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Blockchain strategies and policies for sustainable electric mobility into Smart City

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Abstract— **Electric vehicles (EVs) are spreading more and more in Europe, thanks to CO2 standards, which require car manufacturers to reach an average sales share of 5% EV in 2020 and up to 10% in 2021 and close to 20% in 2025. To allow these new diffusion scenarios of electric vehicles, adjustments to the electricity grid are needed, including an increase in charging points and financing mechanisms. The spread of electric vehicles will contribute to urban sustainability, thanks to the delocalization of air pollution, the reduction of noise pollution, the implementation of the use of renewable sources in widespread generation.**

However, uncontrolled recharging could increase the peak load in the smart grid, which therefore requires distribution-level controls and correct planning for the recharging stations is needed in order to power the EVs avoiding network congestion. In fact, if electric vehicles are charged at the same time in an uncontrolled way, this would lead to an increase in energy demand, with the possible peak increase on the network, contributing to the overload and the need for updates at the distribution level, if not the need to adapt the generation capacity, with modified cost profiles. This opens new models for charging, business and regulatory systems, for managing the fleet of electric vehicles. This paper aims to analyze the new scenarios for Smart Cities that will be outlined from the point of view of tariff and regulatory systems.

Keywords—Electric Vehicle; Blockchain; Smart grid; Incentives, new model business.

I. INTRODUCTION

In the context of Smart Cities, which represent a better quality of life and environmental sustainability, the issue of mobility is crucial. In fact, one cannot ignore the fact that urban mobility, the source of the greatest pollution within cities that are heavily populated, represents a key element for the development and realization of Smart Cities. This interaction must be addressed by looking at the future of vehicles that will no longer use petrol and which will be fully electric. Electric Vehicles (EVs) can represent a challenge but at the same time an opportunity for optimal management of the smart grid, in which the Home and building smart areas interface, as well as all productions from renewables, which are highly random.

Thus EVs become, through their battery packs, microgrids in movement and thanks to IoT and Blockchains they open the markets to new economic scenarios, which must be carefully incentivized and regulated.

II. ELECTRIC VEHICLE MARKET

Several factors affect the distribution of electric vehicles: the performance and costs of batteries, access to the distribution network, the type of business model implemented to provide the consumer with reliable batteries and electricity, the acceptance by the consumer of new types of vehicles.

The spread of electric vehicles is increasing rapidly, this requires a plan for the use and construction of charging stations, to meet demand and encourage the use of electric vehicles instead of those of the ICE (Internal Combustion Engine) type. The number of electric cars worldwide has risen to 5.6 million in early 2019, see fig.1, up 64 percent over the previous year. Electric mobility is developing very dynamically in many countries and particularly in China, becoming the leading country both in terms of the total number of vehicles and new registrations with 2,610,000 electric cars. The United States is in second place with 1,102,450 EVs. More than 290,000 electric cars sold in the European Union in 2019, almost double that of 2018. Norway took third place with 86,340 new registrations in 2018, bringing its total to 298,210 EVs.

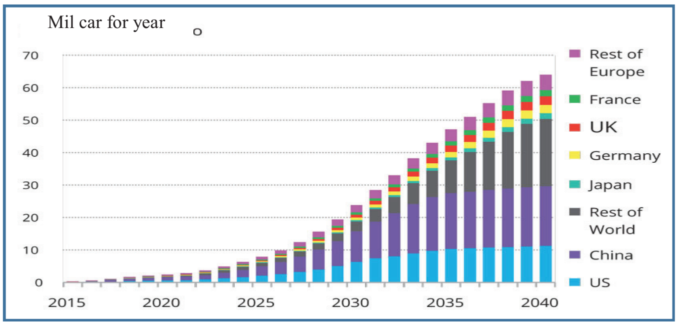


Figure 1: EAFO (European Alternative Fuels Observatory)

