Regulatory Frameworks for Electric Vehicles in Oman

International Best Practices Findings and Prioritized Recommendations

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Energy+Environmental Economics

Table of Contents

List of Definitions

CAN - Controller Area Network

CO2 – carbon dioxide

BEV – battery-electric vehicle: a vehicle that can run solely on electricity. These vehicles are a subset of plug-in electric vehicle (PEVs).

CCS – Combined Charging System

CHAdeMO – Charge de Move

Charge point - a wall- or ground-mounted EVSE structure offering one or more outlets connectors for charging PEVs.

CPO - charge point operator

CRT – cost-reflective tariff

DCFC - direct current fast charging: a type of EVSE that is designed to rapidly deliver direct current to a vehicle's onboard battery, typically restoring an EV to 80 percent state of charge in about 30 minutes

DNO – distribution network operator

Dongle – a small hardware device that connects to a computer or device to provide additional functionality.

E-roaming – use of app to easily access EVSE in any location. Desired information includes location of EVSE, ability to verify charge point availability, cost and reserve charge point.

EU – European Union

EVSE - electric vehicle service equipment: standalone equipment used to deliver charge safely into the battery inside an electric vehicle. Also referred to as a charger.

EVSP - electric vehicle service provider: a non-utility company responsible for installation, maintenance, and/or driver billing services for multiple EVSEs sites.

GDPR - EU's General Data Protection Regulation

GHG – greenhouse gas

IBT – inclining block tariff: tariff structure under which the electric rate increases as customer consumption in each applicable consumption block increases

ICE – internal combustion engine

IEC - International Electrotechnical Commission

ISO - International Organization for Standardization

LDV – light-duty vehicle

Level 1 - charging equipment using standard household electricity voltage

Level 2 - charging equipment using 208 V or 240 V electricity

Make-ready - infrastructure between customer meter and charging equipment

Middle East – Abu Dhabi, Dubai, Jordan, Oman and Saudi Arabia

MoCI – Ministry of Commerce and Industry

MoTC – Ministry of Transportation

MUD - multi-unit dwelling: building or building complex with multiple residential units. Also referred to as multi-unit housing in this report.

OCHP - Open Clearing House Protocol (OCHP) is a standard protocol for communications between EVSPs

OCPP – Open Charge Point Protocol is an open communication standard that allows EV charging stations and various EVSPs to communicate with each other

OPWP - Oman Power and Water Procurement Company

PEV – plug-in electric vehicle: a vehicle that plugs into an outlet or into EVSE to charge. Includes both BEVs and PHEVs

PGE - Pacific Gas and Electric Company, a California investor-owned utility

PHEV – plug-in hybrid electric vehicle. A vehicle that runs on both gasoline and electricity. These vehicles are a subset of plug-in electric vehicle (PEVs).

PLC – power line communication

RFID - radio-frequency identification

Rate base – costs included in the utility's asset base upon which it earns a return

SAE - Society of Automotive Engineers

SCE - Southern California Edison, a California investor-owned utility

SCP - Supreme Council for Planning

SDG&E – San Diego Gas and Electric, a California investor-owned utility

SUV – sport utility vehicle

Telematics – vehicle data monitoring technologies such as GPS and on-board diagnostics providing key data such as location, speed, and time.

Tier – consumption block in an inclining block retail electric rate structure

TNC – transportation network company: an organization that pairs passengers via websites and mobile apps with drivers who provide personal transportation services.

TOU – time of use: time period in a retail rate structure

TSO – transmission system operator

UK – United Kingdom

US – United States

VGI – vehicle grid integration

V1G – passive VGI solutions such as customer response to rate structure signals and active management of charging levels by ramping up or down charging to provide grid benefits. V1G enables the PEV battery to charge or not charge.

V2G - vehicle-to-grid: bi-directional VGI energy transfer capability

ZEV - Zero-emission vehicle: as defined in the US ZEV mandate. This definition covers PEVs as well as fuel cell electric vehicles.

List of Figures

List of Tables

1. Introduction

In 2018, the Authority for Electricity Regulation, Oman (AER) engaged Energy and Environmental Economics, Inc. (E3), with its subconsultant Baringa Partners (Baringa), to prepare a study on international best practices for light-duty vehicle electrification and provide recommendations that AER may consider implementing as it readies the Oman electricity sector for future electric vehicle penetration. This report describes the findings of this project.

"Electric vehicles" can refer to a number of vehicle categories. In this study, we address only plug-in electric vehicles (PEVs). PEVs plug into an outlet or into electric vehicle service equipment (EVSE) to charge. PEVs include both fully battery electric vehicles (BEVs), which run solely on electricity, as well as plug-in hybrid electric vehicles (PHEVs), which run on both gasoline and electricity. Our study does not cover hydrogen fuel cell vehicles or hybrid electric vehicles that do connect to an outlet or to EVSE to charge (such as the Toyota Prius and Camry hybrid models currently available in Oman).

Further, our study includes only light-duty vehicles: cars, sport utility vehicles (SUVs), and small passenger trucks. We consider the use of these vehicles for both personal driving and commercial fleet applications. These vehicles can charge at a range of locations. Personal PEVs generally charge in a home parking area (either in a single-family home or at a multi-unit dwelling like an apartment building), at workplaces, and/or at public charging stations. Commercial light-duty PEVs, like government fleets, taxi fleets and rental cars usually charge at a depot or home overnight (or during down-time), and may also make use of public charging infrastructure while out driving. We consider all of these charging locations and applications in our study.

To complete the study, we combined expert knowledge from E3 and Baringa with extensive literature review, industry interviews, and engagement with key stakeholders. International jurisdictions analyzed are North America (the United States and Canada), Europe, the Middle East, and to a lesser extent, China.

This report is structured as follows:

Section 1 is the Introduction.

Section 2 is the Executive Summary.

Section 3 describes PEV value streams.

Section 4 is an overview of the current state PEV technology and market trends.

Section 5 discusses shared mobility and automation.

Section 6 summarizes barriers to PEV adoption.

Section 7 is international best practices in regulation and policy to support preparing for PEVs.

Section 8 describes methods that regulators can utilize to promote adoption of PEVs.

Section 9 contains prioritized recommendations for AER and other Oman government entities for regulatory changes and actions that should be pursued to ready Oman for PEVs under the two future scenarios: “Preparing for PEVs” and “Promoting PEVs”.

2. Executive Summary

PEVs can provide a range of economic and environmental benefits to Oman. Though PEVs currently carry a higher upfront cost than conventional internal combustion engine (ICE) vehicles, the high-level assessment described in Section 3A suggests that:

- Even at cost reflective electricity prices, PEVs are are expected to have lower fuel and maintenance costs relative to ICE vehicles and are therefore likely to be attractive to drivers on an economic basis;
- If PEVs are encouraged to charge during off-peak periods there could be benefits to all electricity ratepayers through enhanced efficiency in the use of the electricity networks; and
- Relative to ICE vehicles, PEVs can reduce carbon dioxide emissions, improve local air quality, and reduce noise pollution.

The value proposition of PEVs for automakers and drivers is improving fast. Falling PEV battery prices are reducing PEV costs and electric driving range is increasing. Automakers plan to begin selling more than 120 PEV models by 2020, and vehicles with an electric range exceeding 320 kilometers are already on the market. Notably, the new offerings will include the first plug-in electric sports utility vehicles (SUVs), a popular vehicle segment in Oman. Industry players and market analysts are forecasting further reductions in PEV costs and significant increases in PEV adoption. Reasonable forecasts (such as those from Bloomberg New Energy Finance) suggest that PEVs will reach upfront price parity with internal combustion engine vehicles by 2025 and PEV adoption forecasts continue to be revised upward, with forecasts of between ten and fifty percent of new vehicle sales expected to be PEVs by 2040.

Though widescale adoption of PEVs in Oman may lag other markets, Oman will not be immune to these fundamental changes in PEV technology and economics, regardless of whether Oman implements clear PEV policy targets. As PEV adoption increases in Oman, it will be important that public charging infrastructure is installed in key locations.

PEV charging technologies are also improving. At present, PEVs charge at 3 "levels." Level 1 charging is available from a regular electric outlet and is provided with the vehicle. Level 2 charging uses higher powered (7 to 22 kW) electric vehicle service equipment (EVSE). It is popular for home and work charging of full battery-electric vehicles, as well as in public spaces with longer dwell times such as malls, cinemas, parks, hotels and tourist attractions. DC fast charging (DCFC) is the highest-powered PEV charging available and has so far been installed for public charging of personal vehicles as well as fast re-charging of electric rental car and taxi fleets. Recently, a number of companies have begun to install "ultra-fast" DCFCs that can support 350 kW charging and are claimed to be able to provide "200 km [of electric range] in 8 minutes."[1]

[1] Fred Lambert, April 2018, "ABB unveils its 350 kW electric vehicle charging tech, claims 200 km of range in 8 minutes," https://electrek.co/2018/04/24/abb-electric-vehicle-charging-tech/

Even with these improvements, PEVs face a number of barriers to adoption, and these have been broadly the same the world over:

1. Lack of suitable PEV models, which is a likely to be a particularly significant issue in Oman due to the country's preferences for larger vehicles, the small size of the market and extreme heat conditions;
2. Insufficient charging infrastructure and range anxiety;
3. Limited awareness and enthusiasm;
4. Upfront cost premium of PEVs compared with internal combustion engine vehicles; and
5. Lack of dealer incentives to sell PEVs.

The first barrier is the most significant in Oman, and will likely push out any PEV adoption beyond early adopters for at least a few years. However, this barrier is expected to diminish as PEV markets develop and larger vehicle model availability improves, particularly in the GCC market. As it does, Oman will likely begin to see the remaining four barriers dominate the PEV purchase decision. Each of these is explored in section 6. Section 8 describes regulatory and policy changes that can be implemented to help overcome these barriers and promote PEV adoption.

Regarding the regulation of PEV deployment, PEV charging involves four key functions: service connection, make-ready (panel plus customer wiring), provision of EVSE activities, and billing. The distribution utility typically provides the service connection, including any required metering. Players involved in the remaining functions tend to differ by charging location and charging level. Each of these players could potentially be licensed or economically regulated, though thus far most jurisdictions have not done so. There have however been efforts to promote common technical standards and to ensure safety.

Ownership and investment in EVSE infrastructure have generally not been regulated or licensed. A key reason for this has been the desire to promote competition and innovation in the emerging market for PEV charging services. There have been exceptions where government agencies or utilities have provided upfront incentives and where utilities have been allowed to own and recover costs for make-readies and EVSEs. These installations enable deployment in locations where the private sector would likely not invest, particularly in early stages of PEV adoption. Utility ownership of public charging infrastructure is covered in Section 8.

Public charging has taken the form of five key business models:

Model 1 Investment and ownership by site hosts

Model 2 Investment and ownership by automakers

Model 3 Investment and ownership by private-sector electric vehicle service provider (EVSP) networks

Model 4 Investment by government entities; ownership by government or private-sector EVSP networks

Model 5 Investment and ownership by electric utilities

Under the "Preparing for PEVs" scenario, regulators have largely sought to enable private sector investment in public charging through the first three of these models. Models 4 and 5 have been implemented, to varying degrees, by jurisdictions wishing to stimulate the adoption of PEVs and/or ensure the long-term availability and maintenance of public charging networks in order to reduce driver range anxiety during the early stage of infrastructure development. Models 4 and 5 are also explored in Section 8.

Some utilities in Europe and North America offer residential customers specific rates for PEV charging. These are time-of-use (TOU) or seasonal TOU structures that are more economic for PEV charging than the default electric rate structure, provided that charging is carried out during off-peak periods. In addition, in some cases interruptible rate structures or limits on charging capacity have been used to protect local networks with limited capacity while providing additional economic benefits to drivers. In the Middle East, there are no specific rate schedules for PEV usage and most rate structures offered are not TOU, except for the largest commercial customers. Where TOU prices are available for PEVs and the customer does not also wish to have a TOU rate for the balance of their usage a separate utility-grade meter is required and there are no examples at present of utilities employing non-revenue grade meters for billing purposes.

Public facilities may provide electricity for PEV charging free of charge, for example as a residential amenity, an employee benefit, or as an incentive to shop or eat at a retail location. Alternatively, charging hosts may charge drivers a flat monthly fee for use of the charging service, or engage EVSPs to measure and bill drivers for EVSE and/or electricity usage. EVSPs may bill drivers on the basis of a) kWh used, b) time connected to charging equipment, or c) a combination of both. These determinations may be impacted by regulations on the ability of EVSPs to charge drivers for kWh used, dependent on the regulatory and licensing approach taken. For example:

- In Europe, California, New Jersey, Pennsylvania, Hawaii, Ontario, Jordan and Abu Dhabi, electricity rates charged by private sector EVSPs are not licensed or economically regulated;
- In British Columbia, PEV charging was determined to be a public utility service if the EVSP charges for power; and
- In China, EVSPs must pass electricity supply costs through to customers at cost whilst some US jurisdictions regulate EVSPs as suppliers. For example, in the state of Michigan, Indiana Michigan Power's tariff states that resale of electricity to PEV customers is not considered resale as long as it is not charged on a per-kWh basis.

Although there are some examples of regulation of the rate that can be charged to PEV drivers if electricity is re-sold on a per kWh basis, there is no evidence of regulation of the price EVSPs charge for the use of the parking space and the use of charging equipment. In China, Beijing originally capped the fee EVSPs may charge for such services, but recently liberalized these fees.

Despite the widespread absence of economic regulation of EVSE charging facilities, there are detailed international best practices promoting safety in hosting, installing and maintaining EVSEs that EVSPs must comply with. Level 1 and Level 2 EVSEs have risks similar to those associated with installing and using large household appliances such as microwave ovens and air conditioning units. Public EVSE installations, however, require additional safety measures that can include signage, disabled accessibility, collision protection, vandalism protection, power terminal voltage drop limits, testing, and distribution company notification of installation. Abu Dhabi issues a Quality Control and Conformity certification for EVSE requiring achievement of BS EN 61851 (electric vehicle conductive charging system) requirements, the ISO 9001 manufacturer certificate of quality management requirements, ISO/IEC 17025 test certificate, an EVSE installation agreement with a contractor licensed by Abu Dhabi or Al Ain Distribution Company, and payment of fees.

Access to public charging infrastructure is a key barrier to PEV adoption: it must be sufficiently available to minimize range anxiety and enable PEV purchases, but until there is significant PEV adoption there are no viable business models to support private sector investment. This is particularly the case for DCFC, which is much more expensive to install than Level 2 charging. Leading PEV jurisdictions have therefore installed basic public charging networks under two business models: (1) investment by government entities, with ownership by government or private-sector EVSP networks, and (2) Investment and ownership by electric utilities. Each of these models has been widely implemented around the world, and each has pros and cons. The right solution for a given jurisdiction is determined by:

- Regulator views on competition;
- Availability of government and utility capital;
- Utility appetite to own infrastructure; and
- The presence of private EVSP networks that can commit to sufficient maintenance and customer service personnel and that are expected to remain in the jurisdiction for the long term.

If private sector EVSPs are involved in either of these models, then policymakers or regulators should ensure thoughtful contracting and/or alignment of incentives between public agencies, utilities and private sector EVSPs to ensure on-time build out, sufficient power levels, public-interest siting, ongoing maintenance, and plans for eventual removal or replacement of infrastructure. A third, and far less common, model that has been used to promote the provision of a public charging network, is utility ownership of the make-ready infrastructure (up to the EVSE) only.

Jurisdictions actively promoting PEV adoption do so in a variety of ways. Some have established PEV adoption targets; others have proposed bans on the sale of new internal combustion vehicles by a future date. China and a number of US states have introduced targets (i.e., ZEV mandates) based on manufacturer credits, with longer range vehicle earning higher credits than others. These policies are non-binding goals and will require significant supporting actions. For example, a number of governments provide rebates, tax credits or tax exemptions for PEVs whilst public agencies or utilities may provide subsidies on the upfront cost of PEV charging in commercial depots, workplaces and multi-unit dwellings. PEVs may also be exempted from vehicle registration or other government fees.

Cities, municipalities and states have also implemented building codes that require EV readiness. These have typically required that home and/or commercial builders install conduit, wiring and electrical capacity sufficient to support Level 2 charging, though stop short of requiring installation of the EVSE itself. Zoning ordinances have also been employed to ensure that EVSE installation is permissible at the state and local levels. In addition, access to HOV lanes, waived bridge or road toll waivers, waived congestion fees, free or discounted parking, and preferential treatment in vehicle registration lotteries have also been used by Governments and related agencies to spur PEV adoption.

Limited awareness and familiarity with PEVs can be a major barrier to consumer adoption. To combat this, many jurisdictions have adopted efforts to educate consumers, car dealerships and building owners about the existence and potential benefits of electric vehicles. These efforts have been provided by public agencies, automakers and non-profit organisations or through partnerships between these players and have included websites, showroom promotions, 'Ride and Drive' events, dealership training, and developing programs to expand EV exposure through fleets (for example, taxis and shared mobility fleets, rental cars, government fleets, and commercial fleets).

Public fleets can also provide a useful demonstration of PEV technologies. Japan, France, UK, US, China, Canada, Norway and Sweden signed a Government Fleet Declaration in Morocco in 2016 to commit to varying levels of ZEV procurement, Amsterdam and Dubai have recently incorporated fleets of Teslas into their taxi fleets.

Leading PEV jurisdictions are considering and/or have implemented a number of additional measures to improve the experience of PEV drivers. These include:

- Standardizing roadway signage to help drivers locate public charging facilities
- Creation of public databases of locational data for use in government and/or private applications (apps), and navigation systems;
- Communications standards to allow interoperability to support "e-roaming" with common payment systems, although no international standards yet exist; and
- At locations where drivers are sharing charging equipment, it is also important for EVSE hosts to develop systems that provide PEV drivers fast and efficient access to charging, and it may be necessary to restrict use of these areas by ICE drivers and to ensure that PEV drivers only occupy spaces for the necessary or reserved period of charging time.

Lastly, technology plays a prominent role in nearly all aspects of PEV deployment discussions. Light-duty transportation is experiencing two trends that are likely to be heavily intertwined with vehicle electrification:

1. Shared mobility: the increasing share of passenger kilometers coming from shared, on-demand travel modes such as those provided by Uber, Lyft, Scoop, Waze and Chariot, and
2. Automation: the Increasing vehicle market share of driver-assist and self-driving vehicle features.

Together with vehicle electrification, these trends have been dubbed the "three revolutions" in passenger transportation. In combination, they are commonly viewed as the primary drivers of transformation in this space, with the potential to result in dramatic changes (both positive and negative) to the transportation and energy sectors.

Fully automated vehicles could provide a range of potential benefits. Those who are not able to drive a vehicle could have access to greater mobility. People would be able to work, converse or watch television while traveling rather than driving. If vehicles are electric, then automation can enable them to more efficiently share charging, making more intensive utilization of charging infrastructure and lowering the cost of mobility. However, these vehicles could also create significant costs if automation is not combined with pooling and electrification. Because automation lowers the cost of driving and removes the need for a licensed (adult) driver in each vehicle, full automation will tend to increase congestion. The increased kilometers traveled by fully automated vehicles means that without electrification, they would cause increased emissions of greenhouse gases and other pollutants. These interactions suggest that the most significant benefits will be realized when the three revolutions – electrification, automation and pooling – are thoughtfully combined. Enabling this combination will require regulation and policy implementation across a range of government agencies.

The outlook for shared and autonomous mobility in Oman is unclear. Though there may be consumer demand for automated vehicles in Oman in the future, they are not yet being tested in the Sultanate. Shared mobility may or may not enter the market. The Supreme Council for Planning (SCP) is currently investigating the potential for automated vehicles in the Sultanate's long-term plans. In the short term, SCP, Municipalities, the Ministry of Transportation and Communication (MoTC), AER and other government bodies impacted by changes in transportation should focus on learning from cities and regulators elsewhere as they begin to develop regulatory approaches for autonomous vehicles and shared mobility services.

Communication technology choices are intertwined with selection of charging technology, charging mode, charging level, connectors, and EVSE capabilities. Connectors commonly utilized for Level 1 and Level 2 charging are SAE J-1772 and Type 2 connectors. The GSO Final Draft of Standards document from early 2017 lists the Type 2 European connector as the standard for AC connectors; it is therefore likely that this technology, rather than SCE J-1772, will be deployed in Oman. Connectors utilized for DCFC are CHAdeMO, CCS, Tesla, and the Chinese GB/T connector. Because the DCFC connectors supported differ by automobile manufacturer, the availability of both CHAdeMO and CCS EVSE will be necessary in Oman.

Concern often arises in relation to the impact of PEV charging on power quality, such as harmonic distortion, phase unbalance, and transformer overloading. Phase unbalance ceases to be an issue if loads are connected on 3-phase service, which is common in Oman, whilst individual system conditions drive magnitude of transformer loading issues and can often be reduced with careful planning and off-peak charging.

Lastly, data privacy and security issues, while not unique to PEV customers, arise in PEV charging. In Europe, the European Union's General Data Protection Regulation (GDPR) governs how companies must protect personal data. PEV charging will experience cyber security issues similar to those for systems in other industries as well as issues unique to PEVs. In all vehicles, including PEVs, the CAN bus and telematics are avenues through which malware can infiltrate a vehicle. With respect to PEVs, EVSEs do present an additional channel through which this could occur. Additionally, malware installed in PEVs has the potential to affect the electricity grid and/or charging infrastructure[2] which would not be possible with traditional ICE vehicles.

Safety issues for PEVs are related to lithium ion batteries which once ignited can be difficult to extinguish and risk of electrocution in the case of accidents. First responders must receive special training in dealing with these issues. Environmental issues surround lithium-ion battery end-of-life treatment. Solutions include recovery and second-life use of batteries in providing grid services.

The prioritized list of recommendations for AER and other Oman government entities can be found in Section 9.

[2] https://www.iea.org/media/topics/transport/VehicletoGridCybersecurityBrief.pdf

3. PEV Value Streams

PEVs can provide a range of economic and environmental benefits. Though PEVs currently carry a higher upfront cost than conventional internal combustion engine (ICE) vehicles, the high-level assessment in section 3A below suggests that Oman will see favourable economics for PEV drivers due to the low retail price of electricity relative to gasoline and lower maintenance costs of PEVs relative to ICE vehicles. This applies regardless of whether customers pay for electricity at a subsidized residential rate or on a cost-reflective rate (CRT). PEVs can also provide benefits to all electricity ratepayers, *if* PEV charging does not add considerably to peak electricity demand and electricity tariffs reflect the benefits of increased throughput (usage) from PEV consumption through lower rates for fixed cost collections.

The environmental benefits provided by PEVs are three-fold. First, PEVs reduce carbon dioxide emissions relative to ICE vehicles. Second, PEVS improve local air quality by reducing carbon monoxide, nitrogen oxide, sulfur oxide and particulate emissions. Finally, PEVs are significantly quieter than ICE vehicles and can therefore improve noise pollution in cities. The following sections describe these benefits in more detail.

A. <u>Driver economics</u>

As local pricing for PEV and charging equipment is not yet available, detailed analysis of PEV driver economics in Oman could not be calculated. However, a high-level analysis based on fuel and electricity prices in Oman and using technology costs from the United States is described below.

The analysis compares a Chevrolet Bolt (a small, full battery-electric vehicle) with a conventional Toyota Camry featuring an ICE. These two vehicles are of a comparable size. If we assume:

- Both vehicles have a 10-year vehicle lifetime
- The Bolt:
  - Faces an upfront cost differential over the Camry that matches the current cost differential in the U.S.: 3,800 OMR [3]
  - Has an efficiency rating of 5 km per kWh,[4]
  - Charges only at home, using Level 2 charging equipment with an installed cost that is the same as in the U.S.: 874 OMR.[5]
  - Pays the distribution company 443 OMR for initial connection (conservative estimate)[6]

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[3] https://www.iea.org/media/workshops/2018/aces/NikolasSOULOPOULOSBNEF.pdf

[4] https://insideevs.com/instrumented-test-of-chevrolet-bolt-190-miles-of-range-at-steady-75-mph/ (assume 305 km per 60kWh)

[5] Hawaiian Electric Electrification of Transportation Strategic Roadmap, 2018, https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/electric_vehicles/201803_eot_roadmap.pdf

[6] Data received from Majan distribution company (conservative estimate)

- Costs 30 bz/kWh[7] to charge
- Provides the same maintenance savings as would be expected in the United States: 392 OMR over the vehicle's 10-year life[8]

- The Camry:
  - Uses gasoline that costs 230 bz per litre[9]
  - Can drive 12 km per litre[10]

Under these assumptions, a driver in Oman would need to drive 100 km per day to break even on the cost of purchasing and charging a Bolt, versus the cost of purchasing and fueling a Camry. High-level analysis of the limited available public data on Oman suggests that the average driver in Oman drives 101 km per day.[11] This high-level calculation suggests that the Bolt, and PEVs more broadly, could be cost-effective to drivers even in the short term. Again, this analysis is very high-level and PEV costs and benefits may end up varying significantly from the United States input that we used. Further, as described in Section 6, cost is not the only barrier to PEV adoption, and drivers in Oman will likely face issues in the near term with PEV model availability, range and charging infrastructure availability. Still, our analysis was performed with the highest residential rate tier, and today's cost differentials between vehicles. Market analyst forecasts suggest that this upfront price differential will decrease significantly over the coming years. For example, Bloomberg New Energy Finance projects that PEVs will reach upfront price parity with ICE vehicles by 2025.[12] This suggests that as markets further develop and PEVs overcome the threshold barriers they face in Oman over the next several years, they may provide economic benefits to Oman's drivers and see significant uptake.

B. Ratepayer benefits

In addition to providing benefits to PEV drivers, PEVs can create benefits for *all* electricity ratepayers. Analysis performed by E3 and others suggests that utilities' per-kWh *marginal* cost to serve PEV drivers is

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[7] 30 bz is the highest tier for Oman's residential electricity. This price is believed to be close to a cost-reflective rate taking into account reasonable usage at peak times and may therefore be higher than necessary if PEV charging were primarily carried out at off-peak times.

[8] Union of Concerned Scientists, 2017, https://www.ucsusa.org/sites/default/les/attach/2017/11/cv-report-ev-savings.pdf . Maintenance saving of $1,546 USD over a 15-year vehicles life, translated to $1,031 US over a 10-year vehicle life

[9] https://www.globalpetrolprices.com/Oman/gasoline_prices/

[10] https://www.toyota.com/camry/features/mpg/2550/2514/2532/2540 (assume highest km/L)

[11] This is a high-level calculation due to data availability. Average household annual expenditure on transport was was 78.19 OMR in 2010 per Oman National Centre for Statistics and Information database and may include costs other than fuel. Motor gasoline cost was 0.12 OMR per liter in 2010, or 650 liters per household per month. Assuming an Oman household size of 7 (Oman National Centre for Statistics and Information database) and 1 in 4 (215/1000) have cars, 1.75 cars per household (World Bank), 8.5 kilometers per litre, then Oman residents traveled an average of 101 kilometers per day in 2010. Note that while expenditures on transport are stated to exclude air travel, a breakdown of expenses included in NCSI transport costs is not available. If they are in fact included then the daily mileage estimate would reduce.

[12] Bloomberg New Energy Finance, June 2017. "Electric Cars to Reach Price Parity by 2025," https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/

lower than their *average* cost of service, regardless of the time period in which charging occurs, as the average cost of service includes a share of system fixed costs.[13] Thus, if the rates paid by PEV drivers are reflective of utilities' average cost of service for a given class, then the addition of PEV load creates net benefits to utilities and their ratepayers. Put another way, spreading fixed costs for generation, transmission and distribution assets over additional kWh sales from PEVs can lead to a lower overall cost per kWh, provided PEVs do not add materially to peak demand.

