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The market case for electric mobility: Investigating electric vehicle business models for mass adoption

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ABSTRACT

Electric vehicles (EVs) are becoming the next automotive technology to be widely diffused in society. However, many structural challenges remain to be addressed around the EV socio-technical system as the technology progresses from a niche to early and late mass markets. This study investigates the challenges for electric vehicles focusing on their current and future business implications. For this purpose, we rely on a robust sample of 227 semi-structured interviews, conducted by the authors, with transportation and electricity experts from 201 institutions across seventeen cities in Denmark, Finland, Iceland, Norway, and Sweden. Our findings show that EVs currently face an unfavourable business case, led by the legacy of the petrol and diesel car industries, and national market conditions. This results in an unsuitable business model and supply chain that compromises EV production and market offerings. Additionally, we find that for wide diffusion in society, EVs will change the traditional automotive selling chain, directly affecting selling methods (i.e. dealerships), maintenance revenue streams and refuelling (recharging) structures. It is therefore essential to adopt new models, practices and methods of business that are suitable for EV diffusion.

1. Introduction

Electric vehicles (EVs) are recognised as the most feasible technology option to decarbonise passenger transportation across the world, particularly when combined with low carbon power systems [1–4]. However, EVs have historically faced barriers for their mass deployment [5–7] and, despite having positive trends in new car sales, in 2017-18 EVs only accounted for around 0.2–0.3% of the total global passenger fleet [8,9].

Considering EVs are another form of automobility but with electric drivetrain, this technology competes directly with the well-established internal combustion engine vehicles (ICEVs) market. This established automotive regime, led by automotive Original Equipment Manufacturers (OEMs), has contributed to the development of social norms around conventional cars and their use, which represent a strong barrier for EVs [10,11]. Recent research has noted that EVs have an unfavourable business case in comparison to petrol and diesel vehicles which is a result of both the routines and expectations about mobility that stem from the use of ICEVs and government policy that has favoured fossil fuel-based vehicles [12,13]; which is evidenced at a retail level in automotive dealerships where salespeople tend to sell ICEVs instead of EVs [12].

A critical point for EVs is that they are invariably compared against conventional cars in terms of driving capability, style, use and sentiment. For this reason, a plethora of studies have explored the challenges EVs face for social-wide adoption, focusing on different elements or stages across the life cycle of the vehicle and its supply chain, as well as the optimal configuration for the EV ecosystem; particularly its recharging network [14]. Such studies include system analyses from EV adoption and their potential effect on power grids [15–17], to technical elements, such as battery capacity and driving range [18–21], and also socioeconomic elements like taxation and policy incentives [22–24]. Consumer-focused studies have investigated the drivers of acceptance such as pro-environmental attributes [25–27] and other user related challenges linked to charging infrastructure [28], particularly, range

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anxiety [29,30]. While recently, research has further began to focus on consumer segments for EV adoption exploring the potential mainstream EV markets [31].

Notably, EVs are not only a vehicle technology for mobility but, based on their power source and power train, can be involved more naturally in the digital world (i.e. via mobile phone apps), and even be integrated to other systems such as the power grid, via vehicle-to-grid (V2G) [32]. Despite these inherent differences, the automotive industry (traditional OEMS) continues to manufacture EVs in the same manner as ICEVs and more, presents them to consumers under the same lens as a conventional car [13]. This approach is on one hand due to the lack of knowledge in how to develop and push EVs downstream, but also comes from an unwillingness to do so, due to the large investments placed on ICEV infrastructure [13].

EVs thus likely require new business models and structures that are purpose-made for the technology, where EVs are not compromised but rather optimised [13]. Successful examples already exist, such as Tesla, but also plenty of failures, the most well-known being perhaps the battery-swapping model of Better Place [33]. Importantly, these new models have typically come from new companies not involved with the traditional car regime. However, even if successful, the potential of these new business models for social-wide EV adoption has remained rather limited considering the low EV penetration rates into the global vehicle fleet. Additionally, there is limited research on EV business models and business cases to draw from, with a few notable exceptions [13,34,35]. While these few studies have propositioned alternative tools for analysing EV business models [35], or explored current industry developments and propose new alternatives, they have lacked a robust and compressive insight into the minds of experts leading and operating the automotive industry [13,36]. This in particular to understand the reasoning behind the automotive industry, the barriers it faces to integrate a new vehicle technology into its core business, and the interaction between the established ICEV market and the emergent EV market. Moreover, due to the new (the last 10–15 years) and technology-driven nature of EVs, the technology and market of EVs is bound to change rapidly. For these reasons, continuous research with up-to-date primary data is essential in fomenting the development of EVs and their potential business models.

In this paper we set to explore the business challenges of EVs with the aim to provide suggestions that support social-wide adoption. For this exploration, we rely on an original dataset of 227 expert interviews with individuals employed in sectors related to electric mobility across the five Nordic countries. In doing so, we present their perceptions on EVs and what challenges these vehicles and their development raise for industry and society, as well as the perceived opportunities for adoption. Additionally, we discuss the potential for EV adoption based on business structures and selling strategies. The contribution of the analysis is further supported by the inclusion of data from five different national markets, each with their own tax, regulatory, commercial and social conditions as well as different stages of EV penetration. These markets include the global EV leader Norway, to recent intermediate adopters in Sweden and Iceland, and other less developed EV markets of Denmark and Finland. Below the study presents the methodology with a description of the data and assumptions used to create the analysis of the study. It then presents and analyses the results based on the business challenges for potential EV adoption.

