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The Norwegian Charging Infrastructure Ecosystem

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Summary

The Norwegian charging infrastructure ecosystem has evolved into a complex web of actors that follows their individually sensible business models. The sum of their efforts is however not particularly user friendly. To get access to all charging infrastructure in Norway users will need to interact with up to 20 different apps and 13 payment systems which comes on top of other charging issues, such as different plug types and power levels and charger user interfaces. The paper investigates how this system functions in practice, points at potential successful business-models and investigates scenarios for the future development of the system.

Keywords: Market development, Charging, Infrastructure, Business models, Sustainability

1 Introduction

Norway is the world leader in BEV adoption with over 460000 BEVs on the road at the end of 2021 which was 16% of the total fleet of passenger cars. The market share was as high as 54% in 2020 and 65% in 2021. Back in 2000 there were about 3000 BEVs in Norway. Early adopters up to 2010 charged their vehicles at home using outdoor sockets, and when in trouble used publicly available outdoor sockets, for instance outside hotels or restaurants. BEVs could also not be fast charged. Since then, charging infrastructure has emerged as a more important enabler, but also barrier, as BEV buyers have progressed from being technology interested multi-vehicle households into vehicle owners in general. BEV owners now use wall-boxes with built in circuit breakers and separate fuses in the house installation for safe charging at home, at work and in public locations. Fast chargers along major roads enable trips longer than the range of the vehicle, and local fast chargers solves range problems in everyday traffic. Users want to have easy access to all this charging infrastructure, i.e. effortlessly find and use chargers that are in order, pay for charging and avoid queues. User surveys shows that these basic demands are far from being met. Charging queues can be an issue, chargers can be out of order, payment could be easier, and users do not want to use a myriad of apps.

In order for the PEV charging market to be economically sustainable in the long term, there is a need for businesses that generate value for the end customer, and enough value so that there is sufficient return on the huge investments made in charging infrastructure (both hardware and software). In order to achieve this, well-suited business models are needed.

There is a lot of public discussion about ways in which the economics of public charging infrastructure depends on the applied business models, but not so much in the scientific literature, according to [1] Zhang et al. (2018). [2] Greene et al. (2020) points out that as the charging market looks now, there is uncertainty about what are

well-suited business models for public charging, partly because the utilization rate is still generally low and that the roles of the public and private sectors are not well defined. This conclusion is also supported by [3] de Rubens et al. (2020) and [4] van der Kam et al. (2020), who also point out that the difficulties in finding profitable business models are one of the biggest challenges for the roll-out of public charging infrastructure.

Several studies over time point out that it is common for businesses to struggle to find profitability in investments and operations in public charging infrastructure, especially fast charging infrastructure (e.g. [5] Boston Consulting Group, 2021; [6] Deloitte, 2019; [7] Helmus & van den Hoed, 2016; [8] Schroeder & Traber, 2012). This is related to the fundamental fact that the costs of investment and operation are high relative to the size of the customer base, i.e., BEV users and their willingness to pay.

The ecosystem for EV charging covers many different sectors. Within each sector there is a myriad of products and services to deliver to different customer groups. Different companies can provide products and services both within a segment of a sector and across segments and sectors. In other words, there are thousands of possible business models based on combinations of these different aspects. A classical illustration of the enormous range of possible business models can be found in the morphological boxes in [9] Kley et al. (2011) that are used show the potential for new business models in the expanded ecosystem for electric cars, batteries, charging infrastructure and the energy system.

While the range of possible business models in the EV charging ecosystem is enormous, this paper will highlight a few business models in the Norwegian EV charging ecosystem that seems particularly promising and/or interesting. This paper will also present the main aspects of this ecosystem and discuss its complexity and how it delivers on user friendliness. This paper will also outline a range of future scenarios for the direction of the EV charging ecosystem and discuss the implications of these.

