AN ANALYTICAL FRAMEWORK TO ASSESS THE CONTRIBUTION OF NEW TECHNOLOGIES TO SOCIETAL CHALLENGES

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KEYWORDS

Societal Challenges; Energy Technology; Sustainable Development; Sustainable Mobility Solutions; Electric Vehicle; Battery Charging System; Technological Change and the Environment; SWOT Analysis.

ABSTRACT

This paper addresses the topic of impact assessment of a research project (encompassed on a Joint Activities Program) considering the major priorities established under the societal challenges defined under the Horizon 2020 programme. A methodology is proposed and demonstrated for the particular case of a project aiming the development of an electric vehicle battery charging system with novel operating modes, which was tested at a laboratory scale. Firstly, the methodology is based on literature review in order to gather meaningful information about societal challenges addressed to this technology and, secondly, questionnaires and interviews directed to the research team of this project were conducted. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was derived from the data collected in the questionnaires and interviews to identify and assess the interest of the new technology and its barriers. The results show that, especially, the different operation modes for bidirectional energy transfer are a great advance comparing to other competing technologies. Moreover, the technology can contribute significantly to mitigate climate change by reducing the release of carbon dioxide emissions from the transport sector. However, since the project under analysis was tested only at laboratory, some aspects related to the software and hardware still need to be improved and the effective market uptake is still uncertain, as it is also dependent on the car manufacturers' interest.

INTRODUCTION AND BACKGROUND OVERVIEW

Nowadays, there is a clearer perception that the social component may play a relevant role in the development and subsequent deployment of scientific research projects. The organization of funding programmes, including, for example, the Horizon 2020 (H2020) at an European level, or even country-specific ones, clearly emphasizes the need to respond to societal challenges and social sustainability priorities. Namely, energy research is frequently dominated by technical thinking aiming to find solutions with novel low-cost and high-efficiency technologies. Whilst these are key aspects for market uptake of these innovations, the impacts on what concerns to their contribution to societal challenges and overall sustainable development should not be overlooked. This interlinkage is pressing in order to develop inclusive projects, i.e., encouraging the participation of different stakeholders in the energy planning processes, contributing to the development of user-friendly tools and solutions, which are technically robust, affordable, environmentally effective and socially acceptable.

The H2020 programme is considered as one of the biggest European Union research and innovation programmes, allocating a budget of € 80 billion EUR between 2014 and 2020. H2020 comprises three main pillars: (i) excellent science, (ii) industrial leadership and (iii) societal challenges. With regard to the implementation of the work programme, H2020 aims to explore the challenges needed to be surpassed in several fields, such as sustainability, climate change, social sciences, and humanities or marine sciences and technologies (European Commission 2015b). H2020 addresses the societal challenges, in what has become one of the major drivers for research promotion in recent years. The societal challenges have as purpose to identify the EU priorities for innovation and research in order to better understand the real impact benefiting the citizens. In addition, beyond technological concerns, the focus on policy issues should be also considered to address the proposed challenges.

Figure 1, adapted from European Commission website, is organized hierarchically to detail each of the societal challenges by the associated target activities representing lower-level societal challenges and which represent the "backbone" for H2020 strategy implementation. Societal objectives related to energy issues are highlighted in blue. At the detailed level of Figure 1, the activities coding was related to the major challenge being tackled. As such, energy-related activities associated to secure, clean and efficient energy are labeled as S(1-7), while smart, green and integrated transport is designated as T(1-4) and climate action, environmental, resource efficiency and raw materials are described as C(1-6). Moreover, this figure will be further addressed in the methodology section.