The spread of EVs in the area will significantly contribute to the smooth operation of smart grids, becoming a potential source of support for the reduction of the peak load, since generally 90% -95% of electric vehicles spend their time parked. EVs drivers carry out more than 80% of their charging at home, in the same way they could charge their smartphones [1]. Of course, charging installations in the workplace can also provide a valid option for people who do not have charging equipment at home. However, in order to have an effective charging system, it will be necessary to apply easy-to-use, available and affordable prices. The lack of access to electric recharging infrastructures is seen as one of the main disadvantages of the spread of electric vehicles [2]. Most countries in Europe and worldwide have started to reduce transport emissions by encouraging the use of electric vehicles instead of ICE vehicles. This is thanks to the joint efforts of politics and industry in recent years, in particular with plug-in electric vehicles (PEV), which allow users to connect their vehicles and drive exclusively with electricity or in combination with fuel.

Due to the rapid penetration of PEV sales per year, it was necessary to install more charging infrastructure on the roads to adequately serve consumers. Therefore, policy makers can gain a better understanding of the pricing behavior of EV users in order to optimize the locations and characteristics of public charging stations in local municipalities [3]. EV user charging has a significant influence on the distribution network and its reliability. To support EV adoption, charging infrastructure should be expanded in public places and workplaces to serve different types of users.

III. SMART CHARGING

Smart charging points are defined as charging points capable of receiving, understanding and responding to signals sent by energy system operators or by third parties, the parties must indicate when it is the right time to load or unload in relation to the offer and to the overall energy demand. EVs fleets can create a large electrical storage capacity to store surplus production when RES electricity exceeds demand.

Increasing the share of smart charged electric vehicles will also increase the flexibility of the system to compensate for daily changes in the system with a higher renewable share. [4]

According to numerous studies (Eurelectric, 2015; BoA / ML, 2018a; Schucht, 2017) it has been shown that uncontrolled charging of electric vehicles only causes slight increases in electricity production and consumption, however, the impact on peak demand can be consistent.

If as foreseen by a study (IRENA 2018) by 2030 approximately 160 million EVs will be able to connect into power system, uncontrolled recharging will entail a network congestion at a local level, for example for the United Kingdom (United Kingdom) where they are expected 10 million electric vehicles by 2035, peak evening demand with uncontrolled recharge would increase by 3 gigawatts (GW), which requires significant investments in the network and new generation capacity, but would increase by only 0.5 GW if recharging were intelligent (AER, 2018) and charging only during off-peak hours could avoid any increase in peak demand. (RMI, 2016), with smart EV charging, lower price periods could see demand rise by 7 GW (AER, 2018). See fig.2.

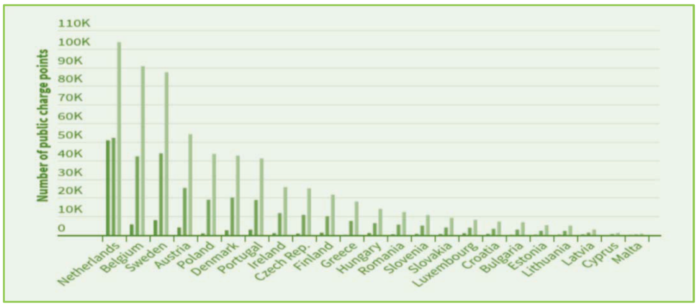


Fig.2: Charging Infrastrcutre Supply and Cost Model (source T&E)

The chargers can be summarized as follows:

A. *Slow Battery chargers* - up to 22 kilowatts (kW) - used, for longer periods of time, for home and office charging:
   - Single phase AC charger (3-7 kW): charges an EV in approximately 7-16 hours
   - Three-phase charger (11-22 kW): charges an EV in about 2-4 hours

B. *Fast chargers,* generally from 50 kW and above, are used in DC systems, used along highways:
   - Fast DC chargers (50-100 kW): charge an EV in 30-40 minutes

C. *Ultra fast chargers* - over 150 kW - as an essential complement for slow charging in the home and office
   - Ultra-fast DC charger (over 100 kW): charges an EV in 10-20 minutes or less.

The power level (in kW) of a charger represents how many kWh of energy an EV can be charged in an hour.

