunities and technologies available it is difficult to find a balance. Property managers and *HOA*s must work to find a business model that does not require the user to spend considerable amounts of money to charge the car.

In the user's requirements we discussed the user needs that must be addressed in the planning of the community *EVCI* stations. As we have stated the community users want to reduce the CO_2 emissions from the community *EVCI* stations to as low as possible. Moreover, the consumer's behavior is fundamental to make an effective use of their time during charging and also in terms of the location. Because users have done such important disbursement for the *EV* the health of the battery has to be considered and the price per charge has to be competitive. The next step of the report is to state and understand the business requirements of property managers and *HOAs*.

2.2 Business Requirements

In order to carry out an effective and coherent planning, it is essential to understand the business requirements of this project. To begin with, the people in charge of the community *EVCI* stations are the *HOAs* and property managers. They have the power to make the relevant decisions regarding the operation and facilities of the community. Table 3 summarizes the factors that this report considers when developing the key business requirements that the community *EVCI* station's needs.

Table 4. Key factors considered in the specification of community *EVCI* stations business requirements.

key business requirements factors
comprehension of EV users
scalability
cost allocation
carbon footprint
policy incentives and rebates
EV education
costs

Every community has a different perspective about how they want to do things. In such a diverse world it would be naive to think that every community needs a community *EVCI* station. This type of infrastructure only makes sense if there is a latent active interest in *EVs* and some participants of the community have bought an *EV* or expect to buy one. For that reason, project managers and *HOAs* need to contact community members to know which are their needs.

Once the *EV* situation of the community members is known, the project is launched. To facilitate the scalability of the project it is a requirement that property managers and *HOAs* contact neighboring communities to offer them to participate and thus unify needs. Furthermore, this union is of great help to small communities as by themselves they might have the capacity to manage and plan a community *EVCI* station. In addition, based on economies of scale a significant cost reduction is achieved to obtain better prices from both the electricity suppliers and the providers of the necessary infrastructure for the installation of the *EVCI*.

Since the project costs large sums of money, someone must be responsible for the payment of the community *EVCI* stations. When it is all completed the community could have appreciated in value and all residents would have gained an intangible benefit. Those who own an *EV* would also get the benefit to use these *EV* chargers, which increase their quality of life. As not all members of the community own an *EV* it is essential to address the problem of who must pay each part, and in what percentage. The *HOAs* and property managers oversee the cost allocation. It is a requirement that this cost is kept at the price levels that the community members are willing to pay. There are two phases of the project that require a clear cost allocation plan. First is the installation phase which involves the necessary infrastructure for the community *EVCI* stations to make it ready for use. The second phase occurs after the infrastructure is carried out and consists mainly of the electricity and maintenance costs of the community *EVCI* stations. In this second phase it must also be stipulated who is responsible to pay these costs which, although they represent a minor burden must be addressed.

In all projects there is a moment to prepare the budget for investment and the decision of if it is worth it. When a new technology that is so beneficial for the environment lacks a clear economic advantage, it normally has certain incentives from the government that makes those projects more affordable. The use of those policies is a clear requirement. Both the property managers and *HOAs,* and society have their interests aligned with cleaner transportation.

There are policy measures of the different governments that encourage projects related to *EVs*. In the *US* there is the Biden-Harris Electric Vehicle Charging Action Plan that aims to have an electric vehicle share of 50 % by 2030 [19]. But more importantly, it aims to catalyze further private investment in *EV* charging. It is not only the *US*, but all other world powers want to achieve this electrification of transport and for instance in *CN* we find plans from the National Development and Reform Commission to offer direct financial subsidies to build charging facilities [20]. *HOAs* and property managers need to take advantage of these subsidies to make this project economically feasible. In addition to subsidies, it is also necessary to take advantage of the rebate programs offered by these same governments. After the project is paid, property managers and *HOAs* must look in the rebate programs what percentage they can get back from the investment. It is a double opportunity to take advantage of both subsidies and rebates.

Moreover, there is also an aspect that sometimes goes unnoticed and that is the user's education about the benefits and the impact of the community *EVCI* station. *HOAs* and property managers should be responsible for conducting a program to educate community members about the costs, benefits, and technical aspects of *EVs*. This would help the community to grow their *EV* population and extract the full potential of its community *EVCI* station.

The *HOAs* and property managers need a clear cost-allocation to plan and implement the community *EVCI* station. Due to the interest of *OECD* governments to get and operate and efficient global network of charging stations, they offer incentive and rebate programs that

HOAs and property managers should take advantage of. It is essential to help educate the community members to understand the benefits of *EVs* so that they help with the investment involved in such a project. All the business requirements mentioned above are addressed in Chapters 2 and 3 of this report.

2.3 Technical requirements

Aligned with the user and business requirements we study the more technical ones. These refer to the aspects related to the electric vehicle supply equipment (*EVSE*), the connection to the grid and the efficiency and health of the *EV* battery. It is a key piece as it is the tool that benefits both users and *HOAs* and property managers. Table 4 summarizes the factors that this report considers when developing the key technical requirements that the community *EVCI* station's needs.

The technology involved in the *EVCI* stations has evolved in recent years. Nowadays, there are several options in terms of types of charging. The two existing options are alternate current slow chargers (*AC*) or direct current fast chargers (*DCFC*) [18]. Each option depends on the type of use we give them. In this report we see which type of chargers adapt better to the different communities and their consumer behavior.

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Another part of the *EVCI* station that requires special attention is the devices responsible to control of the electricity consumption. These are called electric meters. This report focuses on the installation of *EVCI* station in a group of communities. This complicates things in terms of accounting for how much electricity each household has spent since in the study system each community has its own metering system with its own electric meters. In the planning section this requirement is addressed.

The inclusion of utilities that supply electricity from renewable energy resources (*RERs*) or the deployment of microgrids for the supply of green resources are required. The *RER* is not a fully

Table 5. Key factors considered in the specification of community *EVCI* stations technical requirements.

key technical requirements factors
type of charger
metering
safety
carbon footprint
battery storage system
connection to the grid
EV education

reliable source, as it can vary the production that depends on various aspects. Other options are needed to solve this problem. One of the most viable options would be a battery storage unit included in the charging station. This would be a great solution for the problem and would reduce the CO_2 emissions in an important way. One of the aspects that would not help the inclusion of the battery storage is that they are very expensive. However, in this report we give possible solutions that can be found to take advantage of their characteristics.

EV chargers are used by people with no electrical education that most of the time are not careful with the charging equipment. Some protections should be installed to ensure the safety of the user. It is the outdated wires or power supplies that are connected to the *EVCI* station that can provoke a serious fire. Therefore, the community *EVCI* stations need to comply with global certificates and meet certain safety standards.

The existent grid must be able to support the demand created by the *EVs* of the communities. This demand used to be distributed throughout the area around the community as household members would charge their vehicles at work or at public chargers. Now we unify one place to charge and encourage the community members to have more *EVs*. The local grid must take into account this new power supply point.

EV users need to be educated on how to care for and optimize the vehicle’s battery. It is a fundamental component of *EVs* but presents technical concepts that are beyond the reach of knowledge of the average citizen. The most used battery for electric vehicles is the Lithium-ion (Li-ion) battery. This type of battery is used in most portable consumer electronics ai it has one of the highest energies per unit mass at 100-265 *Wh/kg* [21]. Besides, it has other advantages such as low self-discharge, high energy efficiency and low maintenance. Two important battery concepts need to be defined: state of health (*s.o.h*) and state of charge (*s.o.c*). The *s.o.c* is defined as the percentage of the remaining capacity with respect to the maximum available battery capacity [22]. The *s.o.h* is defined as the percentage of the state value with respect to the initial value of the capacity or internal resistance [22]. In Figure 6 we can see how the *s.o.h* change within the cycles of the battery. The *s.o.h* is represented as the capacity in Figure 6, and we can see how it decreases with the increase of cycles. In order to maintain the *s.o.h* of the *EV* battery at their first cycle level the users have to be educated. This directly involves the driver's habit and how to use the *EVCI* stations correctly [23].

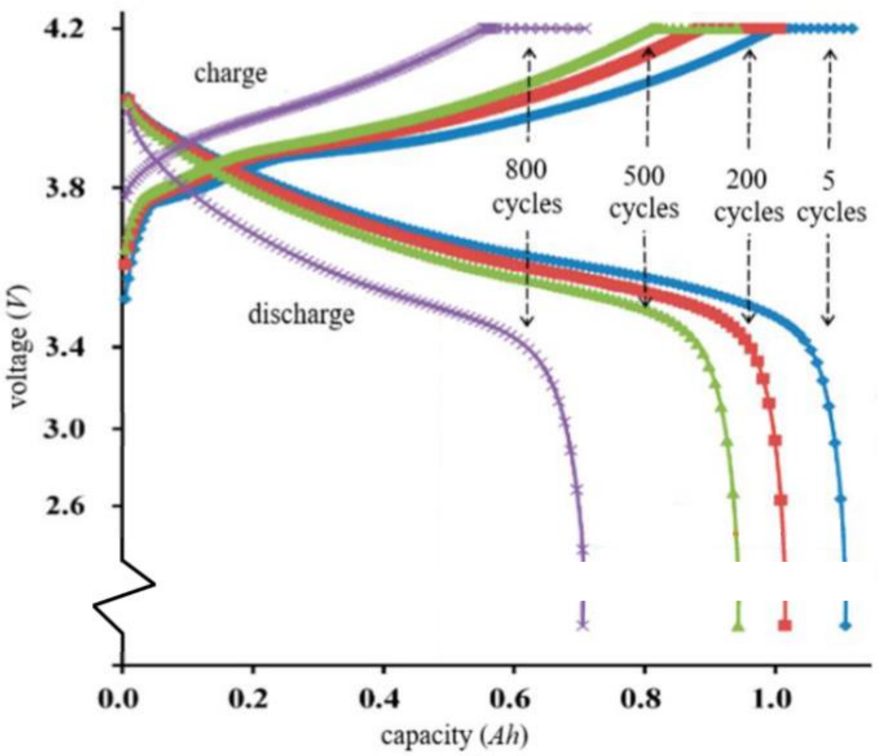

Figure 6. Variations of the voltage versus the capacity of a Li-ion battery at various cycles [23].