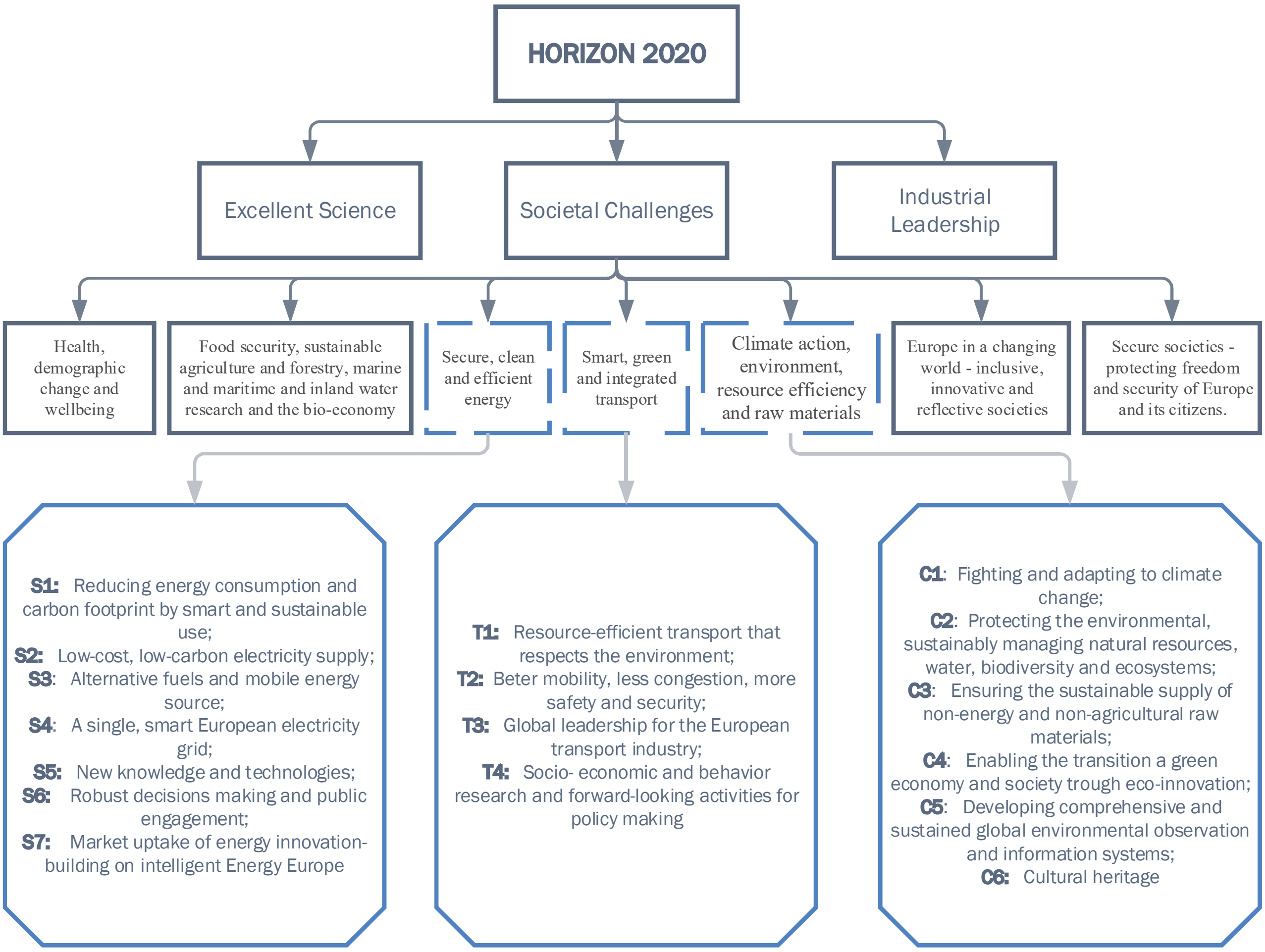

Figure 1: Horizon 2020 – Societal Challenges and main activities - adapted from (European Commission 2019).