There are two aspects of current retail electricity rate structures in Oman that create difficulties with respect to PEV penetration. If rates for electricity are subsidized and if PEVs are not charged primarily during off-peak periods, then the additional kWh used to recharge PEVs will add to the total subsidy paid out to customers. If PEVs are served on Oman's existing subsidized electric tariff, this could represent a significant economic benefit borne by the Sultanate to PEV drivers (and one that is notably no longer paid for gasoline use in vehicles). Secondly, under Oman's multi-year rate determination, rates *increase* with increased throughput, rather than decrease as fixed costs are spread over additional kWh sales. This situation mutes a key benefit of PEVs in providing benefits for *all* electricity ratepayers through lowering the average cost of service delivered through rates.

As discussed in Section 7, utility costs incurred to serve PEVs can be reduced, and benefits to all ratepayers thereby increased, by promoting 'Smart' charging that aligns utility costs with PEV driver behavior. This can be achieved through rate design, utility communication to shape PEV charging profiles, and other driver-targeted programs.

C. Climate benefits

PEVs can provide significant greenhouse gas reductions. The magnitude of these reductions is impacted by the fuel efficiency of both PEVs and conventional vehicles, and most significantly by the resource mix

[13] See, for example,

Ryan, Nancy and Lucy McKenzie, 2016, "Utilities' Role in Transport Electrification: Capturing Benefits for All Ratepayers," *Public Utilities Fortnightly,* https://www.fortnightly.com/fortnightly/2016/04/utilities-role-transport-electrification-capturing-benefits-all-ratepayers

"Hawaiian Electric Electrification of Transportation Strategic Roadmap," 2018, https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/electric_vehicles/201803_eot_roadmap.pdf

"Economic Impacts of plug-in electric vehicles," 2018, https://www.snopud.com/site/content/documents/custpubs/PEV-impacts_618.pdf

M.J. Bradley & Associates, 2017, "Electric Vehicle Cost-Benefit Analysis," https://www.nrdc.org/sites/default/files/electric-vehicle-cost-benefit-analysis_2017-09-27.pdf

E3, 2017, "Cost-Benefit Analysis of Plug-in Electric Vehicle Adoption in the AEP Ohio Service Territory," https://www.ethree.com/wp-content/uploads/2017/10/E3-AEP-EV-Final-Report-4_28.pdf

Seattle Office of Sustainability and Environment, 2017, "2017 Drive Clean Seattle implementation strategy," https://www.seattle.gov/Documents/Departments/Environment/ClimateChange/Drive_Clean_Seattle_2017_Report.pdf

ICF and E3, 2014, "California Transportation Electrification Assessment," http://www.caletc.com/wp-content/uploads/2016/08/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf used to generate electricity. A thorough and often-cited 2015 study[14] from the Union of Concerned Scientists found that if electricity is generated from natural gas, a fully battery-electric vehicle purchased in 2014 provides a 51 percent reduction in carbon dioxide emissions versus a new 2014 gasoline vehicle.[15] This represents a useful starting point for considering the potential climate benefits from PEVs in Oman's natural gas-dominated electric system.

Oman's fuel diversification policy requires that new renewable energy (RE) projects contribute 10% of generation output by 2025.[16] As this occurs, PEVs will achieve even greater carbon reductions relative to their ICE counterparts. Thus, a dual-sector strategy to electrify vehicles while decarbonizing electricity production could support progress toward the Sultanate's commitments under the United Nations' Paris Agreement.[17] This has been the approach of many jurisdictions around the world that are seeking to lower their climate impacts. Section 8 provides international best practices for policies and regulations to support this kind of strategy.

D. Local air quality and noise pollution benefits

Electric vehicles also produce fewer tailpipe pollutants than comparable conventional vehicles.[18] This results in improved air quality in areas where vehicles are driving. A 2015 study jointly produced by the Electric Power Research Institute and the Natural Resources Defense Council investigated the effects of electrifying transportation and found reductions in emissions across a variety of pollutant types that impact human health (NOx, SOx, particulates, and volatile organic compounds).[19] The EPRI study found the highest levels of pollution reduction occurred in major urban areas.

A final benefit of electric vehicles is that they produce significantly less noise than ICE vehicles. PEVs are so quiet that the United States National Highway Traffic Safety Administration recently implemented a requirement that all new hybrid and plug-in electric light-duty vehicles be manufactured to make slight audible noise when traveling under 30 kilometers per hour, to ensure pedestrians can hear them approaching.[20]

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[14] Union of Concerned Scientists, November 2015, "Cleaner Cars from Cradle to Grave," https://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf

[15] This analysis considers electricity available at the wall outlet and includes emissions from power plant feedstocks (e.g. mining) and power plant combustion. Power plant construction emissions are also included. Gasoline vehicle emissions equivalents account for oil extraction and refining of crude oil, but not refinery construction

[16] http://www.omanpwp.com/PDF/7%20Year%20Statement%202018-2024%20English.pdf

[17] https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

[18] US DOE Office of Energy Efficiency and Renewable Energy, "Reducing Pollution with Electric Vehicles," https://energy.gov/eere/electricvehicles/reducing-pollution-electric-vehicles

[19] EPRI, September 2015, "Environmental Assessment of a Full Transportation Portfolio, Volume 3: Air Quality Impacts," https://www.epri.com/#/pages/product/3002006880/

[20] NHTSA, November 2016, "NHTSA Sets 'Quiet Car' Safety Standard to Protect Pedestrians," https://www.nhtsa.gov/press-releases/nhtsa-sets-quiet-car-safety-standard-protect-pedestrians

4. PEV Technology and Market Trends

A. Plug-in electric vehicles

Light-duty PEV technology is in the early commercial stage and is maturing steadily. The value proposition of PEVs for automakers and drivers is improving, as falling battery prices are lowering vehicle costs and the increasing energy density of battery packs is extending electric driving range. Another indication of maturation is the proliferation of new LDV models expected to be introduced in the next few years. As illustrated in Figure 1, automakers plan to begin selling more than 90 PEV models by 2022 in the United States alone. Some vehicles already on the market exceed 320 kilometers (200 miles) in electric range, and this is expected to improve over time. Notably, the market is now seeing the first plug-in electric sport utility vehicles (SUVs), a popular vehicle segment in Oman, and this segment is expected to increase significantly Plug-in SUVs already on the market include, for example, the Kia Niro, Mitsubishi Outlander, Volvo XC90 T8 and XC40 T5, BMW X5 xDrive40e, Mercedes-Benz GLC 350e and GLE 550e, Porsche Cayenne E-Hybrid, and Tesla Model X. With the exception of the Tesla, these vehicles are all plug-in hybrid vehicles with relatively low electric ranges, but this is expected to improve in the near term.

A number of automakers have also made public pledges to further enhance their PEV line-up.[21]

An important motivator of this uptick in PEV model availability is state and national zero-emission vehicle (ZEV) regulations, which effectively require automakers to meet sales targets for PEVs. These sales-focused ZEV regulations mean that automakers must increasingly produce PEVs that meet consumers' transportation needs at an acceptable price point in order to sell sufficient PEVs and avoid paying fines. Section 8 provides additional discussion of these policies. While Oman does not currently have similar mandates, their impact will undoubtedly influence driver economics in Oman.

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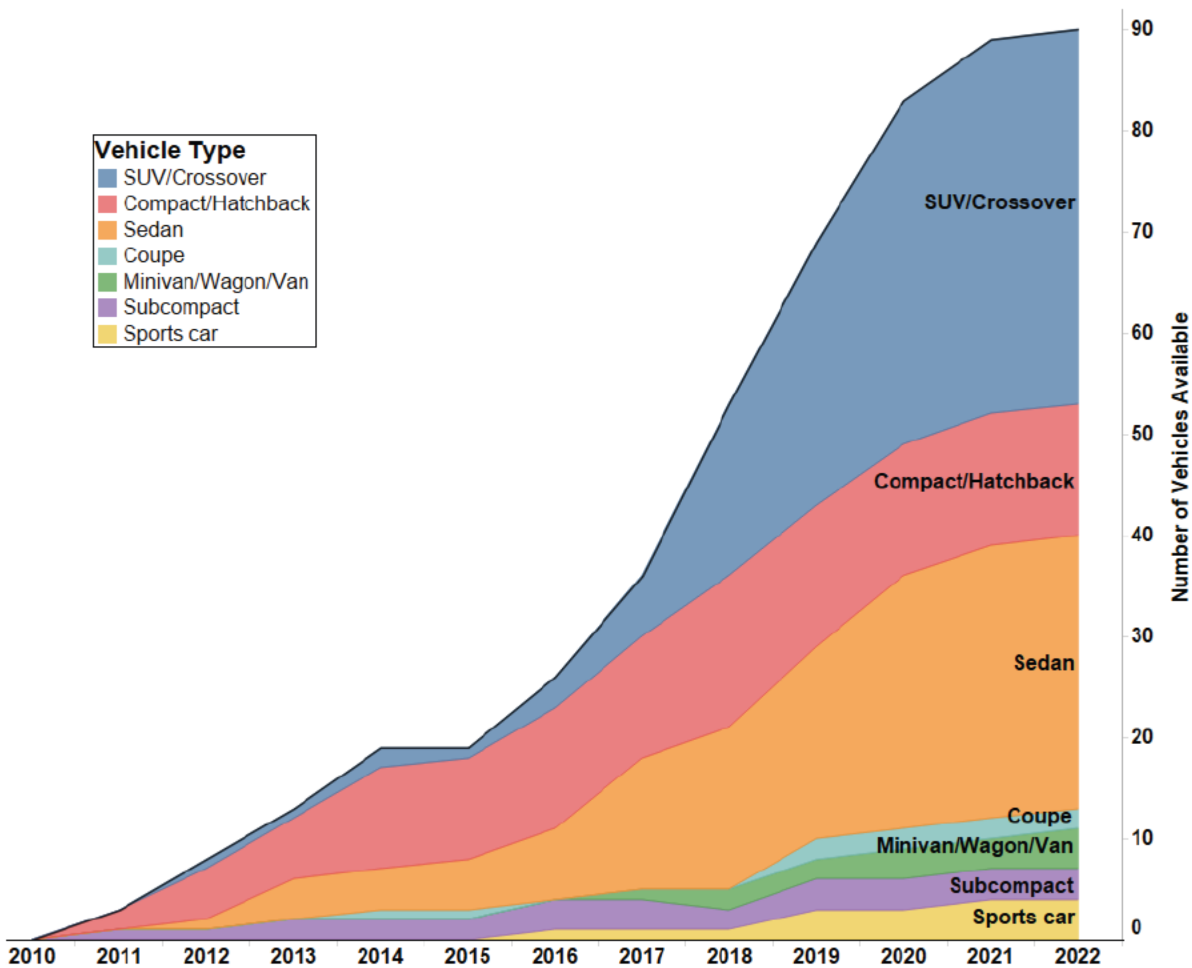
[21] See, for example:
https://mashable.com/2017/10/03/electric-car-development-plans-ford-gm/#r2W7Pv0N5iqb
https://www.motortrend.com/news/every-volvo-will-electric-motor-2019/
https://electrek.co/2017/09/11/vw-massive-billion-investment-in-electric-cars-and-batteries/
https://mashable.com/2017/10/02/gm-electric-vehicle-goals/#HRb8MpSa.qqK
https://www.cnbc.com/2018/08/13/nio-chinese-electric-car-ipo-filing.html
https://www.greencarreports.com/news/1112706_nissan-mitsubishi-renault-to-launch-12-new-electric-cars-by-2022
https://www.reuters.com/article/us-jaguarlandrover-tech/all-new-jaguar-land-rover-cars-to-have-electric-option-from-2020-idUSKCN1BI0OL

Figure 1. PEV models available or forecasted to be available in the United States, 2010 - 2022[22]



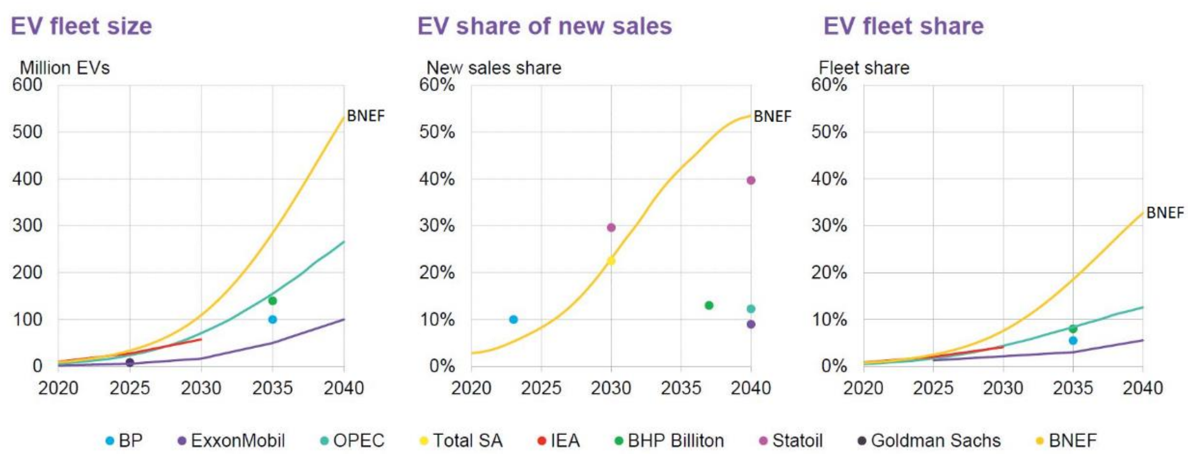
Recent decreases in cost, increases in the number of PEV models available, and significant policy interventions in some countries and states have led to growing PEV demand, though in most markets sales remain fairly low. Differences in market penetration are largely explained by differences in the level of policy and regulatory support provided to PEVs, consumers' income levels, by driving range needs and electric vehicle range performance (including due to extreme heat and extreme cold), and by achievement of inflection points in consumer awareness, public charging infrastructure, and automaker commitments. Section 8 provides examples of public policies that have been used to spur PEV adoption.

Industry players and market analysts are forecasting further reductions in PEV costs and significant increases in PEV adoption. Bloomberg New Energy Finance now projects that PEVs will reach price parity

[22] Electric Power Research Institute, February 2018, "A U.S. consumer's guide to electric vehicles," http://mydocs.epri.com/docs/public/3002012521_Print.pdf

with ICE vehicles by 2025,[23] with others predicting both earlier and later dates. PEV adoption forecasts continue to be revised upward, with forecasts of between ten and fifty percent of new vehicle sales expected to be PEVs by 2040 (see Figure 2).[24]

Figure 2. Bloomberg New Energy Finance summary of worldwide PEV forecasts[25]



B. <u>Charging technologies</u>

PEV charging technologies are also improving. At present, PEVs charge with 3 "levels" of EVSE. These are outlined in Table 1. Level 1 charging is available from a regular electric outlet and is generally only used at home or at a workplace. A connector (cable) for this level of charging is generally included with the PEV at the time of sale. This level of charging is low powered (2 kW to 4 kW), slow, and generally only effective for plug-in hybrid vehicles with smaller battery capacities or vehicles with low daily mileage. Level 2 charging uses a higher power: 7 kW to 22 kW. It is popular for home and work charging of full battery-electric vehicles, as well as in public spaces with longer dwell times such as malls, cinemas, parks, hotels and tourist attractions. Communication capabilities, connectors, and certain safety attributes are intertwined with these charging levels. Additional detail on these issues can be found in Section 7.

Direct current fast charging (DCFC) is the highest-powered PEV charging available and has so far been installed for public charging of personal vehicles as well as fast re-charging of electric rental car and taxi fleets. This narrow use case has been due to its high expense (~$100,000 USD per installation in the United States) and high power draw. It is possible that DCFC installations may be less expensive in Oman than in the United States due to lower labor costs. Until recently, most DCFCs have drawn power of up to 50 kW – 60 kW, with the exception of those installed by Tesla, which draw up to 145 kW (though Tesla's vehicles can only currently draw 120 kW). However, a number of companies have begun to install "ultra-fast" DCFCs that can support 350 kW charging. These are claimed to be able to provide "200 km [of electric

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[23] Bloomberg New Energy Finance, June 2017. "Electric Cars to Reach Price Parity by 2025," https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/

[24] Bloomberg New Energy Finance, July 2017. "All Forecasts Signal Accelerating Demand for Electric Cars" https://about.bnef.com/blog/forecasts-signal-accelerating-demand-electric-cars/

[25] Bloomberg New Energy Finance, July 2017. "All Forecasts Signal Accelerating Demand for Electric Cars" https://about.bnef.com/blog/forecasts-signal-accelerating-demand-electric-cars/

range] in 8 minutes."[26] Automakers have been particularly focused on ultra-fast DCFCs, as they provide the most convenient public charging experience for drivers and come close to providing a conventional service station wait time. Automaker buildouts of public charging networks in progress in the United States and Europe feature these higher power levels.[27] It is important to note that some PEVs are not capable of using any DCFC, no matter the power level. Only two PEVs – the 2019 Porsche Mission-E and the recently-launched Audi e-tron – have been announced as capable of using a full 350 kW power draw, though others are expected to follow.

Table 1. PEV charging specifications

Charging Type	Charging Mode	Power Level (Amps)	Power Level (kW)	Approximate km per Charge Hour[28]	Charging Location
Level 1	Mode 1 Mode 2	120 VAC, ≤ ~20 A 240 VAC ≤ 16 A	~2 kW to ~ 4 kW	8 km under ideal conditions; as low as 5 km with full-time air conditioner use	Home, Workplace, Fleet depot
Level 2	Mode 3	240 VAC 30 A* to 50 A (can be up to 100 A)	7 kW to 22 kW	15 to 100 km under ideal conditions; as low as 9 to 57 km with full-time air conditioner use	Home, Workplace, Public, Fleet depot
DCFC	Mode 4	480 VAC in North America 400 VAC in Europe and in UAE	60 kW to up to 350 kW	80% in 30 minutes	Public, Rental car depot

The recent improvements in fast charging speeds have added to stranded asset concerns: in an April 2018 survey of 495 American drivers that plan to purchase or lease a PEV in the next 24 months, 82 percent

[26] Fred Lambert, April 2018, "ABB unveils its 350 kW electric vehicle charging tech, claims 200 km of range in 8 minutes," https://electrek.co/2018/04/24/abb-electric-vehicle-charging-tech/
[27] Eric Adams, April 2018, "Ride the lightening: Electric Car Charging Technology Is About to Surge Past Tesla's Superchargers," http://www.thedrive.com/tech/20245/porsche-vws-electrify-america-to-surge-electric-car-charging-past-teslas-superchargers
[28] Values net of air conditioning use upper-bound 43% vehicle battery capacity reduction from Rugh, J. 2012, "Electric Drive Vehicle Climate Control Load Reduction," https://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2012/veh_sys_sim/vss090_rugh_2012_p.pdf

agreed at least somewhat that they would avoid using slower "normal" fast-charging stations whenever possible if they had the option of an ultrafast station.[29] Electric vehicle service providers (EVSPs) have therefore begun to focus on developing "upgradable" public charging that can easily adapt as power levels increase.

There are a wide range of business models for home, work, depot and public charging developing, each with their own pros and cons. These are described in Sections 7 and 8. One charging technology that is notably absent from the PEV charging landscape in most countries is battery swapping. Battery swapping is a charging business model that works by replacing reduced-charge batteries with fully charged batteries at purpose-built exchange locations. This concept received attention in the 2012 – 2013 timeframe, before public DCFC stations were as prevalent and as fast as they are today, as a way for PEVs to return to being fully charged in 7 to 8 minutes (versus more time-consuming home and workplace charging). The concept was trialed by Tesla and also through a partnership between Israeli company Better Place and automaker Renault. These trials did not reach scale: Better Place declared bankruptcy in 2013 with less than 1,400 vehicles deployed, and Tesla appears to have retired its single demonstration battery swap station in 2016.[30] A number of factors are thought to have contributed to this decline, including the need for specially-designed vehicles, falling DCFC costs and charge times, and the need to guarantee drivers and automakers that batteries being swapped into vehicles are high quality and will not void their warranties.

Battery swapping has seen a recent resurgence, primarily in China. Chinese PEV automaker Nio opened its first operational battery swap station in Shenzen, China, in May 2018, and has announced plans to install 1,100 more by 2020.[31] Another Chinese PEV maker, Beijing Electric Vehicle Co, plans to set up 100 battery swap stations in Beijing this year.[32] Tesla is also reported to have taken out a new patent in May 2017 for a battery swapping technology that could fit in a trailer,[33] and there has been renewed focus on battery swap technology in India for three-wheeled rickshaw vehicles.[34]

A final technological development in PEV charging is the availability of remote charging and interactive charging maps. Figure 3 provides screenshots showing publicly-available charging infrastructure from PlugShare.com for the United States and Oman.

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[29] Norman Hajjar, 2018, "Understanding EV Driver – Data Analytics," *conference presentation,* EPRI Electrification 2018 International Conference and Exhibition.

[30] Fred Lambert, May 2016, "Tesla is committed to its Supercharger network, but the battery swap program is stalling," https://electrek.co/2016/05/10/tesla-battery-swap-program-supercharger/.

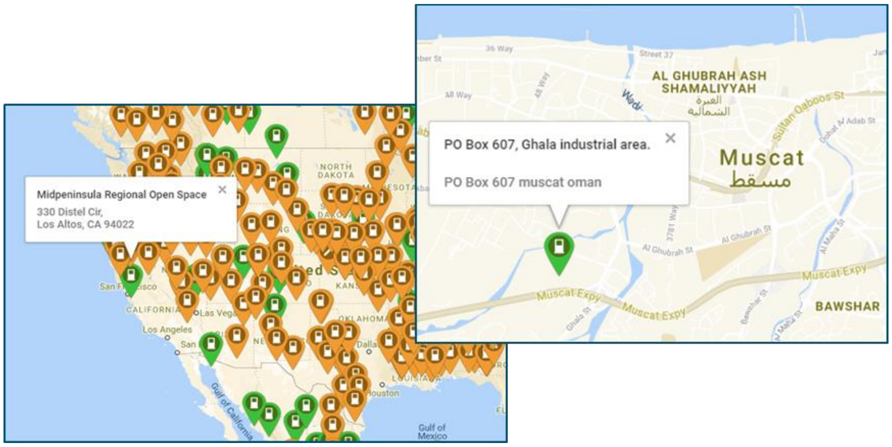
[31] Mark Kane, May 2018, "NIO opens first battery swap station in Shenzen," https://insideevs.com/nio-opened-first-battery-swap-station-in-shenzhen/

[32] Bloomberg News, July 2018, "China's Top EV Maker Starts Battery-Swap Service to Lure Users," https://www.bloomberg.com/news/articles/2018-07-05/china-s-top-ev-maker-starts-battery-swap-service-to-lure-users

[33] Fred Lambert, September 2017, "Tesla is working on a new mobile battery-swap technology to deploy out of a trailer," https://electrek.co/2017/09/15/tesla-new-battery-swap-technology-to-deploy-trailer/.

[34] "The future of e-rickshaws: swappable batteries," February 2018, https://money.cnn.com/video/technology/business/2018/02/09/gayam-motor-works-electric-rickshaws.cnnmoney/index.html

Figure 3. Screenshots from PlugShare.com showing publicly-available charging infrastructure. US (left) and Oman (right)



Most new vehicles and charging networks include the ability to monitor and control charging remotely via smartphone. This could assist in the implementation of future smart charging programs or rates, though doing so raises communications issues (these are investigated further in Section 7). In addition, charging apps and websites like PlugShare.com (international) and zap-map.com (United Kingdom (UK)) provide the locations of public charging infrastructure, and some sites provide real-time data on whether each site is occupied.

5. Shared Mobility and Automation

Light-duty transportation is experiencing two additional trends that are likely to be heavily intertwined with vehicle electrification:

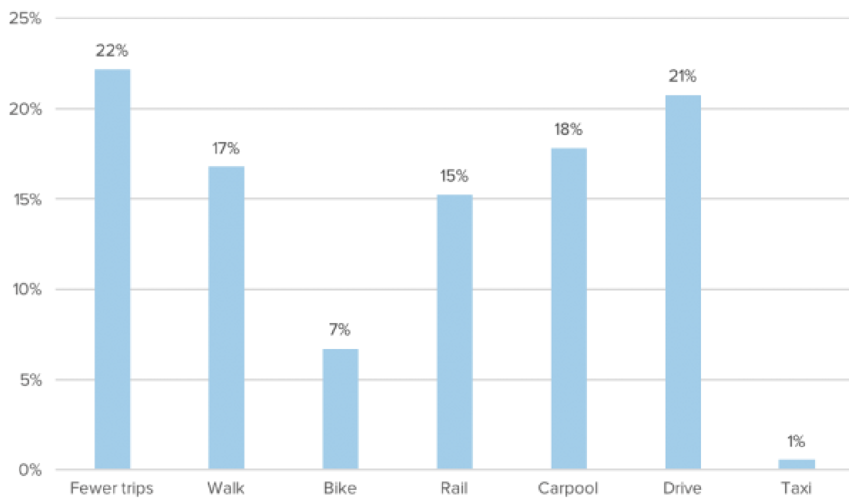
1. Shared mobility: the increasing share of passenger kilometers coming from shared, on-demand travel modes such as those provided by Careem, Uber, Lyft, Scoop, Waze and Chariot; and
2. Automation: the increasing vehicle market share of driver-assist and self-driving vehicle features.

Together with vehicle electrification, these trends have been dubbed the "three revolutions" in passenger transportation.[35] In combination, they are commonly viewed as the primary drivers of transformation in this space, with the potential to result in dramatic changes (both positive and negative) to the transportation and energy sectors.

Shared mobility is by no means a new concept: carpooling both with friends and using more structured systems has existed for decades. The element that is new is the ability to use computer algorithms to match and efficiently route two or more strangers with on-the-way pickup and drop-off locations into a single vehicle. Such services are offered by transportation network companies (TNCs), which provide a paid driver, like Uber's Uber Pool service and Lyft's Lyft Line service), and also by car sharing apps that match individuals needing to get somewhere with others that were already planning to drive their own car to a similar destination (such as Waze Carpool and Scoop). A third model is micro-transit: for-profit van or bus services that drive pre-defined routes based on crowdsourced location preferences gathered from users online. Chariot, purchased in 2017 by Ford, is one example of this service. Shared mobility could result in less total vehicles needed, decreasing road congestion and parking, and increasing availability of curbside space for other uses. It could also reduce air pollutant emissions by reducing the total number of vehicle kilometers traveled. However, both these benefits are dependent on the base case, i.e., what transportation mode passengers would have used but for the shared mobility ride. Though there has not yet been a study on this question specific to shared ride services (i.e. Uber Pool , Lyft Line, etc.), research on TNC use (i.e. Lyft and Uber rides more generally) suggests that although some TNC rides are substitutes for personal driving, some are used in place of public transportation, walking, or not taking the trip at all. For example, Figure 4 shows the results of a study from researchers at the University of California, Davis that sought to understand how TNC users in major cities across America were using three services. Their work suggests that the net effect of TNC availability has been to reduce the use of public transit in favour of more cars. Nonetheless, assuming the emergence of TNCs has increased the use of cars, shared TNC rides are likely to improve congestion relative to this new baseline.

[35] Credit for this terminology goes to the University of California, Davis' Institute of Transportation Studies, which is pioneering research in this space.

Figure 4. How ride-hailing users would travel if Uber or Lyft were unavailable[36]



Automation of light-duty vehicles has also been underway for decades, with on-board computers increasingly assisting drivers (for example with cruise control and lane assist) and gradually taking over some functions entirely (such as lane changing and parking). Visions of self-driving cars ferrying people to and from work and school, running errands and parking themselves currently dominate media coverage of autonomous driving. This future is probably further away than some bolder projections suggest, but autonomous driving technologies are advancing. Vehicle electrification will likely hasten deployment of autonomous driving technologies because PEVs are well suited to automation: their relatively simple electric drive-train is more easily controlled by computers than are the many complex, integrated, mechanical components in conventional vehicles.