2.4 Concluding remarks

This chapter has defined the requirements involved in the project to install an *EVCI* station in a community. These requirements are specified and discussed to establish a clear basis for an intelligent and efficient community *EVCI* stations project planning. This report has focused on three essential requirements. First, the requirements of the *EV*-owning members of the community are defined, as they are the ones who mostly use this new facility. These requirements are focused on user comfort and to facilitate their transition to *EVs*. Second, a study of the requirements of the *HOAs* and property managers that carry out the project and address issues such as the comprehension of users' needs and trends, economy of scale in terms of electricity utility, cost-allocation that includes policy incentives and rebate programs, and user education. Third and finally, the technical requirements of the *EVSE* that have been focused on the objective that the community *EVCI* stations complies to take care of the environment, the *EV* batteries and that it works efficiently.

CHAPTER 3:

KEY STRATEGIC CONSIDERATIONS FOR PLANNING THE COMMUNITY *EVCI* STATION

The line of reasoning of this chapter starts focusing on understanding the *EV* users forecasts and trends in the community. To follow up the reports continues by the considerations needed when *EVCI* site is chosen. Moreover, what equipment is used and what are the best options in terms of needs. Not to forget that it must comply with local safety requirements. Furthermore, we study the operation and management of the demand on the local grid. A key aspect that is not lost sight of in the chapter is the requirement to use *GHG*-free electricity.

We study the considerations a charging system need to work in the most effective, flexible, and adaptable way to meet the new demand for *EVs*. If the project is to be successful in the long term, project managers and *HOAs* must raise awareness and educate the members of the communities involved in the community *EVCI* stations project. Specially, about the safety of the *EV* charging process, how to take care of the *EV* battery and understand the relationship between charging time and kilometers.

3.1 Community *EV* users forecasts and trends

It is essential that *HOAs* and property managers understand if there is a necessity of implementation of an *EVCI* stations in their communities. The best way is to get to know the members of the households and see their *EV* trends. Not only does it help them understand if a project of this magnitude is necessary, but it also gives them information on how to develop it. We can obtain information on whether they plan to own or currently have an *EV* or information as important as their behavior in terms of time to use their vehicle. Therefore, in this report we give some guidelines on how to approach this issue.

This information must be gathered through surveys. Because this project can be carried out by community groups that vary in size, it is important that the *HOAs* and property managers in charge of the project choose the optimal team for the job. This team has the following survey options which depend on the form of application: online survey, in-person survey, telephone survey and mail survey.

The online survey uses the internet as a mean of distribution, is characterized by being inexpensive and has a high response rate. The personal survey consists of a face-to-face questionnaire and must have an interaction between the interviewer and the respondent in which the interviewer captures the respondent's answers. The telephone survey consists of carrying out the questionnaire through a telephone call which makes it very time-consuming. The last option is a mail survey that consists of sending a questionnaire through the postal service so that, after it is answered, it is returned to the sender. To decide which type of survey to use, the team in charge need to state the size of the communities and therefore the number of people to be reached by this survey. We define the size of the community to be large when there are over 1,000 households, medium when there are between 1,000 and 250 households and small when there are under 250 households.

For large and medium communities, the most efficient and consistent options are online or mail surveys. They offer great flexibility since in both we only need email contact information and home address. In terms of cost, online surveys encompass the payment for the software, although there are free versions. In the case of mail surveys, the cost would be those incurred by the *HOAs* and property managers when they print and place the surveys in the relevant mailboxes. The return of these mail surveys is easy as the *HOAs* and property managers have access to the community mailboxes and can enable a special one for this case. In terms of anonymity and privacy, the mail survey option has more advantages since it leaves no trace, while the online survey has to implement a system that respects the user's privacy. The other options in large and medium communities do not make sense since it is an excessively time-consuming task for the interviewer compared with the mail and online survey.

For small communities, telephone and personal surveys make sense. It is a much more manageable task for the interviewer as the number of surveys is smaller. The advantage to choose either of these two types of surveys is that in both there is an individual interaction between the interviewer and the other person, which makes it much more personal and allows the interviewer to better understand the situation and the context of the other person's life. This results in data that better represents the reality of the community. Mail and online surveys are also efficient and consistent options but their cost advantages and flexibility in small communities are not as valuable.

Once the survey model has been chosen, the team in charge must develop the questions. It is essential that these questions clearly answer the information needed for the project. Mainly, the number of *EVs* of each household must be known to obtain the total number of *EVs* that the community *EVCI* stations will supply. In addition, the number of *EVs* that would be added to the community if the members had access to a community *EVCI* stations must also be known. Once all the survey data is obtained, *HOAs* and property managers can use it for planning.

3.2 Site the location of the community *EVCI* stations

When it comes to a project like the *EVCI* stations of a community, planning is critical. One of the most important aspects is the location of the charging station. In private homes that have their own parking is simple to install an *EV* charger. But when we talk about a set of communities that do not have so the facilities in terms of parking and that the installation depends on *HOAs* and property managers we see the need of a more thorough study. The characteristics that the chosen location should have been summarized in user convenience, safety, and accessibility.

In terms of convenience, it is essential that the community *EVCI* station is located close to the users' homes. This is a complicated issue as this project has to be able to encompass both large and small communities that come together to institute this project for their household members. Just to have one charging location is incompatible with being within walking distance of all the households. The proposed possible solution of this report is to include charging stations in the various parking areas of the residential communities (zones A) and a separate charging station location that is close to all communities (zone B). With this proposal, zones A we give community members the convenience to charge their vehicle at the same location where they park it when they are at home and have in zone B a separate location where they can charge their *EV* in a sporadic situation. The next section explains how zone B is of great convenience as it is the equivalent of a gas station for internal combustion engine (*ICE*) vehicles because it is pretended to have fast chargers that charge *EVs* in minutes.

Safety is a vital issue that must be addressed. These facilities and the location of the community *EVCI* stations should provide a safe place for the user, the workers, and the *EV* itself. There are two particularly important aspects that *HOAs* and property managers need to pay attention to. There are regions throughout the world that have extreme temperatures that can affect the *EV*. The battery is especially susceptible to high or low extreme temperatures.

Figure 7 shows how charging temperatures influence the capacity of the Li-ion *EV* battery. Temperatures outside the range of 20 *ºC* to 25 *ºC*, the ambient temperature, have a negative effect on the battery capacity and produce less range to the *EV* [24]. Therefore, places with extreme temperatures should take this into account when they start to build their community *EVCI* stations. The clearest solution to this problem is to cover the charging area and insulate it from the outside. This allows for more moderate temperatures that are not detrimental for the capacity range of the battery. It is worth noting from Figure 7 how maintaining the *EV* at ambient temperature this can result in up to 20 % added range to the 100 % rated range.

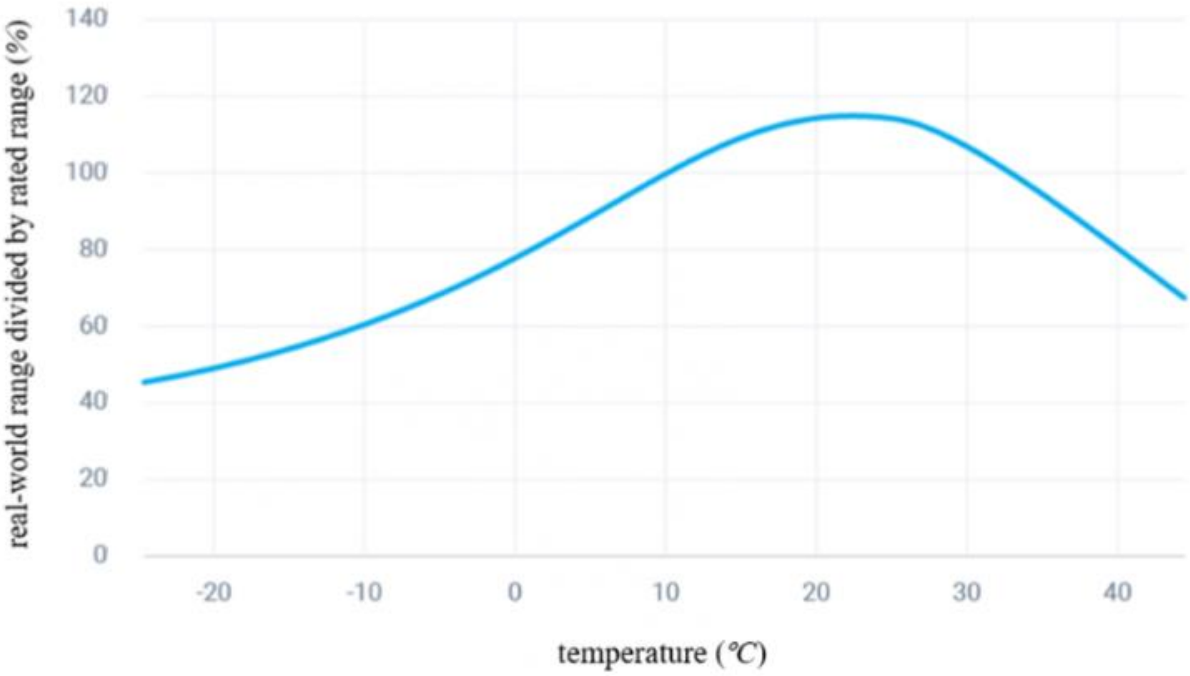

Figure 7. Real range compared with rated range in different temperatures [24].