The importance of challenges related to secure, clean and efficient energy, green and smart integrated transport, as well as climate action, environmental, resource efficiency and raw materials is well demonstrated by the Europe 2020 goals, aiming to foster a transition towards a low carbon and long-term sustainable society (Pacheco-Torgal 2014). In order to face these challenges, a commitment regarding energy and emissions was undertaken, with the following goals: to reduce by 20% greenhouse gas emissions (GHG); increase by 20% energy efficiency; and renewable energy deployment (Eurostat 2016). In order to monitor the progress towards these targets by Europe in 2020, a set of indicators have been suggested (European Commission 2015a). Among the headline indicators specific under the climate change and energy scope, the following ones can be emphasized: GHG emissions, the share of renewable energy in gross final energy consumption and final energy consumption.

For the purpose of strengthening a sustainable society, beyond the energy policies, the Information and Communication Technologies (ICT) play a key role in supporting a less resource-intensive production, thereby enabling to render sectors such as buildings, transport, and energy. In addition, ICT also can provide useful information about household energy behaviour in order to foster awareness and trigger more responsibility for energy use. This has become even more relevant given the biggest challenge that Europe faces in creating innovative solutions toward smart cities, and intelligent and sustainable environment. More than 80% of the population lives in urban areas, where cities are also responsible for over 75% of world energy consumption and produce 80% of GHG emissions (European Commission 2009). Hence, efforts aimed at fostering sustainable urban areas require the development of new, purposely developed and more efficient technologies contributing to tackling these challenges.

The European Innovation Partnership on Smart Cities and Communication, in 2012, launched the target of achieving deployment on smart cities in Europe, focused on the interaction of ICT between energy and transport sectors. Furthermore, the transport sector is one of the largest energy consumer, and through this relationship between both sectors, the development of cleaner and sustainable services provisions will be encouraged, seeking to attain a smarter city, besides promoting the individual energy provision (prosumers) (Sherpa Group 2014). However, the energy consumption in transport sectors is strongly correlated to the end user's behaviour, so it seems important to understand the preferences of the users to support and define suitable policies in order to improve both energy and environmental efficiency (Ben et al. 2015).

This research has as purpose to provide a methodology for assessing the impacts of research projects in terms of the related societal challenges and the potential benefits provided by the development and deployment of new technology. To demonstrate the methodology, a specific project was selected and adopted - an Electric Vehicle (EV) battery charging system, developed and tested at a laboratory scale. In summary, the central aim research of this paper is to handle both the barriers and potential of the emerging technology developed by the project. Therefore, an expert questionnaire was built, consisting of 19 open questions to be answered individually by each member of the project's team, considering the societal challenges being addressed, as well as their direct and indirect impacts. At this starting point of research, a qualitative assessment was thought of, based the use of a SWOT analysis, where exploratory insights can be accommodated and discussed. SWOT acronym stands for Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T). It is a tool suitable to develop strategies for organizations, however, the SWOT analysis is also applied in a wide range of other areas. Furthermore, this method should also contribute to developing a suitable strategy to boost the effective market uptake of the technologies, taking into account the capabilities of the developed technology and its adequacy to tackle societal challenges.

METHODOLOGY

In order to assess the real contribution for the citizens resulting from the development of the new technology of EV battery charging system, this work proposes a methodology consisting of a sequence of five steps as depicted in Figure 2.