2. Research methods and empirical strategy

To explore the business context of electric mobility the authors relied primarily on an original dataset of 227 semi-structured expert interviews with 257 participants from over 200 institutions in the five Nordic countries. A brief summary of the interview participants is presented in Table 1, that among others included members of:

- National government ministries, agencies, and departments including the Ministry of Industries & Innovation (Iceland) or Ministry of Environment and Energy (Sweden);
- Local government ministries, agencies, and departments including the Akureyri Municipality (Iceland) and City of Stockholm (Sweden);
- Universities and research institutes including DTU (Denmark) and NTNU (Norway);
- Electricity supply, transmission, and distribution companies/utilities including Energinet.dk (Denmark), Vattenfall (Sweden), ON Energy (Iceland);
- Private sector manufacturing, service and information technology companies including, Nordpool (regional), IBM (Norway), and Schneider Electric (Norway).

This methodology was applied on a regional context taking the five Nordic countries as place of study, considering these countries are traditionally recognised for having relative progressive climate, energy and transport policy agendas, and emerging as leading nations in EV uptake (Norway), or pioneers of wind energy (Denmark), or geothermal energy (Iceland). The interviews generally lasted between thirty and 90 min, where participants were asked several questions about the business context of EVs and V2G. With previous consent, each but one expert encounter was recorded and given a unique respondent number. Once data collection was concluded, each interview was fully transcribed and subsequently coded on an argument level in NIVIVO. Here, the coded themes for each discussed topic were not predetermined but based on the data available.

This paper is based in two of the semi-structured questions: What are the structural barriers for electric vehicles? And what are the benefits and opportunities for electric vehicles? The results shown on the paper detail the responses to these questions but also including other market case elements mentioned across the interview. Admittedly, this method is open to biases in the steering of questions by the interviewer, or the expertise/background in the interviewee influencing the outcome. For this reason, the results are indicative of the trends, opinions and discourses of the visited countries and the respective sectors across our cases. This furthermore allows the emergence of novel ideas and a qualitative testing of arguments, both during the interview and the subsequent data analysis research [37].

Obviously, our approach to understanding business models for this paper is inherently qualitative, rather than quantitative methods. However, as Sovacool et al. indicate, qualitative research designs are one of seven core approaches widely utilized within energy studies, climate policy, and transport studies, given the complex nature of the topics and the need for inductive insight [38]. Thus, we believe there is great value to our qualitative exploration of EV business models, especially to the extent that can help inform and even complement other research designs and approaches within the field.

3. Results: a business case against electric mobility?

Overall, our interviews indicate that EVs currently face an unfavourable business case that results, for the most part, in unprofitable product lines for industry and unaffordable vehicles for consumers. For industry, the development of EVs particularly affects the nested investments on their ICEV product lines, selling

Table 1
Overview of expert interviews.

Classifications	Interviews (n = 227)	Respondents (n = 257)	% of Respondents
Country			
Iceland (Sept–Oct 2016)	29	36	14.0%
Sweden (Nov–Dec 2016)	42	44	17.1%
Denmark (Jan–Mar 2017)	45	53	20.6%
Finland (Mar 2017)	50	57	22.2%
Norway (Apr–May 2017)	61	67	26.1%
Gender			
Male	160	207	80,5%
Female	40	50	19.5%
Group	27		
Expertise			
Transport or Logistics	73	81	31.5%
Energy or Electricity System	63	75	29.2%
Funding or Investment	10	12	4.7%
Environment or Climate Change	12	16	6.2%
Fuel Consumption and Technology	22	23	8.9%
Other	13	14	5.4%
EVs and Charging Technology	34	36	14.0%
Sector			
Commercial	68	70	27.2%
Public	37	46	17.9%
Semi-Public	40	51	19.8%
Research	37	39	15.2%
Non-Profit and Media	12	13	5.1%
Lobby	23	25	9.7%
Consultancy	10	10	3.9%

Source: Authors. *Focus* represents the primary focus area of the organization or person in question, *Sector* represents the sector the company was operating in (i.e. semi-public referring to commercial companies owned by public authorities, like DSOs).

methods (i.e. dealerships), component manufacturers, maintenance networks and refuelling (recharging) networks. These, in turn, create deterrents for OEMs to dedicate themselves to the development of EVs and have resulted in inefficient production and selling strategies; which are based on routine like ICEVs business practices rather than tailored to the characteristics of EVs and engaging with consumer uncertainty. Additionally, there are business challenges that arise with the potential large-scale penetration of EVs, even once business structures are fitted to optimise EV development. In this way interviewed experts highlighted questions of scalability and sustainability of production lines, such as manufacturing capacity of batteries or development of charging infrastructure models.

Below we present our results in four themes: fossil fuel favouritism (unfavourable business case), mad about maintenance (maintenance business units), supply chain (supply and manufacturing capacity) and charging concerns (charging infrastructure). While the results below aim to show the challenges identified across these themes, Fig. 1 visualizes the breakdown of the experts (n = 62) that offered elaborated responses across these four categories. Subsequently, expert's position on business models will support a discussion on section 4 around recalibrating the business models for electric mobility.

3.1. Fossil fuel favouritism

One of the main, if not the biggest, barrier for EV adoption that emerged in our interviews is the higher retail price in comparison to petrol or diesel vehicle options This unaffordability was said to result in consumer disinterest and, absent any tax incentives, given as the reason why the automotive industry has seen a lack of product sales. Similarly, on the supply side EVs are categorised as not profitable due to high production costs and lack of after-sales revenue streams which deters industry players willingness to engage and sell the technology.

In particular, the high cost of production and high selling price of EVs create significant difficulties for existing vehicle supply business models. In Iceland R034 elaborates on the challenges to integrate and even fully transition to EVs:

> "if somebody will say to me now: "you need to only sell electric cars", I would close down the business."