2 Methods

Many of the insights in this paper have been derived from the extensive research documented in [10] Wangsness & Figenbaum (2022). The analysis is mainly qualitative, building on different types of data sources in order to get a broad overview and to go in-depth on certain aspects of the current charging infrastructure landscape. The data sources have been the following:

- Literature review on business models in the EV charging ecosystem
- Collection of open data from web pages of charging infrastructure actors, news articles
- Anonymous semi-structured interviews with 21 charging infrastructure actors, i.e. Charge Point Operators (CPOs), Electromobility Service Providers (EMSPs), Mobility as a Service (MaaS) companies, Hardware and Software (HW/SW) suppliers, landowners, BEV producers (OEMs), energy companies, public actors

We assess the EV charging ecosystem by systemizing it as a value chain. This approach has been applied in reports such as [11] ADL (2021), [5] Boston Consulting Group (2021), [12] Capgemini (2019); [6] Deloitte (2019) and [13] PwC (2018). We draw inspiration from these when illustrating the value chain in this paper, and we add the supporting functions from both government and membership organizations alongside the value chain. The illustration is given in Fig. 1.

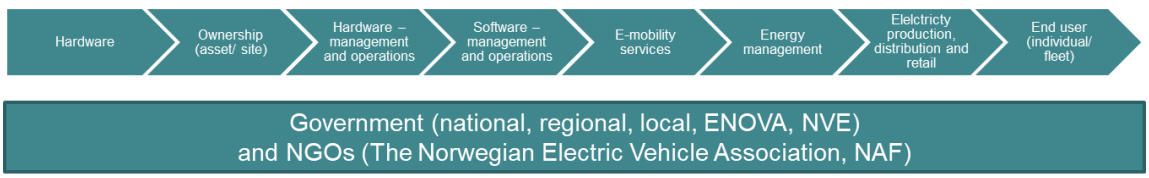

Figure 1: Illustration of the value chain for electric car charging

Finally, based on an internal project workshop, we have constructed and discussed a set of 10 scenarios for the future charging infrastructure landscape. These scenarios were reduced to 5 main scenarios for further discussion.

3 Results

3.1 Assessment of actor roles and motivations

The charging infrastructure market consists of a number of actors from both the public sector and many different parts of the private sector. These actors play different roles in the value chain, and in making the charging market work. We outline the roles and motivations some of the main actors in the following paragraphs. The analyses of the current Norwegian charging infrastructure landscape in the next section shows how and by which actors these roles are filled.

CPOs install, own, and operate charging station hardware and software standalone or in co-operation with land or facility owners. They want as many users as possible to use their chargers. They may offer their network universally to all BEV drivers through national and international roaming networks or more limited to specific EMSPs such as those controlled by OEMs. Some large CPOs (Mer, BKK/Eviny, CircleK) have an integrated EMSP service to provide an integrated network with the motivation to keep more of the income within the company.

EMSPs connect BEV users that want to charge with a charger at one of the CPOs charging stations, starts and stops the charging process and organizes the payment. They take a percentage of what the user pays and sends the rest to the CPO.

Roaming actors integrates several CPO networks into one virtual network and takes care of the transactions between the driver and the CPO. They finance their business through a percentage of the transaction cost. They are often transnational and can offer charging access across national borders.

Facility owners cooperate with CPOs to install chargers to attract more customers to their facilities. Co-location of chargers with facilities has been a strategy for fast charger deployment since 2012 ([14] Pöyry 2012a, [15] 2012b), with the rationale of giving customers something to do while charging and access to toilets, kiosks, restaurants or shops. CPOs can get access to large properties that are suitable for charger installation in many locations through cooperation agreements with these large actors. Large actors can leverage good locations to get chargers installed also in the less attractive locations, while CPOs can include such chargers into their network and build up a national presence.

Landowners cooperate with CPOs on installation of chargers or rent out land that CPOs can install chargers on.

Municipalities are a specific property owner that cooperates with CPOs and EMSPs to install chargers that serve their inhabitants, particularly those that cannot charge at home. Municipalities and Counties may also support economically and facilitate installation of fast chargers on municipal land and in other locations.