Temperature not only affects the actual range of the vehicle battery but also greatly influences the battery life expectancy of the *EV*. This means that if the vehicle's battery is always kept at a neutral temperature or even at cooler temperatures, it has a higher battery life expectancy than in warmer situations. Above ambient temperatures cause the LI-ion battery to have a shortened lifetime [25]. For this reason, the location should be chosen always considering that the vehicle should be close to ambient temperatures. In cases where temperatures are sufficiently high, temperature control measures must be taken. These measures are as in the previous case to control the temperature of the *EVs*. It is necessary to get a place isolated from the outside totally closed or that the charging area has a cooling system to maintain ambient temperatures. In Section 3.6 we discuss how the user's education about the *EV* is essential to let the *EV* users understand that in case they park outside their community *EVCI* station the temperatures are not extreme.

Secondly, *EVs* are surrounded by high-cost equipment, which can attract vandalism. This is a major problem that affects the location the A and B zones of the community *EVCI* stations described above. With the wrong choice of security measurements, the *EVs*, infrastructure and even homes in the communities can be at risk. Therefore, there are several key aspects that *HOAs* and property managers must consider when they choose the location. On the one hand, the A and B charging zones should be in well-lit locations. Since the A zones are within the communities it is assumed that this aspect is covered. In the case of the proposed B zone, we should look for a location where the adjacent streets are busy streets and with lighting systems. On the other hand, the community *EVCI* stations must be in areas where there is a surveillance system either by surveillance cameras or near areas protected by the proximity of a police department that scares away possible vandalism.

In addition, the project team has to take accessibility into account when they make decisions about the community *EVCI* stations. This mainly focuses to satisfy the requirements of the installation and to comply with the guidelines for people with disabilities. Furthermore, makes the charging station usable by all people regardless of their condition. In each part of the world there are different laws that must be complied with in regards of people with disabilities, for example in the *US* the Americans with Disabilities Act (*ADA*), in the *EU* the European Accessibility Act (*EAA*) and in *CN* Article 3 of the Constitution of the People's Republic of *CN* guarantees the protection of people with disabilities.

In this section, we have seen the considerations and possible solutions that exist to site the location of the *EVCI* stations of the communities involved in the project. The *HOAs* and property managers must take care of the user convenience, safety and accessibility aspects described above to achieve the siting of a location that meets the described in key requirements in the previous chapter.

3.3 *EVSE* technical aspects

The community *EVCI* stations project for the communities needs an *EVSE* that meets all the requirements proposed in Chapter 2. This mainly refers to the user requirements and, above all, to the *EV* charging behavior of the *EV* users. Furthermore, the requirement of technical safety of the equipment with respect to the user has to be addressed. This section gives the guidelines for the *HOAs* and property managers in charge of the project that they must follow to comply with the requirements stated above.

To begin with, we must understand the charging behavior of the *EV* users. Figures 4 and 5 show the percentage of *EV* users that plug-in their vehicles on the weekdays and weekends. The pattern seen in the key requirements chapter is clear and shows how users mostly charge their vehicles at night. This study [26] illustrates how the most convenient way to charge an *EV* is at home during the night, as can also be seen in Figures 4 and 5, but also as the second most convenient place would be near the household and with fast chargers. The proposed zones A and B solve these requirements. Although the selection of the *EVSE* such as charger type and electric meters remains to be defined.

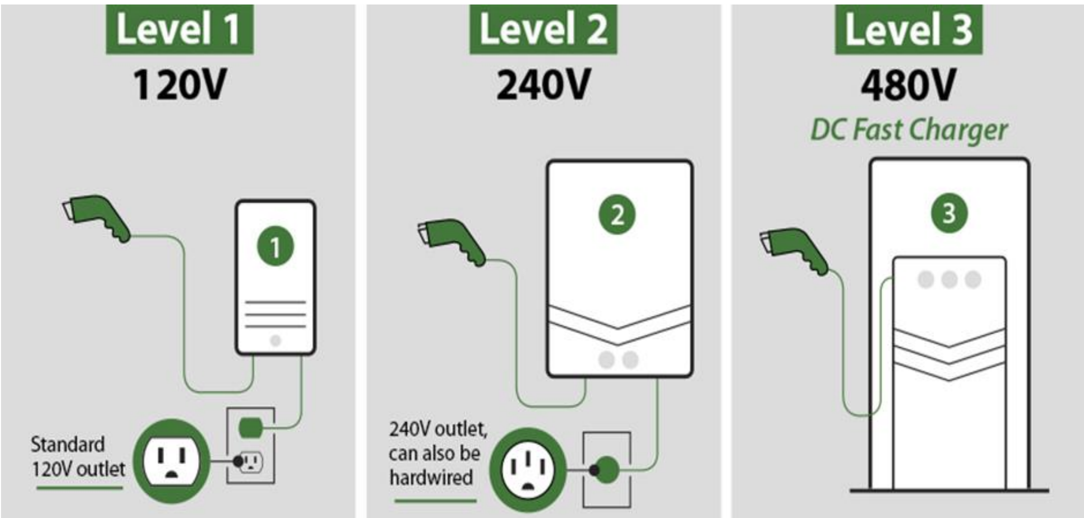

Figure 8. Classification of *EV* chargers by level [27].

In terms of the types of chargers we must explain the three existing types which are Level 1, Level 2 and Level 3. Level 1 and 2 use alternating current (*AC*) and Level 3 uses direct current (*DC*) [27]. Level 1 chargers normally come with the vehicle and is they plug into the wall socket. There is a different voltage level throughout the world, much of America uses 120 *V*; much of Europe, Asia and Africa use 220 *V*. Typically Level 1 chargers deliver 1.4 *kW* [18] with a 120 *V* supply voltage and 2.8 *kW* [26] with a 220 *V* supply voltage. The Level 2 charging system is similar to Level 1 as the electricity supply comes from an outlet, or a unit wired to the vehicle through the connector. These chargers require a circuit of around 240 *V*, and 40 *A*. Typically it delivers 7 *kW* [28]. *DCFCs* are the analogue of gas stations and are the fastest way to charge an *EV*. Typically, it delivers between 50 *kW* to 350 *kW*. Table 5 uses 0.19 *kWh/km* as the average efficiency of *EVs*. In addition, the 100-*km* range is used as a measure that encompasses daily distance averages worldwide. This makes sense since we take the maximum value from Table 2 and add 40 *km* more of range to ensure that most of the population is represented.

Table 6. Relation of the time taken to charge the energy for a 100-*km* range and the characteristics of the charger level.

charger level		*average power delivered (kW)*	*time taken to charge the energy for a* 100-*km range for charger level in hh:mm*
level 1	120 *V*	1.4	13:36
	220 *V*	2.8	06:48
level 2		7	02:42
level 3		200	00:06

When we look at the values in Table 5, we clearly see the time differences between the level of chargers. In this section, we analyze the choice of charger types for zones A and B according to the charging time. In Section 3.6 we show how the charging speed affects the battery and high charging speeds are detrimental for *EV* batteries. In Section 4.1 we analyze according to the recurrent and fixed cost of each type of charger. In this case it can be seen how Level 1 and 2 chargers have a very slow charging time compared to Level 3. On the one hand, with these results *HOAs* and property managers should choose Level 1 and 2 chargers for A zones because the user has all night to charge their *EV*. Users should use the Level 1 charger in the A zones when they want a charge of a few kilometers but slow charging to take care of the battery, as we see in Section 3.6, and the Level 2 charger when they want a longer range of kilometers and therefore need a faster charging speed. On the other hand, Level 3 chargers should be used for zone B where the user simply wants to charge his battery in minutes in a fast way as if he were to refuel at a gas station.

To continue, the amount of electricity consumed must be recorded on the electricity meters so that the utility we have contracted knows how much electricity we spend. Because electric meters require electricity and a utility, electric meters play an essential role. It is essential to see what strategy is followed to place them. The project under study involves one or several communities. This means that the electric meters of this community *EVCI* station reflect the amount of electricity consumed by all the parties. This electricity cost is recurrently paid to the supplier. Each electric meter has an associated electricity bill that goes to the entity or person who owns that meter. For example, if 5 communities join to carry out the project, which community is responsible for the electric meters of zones A and B? As there would be a zone A associated with each community, it would make sense that each community would be responsible for the electric meters of that zone. But the problem would come with zone B since it belongs to the 5 communities. It would not make sense that only one community would be responsible for its expenses. Therefore, this report proposes that the *HOAs* and property managers create an entity called "The Company" composed of the communities present in the project that is responsible for the electricity consumption of all the A zones as well as the B zone. We see later in Section 3.5 how this affects the members of the communities in more detail. The electric meters are independent of the communities' own electric meters.

To conclude this section, the security issue must be addressed. All electrical equipment used by the public must comply with the relevant safety standards and regulations. The user must always be protected from any danger of electric shock. However, the most common hazard of *EVCI* stations is fire, which can be caused by outdated cables and power supplies. Therefore, *HOAs* and property managers have to make sure that the *EVSE* installed in the project complies with the relevant certifications. In Europe it is the Conformite Europeenne certificate [29], in the *US* an *EVCI* station needs the Occupational Safety & Health Administration (*OSHA*) Nationally Recognized Testing Laboratory (*NRTL*) certification [30] and in *CN* the *CN* Compulsory Certificate (*CCC*) introduced in 2002 [31]. This security must be not only physical but also technological. Cybersecurity protocols should be established so that it does not endanger the digital safety of the user. This is a topic that is mentioned superficially as it exceeds the scope of the report.