The lack of overall profitability has resulted in OEMs having to force EVs downstream onto dealerships in an attempt to promote existing EV offerings, even when dealerships are openly reluctant to engage with the technology. This is underscored by the fact that EVs do not provide dealers with additional revenue sources that ICEVs would, resulting in active disincentives to sell an EV. As R107 from Denmark explains:

> "From a profit point of view our dealers as worse off as we are. They are losing money on every EV they are selling. They generally hate the product because there is no business in it for them. It is something we are forcing on them. If we weren't forcing it on them, they wouldn't have the demo vehicle."

Considering that, in general and at the time of our study, EVs are the economically inferior option from the perspective of dealers and industry, it is unsurprising that OEMs have trouble justifying the sale of EVs in favour of ICEVs to their shareholders. In this way, R077 from Sweden argues that industry, dealerships and salespersons have reacted to EVs in a rational way to the to-date automotive market conditions:

> "[Industry and dealerships] have reacted in an economic rational way maybe, because this is a huge investment and they are not sure whether they'll get their money back from the investment"

On the other hand, not all the experts believed that the onus lied on the OEMs. Some experts, such as R101, attributed the current

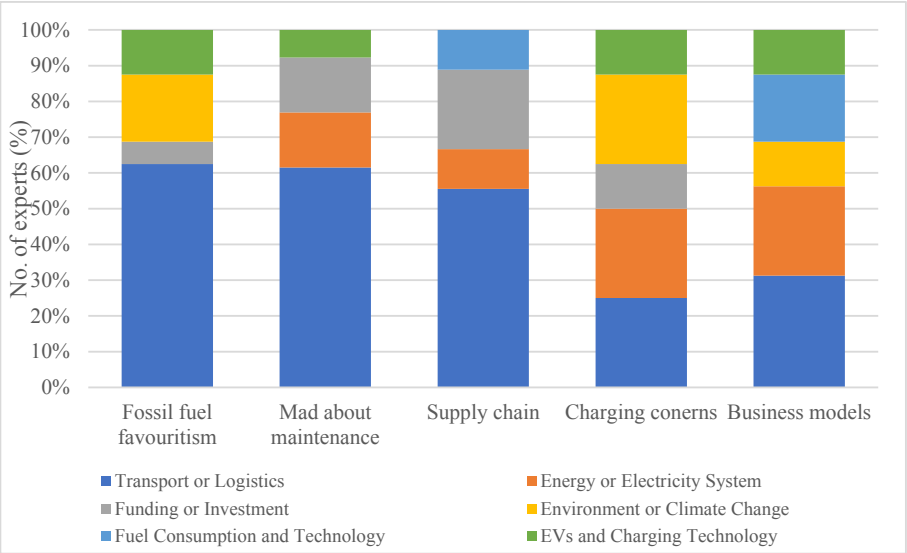

Fig. 1. Breakdown of experts across themes. Source: Authors.

slow EV adoption not to the lack of investments on the supply side, but rather argued that EVs are not available for sale at dealerships simply because consumers do not want them:

> "I'm absolutely confident that car importers or retailers have the product on the shelf for which there are no customers. If there are customers for electric cars, they [would] have electric cars all over. It might take some months before they are there, because there is a limited production capacity perhaps, but if the customer is asking for it, it's there."

This can be misleading considering that for the most part, the average consumer may not even be aware that EVs can be a real purchasing option. Instead, it is frequently automotive OEMs, car dealerships, and salespersons that direct consumers further away from EVs; as recent research has shown [12].

Notably, the automotive market is an intertwined space between industry and government where both have created unfavourable conditions for EVs. Policy directly affects retail markets and eventual EV adoption, which is most evidenced perhaps in Denmark and Norway, but in opposite ways. Norway is the recognised global leader on successful monetary and non-monetary policies for EV adoption whilst, as research has shown, Danish policy makers have created an impossible market space for EVs to operate [12]. This is noted by R107:

> "We are only a company. I have proposed internally that we stop selling EVs in Denmark. We need to make money. If we are not pushed by politicians so that it makes sense for us to sell EVs, we are quite fine with selling vehicles that run on petrol and diesel, it's just bad for society."

The reflection of R107 also points to the complacency of traditional OEM industry players, where despite stated aspirations for sustainability and providing cleaner forms of mobility, the bottom line is directed purely by business interests. Such a view was corroborated by R126:

> "I would say the interest is very limited [on EVs] simply because the bottom line [is], money talks"

There is a negative cycle for EVs everywhere, but in particular in markets like the Danish where policy strongly favours ICEVs [12] while also OEMs are reluctant to adapt business practices for EVs and dedicate investments on the technology. As R107 further elaborated:

> "We are under scrutiny every time we propose investment in EVs [to our shareholders]."

Internationally, OEMs are seen reluctant to dedicate investments towards EVs due to the huge infrastructure assets that lay within the ICEV sector. Driven by returns on investments (ROIs) that remain to be captured, in addition to the ongoing, and new, yearly investments on ICEV technology. These investments are not only monetary but also about creating new models of business, supply and manufacturing that are fit for EVs rather than recycled from traditional ICEV technology [13]. Many experts agree on this as R143 for example mentioned:

> "I am almost a hundred percent sure that if the Tesla never showed up, we [wouldn't] have electric vehicles, because those big companies like BMW, Mercedes, Volkswagen, GM, this kind of, even Japanese, they are protecting their existing product lines."

R084, furthers this point by mentioning that OEMs and industry have no incentive to invest on EVs since they would be affecting their own markets:

> "all the assets they have in the ICEV world, they would have to invest a lot, and why would they invest to take their own market?".