To map the pathway to full automation, the Society of Automotive Engineers (SAE) created the classification system illustrated in Figure 5. Automakers and fleet owners are currently testing Level 4 (High Automation). At this level, vehicles can operate without human oversight under select conditions. These include highway driving and driving on pre-defined, predictable routes such as school campuses, military bases and airports. Public policy will play a key role in enabling testing of autonomous vehicles on public roads. For example, on February 26, 2018, California's Department of Motor Vehicles published new rules allowing testing of autonomous vehicles without backup drivers on public roads.[37] Soon thereafter, Arizona's governor took action by issuing an executive order (2018-04) on March 1, 2018 to allow autonomous vehicles without drivers.[38] A number of other U.S. states have followed.[39]

Light-duty vehicle automation is seeing heavy investment from automakers, TNCs and technology companies. TNC fleets are an attractive use case for electrified automated vehicles due to the cost savings

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[36] "New research on how ride-hailing impact travel behavior By Regina R. Clewlow, Ph.D.," https://steps.ucdavis.edu/new-research-ride-hailing-impacts-travel-behavior/

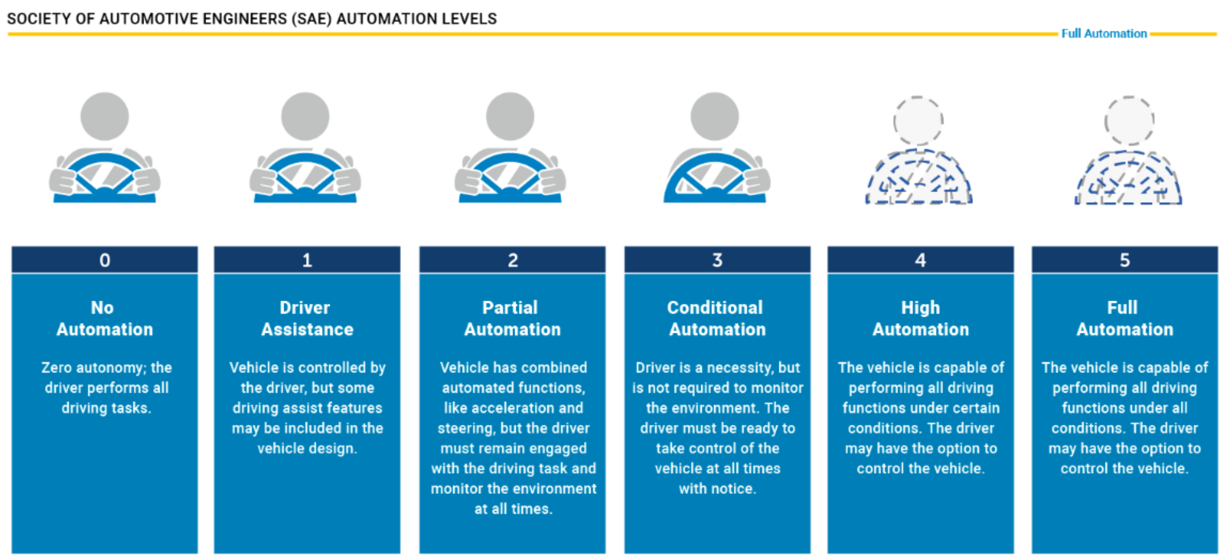
[37] https://www.dmv.ca.gov/portal/wcm/connect/a6ea01e0-072f-4f93-aa6c-e12b844443cc/DriverlessAV_Adopted_Regulatory_Text.pdf?MOD=AJPERES

[38] https://azgovernor.gov/governor/news/2018/03/governor-ducey-updates-autonomous-vehicle-executive-order

[39] Izadi-Najafabadi, "1Q2018 Intelligent Mobility Market Outlook," Bloomberg New Energy Finance, 01FEB2018.

that could be achieved without the need for a driver, and the potential for ownership of full fleets of such vehicles (rather than ownership by individuals) to maximize the use of dedicated DCFC infrastructure and thereby bolster the business case. Waymo and Uber have been testing ride-hailing services using automated vehicles in Arizona, Pittsburgh, and California. In 2016, Ford announced plans to begin deploying a fully autonomous version of its Fusion hybrid in a ride-sharing service by 2021 and last year formed a partnership with Lyft to develop a software interface between Ford's self-driving cars and Lyft's app.[40] The ultimate goal of these trials is to achieve Level 5 automation, at which point the driverless vehicle can operate on any road under any condition without human oversight or input. Only at this stage is a vehicle truly driverless, making it possible to eliminate the time and expense of driving as well as costly vehicle components such as the steering wheel, accelerator and brake pedals.

Figure 5. SAE vehicle automation levels



Fully automated vehicles (Level 5) could provide a range of potential benefits. Those who are not able to drive a vehicle could have access to greater mobility. People would be able to work, converse or watch television while traveling rather than driving. If vehicles are electric, automation can enable them to more efficiently share charging, enabling them to make more intensive utilization of charging infrastructure and lowering the cost of mobility.

However, these vehicles could also create significant costs if automation is not combined with pooling and vehicle electrification. Because automation lowers the cost of driving and removes the need for a licensed (adult) driver in each vehicle, full automation will tend to increase total vehicle kilometers traveled, increasing congestion. Removing the need for a driver reduces the cost of each trip, lessening the incentive to combine drop-offs, errands or deliveries. As an example, with the need for a driver removed, family members may choose to take separate vehicle trips to drop each family member at work

[40] Hawkins, Andrew, 2017, Ford and Lyft will work together to deploy autonomous cars," https://www.theverge.com/2017/9/27/16373574/ford-lyft-self-driving-car-partnership-gm

and school, with the vehicle returning home each time, rather than combining these trips into a single route driven by the whole family. Kilometers traveled could also increase from lower-cost, driverless delivery services for individual meals and everyday items. For full automation to lessen congestion will require careful policy planning to incentivize ride pooling. Examples of such policies include congestion pricing of roadways and high-occupancy vehicle (HOV) lanes.

The increased kilometers traveled by fully automated vehicles means that without vehicle electrification they would cause increased emissions of greenhouse gases and other pollutants, decreasing local air quality and contributing to climate change. Even *with* electrification, automation could increase emissions. Recall from Section 3 that conversion of an internal combustion engine vehicle to a PEV using electricity produced from natural gas reduces carbon dioxide (CO_2) emissions by approximately half. To achieve the same CO_2 emissions, therefore, automation would need to cause less than a two-fold increase in vehicle kilometers traveled. Decarbonizing the electricity sector by using carbon-free resources will reduce emissions from PEVs (automated or not).

These interactions suggest that the most significant benefits will be realized when the three revolutions – electrification, automation and pooling – are thoughtfully combined. Enabling this combination will require regulation and policy implementation across a range of government agencies. To enable a positive automated vehicle future, regulatory frameworks and planning efforts must therefore be forward thinking and coordinated. Efforts made so far to achieve this have revealed a number of challenges. First, the status of automated technologies and the business models envisaged by the companies developing these technologies are not well understood. This information has been kept largely out of the public domain. Second, data on customer preferences and driving patterns is largely held by private sector new mobility companies. These companies consider this data to be an important asset and have so far been willing to provide it to policymakers and researchers only on specific request and for purposes that support their goals. Finally, since much of the development of the three revolutions is new, there do not yet exist many best practices for policymakers to follow. Cities, counties and states are each trying to understand which actions to take and how to best prepare for these upcoming changes to their transportation systems, but are challenged by the constant and sometimes sudden evolution of technology and customer preferences.

The outlook for shared and autonomous mobility in Oman is unclear. Regulators will have control over which vehicles and services are allowed to enter its markets. Though there may be consumer demand for automated vehicles in Oman in the future, they are not yet being tested in the Sultanate. Shared mobility may or may not enter the market. The Mwasalat, Otaxi and Marhaba apps that allow users to call a taxi could presumably be fairly easily transformed to allow for pooling, and the significant number of trips along key roadways in Muscat could be well suited to this service. However, Oman's less urban areas are not well suited to pooling, as there is not likely to be sufficient demand for trips to and from the same locations. Riders in Oman may also not be comfortable sharing rides with strangers, and pooling applications would likely need to split rides by gender. The SCP is currently investigating the potential for automated vehicles in the Sultanate's long-term plans. In the short term, SCP, Municipalities, the Ministry of Transportation (MoTC), AER and other government bodies impacted by changes in transportation should focus on learning from cities and regulators elsewhere as they begin to develop regulatory approaches for autonomous vehicles and shared mobility services.

6. Barriers to PEV Adoption

PEVs face a number of barriers to adoption, and these have been broadly the same the world over[41]:

- Lack of suitable PEV models, which is a likely to be a particularly significant issue in Oman due to the country's preferences for larger vehicles and the small size of the market for new car sales;
- Insufficient charging infrastructure and range anxiety, which is likely to be worsened by the extreme heat conditions in Oman;
- Limited awareness and enthusiasm;
- Upfront cost premium of PEVs compared with ICE vehicles; and
- Lack of dealer incentives to sell PEVs.

Each of these is explored below. Section 8 describes regulatory and policy changes that could be implemented to help overcome these PEV barriers and promote PEV adoption.

A. <u>Lack of suitable PEV models</u>

This barrier covers three elements that combine to create a key, threshold barrier in Oman: the lack of PEV models for sale that can fulfill the needs of drivers. The three elements are as follows:

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[41] A sample of resources on this topic include those below:

Coffman, Makena, Paul Bernstein, and Sherilyn Wee. 2017. "Electric Vehicles Revisited: A Review of Factors That Affect Adoption." Transport Reviews 37 (1). Taylor & Francis: 79–93. https://doi.org/10.1080/01441647.2016.1217282.

Haddadian, Ghazale, Mohammad Khodayar, and Mohammad Shahidehpour. 2015. "Accelerating the Global Adoption of Electric Vehicles: Barriers and Drivers." The Electricity Journal 28 (10). Elsevier: 53–68. https://doi.org/10.1016/J.TEJ.2015.11.011

Hall, Dale, Hongyang Cui, and Nic Lutsey. 2017. "Electric Vehicle Capitals of the World: What Markets Are Leading the Transition to Electric?" https://www.theicct.org/sites/default/les/publications/World-EV-capitals_ICCT-Briefing_08112017_vF.pdf.

Krupa, Joseph S., Donna M. Rizzo, Margaret J. Eppstein, D. Brad Lanute, Diann E. Gaalema, Kiran Lakkaraju, and Christina E. Warrender. 2014. "Analysis of a Consumer Survey on Plug-in Hybrid Electric Vehicles." Transportation Research Part A: Policy and Practice 64 (June): 14–31. https://doi.org/10.1016/j.tra.2014.02.019.

National Research Council of the National Academies. 2015. Overcoming Barriers to Deployment of Plug-in Electric Vehicles (2015). the National Academies of Sciences, Engineering and Medicine. https://doi.org/10.17226/21725.

Plug'n Drive. 2017, "Driving EV Uptake in the Greater Toronto and Hamilton Area How Driver Perceptions Shape Electric Vehicle Ownership in the GTHA." http://www.plugndrive.ca/wp-content/uploads/2017/07/EV-Survey-Report.pdf.

Rubin, Ben, and Michelle Chester. 2013. "Zero-Emission Vehicles in California: Community Readiness Guidebook, Zero-Emission Vehicles on California Roadways by 2025."

Sierzchula, William, Sjoerd Bakker, Kees Maat, and Bert Van Wee. 2014. "The Influence of Financial Incentives and Other Socio-Economic Factors on Electric Vehicle Adoption." Energy Policy 68. Elsevier: 183–94. https://doi.org/10.1016/j.enpol.2014.01.043

1) Large PEV models are not yet widely manufactured. A large number of Oman residents that purchase new vehicles prefer sports utility vehicles (SUVs) and other large vehicles, due in part to the Sultanate's large average family sizes.[42] As shown in Section 4, the first PEV models for these larger vehicles segments are beginning to become available, but the electric range on some will not be very high and it will take time for a broad range of SUVs at a range of price points to become available.

2) Many automakers currently make their PEV models available only in select geographic markets. To date, these decisions have been largely driven by local demand for PEVs and government mandates requiring the sale of PEVs (see discussion of zero-emission vehicle mandates in Section 8). There currently do not appear to be any PEVs for sale in Oman, though registration of PEVs purchased in neighboring countries is possible. Al Amri, the owner of Omani automaker Nur Majan, says that their company plans to open a PEV factory in two to three years.[43] However, information on their planned vehicle offerings is not available. With a population of approximately 4.4 million and about 127,000 annual new car registrations,[44] Oman is a relatively small vehicle market on an international scale. This, combined with the lack of any mandate for PEV sales or other PEV policy drivers, suggests that Oman may not be a high priority market for manufacturers to sell PEVs. That is, even when more large PEV models are manufactured, they may take some time to arrive to the Oman market. One potential counter-prevailing force is that a number of PEV models are currently being sold in Dubai. Automakers may see it as advantageous to leverage this geographic proximity and may offer PEVs in Oman earlier than would otherwise be expected.

3) Extreme temperatures have been shown to impact PEV range. Temperature is an impact primarily due to the added drain on vehicle batteries from air conditioning. A study from the U.S. National Renewable Energy Lab suggests that the use of air conditioning can decrease range by 34 – 43%.[45] These impacts mean that PEVs sold in Oman will require batteries with higher capacities than in other markets to overcome drivers' anxiety about running out of charge mid-trip ('range anxiety'). This may not be such a significant issue in smaller PEVs, which are already capable of electric ranges far beyond the average daily kilometers driven by Oman residents - for example, the Chevrolet Bolt and Tesla's latest models boast 320 km on a single charge, or 182 - 211 km after accounting for air conditioning use,[46] versus the 101 km daily estimated average distance driven in Oman (see Section 3). Oman may therefore see some uptake of these vehicles when they become available, especially in the luxury PEV segment where purchasers are excited by new technologies and have a second (or third) vehicle available for longer trips. This market segment is currently being targeted by Tesla in Dubai. Nonetheless, the uncertainty that extreme heat introduces into the range equation and local preferences for larger cars will likely mean that Oman drivers will need larger batteries than elsewhere to be convinced to purchase PEVs.

These three factors make this barrier the most significant in Oman, and will likely push out any PEV adoption beyond early adopters for at least a few years. However, this barrier is expected to reduce as

[42] Meeting with Toyota dealership, June 27, 2018
[43] https://www.y-oman.com/2018/01/oman-ready-electric-cars/
[44] https://timesofoman.com/article/79270
[45] Rugh, J. 2012, "Electric Drive Vehicle Climate Control Load Reduction," https://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2012/veh_sys_sim/vss090_rugh_2012_p.pdf
[46] Applying the 34% – 43% air conditioning impacts cited above

PEV markets and models develop. As they do, Oman will likely begin to see the remaining four barriers, described next, dominate the PEV purchase decision.

A related concern for vehicle fleet operators is that many PEVs are not offered in the more basic models that fleets often purchase, making it harder for PEVs economics to better those of conventional models despite their advantages in maintenance and fuel costs.

B. Insufficient charging infrastructure

Insufficient availability of suitable and reliable charging infrastructure is a significant barrier to adoption across all applications of light-duty PEVs. This barrier refers to both:

1) the availability of public charging infrastructure, and
2) the challenge in enabling sufficient private charging, most significantly in multi-unit housing and at workplaces.

Public charging represents a sequencing conundrum. Due to anxiety about running out of charge mid-trip ('range anxiety'), drivers often require the existence of a robust public charging network before they are willing to purchase a PEV, even if they do not often need to use it. However, private sector electric vehicle service providers (EVSPs) have struggled to realize business models for public charging, particularly DCFC, except in locations of high EVSE utilization. Many jurisdictions have sought to overcome this issue through government or utility funding of early-stage public charging networks (see Section 8 for more detail).

Private charging has typically encountered similar sequencing issues, but with different underlying causes. Consumers are more likely to purchase a PEV if they have access to workplace charging, but employers looking to install it are faced with the difficulties of a new and often not straight-forward task, and split incentive issues whereby the employer leases a building and provides charging for an employee, benefiting neither from the capital improvement nor the charging service. Employers have therefore tended to only install charging either at the request of a high-profile employee with a PEV, to display environmental commitment, or to help attract highly-qualified employees in competitive hiring markets (for example, in Silicon Valley, California, where many office campuses in high-tech industries boast PEV charging). Public policy and education on workplace charging can help foster PEV penetration in these areas (see Section 8 for additional detail). PEV ownership in many jurisdictions has begun with drivers who own single-family homes and have a second vehicle. These drivers can largely avoid the charging barriers detailed here.

C. Limited awareness and enthusiasm

Awareness of PEVs in most countries remains low beyond early adopters motivated by environmental outcomes and/or a keen interest in cutting edge technologies. Surveys and focus groups have found a widespread lack of knowledge of the commercial availability of PEVs, purchase incentives, fuel and maintenance cost savings, charging options, and awareness of individuals' average daily driving distances.[47] Anecdotal evidence suggests that the same is true in Oman. This is especially unsurprising given that no automakers are currently selling PEVs in Oman, though this may change soon: the Oman Jaguar dealership is intending to obtain 15 iPace vehicles in the near term for sale in Oman.

D. Upfront cost premium versus ICE vehicles

As described in Section 4, PEVs currently carry an upfront cost premium versus conventional, ICE vehicles, though it is declining. Consumers have also been concerned about the lower resale value of PEVs, caused largely by consumer uncertainty around battery life and the quick pace of technology change. Battery lifetimes can also be diminished in extreme hot climates -- automakers and charging manufacturers are trialing technologies to lessen these impacts.[48] The lower resale value of PEVs has made it popular in many places to lease these vehicles, but this driving model can be expensive due to financing costs (which also account for lower re-sale values).

E. Lack of dealer incentives to sell PEVs

Surveys have reported that sales representatives at automobile dealerships are often uninformed about the capabilities and merits of PEVs, and/or try to interest customers in conventional models. Except in jurisdictions with zero-emission vehicle sales mandates, dealerships generally have no express incentive to sell PEVs. In fact, they face a disincentive, as PEVs require less maintenance over time and will therefore generate less business and profit for the service department and parts shop. Individual sales staff can also be unmotivated to sell PEVs, as the need for associated conversations with buyers about charging infrastructure and electric rates can be challenging for the salesperson and can complicate the sales process, risking the loss of a sale.

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[47] Jin,_Lingzhi_and_Peter Slowik, 2017,_"Literature review of electric_vehicle_consumer_awareness and_outreach activities," https://www.theicct.org/sites/default/_les/publications/Consumer-EV-Awareness_ICCT_Working-paper_23032017_v_F.pdf_

[48] See, for example, research efforts funded by the U.S. Department of Energy: https://www.energy.gov/eere/vehicles/parasitic-loss-reduction-research-and-development

7. International best practices in regulation and policy: Preparing for PEV Adoption

This section and the following section provide a review of international best practices in PEV regulation and policy. This section provides best practices that jurisdictions around the world have implemented to *prepare for* PEV adoption. These include:

- Coordinating across sectors impacted by PEVs
- Regulating EVSE deployment
- Technical aspects of connectors and communications
- Utility rate structures for PEVs
- Ensuring safety of EVSE
- Power quality
- Data safety and security
- Additional measures to facilitate driver experience
- PEV safety

Section 8 provides additional best practices targeted at actively *promoting* the adoption of PEVs.

A. <u>Coordinating across sectors impacted by PEVs</u>

PEVs impact, and are impacted by, policymaking, regulation, and market developments in a wide range of sectors. These include, but are not limited to, transportation, economic development and planning, city and urban planning, climate policy, and energy regulation. This broad range of touchpoints creates a need for coordination and strategic alignment among the many stakeholders working on different aspects of PEV manufacturing and policymaking. Such coordination will help ensure that the different pieces of the PEV ecosystem – vehicle technology, charging availability, electricity system upgrades, urban planning changes – are being addressed in concert to maximize efficacy and returns on investment.

This coordination should be ongoing to ensure continued alignment and adherence to best practices as PEV technologies and markets rapidly evolve. In leading PEV markets, this coordination has been both through formal processes with structured delineation of responsibilities, and through informal information sharing at conferences, workshops and professional groups. Figure 6 provides an example of a more formal coordination effort among government agencies involved in PEV policy and regulation, in Washington state in the United States.

Figure 6. Governmental roles in PEV policy, Washington State, United States

Agency	Traditional Role	Role in PEV Policy and Planning
WASHINGTON UTC UTILITIES AND TRANSPORTATION COMMISSION	Economic regulation of private utilities and transportation companies	• Determines role of electric utility investment in electric vehicle charging infrastructure • Frames and approves utility PEV programs
Washington State Department of Transportation	Construction and management of transportation infrastructure	• Develops Electric Vehicle Action Plan and overarching planning role • Coordinates and partially funds Washington State PEV charging corridor on interstate highways
Department of Commerce Innovation is in our nature.	Promotion of economic activity in Washington	• Developed electric vehicle integration guidance for local governments (zoning and land use)
DEPARTMENT OF ECOLOGY State of Washington	Environmental regulation including air quality	• Administers PEV charging infrastructure funds paid by Volkswagen as a U.S. Environmental Protection Agency penalty for cheating emissions standards

Stakeholder processes are another form of formal coordination on PEVs, and have been used by electric utilities, regulators, cities, and state and national governments to incorporate industry updates and customer insights into PEV-related policy. Opportunities for less formal coordination and information sharing are plentiful in leading PEV jurisdictions through PEV conferences and workshops. As an example, thousands of international PEV experts descend on the International Electric Vehicle Symposium, held every 1.5 years by a different host nation.[49]

Implications for Oman

In Oman, a number of entities will be involved in the ongoing evolution of PEVs. For example:

- Automakers and charging providers are continually assessing their offerings in Middle East and Oman markets;
- AER regulations and policies will affect the provision of electricity to PEV drivers;
- Royal Oman Police is responsible for vehicle inspection and licensing;
- Municipalities are responsible for issuing building permits and parking permits;
- Distribution company and Oman Power and Water Procurement Company (OPWP) regulations and planning efforts will need to reflect policy goals and changes by AER, ministries and the SCP;

[49] http://www.evs31.org/overview/

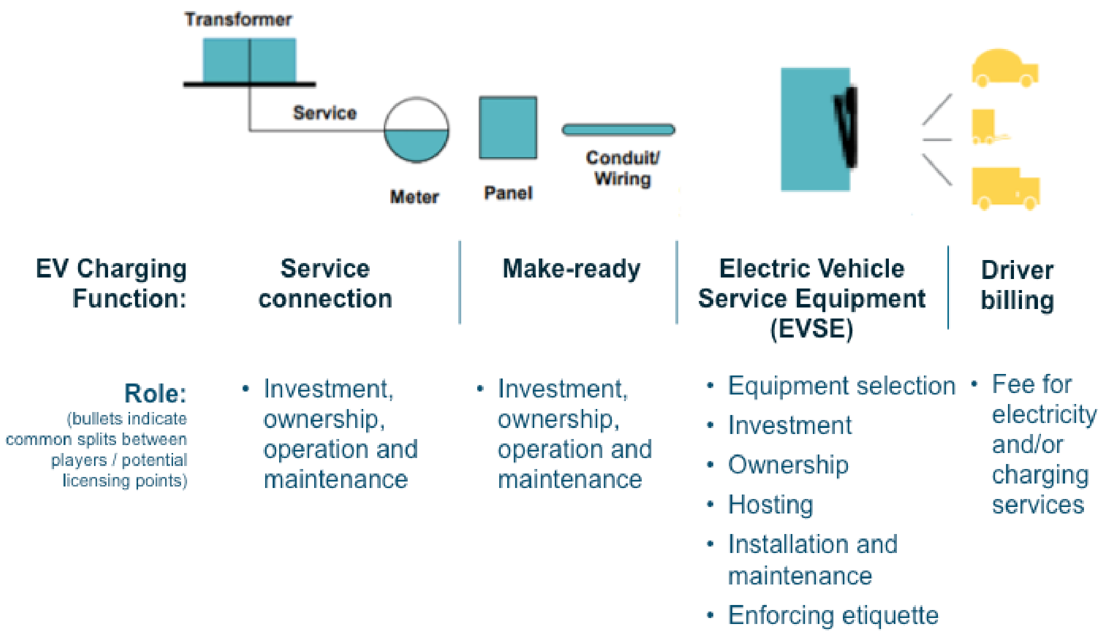
- PEVs will likely play a role in the Ministry of Environment and Climate Affairs' efforts to meet the Sultanate's commitments under the United Nations' Paris Agreement;
- PEV and EVSE standards are under Ministry of Commerce and Industry (MoCI) purview;
- The Ministry of Transportation's (MoTC) plans and implementation strategies will have implications for PEV planning; and
- The Ministry of Oil and Gas will impact PEV adoption through its pricing of petroleum and may also see impacts as more consumers move to PEVs.

AER should continue coordination on PEVs with distribution companies, ministries, OPWP and the SCP. Specific points of intersection are addressed throughout the recommendations below, but high-level, ongoing engagement between all impacted entities is recommended as new market developments occur in PEVs and charging, and further national strategies develop on economic development, climate, electric rates, electricity procurement, and gasoline pricing. AER engagement could also include international parties such as Abu Dhabi Water and Electricity Authority (ADWEA), the UAE regulatory and Supervision Bureau (RSB), the Dubai Electricity and Water Authority (DEWA), the Saudi Electricity Company (SEC) and Jordan's Energy and Minerals Regulatory Commission (EMRC).

B. Regulating EVSE deployment

As shown in Figure 7, PEV charging involves four key functions. The service connection involves the provision of the electricity system distribution network up to a PEV customer's meter. The make-ready may involve a panel upgrade, as well as additional conduit and wiring needed to extend to the EVSE (sometimes referred to as the 'charging station'). EVSE functions capture PEV charging activities. And finally, drivers may be billed for electricity, the charging service, and/or for time charging.

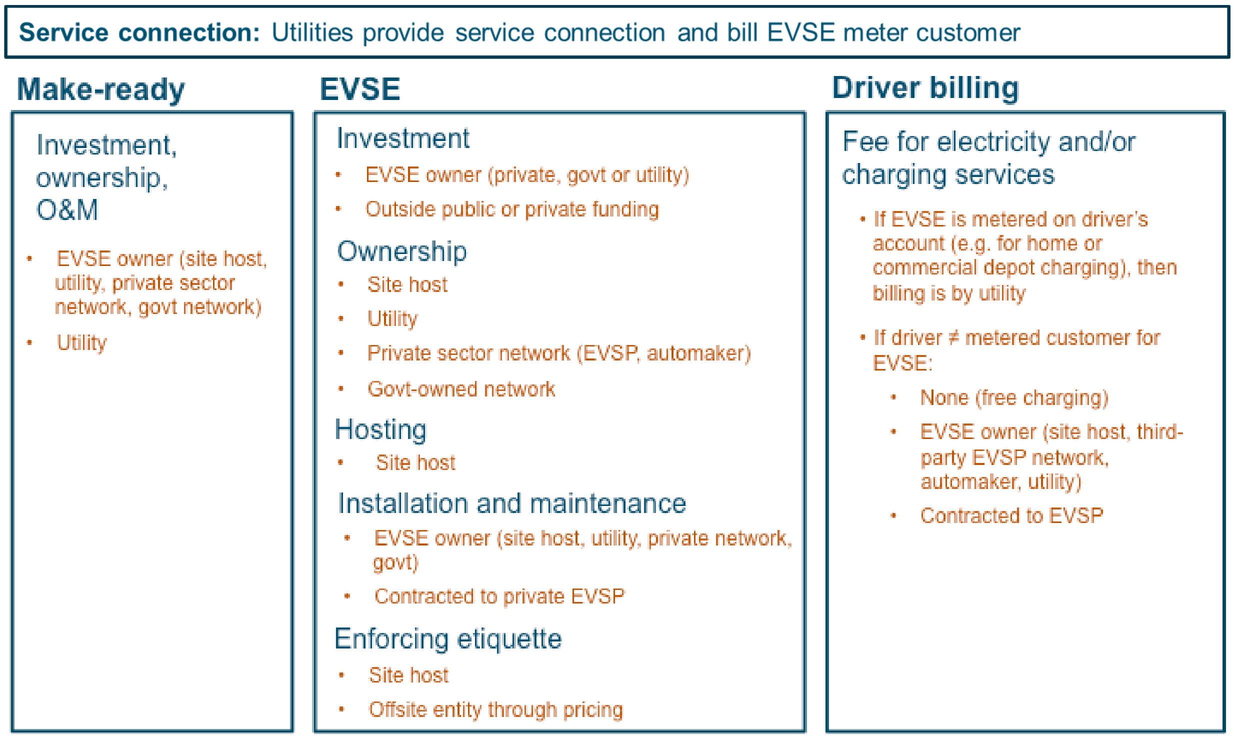
Figure 7. PEV charging functions and associated roles



As further shown in the figure, each of these functions may involve a number of roles (blue font). The location of the charging (single-family home, multi-unit home, workplace or public) as well as the charging level (Level 1, 2 or DCFC) will determine which of these roles is required. An installation at a single-family home, for example, may only require the distribution utility (to provide the service connection), a licensed electrician (if the EVSE is Level 2, to perform a panel upgrade, if needed, and install the equipment), and the home owner or renter (who would host, invest in and own the charging infrastructure). A public, workplace or multi-unit housing charging site may involve additional roles.