3.4 Connection to the grid

The demand for *EVs* increases over time and seems to be gradual in nature. This allows electric grids time to increase electricity supply and upgrade existing distribution systems. These increases have already been experienced when refrigeration devices such as air conditioners, cooking devices such as ovens or microwaves, entertainment devices such as televisions and washing machines were introduced into homes. This process starts with certain regions that have greater facilities and incentives that cause a local increase that may have a negative effect on the local electricity grid. *HOAs* and property managers must address this situation with intelligent load management. This requires taking care of the *EV* charging schedules in the community *EVCI* station, add a battery storage system, or use renewable energy resources of electricity.

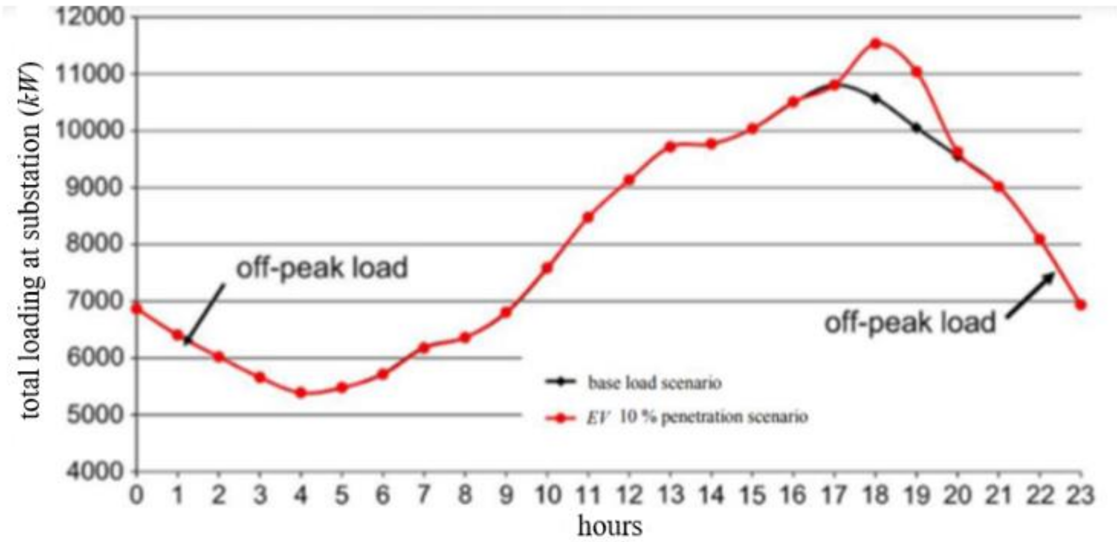

Figure 9. *EV* demand with a 10 % penetration added to the base load scenario [32].

In Figure 9 we see the case where the *EVs* start charging at the same time at 18:00. It can be seen how the peak of demand of the base load scenario was around 18:00 and that after including the *EVs* charging it increases even more, sharpening that peak [32].

Figure 10 shows the change that occurs if the 10 % penetration caused by *EV* charging is added to the base load scenario but distributed between 21:00 and 1:00 [32]. This causes the increase in demand to be mitigated by the distribution of the load over a longer time range. Most importantly, this increase coincides with the off-peak load on the local grid, which ensures that there are no problems for the grid. There are other added benefits to seek off-peak, such as lower electricity prices due to lower demand.

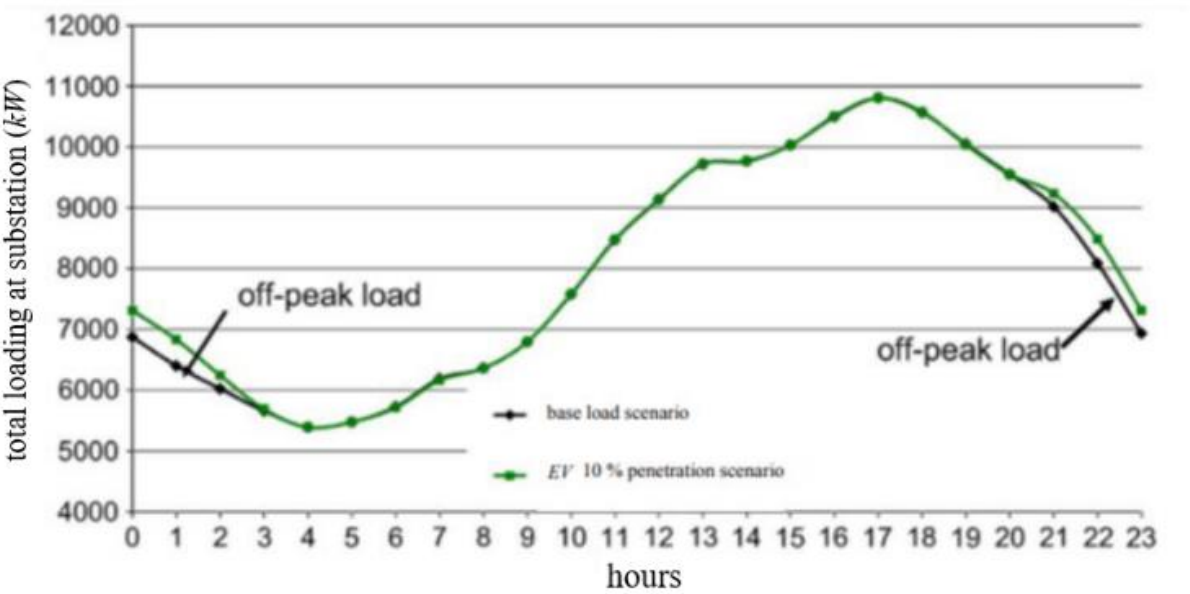

Figure 10. EV demand with a 10 % penetration added smartly to the base load scenario [*32*].

HOAs and property managers should set up or create a team that understands the electricity demand in the area where the project is to be carried out. This can be used to analyze and find the off-peak demand time slots that vary throughout the year. Weekdays have a different local demand curve than weekends, and in summer there is a different local demand curve than in winter. All this study is fundamental and should be implemented in the community *EVCI* station. One option proposed in this report would be to introduce the results of the study in the application software, explained in Section 3.5, and that the system manages with the number of *EV* users, the available charging time, and the best smart charging option. If a more extreme option is sought, a charging schedule could be managed, and charging could only be done during off-peak demand. This smart scheduling charging concept only makes sense in the case of the A zones, as vehicles left parked for long periods, such as overnight, gives more flexibility to the system to choose the time in which the vehicle is charged. In the case of zone B, the user requires spot charging and there is no option to decide to find the best time to charge the *EV*.

In many cases *EV* users need to charge their *EVs* at times of the day when electricity demand is high and in this case an energy storage system (*ESS*) as part of the community *EVCI* stations can play a key role. The idea is to use the low off-peak demand prices and charge the *ESS* so that when we want to charge an *EV* during high demand hours, we use the stored electricity from the *ESS*. A very interesting option to compose the *ESS* is with vehicle batteries from *EVs* that are no longer in use. These batteries may no longer have a *s.o.h.* suitable for *EVs* but can be used as an *ESS* network when linked all together. With this system, batteries that are no longer useful in *EVs* are used and flexible load management is achieved.

One of the most important requirements is to make the community *EVCI* stations as green as possible. Therefore, it is important not to forget where the electricity is obtained from. *HOAs* and property managers must ensure that part of the electricity that powers the community *EVCI* stations comes from a renewable energy resource (*RER*). This has a problem because there are types of *RERs* such as photovoltaic plants (*PV*) or wind farms that produce an irregular supply of electricity that depends on the hours of sunshine and wind speed respectively. In this aspect, the load demand of the community *EVCI* stations can absorb the electricity supply of irregular *RERs*. Especially the *PV* plants that generate electricity, if there are no clouds, from sunrise to sunset in zone B. This zone B represents the charging demand of *EVs* charging away from home and according to the study [33] this is primarily during the 5:00 to 18:00 time range. This slot includes part of the peak demand of the day and absorbs the impact that zone B would have. In contrast, wind farms can provide electricity at all hours of the day and the possible overnight supply can be used either to charge *EVs* directly or to use the *ESS* for future charging.

3.5 Potential schedule and charging system

This section offers a possible charging system that addresses charging flexibility in terms of schedule, adaptability to the growth of demand for *EVs* and efficiency in terms of the procedure of charge. This charging system is studied as two parts that work to achieve compliance with these requirements. On the one hand, there is the option to add chargers with a larger number of ports but to include an intelligent control management system. On the other hand, an application software that manages the moments in which each user charges his *EV*.

If in A zones *HOAs* and property managers include Level 1 and Level 2 chargers, they encounter a problem with Level 2 chargers as they require an additional installation to the current conventional sockets used by Level 1. In this section, we focus on the problem that comes with Level 2 chargers as they are the ones that due to their higher speed and with the charging system proposed by the report offer more options for *EV* users. Level 2 chargers can be single port or dual-port as seen in Figure 11 [34]. The most space efficient way is to include the dual-port power connection, so we have one charger with two independent branch circuits integrated.

Figure 11. Level 2 commercial single-port and dual-port charger from left to right [34].