R107 adds to the point, but also elaborates that EVs will be supported when they appear to be profitable for industry, their attachment is not to a particular technology but the business of it:

> "Of course from a business perspective, we are unable to support an initiative that would decrease the car market because that would decrease our potential income. But if the combustible market decreased and the EVs market increases accordingly so that the total is the same, we would be happy to support that."

Nationally, governments (outside of Norway) do not harmonise transport policy and where currently the net market benefits still favours ICEVs making these vehicles the most attractive option for industry to sell and consumers to buy [12]. These negative effects for EVs are evidenced on actual vehicle purchases but also in our interviews where it was particularly experts from Denmark, Iceland, Finland and Sweden noting the challenges that arise from uncompetitive market prices for EVs. For example, since 2015, multiple policy changes in Denmark – among them restarting the introduction of purchase taxes on previously exempt EVs – completely stalled sales in the country [12]. Whereas in Iceland, R036 describes the international up-to-this point situation with electric cars as:

> "*If I had a dealership, I would tell my guys 'hey guys, sell gasoline cars, the margin is there and we'll get everything'. You would be stupid [to say]: 'hey guys, focus on the electric cars, we'll get nothing when we sell it or we'll get small thing when we sell it, but nothing after that, let's go for that guys'. The model is not there, so it's not like a conspiracy.*"

Consequently, there continues to be a need for business models that are fit for EVs, where we create manufacturing processes, marketing and training campaigns, sales and after-sales strategies that optimise the deployment of EVs and support its wide-scale adoption. Particularly in markets where governments cannot recreate, or are reluctant to do so, the monetary EV incentives of Norway that resulted in the world leading EV adoption rates.

3.2. Mad about maintenance

The lack of business case can be linked to different elements as we have seen on the previous section. However, the after-sales markets, in particular the lack of maintenance required by EVs, comes as a key barrier for industry that deters EV supply irrespective of location, according to the interviewed experts. While it is recognised that EVs do not require as much maintenance as ICEV [39,40] and this affects the overall profitability of the EVs, both the level of impact and also the potential alternatives for OEMs remain relatively underexplored. Our respondent, R010, explains the rationale of industry behind the after-sales market of EVs and ICEVs:

> "There is a lack of incentive for the big companies there [with EVs], because they foresee if you sell, a regular gasoline car, 'I am Volkswagen, I know for every car that I sell, I can say I have sold a subscription to certain revenue over the lifetime of a vehicle, say 7-10-15 years, and I know my dealership support network, there an instant subscription of certain revenue. Because the car will have to come in, I will sell some spare parts, I will blow up prices so I will continue to get revenue from that vehicle. If it is an electric vehicle, I don't hear from the client again."

In our interviews, experts mention that EVs have 80%–90% less maintenance expenses post-sale in comparison to ICEV, as for example R010 continues to elaborate:

> "The maintenance is maybe 10% of it. [OEMS] either have to gain the same revenue by either having to price the EV a lot higher or come up with other ways to gain money from it."

Even more striking, a regional expert (R158) mentions that for car dealers the service and maintenance unit is typically about 50% of their entire business, and therefore the transition to an all-EV sales portfolio means that almost half of the business revenue would cease to exist:

> "a little bit less than half of the company money is from selling cars and about half of the money form service business. So this is also something that they suddenly consider that of course EVs don't need much service and they are decreasing their business."

Similarly, in Denmark a regional expert from a leading OEM (R114) agreed that the lack of post-sale maintenance is a superior technological position for EVs and that it is of certain benefit for consumers. However the expert also remarked that it creates concerns for the automotive industry and a critical need to develop new revenue streams if EVs are set to become the mainstream mobility option:

> "they say [you] save at least 80% on maintenance on electric vehicles. Because there's nothing wrong with them. There's no oil change there's no, oil filter, there's no tail pipe. So that's a huge challenge in the industry to come. How are we going to make money when we have mainly EVs?"

To which R036 mentions there is no other solution than changing the existing business model:

> "they will have to change the business model. They can't afford these big showrooms, they can't afford all these big, bunch of people, because the car is just, you sell it its gone … [If not] they will slowly die, like Kodak."

The lack of maintenance does have a direct impact on the core business of OEMs and car dealerships but this is more of a longer-term perspective, when full-EVs become mainstream. In the interim, as R233 of Norway mentions, the automotive industry offers Plug-in Hybrids (PHEVs), which have a small electric battery but, for the most part, have at their core a combustion engine running on petrol or diesel. PHEVs are thus being pushed into the market by OEMS as it allows them to comply with European and US fleet emission targets and consumers desire for more range, but also to continue to feed the current petrol and diesel infrastructure and maintenance networks. Considering these networks can continue to serve PHEVs and provide significant revenue for automakers and its surrounding network. This is an explanation into why the automotive industry opting to push PHEVs instead of full EVs into the market. Interestingly, however, R233 mentions EVs have already impacted certain car lines, which have been taken offline due to the reduced demand, particularly of diesel engines.

Ultimately, the lack of after-sales markets is a pressing barrier for EV adoption considering OEMs have so far continued to operate under traditional automotive supply structures, which are dependent on maintenance revenues for each sold product. However, this has and will continue to force the automotive industry to innovate and go beyond the business of simply selling cars. As R114 notes:

> "We know this is going to happen. You can see for instance Volkswagen, they are moving into the industry of infrastructure. They are developing a huge business within the business as infrastructure provider. Because there's only much you can live off from selling cars … The core business is no longer enough."

In short, our results show a consistent message that the future of OEM business models may change significantly as they shift from

ICEVs to EVs. Even experts from leading OEMs recognised the inherent need to revise models that are tailored for EVs. Currently, without a shift in their business models, the lack of maintenance revenue provides a stark disincentive to sell EVs. This can further result in the promotion of PHEVs as opposed to full EVs, as shown above, since it allows the industry the continued use of petrol and diesel infrastructure and support networks. Therefore, if decarbonisation targets are meant to be fulfilled, one means of accelerating the adoption of full-EVs may be to assist OEMs in finding new business models to make after-sale revenue of EVs more appealing.