Figure 8 shows the range of players (red font) that have filled each PEV charging role, based on a review of our studied jurisdictions. The distribution utility typically provides the service connection, including any required metering. Beyond the service connection, players involved tend to differ by charging location and charging level.

Figure 8. Players who have filled each PEV charging role



Each of these roles and players could potentially be licensed or otherwise regulated, though thus far many have not. The following discussion describes regulatory and licensing issues that have arisen in each charging location: single-family homes, multi-unit housing, workplaces, commercial depots and in public.

For ***Level 1 charging in single-family homes***, all functions have typically been undertaken by the home owner or renter. Since Level 1 charging simply uses the plug that comes with a PEV and a regular socket (120V in the US and Canada, 240V in Europe and Oman), there has been no need for any regulation beyond ensuring that common electrical and building standards are met for the wall outlet, the vehicle (Section 7I) and the Level 1 charging equipment (Section 7E).

For ***Level 2 charging in single-family homes***, homeowners (or renters) have typically engaged a licensed electrician to upgrade the panel, when needed, and to install and maintain the EVSE. In many jurisdictions, a licensed electrician must install the EVSE, however in some jurisdictions a certified EVSE installer may do so. The Hashemite Kingdom of Jordan requires a specific license to install both public and private EVSE, with requirements that relate to the installation of this equipment (see Section 7E). The only additional regulation governing Level 2 EVSEs at single-family homes has occurred where government agencies or utilities have provided upfront incentives that pay for charging infrastructure. Such incentives have been provided with the aim of promoting PEV adoption, sometimes with an additional focus on incentivizing equipment that can enable vehicle-grid integration by the utilities or aggregators (see Section 7C). Such incentives bring government agencies or utilities into the EVSE investment function and are often provided to the driver with regulatory strings attached. For example, some utilities offering incentives require the installation of networked EVSE that will enable future demand response programs or dynamic rates, while others require the driver to provide their utility with charging and driving data. For both Level 1 and Level 2 charging in single-family homes, the customer's utility bills them directly for their PEV electricity usage.

Commercial light-duty PEV fleets, including government owned vehicles used by employees or privately owned vehicles such as rental cars, are often charged overnight or between shifts at a depot using Level 1, Level 2 or DCFC EVSE. From a regulatory perspective, depot charging of these fleets is similar to single-family home charging. In this case, all functions are typically undertaken by the depot owner or lessee. Note that these vehicles may also require access to charging along their driving routes. In this report, this on-route charging is considered 'public charging', and is covered below.

For ***Level 2 charging in multi-unit housing or workplaces***, there are two common ownership models:

1. Residents or employees select and own EVSE equipment for their own individual parking space.
2. EVSEs are installed as a shared resource owned by the building owner. Installation and maintenance costs are either paid by the building owner or lessee, or shared through home-owners' association fees, by employees, or through other communal accounting.

Since EVSE investment under these models is generally provided by a building owner, lessee, resident or employee, there is usually no need for regulation of the investment and ownership roles, except where utilities and government entities have provided EVSE rebates. For example, in Abu Dhabi, ownership of EVSE is not a regulated activity pursuant to Article 71 of Law No. (2). In Europe and the United States, non-utility ownership is not regulated. Investment and ownership of PEV charging in multi-unit housing and workplaces may face the barrier of split incentives: often the building owner, who needs to agree to the installation of wiring and EVSE infrastructure, is not the same as the tenant that uses the charging. In an effort to ensure that MUD residents can install charging, the US state of Colorado has legislated that landlords and homeowners' associations (HOAs) cannot prohibit tenants from installing PEV charging at their own expense on leased premises. Similarly, Oregon requires homeowners' associations to approve applications by homeowners to install PEV charging, subject to conditions, where homeowners are liable for all costs.[50] A third, far less common investment and ownership model, is that in which utilities have been allowed to own and recover costs for make-readies and EVSEs in multi-unit housing and workplaces. This utility ownership has been allowed by regulators in just a few jurisdictions, all in the United States. It aims to a) help overcome split incentive issues between owner and renters or between owner-tenants (whereby the party that uses the charging equipment may be different from the party that sees the costs and benefits of capital investments in the building), and b) reduce the high installation costs typical in these building types due to greater trenching and wiring distances. Regional Washington state utility Avista in the United States has been allowed to own and recover costs for EVSE in multi-unit housing and workplaces. In the state of Massachusetts, utility Eversource received approval to own and recover costs for make-readies in workplaces.

In California, the California Public Utilities Commission initially banned utility ownership of all EVSE except in very specific circumstances, but in 2014 began allowing it under a balancing test that weighs market

[50] CO. Rev. Stat. SS 38-12-601 and 38-33.3-106.8; OR. Rev. Stat. 94.550

transformation benefits against potential anti-competitive effects of utility ownership. As a result, two of the state's investor-owned utilities, San Diego Gas and Electric (SDG&E) and Pacific Gas and Electric (PG&E) are now allowed to own and recover costs for a capped quantity of make-readies and EVSEs in multi-unit housing. The state's third IOU, Southern California Edison (SCE), is allowed to own and recover costs for make-readies. US energy company NRG's non-regulated EV charging arm - EVgo - is also required to invest in make-readies in California as part of a regulatory settlement. One best practice introduced by California utilities and regulators as part of these programs is a requirement that site hosts pay a 'participation fee' before utilities provide make-readies of EVSE units. This requirement is intended to help ensure that site hosts remain engaged in ongoing maintenance of the station. This policy is based on negative experiences in the United States' "EV Project," a federal government investment that installed hundreds of EVSE sites at no cost to the host and saw a number of them fall into disrepair because hosts were not invested in their upkeep. Regulators have waived this fee for low-income and environmentally-disadvantaged communities.

For installation and maintenance in multi-unit housing and workplaces, building owners, renters or employees can contract directly with licensed electricians for installation and rely on standard or extended warranties from EVSE manufacturers. Alternatively, EVSPs can provide comprehensive solutions, coordinating with building owners, renters, electricians and EVSE manufacturers to provide installation and ongoing maintenance. For utility programs in multi-unit housing and workplaces, regulators have required that utilities contract with pre-qualified EVSPs to provide installation services. For example, San Diego Gas and Electric's minimum pre-qualification criteria for EVSPs that wish to install EVSE under its program are as follows:[51]

- Ability to send hourly rate day-ahead to customers
- Allow customer/driver to set charging needs
- Collect EV charging usage data and send to SDG&E for billing processing
- Minimum vendor capabilities, experience and qualifications
- Bid evaluation includes preliminary meter test by a third party

The building owner or lessee may provide electricity to PEV drivers free of charge, for example as a residential amenity or an employee benefit. Alternatively, they may either charge drivers a flat monthly fee for use of the charging service or engage EVSPs to measure and bill drivers for EVSE and/or electricity usage.

Finally, if EVSEs at multi-unit housing and workplaces are shared by multiple drivers, then it is advisable for hosts to encourage driver charging etiquette that reduces congestion and makes maximum use of infrastructure. Methods for achieving this are explored in Section 7H. These methods do not require the introduction of any additional regulation.

Public charging at Level 2 and DCFC is utilized by PEV drivers using vehicles for their personal use, as well as rental cars, taxis and other commercial fleet vehicles. Public charging has thus far involved many

[51] See SDG&E, November 14, 2013, "Electric Vehicle-Grid Integration Pilot Program ("Power Your Drive" Fourth Semi-Annual Reoprt of San Diego Gas & Electric Company, https://www.sdge.com/sites/default/files/regulatory/FINAL_Power_Your_Drive_Semi_Annual_Rpt.pdf

business models (i.e. many combinations of players filling the roles in Figure 8). Public funding business models can be segmented according to investment and ownership structure:

Model 1 Investment and ownership by site hosts

Model 2 Investment and ownership by automakers

Model 3 Investment and ownership by private-sector EVSP networks

Host sites choosing to own public charging (Model 1) are generally motivated by environmental goals or by the promise of luring PEV drivers to spend time and money at their retail or restaurant location. Hosts either contract with a licensed electrician to provide installation and maintenance of EVSE, or contract with a full-service EVSP to provide these services. Hosts may provide charging for free, or may bill parking, kWh, or charging services (often through an EVSP). Examples of EVSPs providing installation, maintenance and billing services are ChargePoint, Volta, Greenlots, Aerovironment, ABB and eMotorwerks. In addition to these services, ChargePoint provides drivers with a map of all their public charging locations, indication of whether they are occupied, and a single payment system. The high cost of permitting, purchasing and installing DCFC (~$100,000 in the United States) has meant that few hosts worldwide have been wiling to pay the upfront cost of this high-powered charging. Even Level 2 public charging, with an installed cost of roughly $15,000 - $25,000 in the United States, is too expensive for many hosts when compared with the uncertain future utilization and retail revenues it may bring. Therefore, until a jurisdiction reaches significant PEV penetration, the host ownership model (Model 1) is unlikely to provide a robust public charging network without funding from outside sources. In a number of jurisdictions, policymakers seeking to promote PEV adoption have provided subsidies to cover upfront costs for hosts willing to own public charging. In the US, EVSP Volta has employed a novel approach to overcome this barrier. The company installs public Level 2 EVSEs at retail locations for free and sells advertising projected on a screen on the EVSE to pay for the station and cover their profits.

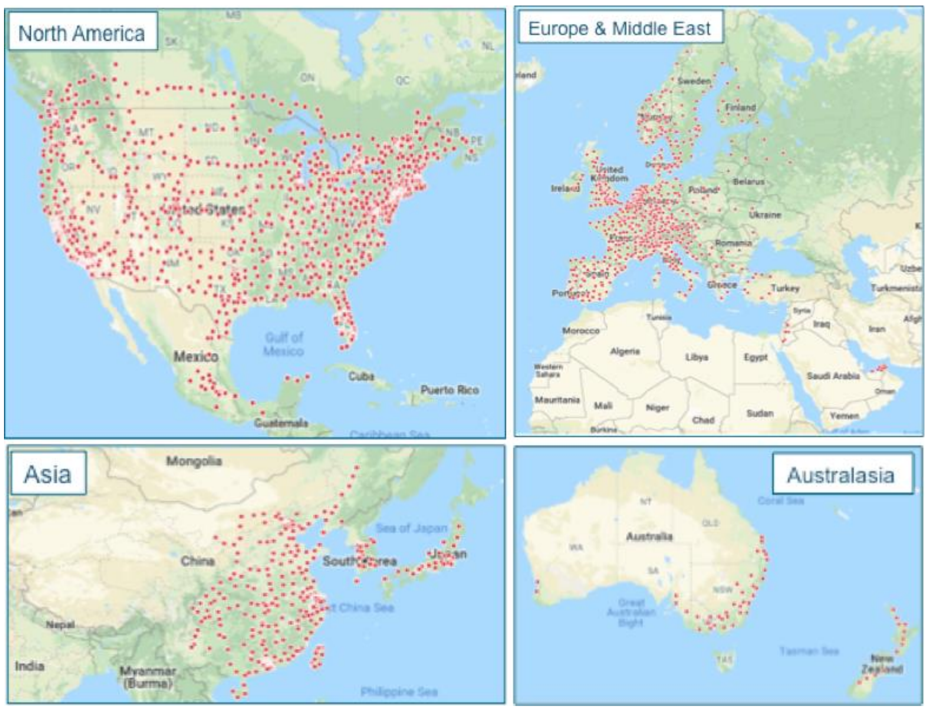
Automakers (Model 2) have recently shown significantly more interest in funding and owning public charging as they have developed more PEV models, DCFC power levels have increased, and ZEV mandate requirements have ramped up. Automakers are motivated to sell vehicles and increase customer convenience. They have therefore generally focused on DCFC sites, which offer drivers the shortest possible charging times, and at locations along major long-distance corridors that will reduce range anxiety and thereby facilitate the decision to purchase a PEV. They have also focused on locations where they foresee significant PEV sales, as driven by consumer demand and/or PEV policy.

Examples of automaker public charging include:

- Tesla's extensive network of 145 kW EVSE, which provides only Tesla connectors and therefore only serves Tesla vehicles (see Figure 18, and further detail on connectors in Section 7C),
- The Ionity network, which is a joint venture of BMW, Daimler, Ford and Volkswagen and aims to to install four hundred 350 kW DCFC stations in Europe with Combined Charging System (CCS) connectors by end of 2019. Only seven of these stations have been installed so far, but Ionity has announced a partnership with Shell to host 80 stations at its service stations.
- Electrify America, Volkswagen's planned network of 290 50 kW to 350 kW stations with CHAdeMO and CCS connectors in the United States. Only ten of these stations are operational

so far, but deployment is planned to scale rapidly, including at 100 Walmart stations. The installation of this network was mandated by the United States Environmental Protection Agency after Volkswagen was found to be providing misleading vehicle test results in its emissions testing.[52]

Figure 18. Tesla's DCFC network



Private sector EVSP networks owning charging (Model 3) are generally motivated by the profits that they can achieve from the sale of charging services. Examples of these EVSP networks include EVgo, AeroVironment, Blink, ChargeMaster (acquired by BP plc), PodPoint, FastNed, Allego, eCharge, Fortum Charge & Drive and Grønn Kontakt. These networks are active in Europe, the United States, Canada, China, and the Middle East (in Abu Dhabi and Jordan), with higher concentrations of companies and more significant investments in locations with high PEV adoption. Some of these networks (for example, Allego and EVgo) are unregulated business arms of utilities. Absent government, utility or other outside funding (explored in Section 8 – "Promoting PEVs"), private-sector EVSP networks generally only appear once there is sufficient PEV adoption to enable the utilization needed to provide profits. Due to the high cost of DCFC, these private sector EVSP networks have generally focused on Level 2 charging, though in high-adoption locations such as parts of California and Norway they have also invested in DCFC stations. Under this model, the EVSP generally pays licensing fees to the site host for the right to parking spaces. These fees may include some share of revenue. An exception to this arrangement is used by eCharge, an EVSP

[52] US Environmental Protection Agency, "Volkswagen Light Duty Diesel Vehicle Violations for Model Years 2009-2016," https://www.epa.gov/vw.

serving Europe that provides EVSE free to hotels and receives a fee per charge session. The EVSP installs and maintains the EVSE and also implements pricing and payment systems consistent with the remainder of its network. Driver etiquette policies are implemented and policed by the site host, or the EVSP may encourage drivers to move on once they have sufficiently charged by increasing the cost of charging after a set time interval (this practice is used, for example, by EVgo).

EVSPs may bill drivers on the basis of a) kWh used, b) time connected to charging equipment, or c) a combination of both. In multi-unit housing and at workplaces, the site host generally sets the basis and cost for access to EVSE and electricity used. These determinations are impacted by regulations on the ability of EVSPs to charge drivers for kWh used, and restrictions on the rates that may be charged for this use. In Europe, Jordan and Abu Dhabi, electricity rates charged by private sector EVSPs are generally not regulated. In China, EVSPs must pass electricity supply costs through to customers at cost. Canadian provinces evidence a wide range of approaches. In British Columbia, PEV charging was determined to be a public utility service if the EVSP charges for power; while the rate charged by one private sector EVSP that is charging for power, EcoDairy, does not appear to be regulated, EcoDairy is charging the same rate as the crown corporation utility. In Ontario, the Ontario Energy Board determined that the selling of PEV charging services do not constitute distribution or retailing, in part because the service procured from an EV charging station can only be used to refuel an EV.[53]

In the United States, because states and utilities differ in regulatory regimes, there are various approaches. In several states including Hawaii, Pennsylvania, New Jersey and California, electricity resold for light-duty PEV charging is specifically exempt from utility resale regulations.[54] In these states, PEV rates are not regulated. In jurisdictions where resale of electricity will require that EVSPs are regulated as suppliers, EVSPs may avoid this treatment by not charging tariffs on a kWh basis (i.e., instead charging by parking space or per time spent charging). For example, in the state of Michigan, Indiana Michigan Power's tariff states that resale of electricity to PEV customers is not considered resale as long as it is not charged on a per-kWh basis.[55]

In the United States, the case of master meter customers sub-metering in usage situations similar to PEV charging provides a further, illustrative example of regulatory restrictions that could be placed on electricity for resale. For example, for cold ironing ship calls, recreational vehicle parks and berths at marinas, the bill charged for sub-metered usage cannot exceed that of the master meter customer. In California, PG&E stipulates that electricity costs for short-term recreational vehicle parking must be incorporated in rental fees and that the rental fees cannot vary month to month.

Despite the above examples of regulation of the rate that can be charged for *kWh* used by PEV drivers, there is little evidence of regulation of *fees for charging services* that are charged by EVSPs, i.e. use of the parking space and charging equipment. In China, Beijing originally capped the fee EVSPs may charge for charging services, but recently liberalized these fees. A review of the remaining jurisdictions did not reveal any evidence of these fees being regulated.

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[53] https://www.oeb.ca/oeb/_Documents/Documents/OEB_Bulletin_EV_Charging_20160707.pdf

[54] See https://www.hawaiianelectric.com/Documents/my_account/rates/hawaiian_electric_rules/15.pdf, https://www.pabulletin.com/secure/data/vol48/48-24/922.html and https://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_18.pdf.

[55] https://www.michigan.gov/documents/mpsc/IM16_current_A_B_C_D_623340_7.pdf

Under the “Preparing for PEVs” scenario, regulators have largely sought to enable private sector investment in public charging, i.e., Models 1, 2 and 3. However, a number of jurisdictions wishing to stimulate the adoption of PEVs and/or ensure the long-term availability and maintenance of public charging networks have developed other models, described below as Model 4 and Model 5.

Model 4 Investment by government entities; ownership by government or private-sector EVSP network

Model 5 Investment and ownership by electric utilities

Under Model 4, jurisdictions have funded EVSP networks to install and maintain public charging. Some jurisdictions have additionally or exclusively allowed utilities to own public charging (Model 5). These two models are investigated in Section 8.

Implications for Oman

- Oman, with a population of about 4.4 million and about 127,000 annual new car registrations[56] is a relatively small vehicle market on an international scale. With limited near-term (2019 – 2021) demand expected for PEVs due to the barriers discussion in Section 6, and a lack of mandate for automakers to sell PEVs, Oman is unlikely to see EVSPs operating in Oman or the deployment of public charging networks by automakers in the near term.
- EVSE ownership, investment and hosting should not be regulated or licensed, except in the case where distribution companies may own EVSE (see Section 8).
- EVSPs operating in international markets will bring the expertise required to deploy and maintain charging solutions for PEV driver at home, work, commercial depots, and in public. AER and others should remove regulatory barriers to their operation. Enabling private sector EVSP ownership and investment does not preclude distribution company ownership and investment at a future date if Oman desires to promote PEV adoption.
- AER and other agencies should focus on enabling private sector EVSPs to enter the market when they are willing.
- AER should not regulate EVSPs engaged in resale of electricity for PEV charging as electricity suppliers. There are several reasons for this. EVSPS cannot fulfil the obligations placed on suppliers under the Sector Law including meeting reasonable demands for supply and procuring electricity only from OPWP. Additionally, Sector law regulates the supply of electricity to any Premises, where Premises is defined to be “any plot of land, building, or structures occupied or used by any Person.” PEVs do not appear to fall under the definition of Premises.
- If private sector EVSPs are not suppliers, AER should not regulate the rate structure that private sector EVSPs utilize to bill drivers for charging services.
- Private sector EVSPs, if they are not electricity suppliers under the law, should be allowed to re-sell electricity at a price exceeding the tariff rates that licensed suppliers are obliged to charge. This would enable private sector EVSPS to recover the additional costs they will incur in providing charging services. AER should support this interpretation with any government entities that may be involved in regulating resale of electricity by private sector EVSPs.

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[56] https://timesofoman.com/article/79270

- AER should ensure that electricity supply is billed at cost in the case of master meter customers sub-metering electricity for PEV charging in multi-unit dwellings with assigned spaces or in the workplace with assigned spaces.
- Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) could introduce regulation that prevents landlords and homeowners' associations from blocking installation of EV charging.

C. Technical aspects of connectors and communication

As depicted in Table 1, communication technical standards are intertwined with charging technology, charging mode, charging level, connectors, and EVSE capabilities. These can also have significant impacts on the safety, efficacy and convenience of electric vehicle charging. Descriptions of these attributes, as well as discussion of their interrelationships, are provided in this section.

The attributes of conductive and inductive charging technologies are summarized in Table 2 below. Because inductive charging is in its infancy, discussion in this report focuses on conductive charging.

Table 2. Attributes of conductive versus inductive charging

Attribute	Conductive Charging	Inductive Charging
Connection	Uses a wired plug See this section of the report for additional discussion	Uses an electromagnetic field to transfer energy wirelessly. Charging distance must be very close; on-route technologies are still in development. The power transfer in inductive charging is AC and gets converted to DC using a rectifier on-board the vehicle.
Benefits	Proven technology	Avoids need (to remember) to plug in, can potentially be used to charge on-route
Safety issues	Described in Section 7E	Magnetic field exposure, potential for changes to electric code: electrical shock and fire hazards
Other		Automakers may not warranty inductive charging Technology not yet widely commercially available

Charging modes are summarized in Table 3 below. Charging modes are specified per IEC standard 61851, which defines the electric vehicle conductive charging system.

Table 3: Charging modes

Mode	Description
Mode 1	• Charges via a standard outlet (single-phase or 3-phase) • Not permitted in Abu Dhabi due to lack of safety measures (lack of a residual current device to prevent electric shock and power draw protection)
Mode 2	• Single phase and 3-phase charging • Cable does not draw power when unplugged from car or if under strain • Enables communication from car to charger • Car stops drawing power when it is full
Mode 3	• Single and 3-phase charging • Draws power when plugged in at car and EVSE • Car detects EVSE and connector capacities and charges within these constraints • Car communicates when battery is fully charged and the charging point turns off the power
Mode 4	• Used for DC fast charging: off-board AC to DC converter and direct battery connection bypasses on-board charger that would otherwise perform AC to DC conversion • EVSE turns off power once car is fully charged

Connector standards are specified per ISO/IEC 62916 and cover physical, electrical, operational and communication requirements. Connectors commonly utilized for Level 1 and Level 2 charging are SAE J-1772 and Type 2 (Mennekes). Images of these connectors are provided in Figure 9 below[57].

Figure 9. SAE J-1772 and Type 2 connectors

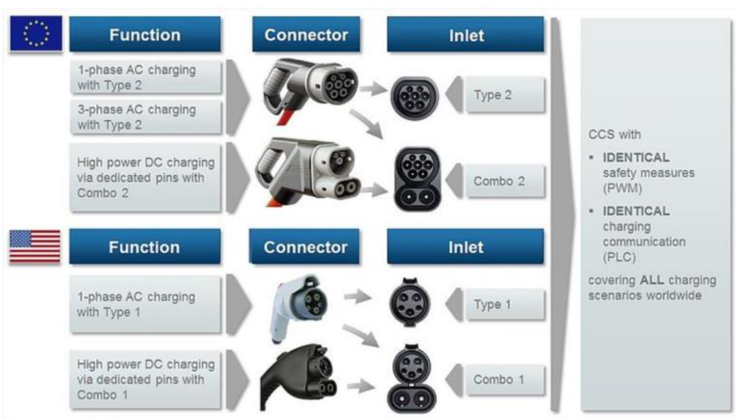
SAE J-1772 Connector	Type 2 Connector
	

[57] Image sources: https://en.wikipedia.org

The SAE J-1772 connector is widely used in the US and Japan. It supports only single-phase charging and in the U.S. carries a maximum current of 80 amps. In Europe, the European Union (EU) introduced the Type 2 connector as a standard in 2014, but by that time some EVSEs using a Type 3c (Scame) connector had already been installed. Therefore, most of Europe uses a Type 2 connector, however there are some Type 3c connectors in Italy and France. The Type 3c connector has additional protection to shield users from direct electrical contact. The European connectors support single-phase and three-phase charging. The Type 2 connector supports a maximum current of 70 amps.

Connectors utilized for DCFC are CHAdeMO (Charge de Move), CCS, Tesla, and the Chinese GB/T connector. CHAdeMo and CCS connectors are depicted in Figure 10 below[58].

Figure 10. CHAdeMo and CCS connectors

CCS Connectors	CHAdeMO Connector
	

The CHAdeMO connector operates as DC only. Automobiles utilizing CHAdeMO include Kia, Citroen, Mitsubishi, Peugot, Nissan, and Tesla (with an adaptor). CHAdeMO currently supports charging up to 350 kW. The CCS connector supports AC and DC charging and also currently supports DC charging at up to approximately 350 kW. US and European versions are available. Automobiles utilizing CCS are Audi, BMW, Daimler, Ford, General Motors, Porsche, and Volkswagen. Many DCFC stations have both Combo 2 and CHAdeMO connectors. The GB (guobiao)/T connector is widely deployed in China and China and India, and automakers including Tesla are modifying cars to be compatible in China. Tesla's Supercharger network is proprietary to Tesla owners. Not all cars are DCFC capable, and for those that are, maximum charging power limits vary by automobile manufacturer.

In the Middle East, the GSO Final Draft of Standards document from early 2017 lists GSO IEC 62196-2, the Type 2 European connector, rather than the SAE J-1772 connector, as the standard for AC connectors; the GSO IEC 62196-3 is listed as the standard for DCFC connectors. It is not currently clear which DCFC

58 Image sources: https://www.charinev.org/ccs-at-a-glance/ccs-specification/ and https://chargedevs.com

technologies are supported by the GSP Final Draft Standards. In Dubai, DEWA is utilizing CHAdeMO and SAE Combo connectors and EVSE 50 kW DC capacity, and Type 2 connectors and EVSE with 43 kW AC capacity. In Saudi Arabia, SEC has engaged Tokyo Electric Power Company (TEPCO), Nissan Motors and Takaoka Toko on an EV pilot project for 3 fast charger stations and will borrow 3 electric Nissan vehicles. These likely employ CHAdeMO technology. In Jordan, the German company eCharge has been engaged to build more than 10,000 EVSE[59]; DCFCs are expected to have both CHAdeMO and CCS connectors. Dubai has deployed both CHAdeMO and CCS technologies.