One of the most common situations that occur with chargers in communities is the problem of leaving the vehicle charging all night when we only needed a few hours of charging, and someone arrives when we have already spent those hours and cannot charge it because the charger is busy. The next step is to study this situation; there is a Level 2 dual-port charger, and 4 *EVs* want to charge the battery, which only needs three hours to be fully charged, but the users will leave it overnight. In principle only the first in could charge their *EV* because even if the three hours passed the charger remains connected until the user removes it. Now we define from that charger that the two independent branch circuits associated to the two ports are circuit 1 and circuit 2 indistinctly. Now we add two ports to circuit 1. In circuit 1 we add an intelligent control management system that does not allow the two ports to work at the same time, so the port that works offer the 7 *kW* that gives a Level 2 charger. In the proposed situation with the modified dual-port Level 2 charger the 4 *EVs* come, and they are all able to charge regardless of who arrives first. The 4 *EVs* are connected by the 4 ports and if we focus on what happens in circuit 1, since circuit 2 is symmetrical, the same thing happens. So, 2 vehicles are connected to the two ports associated with circuit 1. We define port 1 to the vehicle that arrived first and port 2 to the one that arrived second. Port 1 starts charging the first vehicle and during the 3 hours of charging port 2 does not offer power due to the intelligent control management system that blocks this port. When this time has elapsed, port 2 starts charging and port 1 is blocked. The charging time and port switching is managed by the application software embedded in the Level 2 charger and controlled by the user from an application on his smartphone. This application software is described in the following paragraphs. By doubling the number of dual-port ports to 4 ports of the Level 2 chargers we have been able to serve twice as many *EV* users in an overnight charge. This allows for flexibility in charging schedules, adaptability to new *EV* demand and is clearly more efficient. We have only studied a Level 2 solution since Level 1 and Level 3 do not present these problems. Since Level 1 is the conventional supply voltage socket itself, it does not cost a lot of work or a lot of money to install, as we see in Section 4.1. So, in zones A there are always enough Level 1 chargers to support the demand. As for Level 3 these problems do not exist either as the *EV* users are always keeping an eye on the charging and when it is over, they leave allowing the next people to charge their car. This operation is like the one of *ICE* vehicles a gas station.

The application software connects the user to the Level 1, Level 2 and Level 3 chargers. The application allows the user to activate the charger connected to their vehicle, program the number of kilometers to be recharged, recharge schedules and offers a payment system to The Company. The *EV* user activates with his smartphone the charging port either Level 1, Level 2 or Level 3 and connect it to his *EV*. The application asks for the charging time, the user must know how to link charging time with kilometers of range, and it is addressed in Section 3.6. The next step is to choose the area where we are, and it can be zone A or zone B. In zone B it means that the vehicle directly starts charging until the selected time is over. On the other hand, in zone A there is not such a hurry because the user at home sleeps or does other activities as shown in Figures 4 and 5 and this is where this knowledge can be used. The application gives two options which are to charge in the moment or to allow the option to charge in an intelligent way taking advantage of several factors that we proceed to explain. If the first option is chosen the system checks if we are in a Level 1 or Level 2 charger. If it is Level 1 there is not a problem, and it starts charging the *EV*. If it is Level 2 the system checks if it is in a port enabled to charge now or it is blocked by the intelligent control management system. In case it is blocked it indicates the available options of Level 1 and Level 2 ports ready to charge and the location for the zone B where we can charge it without having to wait. If the port is ready to charge, the charging starts. If we choose the second charging option, it asks us the time when the user comes to pick up the car. This option only works for Level 1 and Level 2 chargers, so in zone B there is no such possibility. The system checks if we are in Level 1 or Level 2. If we are in Level 1 then the intelligent system studies with the charging time and the user's pick-up time which slot is the best to charge the *EV*. It uses the demand variables in the network to find the off-peak hour and in case *HOAs* and property managers decide to charge for *TOU*, it studies the cost and the user's payment method that will be further developed in Sections 4.2 and 4.4, it comes out cheaper. In case it detects that we are in Level 2, the same happens as in Level 1, but the intelligent system considers as a variable the schedule of the *EV* connected to the port of the same branch circuit. It is worth noting that the charging of the vehicle can be stopped at any time if the user disconnects the vehicle port.

On paper, this system assumes that the users of the community *EVCI* stations respect the use of the chargers and that they respect other users. But this does not happen. There are some fundamental aspects that need to be studied. This system can stop working properly and serve all users equally if it starts to have monopolistic attitudes. Therefore, the system must guarantee that this does not happen. A possible solution is to limit the hours of use by zones. For instance, that each person has a limit of daily load per day and that the application software does not let him/her activate the port so that he/she does not use it. Another possible solution would be to economically penalize several charging sessions during the same day by increasing the price per *kW*. This allows the community *EVCI* stations to accept cases of extreme *EV* charging need which the other option did not allow. This helps the nature of the project as it favors all users of the community who could not charge their *EV* and now have an efficient, flexible, and adaptable way to do it.

3.6 Education of the community members

The general public is uninformed about *EVs* and their potential benefits. This is one of society's main problem, but it can be fixed within the community. For this project to succeed, *HOAs* and property managers need to raise awareness of *EVs* among all members of the community and have educational initiatives on this topic so that the community *EVCI* stations makes sense in that community. A team with expertise in *EVs* and knowledge of the entire project of the community *EVCI* station should held office hours. Initiatives such as webinars, educational emails or letters to homes explaining the community *EVCI* stations have a very positive impact. In this section, we mainly focus on targeting the education of community *EV* users.

The project studied in this report is to create *EVCI* stations for a group of communities. But its users must know how to use it in the most coherent and efficient way. For this reason, three fundamental aspects are studied. Firstly, the safety of the users is paramount and although the whole *EVSE* and its installation must respect the local certifications, it is never too much to explain to the users the most important aspects of electrical safety when charging a vehicle. The following safety recommendations [35] should be included by the *HOAs* and property managers in the community *EVCI* stations guidelines for the user:

- follow manufacturer's guidelines when charging your vehicle;
- place all components of the charging device out of the reach of children when not in use;
- signs of excessive wear may indicate possible damage to the charger;
- never use an electric vehicle charger with obvious signs of damage; and,
- cover the electrical outlet of the electric vehicle charging station to prevent water from entering.

Secondly, when they use the application on the smartphone to charge the phone, the users must know how to relate the charging time to the kilometers. Therefore, *HOAs* and property managers should explain to the *EV* user the following explanation. Each *EV* has its battery with a certain efficiency that measures how much energy in *Wh* is needed per traveled kilometer (*Wh / km*).

In Table 6 we can see how the efficiency of the *Wuling Hong Guan Mini EV* stands out among the best-selling vehicles [36]. It has such low efficiency because it is a city *EV* that it could not make long trips like the other *EVs* shown. We now proceed to calculate from those efficiencies the estimated times to charge a vehicle with the worst-case scenario of daily average traveled kilometers from Table 2. In this case it would be 100 *km* as the metric used in previous data.

Table 7. Efficiency of the five best-selling *EVs* of 2021 [36].

EV model	*efficiency (Wh/km)*
Tesla Model 3	151
Wuling Hong Guan Mini EV	81
Tesla Model Y	172
*Volkswagen ID.*4	182
BYD Han EV	140

This equation is used for the different supply powers that the three load levels have. For Level 3 as the power ranges from 50 kW to 350 kW we have taken the average which is 200 kW. The results are shown in the following table.

$$time\ in\ hours = efficiency\ (Wh/km) * \frac{100\ km}{kW\ delivered\ by\ the\ charger}$$

The table 7 would be of great use to users as many own these *EVs* and at a glance they are able to see how long they have to charge their vehicle for the average case of 100-*km* range. This should be included in the mobile app so that the user themselves have a guidance on how much time they should charge their *EV*.

Thirdly, the vehicle's battery is the most expensive and important part of the *EV*. The *EV* user must always think about to maintain the appropriate *s.o.c.* and *s.o.h.* The *HOAs* and property managers should take care to include in the community *EVCI* stations the following recommendations on how to preserve an *EV* battery:

- preserve room temperatures while your *EV* is parked;
- avoid reaching a 100 *% s.o.c* while in charge; and,
- limit the use of Level 3 chargers.

Table 8. Charge time of the energy needed for a 100-*km* range for the best-selling *EVs* of 2021 and in each charger level.

EV model	*efficiency (Wh/km)*	*time taken to charge the energy for a* 100-*km range for charger level in hh:mm*			
		level 1		*level* 2	*level* 3
		1.4 *kW*	2.8 *kW*	7 *kW*	200 *kW*
Tesla Model 3	151	10:47	05:24	02:09	00:05
Wuling Hong Guan Mini EV	81	05:47	02:54	01:09	00:02
Tesla Model Y	172	12:17	06:09	02:27	00:05
*Volkswagen ID.*4	182	13:00	06:30	02:36	00:05
BYD Han EV	140	10:00	05:00	02:00	00:04

The following lines of this paragraph further develop the recommendations. In previous sections we have seen how extreme temperatures affect the *s.o.h.* of the battery and that the user should always try to keep his vehicle at temperatures close to 25 *ºC* when he leaves his vehicle parked. But there is one aspect that usually goes unnoticed but is key to optimize battery life expectancy. Although this degradation is slight, it is quantified in that 8 years of Level 1 or 2 charging gives we 10 *%* more battery life compared to 8 years of using Level 3 chargers [37]. Therefore, whenever we can, we should charge on Level 1 or 2 chargers. Moreover, a crucial aspect is the *s.o.c.* to which the *EV* must be charged. If users keep the vehicle's battery between 15 *%* and 85 *%*, they improve battery life performance. Continuous charging to 100 *% s.o.c.* is detrimental to the battery's lifespan.

3.7 Conclusions

This chapter has studied the various strategical considerations involved in a project of community *EVCI* stations. The keys that *HOAs* and property managers should focus on are to start by the comprehension of the needs and trends that the members of the communities belonging to the project have. This is done through surveys that depending on the type of community can be of one type or another. Mail and online surveys are useful for large and medium communities and telephone and personal surveys are preferred for smaller ones.

