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Preparing Charged Vehicles in the Prosumer's Ecosystem

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Summary

The current trends of vehicle electrification, micro-production of electricity by renewable power sources like solar panels, and digitalization meet in smart homes where car manufacturers need to understand the business potential and prepare their vehicles for future possibilities. This paper explores some of the upcoming potentials, issues and need of research when migrating to new generations of electromobility taking power production and remote distribution of energy into consideration.

Keywords: electric vehicle, smart home, user behaviour, prosumer, solar energy

1 Introduction

One current trend in society is that electrified vehicles increase in numbers. Sales of new electric cars worldwide surpassed 1 million units in 2017. This represents a growth in new electric car sales of 54% compared with 2016. The global stock of electric cars surpassed 3 million vehicles in 2017 [1]. Most manufacturers of vehicles can already today offer car models with different features and degrees of electrification. Electric vehicles (EV) include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV) and fuel-cell electric vehicles (FCEV).

Another clear trend is that renewable power sources like wind or solar power increases [2], [3]. Solar panels have decreased in price resulting in an increased number of households with solar panels installed on the roof of the house or on the ground have increased. People installing solar panels in their homes thereby become natural prosumers, i.e. they are both producing and consuming their own electrical energy.

Figure 1: Smart home with renewable power sources, like solar panels or windmills, where electric vehicles with battery storage possibilities can lower the cost in the prosumer's eco system. The car on the picture is charged via induction for user convenient reasons but could as well be charged by a cable from an energy balance point of view.

Digitalisation is another megatrend that will influence all people and the building of the future society. Digitalisation gives the ability to find ways to bypass obstacles, innovate new values, solve challenges in society and improve the quality of life of individuals. Digital transformation is not only a technological shift, but an organizational change at the intersection of technology, business and people [4].

Digitalisation actually entered the car manufacturing industry several decades ago, initially with services in navigation and entertainment. Today, many vehicles are connected and equipped with internet access which allows them to share data with other devices both inside as well as outside the vehicle. Connected cars enable smart services like remote diagnostics, remotely open and lock the cars, and route planning based on traffic situation.

Digitalisation also entered homes decades ago enabled by devices that are interconnected and identifiable through digital networks and internet of things, catalysed by smartphones and tablet computers. Nowadays, smart home is a concept used for homes with connected devices enabling a range of smart services, like remotely putting on or off coffee, washing, start the dishwasher machine or turning on or off the security alarm. Smartness is also put in e.g. refrigerators that can create dinner recipes based on the ingredients stored inside or trash cans that monitor what you throw away and generate online orders for replacements.

The inevitable merger of the connected car and smart home technologies, cf. Figure 1, promises exciting opportunities for consumers. Consumers are unlikely to accept less than a seamless transition from car to home as they wade deeper into the connected lifestyle. Combining renewable electricity production in form of solar panels and electric vehicles with storage possibilities may be a better business case than having no renewable sources and drive a fossil fuelled car, at least when prices for the new technology decrease.

Potential benefits

Some of the potential reasons of installing solar panels and buying electric vehicles are:

- *Economy*
    - The energy bought from the energy company, measured and discounted through the meter, will be lower due to own electricity production and hence the upcoming electricity costs will decrease. When the break-even point gets closer in time, the willingness to make the investment increases.
    - A possibility to get paid for excessive electricity generated back to the grid from the house. When the supply and demand of electricity varies in the grid, sufficiently many micro-producers can help stabilizing it [5]. The payment for excessive electricity generated back to the grid may potentially be high.
    - Balancing production and consumption locally in the house. Some customers pay for the electricity not only based on an energy tariff but also a power tariff [6]. This means that there is an economic value of keeping the energy peaks down. Peak shaving, i.e. smoothing out the electricity variation, measured through the meter, has an economical value in general. The battery of an electric vehicle, single or in combination with an additional stationary battery in the house, has a potential to be filled up with excessive energy and provide energy when needed, if vehicle-to-grid (V2G) is supported.
    - With peak shaving, the main meter fuses in the houses can potentially be down-sized. Smaller fuses in general cost less. The price difference differs between countries but there is money to save in the magnitude of hundreds of Euro per year and household by balancing the consumption Swedish houses, see for instance the fuse tariff in [7].
- *Convenience and better life*
    - Some people like the comfortable feeling of being self-sufficient with electricity and becoming insensitive to price variations of electricity, which makes the prognosis of future costs more predictable. This customer value can be the decisive for some people to make the investments even though the long payoff time.
    - Combined solar panels and electric vehicles in a smart home have the potential to provide convenient solutions with respect to maintenance and usability. Solar panels have no moving parts and electrical machines in electric vehicles have the potential to have a longer life time than combustion engines, with their more complicated design and more moving parts that need lubrication. Electric vehicles are advantageously charged where standing still, preferably at the

home or workplace. If supplied with inductive charging, no cables need to be connected, providing a convenient customer solution [8], see Figure 1.