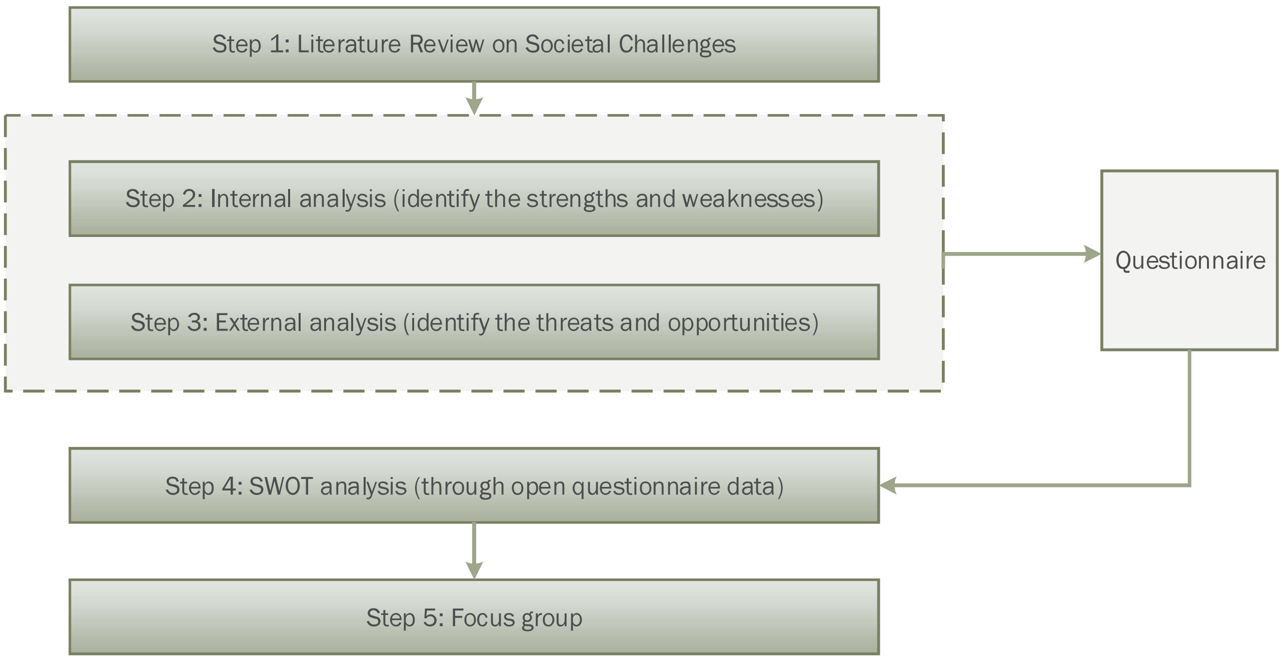

Figure 2: Methodology for impact assessment of the new technology.

Step 1: Literature Review on Societal Challenges

Firstly, in order to clarify the purpose of the study, a literature review was performed, identifying the societal challenges favored by the EU for R&D competitive financial support and assessment indicators. The extent to which financed R&D projects contribute to tackling those challenges is yet requiring assessment contributions. Three challenges were identified to be addressed in this research, as it was mentioned in the previous section, namely: Secure, Clean and Efficient Energy; Smart, Green and Integrated Transport; and Climate Action, Environment, Resource Efficiency, and Raw Materials

Step 2 and Step 3: Internal and External analysis

According to the literature, there are numerous sources of information that may be useful for collecting the expert opinions (e.g., workshop; interviews; questionnaires). In this work of collecting opinions and points of view of the research team, an interview and an expert questionnaire were considered. Prior to the administration of the questionnaire, two meetings were conducted in order to support this study: (i) a first meeting aimed to get familiarized with the developed technology; (ii) the second meeting, performed with some of the research team, intended at clarifying the purpose of the research and of the pertinence and appropriateness of each question to be posed into the questionnaire that would later be carried out. Additionally, suggestions were asked for alterations, if needed, and the inclusion of additional topics thought to be relevant.