3.3. Supply chain segmentation

Another key barrier expressed by experts relates to the supply chain, in terms of: producing new vehicle models that fit different car segments; producing the mass volume for EVs to eventually meet mainstream demand; and also producing infrastructure around them, particularly charging infrastructure. Notably, the visited countries of this research do not have a well-developed automotive manufacturing industry – the core exception being Sweden with Volvo and NEVS, that are now largely owned by foreign capital – and rather mostly import their personal vehicles. Therefore, expert responses refer to the regional and international vehicle supply capacity. Here the initial suggestion is that the automotive industry has long lead times to turn one prototype vehicle into a commercially available option, and therefore highlights a two-fold complexity for EVs: the long lead time to develop the assembly lines for full-EVs and a reluctance from OEMs to do so, considering the lack of profitability of such vehicles. To this end R010 noted:

> "… big companies said yeah we will have this [EV] available in 2 or 3 years, but in reality, they couldn't do it because of the complexity and size of the assembly line … to produce a new model … it takes [OEMs] about 5–7 years to organize and put together the supply channels, an everything, for the new type."

Industry, R213 from Norway mentions, has had EV technology available for commercialisation since around 1990s (not considering their historical initial developments in 19th century [41]) but has not had the capacity to put the infrastructure in place for delivering vehicles and scale up production to meet demand.

> "Because you have the technology, but how the hell do you scale up."

To which R010 in Iceland agrees and further elaborates that is not only the OEMs themselves that lack capacity but also the component manufacturer's:

> "Sure, they have the technology, they have these and other kinds of vehicle-to-grid technology, etc. However, they weren't able to produce it because they didn't have the manufacturing capability and we're not talking about the car manufacturers but the component manufacturers."

Every vehicle can have hundreds or thousands of different components, depending on the technology, and issues arise when each of those components needs the supply capacity to timely deliver thousands of parts for a particular product. The complexity of this process is described below by R010:

> "I visited that company. They were trying to get funding to put up a new factory to be able to produce 10,000 units, and they needed 50 million euros or whatever it was to put up their factory and it took them 3–4 years to make a good business case, get the funding, get the foundation of their factory, build the house, go through zoning in their environment and get building permits … and then I realized oh my god and that's just one piece of the puzzle, there are so many pieces that have to come together."

To which, the respondent furthers:

> "[and] if there's one component missing, then the car, a complete unit that is made of 30,000 components, will not come off the assembly line."

This complexity of the automotive supply chain was not only referred for the purpose of producing EVs but also to highlight that OEMs and component manufacturers have significant investments nested on petrol and diesel cars supply chains. Particularly, with long term commitments and implications which limits their willingness to invest in R&D or divert production away from ICEV lines [42]. As R022 mentions:

> "… factories have been built for millions of euros to produce petrol cars. They have a rental period of God knows what."

A key point of focus within the EV supply capacity is the battery. There are many questions associated with EV batteries, such as their sustainability, durability and efficiency. However supply-wise experts' question both the capacity to source enough materials to produce them, as well as having the actual capacity to manufacture them, as R213 in Norway mentions:

> "The big question is how you get enough batteries. Not the price, not the efficiency. [But] how do we replicate enough speed-up production of today's existing technology?"

R043, a battery expert, furthers this point and elaborates on the scale of investments needed for EVs to become mainstream globally:

> "We need 200 giga factories, but where are you going to get the materials? I don't see the government … they are not going to solve this problem. It will be private investment and investors."

This manufacturing and supply capacity is noted by our interviewed experts as a business barrier, that governments could support also for employment reasons to create momentum for EVs and their mainstream production. However, as R043 stated above, R079 also argues that the real push will not come from the government alone, but rather that businesses need to get involved.

> *"Yeah it's a business barrier form the supply side exactly. And it's important that the politicians do this, to promote technology and to get the wheel spinning. But they can't do everything, they can't, it has to be a market based because we live in a market economy and we don't have 5 year plans today - and that's a good thing by the way."*

To which R043 adds:

> "… we know that's not going to happen from the government. But that sort of number doesn't frighten big investors … And if you multiply that by 20-30-50 giga plants, that is what is the reality and we would be sensible of have 1 or 2 in Scandinavia. 1

in west coast of Denmark, one somewhere here and one in Norway to satisfy the EV needs"

The supply capacity, or lack thereof, has already impacted the industry which arguably was not expecting EVs to become popular in such a short time frame as R217, a Norwegian expert from a leading OEM, mentions:

"I can promise you the first time we were giving our estimates to factory, they were saying 'are you mad? Are you completely mad?' They would never believe that we would estimate so many cars."

Respondent R057 in Sweden, further elaborates on the limitations of the supply of components for batteries, which might limit the eventual mass deployment of EVs in society. This is a point towards the diversification of powertrains, not referring to society needing ICEVs, but rather other clean technologies such as hydrogen-fuelled vehicles.

"… we can't all go electric either. Because if in 30 years if everyone is electric, there is not only the energy supply but there is a constraint on the components that also use rare metals. So the best option is to have a range of good renewables but different kinds. Hydrogen might also start to become something, so that there is a mix. A big issue is when a mass goes for one thing because then everyone needs and wants it. From an environmental point of view, it is best to have a range."