In Section 3.2 the considerations and possible solutions that exist to find the ideal location of the *EVCI* stations of the communities involved in the project are studied. The *HOAs* and property managers should install one *EVCI* station in the parking lots of the communities and another one with a higher charging speed in a separate area but located in a strategic area for the convenience of the users. These zones called in the report A and B respectively in case of areas of the world with high or low extreme temperatures for safety reasons regarding the performance of the battery should be in places isolated from the outside. Moreover, to avoid vandalism and to preserve the safety of the users they should be located in places where there is good lighting around and near the local police headquarters. Finally, this location must follow accessibility laws.

In addition, the community *EVCI* stations must have the *EVSEs* that best fit the needs of the community. It is explained how the types of chargers' work, how the creation of The Company described in section 3.3 is necessary due to the issue of electric meters and that the community *EVCI* stations must comply with the necessary local safety standards and certificates. Further on, it is presented how the connection to the local grid may have some negative impact. A control management system is proposed based on a smart charging schedule that focuses on off-peak demand times and an *ESS* that manage loads at peak demand times. In addition, it is discussed how *RERs* address the requirement for clean energy. Section 3.5 provides a potential charging system that meets the requirements of flexibility, adaptability, and efficiency. This section provides a Level 2 chargers model and a software application model to achieve optimal smart charging required.

To conclude, and of vital importance, *HOAs* and property managers must raise awareness and educate the members of the communities participating in the project about the safety of the *EV* charging process, how to take care of the *EV* battery and understand the relationship between charging time and kilometers.

CHAPTER 4

KEY ECONOMIC CONSIDERATIONS FOR PLANNING THE COMMUNITY *EVCI* STATION

This project has to meet the requirements set out in Chapter 2. But especially one of the major barriers to *EV* adoption is the cost involved. In this section, of the report guidelines are given to help the *HOAs* and property managers must take into account the economic considerations needed for the project. There needs to be a budget that ensures that the cost paid for the community *EVCI* stations by the *EV* user in the community is not too high. This is achieved with a coherent and efficient planning aided by the guidelines given in this section. The project must be supported by a clear business model that fits the needs of the community. In addition, a cost allocation that makes sense with the chosen business model and that also encourages *EV* adoption in the community. Over time, communities around the world consider having *EVCI* stations and it is essential to try to get neighboring communities to join to carry out the project together. This is beneficial as it favors the scalability of the project and generates synergies. Due to the current situation where *ICE* vehicles predominate over *EVs*. Local governments around the world offer incentives and rebates programs to encourage adoption that *HOAs* and property managers should try to take advantage of.

4.1 Costs of the *EVCI*

To study and analyze the economic considerations in this section we understand the costs that *EVCI* stations entails for the community. These costs are grouped into fixed costs and recurrent costs. In this report fixed costs refer to the investment in capital or fixed assets made by a company to acquire, maintain or improve the community *EVCI* stations. In this report recurrent costs refer to the expenses required for the operation of the community *EVCI* stations.

Firstly, we analyze all the terms that are important for fixed costs in this project. These are the costs listed in Table 8.

The *EVSE* costs are mainly composed of the charge station hardware, transformer, and the electrician materials such as conduit or wire. According to the model proposed in Chapter 3 we have at most the costs of the three types of chargers. In zone A Level 1 and Level 2 and in zone B Level 3. In the latter case it is necessary to add the relevant transformer for Level 3.

Table 9. Fixed costs factors involved in the community *EVCI* stations.

fixed costs
EVSE
labor associated with installation
signage
application software
parking acquisition
certification costs

The *EVSE* costs are mainly composed of the charge station hardware, transformer, and the electrician materials such as conduit or wire. According to the model proposed in Chapter 3 we have at most the costs of the three types of chargers. In zone A Level 1 and Level 2 and in zone B Level 3. In the latter case it is necessary to add the relevant transformer for Level 3.

Table 10: *EVSE* component costs for each charger level [38] [18] [39].

EVSE	*component costs in $ for each charger*		
	level 1	*level* 2	*level* 3
transformer	0	0	32,500
EV charger	150	750	23,500
wiring	100	360	450

In Table 10 we can see how the Level 3 charger costs 375 times more than the Level 1 and 75 times more than the Level 2. The number of Level 3 chargers must be reduced, and it is the one that has more weight in the budget in terms of the type of charger. In the B zones the *HOAs* and property managers have to study what is the necessary number of Level 3 chargers based on the budget and the needs of the community. As for the A zones, the difference between Level 2 and Level 1 is not so big in relation to the total budget. The choice of Level 1 and Level 2 as we have seen is merely to adapt to the *EVs* demand growth.

The signage in community charging zones, whether in zone A or zone B, must be considered. The places to charge the *EVs* must be marked to avoid confusion from other vehicles that simply want to leave their vehicle parked and would not let space for the *EV* users who want to charge. This can be achieved, for example, by marking the ground with drawings of a vehicle charging or even the word *EV*. In addition, at each site it is essential that there is relevant guidelines considered in Section 3.6 are in place. A reasonable total price could be of *$* 500 [40].

The software application is needed for the community *EVCI* stations to work efficiently and to have a schedule and charging system that functions intelligently. As we have seen in Section 3.5 for communities, a software application is recommended. Due to the difficulty to create the application, *HOAs* and property managers should hire a software developer to design and implement the idea. There are several platforms to hire this type of work, and the price for a mobile app developer would be or around *$* 90 [41].

The labor required for the community *EVCI* stations installation needs professionals and experts to carry it out. Labor is responsible for the installation and connection to the existing local grid. This work requires an economic cost.

Table 11. Installation labor costs for each charger level [38].

installation labor costs in $ for each charger		
level 1	*level* 2	*level* 3
0	610	4,125

We can see in the Table 11 how the more complicated the work is, the higher the cost. This is because the workers are paid per hour and spend more hours with Level 3 [38]. *HOAs* and property managers must be efficient and have everything planned and studied so that the workers know what they must do and do not encounter problems.

Not all communities have to acquire a parking lot for the *EV* charging areas. It may be that these parking spaces are rented or that they are already owned by the community. If the parking space has to be purchased, then there is a cost to be borne. It can be a plot of land on which the parking spaces are built or an already built parking lot. Depending on the situation, one option is better than the other. The price of the plot depends extremely on the geographic location since it costs more in the center of the cities than in the suburbs. What does remain more regular is the price to pay for construction and materials, which averages between *$* 2.50 and *$* 7 per square foot [42]. So, a 20 *EV* charging spots with 8,000 square feet would cost approximately *$* 20,000. If a community has enough land to include the A and B zones proposed for charging stations, then it is best to build the parking lot. If it is in a city, *HOAs* and property managers need to conduct a study to see if it is better to build or buy the parking lot.

Secondly, we analyze all the terms that are important for the recurrent costs in this project. These are the ones listed in Table 9.

Table 12. Recurrent costs factors involved in the community *EVCI* stations.

recurrent costs
electricity utility
maintenance
parking rental

Firstly, the community *EVCI* stations is powered by electricity to be able to charge the *EVs*. This electricity is provided by the electricity utilities in each region. The prices therefore depend on the location of the community *EVCI* station. The average price for households from June 2021 is *$* 0.14 per *kWh* [43]. Moreover, *HOAs* and property managers should get a better price because they operate as a business. The average price for business from June 2021 is *$* 0.12 per *kWh*. In Section 4.2 we discuss the possible scalability and benefits this may bring to suppliers, including electric utilities.

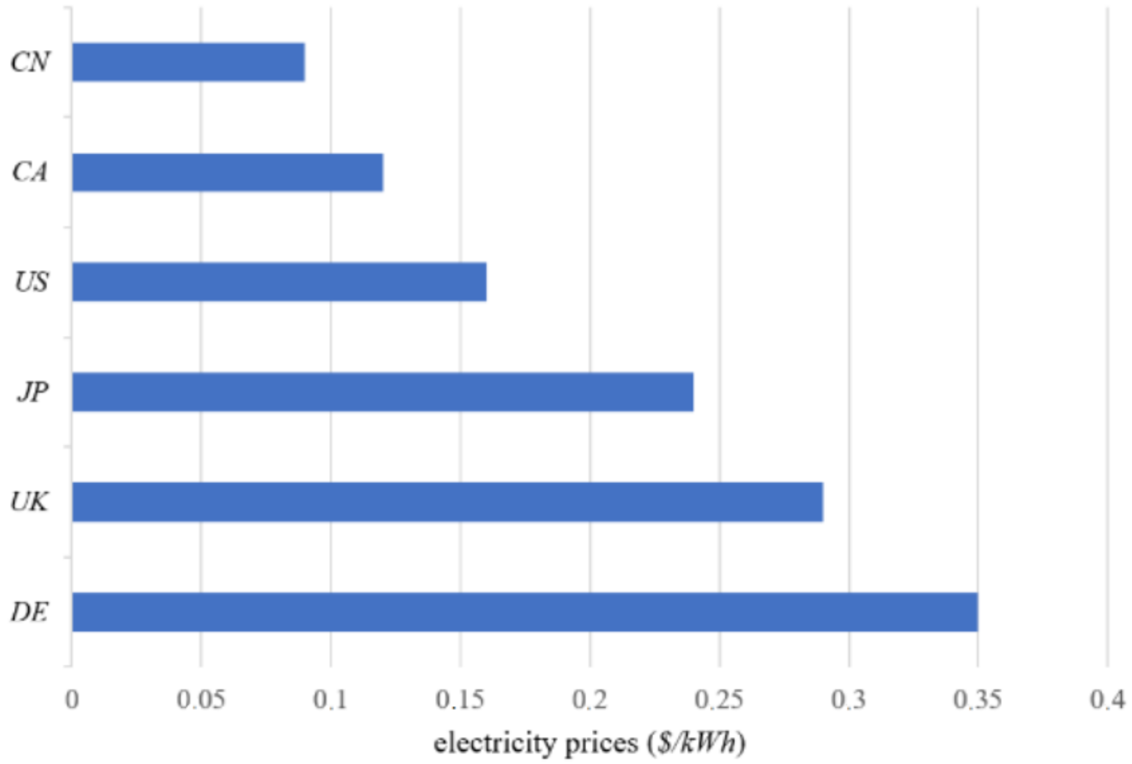

Figure 12. Prices of electricity rates throughout the world [43].