The resulting questionnaire comprised 19 open questions, which address several fields such as environment, smart cities, EVs market, behavioural and economic barriers and potentials linked to the deployment of EVs battery charging systems. The questionnaire was built in order to gather data that could be organized in a common framework to assist identification of the expected impacts and potential barriers for the effective uptake of the technology. The construction of this questionnaire was divided into two parts: (i) general issues (table A1), adapted from (Rizzo 2005), (Srivastava et al. 2005) and www.diytoolkit.org; and (ii) specific questions (table A2), with the purpose to better understand the real impact of the deployment of the technology, referring to the societal challenges (Burgelman et al. 2014) and (European Commission 2013a, 2013b, 2013c). For the sake of simplicity, and to choose the questions that better fit the study of this early stage technology, a combination of criteria suggested by (Alonso et al. 2015) and (Alves et al. 2016) was adapted to serve the objectives of this study, namely: (1) Relevance; (2) Sensitiveness; (3) Transparency; and (4) Unambiguity. A total of 4 experts, which were all team members, answered the questionnaire, in February 2019.

Step 4: SWOT Analysis

To organize the internal and external analysis of the EV battery charging system, a SWOT analysis was applied, as an efficient strategic planning and development tool. It enables to analyse the results of the interviews and organize the responses to identify the key internal and external factors that are relevant for the technology development and reach significant societal impacts. The main goal of this analysis is to separate internal analysis, that is controllable, which allow to have an in-depth knowledge about strengths and weaknesses, from external analysis, non-controllable, where opportunities and threats are considered. Furthermore, this method has been widely used as a strategic planning tool since this analysis enables to understand and plan how to use the strengths and exploit the opportunities. At the same time, it allows identifying and avoiding, or mitigating, the weaknesses and to defend against any threats. Moreover, this method can be used at the decision-making level - whether this technology should or not go into the market. In summary, the use of the SWOT method for the analysis of the information provided by the developers is justified by its simplicity and high recognition by practitioners and researchers. As highlighted in (Helms and Nixon 2010), it is widely used not only in business, but also as a tool to assess alternatives and complex decision situations.

Step 5: Focus Groups

The final step aims to analyse and validate the results of the questionnaire and the resulting SWOT analysis on a focus group, which will bring together the researchers. This phase should provide feedback on the main outcomes and will open the possibility for identifying other impacts (negative or positive), considering additional barriers and even outline strategies to overcome them.

RESULTS AND DISCUSSION

The methodology described as applied to assess the contributions and impacts of the EV battery charging system. Given that the technology is still under development and the proposed impact assessment framework is also an on-going research project, this paper will address steps 1 to 4, from which resulted the SWOT analysis. Step 5 will be conducted in the following stage.

The analysed technology owns features that make it appealing under a smart and sustainable city context as it can be used in smart homes or in smart grids, since different operation modes can be considered for the EV battery charging system. Therefore, besides the well-established grid-to-vehicle (G2V) and vehicle-to-grid (V2G) modes, where active power is exchanged in a bidirectional mode with the grid, the EV charger can also operate with innovative modes as: (1) Home-to-vehicle (H2V); (2) Vehicle-to-home (V2H); (3) Vehicle-for-grid (V4G). The H2V mode consists in controlling the EV operating power as a function of the appliances operating in the smart home. This mode can be linked with the G2V and V2G modes, allowing charging or discharging the battery according to the appliances. The V2H mode consists in using the EV as a voltage source (e.g., in camping) or as an uninterruptible power supply (UPS) in a smart home context (only applied during power outages). The V4G mode consists in using only the EV battery charging system for providing services for the grid, i.e., the battery is not used to exchange reactive energy with the power grid, representing an attractive mode for smart grids and smart homes. This operation mode contributes to the smart grid or smart home, since it can produce reactive power, or it can compensate current harmonic caused by appliances. The distinct modes were already validated based on experimental results employing a 3.6 kW EV battery charging system (Monteiro et al. 2017).

The SWOT analysis was derived from the data collected in the questionnaires in order to explore the opportunities and threats in an external context and the strengths and weaknesses inherent to the developed technology. The results were obtained in two steps. Firstly, the strengths, weaknesses, opportunities, and threats related to the development of the technical aspects were assessed. Secondly, the same approach was followed, but with the aim of matching the societal challenges within the SWOT categories. Table 1 summarizes the main outcomes of the proposed methodology. In the appendix, this information is detailed, with the identification of the questions and their relation to both SWOT contents and H2020 challenges. The main results are discussed in the next sections.