- *Energy security*
  - An energy storage in form of a stationary battery or electric vehicle can be used as a backup when there is an interruption in the grid electricity supply. In some parts of the world this happens more often than at other places, e.g. Japan where earthquakes are common; then there is an added customer value for some people to have this form of backup solution.
- *Environment*
  - The prosumers participate to lower emissions and thereby contribute to saving the world from increasing in temperature and pollutions in cities. Before the economical incitements are so obvious so that most people having a house and car will make the investment, the category of people belonging to innovators and early adopters who care about the environment will be the ones taking the step.

Different market approaches

It is possible to discern business possibilities for a lot of companies and actors in the eco-system around smart houses, solar panels and electric vehicles, where the devices are connected enabling a range of smart services. However, it is not obvious how to enter the business and how to provide devices and services that create value for the customer; an offer including several actors in the ecosystem might be of higher value and a necessity for customers to buy the device or service. Today, many smart devices or services lack in that they are often based on incompatible technology platforms and sold at a price point that is prohibitive for the average consumer.

Car manufacturers approach the smart home business potential with different strategy. Some of them are early into the market and have developed and adopted their vehicles. In Japan, *Toyota* has a showroom for a smart house that provides residents with optimal conditions in environmental and cost terms by generating, storing and saving the energy they use in the home. Toyota aims also to support the realization of a new power grid, developed from the vehicle user's perspective, controlling power supply utilizing IT. The reason is that with vehicle recharging being concentrated in certain time periods, peaks on public power demand can occur [9].

Nissan is providing smart home solutions where the car is connected and integrated in the house with solar panels. Nissan Energy Solar householders can use the solar battery storage system to store excess energy from their solar panels and use it during the night and on cloudy days. Nissan Energy Solar's new product includes a home energy management system that will allow users to control how and when they want to use their energy [10].

Tesla provides, in a similar way, smart home solutions including stationary batteries and solar panels. The stationary battery is charged with energy produced by solar panels, making that energy available when needed. The stationary battery also enables the solar panels to produce energy during grid outages [11].

There are also several actors that are not car manufacturers that market solar panels, like e.g. the multinational furniture company *IKEA*. They started to sell solar cells in Great Britain in 2013, followed by Switzerland, the Netherlands, Belgium, Poland and just recently Germany. The goal is to sell solar cells on all markets in 2025. IKEA wants to provide customers with simple solutions, but they say that it is not that straight forward to do. In Great Britain and Switzerland, IKEA also sells stationary batteries for households. They also think about starting home solutions for charging electric vehicles [12].

Issues

From above, it would seem that the path forward for car manufacturers and other stakeholders in smart homes is staked out. It is not. There are plenty of issues that need to be sorted out, from understanding user behaviour and customer values to figuring out the business case and the ecosystem of actors having interest in smart homes that potentially together can provide solutions increasing customer values; and to prepare future vehicles with the right technology and interfaces. Therefore, every car manufacturer, and all actors with a business interest in the area, need to spend time on understanding what is happening and how to prepare their products with the right features in the right time.

Volvo Car Corporation has an interest in this business as well and has joined forces with RISE – Research Institutes of Sweden – to build a common knowledge in the area. Volvo Cars' interest is to provide customers with cars for the future but also to contribute the transformation to a fossil free society.

The development of smart houses with renewable energy sources like solar panels in combination with connected cars and other forms of stationary energy storages has the potential to become an attractive marriage giving both the solar panel and the electric vehicle markets a push, thereby speeding up the transformation, from today's massive fossil fuel usage in generation of electricity and transport to a low carbon counterpart. The pace in this transformation is urgent. The greenhouse emissions to the atmosphere must decrease rapidly during this century to keep the global temperature rise well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. After a temporary slowdown, the global carbon dioxide emissions again rose by 1.6% in 2017, and new data indicate emissions seem to rise more than 2% in 2018 on the back of sustained increases in coal, oil, and gas use [13]. To get back on track, the revised targets in the Paris Agreement must be more ambitious than those pledged in 2015 [14].