The Figure 12 shows how the price of electricity is highly dependent on location. In cases such as the Netherlands, the average price is three times higher than in India [43]. These prices are an average and this price varies according to the time of the day. With the study of the economic considerations, it makes sense to talk about this approximation as it gives us an idea of the prices at which *HOAs*, and property managers are going to find themselves.

Secondly, one of the most recurring and often overlooked expenses is the maintenances of the community *EVCI* stations. This includes keeping the equipment clean and the charger hardware in good condition. Furthermore, this cost includes unplanned maintenance costs such as repairing a broken charger or any act of vandalism among other things. This cost is difficult to predict but a good approximation according to the *US* Department of Energy is *$* 400 per charger per year [44].

Thirdly, if the communities involved in the project do not have parking available to develop the project, then they must build or rent one. Rental is recommended when we do not want to make a large initial payment and we want greater modularity and flexibility. As with the price of electricity, there is a big difference in price depending on the country. and, if it is near the city or in outskirts. Therefore, it does not make sense to give prices of parking rent in this report and depending on the location of the community *EVCI* stations are a price or another.

4.2 Opportunity in scalability

This project requires a large investment and careful planning to bring it to fruition. There is one aspect that is fundamental to achieve that the project goes ahead addressing the requirements of adoption to a demand growth and to have a low cost. These requirements are solved with a project that presents scalability. Scalability is defined in this case as the ability of the community *EVCI* stations to adapt and respond to the increasing demand in the community of *EVs*. The global perspective of growth of *EVs* in the world is about 24.3 % for 2021 – 2028 period [45]. This means that the household members of the community progressively acquire an *EV* over the years and the community *EVCI* stations must be scalable to be able to absorb this demand. The *HOAs* and property managers in order to make the project scalable, they must benefit from economies of scale and make the project modular in nature.

It is key that the community interested in an *EVCI* station seek support from other communities and do the project together. The more communities involved, the more they can benefit from economies of scale and reduce fixed and recurrent costs since better prices are obtained and the cost is distributed among more people. This can be clearly seen in the Figure 13 [39].

This reduction in the cost per charger occurs mostly in the purchase of *EVSE*, labor cost and in the electricity cost of the utility, since in the other fixed costs items it does not represent a benefit.

Since the payment of electricity is very recurrent over time and as we see in Section 4.4 the cost is borne entirely by the *EV* user. It is key to obtain a competitive utility electricity cost. This is achieved with the economies of scale by grouping several communities to the project in order to grow in size. The rate that can be obtained from the utilities is lower since the community *EVCI* stations consume large amounts of electricity. The average cost of electricity in June 2021 for a household is $0.14 per *kWh* and the average price for businesses as of June 2021 is $0.12 per *kWh* [43]. The community *EVCI* station would be priced as if it were a business, and the *EV* user would be charged at a lower electricity rate than if they charged their household.

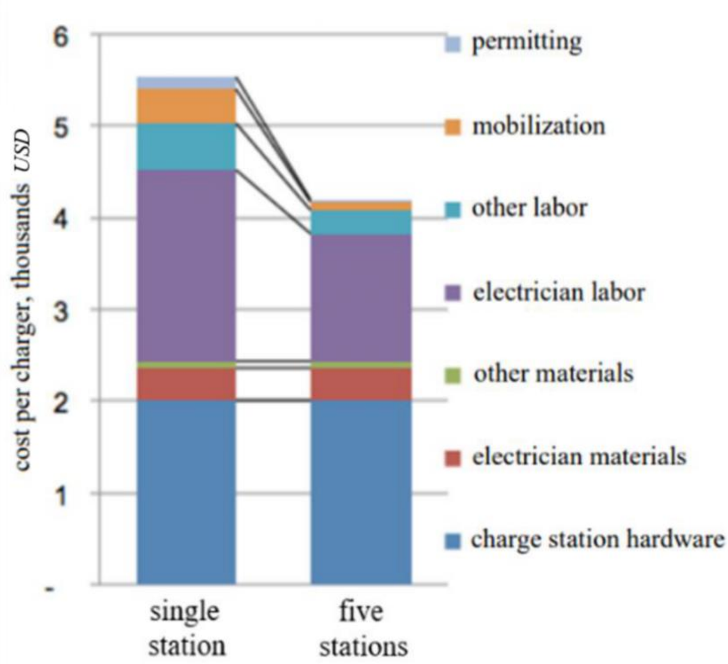

Figure 13. Cost comparison of single station versus five stations [39].

After the *HOAs* and property managers manage the project jointly with other communities, they must be able to absorb the demand for *EVs* from the community itself. This is where the concept of modularity makes sense. The goal is for the community *EVCI* stations to be modular in nature. The way to achieve this proposed in this report is for the *HOAs* and property managers to make sure that in the parking lots where the A and B zones are located, they can rent the number of new *EVs* included in the community *EVCI* stations for the following year. This can be done by the *HOAs* and property managers by signing a contract with the parking lot to rent as many new parking spaces as new *EVs* are added to the communities involved in the project in the following year. The number can be calculated by the estimated demand for the next years. The modular aspect comes when the community *EVCI* stations are created as a set of groups of vehicles that have the charger they use assigned. The vehicles from a household can be assigned a certain number of chargers and can only use that one. When there are new *EVs* adopted then they are assigned a specific new charger to the new rented parking spot. This presents an organized system and can allow the *HOAs* and property managers to assure they can always offer a charger to the new *EVs*. Therefore, allowing it to be scalable.

4.3 Policy incentives and rebate programs

Section 4.1 discussed all the costs involved in an *EVCI* station in a community. These costs compared to those of an *ICE* vehicle are much higher. This is due to the fact that the gas stations infrastructure for these vehicles is already in place and there is no clear infrastructure for EVs. In this situation, if we want to achieve this overtake of the number of *EVs* with respect to *ICE* vehicles, governments have begun to develop a program of incentive policies and rebates to encourage this inclusion. *HOAs* and property managers should focus on taking advantage of these incentives to carry out the community *EVCI* stations project.

These policies are a tool to be used in the economic planning of the project. They are mostly offered by *OECD* countries and are focused on the following support:

- economic incentives by local governments in relation to the required *EVSE* of new recharging networks to be included in the *EVCI;*
- the availability of financial resources, such as loans on attractive terms, made available by local governments;
- to streamline and to bundle of the certificates required for the use of users; and,
- the facilitation of the necessary access permits to integrate the community *EVCI* stations into local grids.

In the case of the *US* on March 15, 2022, President Joe Biden signed a $1.5 trillion spending bill for fiscal year 2022. Of which about *$* 250 million are dedicated to tax credits for the installation of *EV* chargers and *$* 1 billion for purchases of *EVs*. In *CN*, we find how the government incentivizes with a tax exemption on the purchase of *EVs* and promotes the development of the community *EVCI* stations with programs that involves two utility companies owned by the state which are *CN* State Grid and *CN* Southern Grid [46].

In the case of *CA*, there is a Zero Emission Vehicle Program (*ZEVIP*) that supports 50 *%* of the total project up to *$* 5,000 per Level 2 charger and *$* 50,000 per Level 3 [47]. In *DE* the subsidy is 80 *%* of the total cost of the charger and installation, up to *€* 4,000 for Level 2 chargers and *€* 16,000 for Level 3 chargers [48]. In the case of the *UK*, Prime Minister Boris Johnson requires under new legislation that new buildings have electric chargers installed [49]. In Japan the government is going to dedicate 25 billion yen (*$* 200 million as of April 2022) for the purchase of *EVs* and 6.5 billion yen (*$* 53 million as of April 2022) for new *EV* charging stations [50].

All this money that is invested in new *EVCI* stations around the world should be used by *HOAs* and property managers of communities to save costs.

4.4 Business model

For the economic considerations, it is essential that *HOAs* and property managers have a clear business model. This helps future decisions to be made because there is a clear objective. Depending on the objective of the project, the economic outlook can be one or another. On the one hand, the project, as already explained, has the participating communities and their representatives such as *HOAs* and property managers who are in charge of the project and who have to carry out the business model. On the other hand, there are the community members who are the users of the community *EVCI* stations.

To begin with, this project is born to fulfill the requirements established in Chapter 2. In economic terms the business model should focus to keep the price low so that it is attractive to the client and not so low as to allow the *HOAs* and property managers to stay at least in a breakeven profit. The communities involved do not look to be profitable based on their own members' money, they are looking to satisfy their needs since the interests of both are aligned. Remember that in the proposed model there are A and B zones, where in the A zones only members of the community can charge their *EVs* and in the B zones other *EV* users can be allowed to charge their vehicles. It would be in the case of the B zones where users come from outside where higher rates could be requested and a profit could be obtained. This profit would be used mainly to pay the fixed costs that are still to be paid and the recurrent costs such as maintenance or renting of the parking spaces.

It must have the characteristic of seeking to earn grants and subsidies to reduce costs as much as possible as we have explained in Section 4.3 and the capacity for scalability as explained in Section 4.2. The most important and primordial aspect for *HOAs* and property managers is to carry out the cost allocation.