Owners of parking facilities facilitate installation of chargers in their facilities, for instance in public parking areas or in the parking garages of flat owners. They cooperate with or buy from suppliers of turn-key solutions for EV charging.

OEMs first and foremost sell vehicles. They compete fiercely with each other, and Tesla's Plug & Charge solution is the target that all strive to match. Plug & Charge is tested out at Ionity charging locations and some manufacturers plans a roll-out for new models in 2022. Others integrate CPOs chargers into their own EMSPs and into the vehicles navigation systems. This can be done via roaming platforms for CPOs that offer their services through these actors or as bi-lateral agreements between OEMs and CPOs. The latter is the solution pursued by the integrated CPO/EMSPs such as MER and BKK.

RFID card issuers are often car dealers (Møller Bil, Bertel O. Steen) wanting to give their customers an easier charging experience in spite of the lack of roaming solutions and NGOs doing the same for their members such as the Norwegian Automobile Federation (NAF) and the EV Association (EVA). RFID cards allows for semi-automated identification and payment if the user registers the card number and payment details with the CPOs they use. The EV Association has launched a new RFID service that functions as a roaming solution were the

RFID card is linked to an account that handles billing with the three CPOs that currently offers roaming. This can further reduce the complexity of charging if the user sticks to these three actors. should be numbered as above.

Electromobility as a Service (MaaS) actors offer mobility services for users that need charging infrastructure to be able to use the vehicles offered by the MaaS actors.

Route planners and Map services shows the location and type of publicly available chargers irrespective of operators.

Software providers (SW) develop and supply software required to make the ecosystem functioning, such as back- and frontend systems for CPOs and EMSPs, and database services with charging infrastructure location data and technical characteristics.

The energy sector sells the electricity that chargers use. They are often involved as owners of CPOs, or individual chargers and locations within a CPO network. Some of these actors bundle rebates for charging with the electricity supply contract of its customers.

In addition, there are a number of supporting functions around the ecosystem, such as electricians, entrepreneurs, payment system providers, and structural elements such as laws and regulations, authorities, support schemes etc.

3.2 The Charging Infrastructure Ecosystem Landscape

Up to 2009 very little public charging infrastructure was available. BEV owners charged at home, using standard 230V/10-16A outdoor power sockets of the Schuko type. This charging method is not recommended anymore due to the possibility of overheating, and the lack of EV supply equipment (EVSE) features such as dedicated fuse, ground fault detection and circuit breaker that are inside the wall-boxes installed nowadays. BEVs still come with such cables to enable emergency and occasional charging.

Economic support programs (Transnova, Enova, Municipalities, Counties) have since 2010 been put in place for the deployment of fast chargers along major roads and normal chargers in cities, at shopping centres, workplaces, and in parking facilities for flat owners. As all actors have pursued individually sound business models, the complex overall charging infrastructure ecosystem shown in Fig. 2 emerged, a form of "tragedy of the commons" which does not take sufficiently care of user needs. BEV owners need in 2022 up to 20 apps and must use one of up to 13 different payment methods ([10] Wangsness and Figenbaum 2022) to be able to access all chargers in this ecosystem. The payment methods include apps, RFID cards, web page payments accessed manually or via QR code scanning, Plug & Charge, tap to charge, instant payment solution apps (the Norwegian payment solution Vipps) or QR codes, variants of subscription services, integration with vehicle navigation system and OEMs electromobility services. The first CPO that offered bank card payment opened their first station in 2021.

The core actors in the Norwegian charging infrastructure ecosystem are the **CPOs** (Mer, Recharge, BKK/Eviny, Lyse, Ionity, Kople, CircleK, Tesla and others). CPOs may have an integrated EMSP service or offer such services via a broader roaming service. EMSPs (Mer, BKK/Eviny/Lyse, CircleK, Kople, Elton, Fortum Charge & Drive) connect BEV drivers with CPOs via an app or RFID card. RFID cards can work as identification, but payment information has to be linked to the RFID card number within each CPO/EMSPs APP. International roaming actors (Hubject, Digital Charging Solutions, Plugsurfing, Shell NewMotion), aggregates CPOs into larger charging networks, facilitates payment between actors and are accessible for EMSPs. Landowners, i.e., municipalities and other public property owners, hotel chains, shopping centres, grocery chains and other store chains, fast food chains, rent out land to put chargers on, often where there are nearby facilities. Facility owners cooperate with CPOs to get chargers installed at their facilities.