The impact of fast charging on the grid will need to be assessed for installing charging points in areas that have a low impact on local demand and peak congestion.

Another key factor is represented by the load characteristics: for example, the impact of uncontrolled EV charging will be more consistent where a high distribution of electric heating is expected, but at the same time it could be installed as the networks in those points are already sized for higher peaks.

The higher the power, the greater the capacity required by the distribution network, this means that the locally installed charging station / cables and the vehicle must be able to manage this power. [5],[6].

The solutions from the technical point of view are obviously feasible but they have a price:

- faster charging stations and larger cables and transformers must be connected to the network;
- charging stations require more expensive electronic components, coolers and protection;
- active cooling of the charging cable is required if very heavy cables are to be avoided;
- EVs need more expensive electronic components and protective devices.

Congestion in the distribution network, in the free market, must consider:

- Simultaneity factor: applied according to the size of each grid and each operator of the distribution system considers a different simultaneity factor.
- Low voltage generation activities: the introduction into the grid of high powers from RES could be facilitated by intelligent recharging, while in positions with a low percentage of RES, the EVs would increase the voltage on the local grids.
- Limits of national grid codes and other regulations: they define physical constraints in terms of voltage and frequency variations that can be overcome for EVs recharging, and therefore the distribution system operators, having to respect these limits, would face further investments.

IV. IMPACT OF PUBLIC POLICIES AND INCENTIVES

State incentives and the reduction / abolition of motor vehicle taxes are at the basis of the growth of EVs, in fact at the moment those who own one pay about 40% less taxes than an ICE owner, yet it is still not enough. All public EVs recharging points must be equipped with an intelligent measurement and communication system, with bidirectional information, on costs and prices to be provided to both system operators (or aggregators) and prosumers. The requirements of these interchange systems should be harmonized between countries. Many factors could be the basis for estimating demand, such as:

(i) consumer purchase and approval,

(ii) availability of charging points,

(iii) battery charging profile,

(iv) generation time and additional relevant infrastructure,

(v) technological improvements in EV and their parts such as the battery pack,

(vi) influence on the current electricity grid.

Public charging points should:

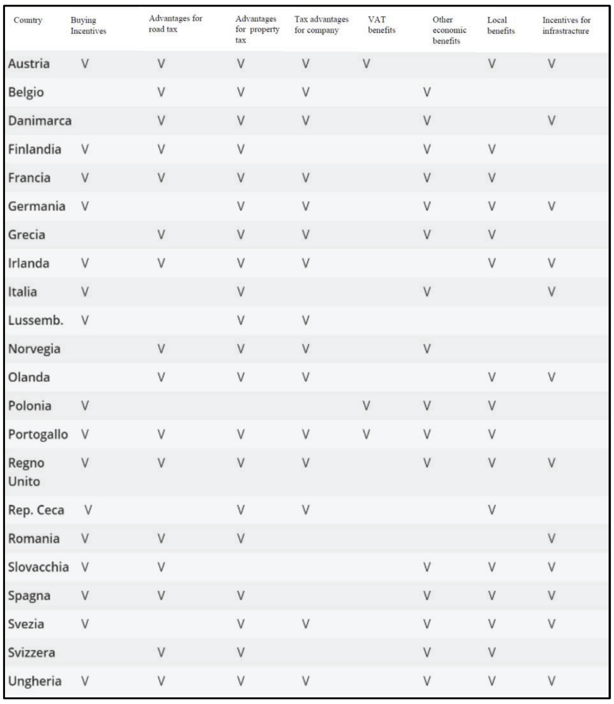
- be available 24 hours a day, 7 days a week, on an open and non-discriminatory basis for all users;
- provide fair and transparent prices;
- standard interoperability protocols for communication between the EV, the charger and the central management system, such as the Blockchain.

In order to speed up this process of penetration of EVs, decision makers should consider:

- incentive mechanisms for the purchase and use of electric vehicles (in this way also car manufacturers would be incentivized for production);
- planning for sustainable urban mobility;
- implementation of regulations and regulations;
- incentives and financial instruments;
- support scientific research;
- lower registration fees;
- possibility of access to urban areas with limited traffic;
- dedicated and free public car parks;
- parking spaces compatible with electric vehicles;
- dedicated access roads or lanes.