2 Research methodology

Explorative research is the methodology applied in this paper based, which in turn is based on the project in [15], and can advantageously be used to develop a company within a new business area. The expectation has been to increase the knowledge how connected cars and smart home can benefit from each other and how Volvo Cars can prepare their upcoming vehicle models for future possibilities and even be in the forefront leading the way into a sustainable fossil free society.

The specific techniques that has been used are:

- Reviewing available literature and existing propositions on the market. Research literature is important since it points out the state of the art from a research point of view. However, for companies, like car manufacturers, research is only a means to increase the knowledge to be able to innovate valuable products and services to the customers. The smart home market is still quite unmatured and existing propositions is in embryo, and either provides no or less value for the customer, or the solutions are proprietary which creates locking effects for the customers.
- Expert inputs in form of two specialists from each RISE and Volvo Cars per technology area (user interfaces and interaction design, automatic detection and navigation of parking and loading area, fully automatic charging of the car, charge balance between the car's battery, stationary battery and power supply, connection to the cloud for coordination of transaction information like energy transfer and payment) together with their closest employees analyse how the car is affected by the concept solution.
- Workshops and meetings for knowledge update and discussions to create a common understanding of the explored area.
- Interviews with external parties from the electricity sector, to understand the grid perspective and issues.

Customer perspectives have always been central for car manufacturers since high selling numbers only will happen if the users are satisfied with the product and services. From a car manufacturer point of view, there is a tight focus to develop technical solutions, systems and architectures [16] that fit the needs of the vehicle users. With electrification, the distribution of electrical energy will be part of a new user interface for energy fuelling, which potentially could cause frustration and complication. With smart homes, the complexity increases even more since the car will be one part of a bigger system. Cars connected to smart homes have joint capabilities to create a new, more complex, system which offers more functionality and performance than simply the sum of the constituent systems; hence it forms a system of systems. Currently, systems of systems is a critical research discipline for which reference frames, thought processes, quantitative analysis, tools, and design methods are incomplete. Systems of systems promotes a new way of thinking for solving challenges where the interactions of technology, policy, and economics are the primary drivers. System of systems studies are related to the general study of design, complexity and systems engineering, but also brings forward additional design challenges.

3 Results

3.1 User scenarios

As part of the understanding and design process, user scenarios have been developed to help understand what motivates home and car users when they interact with the surroundings and each other. User scenarios very seldom represent all possible users, but if properly stated they can represent the most common users and their motivations. Developing user scenarios serves as a good starting point when sorting out how to prepare cars for smart homes.

A use case study has been performed from a car manufacturer point of view, to understand and define the eco-system for a prosumer-oriented charging infrastructure. Some of the use cases are listed below. Most of the user scenarios described are already known, but there is still a lot of research and innovation needed to implement valuable solutions.

Charging the electric vehicle while parked at home or remotely with energy produced at home

Charging the electric vehicles with micro-produced energy at home is quite straightforward, and basic solutions exists already today. However, access to real time electric energy production at the prosumer's site at *any remote* charging point regardless of charging operator is not straightforward, cf. Figure 2.