Communication is a critical issue related to connector technology. CHAdeMo uses CAN (Controller Area Network) bus protocols to communicate between the charging station and the car. This creates difficulties in carrying out seamless vehicle to grid communication because additional steps are required to identify the vehicle, communicate energy requirements and departure time information critical to driver needs. Similar to CHAdeMO, the Chinese GB/T technology uses CAN communication protocol. CCS uses Power Line Communication (PLC) protocols between EVSE and the car. ISO/IEC 15118, a standard specifying communication among PEVs and the EVSE, is based on PLC protocols. GSO draft standards specify ISO/IEC 15118 for vehicles but EVSE communication requirements are not specified.

Note that no utility communication is possible under Level 1 charging, therefore if some level of utility or aggregator control of charging is expected to be desirable in Oman at some stage in the future then ensuring deployment of at least Level 2 EVSE with ISO/IEC 15118 specification in both the EVSE and the EV should be considered. ISO 15118 on Level 2 EVSE can enable smart charging without the need for additional equipment or separate metering of PEV loads. Some utilities are offering incentives for installation of Level 2 chargers in exchange for participation in TOU rate programs.[60] With respect to DCFCs, deployment of CCS technology is desirable because CHAdeMo utilizes CAN bus protocols, in contrast to CCS protocols which are based on PLC protocols.

The ability to monitor and control residential loads separate from the rest of household loads can be valuable to the utility. For example, air conditioning load control for demand response can be carried out through a direct load control device operating with one-way paging technology, or with utility-approved programmable communicating thermostats that are operable and compatible with the utility's smart meter through communication protocols such as ZigBee.

With respect to PEV loads, vehicle-grid integration (VGI) encompasses the many ways in which a vehicle can provide benefits or services to the grid, to the EV driver, or to the EVSE site host, by optimizing plug-in electric vehicle (PEV) interaction with the electrical grid.[61] VGI encompasses passive solutions such as customer response to rate structure signals as well as active management of charging levels by ramping up or down charging to provide grid benefits (V1G), and bi-directional energy transfer capability (V2G or vehicle-to-grid). V1G enables the battery to charge or not charge. Under V2G, the battery can also be discharged. Vehicle to Home (V2H) and Vehicle to Building (V2B) services, whereby the EV battery provides backup AC power to a facility that has been islanded from the grid, are also possible. Due to existing system capabilities, V2G, V2H and V2B services are not likely to emerge on the Oman system in the near to medium term. Entities that can be involved in VGI are the PEV owner/driver, the distribution

[59] http://www.jordantimes.com/news/local/10000-electric-car-charging-stations-be-built-jordan%E2%80%99
[60] See LADWP's Charge-up LA program and SCE's Charge Ready program.
[61] http://www.cpuc.ca.gov/vgi/

network operator and power supplier, aggregators, utility customer, site host, the PEV itself, the DC power converter system, EVSE, the energy meter, and the building management system.[62]

Active control of PEVs can enable PEVs to provide grid services including generation capacity, reserves, frequency regulation, locational distribution services, load following and ramping for renewable integration, distribution upgrade deferral, and voltage support. Some of these services, such as provision of ancillary services and load following, require that the PEV battery discharges energy to the grid. Because such V2G services are not expected to emerge on Oman's grid in the near to medium term, the focus of any active communication and control is on managed charging, enabling a utility, EVSP or aggregator to reduce or increase charging levels in response to grid conditions.

Communication channels that are important to the utility being able to implement V1G PEV charging occur between the utility and EVSE or charge point operator (CPO), the EVSE and PEV, and the utility and PEV. Common utility to EVSE communication protocols for these channels are described below.[63]

- **OpenADR version 2.0b[64].** Open Automated Demand Response (ADR) version 2.0b is a utility demand response communication standard. It sends energy consumption change needs as well as price information using Internet Protocol (IP)-based communications. Other protocols are needed to translate the OpenADR signal into a PEV charging decision[65].

- **Open V2G or ISO/IEC 15118**. The OpenV2G communication protocol, also known as ISO/IEC 15118, facilitates seamless incorporation of charging costs, owner preferences, and vehicle-specific parameters such as battery wear and state-of-charge to carry out automated charging.

- **IEEE 2030.5** or **SEP 2.0**. Institute of Electrical and Electronics Engineers (IEEE) 2030.5, also known as Smart Energy Profile (SEP) version 2.0 is an on-vehicle communication protocol, a utility standard interface protocol, and also a communication protocol between devices in a Local Area Network (LAN). Communications can be performed between the utility and the EVSE directly, and between the PEV and utility through vehicle telematics.

- **OCPP version or 2.0.** Open Charge Point Protocol (OCPP) version 2.0 is an open communication standard that allows EV charging stations and various EVSPs to communicate with each other. It was developed by the Open Charge Alliance and is used in Europe and North America. It provides site owners the option of changing network administrators without stranding equipment assets.[66] OpenADR 2.0b can be combined with OCPP to enable utility to EVSE communication.

PEV Communications can be carried out in a variety of ways. The utility or the EVSP or aggregator can instruct charging or send price or grid stress signals directly to the vehicle via a WiFi or cellular communication through the vehicle's onboard communications system or an on-board diagnostic interface (OBD2). Vehicle charging can also be managed through vehicle telematics. The utility can communicate with an individual customer smart meter using Wi-Fi, RF, wide area telecommunications network (WAN), or PLC protocols that communicate directly through power lines. The smart meter can

[62] http://www.cpuc.ca.gov/vgi/
[63] http://www.cpuc.ca.gov/vgi/
[64] https://www.openadr.org/
[65] http://www.cpuc.ca.gov/vgi/
[66] http://emotorwerks.com/images/PR/Articles/sepa-managed-charging-ev-report.pdf

be connected to a local area network through a protocol such as Wi-Fi or ZigBee which is commonly used to communicate with home devices. In response to a utility signal to a CPO to change consumption, the CPO can communicate among EVSEs in various ways including via a wired Ethernet connection within a local area network, or via a cellular or Wi-Fi signal.

While aggregators are not currently present on Oman's system, they could emerge in coming years. Aggregators are distinct from the utility, the EVSP and the power supplier. They can aggregate over many meter points and sell this flexibility into wholesale markets as long as they can demonstrate the physical response.

Many pilots are being carried out to test the ability of VGI to deliver grid benefits. Tables 4 and 5 provide examples of such US and UK Pilots. These pilots represent a range of applications including provision of V2G.

Table 4. Examples of US VGI pilots

Utility	Application	Approach
SDG&E (California)	Integrate solar power and manage distribution grid	Dynamic rates with locational component
PG&E/BMW (California)	Integrate solar power	Demand response
Eversource (Massachusetts)	Peak shaving	Modulate Level 2 charging
SCE/USAF (California)	V2G: provide ancillary services to grid using vehicle's battery	Bid into CAISO ancillary services markets

Based on preliminary observations, Hawaiian Electric believes that EVs will be capable of delivering capacity, replacement reserves, regulating reserves and fast frequency response. EVs are expected to play a significant role in delivering local distribution services as well, although testing has not yet been performed to demonstrate this capability.[67]

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[67] https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/electric_vehicles/201803_eot_roadmap.pdf

Table 5. Examples of European VGI pilots

Project	Country / Region	Description
Westnetz	Germany	Dedicated mains connection for controllable loads, such as EV. Smart Meter used as control channel.
INVADE	Norway	Aggregator optimizes home based on distribution network operator (DNO) price publication.
USEF	Netherlands / Utrecht	Aggregator offers flexibility to DNO with flexible pricing.
FlexPower	Netherlands / Amsterdam	Flexible power profile provided by DNO applied by CPO. DNO sends neighbourhood-specific maximum charging capacity profiles to CPOs which then restrict charging rating (kW) on charge points accordingly.
My Electric Avenue	UK / SSEN	Temporary curtailment of charging with direct substation – charge point communication.
City-ZEN	Netherlands / Amsterdam	Aggregator handles bidirectional charging within dynamic capacity profile of DNO.
TenneT	Germany & Netherlands	Transmission system operator (TSO) signals need for balancing services which, via an aggregator, instructs home batteries and electric vehicles to interrupt charging.

Careful procurement and/or standards development can help ensure that the EVSEs installed are cost competitive and include the necessary technical, communication and safety features. The Electric Circuit, Canada's first public charging network for PEVs, issues international calls for tenders, and any company with a product that meets the criteria in the tender call document can submit a bid[68]. In California, SDG&E's Power Your Drive program pre-qualified EVSPs authorized to provide EVSE networks and software services necessary for the program. To shape the RFP, SDG&E first issued a request for Information (RFI). Responses from the responding industry and subject matter experts shaped the RFP[69]. RFI criteria included signaling hourly day-ahead rate data to customers, enabling the customer/driver to set charging needs, collecting EV charging usage data and sending data to SDG&E for billing, and vendor capabilities qualifications. Bid evaluation also included subsequent testing of preferred bidders to confirm performance to RFP standards.

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[68] https://lecircuitelectrique.com/Containers/Item/Display/334?culture=en-US

[69] https://www.sdge.com/sites/default/files/regulatory/FINAL_Power_Your_Drive_Semi_Annual_Rpt.pdf

Implications for Oman

- Technology continues to evolve rapidly. AER should begin continuously investigating Level 2 and DCFC communication and metering communication options to ensure that EVSEs eventually deployed will have the necessary communications attributes including ability to instruct charging, send price signals, customer charging time needs, battery state-of-charge, and interoperability.
- AER should at some stage investigate how active control of PEVs to provide V1G services can best be accomplished on its system. This could be directly via distribution company instruction to individual PEVs or EVSPs, or through instruction to EVSPs or aggregators.
- AER could also, in due course, allow a distribution company pilot to test appropriate architectures, communication avenues and technical configurations. Solutions to power quality issues could also be tested.
- AER should work with MoCI to ensure that vehicles and EVSE brought into Oman incorporate ISO/IEC 15118 protocols. GSO draft standards appear to specify ISO/IEC 15118 for vehicles.
- MOCI should clarify PEV charging connector standards with GSO. The GSO final draft standard specifies IEC 62196-2 but not whether the connector is Type 1 (US) or Type 2 (European) connector. Specification of only the European standard on vehicles (to the extent this is true) could help reduce proliferation of plug types. GSO final draft standards do not specify CHAdeMo, CCS, CCS Combo, Tesla or G/TB connectors. GSO should clarify that DCFC should include at least both CHAdeMO and SAE Combo connectors until such time as the automobile industry adopts a single standard.
- AER and MoCI should work together to ensure communication interoperability of public charging stations among private sector EVSPs and any distribution company-owned EVSPs. One way this could be accomplished is by ensuring public charge points are OCPP compliant. This may also require some form of regulation of EVSP ownership. In Dubai, OCPP compliance is a requirement of public infrastructure.
- AER should encourage adoption of Level 2 chargers with IEC 15118 communication protocols. One way this could be supported is through offering rate structure(s) with attractive off-peak charging costs to (separately metered) PEV loads. While deployment of Level 1 charging in Oman is a sub-optimal outcome due to the lack of communication and control abilities, low penetration of this charging technology, low power draw and the opportunity for low off-peak TOU charging rates may mitigate negative impacts on Oman's grid.
- Distribution companies should be empowered to work with EVSPs to reduce new connection and upgrade costs through locating chargers in locations that are both convenient to customers and where there is sufficient capacity on the distribution system, as well as through performing smart charging to reduce distribution system congestion. Distribution companies could start to identify locations with sufficient capacity for public charging infrastructure.

D. Utility rate structures for PEVs

Customer response to electric rate price signals is the simplest form of V1G, requiring electric rate structures that signal system benefits and meters capable of recording consumption by time of use. For utilities that offer residential customers specific rate schedules for PEV charging, in Europe and North America these are TOU or seasonal TOU structures that are more economic than the default structure, provided that charging is carried out during off-peak periods. In the Middle East, there are no specific rate schedules for electric vehicle usage.

A common issue for residential PEV electricity service is whether PEV usage should be metered separately from the balance of home consumption. This is because whole-home TOU structures can be un-economic if the household has material on-peak consumption (e.g., from air conditioning load) and because the incremental meter cost for a dedicated PEV-specific rate can make the economics of such a rate structure difficult. Although perhaps not required in Oman at the present time and potentially complicated to implement with respect to customer understanding aspects of service quality, it is interesting to note that in Germany, Legislators have created a provision in the Energy Industry Act (EnWG § 14a) under which PEV users can take service on an interruptible rate, thereby benefitting from significantly lower distribution network charges[70]. The aim is to prevent unnecessary network expansion and to reduce CO2 emissions. The rate requires a separate meter as a controllable consumer and the DNO charges a reduced network fee in return for the ability to control loads with a separate metering point. The network operator may interrupt service for up to two hours, however overnight supply is expected to be available without interruption.

Most commercial PEV customers are served on default tariffs or non-PEV TOU rate options offered by their utility. Commercial rate structures specific to PEV usage are typically TOU designs but may be flat structures in the case of DCFC. There are no examples of electric rate schedules for PEV fleets, however in Europe some DNOs are offering innovative solutions to avoid costly network reinforcement by offering timed connections. For example, UK Power Networks, the DNO for the London area, provided an electric bus fleet with a timed connection which limits the connection capacity during peak hours.[71] Electric rates applicable to both residential and commercial PEV users are rare.

In Europe, North America and the Middle East, rates charged by private sector EVSPs are generally not regulated. Because of this, EVSPs may pass price signals to PEV customers that differ from the underlying utility tariff that serves the charging station. This means that EVSPs may not pass TOU price signals through to customers and that in such cases limited or no customer response may occur.

Regarding metering of PEV usage, a separate utility-grade meter is required if the customer selects an electricity rate structure for PEV usage and a different rate structure for the balance of facility or residence usage. The utility typically supplies this meter and meter costs are recovered through the relevant tariff.

Regarding communication, for behaviour-induced load reduction programs such as critical peak pricing (CPP) events, utilities typically notify customers day-ahead via telephone number, email, or a short messaging service (SMS) text.

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[70] https://compliance.zar.kit.edu/downloads/raabe_ullmer_itit.2013.0008.pdf

[71] https://www.ukpowernetworks.co.uk/internet/en/our-services/documents/A_guide_for_electric_fleets.pdf

Implications for Oman

- Oman's PEV customers should not be forced to take service on a rate specific to PEV end uses. However, if PEV customers can be offered a rate option with an attractive off-peak rate (potentially lower than the marginal inclining block tariff (IBT) rate) then they should desire to take service on the more economic rate.
- AER should conduct a cost of service and rate design study. Study scope should include determination of whether PEV-specific TOU rate(s) can be designed to be lower cost than the default permitted tariff IBT and CRT structures if charging is accomplished during off-peak hours. Such PEV rates could potentially reflect the differentials that exist in the bulk supply tariff, either in a full or simplified version. In due course, when quality of service reporting data has been fully established it may also be possible to incorporate some discounts for interruptible service (generation capacity and network capacity) should there be clear benefits from such an arrangement. PEV rates can be examined for both residential and commercial customers.
- Under the current mechanics of Oman's multi-year rate determination, allowed revenue increases with increased loads and there is not a corresponding decrease in rates due to increased throughput. This should be examined in AER's future ratemaking analysis.
- There is an example in Oman for rate discounts to incentivize customer behavior. Industrial customers that use natural gas can receive a discounted natural gas rate if they offset their usage from electricity with on-site renewable power. Note this example is from the natural gas industry and involves on-site generation rather than consumption change.
- It will likely be more expensive to charge away from home if home charging would be carried out under a subsidized tariff or at a low off-peak rate versus on a cost-reflective tariff in public locations.
- Under current subsidized residential rates, it is not likely that customers will pair solar PV with PEV adoption if this choice is driven by economics. Under the Sahim program, generation that is exported to the grid is compensated at un-subsidized costs while customers with PEV usage will want to charge with lower cost power. Additionally, if a TOU rate can be designed to signal off-peak PEV usage, the PEV load will be on a separate meter.
- AER should ensure that distribution companies are able to install appropriate utility-grade metering for any TOU rates. Existing residential meters have 30-minute usage resolution and are likely appropriate for metering a separate PEV TOU structure.
- AER should ensure that distribution companies update their plans periodically to reflect expected PEV adoption, and that distribution companies start including PEV uptake formally in their demand forecasting process.

E. <u>Ensuring safety of EVSE</u>

The safety risks associated with installing and using EVSEs in residential locations are similar to those associated with installing and using other large household appliances such as microwave ovens or air conditioning units. Generally, residential EVSEs are installed in garages, however outdoor-rated EVSEs are available if the installation will be outdoors. An EVSE installation should comply with all requirements. Common requirements across the international jurisdictions surveyed include the following:

- Dedicated circuit not supplying other loads
- Circuit sized to at least 125% of maximum circuit loads
- Overcurrent protection in the meter pedestal/circuit breaker panel
- Supply isolation device between circuits
- Backfeed prevention device
- Maximum EV supply cable length about 7.5 meters (about 25 feet)
- EVSE height recommendation varies: 45 cm to 122 cm above floor
- Grounding
- Adherence to relevant building codes and local permitting requirements
- Installer must notify utility of the installation
- Distribution company inspection of the EVSE installation prior to energization, or prior consent required from utility prior to installation

Additional considerations for public installations include:

- EVSE installed outside of areas where potentially explosive atmosphere exists
- Signage requirements
- Disabled accessibility for public locations (as applicable)

EVSE installations may also be licensed. In Jordan, for example, in Jordan, EMRC's license terms[72] for both public and private installations include the following:

- Ensure safety of customers and other people
- Concrete wall at least as tall as the charging station if located in a petrol station
- Disconnection switches on supply and connection sides of charging station
- Collision protection
- Sufficient parking area
- Process of charging shall not damage connectors or EVSE
- The height of the plug of must be at 75 to 120 cm from the ground
- Electrical wiring and connections not in pedestrian paths
- Sufficient ventilation and cooling if in an enclosed area; devices should run interlock with operation of the charging substation
- Appropriate equipment protection from weather, dust, water; outdoor equipment equipped with water isolator material
- Disconnection of electrical current if leakage of current or voltage variation
- High power circuit breaker, earth leakage protection and lightning protection
- Vandalism protection
- Metering of consumption and display of the cost charging and the power consumption

[72] http://www.emrc.gov.jo/images/electric/electric_charg_lice_en.pdf

- EVSE two year equipment warranty

Criteria unique to Abu Dhabi include[73]:

- Voltage drop at power terminals of EVSE should be within appropriate limits
- Urban Planning Council's Estidama requirements (sustainable planning criteria) with respect to the urban streets and public realm Design Manuals
- Conformance with electricity wiring regulation (based on BS 7671 and similar to IEC 60364)
- Distribution company receipt of electrical installation certificate, electrical inspection report and testing report

Abu Dhabi also issues a Quality Control and Conformity certification[74] for EVSE installations. Abu Dhabi requires the following:

- Description of EVSE product specifications, data sheet, installation manual, and photos
- Must meet requirements for BS EN 61851 (electric vehicle conductive charging system)
- ISO 9001 certificate of manufacturer
- Test certificate issued by ISO/IEC 17025 accredited conformity assessment body and testing reports
- EVSE installation agreement with a contractor licensed by Abu Dhabi or Al Ain Distribution Company
- Payment of fees

Installations must be performed by qualified personnel. These may be licensed electricians or installers that are certified in EVSE installation. For example, the state of Illinois in the US requires that all EVSE installers be certified by the Illinois Commerce Commission. The certification process includes successful completion of the training program and carrying out 5 successful installations. In Illinois, installers are not required to be licensed electrical contractors but must comply with insurance and records requirements. New York's EVSE installer training program provides training and certification to electricians interested in installing charging stations and covers topics including utility policy, site design, EV charging site assessment, codes, safety, and first responders.

There are international examples of post-installation testing of public EVSE covering safety and measurement aspects. Regarding safety, in Abu Dhabi, the Quality and Conformity Council describes annual audit and surveillance requirements. These cover the ISO/IEC 9001 certificate (quality management), IEC 61851 (conductive charging system), IEC 62196 and IEC 60309 (connectors and plugs), IEC 60529 and 62262 (enclosures), and IEC 60068 (environmental testing).

Regarding measurement, in the US, states are responsible for developing weights and measures laws. California's Division of Measurement Standards amended section 3.40 of the National Institute of Standards and Technology's Handbook 44, "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices," to accommodate EVSE. This covers EVSEs measurement of both kWh and time. Under this regulation, California EVSPs must display rates and consumption, and must bill

[73] http://rsb.gov.ae/assets/documents/191861/installation_of_electric_vehicle_supply_equipement_-_guidance_document.pdf

[74] https://qcc.abudhabi.ae/Documents/en/AssessmentandSurveillancePlanforElectricVehicleSupplyEquipment.pdf

for each rate component. If more than one price is offered, selection of the unit price may be through the purchaser using controls on the EVSE, through the purchaser's use of personal or vehicle-mounted electronic equipment communicating with the system; or through verbal instructions. Counties within California are responsible for registering commercial EVSE so that they can be examined and sealed for measurement purposes. California's guidelines for sealing cover situations where there is no remote configuration capability as well as situations with remote configuration with access controlled by physical hardware or through software.

Implications for Oman

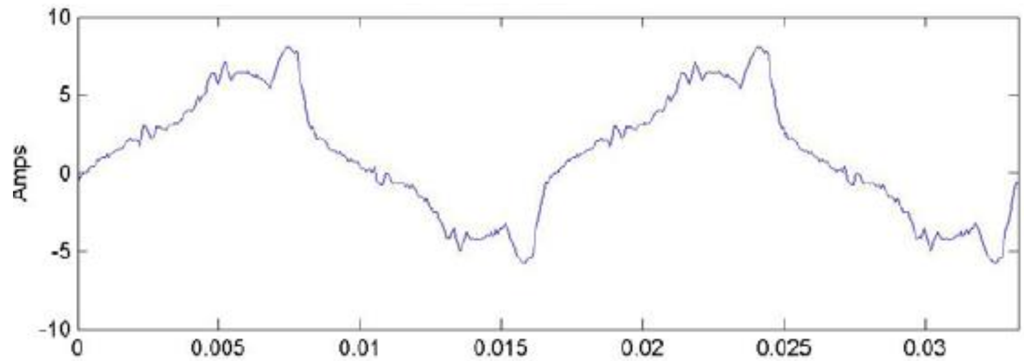
- It is not necessary for any entity in Oman to license EVSE installations provided that supporting codes and standards (i.e., building, wiring & installation codes) are adequate.
- Only licensed electricians should install EVSEs. Installer should be required to notify utility of the installation and distribution company should be given the opportunity to inspect the EVSE installation prior to energization, or be provided with electrical installation certificate, electrical inspection report and testing report.
- Electrician license should be modified to require the distribution company, and perhaps MoCI, be notified of the installation, and [entity TBD] should consider modifying electrician license procedures to include special training in installing EVSE including issues such as utility policy, site design, EV charging site assessment, codes, safety and first responders.
- MoCI should establish standards for EVSE entering Oman should specify a minimum warranty (e.g. 2 years) and specifications similar to those required by Abu Dhabi such as achievement of BS EN 61851 (electric vehicle conductive charging system) requirements, the ISO 9001 manufacturer certificate of quality management requirements, ISO/IEC 17025 test certificate, and appropriate outdoor ratings for GSO countries.
- Government bodies relevant to building codes (i.e., SCP, municipalities) should become familiar with EVSE requirements and update building codes to ensure that they incorporate appropriate safety requirements specific to EVSE.
- City planning and permitting officials should become familiar with any modifications made to building codes, wiring regulations or electricians licenses and adopt any appropriate requirements into their own regulations.
- MoCI should develop installation requirements for residential and public EVSE covering non-electrical safety aspects.
- MoCI should develop a plan for periodic testing of public EVSE covering equipment safety and measurement aspects, including ensuring EVSE is not vulnerable to malware. The cost of implementing this program could be covered by annual testing fees. MoCI could also consider including an equipment reliability criteria in the testing requirement to support availability of charging stations. Safety testing could also be considered for workplace and multi-family charging.

F. Power quality

PEV charging can create power quality issues on the distribution grid. Common power quality issues are harmonic distortion, phase unbalance, and transformer overloading.

Harmonic distortion results from conversion of power from AC to DC in inverter/rectifier in EV battery and non-linear EV loads. It leads to deviation of waveform from sinusoidal shape. An example is shown in figure 11 below.

Figure 11. Example depiction of PEV-related harmonic distortion[75]



Harmonic current distortion causes voltage distortion, equipment overloads, can reduce the lifetime of distribution assets (esp. transformers), and can lead to increased power losses. The impact is greater if the grid is weaker (i.e., charging is occurring far from substation). Harmonic limits on a utility's distribution system are based on harmonic voltage limits which are driven by harmonic current and impedance.[76]

It is unclear when/if harmonic distortion may become a problem for individual utilities. It depends in part on specific equipment (automobile/manufacturer), charging voltage and total charging load. A Chinese simulation study showed that the total harmonic distortion decreased as the charging power and the number of chargers increased[77]. A US study showed that for both single-phase and three-phase charging, the greatest impact occurs during the "trickle charge" mode used when topping up the last portion of battery capacity[78]. Note in many cases charging will end when the battery has been filled to about 80% of total capacity therefore harmonics related to trickle charging may not become an issue. Solutions include source/input impedance and installation of stationary energy storage[79].

Phase unbalance is a single-phase distribution service issue. A large number of EVSEs on a single phase can result in heavier loading on one phase versus another. Faster charging points will connect as higher voltage three-phase loads so unbalance issues are not likely for these types of loads. Phase unbalance leads to voltage drop, and losses which grow exponentially with higher loading levels on a given phase.

75 https://pdxscholar.library.pdx.edu/ece_fac/166/

[76] https://www.westernpower.co.uk/docs/Innovation/Current-projects/Electric-Vehicle-Emissions-Testing/EV-Emissions-Report-Final-rev5-Final.aspx

[77] http://www.ces-transaction.com/CN/article/downloadArticleFile.do?attachType=PDF&id=1491

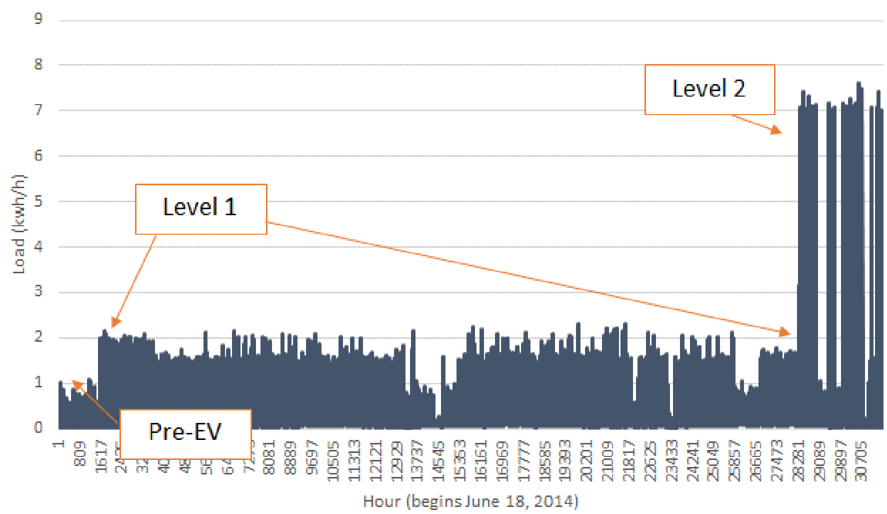
[78] 78 https://pdxscholar.library.pdx.edu/ece_fac/166/

[79] https://www.theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf

Available solutions for phase unbalance include reconnection or re-phasing of loads, better planning for connection of new DER, certain smart meters may provide data to help identify this issue, and deployment of battery storage. Charging during off-peak hours should limit under-voltage and losses issues.

Overloading of local distribution transformers caused by clustering of EV charging can lead to shortened transformer life or failure. An example of load increases relating to level 1 and level 2 PEV charging in a California residence is shown in figure 12 below.