Table 1: SWOT analysis summarizing the main outcomes of the proposed methodology.

ENVIRONMENTAL	POSITIVE	NEGATIVE
Internal	**Strengths**	**Weaknesses**
	A) New technological functionalities B) Contribution to the reduction of greenhouse gases emission	A) Required developments for the technology
External	**Opportunities**	**Threats**
	A) Contribution to developing a sustainable urban area B) Energy targets (reduction of primary energy consumption and increase the share of renewables sources) C) Energy behaviour of end-users D) Creation of jobs and boost of economic growth E) Electric vehicles	A) Electric vehicles market B) Government contributions

Strengths

The identification of strengths enables to underline the potential of this technology and allows developing, supporting and underscoring the best features of this technology.

New Technological Functionalities

Concerning new technological functionalities, the stakeholders involved in the development of this technology have highlighted the ability of the EV battery charging system to respond and pursue emerging technological trends, such as the new paradigm of smart grid targeting sustainability and energy efficiency. In fact, it presents innovative operation modes that are related with a bidirectional energy transfer, power quality aspects, and controlled operation, making it useful for different sectors such as residential and industrial ones. Since the EVs could be charged at home with lower energy price, it also enables selling or consuming energy in peak times, encouraging the use of renewable sources.

Contributions to the Reduction of Greenhouse Gases Emissions

The development of the EV battery charging system can actually positively benefit the environment, since this equipment can be employed for different purposes concerning the operation of the power grid, helping to contribute to stabilizing the energy production and consumption. Notwithstanding, the complementary features of this technology could trigger greater energy efficiency and subsequent encouraging end-user to replace conventional vehicles by EVs, since the electric motor is CO_2 neutral and, therefore, it contributes substantially to reducing GHG emissions and to achieve the environmental targets.

Weaknesses

The identification of the weaknesses aims to disclose the limitations of the developed technology. With this purpose, the research team addressed the aspects that could be improved and the elements that need to be enhanced.

Required Developments for the Technology

Some of the apparent faults related, in particular to the hardware, resulting in achieving a reduction of volume and size (e.g., related with the passive filters) maintaining the same features and, consequently, the energy efficiency can be improved. Taking into account the software, the communication channel could also be further improved in order to obtain more robust data sharing, besides improved interface capabilities with other external devices of the EV.

Opportunities

The opportunities refer to a favourable external factor that can be important to ensure a competitive advantage. As such, the differing aspects from other competitors were analysed. The research team highlights the differencing aspects that are related with the operation modes (e.g., V2H), in particular, the contribution for the power quality assurance, where when the EV is parked, the power electronics system may be operating as an active power filter, thereby compensating power quality problems. It should be noted that the conventional equipment only allows a single operation mode denominated G2V, i.e., the normal charging process from the power grid.

Contribution to Developing a Sustainable Urban Area

The introduction of the EVs, linked with the mentioned technology in terms of operating modes, can be useful for mitigating the consequences of the intermittent energy production from renewables (where the EV can operate for charging or discharging the batteries), allowing to reduce the need for compensating the intermittency of renewable electricity production with non-renewable sources. Besides, in order to proceed with the EV battery charging, the required energy can be provided from renewables, instead from the power grid, contributing to sustainable urban areas.

Energy Targets (reduction of primary energy consumption and increase the share of renewable sources)

The deployment of the aforementioned technology could also contribute to increasing the share of renewables, as well as for reducing the energy primary consumption. The integration of renewables into microgrids and smart grids makes possible to achieve a more efficient electrical system. In fact, when producing energy at the place of consumption, the efficiency can be increased. Moreover, taking advantage of power electronics, the energy from the braking can be harnessed to recharge the batteries, increasing the autonomy of the EV and, consequently, decreasing the energy dependence.