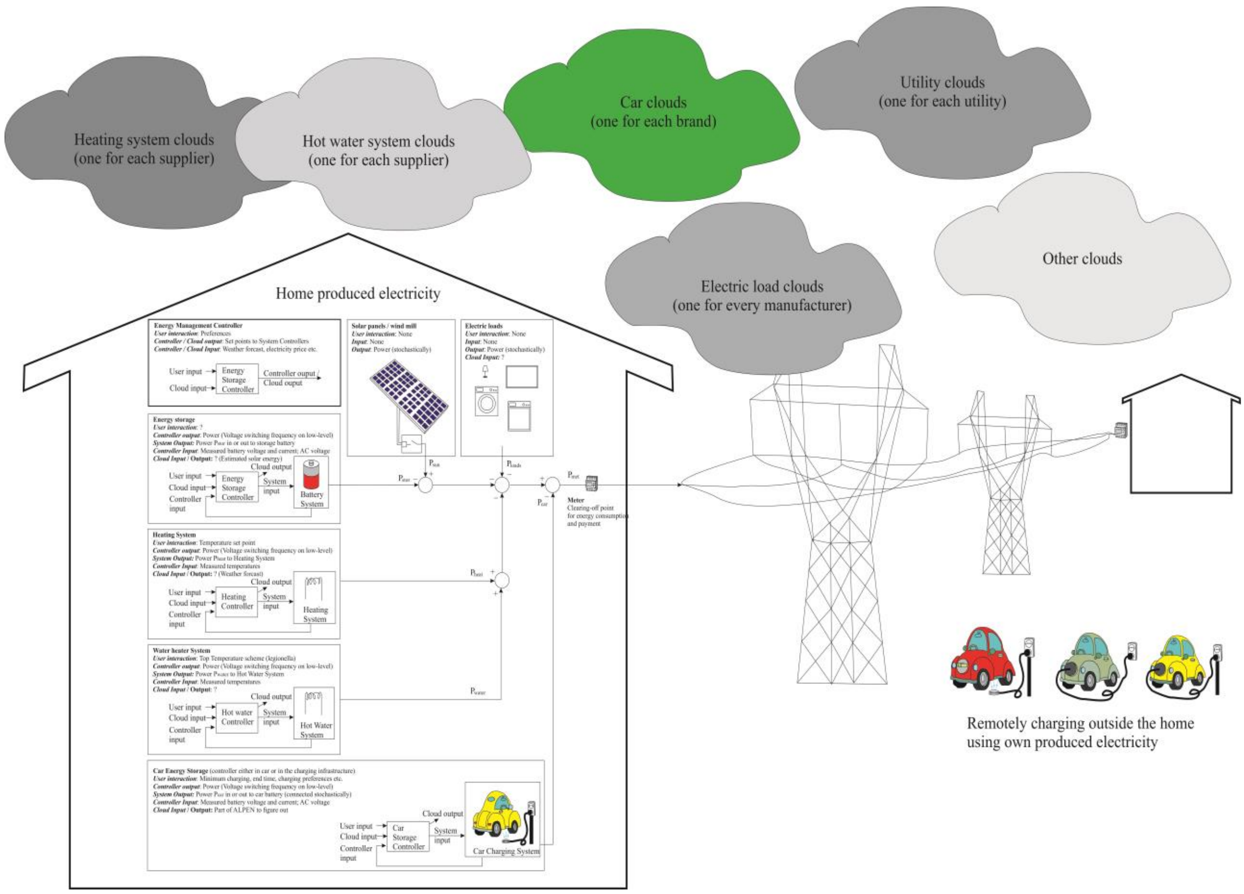

Figure 2: Smart homes need device controllers to communicate to end up in a valuable solution for the customers.

Obviously, it is not charging the vehicle with the home-produced electrons that is important but rather that the customers potentially will question why they need to pay excessive for the energy filled up at remote places when they produce the energy themselves at home. The customer-oriented discussion has started in Sweden around solar energy where some of the politic parties officially have said that they will allow homeowners to sell their solar produced electricity directly to their neighbors [17]. To succeed in case of remote charging of homeowners' electricity, an eco-system connecting prosumer and charging infrastructure together needs to be set up, including contracts for handling the business transactions. The energy and taxation laws also need to be adapted so that taxes not appear twice when sending out the energy on the grid and when consuming it at the remote charging spot, all of which does not happen in a snap.

Control while charging

Today, most cars immediately start charging directly when the car is connected to the grid. However, starting the washing and dishwashing machine at the same time, in addition to running a heat pump and/or water heater may cause energy peaks in the house, which in turn may cause problems in the neighborhood at local or regional transformation stations if many households creates peaks at the same time. It can also potentially cause problems at higher levels including the electricity power plants in a country due to limited capacity [18]. Load balancing is one solution to the peak problem, preventing or postponing investments in grid and electricity power plants.

Load balancing, in the context of energy systems, aim at better matching production and consumption of energy. For a car, this means that it preferably should be charged when there is excessive energy in the system (like when parked at home) and not charged otherwise. Providing a car with charging scheduling possibilities increases the chances to avoid energy peaks. This was early studied and implemented in the ELVIIS-project, see [19], where the developed concept allowed the car to start recharging immediately and as fast as possible when the car is connected to the grid. However, this is done only until a certain recharging level is reached, corresponding to a user specified minimum range. The car is then recharged based on a scheme that someone outside the car provides, for instance the utility company. The car could also be charged to a desired level at a certain time specified by the user. Several car manufacturers now provide this possibility e.g. [20].