OEMs give BEV access to chargers through their ecosystems (VW We charge, Mercedes Me Charge, Kia Charge and others), and enable interaction with charging infrastructure via the vehicles navigation system aided by software actors such as Digital Charging Solutions. For the future, they pursue Plug & Charge, mainly in co-operation with Ionity (OEM owned ultra-fast charger network CPO). MaaS actors (imove, Bilkollektivet, Bildeleringen, MoveAbout, Vy, Hyre, Leaseplan, Easly, Hertz, Avis, and others) rent out BEVs over longer or

shorter periods but often leave it to the user to find out how to charge it. Map services (A Better Route Planner, Google maps, Ladestasjoner.no, Elbil.no, Opplysningen1881, and others) use the Nobil database of all public charging infrastructure. Other Norwegian and international software companies provide back-office and white label charging infrastructure management software (Driivz, Current, Virta, and others). The energy retail sector (Fjordkraft, Hafslund Eco, BKK and others) sells charging solutions that allow users to shift BEV charging to off peak hours. Peer to Peer charging is also explored by actors (Plugshare, Cloudcharge, ChargeBnB). Finally, there are a number of actors that develop, sell and install chargers in parking facilities (at workplaces, apartment buildings), many of which are involved also elsewhere in the charging infrastructure ecosystem.

In Fig. 2 we place the main actors in the ecosystem in relation to each other, and mark how they interact through e.g., roaming transactions, location cooperation, or other cooperation. The figure allows us to see where the cooperation between actors in different sectors of the ecosystem is most and least extensive, and it gives a good illustration of how something as seemingly simple as charging BEVs actually involves a very complex business landscape.