It should be noted that for cost allocation, recurrent and fixed costs should be treated differently in nature. Fixed costs are paid upfront and require a significant amount of capital. Recurrent costs reflect recurrent payments that are not large in amount. Due to the structure of a community the money that *HOAs* and property managers would use to carry out the project would come from community fees to household members. Therefore, the cost of the project would be borne by the members of the community. To obtain this capital, one could either require the community at the time of the expense or ask for a loan and then through monthly community fees get the money to pay the loan. In both cases it could be applied to local government incentive programs and rebates. Where there is variability is who to charge the community fees to in relation to the project. All members of the community benefit from the installation of a community *EVCI* stations. Although, the members of the community without *EVs* are indirect beneficiaries that participate in the community to gain attractiveness and revaluation, and the members of the community with *EVs* are direct beneficiaries since they also benefit of having a charging station. Therefore, the cost allocation is not trivial.

The fixed cost is the cost that generates the revaluation of the community, so everyone is an equal participant. Therefore, the community fees should be divided among all the participants of the community. The recurrent costs symbolize the operation of the infrastructure from which the member of the community with *EV* who is the user of the same is benefited. Therefore, the users of the community *EVCI* stations should bear this cost. Among the recurrent costs, the cost of electricity for the utility is the most difficult to pass on to the user. It could be charged to the user by fixed rates or charged the same as the time of use (*TOU*) billing rate from the utility to the community. The first option would give the user the peace of mind to know that at any time of the day the price is the same. On the other hand, the second option of *TOU* rates incentivizes people to charge their *EVs* during off-peaks to get a better price. This incentive is efficient because as seen in Section 3.4 this type of charging does not saturate the grid. With this electric cost plus the cost of the maintenance and if it is the case that of the renting parking, we would have the cost of the month rate that each *EV* user of the community would have.

Furthermore, *HOAs* and property managers must obtain an electric utility that provide them with the lowest possible price. This is achieved as we have seen in Section 4.2 with economies of scale. In addition, *HOAs* and property managers must take advantage of *TOU* billing rates. In Section 3.4 of this report, we have analyzed how it is fundamental for the correct load management of *EVs* that the loads are made in the off-peak. Moreover, with the *TOU* billing rates it is possible to take advantage of the low price in those hours and obtain a double benefit. Other billing rate options such as fixed rates are not recommended as they do not take advantage of consumer behavior in terms of *EV* charging times.

Other emerging opportunities to optimize and take advantage of community *EVCI* stations include the vehicle-to-grid (*V2G*) technology. *V2G* is a charging technology that enables *EV* batteries to feed energy back into the grid. It uses bi-directional charging to draw or send power to/from connected vehicles based on the demand for electricity at any given time. Uses batteries not only as tools to power vehicles, but also as backup storage for the grid. This is part of a broader initiative known as vehicle-grid integration. This additional energy can be used to supply anything that is in demand connected to the grid. This allows the community *EVCI* stations to act as suppliers of electricity on certain occasions and generate revenue by selling that electricity.

It can be seen in Figure 14 that the number of projects carried out and how the technology is still in a development phase. It has 100 projects with more than 6400 chargers carried out in 24 countries around the world [51]. The *HOAs* and property managers should track future improvements so that they can be implemented in the community *EVCI* stations in the future.

Figure 14. Number of *V2G* projects in each region of the world [51].

4.5 Concluding remarks

In this chapter we have been able to analyze all the considerations that exist in the economic aspects of the community *EVCI* stations. The first aspect that has been analyzed has been the fixed and recurrent costs that affect the project. The fixed costs predominate mainly due to the installation of the necessary infrastructure required to recharge an *EV*. Recurrent costs are dominated by the recurring cost of electricity which, as shown in Section 4.4, is borne by the user.

Scalability is essential to achieve a lower pricing to meet users' low-cost requirements. Economies of scale for the electric utility and the modularity of the stations achieve the proposed objectives. Furthermore, *HOAs* and property managers should conduct a situation study on the incentives and rebates proposed by local authorities. This reduces the fixed and recurrent costs of the community *EVCI* stations.

All this is included in the business model that *HOAs* and property managers have to carry out. As analyzed in Section 4.4, the objectives of this model must be aligned with those of the *EV* users and not penalize them with high prices. The objective is to offer a community service and that all revenues are reinvested in the project. In addition, technologies such as *V2G* should not be overlooked as they can offer a great opportunity to help finance community *EVCI* stations.

CHAPTER 5:

CONCLUSION AND FUTURE OPPORTUNITIES

This report has focused to analyze the different considerations in the planning of a community *EVCI* stations. In Chapter 2, by studying the user, business and technical needs, a series of essential requirements have resulted that serve as metrics for planning. This list of requirements has been developed and explained so that *HOAs* and property managers read this report and realize the real needs that must be addressed during the project.

In Chapter 3, based on the metrics studied in the previous chapter, fundamental aspects of the planning are developed, such as the location of the community *EVCI* stations, technical aspects of the *EVSE*, connection to the grid, schedule charging system or the education of the community members. The focus on these key points of the community *EVCI* stations implementation and planning according to the report makes the project successful.

As several of the main concerns of the community *EVCI* stations project are related to economics, the report focuses on Chapter 4 on developing the relevant economic considerations. This results in a breakdown of project costs and the possibility of business models. It should be noted that this chapter also assesses the scalability in terms of a unification of several communities in order to obtain lower prices by using economies of scale. Not only that, but part of the feasibility of these projects is to take advantage of incentive grants and rebate programs provided by local governments.

5.1 Summary of contributions

Due to the lack of information on community *EVCI* stations projects, the main contribution of the report would be the three main Chapters 2, 3 and 4 where an analysis of considerations for the planning of these projects is developed. It has been divided into two parts, the first one is Chapter 2 to collect the relevant user, business, and technical needs, and then Chapters 3 and 4 where it goes in depth to solve those needs in terms of planning.

Section 3.5 is one of the major contributions of the report. Because one of the biggest barriers to not developing *EVCI* stations in communities was the problem of the loading schedule and how to do it. In this section, by means of charging in zones A and B, proposed by the report, added with the software application and with the new design of electric chargers with double closed circuit and dual-port in each one, it is possible to overcome this barrier.

In terms of economics, we find several additional contributions. On the one hand, taking advantage of economies of scale by having several communities agree to join in a common community *EVCI* stations project instead of several separate ones. This allows costs to be reduced considerably and allows this electricity demand to be treated at a company price rather than the private price of a normal household. On the other hand, regarding the possibilities of taking advantage of the community *EVCI* stations and cost reduction we find the use of the *TOU* rates since it is observed that the results of price versus other rates are that in the *TOU* rates, we obtain a cost reduction. This is since the demand for *EVs* takes advantage of the off-peak demands where the electricity supply exceeds the electricity demanded.

5.2 Direction of future contributions

For all the work of transitioning to electrified transportation to make sense, there must be an increase in demand for *EVs* over the next few years. community *EVCI* stations projects must be a top priority in order for that demand to be absorbed. *RERs*, *EV* education for community members and *V2G* technology are the aspects to be considered in future years and to encourage their development.

The first thing to observe in the future is to achieve a transition to obtain electricity in such a way that there are no CO_2 emissions, and this is achieved through *RERs*. These types of resources are irregular as they depend on natural resources that are not very predictable. In the current scenario, great progress is being made but greater inclusion in the electricity grid is still lacking.

As for the education of community members, it is essential for them to understand that the transition to *EVs* occurs because of the benefits it has for both the user and society. It is a work to be done every year to bring a real change in the way people think. This report serves as a start towards this new panorama of transportation and specifically of *EVCI* stations.

The new demand for *EVs* brings a paradigm shift in how we understand the electric grid. It is thought to be only unidirectional and in cases such as *EV* charging it can be bidirectional. vehicle batteries provide electricity storage that is useful in times of high demand where electricity can be supplied from the *EV* battery. This is called *V2G* and is currently under development, with several projects open throughout the world. It is a new technology that is to be developed in the coming years and would add great value to the current *EVCI* stations and therefore to the community *EVCI* stations projects.

APPENDIX A: LIST OF ACRONYMS

AC	alternating current
ADA	Americans with disabilities act
CCC	*CN* compulsory certificate
DC	direct current
DCFC	direct current fast chargers
EAA	European accessibility act
ESS	energy storage system
EV	electric vehicle
EVCI	electric vehicle charging infrastructure
EVSE	electric vehicle supply equipment
GDP	gross domestic product
GHG	greenhouse gas
HOA	homeowner's association
ICE	internal combustion engine
MUD	multi-unit dwelling
NRTL	Nationally recognized testing laboratory
OECD	Organization for economic co-operation and development
OSHA	Occupational safety and health administration
PV	photovoltaic plants
RER	renewable energy resource
s.o.c	state of charge
s.o.h	state of health
TOU	time of use
V2G	vehicle-to-grid
ZEVIP	Zero emission vehicle program

APPENDIX B: *UN* SUSTAINABLE DEVELOPMENT GOALS

This report is aligned with the following sustainable development goals:

- Goal 7 “Affordable and clean energy”: There is a need right now for accelerated actionon modern renewable energy, especially in the transport sector. This report helps the turnaround in this topic as with the community *EVCI* stations proposed we can increase the share of the total consumption of modern renewable energy. The report poses the idea and conviction of obtaining the electricity partly from renewable energy sources.

- Goal 11 “Sustainable cities and communities”: This report is focused on the *EVCI* stations in communities to make them more sustainable. This report is a clear example of a project that addresses Goal 11. A community *EVCI* station makes the adoption of *EV*s in the community much easier creating a community less reliable in fossil fuels.

- Goal 13 “Climate change”: This goal focuses in taking urgent action to combat climate change and its impacts. E-mobility is a great factor that reduces greenhouse gases in the environment. The creation of community *EVCI* stations will make the *EV* population grow taking the share market of the *ICE* vehicles which will then contribute to take the CO_2 in the atmosphere out of the picture.

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