Figure 12. Pre-PEV, Level 1 and Level 2 residential charging



Individual system conditions drive magnitude of transformer loading issues. DCFC may lead to reduced transformer heating and wear if load factor is low in early years of PEV take-up. In China, systems are generally oversized to accommodate load growth, and cities with high PEV penetrations plan to achieve low SAIDI/SAIFI metrics.

Utilities are beginning to factor PEV adoption into their distribution system planning processes. The impacts of PEVs on distribution networks are highly depending on the degree of spare capacity already available throughout the network, charging power level, and the degree of PEV clustering. Multiple US studies performed by E3 for utilities found minimal distribution upgrades were required with Level 2 charging.[80] In these cases, the feeders and substations studied contained significant excess capacity.

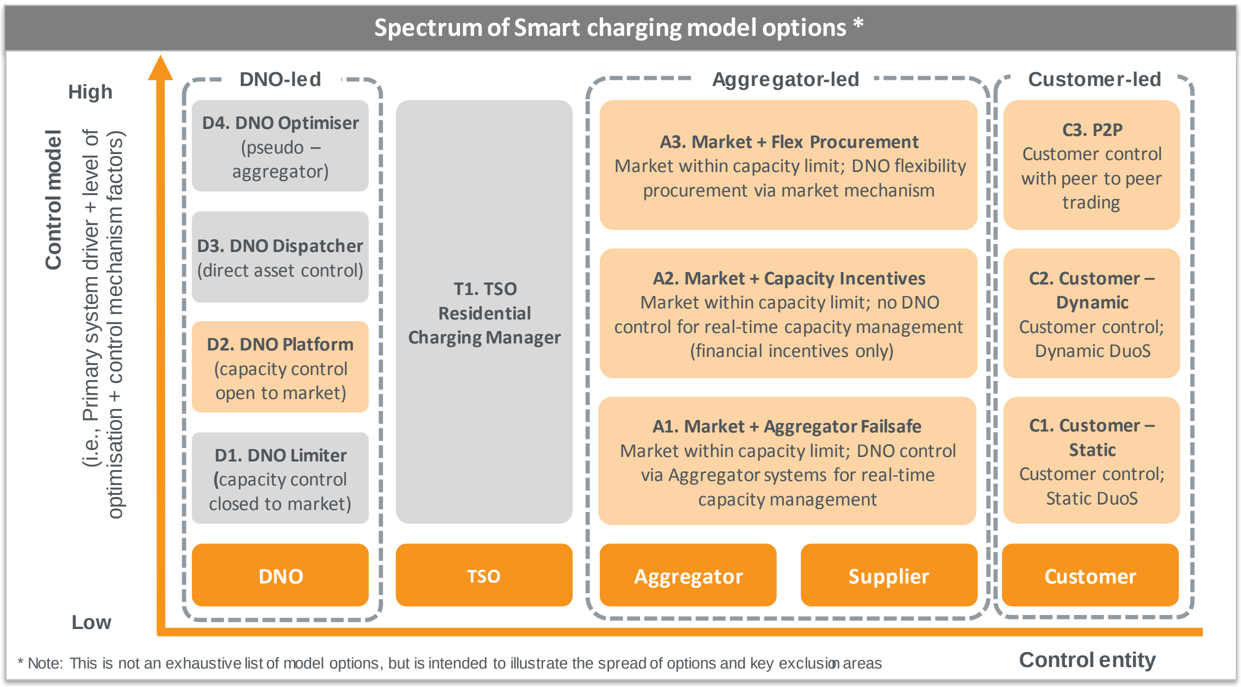
[80] See, for example,

"Economic Impacts of plug-in electric vehicles," 2018, https://www.snopud.com/site/content/documents/custpubs/PEV-impacts_618.pdf

E3, 2017, "Cost-Benefit Analysis of Plug-in Electric Vehicle Adoption in the AEP Ohio Service Territory," https://www.ethree.com/wp-content/uploads/2017/10/E3-AEP-EV-Final-Report-4_28.pdf

In the UK, measures to avoid or defer reinforcement where PEV load may lead to overloading are a key focus. Smart charging is seen as very important but there are multiple architectures under consideration to address this issue. Figure 13 below shows the options framework that UK Power Networks, a UK DNO, is examining to mitigate transformer overheating.

Figure 13. UKPN options framework for mitigating transformer overheating



UKPN's framework shows in the horizontal dimension different possible control entities (the DNO, the TSO, an aggregator or supplier, and the customer themselves) and in the vertical dimension different levels of control associated with the alternatives, with less direct options at the bottom and more direct options at the top. For example, the options for the DNO as controller run from a simple curtailment through to the DNO acting to optimize charging acting as an aggregator. Similarly, with the customer in control the options span from a static time-of-use charge for the distribution network to dynamic capacity trading through a peer-to-peer platform. In addition to smart charging options, storage can also be deployed to mitigate the need for distribution capacity additions.

In factoring PEV adoption into distribution system planning, it is important to note that early adopters of PEVs will not necessarily have the same charging habits, cluster in the same areas, drive the same

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Seattle Office of Sustainability and Environment, 2017, "2017 Drive Clean Seattle implementation strategy," https://www.seattle.gov/Documents/Departments/Environment/ClimateChange/Drive_Clean_Seattle_2017_Report.pdf

ICF and E3, 2014, "California Transportation Electrification Assessment," http://www.caletc.com/wp-content/uploads/2016/08/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf distances or use the same charging power as later adopters. Periodic re-assessment of likely distribution impacts can therefore be valuable. One of the challenges in performing these forward-looking analyses has been the difficulty in obtaining data from vehicles. Automakers view this data as proprietary, and even when they are willing to provide it, data contracts must be signed with each automaker. Private sector companies such as FleetCarma provide dongles that can instead attach to PEVs from all automakers and, with the consent of drivers, track driving and charging behaviour. For example, Salt River Project, a utility in the US state of Arizona, enrolled 100 PEV drivers to use the FleetCarma device and collected data during charging events (voltage, current, location, and state of charge) and mileage. [81] They examined differences in these metrics between three major PEV model types -- the Nissan LEAF, Chevy Volt, and Tesla.

Implications for Oman

- There are no power quality measures specific to PEVs. As with all end uses, distribution companies should take adequate measures to ensure minimum power quality standards are achieved.
- In residential installations, Level 2 (versus Level 1) EVSE should be encouraged to mitigate potential phase imbalance issues. The average residential customer contribution to coincident peak is 7 kW. If residential customers install a Level 2 charger, and provided the utility is notified of the EVSE installation, the residence will likely be placed on three-phase service (if this is not already installed; in Oman, residential service above 20 kW is typically provided as three phase). This will reduce the likelihood of phase unbalance occurring.
- AER should empower distribution companies to work with EVSPs to reduce new connection and upgrade costs through locating chargers in locations that are both convenient to customers and where there is sufficient capacity on the distribution system, as well as through performing smart charging to reduce distribution system congestion.
- AER should update wiring regulations to ensure that they incorporate appropriate safety requirements specific to EVSE

G. Data safety and security

Data safety and cyber security issues encompass data privacy (interception of data), alteration of data or control software, and installation of malicious software (malware).[82] PEV customers, EVSPs, the PEV and/or the utility could be impacted.

Data privacy and security issues are not unique to PEV customers. For example, in California, Public Utilities Code Section 8380 discusses the sharing of and protection of customer data. Key aspects of this code state that the California Public Utilities Commission jurisdictional utility shall not share, sell, or provide an incentive or discount for sharing, a customer's data (i.e., the name, account number,

[81] Salt River Project and EPRI, "Electric Vehicle Driving, Charging, and Load Shape Analysis: A Deep Dive Into Where, When, and How Much Salt River Project (SRP) Electric Vehicle Customers Charge," https://www.srpnet.com/electric/home/cars/PDFX/EPRI_Report_July2018_EVGridImpactStudy.pdf

[82] See http://www.cs.ru.nl/~F.vandenBroek/pub/EVcharging.pdf and https://www.iea.org/media/topics/transport/VehicletoGridCybersecurityBrief.pdf

consumption, address) except upon the consent of the customer. The utility must protect unencrypted data from unauthorized access, destruction, use, modification, or disclosure, however aggregate data can be used for analysis, reporting or program management if individual identities are protected. The customer must consent to any third party uses customer data for a secondary commercial purpose, and third parties accessing customer data must implement and maintain reasonable security procedures to protect the personal information from unauthorized access, destruction, use, modification, or disclosure.

Per California Public Utilities Code Section 8380, if a customer chooses to disclose its consumption data to a third party that is unaffiliated with, and has no business relationship with, the utility, the utility is not responsible for the security, use or misuse of that data. For example, in the United States, private sector EVSPs delineate data policies in customer contracts. Data collected typically includes information on the customer, PEV, location, time of and duration of charging session, power usage and battery state of charge during each session. Information can typically be used for various purposes including research or marketing. EVSPs must retain certain data for tax and legal purposes. Such data is commonly encrypted.

Oman's data privacy regulation will be modeled on the EU's General Data Protection Regulation (GDPR). GDPR regulates how companies must protect personal data. Key provisions of GDPR include security and anonymization, consent for data processing, provision of data breach notifications, data portability features so that personal data may be transferred to different service providers more easily, and the right to request deletion of data in certain circumstances. Companies that fail to achieve GDPR compliance are subject to penalties. The EU's Green eMotion regulations introduced in 2015 aim to unite communications for the multiple international programs within Europe but do not properly address protection of user data.

In Abu Dhabi, the RSB publishes data requirements in its Customer Metering Regulations. These state that metering equipment shall have a programmable facility to restrict access to recorded data and associated hardware. Multi-user access is accepted if controlled through defined levels of access in accordance with IEC 62056-21 which covers standards for exchange of electricity metering data. Particular attention is required to ensure a rigorous and robust authentication and authorization process so that unauthorized parties cannot gain access to or disrupt data.

With respect to data security issues in PEV charging, similar to networks and systems in other industries, EVSP wireless networks and IT systems as well as systems belonging to utilities, aggregators and payment settlement entities can be vulnerable to cyber attacks. Under ISO/IEC 15118, metering data can be digitally signed by the vehicle and the charging point enabling mutual (server and vehicle) authentication which improves security. Vehicles can be vulnerable to additional security concerns, however these are not limited to PEVs. For example, the CAN bus and telematics are avenues through which malware can infiltrate a vehicle. With respect to PEVs, EVSEs do present an additional channel through which this could occur. Additionally, malware installed in PEVs has the potential to affect the electricity grid and/or charging infrastructure[83] which would not be possible with traditional ICE vehicles.

Implications for Oman

- AER, with responsibility for industrial cyber security impacting the security of supply and safety, and other entities in Oman impacted in regulating PEVs (i.e., MoCI), should ensure that

[83] https://www.iea.org/media/topics/transport/VehicletoGridCybersecurityBrief.pdf

appropriate cyber security criteria, including data policies, are established for EVSPs, as applicable to each entity's area of responsibility.

- Generally, AER should consider including in its Cyber Security Standard ensuring that for distribution company systems, customer data (name, address, account number, consumption) is secure and not disclosed except to authorized third parties with appropriate security procedures.
- AER should consider including in its Cyber Security Standard ensuring that distribution companies are not held responsible for the security, use or misuse of that data in a scenario where a customer chooses to disclose its consumption data to a third party that is unaffiliated with, and has no business relationship with, the utility.
- MoCI should regularly inspect EVSE metering equipment for accuracy, and to ensure EVSE is not vulnerable to malware.
- AER should investigate the extent to which distribution company systems could be vulnerable to malware installed in PEVs or EVSE and should ensure that appropriate security measures are described in its Cyber Security Standard.

H. Additional measures to facilitate driver experience

Leading PEV jurisdictions have implemented a number of additional measures to improve the experience of PEV drivers. These include standardizing roadway signage for public PEV charging, providing data on public charging, implementing measures to manage congestion at shared charge points, and preparing utilities for questions on PEVs.

Standardizing roadway signage helps drivers locate public charging. For example, the US Federal Highway Administration and federal authorities in Canada have approved a common sign to indicate PEV charging (see Figure 14).

Figure 14. US Federal Highway Administration standard road sign for PEV charging

A further way to assist drivers to locate public charging infrastructure is to create a public database of locational data for use in government or private applications. A best practice example is provided by Norway, who developed such a public national database guided by the following principles:[84]

- The database should have public ownership to ensure that it would include data from all owners of charging infrastructure without discrimination.
- The information should include key data which meet the needs of EV users. For this reason, EV users should be active in the development in order to make the database usable and attractive.
- Prioritize a high level of quality for the data, with a thorough verification process, instead of prioritizing registration speed. A database has to be reliable.
- Draw a clear boundary between the database itself and the services built on the data provided by the database. The services/applications were assumed to be commercially interesting. However, in an early phase they could be given funding to kick-start the activities and increase the value and awareness of the database.
- The data should be freely available for anyone aiming to create useful tools for owners of chargeable vehicles, to maximize the promotion effect and dissemination of the knowledge.

Charging providers, drivers and other participants can easily enter data through a web-based user interface. The database is currently used by a number of automakers, charging providers, map sites and users to provide drivers and prospective PEV purchasers validated, up-to-date data on the whereabouts and availability of EVSE across Norway's extensive public charging network.

The United Kingdom has similar aspirations for this kind of data. Following passage of the Automated and Electric Vehicles Act in July 2018, the UK is able to pass regulations requiring operators of public charging to make available "such information as the Secretary of State considers likely to be useful to users or potential users of the point, for example information about

- the location of the point and its operating hours;
- available charging or refueling options;
- the cost of obtaining access to the use of the point;
- the method of payment or other way by which access to the use of the point may be obtained;
- means of connection to the point;
- whether the point is in working order; and
- whether the point is in use."[85]

At locations where drivers are sharing charging equipment, it is also important for EVSE hosts to develop systems that provide PEV drivers fast and efficient access to charging. There are a number of ways that regulators and site hosts have achieved this.

[84] The Norwegian Charging Station Database for Electromobility, http://info.nobil.no/images/downloads/nobilbrosjyre.pdf
[85] http://www.legislation.gov.uk/ukpga/2018/18/contents/enacted

The first is passage of “Anti-ICE laws” that create fines or penalties for ICE vehicles that are found to be occupying PEV spaces. Such laws have been enacted, for example, in leading US PEV states.[86] The second is to require the use of standardized signage at public PEV charging stations. For example, Washington, Oregon and California state law require the use of the signs shown in Figure 15 as well as green pavement markings to denote PEV charging spaces. EVSP networks are also often interested in incentivizing PEV drivers to move on after they have finished charging. Tesla and EVgo reduce congestion at their charging stations by increasing the price of charging after a specified time interval (after which the vehicle should be close to full). Finally, automakers and charging providers can provide PEV drivers with charger hang tags such as those shown in Figure 16, and provide advice on systems to effectively share charging at multi-unit housing, workplaces and hotel charging. These can include use of a valet to rotate vehicles or simple online booking systems (for example through shared calendars).

Figure 15. PEV signage and green pavement lines required in Washington, Oregon and California[87]

[86] See, for example, Arizona Revised Statute 28-876; California Vehicle Code section 22511; Hawaii HRS § 291-72
[87] “West Coast Green Highway,” http://www.westcoastgreenhighway.com/evsigns.htm

Figure 16. Charger hang tags to indicate charging status and provide driver contact information

A final measure implemented by jurisdictions across the world to enhance PEV drivers' experience is the development of internal expertise on PEVs by electric utilities. Customers are accustomed to calling their electricity provider when they have questions about electricity use. As prospective PEV drivers have become curious about PEVs, they have begun to reach out to utilities with questions regarding PEV rates, safety, charging, metering and other infrastructure costs. Charging infrastructure providers also seek information on interconnection costs and processes and auto dealerships request information that they can pass on to their prospective customers. Utilities have therefore needed to prepare their customer service staff with the necessary answers. A number of utilities have attempted to lessen the need to provide customer service over the phone by creating website pages that display PEV information.

Other best practices for these public charging models, beyond those already raised, serve to simplify driver payment and communication experience. In Norway, use of radio-frequency identification (RFID) tags is the preferred way to start fast charging sessions.[88] This is viewed as an easier solution than credit card or cash payments, however the process for registering the RFID tags should be simple and it is important to have backup payment solutions (i.e., apps). This solution is also utilized in Abu Dhabi. An RFID system identifies a vehicle approaching the charging station at a distance of about 20 meters[89]. In Dubai, the Dubai Energy and Water Authority (DEWA)'s Green Charger program requires use of a Green Charger card. Obtaining the card requires registration of the car, of an Emirates identification card, driving license, vehicle license, and payment of a fully-refundable security deposit of AED 500.[90] In Jordan, at

[88] https://wpstatic.idium.no/elbil.no/2016/08/EVS30-Charging-infrastrucure-experiences-in-Norway-paper.pdf
[89]http://smartgrid.ucla.edu/pubs/Design%20of%20RFID%20Mesh%20Network%20for%20Electric%20Vehicle%20Smart%20Charging%20Infrastructure.pdf
[90] https://www.dewa.gov.ae/en/customer/innovation/smart-initiatives/the-green-charger-card

eCharge's stations, payments will be made through a smartphone app (mobile device application) that employs blockchain technology and eCharge's blockchain currency eCHG[91].

Communications standards to allow interoperability and "e-roaming" between charging station networks are desirable and initiatives to foster this are gaining regulatory traction. The multiple international programs within Europe cannot currently work together, but EU policymakers hope to unite these efforts with common standards through the Green eMotion regulations introduced in 2015. In Europe, the Open Clearing House Protocol (OCHP) is backed by many providers including operators in Germany, Netherlands, Belgium, Luxembourg, Austria, Ireland and Portugal. OCHP provides a standard protocol for communications between EVSPs, electricity suppliers and other actors across charging point networks to support "roaming platforms" in continental Europe. International Organization for Standardization / International Electrotechnical Commission (ISO/IEC) 15118 also facilitates e-Roaming, facilitating driver access to all charging stations with one contract through automatic payment authorization.[92]

In Europe, "roaming" systems are regional or national. EU-wide legislation on interoperability of payment systems was introduced in 2014 (the EU Alternative Fuels Directive 2014/94/EU), however this was after a variety of non-compatible systems had already evolved. Under this regulation, all charge points which are accessible to the public must be usable by anyone without the need to enter into a pre-existing contract: operators must provide a "pay-as-you-go" option. Prices must be "…reasonable, easily and clearly comparable, transparent and non-discriminatory" and health and safety compliance is defined to be the responsibility of the CPO. In the U.K., the Electric Vehicles Bill implementing EU Directive 2014/94/EU states that CPOs must ensure public charge-points are compatible with all vehicles, standardizes how charging sessions are paid for, and establishes reliability standards. More time (and further legislation) are needed for full interoperability.

Implications for Oman

If Oman desires to take steps to facilitate driver experience, the Ministry of Transport should:

- Standardize roadway signage for public PEV charging
- Require the use of standardized signage at public PEV charging stations
- Fund a public database of locational data on public PEV charging, for use in government or private applications
- Encourage automakers to provide information to PEV purchasers on charging etiquette, including plug hangers

In addition, AER should ensure that distribution companies develop internal expertise on PEVs as part of their commitment to customer service. Distribution companies could lessen the need for customer service provision over the phone by creating website pages that display PEV information. Distribution companies could also consider establishing a PEV coordinator role to coordinate PEV activities.

- MoCI should evaluate enacting regulations, or licensing the driver billing function, to ensure interoperability of payments systems similar to the EU Alternative Fuels Directive 2014/94/.

[91] http://echarge.work/
[92] http://emotorwerks.com/images/PR/Articles/sepa-managed-charging-ev-report.pdf

MoCI could also consider requiring interoperable radio-frequency identification (RFID) or a future similar technology.

- MoCI should evaluate enacting regulations to ensure "e-roaming" capability, such as the Open Clearing House Protocol (OCHP).

I. Ensuring PEV safety

Similar to ICE vehicles, PEVs must undergo normal vehicle testing and safety standards. In addition, PEVs require safety measures unique to the PEV propulsion system. These include isolation or de-activation of the high voltage electric system in case of an accident as well as battery protection measures. Additionally, PEVs have a lower center of gravity than conventional vehicles, making them less likely to roll over. PEV safety issues include their quiet operations which can lead to safety hazards because pedestrians are not aware of their approach, as well as the risk of tripping over the power cord while the vehicle is connected to a charging source. Conventional ICE LDVs also experience safety issues such as the potential for ignition of an oil or fuel leak, and fires occurring while vehicles are refueling.

For a PEV, the key safety concern is the battery. Most PEV battery technologies are not expected to be present in Oman. These include flooded lead acid batteries which have poor energy per unit mass and if overcharged can produce hydrogen sulfide which is poisonous and flammable; nickel iron batteries which also release hydrogen; nickel cadmium batteries which have high self-discharge rates as well as end-of-life cadmium disposal issues; and nickel metal hydride batteries which also have high self-discharge rates, particularly in high temperature environments. Battery safety issues are therefore likely those related to lithium ion batteries.

The critical issue related to lithium ion batteries is ignition. While battery management protection devices are installed to prevent over charging and vehicle batteries have crush and puncture protection, there are many instances of lithium ion batteries igniting. Lithium ion batteries burn at over 900° F, are difficult to extinguish they have ignited, and can re-ignite. Lithium ion batteries can also experience a phenomenon known as thermal runaway under which temperature increases facilitate further temperature increases leading to overheating and fires. Furthermore, while PEVs are manufactured to high safety standards, there remains the potential for electrocution if the PEV is involved in an accident. First responders must receive special training in dealing with these situations.

Lastly, there is a global awareness surrounding end-of-life issues for lithium ion batteries. For example, China is implementing rules to make carmakers responsible for expired batteries and to keep them out of landfills. The EU is examining whether existing EU laws limit re-use of EV batteries for uses such as energy storage. Several end-of-life options for lithium ion batteries have been proposed. These include recovery of any valuable materials through smelting, or direct recovery and second life use as a grid resource to provide peaking capacity and ancillary services. It is currently unclear whether degradation, duration and reliability issues may impede this potential solution.

Implications for Oman

- There are no specific safety recommendations for PEVs in general. PEVs that enter Oman will meet manufacturer safety criteria as well as Omani safety criteria which are expected to be largely based on GSO standards.
- PEV batteries are expected to be Lithium Ion. Public Authority for Civil Defence and Ambulance should ensure that first responders have appropriate training in dealing with PEVs if they are involved in accidents. Note that PEVs from neighboring countries may also be on the roads in Oman so if Oman has more stringent requirements they may not be universally applicable.
- With a view to stimulating Oman's economy, lithium-ion battery recovery industries and pilot projects for second-life uses of batteries could be investigated by the SCP.

8. International best practices in regulation and policy: Promoting PEV adoption

There are a number of policies that have been enacted around the world with the goal of overcoming the PEV adoption barriers described in Section 6. These can serve as models for Oman if and when the Sultanate determines that promoting PEV adoption is a policy priority.

Measures included in this category include:

- Ensuring sufficient and reliable public infrastructure
- PEV sales mandates
- PEV adoption goals and ICE bans
- Increasing charging infrastructure in parking structures, workplaces, and multi-unit housing
- Education and outreach
- Reducing upfront vehicle costs and fueling costs
- Providing non-pecuniary benefits
- Converting government or commercial fleets
- Incentivizing dealers to sell PEVs

These are further explored below. The first of these measures – ensuring sufficient and reliable public charging infrastructure - will likely involve the most significant action by AER. The remaining actions would likely require significant action by other stakeholders.

A. <u>Ensuring sufficient and reliable public charging infrastructure</u>

As described in Section 6, access to public charging infrastructure is a key barrier to PEV adoption. The lack of public charging in Oman will likely reduce the willingness of aspiring early adopters of PEVs to purchase vehicles. As PEV markets then develop and provide more PEV models suitable for the Oman market, public charging infrastructure is likely to emerge as a top barrier to more widespread adoption. The provision of public charging is a 'chicken and egg' problem: it must be sufficiently available to minimize range anxiety and enable PEV purchases, but without significant PEV adoption it does not provide viable business models for the private sector. This is particularly the case for DCFC, which is much more expensive to install than Level 2 charging. To solve this issue, leading PEV jurisdictions have installed networks of public charging funded by government agencies or utilities. As discussed in Section 7B, these public charging installations have generally used two business models:

Model 4: Investment by government entities, with ownership by either government or private-sector EVSP networks, and

Model 5: Investment and ownership by electric utilities

In addition to filling the general need for public infrastructure, these two models allow policy makers and regulators to have control over the specifications and locations of the initial public charging network. For example, they can define specific installation locations to maximize driver convenience, avoid network gaps and minimize impacts on utilities' distribution networks,[93] and can specify connectors, payment systems, interoperability and other technical specifications. These models can also enable jurisdictions to ensure ongoing maintenance of stations, either through contracts with EVSPs or by compelling utilities to ensure stations remain in working order.

There are a number of examples of Model 4. The United States' Department of Energy's EV Project installed approximately 14,000 Level & 300 DCFCs EVSEs in 2011 – 2013, including many in public. These were subsequently sold to the Blink network. Also, in the United States, the West Coast Electric Highway was funded by state government agencies in Washington, Oregon and California to connect these west coast states for PEV drivers. In Quebec, Canada, the province funded its extensive "Electric Circuit" public charging network by combining funds from municipalities, government entities and businesses. In Ontario, Canada, the Electric Vehicle Chargers Ontario program provided $20 million to expand the province's Level 2 and DCFC charging network. In Europe, Estonia's government installed a national PEV charging network, 165 DCFCs in 2012 - 2013, contracting with ABB to install and maintain the network. In August, Estonia's state-owned electricity distribution network purchased the network in an auction, with the obligation to continue offering the service for at least 5 years and to improve service and user-friendliness. The Netherlands' National Charging Infrastructure Knowledge Platform Foundation allowed local authorities to apply for federal funds for public charging, as long as a private sector partner also contributed. In Norway, public agency Enova has been the main sponsor of public charging. Enova is funded through natural gas and petroleum sales and promotes greenhouse gas (GHG) emissions reductions and energy efficiency. In London, a consortium of public and private organizations partnered to fund and install the Source Network of more than 1,400 PEV charge points.

A final, novel example of this model is the recent partnership of a number of cities (London, Los Angeles and Seattle) with private sector EVSP Ubitricity. Ubitricity installs plugs in streetlights, and drivers can then purchase a connector that includes a Level 2 EVSE and plugs into these plugs. Cities have sometimes kept the marginal costs of installing this solution low by rolling it out at the same time as a planned upgrade of streetlights to LEDs (light-emitting diodes). This solution relies on streetlights being near medium- to long-dwell time parking, and drivers may require a significant network of these plugs to ensure access (barring a ban on non-PEVs parking in these spaces). While it does not fill the need for DCFC, the business model may prove valuable in a portfolio of public charging solutions, and early trials will shed more light on benefits and drawbacks.

This model takes advantage of the significant experience of private sector EVSPs in siting, installing and maintaining EVSE and serving drivers. It can also help ensure the ongoing presence of private sector charging networks, which has been a priority for some regulators aiming for EVSP investment once PEV adoption is sufficient and who have been concerned that utility ownership may drive out the existence of the private sector in the meantime. However, this model requires thoughtful contracting and/or alignment of incentives between public agencies and private sector EVSPs to ensure on-time build out, sufficient power levels, public-interest siting, ongoing maintenance, and plans for eventual removal or replacement of infrastructure. These objectives have not always been achieved. For example, the Ontario

[93] Additional recommendations for siting DCFC can be found here: https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/EPIC-1.25.pdf

network experienced installation delays, insufficient installations in corridor locations (versus city locations) and poor maintenance. Power level for the DCFCs was also not specified, and because the EVSP selected to develop the stations bills based on time spent at the station, they installed "fast charging" with a power level of only 20 kW. The network in London saw poor maintenance outcomes because maintenance responsibilities were unclearly defined between the City's local Boroughs, equipment manufacturers, and retail hosts. To succeed, this model also requires a private sector EVSP that is willing to dedicate sufficient maintenance and driver support staff in the region, and has a viable operation to ensure they will remain in business for the long term. Jurisdictions that are geographically isolated or represent small or nascent PEV markets may struggle with this requirement. One way to lessen the impacts of a potential EVSP exit is to prescribe equipment and communications systems that can be easily maintained and engaged with by multiple EVSPs.