It is still uncertain how the scheduling should be done in an efficient way. As illustration, consider again Figure 2. This figure illustrates a home with solar panels, heat pump, water heating system, stationary energy storage, car battery and household consumers like washing machine, dishwasher, tv, etc. Earlier, all these machines lived their own life and the controllers, one for each device, made their own choices based on its own sensor data and no communication was done between the devices. Nowadays, the devices begin to get connected to the internet, illustrated by the clouds in the picture. Each device has its own cloud and every brand have its own cloud. However, the information exchange between the devices is in its infancy, even though standardized protocols or solutions exist like Home Connect. A home with smart devices that does not communicate is not a smart home. Think of a car that is smart and tries to figure out when to charge the vehicle efficiently. If you provide it with measurements of the total consumed power in the house and the energy produced by the solar panels, it can potentially learn when to charge to avoid energy peaks in the house. However, if the water heating system also is smart, and the stationary battery and other devices in the house, then you may end up in deadlocks and bad performance, like a car that is not charged when the user takes it in the morning. One solution is to have a device in form of an energy broker in the house that makes sure that the energy management is done properly, see the Energy Management Controller in the upper left corner of the house in Figure 2.

It seems there are many actors that want to be the energy broker providing a device that makes the energy management scheduling. As earlier mentioned, Nissan provides home energy management systems [10]. SMA is another provider belonging to the Home Connect ecosystem. In the long run, it is important to avoid lock-in for customers, so open and standardized solutions, where many different devices or brands can be connected, is crucial for a faster adoption.

In the future, an energy broker will take inputs from all relevant energy consumers and producers locally in the house and give the different devices schedules how to consume energy. The broker will also take electricity prices into account and, if advantageous, help to balance the grid locally in the neighborhood and globally in the country. How this will be done is still not clear, and much research and innovation is needed before the smart homes really become smart.

User preferences

In the case of houses and cars connected to a smart home, user preferences are not at all obvious, so devices and features are suggested hoping that customers find values. It is a matter of timing as well. Providing only one or a few connected devices will not really satisfy customers, so it is important to introduce possibilities in a future safe manner, otherwise customers will not invest. In the case of cars, the user potentially selects preferences for charging, but what are the options that the car manufacturer will provide in the future? Should they give the option to charge as fast as possible (as is done today), to charge when only self-produced excessive renewable energy is available (which is desired in homes with solar panels) or to charge when it is as cheap as possible or in some other way? Regarding costs, it is important to have control of the battery as well, since different scheduling strategies affect battery life differently, and hence the total cost for the house and car owners. In a house with a stationary battery, the energy flows in and out in the battery, but so far, most car manufacturers do not support feeding back energy to the house or grid since it wears out the car battery faster. However, it is a matter of cost in the end and when the price of the batteries has decreased to a certain level and the car manufacturers have learned how to more accurately control them, this could be a viable option. The user selected choices should be an input to the energy broker, fulfilling the car user and other home user preferences.

Uncertainties in the user preferences, together with forming the user interface in an understandable way, needs more research to innovate simple and valuable customer features.

3.2 Financing and carbon footprint

To better understand the development of smart houses with solar panels and electric vehicles, a framework for estimating the prosumer, corporate and State finances over time has been developed. The basis of the calculations are different scenarios for migration from internal combustion engines (ICE) to electrified cars.

Cost for car customer versus time

Figure 3 exemplifies the rough accumulated running car costs for a prosumer when producing electricity at home and charging it at home or remotely, the latter without distribution costs.

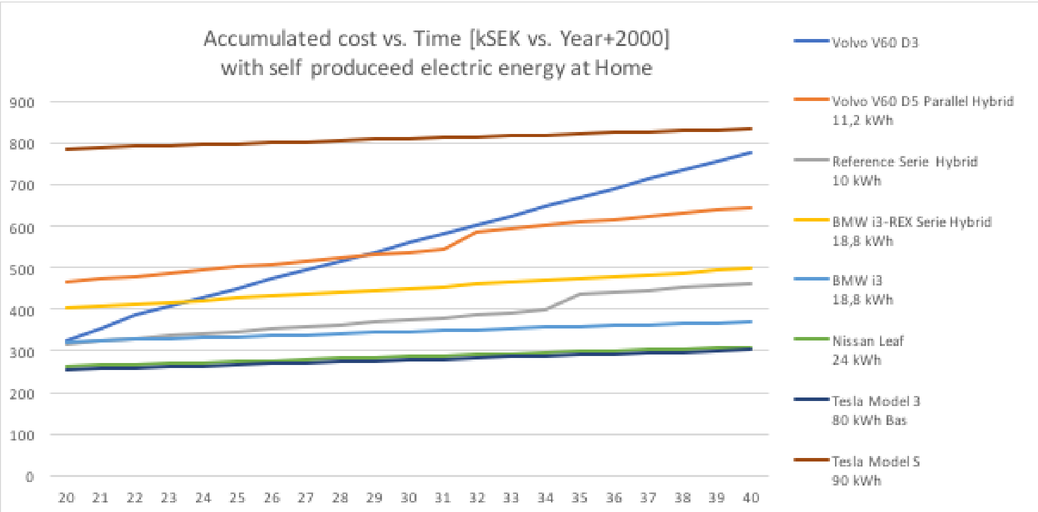

Figure 3: Accumulated cost for car versus time with self-produced electric energy at home. To get the prices in Euro, divide the costs by 10 for a rough estimate.