Energy Behaviour of End-Users

The deployment of the aforementioned technology can influence the end-user behaviour to be more aware of energy usage given the potential of the innovative EV modes of operation, for instance, when the EV is used for delivering energy into the power grid, the user will be refunded. Moreover, the user can benefit from the changes of the smart house behaviour in terms of energy management, since the EV can be controlled according to the other electrical appliance's usage, allowing to reduce the energy dependence of public electricity grid, i.e., the end-user becomes "prosumer", producer and consumer of energy.

Creation of Jobs and Boost of Economic Growth

The development of the aforementioned technology can contribute to generating employment opportunities, where job creation in the automotive industry seems to be required. To develop the technology, advanced manufacturing is needed as such, training programs and skilled workers are also needed. Besides, job positions can also be created in the energy sector. As the development of this technology requires experts, and this serves to create numerous jobs of high value, it helps foster economic growth.

Electric Vehicles

With the development of aforementioned technology, it is expected an increase of EVs in circulation, since the EV can be used for several purposes for smart homes or smart grids applications, bringing advantages for the user and for the power grid. As an example, the EVs are enabled through their charging in the off-peak hours, storing electricity on their batteries for critical on-peak hours usage avoiding overload of the electrical grid. It also enables to drain surplus energy that usually occurs during the night time and results, for instance, from high wind generation. This would also contribute towards relevant social issues associated with climate change concerns, such as the use of renewables and related reduction of emissions.

Threats

The identification of threat allows determining what could be harmful for developing the technology. The research team mentioned that the main client of this technology would be the automotive manufacturers. At present, the researchers are not able to capture their attention yet, since the technology was developed at a laboratory level. However, the end-user may come to show willingness and interest to undertake this technology, since, for instance, in the new models of EVs introduced by Nissan, the V2G operation mode (injecting energy from the vehicle into the power grid) is predicted as a reality for specific purposes.

Electric Vehicle Market

Considering the more general aspects associated to the EV market, it can be said that overall the uptake of the technology by the automotive market, is conditioned by the interest in disinvestments in electric mobility. At the same time, it should also be considered the prices for charging the EV batteries and the prices that can be established for the new EV operating modes. As such, measures must be taken to stimulate investments in electric mobility, such as increasing the number of charging stations, increasing the financial incentive, and, above all, improve the price and capacity of the batteries for increasing the EV autonomy. Regarding the specific aspects associated with the deployment of the technology, more coordination between the EV utilization and the power grid should be provided in order to foster energy management strategies. Therefore, a bidirectional control strategy for data sharing will be fundamental for a massive introduction of EVs. Yet, for a more in-depth perception of other threats related to this particular technology, could be achieved by a detailed interview focusing issues regarding market regulation, and other technology-related features.

Government Contributions

Financial incentives and tax incentives could play a fundamental role in the development of the technology, not only in the purchase of EVs, but also fostering the use of renewables, (e.g., installation of photovoltaic panels at residential level). However, as the technology is still an emerging technology at the laboratory scale, therefore there is still a long pass toward for achieving an economic viability at the market level. In this context, these incentives should not be taken as guaranteed.

CONCLUSIONS AND FURTHER RESEARCH

The study aimed to describe a framework to support the assessment of the contribution of novel technologies for the societal challenges identified under the H2020 programme. For this, a qualitative approach was proposed, based on interviews with the technology developers to integrate their specific experiences and views. The framework was applied for the case of an EV battery charging system with new operation modes.

From the resulting SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, it is evident that the strengths are mainly related to the possibility of relying on different operation modes for bidirectional energy transfer with the electrical grid. This should contribute to encouraging EVs owners to be more active in the energy market. This mechanism can be an important tool to foster the deployment of other related smart grid concepts, such as demand response programs. Therefore, the technology will have an important role for addressing concerns related to the access of affordable energy to the entire population. At the same time, this technology could contribute for reducing the greenhouse gases effect by reducing carbon dioxide produced by the transport sector.