To which an expert from a traditional OEM mentioned that some brands are in fact ready for EVs and indeed have planned the transition for years, to launch their all-electric vehicles when the market is ready, which is now. For example, R057 argues that the car industry is changing, and their company has been preparing for such a change over the last several years:

"What also shows that we are serious about this is that … Our platforms are ready made for full electric. So they can either be combustion or fully electric without compromising on interior or luggage space. So that shows we are ready. When the market is there, we are ready to go. We are that many years in preparation. It's not like a phone or cycles with 7 years. It is many years in the making, we have seen it coming for a while and are prepared."

Therefore, it appears that some manufacturers have started and are making the supply chain modifications that are tailored for EVs. As another expert (R217) from a different leading OEM mentions, their brand will roll-out a modular platform to delivery several types of EV models for different car segments:

"From our side, 2019 production will be on a completely new platform. The module for electric, yeah. And that will facilitate all these new models coming from this new EV platform."

3.4. Charging concerns

While the above challenges essentially relate to the production of EVs, another challenge affecting the EV business case transition can be found in respect to its recharging infrastructure, public charging stations in particular. These stations are desired by consumers in an effort to mitigate their range anxiety and are deemed a plain necessity for inter-city mobility. Hence, the fourth element most commonly discussed by experts when talking about the EV business case issues was the charging infrastructure network. There are many questions around EV charging, from types of charger, speed of charging, availability and so on. Here, however, we focus on elements of ownership and responsibility and the role of different actors regarding EV charging infrastructure, as well as the expert's expressed lack of a suitable business model.

In our study, interviewed experts begin with the question of ownership and responsibility, as there is uncertainty and controversy on who should lead (and pay) for the deployment of charging points across different regions, as R014 elaborated in Iceland:

"… the business concept its quite complicated for all [EV] infrastructure for example. Government doesn't know its role; energy companies don't know their role and the oil companies don't know their role. The question is how to build these [charging] plugs."

To which the responded added that from the businesses perspective, and following the above discussed 'money talks' mentality of the industry, it should be governments leading the charging networks not the energy or automotive industries. Particularly, as it is governments that are striving for decarbonisation, and the business case of Electric Vehicle Supply Equipment (EVSEs) is too weak for private companies to take the lead in developing such infrastructure:

"The energy companies are wondering is it our responsibility to build them? Shouldn't the government participate? Because it's the government that wants to get rid of the import of fossil fuels. [And] you participate either with grand funding or some basic funding. So that's the kind of difficulty of who would do what?"

Additionally, when one looks at the roles of ownership and responsibility of EV charging networks, subsequent questions arise regarding the actors that are involved in developing such infrastructure. From natural players such as EVSE providers, power utilities and public bodies, to others that may appear not related to electric mobility, but are a main driver behind the competing ICEV market. For instance, some experts discussed the oil sector and their role in the current ICEV automotive regime and its growing presence in the electric mobility market where it currently supports the fuelling of conventional vehicles. In this way R014 adds:

"but oil companies don't know what to do, what business is it for them?"

Inherently one could consider that oil companies do not have much of a role in transitioning to EVs, apart from contributing to continue to better the ICEV business case and supports its refuelling networks. Nevertheless, some traditional oil players have started to place EVSE on existing refuelling stations and others have acquired EVSE start-ups, like Shell has done with New Motion [43].

While there is uncertainty on who should lead the wide-scale implementation of a charging network and what precisely is the role of existing players that support re-fuelling ICEV stations, there are many different business models for charging infrastructure already rolled out for different segments. However, the level of success of these is questioned by experts with no clear model that is scalable and profitable. In this way, R055 from Sweden mentions that initially the model has been to not charge for the actual use of public chargers:

"Yeah there are a lot of different ones. In the cities, normally you pay for the parking. Like Stockholm, Stockholm Parking

Company, they don't charge an extra for the use of the charging for public use."

The free access to public charging has been used to promote EVs in most countries, but experts recognise that it is a model that is not sustainable. Subsequently, municipalities and public charging owners are beginning to charge for their use, as R055 elaborates:

"… then they have to pay for the electricity and the use of that charger station. But when we will start this business next year, everybody will have to pay also for the use of the charging system."

Thus, the EV market will not only introduce prices to public charging, but depending on the type of charger, the introduced prices will be set at different levels according to for example the speed of charging. This will be done with the aim to mitigate the high costs of such infrastructure, as R059 elaborates that fast-charging stations require a higher pricing due to their high investment costs. However, there is no established model for charging, whether this is at home, work or a public space. Where R055 continues to elaborate that in Sweden there is not an established norm yet, and some players still provide the service for free:

"That's our business model. But it varies very much. And also I mean the fast charging stations, normally you pay for using them of course. Since investments are high. But it varies, I've also seen Malmo parking company, they don't charge anything extra today either. Not today."

Notably, though, the respondent remarks the importance to develop suitable EV charging business models because the variability in type of models currently creates deterrents for EV adoption. Specifically, experts note that it is industry and government that, through the uncertainty with charging networks, create messages to consumers that deter EV adoption. Both by creating uncertainty for consumers on what to expect at re-charging stations – if these are free to use, for how long they can be used, and how the eventual price per kWh will be – and also contributing to the general idea that EVs are expensive. As R059 notes:

"… and then there was a lot of debate [about] the utility companies, governmentally owned, Vattenfall and so on, [and whether they] should actually take a price [on charging, as that would] give a signal to society that don't buy an electric vehicle because it is very expensive, and so on."

However, the current reality is that charging networks are limited in most regions, both in the total number of EVSE available and also in the EVSE per vehicle. Table 2 shows the total number of EVSEs per country and how these compare against national EV fleets and also total vehicle fleets.