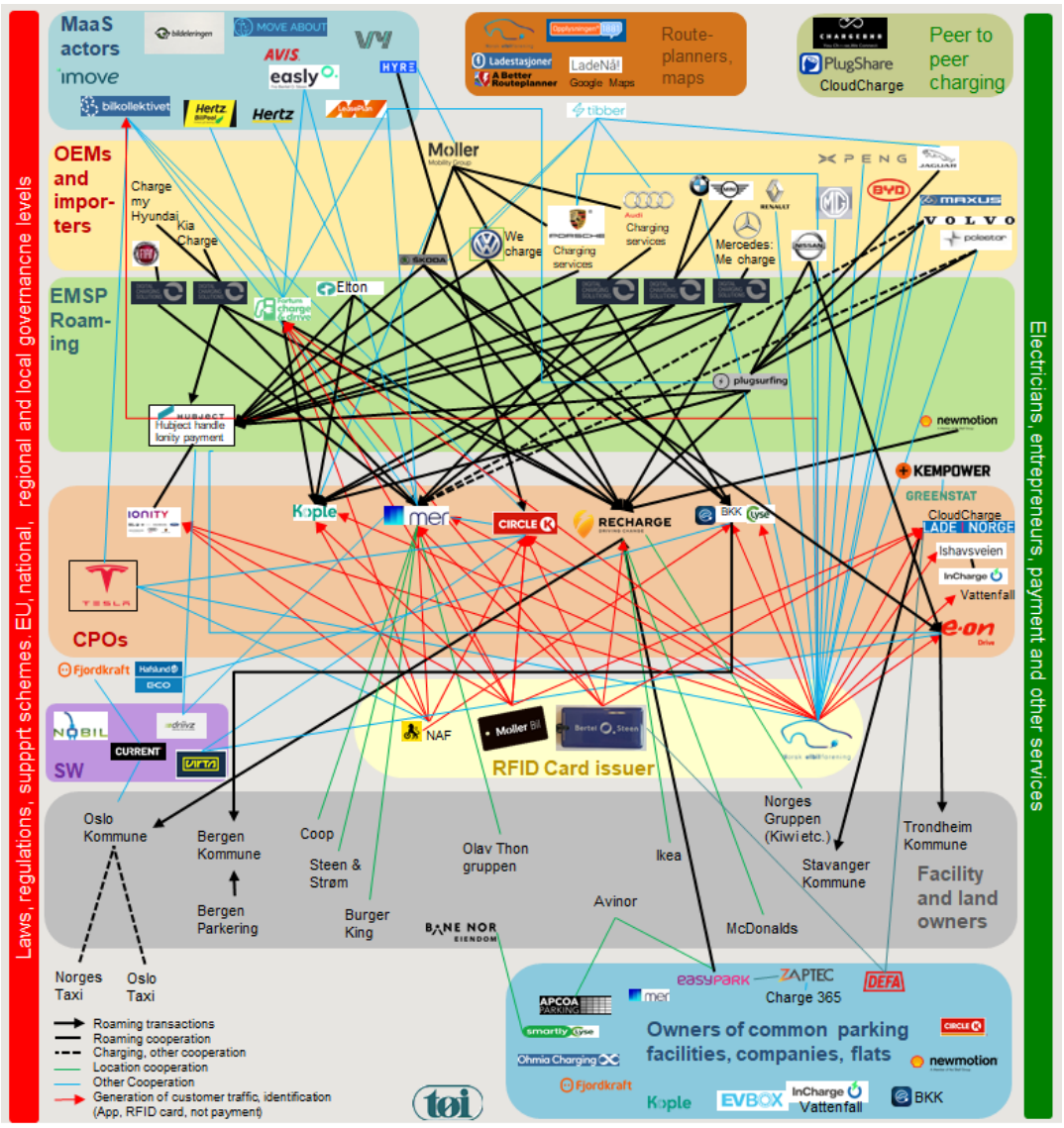

Figure 1: The Norwegian Charging Infrastructure Ecosystem

3.3 User experiences and needs

Another EVS35 paper [16] presents the user experiences with the current charging infrastructure and the needs and wants of users. Readers interested in that aspect should read that paper as well to get the complete picture of how the charging infrastructure ecosystem in Norway works. The main point is that users want to get access to chargers, either via one app (young drivers) or and RFID card/direct payment method at the charging station (older drivers). The Norwegian EV Association promotes that it should be possible to pay with bank/credit card, an option currently used in less than 5 charging locations for test purposes. Even more important than the payment solution is the avoidance of queues and making sure that chargers are in order when users come to charge.

Users predominantly have access (>90%) to charging at home [17], especially owners of detached and semidetached houses, whereas flat owners are dependent on the installation of charging systems in the buildings common parking facility. Fast chargers delivered about 5% of the energy used by Norwegian BEVs in 2018 [18].

Earlier research has shown that users do experience fast charger queues, most often on peak travel days, but some also in everyday traffic. Solving these peak travel day charging demand issues will be one of the remaining barriers to overcome in the Norwegian market. While at the fast charger station, users engage in a host of activities while waiting, of which using the facilities (for instance toilets, kiosks, cafés), taking a stroll, and doing e-mails and social media activities, were reported by over 50% of users [17]. Most other types of activities were only mentioned by about 10%, for instance being bored, listening to radio, longing for fast charging. A slightly higher share chatted with passengers. Only about 17% are willing to accept more than 29 minutes of charge queues and they would on average accept 1-3 charge stops on long trips (ibid.).