Tariffs should be proportionate and transparent to encourage and avoid disparities, based not only on the consumption of kWh, but also on the time spent, in order to induce the vehicle to move, if loaded, in order to allow a continuous replacement at the recharge [7]. In table I the different tax advantages for the different countries of the European Community are identified.

TABLE I: TAX ADVANTAGES IN EUROPEAN COUNTRIES



Country	Buying Incentives	Advantages for road tax	Advantages for property tax	Tax advantages for company	VAT benefits	Other economic benefits	Local benefits	Incentives for infrastructure
Austria	V	V	V	V	V		V	V
Belgio		V	V	V		V		
Danimarca		V	V	V		V		V
Finlandia	V	V	V			V	V	
Francia	V	V	V	V		V	V	
Germania	V		V	V		V	V	V
Grecia		V	V	V		V	V	
Irlanda	V	V	V	V			V	V
Italia	V		V			V		V
Lussemb.	V		V	V				
Norvegia		V	V	V		V		
Olanda		V	V	V			V	V
Polonia	V				V	V	V	
Portogallo	V	V	V	V	V	V	V	
Regno Unito	V	V	V	V		V	V	V
Rep. Ceca	V		V	V			V	
Romania	V	V	V					V
Slovacchia	V	V				V	V	V
Spagna	V	V	V			V	V	V
Svezia	V		V	V		V	V	V
Svizzera		V	V			V	V	
Ungheria	V	V	V	V		V	V	V

To reduce recharging and therefore waiting times, it is possible to manage the columns in order to have:

1) different times for charging, fast, medium, slow;

2) smart charging (V2SG, V2SH,..)

3) battery swapping;

4) prices based on time of use;

5) car sharing;

6) encouraging charging when electricity is the cheapest ;

7) communication protocols must be standardized;

8) charging stations must be interoperable;

8) position the columns powered by RES, where are most present;

9) support to the guide and the routes, for choosing the most suitable charging point, in relation to the boundary conditions;

10) stimulate charging in car parks, where cars remain parked for a long time (shopping centers, workplaces, home, restaurant, theater, etc.).

In any case incentive strategies must always consider that EVs are systems for mobility and not for network regulation and Interoperability is the key to enabling economic connectivity of electric vehicles with different charging and metering infrastructures. Charging electric vehicles will have an impact on investments in the distribution network. How much network investment (in terms of cables and transformers) will depend on the characteristics of the local distribution network, by each operator of the distribution system, the presence of RES, etc.

V. BUSINESS MODEL

With smart charging, prices are used to prevent peaks in grid loads, and to make charging coincide with renewable energy production or to power the grid during high energy demand. The tariffs are managed centrally by the aggregators, as the individual prosumers do not have a sufficient impact to make individual transitions on the energy market.

To encourage the electrification process, new business models will have to be started, especially mobility as a service, both for balusters and for shared vehicles. In addition, this will allow you to acquire data for forecast analysis in the use of EVs, allowing you to optimize the refills avoiding them in moments of peak load, but at the same time to provide services to prosumers, such as cooling/heating the car, in relation to the different uses of the Prosumers.

Electric mobility systems are decentralized, with on-demand service mechanisms, this makes the use of blockchains suitable.

For grid operators, Blockchain (BC) systems offer a market-based solution that could be used for optimized management and coordination of electric vehicle charging. Users can access real-time information on prices and transactions within the network, in order to choose whether and when to charge/discharge the batteries, making them in fact Prosumers. The charging methods can be flat-rate, time-based or kWh-based, rates for family groups or businesses can be created.

With the possibility for prosumers to choose and pay for the desired energy supplier, both when it is most convenient, and at any charging station, integrated with other services, such as parking, car-sharing, rental, etc., Dynamic Smart Contracts, prices that reflect the real-time cost of energy and the grid at hourly or even smaller time intervals, are established, through a platform that generates automated cash flows, managed through the BC ledger (without an aggregator) and controlled via a mobile app. Any member of the network can monitor and track all transactions that compete with him.