In the calculations it has been assumed that the battery cost corresponds to the best daily price for batteries and is set at about $200/kWh for complete system, and that the battery can handle 4000 discharges down to a DoD (Deepth-of-Discharge) of 80%. Calculations according Figure 3 have been made for three alternative scenarios: large-scale electricity production, charging with own-produced electricity at home and remote charging with own-produced electricity. The differences in energy costs for the prosumers are small and very small relative to the purchase price of taxes and insurance for the vehicle itself. Depreciation costs are for simplicity reasons included in the purchase price. Interest rates have not been included in the analysis.

The calculations are done for the existing Swedish bonus-malus system, where cars with carbon dioxide emissions up to 60 g/km are rewarded with a bonus of a maximum of SEK 60,000 (~Euro 6000), and a malus is given in form of increased vehicle tax during the first three years for petrol- and diesel-powered cars [21].

Observations from Figure 3 are:

- Data for the Volvo V60 D3 is relatively accurate for an approximately 3-year-old car. Also, data for the Volvo V60 D5 Parallel Hybrid with 11.2 kWh battery is relatively accurate. However, this car was launched in 2012 and is of a design which is about 10 years old. Both cars' curves would drop if they were redesigned today, however the V60 D5 Parallel Hybrid would likely drop more, suggesting that both car models are approaching each other so it is economically viable to buy the hybrid.
- If two equivalent cars are compared (Volvo V60 D3 and V60 D5 Parallel Hybrid), the PHEV will be cheaper for the prosumer after about 6 years. A similar reasoning applies if, for example, Nissan Leaf is compared with an equivalent ICE.
- The bend in 2022 (labelled 22 in the figure) on the curve for the Volvo V60 D3 comes from the malus ending three years after purchase.
- The steps in 2031 and 2034 for the Volvo V60 D5 Parallel Hybrid and Reference Series Hybrid 10 kWh respectively are due to the batteries being replaced due to theoretical life length. This will likely not happen since few have the desire to buy a new expensive battery only because the battery has become slightly degraded.

Table 1 highlights specially the Nissan Leaf and Tesla Model S for the three alternative scenarios.

Table 1: Total cost (SEK in thousands) for 20 years' usage of different electric vehicle alternatives.

	Nissan Leaf 24 kWh	Tesla Model S 90 kWh
Large scale production of electric energy	348	891
Self-produced electric energy at home	302	834
Self-produced electric energy - remote	318	848

As can be seen from Table 1, the profit after 20 years using self-produced electric energy at home compared to Large scale production of electric energy is SEK 46,000 for the Nissan Leaf and SEK 57,000 for the Tesla Model S.

Regarding investment in solar power plant; assuming that a Nissan Leaf on average consumes about 5 kWh/day and a Tesla Model S on average about 7 kWh/day, and for simplicity that a solar cell area of 1 m^2 on average produces about 140 kWh/year and that the investment price for the prosumer is SEK 1,500/m^2. Then about 13 and 18 m^2 solar cells are needed for each car, i.e. an investment cost of about SEK 19,500 and SEK 27,000 respectively for the Nissan Leaf and the Tesla Model S. In other words, with the prerequisites of the above example, it is likely to be economically justifiable to invest in a solar cell plant solely for driving an electric car.

Tax revenue for the State versus time

Figure 4 exemplifies the accumulated tax revenue for the state if the car owner produces electricity at home (without distribution costs). Note that the decided indexed change of petrol/diesel tax of 2% per year is included in Figure 4.

Not unexpectedly, the state tax revenue drops drastically when electrifying the car fleet. On the other hand, indirect expenditure is expected to be reduced due to lower impact from cars on the environment. However, replacing internal combustion engines with electrified cars is a very slow process. If we assume that the sale of electrified cars will increase by 10% per year, then new car sales of internal combustion engines have only ceased in about 30 years. In other words, the state has plenty of time to adjust the tax levels to compensate for the tax loss due to electrification of the cars.

Figure 5 shows the total tax revenues for the state if new sales of electrified vehicles increase 10% per year from 2020. The calculations are based on three types of reference vehicles, an ICE in form of a Volvo V60 D3, a reference series hybrid with10 kWh batteries and a BEV in form of a Nissan Leaf 24 kWh. It has been assumed that the fuel tax is constant.