There are also many examples of Model 5: utility ownership of public charging infrastructure. Regulatory decisions on the cost treatment of utility-owned charging have differed. In Dubai, under the Green Charger Initiative, the Dubai Electricity and Water Authority (DEWA) installed 100 EVSEs, including a number in public locations offering free electricity until 2019.[94] This will increase to 200 EVSEs in 2018. How the cost of these charging stations is treated from a regulatory perspective has not been made public, and private sector EVSPs are also in operation. In a smaller pilot, Saudi Electricity Company recently signed an agreement with Tokyo Electric Power Company, Nissan Motors and Takaoka Toko to install three DCFCs. Cost sharing arrangements in this agreement have not been made public. In Canada, BC Hydro owns and maintains 30 DCFCs, leasing them to operators (mostly municipalities) for a small fee and charging the operator standard electric rates. Operators maintain half of these stations, while BC Hydro maintains the remainder and must ensure that all stations remain operational. In the United States, utility ownership in has been most strongly supported in states where legislation expressly defines a role for utilities in supporting transportation electrification and states with bold GHG mitigation goals. Examples of utilities that have received regulatory approval for cost recovery of public charging through rate base include Hawaiian Electric (Hawaii), Avista (Washington State), Rocky Mountain Power (Utah, Wyoming and Idaho) and Portland General (Oregon). However, some of these approvals are only for small pilots intended to jumpstart public charging networks.

In Europe, most of the early deployment of charging infrastructure in the Netherlands was facilitated by ElaadNL, an initiative set up by 7 electric grid operators. ElaadNL installed and maintain 3,000 public charge points. Ireland's ESB Networks (ESBN), the national transmission and distribution company, developed in 2013 a proposal for an "Electric Vehicle Pilot" to carry out a nationwide network of PEV charge points and supporting infrastructure, including 75 DCFC and 840 AC chargers across the country as well as some home charging units installed for free in the houses of private PEV drivers, and supporting operating software and systems.[95] The proposal was approved by the energy regulator in March 2014, enabling the budget of €25 million to be recovered by ESBN through distribution system charges. However, the regulator also determined that the ownership of the infrastructure would not be put in ESBN's regulatory asset base. Given the trajectory of Government policy (with a stated target that all new cars in Ireland should be zero emission by 2030), the regulator determined that ESBN should hold and

[94] Derek Baldwin, 2014, "Electric cars in Dubai come with these four free perks," https://gulfnews.com/news/uae/transport/electric-cars-in-dubai-come-with-these-four-free-perks-1.2095098

arrange for operation of the assets for a transitional period, with a view to selling the assets at a future point, timed to maximize the value that can be realized. In China, grid companies own some EVSE at highway locations. The regulatory treatment of their costs has not been made public.

A number of the utilities that own these networks contracted with EVSPs to provide installation, ongoing maintenance and billing for these stations. As noted previously, private sector EVSPs can bring valuable experience to these functions. Also, given the rapid increases in DCFC power levels, a best practice is emerging whereby distribution system upgrades required at public charging sites (particularly for DCFCs) are oversized to allow sufficient capacity for the installation of 1 – 5 additional EVSEs in the future, and/or distribution engineers take steps to help ensure equipment can be more easily upgraded. This has been the case, for example, for Hawaiian Electric's ongoing installation of DCFC EVSE. The applicability of this practice to any particular depends on a site-specific cost-effectiveness assessment that takes account of the ground surface materials, cost of distribution infrastructure, and the magnitude of likely loads from EVSE and other sources in the future.

Electric distribution utilities can be particularly well suited to address the infrastructure development challenges impeding PEV adoption. Their business model is designed to finance long-lived network assets through gradual recovery of the initial investment from its beneficiaries. The historic regulatory compact between investor owned utilities and their state regulators has kept financing costs in check by providing near certain recovery of capital outlays along with a fair rate of return. Public and municipal utilities are directly overseen by local government or elected governing boards, and local taxpayers are accountable to repay lenders any costs that cannot be recovered through rates. Finally, utilities are generally stable entities that will remain in a jurisdiction for the long term, unlike EVSPs that could fold at any time if they are not sufficiently successful in emerging PEV markets.

Nonetheless, there have been concerns raised in some jurisdictions, particularly in the US, about the potential for utility ownership of public EVSE to crowd out investment by private sector EVSPs. While utilities such as those described above have been instrumental in building charging networks, distribution operators in the United Kingdom and Germany are not permitted to own such infrastructure (though UK supply companies can), and regulations in many US states remain unclear regarding utility ownership and operation of EVSE. Some jurisdictions have preferred Model 1 – using public funds to contract with private sector EVSPs – as a way to help ensure private sector EVSPs can remain in business until such time as PEV adoption is significant enough for them to see viable business models and independently invest in public EVSE. As noted above, however, that model depends on the presence of a private sector EVSP able and willing to remain in the area for the long term.

There have been two other major criticisms of the utility ownership model. The first is that depending on utilities' compensation mechanism, they may be incentivized to install the equipment and collect a return on capital, but not necessarily incentivized to maintain EVSE if their electricity revenues are based on cost of service. This can be avoided by strict, enforceable requirements on maintenance. The second criticism has been that utilities are not experts in transportation (nor in modeling driver habits) and may therefore not have the best data or expertise to site charging for driver convenience or to ensure drivers' charging needs are met as they deploy and maintain EVSE networks. These are arguments for Model 1, involving private sector EVSPs, but these issues could also potentially be resolved by public agency funding of siting studies, and requirements that utilities learn from PEV experts before engaging in the business of PEV charging.

A third, and far less common, model that has been used to promote the provision of a public charging network, is utility ownership of only the make-ready infrastructure. Only two examples of this model have been seen, both in the United States: Pacific Gas and Electric in California and Eversource in Massachusetts. The intention of regulators in approving these programs is to stimulate investment by private sector EVSPs, non-profit organizations and local governments in public EVSE by lessening the magnitude of the investment required. Regulators approving these programs also cited the benefits to supporting a competitive EVSP market and limiting ratepayer investment versus full utility ownership. Both of these programs are just recently underway, so it remains to be seen whether this investment will be sufficient to stimulate significant public EVSE investment by private sector parties in these jurisdictions.

Implications for Oman

The lack of public charging in Oman will likely reduce the willingness of aspiring early adopters of PEVs to purchase vehicles. As PEV markets develop and PEV models suitable for the Oman market become available in Oman, public charging infrastructure is likely to emerge as a top barrier to more widespread adoption.

Oman, with a population of about 4.4 million and about 127,000 annual new car registrations[96] is a relatively small vehicle market on an international scale. With limited near-term demand for PEVs and a lack of mandate for automakers to sell PEVs, Oman is unlikely to see private-sector EVSPs operating in Oman in the near term, or the deployment of public charging networks by automakers.

Oman could engage automakers and private sector EVSP networks to confirm this understanding and gain insights into the barriers they face in Oman, and changes they would require to incentivize their investment in public charging infrastructure

If promotion of the PEV sector is desired, distribution companies are well placed in Oman to deploy a limited number of DCFCs in key public charging locations. In the short run, the focus of public charging should be on DCFC for corridor charging to enable longer trips, reduce range anxiety and avoid vehicle stranding. DCFC sites are the best match with dwell times and driver needs on these longer trips, and are most appealing to drivers. Distribution company ownership can help ensure availability and reliability of this core network. The positive PEV adoption impacts of this network may help to enable viable utilization levels and business models for private sector EVSP networks to enter and provide public Level 2 charging.

If distribution companies deploy this network, they should focus on public 350 kW DCFC EVSEs at key corridor locations, e.g. petrol stations or rest stops, sufficient to drive major long-distance routes across Oman and into neighboring countries. Lower-powered DCFCs (50 kw to 60 kW) face high asset stranding risk, as drivers will move to using best-in-class charging speeds as soon as they're available. Such infrastructure could be treated identically to conventional distribution infrastructure with respect to capital and operating cost recovery; alternatively, if distribution companies own infrastructure through an unregulated subsidiary, any AER regulation will likely depend on the subsidiary's sources of funding.

At least 2 DCFCs should be installed at each site, to create redundancy. If distribution system upgrades are required at these sites to install DCFCs, utilities should investigate the cost-effectiveness of oversizing installed capacity to allow for the installation of up to 5 additional EVSEs per site in the future, and/or

[96] https://timesofoman.com/article/79270

distribution engineers should investigate any steps that can be taken to help ensure equipment can be more easily upgraded in the future.

If private sector EVSPs are operational in the region at the time that AER seeks to enable utility-owned networks and if they are deemed to be sufficiently committed to long-term operations in Oman, then if distribution companies are allowed to invest in EVSE (Model 5) then distribution companies should consider contracting with EVSPs to provide installation, maintenance and billing for EVSEs. This will require clear contracting that ensures fast response to maintenance issues, and the provision of a direct line of contact between drivers and the EVSP as drivers encounter issues in real time. Private sector EVSPs could bring valuable experience to these functions, but at this early stage of PEV market development, they may not be well established, leading to the risk that they are not successful. If distribution utilities engage EVSPs in this process, then they may wish to pre-qualify them using criteria similar to those used by California utilizes in their PEV programs, as referenced in Section 7. MoCI would likely have a role in this process.

If EVSPs are not well established at the time AER were to move forward with this initial buildout, then distribution companies should install and maintain DCFC stations. Provided utility-owned EVSE are defined as part of the distribution companies' distribution networks, distribution companies would be responsible for maintenance of this equipment as defined under their distribution and energy supply license. As a high-level illustrative example, placing DCFC every 50 km on the 270 km Oman stretch of the Muscat to Dubai route (taking the Al Batinah Expressway) would require installing DCFC at 6 sites. Assuming 2 DCFC ports at each site, and using U.S. cost estimates of $150,000 per site if 2 DCFC are installed at each site, this would cost approximately $900,000 USD or 350,000 OMR.

Further, MoTC should require petrol station tenders on new roadways to include at least two DCFCs. The obligation should be placed on the service area franchisee so that it is an integrated part of the bid for the franchise. The distribution company should be responsible for installing the service connection. The potential for the distribution company to install make-readies could also be examined; it is unclear whether this could be enabled under sector law.

B. <u>PEV sales mandates</u>

In an attempt to ensure the development and affordability of PEV models, ten US states (California, Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland and Oregon) have enacted a ZEV mandate that requires all car manufacturers to ensure a minimum number of credits earned by selling vehicles that are defined as zero-emission under the program, i.e. PEV or hydrogen fuel cell vehicles. Credits are allocated based on ZEV type: full battery-electric and fuel cell-electric vehicles receive more credits (1+ credit per vehicle) than plug-in hybrid vehicles (0.4 - 1.3 credits).[97] Vehicles with greater electric range receive more credits. For example, sale of a Tesla Model S (with a range of approximately 320 electric kilometers) provides 3.3 credits, whereas a Nissan Leaf (135 electric kilometers) is worth 1.8 credits. Manufacturers who exceed their minimums can sell tradable credits, though there are restrictions on the cross-state flow of credits. The ZEV credits required increase over time, growing about 4-fold between 2018 and 2025. Because PEV ranges vary between vehicles and are changing over time, it is not possible to translate with accuracy between credits required by the program

[97] Full rules can be found here: https://www.arb.ca.gov/msprog/zevprog/zevregs/1962.2_Clean.pdf

and percent of new vehicle sales. However, recent assessments suggest that automakers will need to reach less than 8% ZEV sales by 2025 in ZEV states.[98]

Motivated by air quality issues, China adopted the New Energy Vehicle Mandate, a modified version of the US ZEV mandate, in 2017. Based on the structure of the policy, estimates suggest that the policy will result in ZEV sales of approximately 3% in 2019 and 4% in 2020.[99] The EU is currently considering establishing a minimum production quota for electric vehicles for auto manufacturers.

Implications for Oman

Oman could set a zero-emission mandate which would require automakers to make sufficient sales of zero-emission vehicles in Oman to gain a defined number of ZEV credits in each year. This action would increase PEV adoption by forcing automakers to sell PEVs in Oman and would likely spur automakers to offer more vehicle models in the Oman market. This action should be dependent on automakers having developed the PEV models that consumers in Oman are willing to purchase.

C. PEV adoption goals and ICE bans

A number of jurisdictions have adopted PEV targets. These kinds of goals signal policy commitment by the government. They can be used as an anchor for further policy change and implementation and can send an investment signal to the private sector that PEV adoption will be encouraged and is expected to increase. For example, Washington State is aiming for 50,000 PEVs by 2020, and Germany seeks to have 1 million PEVs on the road by 2020. A number of cities and countries have proposed bans on the sale of new internal combustion vehicles by 2030, 2032 or 2040, including Mexico City, Paris, Madrid, Rome, Athens, Copenhagen, Germany, France, Norway, India, Ireland, Israel, and the Netherlands. Many of these are specific to diesel and linked to cities or countries facing poor air quality. Importantly, these policies are non-binding goals, not formal legislative or regulatory policies. Given the barriers described in Section 6, significant supporting actions and policies will be required to achieve these goals.

Implications for Oman

Oman could set a goal for the number of PEVs or ZEVs sold or on the road by a given year. Note however that such a goal may have little impact if not accompanied by additional policies to address adoption barriers, such as those described in the remainder of this section.

D. Increasing charging infrastructure in parking structures, workplaces and MUDs

There are a number of ways that stakeholders throughout the PEV ecosystem can enable charging infrastructure in commercial depots, workplaces and multi-unit dwellings. As mentioned in Section 8A, a number of public agencies and utilities provide subsidies on the upfront cost of PEV charging in these

[98] Honyang Cui, 2018, "China's New Energy Vehicle mandate policy (final rule)," https://www.theicct.org/sites/default/files/publications/China_NEV_mandate_PolicyUpdate%20_20180525.pdf
[99] *Ibid.*

locations. A number of not-for-profit groups and public agencies centered around environment and health also offer free workplace or public charging.

Cities, municipalities and states have also implemented building codes that require EV readiness. These have typically required that home and/or commercial builders install conduit, wiring and electrical capacity sufficient to support Level 2 charging but stop short of requiring installation of the EVSE itself. For example, the city of Atlanta in the United States requires all new residential homes be EV ready and also requires 20 percent of the spaces in all new commercial and multifamily parking structures be EV ready.[100] California has similar conditions on single-family homes, and requires that parking lots with over 100 parking spaces have EVSE conduit and service panel capacity to cover 3% of the parking spaces.[101] San Francisco's regulation goes even further than the state requirement, requiring that all new residential, commercial, and municipal construction have service capacity to simultaneously charge electric vehicles at 20% of parking spaces and also have the supporting infrastructure in place to install outlets at 100% of spaces.[102] New York City requires 25% of new parking spaces to be PEV-ready, i.e. equipped with wiring and panel capacity to supply charging.[103]

Finally, cities, municipalities and states have used zoning ordinances to ensure that EVSE installation is permissible at the state and local levels. For example, the state of Washington in the United States has a targeted approach to siting EVSE through municipal zoning, and provides model ordinances for use by its cities.[104] Alternatively, officials can incentivize the installation of EVSE by providing bonuses like additional floor area or reduced parking requirements in exchange for the inclusion of EVSE in new construction.

Implications for Oman

Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) should investigate the incremental cost and feasibility of including PEV readiness wiring (but not full charging infrastructure) in residential and commercial building codes. Note that this is included in our recommendations under the 'Preparing for PEVs' scenario. Even though it is a measure that has often been implemented to promote PEVs, the potentially low cost of this measure compared to the benefits it may bring to drivers in Oman makes it worth investigating even in a 'Preparing for PEVs' scenario.

E. Education and outreach

Limited awareness and familiarity with PEVs can be a major barrier to consumer adoption. To combat this, many jurisdictions have adopted efforts to educate consumers, car dealerships, building owners about the existence and potential benefits of electric vehicles. These efforts have been provided by public agencies, automakers, non-profit organisations, automakers, or through partnerships between these players. Activities have included providing information to consumers and dealerships via websites, utility

[100] Pamela Miller, 2014, "Atlanta passes "EV Ready" ordinance into law," https://www.ajc.com/news/local/atlanta-passes-ready-ordinance-into-law/N8rAik2uaeCOFwobjLtfkN/

[101] Charles Morris, 2014, "California Building Code to require all new construction to be EV-ready," https://chargedevs.com/newswire/california-building-code-to-require-all-new-construction-to-be-ev-ready/

[102] San Francisco Department of the Environment, 2017, "San Francisco Green Building Code," https://sfenvironment.org/green-building-ordinance-sf-building-code.

[103] https://www.theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf

[104] https://www.psrc.org/sites/default/files/electric-vehicle-guidance.pdf

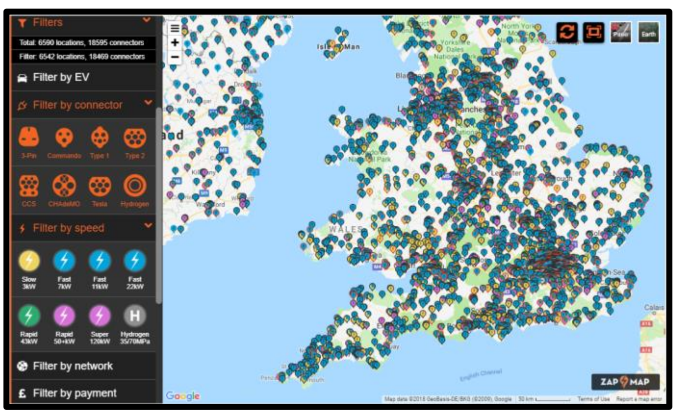
bills, showrooms, ‘Ride and Drive’ events, dealership trainings, and developing programs to expand EV exposure through fleets (for example, taxis and shared mobility fleets, rental cars, government fleets, and commercial fleets).

Key objectives in educating prospective drivers are to:

- Educate consumers on PEV types (BEV / PHEV), features, range and model availability;
- Provide tools for cost comparison between ICE vehicles and PEVs;
- Inform consumers regarding incentives;
- Introduce consumers to PEV charging options; and
- Help consumers understand PEV range and safety, and address range anxiety.

One example is the Go Ultra Low campaign (goultralow.com), a joint campaign of UK governments and industry to educate consumers about PEVs and provide tools for comparing ICE and EV costs, selecting a PEV, finding chargers, and other details. Screenshots from this campaign are shown below in Figure 17.

Figure 17. Screenshots from the UK's Go Ultra Low campaign showing a map of charging infrastructure and a cost comparison between PEV and ICE vehicle options



Key objectives in educating vehicle dealerships are to:

- Educate dealers on features of PEVs to prepare sales team to educate consumers on PEV and charging features and costs;
- Provide dealerships information regarding incentives available to consumers; and
- Help prepare dealerships to respond to common questions and anxieties of prospective PEV owners.

While the work of educating dealerships has fallen largely to automakers, funding from non-profit and government agencies has been made available for this purpose in jurisdictions focused on rapid growth in PEV adoption.[105]

Implications for Oman

- AER should ensure that distribution companies develop internal expertise on PEVs as part of their commitment to customer service. This would likely be a new stipulation in the distribution and supply license. Creation of websites could be helpful in providing some of this information.
- AER could enable distribution companies to engage in proactive driver, dealership, building owner and employer education campaigns on the availability and benefits of PEVs, e.g. through mailouts, advertising and 'Ride and Drive' events.
- Oman could embark on proactive education campaigns targeted at drivers, fleet owners, building owners, employers, homeowners' associations, and dealerships on the availability and benefits (including lower fueling cost) of PEVs and the details of PEV charging. Such education campaigns could include mailouts, advertising, 'Ride and Drive' events, dealership trainings, and workplace / multi-unit housing 'how to' guides for EVSE deployment.

F. Reducing upfront vehicle costs and fueling costs

A number of governments provide rebates, tax credits or tax exemptions for PEVs. In Europe, a number of countries provide value added tax (VAT) exemptions for PEVs. In addition, upfront rebates are offered in Belgium, France, the UK, Germany and Sweden, and range from €4,000 to €10,000. The United States provides a $7,500 federal tax credit for full battery-electric vehicles and a $2,500 tax credit for plug-in hybrids,[106] though these rebates are capped at 200,000 vehicles per automaker and Tesla recently became the first manufacturer to reach its cap.[107] The International Council on Clean Transportation found that additional rebates, tax credits, or substantial tax exemptions were available in 19 of the 50 leading PEV US metropolitan areas they studied, mostly provided by states. The value of these incentives ranges from $1,750 (Pennsylvania) to $5,000 (Colorado).[108] In Canada, British Columbia offers a rebate up to $5,000, with additional money available to those scrapping old vehicles and Quebec provides up to $8,000 depending on the retail price of the vehicle.[109]

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[105] https://www.zevstates.us/wp-content/uploads/2015/12/Dealership-Recognition-Programs-and-Recommended-Practices1.pdf
[106] https://www.energy.gov/eere/electricvehicles/electric-vehicles-tax-credits-and-other-incentives
[107] Fred Lambert, 2018, "Tesla confirms hitting federal tax credit threshold, $7,500 credit cut in half at end of 2018," https://electrek.co/2018/07/12/tesla-tsla-federal-tax-credit-threshold/
[108] Peter Slowik and Nick Lutsey, 2018, "The continued transition to electric vehicles in US cities," https://www.theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf
[109] https://emc-mec.ca/ev-101/ev-incentives/

PEVs may also be exempted from vehicle registration or other government fees. For example, a package of PEV benefits unveiled by Dubai in 2014 includes free vehicle registration and renewal fees for PEVs.[110] This is also the case in US states California and Arizona.[111]

It is also worth noting that since full battery-electric PEVs do not use gasoline, they do not pay local, state and federal gasoline taxes. However, some jurisdictions have implemented or are considering other methods for collecting roadway infrastructure costs usually paid for by gasoline taxes, for example through an *addition* to registration fees or a fee based on vehicle kilometers traveled.

Implications for Oman

Oman could lower the upfront cost of PEVs by providing upfront subsidies, tax credits, tax exemptions or registration fee exemptions on vehicles and/or charging equipment. However, depending on when Oman were to begin promoting PEVs, the level of incentive needed may be small or zero due to expected cost declines in PEV batteries.

G. Providing non-pecuniary benefits

There are a number of additional benefits intended to increase PEV adoption. For example, high-occupancy vehicle (HOV) lane access, which is typically limited to vehicles with 2 or more occupants (or 3 or more) vehicles, is provided for PEVs with only one occupant in some jurisdictions. For example, in California's congested areas, especially the Los Angeles area and the San Francisco Bay Area, it is considered a significant benefit.[112] This HOV access is sometimes combined with a waiver on bridge or road tolls. This is the case for the Oakland to San Francisco Bay Bridge. Dubai provides free SALIK tags to PEVs, though trips through the SALIK gate are still charged, i.e. PEVs are not exempted from the tolling fees themselves.[113] London provides a waiver for PEVs on congestion fees paid by residents to access its city center.[114] A number of local jurisdictions also provide free or discounted municipal or airport parking to PEVs. Examples of this are 220 free city parking spaces in Dubai,[115] discounted street parking in the UK town of Westminster,[116] and free airport and downtown parking in Honolulu, Hawaii.[117] China also provides a novel incentive to buy a PEV. In order to restrict the total number of vehicles on the roads, municipal governments in some provinces and municipalities in China in Beijing and Guiyang run lotteries for new vehicle registrations and associated license plates. PEVs are provided preferential treatment in this system. For example, in Shanghai, PEVs are not required to pay auction fees for license plates,

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110 Derek Baldwin, 2014, "Electric cars in Dubai come with these four free perks," https://gulfnews.com/news/uae/transport/electric-cars-in-dubai-come-with-these-four-free-perks-1.2095098

111 Peter Slowik and Nick Lutsey, 2018, "The continued transition to electric vehicles in US cities," https://www.theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf

112 Gil Tal and Mike Nicholas, 2014, "Exploring the Impact of High Occupancy Vehicle (HOV) Lane Access on Plug-in Vehicle Sales and Usage in California," https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2355.

113 https://www.salik.gov.ae/en/news/free-salik-tags-for-electric-cars-in-dubai

114 https://tfl.gov.uk/modes/driving/congestion-charge/discounts-and-exemptions

115 Shafaat Shahbandari, 2018, 220 free parking slots for electric cars," "https://gulfnews.com/news/uae/transport/220-free-parking-slots-for-electric-cars-1.2150427

116 https://www.westminster.gov.uk/electric-vehicles

117 http://energy.hawaii.gov/testbeds-initiatives/ev-ready-program

reportedly about 40,000-60,000 yuan per quarter. The Beijing government has announced lower and lower quotas for allowed new vehicle registrations, with higher and higher percentage carve-outs for ZEVs.

Implications for Oman

- Oman could offer free public parking to PEVs at any paid locations, as well as free airport parking.
- MoTC could provide high-occupancy (HOV) lane access and waivers on toll roads to PEVs, if and when these forms of congestion management are implemented in Oman.
- Oman could provide upfront, priority parking spaces with charging to PEV drivers at government buildings, and encourage retail locations to do the same.

H. <u>Converting government or commercial fleets</u>

Commercial fleets have often provided some of the best economic cases for PEVs because they often drive more kilometers than personal vehicles, and therefore see larger gasoline and maintenance savings versus conventional vehicles. Public fleets can provide a useful demonstration of PEV technologies for others to follow. Recognizing this, Japan, France, UK, US, China, Canada, Norway, Sweden signed a Government Fleet Declaration in Morocco in 2016 to commit to varying levels of ZEV procurement in their government fleets.[118] Some utilities have also begun engaging with their fleet customers to advise then on the benefits of electrification. Amsterdam and Dubai have recently incorporated fleets of Teslas into their taxi fleets.[119]

Implications for Oman

- Oman could set PEV fleet conversion targets or mandates for government fleets
- AER could engage fleet vehicles as early adopters when viable:
    - Engage distribution companies to use a small number of PEVs in their fleets as they become available and affordable.
    - Leverage energy efficiency auditing efforts to engage public and private fleets on PEVs as they become available and affordable in Oman.

  However, engaging with these users before PEVs are available and affordable will likely not be successful.
- Oman could engage rental car companies to assist in enabling PEV conversion of these fleets as existing vehicles are retired
- Short of mandating PEVs in licensing, conversion of Oman’s taxis to PEVs through policy or regulation is likely to be a challenge, as taxis are owned by individual drivers. However, Oman should engage Mwasalat to assist in continue assessing drivers’ appetite for PEV vehicles and

[118] https://www.iea.org/media/topics/transport/EVI_Government_Fleet_Declaration.pdf
[119] https://insideevs.com/dubai-officially-deploys-tesla-model-s-x-taxi-fleet/; https://electrek.co/2018/04/23/tesla-taxi-fleet-amsterdam-airport-updated-model-x/

provide assistance where it can, for example in providing education on the potential for PEVs to provide beneficial economic cases for individual drivers.

I. Incentivizing dealers to sell PEVs

As mentioned in Section 6, incentivizing vehicle dealership staff to sell PEVs can be a challenge, even when automakers carry the vehicles, due to the lack of knowledge often held by dealers about these vehicles and the perceived added complexity of the sale versus for a conventional vehicle. Efforts to reduce this barrier have largely focused on education programs (see Section 8E above), but there have been a small number of non-automaker programs that offer financial incentives to dealers to sell PEVs. One example is a program in the US state of Connecticut that provides incentives to dealers as well as awards to dealers with the most PEV sales in the state.[120] Funding is currently provided Avangrid as the result of a Settlement Agreement between Iberdrola USA Inc and UIL Holdings Corporation and was previously funded as part of a broader energy efficiency initiative from a different settlement related to a utility merger.[121]

Implications for Oman

Oman could offer financial incentives to dealers to sell PEVs.