Batteries can provide the quick response needed for some auxiliary services, but their power supply capacity is limited; therefore a single EV cannot provide these services for the period of time necessary for system power. However, electric vehicles as a grouping, result as a VVP (Virtual Power Plant) with a rapid response and the ability to provide services for the period of time necessary.

Limits are due:

- privacy, as blockchains are public records, so the information on the daily position and movement of users must be anonymous.
- safety, to prevent compromising electric vehicles.
- interoperability standards, to allow EVs to charge anywhere.

Flat rates do not provide any incentive for smart charging, there must be dynamic tariff plans, which encourage smart transitions also at the retail level, where prices can fluctuate based on the supply and demand for energy. The definition of prices can also be decided dynamically based on the decisions of the drivers, for example they are willing to pay more to ensure the availability of the charging station. However, as there are operators of the charging point, EVs drivers, Smart grid operators, renewable energy producers, parking managers, etc., the dynamic setting of the tariffs must consider all interests and it is said that they are advantageous for drivers of EVs, this could be a big limit to the penetration of EVs..

VI. BLOCKCHAIN FOR DYNAMIC PRICING MODEL

Blockchains (BC) are secure distributed ledgers that allow transactions safely and economically. They function as distributed databases that contain a constantly growing list of data records, the so-called blocks. Transactions are verified by nodes, which are computers managed by the Prosumers of the network. Therefore, no third party is needed to ensure that a transaction has taken place correctly.

EVs batteries can contribute to balancing the grid at peak times, rather than unbalancing it, and through BC it allows connected EVs, when it is necessary to increase the grid power, to register the willingness to give up the charge, to interrupt it or make it slow, against this the Prosumer is rewarded, with payments managed by the Blockchain, in a personal Wallet.

The transactions due in the use of electric vehicles are established by smart contracts and stored in a BC ledger, as EVs become energy resources and therefore sell excess energy to other consumers to earn Bitcoin (or RESCoin, digital currency linked to production from RES [8]).

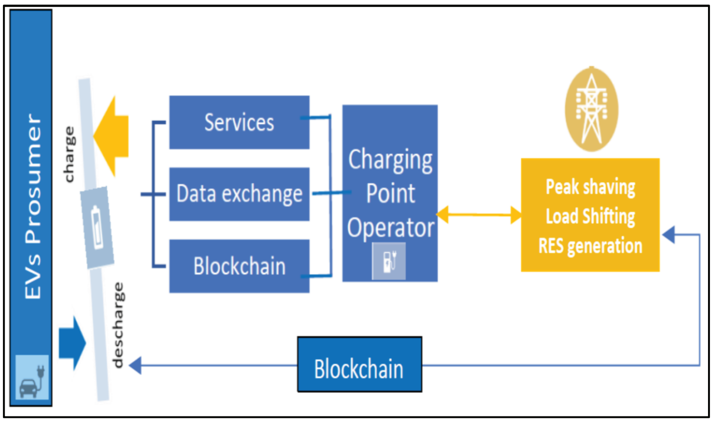


Fig.3 : Scheme of Business Model

In fig 3 the business model scheme is illustrated, where EVs prosumer can decide whether to load or unload the vehicle, while it is at the smart charging point or directly at the smart grid, through Blockchain-type decentralized transactions. In this way a virtual wallet is generated, in which it is possible to circulate RESCOin, that is virtual currency, produced by RES, both for the purchase and for the sale.

The open public network (Unpermissioned ledgers), does not have a "property" or a reference actor and is designed not to be controlled, the objective is to allow each participant (Nodes) to the network, to contribute to the updating of the data on the Ledger and to have, as a participant, all the immutable copies of all the operations, or to have all the identical copies of all that is approved thanks to the consent. In this BC model, no one is in a position to prevent a transaction from taking place and being added to the Ledger once it has gained the necessary consensus between all nodes in the BC. This type of network makes all documents / transitions that require maximum security in terms of consent unchanging over time, such as energy contracts (RESCoin).