The low levels of EVSEs, reflects the hesitancy of industry players and governments to lead a large-scale rollout following the uncertainty of recapturing the investment returns. R49 puts it in simple words when comparing it to current ICEV stations:

"Just like a petrol station, they don't exist because the authorities tell them [petrol and gasoline suppliers] to, they exist because they want to make money."

To which R014 further highlights the lack of business case for charging infrastructure, while pointing out that the only business that currently results from them is for utility companies as they earn from the additional electricity that is being used by EV drivers at home or at work:

"There's no [current] business case in it, because how much are you going to charge to be able to pay back the investment cost of the infrastructure, so you're losing money, so you're using it as a market tool or it's the utilities that own the plugs and they lose the money at the plugs and then they earn the money back when I charge at home or at work, when I'm actually buying the electricity from them."

The flaws on the existing business case for a public charging market are the result of two main elements of the business model: the lack of volume of customers and the potential high prices companies would need to charge customers. As R076 mentions:

"… it's a large number of vehicles that is needed in order to make public charging worthwhile or profitable."

And R075 adds:

"… several of the companies charge up to almost 1 euro per kWh when you charge along the highway and very few people are willing to pay that."

The acknowledgement of the lack of a business model for charging infrastructure was consistent across experts, as R054 agreed:

"… there's no business model around this yet."

Nonetheless, experts also pointed out that, just as with the supply chain models, EVs need tailored solutions for charging network models, and that in particular for home and work charging there is no need of a model itself, as R075 adds:

"There is not [a current business model], and in terms of housing there does not have to be."

This, considering that most of EV charging occurs at home or at work, and therefore even when EVs become mainstream in society, there are going to be limited public charging business opportunities

Table 2
EVSE stations in the Nordic countries 2018.

	<22kv EVSE[a]	>22kv EVSE[a] (fast chargers)	Total EVSE[a]	EVs per EVSE[a]	~Total vehicle fleet	EVSE% of total vehicle fleet[g]
Denmark	2124	492	2616	5	3,037,687[b]	0.09%
Finland	706	259	965	10	2,692,785[c]	0.04%
Iceland	40	87	127	57	344.664[d]	0.04%
Norway	8774	2421	11,195	19	2,719,395[e]	0.41%
Sweden	2731	5493	8224	12	4,845,609[f]	0.17%

Source: (a) European Alternative Fuel Association, (b) Statistics Denmark, (c) Statistics Finland, (d) Iceland Monitor, (e) Statistics Norway, (f) Official Statistics of Sweden, (g) authors.

as R010 mentions:

> "… you will charge at home probably 95–98% of the time, I think, so in reality the business of owning complete infrastructure and selling the car with access to the infrastructure, that idea becomes obsolete and its more about location of having the juice at the right location exactly when needed and sell it there for premium, that's more suited. You know you come down the mountain, and you come down and your car its empty and right at that spot you're willing to pay premium for the extra use of the car."

This was corroborated by a charging infrastructure expert, R076, who noted that the business of owning a public charging network is limited, and that the industry's investments are a reflection of it.

Moreover, this discussion also turns the focus to other business models for when the charging network is shared via roaming services.

> "I mean, the more we roam the less we need to invest in infrastructure. The charging unit is expensive and we cannot see a return on that in any kind of reasonably time. So, we try to invest as little as possible. But we do invest. As I said we invest where we don't have partners and we see that our partners expect us that we have chargers, so that we have a full coverage for Sweden and Norway."

Thus, experts suggest that from a business perspective the lack of charging infrastructure is due to the lack of a profitable business model which allows for the recapture of the hefty infrastructure investments. This opens questions regarding roles and responsibility of ownership, considering there is currently not a business case behind it. However, while a public charging business model is necessary for inter-city mobility and addresses consumer concerns such as range anxiety, EV charging is expected to mostly occur at home and at work. The business focus therefore may turn to these locations, particularly as EVSE owners would find the necessary volume and the certainty of charging at these locations.

4. Discussion: recalibrating business models for electric mobility

Currently, despite all of their proclaimed promise and hype, our evidence suggests that EVs face unfavourable market conditions. Led in particular by the legacy of the petrol and diesel car industries, as well as regulatory and policy frameworks that continue to support those industries and their products. Our findings show that the lack of a favourable business case is a result of an unsuitable business model and a supply chain that is not internally incentivised to optimise the production and delivery of EVs to automotive consumers. This creates deterrents on both the demand side, with only a few overly-priced vehicle offerings, and on the supply side, with an unprofitable product that also damages nested investments from ICEV product lines and support networks. For industry, the development of EVs particularly affects the selling methods (i.e. dealerships), component manufacturers, maintenance networks (and revenue streams) and refuelling (recharging) networks. Moreover, the development of EVs also brings business questions in terms of scalability and sustainability of production lines. This is mainly related to the capacity of industry to meet production demand, as well as develop the support networks around EVs, if these are set to become mainstream in society.

Therefore, new business structures need to be created to fit EVs and optimise their production and market delivery. These business models for EVs must fit within, or at least not entirely disrupt, automotive industry's structure and method of selling cars. On the production side of EVs, our results show that the lack of profitability comes largely from unsuitable assembly lines. These can be attributed to the lack of investment in EV technology, as OEMs are trying to protect their ICEVs investments, by assembling EVs under the same structures as ICEVs. This strategy makes the production of EVs inefficient and is not particularly suited for their specific characteristics, such as fewer movable parts and arguably simpler assembly. Experts hence called for its own bespoke modular chain that optimises the interior space and weight of each design as well as the operational process of production. Our results also show that two of the interviewed OEMs expressed the implementation of this modular approach to be launched as early as 2019, which would result in a decrease in production EVs costs, therefore directly bettering their profitability and affordability.