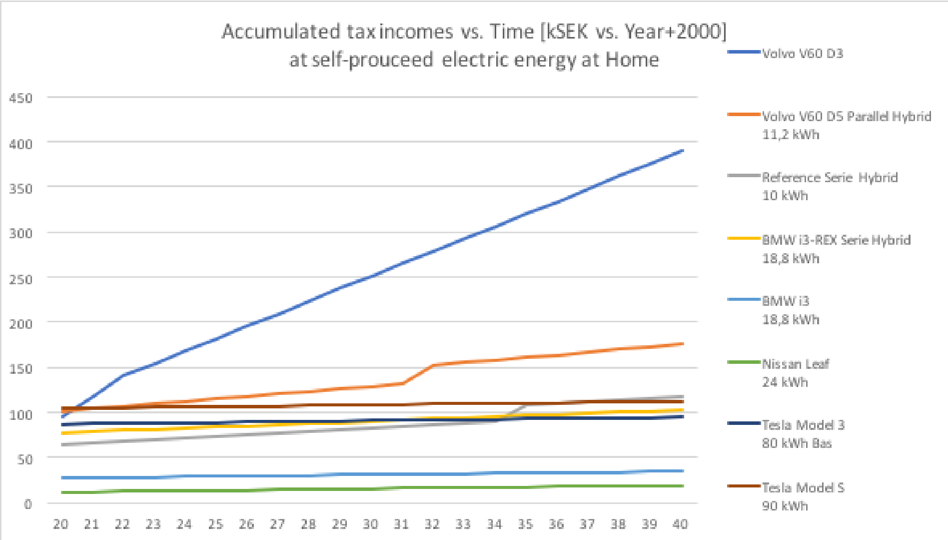

Figure 4: Accumulated tax income per vehicle with self-produced electric energy at home.

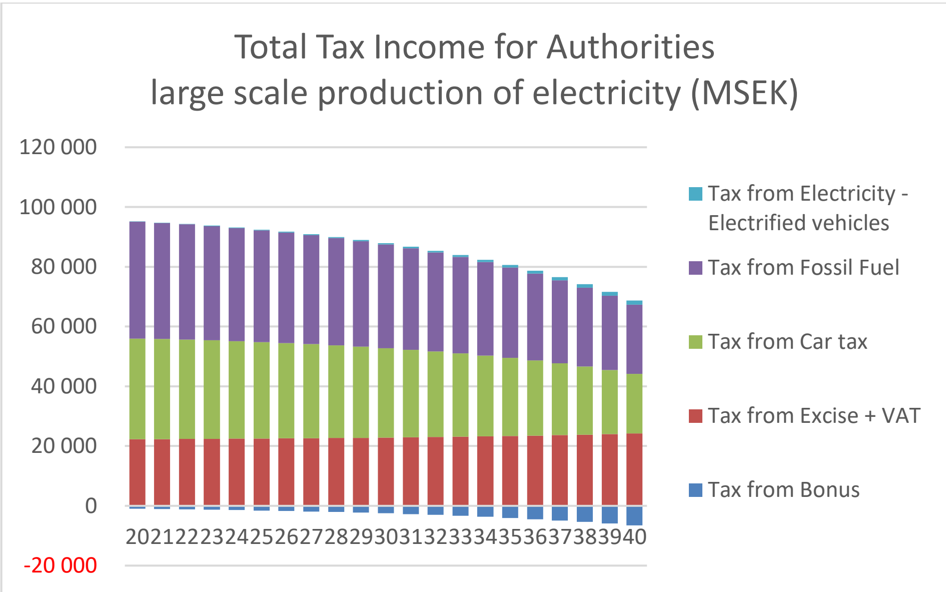

Figure 5: Total tax incomes in Sweden from vehicles.

Some observations from Figure 5 are:

- If the indexed increase of 2%/year of the petrol/diesel tax is taken into account, ”Tax from Fossil Fuel” decreases approximately SEK 7 billion from 2020 to 2040. In this case, the purple bars will be almost constant up to approximately 2035 and then fall steeper.
- The car tax drops as a result of the fact that malus is influencing less and less when the electrified vehicles increase.
- Excise and VAT rise slightly due to that the product cost is higher for the electrified vehicles.

It is not too daring to say that from an economic perspective, the Swedish state has positioned itself well for the upcoming years. If politically possible, the state can easily raise malus or the indexed gasoline diesel tax to compensate for the tax losses. Unfortunately, the focus to reduce the carbon dioxide load fails.