In this case the Blockchain protocol must contain in the ledger:

- **Real Time Clock** (RTC), the time elapsed between an offer and the acceptance of the request, which must always remain in line with the average confirmation time, to reduce the computing power;
- **data storage**, by 8 to 32 bytes per transaction, being a decentralized database;
- **transaction value**, always vary according to the characteristics of the transaction. In order to maximize profits, BC typically prioritizes transactions by paying at higher commission levels.
- **transaction fees:** in order not to interrupt the network from unnecessary transitions, a commission if the transition does not take place;
- **total hash rate**: processing power of the RESCoin network, the greater the hashing power in the network, the greater its security and its general resistance to attacks.

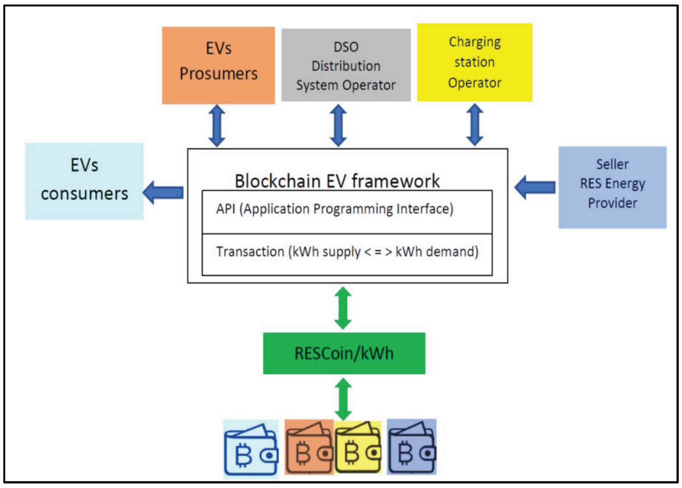


Fig. 4: Blockchain EVs Framework

Figure 4 shows the framework for the Blockchain dedicated to EVs. There are the different "Participants", who sell or purchase energy produced from renewable sources, depending on whether the energy offered is greater or less on the market, at the time you for the next 15 minutes, a price is determined, (RESCoin / kWh), which accumulate or are spent by each individual BC Wallet. [11], [12]

The public nature of the incentives and the often private nature of the charging stations is to offer a cheaper price.
The protocol must be designed to "be light" and with little communication in it to minimize the amount of data to be stored in the BC. Thus the offers are "kept" for a period of time, until an EV's Prosumer decides to accept, however, after a certain period of time has elapsed, the process is interrupted and the offers must be resentful. [9]

Participants are those involved in charging / discharging batteries, i.e. EVs prosumers / consumers and managers of charging stations. Each owner of EV is registered using some parameters: "wallet", "IDName", "email or smartphone number"

VII. CONCLUSION

EVs will replace ICE vehicles, this evidence is evident both from what the car companies are developing, and because many countries are preparing plans to encourage the use of EVs. However, to overcome this challenge it is necessary to create a market, through careful strategic planning, with the mediation of public interventions and private initiatives. EVs will have to achieve near zero cost parity with ICE vehicles and provide services (such as charging comfort) so that prosumers do not consider them inferior or comparable to ICE vehicles. The development of common advanced standards for safety, environmental performance and interoperability are considered needful. The obstacles to the adoption of EVs are gradually decreasing as technological costs decrease. However, deploying and scaling the smart charging infrastructure remains the key element. If policy actions are taken to establish standards, interoperability and secure transitions via Blockchain, smart charging will move from promise to practice by 2030.

With this paper, the key aspects of an EVs market have been considered, from a technical, economic and political point of view, which are the basis of adequate knowledge for decision-makers. The goal is to build a public (but also private) business model, in which there is no discrimination, in which the use of electric vehicles is encouraged, without however unnecessarily filling the charging points, as if they were parking lots, but to encourage less time positioning and monetization following the transfer of the battery charge, in the event of peak load or recharge in the moments of greatest production (e.g. from photovoltaic), through a safe and reliable system such as Blockchain.

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