Moreover, EVs directly affect the existing ICEV business structures by almost eliminating the volume of work from maintenance business units, as shown in our results. For this reason, a potential new model for EV sales is to reduce or even remove the unit of car dealerships from the automotive selling chain. Tesla is well known for entering the industry with a business model that uses dedicated showrooms, more for branding and positioning, with specialised sellers that act more as product consultants, instead of a large-scale network of dealerships on every location. To this end, our respondent R036 (below) takes this concept further and mentions the EV model should drop the dealership model entirely, even showrooms, to help reduce the costs per EV unit. This model would help EVs to become more profitable for OEMs, be more accessible for consumers, and also fit a modern automotive purchasing trend where, as R022 mentioned, most of the purchasing decisions are made from peer-to-peer information and online research before any actual engagement with dealerships:

> "So we basically skipped the cost of having to have huge [selling units] like all this dealerships today. Yea, they are huge, with a lot of people working and a lot of cars inside. All this, it's gone. So, it will be like Amazon for cars, so that's why you get the price of cars much lower than if you go and buy it."

Admittedly, eliminating entirely the dealership model can be challenging, considering the dependencies the system creates, such as local investments (warehousing or product-stocking), and employment. Alternatively, to increase sales, EVs business models can be fitted to the benefits but also limitations of the technology, for example when referring to matching real EV driving range with expected consumer driving range. This is explained by respondent R051:

> "Swedes are choosing their car for 5% of their usage. The 5% rule I call it. Because in 5% of the cases they need the station wagon, because they need to pack and so on, and they need the toe hitch for caravan, and 4-wheel drive because of the weather. 4-wheel drive today its very common, but it's used 5% [of the time]. The other 95% you use the car to go to work, to go to day-care, shopping and you don't need it. But with another business model could you find a way to cover those 5%, so that you could actually drive a Nissan Leaf 95% [of the time] and when you need the toe hitch, perhaps you can turn your car to the dealership, they wash it, you can borrow a large pick up, and that's free of charge. So that's the business model."

This model would require a way to deal with the potential peaks in demands during holiday weekends, and the potential other uses

a SUV-pickup truck fleet could have when not used. However, in principle it can help remove the mental range anxiety and extreme use case barriers around EVs. Moreover, in creating avenues for EV access to consumers, a leasing model needs to be commercially available for private consumers. As R062 mentioned, there is currently a lack, or no offerings, of this kind for EVs. This model can take advantage of the fast-changing technological nature of electric cars and mitigate two currently expressed barriers for adoption: high purchase prices and battery concerns. Within an EV leasing model, returned cars can be refurbished with newer and better batteries, to then be either given back to the leasing customer or made available to the wider market. In turn, the removed batteries can be re-used as part of stationary storage solutions for demand response and power balancing. This model was supported by experts, such as R114 of a major OEM:

> "… you can opt for buying the first version with a sixty amp [battery], and you can buy the new battery package, increasing range. So just a thought for the future, when we get our used EV car back, say you strip it for battery and you install a new battery and you push into the market again, with a same car, same driveline but a new battery with increased range."

This leasing option is also the way through which sellers can further incorporate and levy the costs of charging infrastructure networks, via subscription services depending on the range, the access to charging points, or the volume of driving. There are some players already moving into this space, either in a Tesla-like model where, as expressed by R075, the cost of charging is included in the premium vehicle price. Alternatively, other have formed partnerships between charging providers and automotive brands to offer a home-charging package at the moment of EV sales. This too is a model that can be made available for leasing options. R075 continues to elaborate:

> "… including it [the cost of charging] in the pricing of either the car or your annual electric bill for your housing is I think the way forward here."

In dealing with the lack of EV volume to support their business case and the development of a charging network, an EV model can adopt its selling method by targeting mass adoption of EVs by public authorities and other initial market entry points. This is the case in Denmark for example – and rather successful considering the significant market barriers for EVs at a retail level there. Elsewhere too OEM brands have targeted municipalities to increase visibility, presence and eventual sales of EVs, as R114 explains:

> "When you're in the car business, you know cars sell cars. When you see cars in the street, people see them and they want it. EVs are not there yet. We have Teslas but that's it. So, we kind of thought, ok if we, let's say, spend 50 hours on selling an EVs, we could spend those 50 hours selling EVs to normal people, and you might be lucky to sell 10. We [instead] focus on municipalities that have a political agenda saying they want [EVs] and we might be able to sell 500."

While this method also faces limitations, like public authorities' budget constraints and differing sustainable aspirations, it does have the potential to reduce operational costs and time expenditure for dealers, and it optimises to overall sales potential of EVs as there are more EVs on the streets thereby encouraging prospective sales.

5. Conclusion & policy recommendations

In sum, this paper has shown that the reasons for an inferior EV business case are arguably straight forward, as identified by our expert interviewees. With an industry that is trying to protect their ICEV investments, has a lack of suitable business models, practices and production methods tailored for EVs, and faces a lack of government support for the technology, EV adoption is limited on both the supply side and the demand side. In combination, these elements have to date tempered the EV adoption and resulted in an unprofitable product for industry to sell and overly-priced vehicles for consumers to buy.

These symptoms would appear to be a result of the legacy of the ICEV market and could be organically overcome in time as the EV market progresses. However, as noted by experts, a key aspect of the industry entails the long lead times to deliver products. Considering that EVs are indented to be used as a tool for decarbonisation, the duration of these lead times has to be reduced. To do so, both industry and government have to continue to innovate their strategies, planning and models to optimise the delivery of EVs to the automotive market. In this paper we have shown avenues for this purpose, such as an optimisation of the EV production and selling methods, to create a profitable product for industry and an accessible one for consumers. In this way, EVs could – and should – move from their current limited market segment into the mainstream.

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