3.4 Promising business models

In [10] Wangsness and Figenbaum we have evaluated more than 40 business models in use in Norway in all 7 steps of the value chain according to these criteria (which also were applied in [19] Spöttle et al. (2018)):

- Profitability
- Scalability
- Contribution to public charging infrastructure

Seven business models were highlighted as particularly interesting (examples of relevant actors in parenthesis):

1. Integrated location owner + CPO + EMSP + charging system supplier for housing cooperatives/condominiums, private households and companies, semi-closed but cooperates with other CPOs (Circle K)
2. Integrated CPO + EMSP + charging system supplier for housing cooperatives/condominiums, companies and pop-up charging, open for roaming (CPO services for municipalities / counties) (Kople)
3. Roaming EMSP with map services (Elton)
4. Manufacturer of hardware and software - all segments (up to 24 kW) (Easee and Zaptec)
5. Provider of platform solutions for CPOs, EMSPs, installers, electricity producers and grid companies, which enable operation and management, smart charging and (eventually) V2G (Current)
6. Electricity supplier EMSP (without roaming) + supplier of hardware and software solutions for charging at homes, housing cooperatives/condominiums, workplaces and destinations (Fortum Charge & Drive)
7. Integrated CPO + EMSP + charging system supplier for housing cooperatives/condominiums and companies, semi-closed. Can also be asset owner (and in some cases site owner) (MER and BKK)

These seven business models are discussed further below.

An important case is **Circle K**. It is highlighted in several places in the reviewed literature (e.g., [20] Pagani et al., 2019; [13] PwC, 2018; [8] Schroeder & Traber, 2012; [1] Zhang et al., 2018) that much of the profit potential in the charging market will come from being able to combine several revenue streams. CircleK is doing just that.

Their energy stations make money from EVs charging there, where they act as both CPO and EMSP for several of the charging points. With larger volumes to the energy stations, they can draw greater revenue from the retail part of the business. In addition, they sell hardware, software and support solutions to homes, housing communities, property developers, and workplaces.

Kople also has a business model that stands out. They act as a "turnkey provider" for apartment buildings, workplaces, and destinations (hotels, shops, etc.) and an "End-to-End Integrator" as owner, CPO and EMSP for its charging network with normal, fast, and ultra-fast charging. Their charging network is also open for roaming, which means that they contribute to a larger charging network for their EV customers.

Although the literature we have reviewed does not often refer to aggregators/roaming hubs, they are relatively often highlighted as a promising business model, including by [5] Boston Consulting Group (2021) and [12] Capgemini (2019). **Elton**'s business model is interesting in this respect. After a few months of developing the solution, it became possible to use their platform and app to roam between major players such as Ionity, ReCharge and Kople, in both Norway and Sweden, with the possibility to search for the fastest and cheapest charging in the app.

Vehicle-to-grid (V2G) services are considered to have a very high revenue potential ([11] ADL, 2021; [21] Bland et al., 2020). In the Norwegian ecosystem, **Current** stands out. In addition to providing platform solutions to CPOs, EMSPs, installers, power producers and grid companies, enabling operation and management of charging services, the platform also supports smart charging and V2G functionality. They provide software solutions to several stages of the value chain, and several charging segments, and support both roaming through open standards (where they also offer certification), smart charging and V2G.

Fortum Charge&Drive is also an interesting business model as a large EMSP that is also an electricity retailer that sells home charging equipment. They are thus close to being an "End-to-End Energy" business model with multiple revenue streams, but without having to take the risk with the investment and operation of hardware, that a CPO must do.

It will be interesting to follow the business model of more closed CPOs (that do not offer roaming in general, but they cooperate with some OEMs) going forward and see if they manage to grow while retaining a firmer grip on their customers. In the Norwegian ecosystem, **MER** and **BKK** stand out. If they manage to deliver a large enough network alone to their customers and ensure loyalty, as well as bring in new customers through their large presence, then it can prove to be more profitable and ensure higher utilization of their own infrastructure than if they chose a more open strategy with roaming.

3.5 Scenarios for the future

Time will tell which business models will deliver on long-term profitability and scalability. The ecosystem for electric car charging is developing rapidly and there is great uncertainty about what this ecosystem will look like in e.g. 10 years. In such instances it is useful to construct a set of scenarios for the different directions the ecosystem can take. A total of ten different scenarios were identified. All of these scenarios are described and discussed in more detail in [10] Wangsness and Figenbaum. For the purpose of this paper, se summarize the scenarios briefly.