4 Future research

There are plenty of research and innovation that need to be done in the development of smart houses with renewable energy sources like solar panels in combination with connected cars and other forms of stationary energy storages. From a car manufacturer perspective, the research that needs to be done is to better understand the customer to innovate user friendly interfaces and preferences, both in car and in apps in smart phones. The car needs to be wirelessly connected to the home and provide information to the energy broker for scheduling the charging of the car and the rest of the energy consumers in the house. Remote charging needs to be supported, which needs contracts for handling the business transactions and legal changes to avoid double taxation at the meter measuring energy sent out from the house and at the place where the car remotely is charged. Figure 6 gives a more detailed architecture of the framework in Figure 2, centered around the electrified vehicle connected to the clouds.

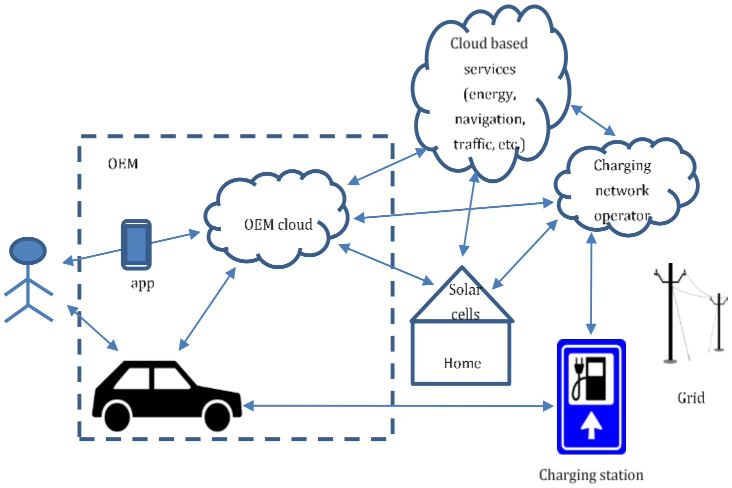

Figure 6: Car-centric information exchange. Arrows indicate information exchanges between the different actors and devices, seen from a car manufacturer perspective, which not yet is established. To make a proper design, the research that needs to be done is to better understand the customer to innovate user friendly interfaces and preferences, both in car and in apps in smart phones.

All the arrows indicate information exchanges between the different actors and devices which all not yet exists but needs to be established. There are established protocols and standards, e.g. between the car and the charging station through the cable, see for instance [22], but they do only cover a small part of what is needed. Besides, for new charging technologies like inductive charging, standards and protocols are still missing.

The next natural step in the development is that the car manufacturers implement realistic scenarios in smart homes to figure out user preferences, realizing smart charging as a part of the energy brokering and using artificial intelligence to make efficient decisions. This would give a better understanding for discussions with the state about how renewable micro-production and electric vehicles faster can be promoted.

5 Conclusions and discussion

Solar panels and electric vehicles need a large initial investment which constitutes a barrier for many customers. However, lower running and maintenance costs mean that the break-even point is not too far away and within the products lifetime. This mean that the Total Cost of Ownership (TCO) for a prosumer to charge an electric car with self-produced electricity from solar cells is lower compared to owning a fossil fuel-driven car. This means that the barrier for the adoption can be overcome by new business models offering some kind of annuity, e.g. by monthly payments. Furthermore, the results also indicate another barrier; the state tax revenues from vehicles with the current tax model will fall at the transition to a society with electric vehicles that are charged with self-produced electricity, so the state needs to somehow compensate for the tax loss.

The actors in the eco-system of smart houses with renewable energy sources and car manufacturers are not yet synchronized. Car manufacturers have deep knowledge about how to make conventional cars and have started to understand electric vehicles but have in general less knowledge about the electrical grid and smart house functionality. The same thing is true for other actors – no one fully understands the complete picture. Hence, time needs to be spent on understanding each other, the potentials and barriers for future innovations and common *system of system* offers. The user perspective is crucial. Common research and innovation projects are a necessity for finding valuable customer offers.

The lack of knowledge around smart houses with renewable energy sources and car manufacturers is apparent also at the Swedish funders. In Sweden, there is a clear distinction between funding for car manufacturing projects, which is given through the FFI-program, and other programs funding grid and renewable research, which implies to that it is hard to get funding for these types of projects and the different programs point at each other. The result is a slower pace in the transformation from massive fossil usage in the generation of electricity and transport to a low carbon counterpart.

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