The weaknesses cover the technical aspects since the technology is based on a laboratory prototype, where some issues related to the software and hardware still require improvements in order to reach a satisfactory degree of ripeness to try to catch the attention of automotive manufacturers. Another weakness that could have a negative effect on the acceptance of this technology by the final EV user is the fact that this technology involves innovative operation modes and some of them are very specific. If not well explained and promoted, this complexity can be an important barrier for end-user acceptance.

Analysing the external factors, we conclude that the opportunities created by the new technology respond positively to the European-Union directives, such as fostering the use of renewables, reducing the primary energy consumption and combating the climate changes, thus will send a positive signal to the potential buyers, facilitating market entry. On the other hand, the EVs market is highly competitive and innovative, meaning that, other technologies are already being developed and newcomers can have difficulties raising the manufacturer's interest.

Among the limitations of the existing study, it should be noted that in the research outline, preference should be given to individual or group interviews for data collection. These interviews would enable a more detailed insight into the research team viewpoints; however but would require efforts regarding schedule compatibility for all participants and time length control. On the other hand, there are restrictions regarding the data processing procedure, which might lead to inadvertent losses in information due to the translation of the interview.

This preliminary study showed the importance of analysing the potential impacts of novel technologies for EVs under the societal perspective. For the particular case under analysis, in next stage of this work we will proceed with the focus group (step 5) with the research team, aiming not only to validate these outcomes, but also to assess if other aspects should also be included. In addition, the proposed methodology is also planned to be applied to other energy-related technologies. The main goal is to show, firstly, the contribution of these technologies for society wellbeing and, secondly, to analyse the barriers to their effective development and propose strategies to overcome them. In fact, the potential of advanced technologies can only be realized if developers truly acknowledge both its technical and social value, along with the difficulties that they may face in bringing the technology to the market.

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APPENDIX

Table A1 – Construction of questionnaire – part 1

Questions		Internal Factor	External factors
What could	Be the main factors that support this technology?	Strengths	
	Make this project unique?	Strengths	
	Be improved	Weakness	
What	Is not done appropriately?	Weaknesses	
	Element needs strengthening	Weaknesses	
	Are thing that the potential users might see as a weakness	Weaknesses	
	Are you doing differently from other competitors?		Opportunities
	Is there an issue with finances?		Threats
	Do the relevant end-users show their willingness and interest to support the technology developed by the project?		Threats

Table A2 – Construction of questionnaire – part 2

Topics covered	Questions		Internal Factors	External factors	H2020 scope
Environmental issues	With the development of this technology …	Could positively benefit the environmental?	Strengths		S1; C1; C2
Smart cities	With the development of this technology …	Contribute to building sustainable urban areas for future human life?		Opportunities	S1; S4; S5; S7; C4
Electric Vehicles	With the deployment of this technology …	Could increase the number of EVs in circulation?		Opportunities	S1; S2; S3; S5; S7; T1; T3; C1; C4
	Which	changes in EVs market are requested to deploy this technology?		Threats	S1; S2; S3; S5; S7; T1; T3; C1; C4
		Threats could be encountered into EVs market that would affect the deployment of this technology?		Threats	
Energy issues	The deployment of this technology	Could reduce primary energy consumption?		Opportunities	S1; S2; S5; S7; C1; C4; C5
		Could increase the share of renewables sources?		Opportunities	S1; S2; S5; S7; C1; C4; C5
Behavioural and Economic aspect	Which changes …	Could occur on energy behaviour of the end-users motivated by the deployment of this technology?		Opportunities	S6; T4
		G2overnment could occur that would encourage the deployment of this technology?		Opportunities	S6; T4
	The deployment of this technology…	Could improve the employment level and boost economic growth?		Opportunities	S6; T4

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