1. Business-As-Usual with many and probably increasing number of players
   Voluntary roaming is limited and none of the CPO networks are large enough so that BEV drivers can get by with only one user interface on a long trip to a new destination.
2. Consolidation into large, vertically integrated semi-closed CPOs
   The least profitable CPOs has dropped out of the market or merged with the large, remaining ones. The remaining ones grow alongside the BEV market and tend to have large horizontal coverage (multiple charging customer segments) and vertical coverage (e.g., energy retail and energy stations with convenience products).
3. Interaction- and roaming platforms connect all/most charging infrastructure players with charging customers

Interaction- and roaming platforms gain enough volume so that it becomes hard for the "stubborn" CPOs and EMSPs to "lock in" their customers.

4. "The people want to roam freely!" - roaming becomes the industry standard
   Preferences of both charging customers for maximal roaming possibilities and site owners for maximal volumes will favour CPOs that agree to roaming and put pressure on the CPOs that follow a more closed strategy.
5. Car manufacturer (OEM)-controlled future where charging is integrated into the car's navigation system
   OEMs will directly or indirectly provide EMSP services through the cars' navigation system, as a part of their expanded service portfolio pursued to compensate for the maintenance revenue decline. OEMs will have leverage to get seamless access to CPO networks and even be a force for expanded roaming possibilities.
6. Plug and charge, the cars identify themselves automatically and payment is seamless
   Some OEMs and CPOs will lead the way towards increased use of plug and charge, in order to compete with the customer experience of Tesla, which already offers this service.
7. Regulation requiring a splitting into pure CPOs and eMSPs
   In order to ensure more competition and less "lock-in" of customers, regulators require CPOs and EMSPs to be separate, and require CPOs to give fair access to all EMSPs.
8. BEVs get longer range that allows charging mainly at home and at destinations
   Fast-charging CPOs will be of less relative importance compared to home- and destination charging, as this is much cheaper. Strong growth in "become-your-own-CPO-solutions" and peer-to-peer charging solutions.
9. The EU sets the standard for ensuring seamless charging across national borders in Europe (incl. Norway)
   The regulation will make ad-hoc payment simpler and more transparent, allow the BEV user to be anonymous, and reduce the need for EMSPs. It also reduces CPOs ability to "lock in" customers.
10. The technology giants will take over
    Tech giants (e.g., Google and Apple) become the dominant EMSPs as they provide services through products the charging customer already uses, the smart phone, and already have payment solutions and ample amounts of data for prediction to fine-tune their services. OEMs will have strong incentives to give the tech giants' platforms access to their navigation systems.

The five most likely scenarios (authors assessment) are in Fig. 3 differentiated across the degree of consolidation in the market and whether the market development is steered from charging players or outside players. It can be useful to have a mix of main scenarios A and B in mind when making a strategy in the electric car ecosystem, and to be aware of the snowball effect of an increasing number of players and platforms offering e-roaming. Tech giants can also get in the lead if they get access to the navigation systems in the vehicle or the display. Better customer experiences can also be achieved through interaction platforms as in scenario E, or regulation of the market as in scenario D. The latter may be required if the market actors themselves cannot manage to establish an overall acceptable customer experience, through co-operation or some sort of consolidation.

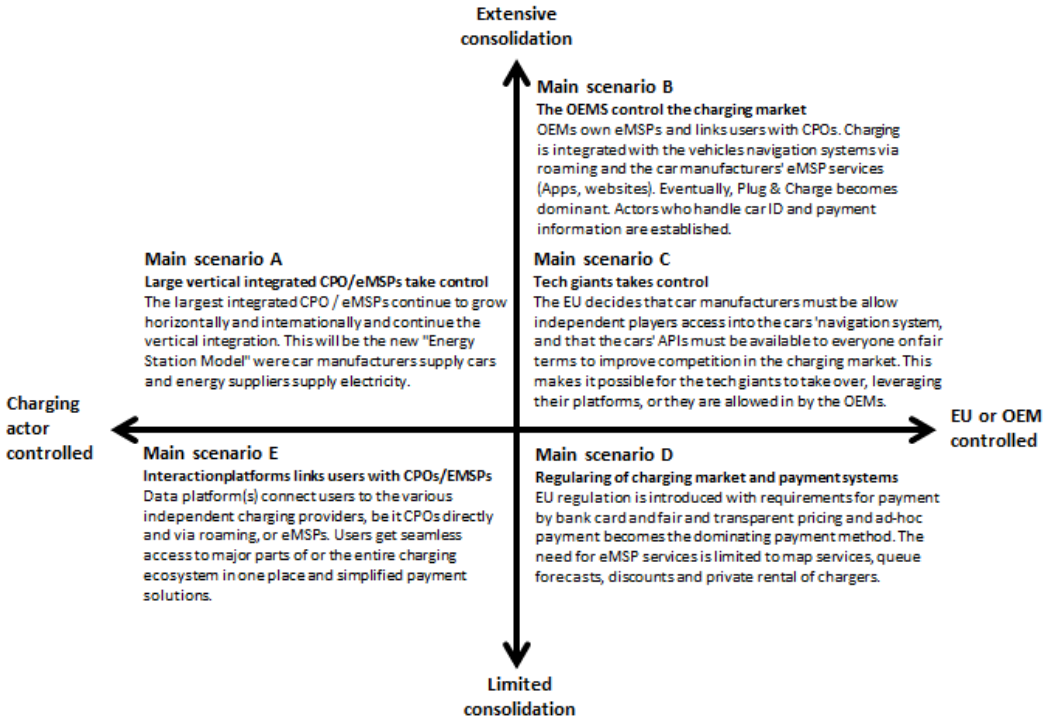

Figure 3: Main scenarios for the future development of the Norwegian charging market

4 Discussion and conclusion

The Norwegian BEV ecosystem has been built up over 30 years with incentives for purchase and use of BEVs and deployment of charging infrastructure that have been publicly supported since 2010. These incentives have built up a large competitive free BEV market that developed autonomously. This also applies to the charging infrastructure. Enova, Transnova, and others that provide charging infrastructure deployment support have specified minimum technical standards and required that at least one common payment system should be available in supported locations. Within these public support schemes and tenders, actors have competed and developed their own payment solutions. These solutions originated from the time when BEVs had small batteries and each charging transaction had a low monetary value. Low transaction costs had therefore priority over user friendliness and actors pursued many different solutions to this end. This development may have made it possible to install more chargers early in the BEV diffusion process but is a challenge for the future.

The overall charging infrastructure ecosystem has thus been built up by individual actors that each pursues their strategic goals and business objectives. While the total charging infrastructure network has expanded significantly, the system is not intuitive or simple to use for BEV owners. The system is likely to continue to evolve but the direction is not clear. Business as usual will increase the overall complexity as new actors joins. Consolidation of the Norwegian actors into larger and fewer actors can reduce the complexity. OEMs have a key role by controlling the vehicle navigation system and may be able to force actors to realign. Integrated CPO and EMSPs may need to be split into separate EMSPs and CPOs. Tech giants such as Google or Apple may disrupt the charging infrastructure market by linking their map services with traffic flow data to the charger status data and their payment systems (Google pay, Apple pay).

We emphasize that the ecosystem for EV charging is complex and that all of the qualitative assessments in this paper are subject to uncertainty and must be interpreted with caution. However, the paper gives a useful overview

of the ecosystem that serves as a basis for future research. There are many ways to extend the research on this ecosystem. Further research on the topic can expand the analysis of the ecosystem with financial data. Even if financial data at the desired level of detail are not available, official financial data may over time be able to say something about the magnitudes and development of importance for the ecosystem.

Since this ecosystem is a rapidly evolving field, it is of great interest to follow, document and analyze the most important changes that are taking place. This is to better understand the dynamics of the ecosystem, and to be able to ensure lessons learned about success factors and pitfalls in the transition to an electrified transport sector. Furthermore, it will provide the opportunity to evaluate the scenario assessments we have made in this paper, which enable improvement of the procedure and thus better scenario assessments going forward.

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