[120] https://www.autoblog.com/2014/05/06/ct-incentivizing-dealers-instead-of-buyers-to-sell-more-evs/;
https://energycenter.org/program/connecticut-hydrogen-and-electric-automobile-purchase-rebate-program
http://www.govtech.com/fs/Cash-Incentive-Program-Part-of-Electric-Vehicle-Push-in-Connecticut.html
[121] https://www.ct.gov/deep/cwp/view.asp?a=2684&q=561426&deepNav_GID=2183#faq3

9. Summary of Oman-specific recommendations

The assessment laid out in this report suggests that, barring the introduction of policy mandates, PEVs will take until 2021-2023 to be offered and adopted in Oman at a level material to planning efforts and costs borne by Oman's distribution companies. This is due to the barriers described previously:

- The inability of current PEV models to satisfy local driver preferences for large vehicles;
- The relatively small automotive market in Oman with no zero-emission vehicle mandate, making it unlikely that the country receives larger PEV models immediately even once they are being produced;
- The need for large vehicle battery capacities in Oman, due to the significant average driving distances and the battery drain caused by air-conditioning;
- The lack of public charging infrastructure; and
- The upfront cost premium for PEVs over internal combustion engine vehicles, which will likely negatively impact PEV sales even if low-cost electricity and lower maintenance costs makes PEVs economic on a total cost of ownership basis.

However, when such vehicles are readily available, the economic and other benefits suggest that customer demand will grow quite quickly. It is therefore essential to use the interim period to prepare the overall framework. The short term (1-3 year) "Preparing for PEVs" recommendations provided below are therefore designed to lay the regulatory groundwork to ensure safety, minimize system impacts and maximize driver convenience as PEVs begin to see more significant adoption in the mid- to longer-term. Recommendations for the medium term (4- 6 years) suggest factoring PEV adoption into distribution, procurement and labour planning. In the longer term (7+ years), it is recommended that AER and other entities in Oman periodically reassess their actions against evolving PEV technologies and market developments.

Recommendations for AER and other Oman government entities follow below. Within the 1-3 year time frame, our recommendations for AER and distribution companies are prioritized as high (H), medium (M) and low (L) based on the expected regulatory impact of the recommendation.

PREPARING FOR PEV ADOPTION

<u>'Preparing for PEVs' recommendations to be implemented by *AER* in the short term (1-3 years):</u>

Priority	Category	Recommendation for AER	Rationale
H	***Licensing and regulating third-party EVSPs***	• **AER should support enabling third-party EVSPs to operate in Oman** ○ EVSE *<u>installation</u>* should not be licensed but should conform to relevant building, wiring & installation codes. ○ EVSE *<u>ownership,</u>* *<u>investment</u>*, *and* *<u>hosting</u>* should not be regulated or licensed, except in the case where distribution companies may own EVSE (see 'Promoting PEVs' below).	• EVSPs operating in international markets will bring the expertise required to deploy and maintain charging solutions for PEV driver at home, work, commercial depots, and in public. AER and others should remove regulatory barriers to their operation • Enabling third-party EVSP ownership and investment does not preclude distribution company ownership and investment at a future date if Oman desires to promote PEV adoption.

Priority	Category	Recommendation for AER	Rationale
H	***Licensing and regulating third-party EVSPs***	• **AER should not regulate EVSPs engaged in resale of electricity for PEV charging as electricity suppliers.** EVSPs cannot fulfil the obligations placed on suppliers under Sector law such as in relation to meeting reasonable demands for supply, and procuring electricity only from OPWP. Additionally, Sector law regulates the supply of electricity to any Premises, where Premises is defined to be "any plot of land, building, or structures occupied or used by any Person." • Third-party EVSPs, if they are not electricity suppliers under the law, should be allowed to re-sell electricity at a price exceeding the tariff rates that licensed suppliers are obliged to charge in order to permit them to recover the additional costs they will incur in providing charging services. **AER should support this interpretation with any government entities that may be involved in regulating resale of electricity by third-party EVSPs.** • If third-party EVSPs are not suppliers, **AER should not regulate the rate structure that third-party EVSPs utilize to bill drivers for charging services.**	• Many international jurisdictions do not regulate EVSPs as suppliers, specifically carving out PEV charging as exempt from regulation. Sometimes this regulatory treatment is limited to LDV charging. In these cases, tariffs paid by EVSP customers for PEV charging are also not regulated. • In jurisdictions where resale of electricity requires that EVSPs be regulated as suppliers, there are examples of EVSPs re-selling electricity if they are not charging fees on a per unit of electricity consumption basis (i.e., by parking space or per time spent charging).

Priority	Category	Recommendation for AER	Rationale
H	***Licensing and regulating third-party EVSPs***	• **AER should ensure that electricity supply is billed at cost** in the case of master meter customers sub-metering electricity for PEV charging in multi-unit dwellings with assigned spaces or in the workplace with assigned spaces.	• This recommendation reflects common international best practices regarding submetering in the case of electricity resale. • Distinction between sub-metering at cost and offering additional charging services above cost needs to be clarified in these situations.
H	***Data safety and security***	• **AER should investigate the extent to which distribution company systems could be vulnerable to malware installed in PEVs or EVSE** and ensure appropriate security measures are described in its cyber security standard.	• Malware installed in PEVs has the potential to affect the electricity grid and/or charging infrastructure.
H	***Rate design and metering***	• One of the important benefits of PEV penetration is that rates for all customers can decrease with increased throughput because fixed costs are spread over more usage provided that charging is carried out during the most economic time periods. Under the current mechanics of Oman's multi-year rate determination, allowed revenue increases with increased loads and there is not a corresponding decrease in rates due to increased throughput. **This should be examined in AER's future ratemaking analysis.**	• If the throughput effect will not occur under the mechanics of the multi-year rate determination, key benefits of PEV penetration will not accrue to ratepayers.

Priority	Category	Recommendation for AER	Rationale
H	***Safety of EVSE***	• **AER should update wiring regulations** to ensure that they incorporate appropriate safety requirements specific to EVSE	• To ensure safety
H	***Regulating EVSE***	• **AER should work with MoCI to ensure that vehicles and EVSE brought into Oman incorporate ISO/IEC 15118 protocols and that public EVSE are OCPP compliant.** GSO draft standards appear to specify ISO/IEC 15118 for vehicles. • AER and MoCI should work together to ensure communication interoperability of charging stations. This may require some form of regulation of EVSP ownership.	• This will facilitate interoperable infrastructure and future smart charging programs implemented by distribution companies, third-party EVSPs, or other aggregators.

Priority	Category	Recommendation for AER	Rationale
H	***Rate design and metering***	• **AER should conduct a cost of service and rate design study.** Study scope should include determination of whether PEV-specific TOU rate(s) can be designed to be lower cost than the default permitted tariff and CRT structures if charging is accomplished during off-peak hours. Such PEV rates could potentially include discounts for interruptible service (generation capacity and network capacity) or demand subscription mechanisms. PEV rates can be examined for both residential and commercial customers. Additional issues that could be examined include the interplay of the Sahim program with PEV charging and multi-year rate determination throughput impacts.	• Off-peak charging prices lower than the subsidized residential rate will help incentivize PEV adoption, particularly for customers who want to invest in Level 2 charging. • There is an example in Oman for rate discounts to incentivize customer behavior. Industrial customers that use natural gas can receive a discounted natural gas rate if they offset their usage from electricity with on-site renewable power. Note this example is from the natural gas industry and involves on-site generation rather than consumption change. • Oman's PEV customers should not be forced to take service on a rate specific to PEV end uses. However, if PEV customers can be offered a rate option with a lower off-peak rate than the default tariff for off-peak PEV charging then they should desire to take service on the more economic rate.

Priority	Category	Recommendation for AER	Rationale
M	***Communication enabling vehicle-to-grid integration***	• Technology continues to revolve rapidly. **AER should begin continuously investigating Level 2 and DCFC communication and metering communication options** to ensure that EVSEs eventually deployed will have the necessary communications attributes including ability to instruct charging, send price signals, customer charging time needs, battery state-of-charge, and desired interoperability. • **AER should investigate how active control of PEVs to provide V1G services can best be accomplished on its system.** This could be directly via distribution company instruction to individual PEVs or EVSPs, or through instruction to EVSPs or aggregators. • **AER could allow a distribution company pilot to test appropriate architectures, communication avenues, and technical configurations.** Additionally, solutions to power quality issues could be tested.	• Active control of PEVs can provide benefits to the grid incremental to customer behavioral response to rate structures • As more PEVs are added to Oman's grid, it is likely that the value of this functionality will become material

M	***Inter-agency coordination***	• **AER should continue coordination on PEVs with distribution companies, ministries, OPWP and the Supreme Council of Planning**. • Specific points of intersection are addressed throughout the recommendations below, but high-level, ongoing engagement between all players is also recommended as new market developments occur in PEVs and charging and further national strategies develop on economic development, climate, electric rates, electricity procurement, and gasoline pricing as these may impact provision of electricity. • **AER engagement should also include international parties** such as Abu Dhabi Water and Electricity Authority (ADWEA), the UAE regulatory and Supervision Bureau (RSB), the Dubai Electricity and Water Authority (DEWA), the Saudi Electricity Company (SEC) and Jordan's Energy and Minerals Regulatory Commission (EMRC).	• This is an international best practice in PEV planning and policy, as PEVs impact and are impacted by policymaking and regulation in transportation, economy, city planning, climate and energy. In Oman, a number of players will continue to be involved in the ongoing evolution of PEVs: o PEVs will likely play a role in the Ministry of Environment and Climate Affairs' efforts to meet the Sultanate's commitments under the United Nations' Paris Agreement Regulation of vehicles and charging infrastructure is under Ministry of Commerce purview o Ministry of Commerce and Industry will be approving PEV and EVSE specifications o Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) will need to adapt building codes, zoning and planning o The Ministry of Transportation's plans and implementation strategies will have implications for PEV planning o The Ministry of Oil and Gas will impact PEV adoption through their pricing of petroleum and may also see impacts as more consumers move to PEVs o Distribution company and OPWP regulations and planning efforts will need to reflect policy goals and changes by AER, the ministries and the Supreme Council of Planning, including ensuring ability for

Priority	Category	Recommendation for AER	Rationale
			demand-side participation in wholesale and ancillary markets
M	***Power quality***	• **In residential installations, AER should encourage installation of Level 2 (versus Level 1) EVSE with IEC 15118 communication protocols.** ○ To encourage Level 2 charging, AER could offer rate structures with very low off-peak charging costs in exchange for separately metered PEV loads.	• Increases in electrical loads related to penetration of PEVs will eventually require addition of generation capacity unless charging can be accomplished during off-peak periods • Phase imbalance is a single-phase service issue. In Oman, residential service above 20 kW is typically provided as three phase. This level of load can likely be achieved (if not already present) with the addition of Level 2 charging. • Off-peak charging prices lower than the subsidized residential rate will help incentivize PEV adoption, particularly for customers who want to invest in Level 2 charging.
M	***Rate design and metering***	• **AER should ensure that distribution companies are able to install metering appropriate for implementing desired rate structures and/or to enable any DR program functionality that would be accomplished via smart meters**. Existing residential meters have 30-minute usage resolution and are likely appropriate for metering a separate PEV TOU structure.	• Necessary to enact rates and programs.
L	***Distribution company ownership of PEV infrastructure***	• **In the 'getting ready' scenario, AER is assumed to not allow distribution companies to own or install make readies in any charging locations**. See 'Promoting PEV' for further discussion of utility ownership of charging infrastructure.	

Priority	Category	Recommendation for AER	Rationale
L	***Data safety and security***	• AER should consider including in its Cyber Security Standard: ○ Ensuring that for distribution company systems, customer data (name, address, account number, consumption) is secure and not disclosed except to authorized third parties with appropriate security procedures. ○ AER should consider including in its Cyber Security Standard ensuring that distribution companies are not held responsible for the security, use or misuse of that data in a scenario where a customer chooses to disclose its consumption data to a third party that is unaffiliated with, and has no business relationship with, the utility.	• If third party EVSPs are allowed to operate in Oman, EVSPs will possess driver electricity consumption data. It will be important for AER to delineate where its responsibilities lie with respect to this data. • The CAN (Controller Area Network) bus and telematics are avenues through which malware can infiltrate a vehicle. EVSEs do create an additional channel through which this could occur.

‘Preparing for PEVs’ recommendations to be implemented by *distribution companies* in the short term (1-3 years):

Priority	Category	Recommendation for Distribution Companies	Rationale
M	***Distribution company provision of information***	• **Distribution companies should develop internal expertise on PEVs as part of their commitment to customer service**. This would likely be a new stipulation in the distribution and supply license. o Distribution companies could lessen the need for customer service provision over the phone by creating website pages that display PEV information o Distribution companies could consider establishing a PEV coordinator role to coordinate PEV activities	• Utilities around the world have reported that they are often asked to provide this information to customers and industry: because electricity is the “fuel” for these new vehicles, distribution companies will increasingly become a public-facing fuel provider. This could also represent a point of differentiation among the distribution utilities if they are looking to develop supply customers outside their current geographic footprint once supply competition is in place. • As prospective PEV drivers learn more about these vehicles, they will reach out to distribution companies for questions regarding PEV rates, safety, charging, metering and other infrastructure costs. Distribution companies will need to prepare customer service staff with answers. • Distribution companies should expect similar questions from automaker dealerships • Charging infrastructure providers will wish to know interconnection costs and processes
L	***Distribution system planning***	• **Distribution companies should formally include PEV adoptions in their demand forecasting process and update their plans periodically to reflect expected PEV adoption** as a result of any PEV market developments, policy directives or goals established by automakers, ministries or Supreme Council plans	• This work will assist distribution company planners to factor PEVs into their future planning, design of future smart charging programs and rates. • Low priority in the near-term because PEV load penetration is not likely to be material during this period.

'Preparing for PEVs' recommendations to be implemented by *other entities* in the short term (1-3 years):

Category	Recommendation	Rationale
Improving driver experience	• When they begin selling PEVS in Oman, automakers should provide information to purchasers on charging etiquette, including plug hangers that are attached to charging connectors to indicate the PEV driver's level of charging need and provide their contact information. • MoTC should require the use of standardized signage at public PEV charging stations. • MoTC should evaluate funding a public database of locational data on public PEV charging, for use in government or private applications. • MoTC should work with MoCI to investigate the viability of including a requirement that compels EVSPs to provide data on public stations for use in this database, weighing the value to PEV drivers, the burden on EVSPs, and MoTC's ability to make use of specific data fields and to arrive at the right set of data fields for collection. • Municipalities should pass "anti-ICE laws" that create fines or penalties for internal combustion engine vehicles, or PEVs that are not plugged in, from occupying PEV EVSE parking spaces	• These recommendations will promote driver ease of use for charging stations, help enable PEV drivers to charge when they need to, and maximize return on investments in charging infrastructure.

Category	Recommendation	Rationale
Building codes and wiring regulations	• Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) should investigate the incremental cost and feasibility of including "PEV readiness" wiring (but not full charging infrastructure) in residential and commercial building codes • Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) should update building codes to ensure that they incorporate appropriate safety requirements specific to EVSE (See Section 7 for additional detail). • City planning and permitting officials should become familiar with any modifications made to building codes, wiring regulations or electrician licenses to accommodate EVSE requirements, and adopt any appropriate requirements into their own regulations	• Trenching, boring and panel upgrades can be much less expensive at the time of new construction than as retrofits. If PEV forecasts for other parts of the world hold true for Oman, large numbers of Oman residences will benefit from PEV charging within each building's expected lifetime. However, not all homes and workplaces will desire PEV charging. It will therefore be useful to compare the incremental cost of wiring for PEV charging upfront, assuming some buildings never use it, to the cost savings achieved by installing this infrastructure at the outset. • Changes to building codes and wiring regulations will help ensure the safe installation of EVSE.
Autonomous vehicles	• All impacted government bodies should learn from cities and regulators elsewhere as they begin to develop regulatory approaches for autonomous vehicles	• These vehicles will likely have a significant impact on Oman's transportation systems, but they are currently only in the pilot stages so such lessons are only just now beginning to become available.
PEV safety	• PEV batteries are expected to be Lithium Ion. Public Authority for Civil Defence and Ambulance should ensure that first responders have appropriate training in dealing with PEVs if they are involved in accidents. Note that PEVs from neighboring countries may also be on the roads in Oman so if Oman has more	• These recommendations will help ensure the safety of PEV vehicles.

Category	Recommendation	Rationale
	stringent requirements they may not be universally applicable. • With a view to stimulating Oman's economy, lithium-ion battery recovery industries and pilot projects for second-life uses of batteries could be investigated by the Supreme Council for Planning.	
Standards for vehicles and EVSE	• MOCI should clarify DCFC charging connector standards with GSO. GSO final draft standards for CCS connectors do not specify CHAdeMo, CCS, CCS Combo, Tesla or G/TB connectors. GSO should clarify that DCFC should include at least both CHAdeMO and SAE Combo connectors until such time as the automobile industry adopts a single standard. • MoCI should establish standards for EVSE entering Oman should specify a minimum warranty (e.g. 2 years) and specifications similar to those required by Abu Dhabi such as achievement of BS EN 61851 (electric vehicle conductive charging system) requirements, the ISO 9001 manufacturer certificate of quality management requirements, ISO/IEC 17025 test certificate.	• These recommendations will increase PEV driver convenience and help avoid investment in infrastructure that may not be required.

Category	Recommendation	Rationale
Licensing and regulating third-party EVSPs	MoCI should regulate certain aspects of EVSE: ○ For public EVSEs, the requirement for periodic testing of EVSE covering equipment safety and measurement aspects including ensuring EVSE is not vulnerable to malware. Safety testing could also be considered for workplace and multi-family charging locations. ○ A requirement for payment inter-operability at public EVSEs should be ensured, similar to the EU Alternative Fuels Directive 2014/94/. MoCI could also consider requiring interoperable radio-frequency identification (RFID) tags or a similar user-friendly solution. ○ MoCI could also consider establishing standards for the implementation of future e-roaming solutions such as the Open Clearing House Protocol (OCHP). ○ [entity TBD] should ensure that data policies of EVSPs fall under Oman's general data policy regulations	• These recommendations will ensure safety, accuracy, interoperability, and customer ease of use of EVSEs installed in Oman
Licensing and regulating EVSE installers	• No specific license for installing EVSE is recommended • Individuals installing and maintaining EVSEs should be required to be licensed electricians. • [Entity TBD] should consider modifying electrician license procedures to include special training in installing charging stations including issues such as utility policy, site	• These recommendations will help to ensure the safety and functionality of charging equipment.

Category	Recommendation	Rationale
	design, EV charging site assessment, codes, safety, and first responders. • Electrician license should be modified to require the distribution company, and perhaps MoCi be notified of the installation. The distribution company should be given the opportunity to inspect the EVSE installation prior to energization, and/or be provided with electrical installation certificate, electrical inspection report and testing report. • Building codes, wiring regulations and Electrician license should be reviewed to ensure that they incorporate safety requirements specific to EVSE • City planning and permitting officials should become familiar with any modifications made to building codes, wiring regulations or electrician licenses to accommodate EVSE requirements, and adopt any appropriate requirements into their own regulations	
Data Safety and Security	• Entities in Oman impacted in regulating PEVs (i.e., MoCI), should ensure that appropriate cyber security criteria, including data policies, are established for EVSPs, as applicable to each entity's area of responsibility.	• Malware in PEVs and EVSE have the potential to affect customer data and the electricity grid.

<u>'Preparing for PEVs' recommendations to be implemented by AER and distribution companies in the *medium term (4-6 years):*</u>

Category	Recommendation for AER	Rationale

Distribution system planning and operations	• AER or distribution companies should model future PEV impacts on Oman's distribution system costs under low and high adoption scenarios and varying charging level, time of use and location mixes • AER or distribution companies should partner with automakers, or PEV data providers to track PEV drivers once there are sufficient numbers on the system. Information should be collected on charging locations, levels and timing, as well as influences on PEV and EVSE purchasing decision • AER should ensure that distribution companies are empowered to work with EVSPs to reduce new connection and upgrade costs through locating chargers in locations that are both convenient to customers and where there is sufficient capacity on the distribution system, as well as through performing smart charging to reduce distribution system congestion. Distribution companies could start to identify locations with sufficient capacity for public charging infrastructure. • There are no power quality measures specific to PEVs. As with all end uses, as PEV penetration increases, distribution companies should take adequate measures to ensure minimum power quality standards are achieved	• This data will help inform distribution and procurement planning as adoption levels begin to increase. If PEVs are separately metered, then (any only then) meter data will be available to estimate kWh usage by PEVs, by location. However, tracking of the vehicles themselves is required to understand drivers' preferences between charging location options and whether/how these vary between PEV models and customer types. These insights will assist planners as the look forward toward more significant PEV adoption. • Increases in electrical loads related to penetration of PEVs will require additional distribution capacity unless EVSE can be installed in locations that both already have sufficient spare capacity and are in areas where customers will want to perform charging. This will also help mitigate transformer overloading. • Transformer overloading can be controlled with knowledge of installations, customer responsibility for full cost of new connections, and cooperation in locating charging infrastructure.

'Preparing for PEVs' recommendations to be implemented by *other entities* in the medium term (4-6 years):

Category	Recommendation	Rationale

Labour	• The Supreme Council for Planning should work with automakers to ensure there will be sufficient trained PEV technicians to meet projected PEV demand.	• PEV adoption may result in disruptions to the labor force, requiring new skills
Planning	• The Council of Supreme Planning should engage with automakers to gauge and understand PEV rollout plans.	• Information on PEV model availability will assist policymakers, including AER, to determine when PEVs may be sold in larger numbers and refine PEV adoption forecasts.

‘Preparing for PEVs’ recommendations to be implemented by AER in the *longer term (7+ years):*

Category	*Recommendation for AER*	*Rationale*
Periodic re-assessment	• AER should continue prior efforts, reassessing adoption, smart charging efficacy and regulatory barriers to ensure ongoing driver convenience and lowest possible electricity system costs.	• The PEV landscape is consistently changing and AER’s regulations will benefit from incorporating the latest information.

PROMOTING PEV ADOPTION

The recommendations below could be implemented by AER and other agencies in Oman to promote the adoption of light-duty PEVs. As mentioned previously, limited vehicle model availability and the need for higher electric ranges due to heat impacts will mean that even early adopters will not adopt PEVs in significant numbers for one to five years. The exception to this may be in luxury vehicle markets, where purchasers are more comfortable with technology experimentation, higher income, and are buying a second (or third, or fourth) vehicle intended to drive relatively short distances. Most PEV promotion activities should therefore begin in the medium term (4 – 6 years).

‘Promoting PEVs’ recommendations that could be implemented by AER in the short term (1-3 years):

Category	Recommendation for AER	Rationale
Private EVSE & Communication	• AER could consider allowing the distribution companies to offer customer incentives for installation of Level 2 EVSE with desired communication functionality at homes, workplaces and in public	• This will facilitate future communication to carry out VGI. • This would also lower the cost of charging infrastructure to site hosts, which could make more charging locations available to drivers and enable more PEV ownership

‘Promoting PEVs’ recommendations that could be implemented by *distribution companies* in the short term (1-3 years):

Category	Recommendations for Distribution Companies	Rationale
Public DCFC infrastructure	• **Create critical public charging infrastructure for major corridors:** ○ Distribution companies could be allowed to own a small number of public 350 kW DCFC EVSEs at key corridor locations, e.g. petrol stations or rest stops, sufficient to drive major long-distance routes	• In the near term, with low driver utilization, no business model will exist for private sector EVSPs to invest in DC fast charging. Without this initial ‘DCFC jumpstart’ to the market, any significant PEV adoption (and associated DCFC utilization) is unlikely. Distribution company ownership can

Category	Recommendations for Distribution Companies	Rationale
	across Oman and into neighboring countries. Such infrastructure should be treated identically to conventional distribution infrastructure with respect to capital and operating cost recovery. ○ At least 2 DCFCs should be installed at each selected site ○ In addition to a limited number of DCFCs owned by distribution companies, petrol station tenders on new roadways should be required to include at least two DCFCs. This obligation should be placed on the service area franchisee so that it is an integrated part of the bid for the franchise. Distribution company should be responsible for installing the service connection and make-readies for these installations. If distribution system upgrades are required at these sites to install DCFCs, installed capacity should be oversized to allow for the installation of 3 – 5 EVSEs per site in the future, or ensure that equipment can be easily upgraded ○ If private sector EVSPs are operational in the region and deemed to be sufficiently committed to long-term operations in Oman, then distribution companies should contract with EVSPs to provide installation, maintenance and billing for these stations. Private sector EVSPs will bring valuable experience to these functions, but at this early stage of PEV market development, they may not be well established, leading to the risk that they fold. If EVSPs are not well established at the time AER moves forward with this initial buildout, then	help ensure availability and reliability of this core network. The positive PEV adoption impacts of this network will also help to enable viable utilization levels and business models for private sector EVSP networks to enter and provide public Level 2 charging. • In the short run, the focus of public charging should be on DCFC for corridor charging to enable longer trips, reduce range anxiety and avoid vehicle stranding. DCFC sites are the best match with dwell times and driver needs on these longer trips, and are most appealing to drivers. • Lower-powered DCFCs (50 – 60 kW) face high asset stranding risk, as drivers will move to using best-in-class charging speed as soon as they're available. • Installing at least two DCFCs at each site will create reliability through redundancy. • Ensuring maintenance is crucial to ensuring driver satisfaction and promoting PEV adoption. Unreliable charging infrastructure adds to range anxiety, and stories of delays in repairing broken infrastructure can have lasting impacts on drivers' willingness to purchase and drive PEVs. • Ensuring equipment meets EVSP license requirements, even if selected by distribution

Category	Recommendations for Distribution Companies	Rationale
	distribution companies should install and maintain DCFC stations. ○ Provided utility-owned EVSE are defined as part of the distribution companies' distribution networks, distribution companies will be responsible for maintenance of this equipment as defined under their distribution and energy supply license. If they contract this responsibility to a third-party EVSP, this should be done through clear contracting that ensures fast response to maintenance issues, and the provision of a direct line of contact between drivers and the EVSP as drivers encounter issues in real time.	companies, will maximize PEV driver convenience and safety.

‘Promoting PEVs’ recommendations that could be implemented by AER in the *medium term (4-6 years):*

Category	Recommendation for AER	Rationale
Education and outreach	• AER could leverage energy efficiency auditing efforts to engage public and private fleets on PEVs as they become available and affordable in Oman.	• PEVs offer energy efficiency benefits versus gasoline and diesel vehicles. Commercial fleets have often provided some of the best economic cases for PEVs because they often drive more miles than personal vehicles, and therefore see larger gasoline and maintenance savings versus conventional vehicles. Public fleets can provide a useful demonstration of PEV technologies for others to follow. However, engaging with these users before PEVs are available and affordable will likely not be successful.

‘Promoting PEVs’ recommendations that could be implemented by *distribution companies* in the medium term (4-6 years):

Category	Recommendations for Distribution Companies	Rationale
Education and outreach	• AER could enable distribution companies to engage in proactive driver, building owner, employer and fleet owner, education campaigns on the availability and benefits of PEVs beyond a static website, e.g. through mailouts, advertising and ‘Ride and Drive’ events • Distribution companies could incorporate PEVs in their fleets as they become available and affordable	• Knowledge of PEVs has been shown to be a key adoption barrier in all jurisdictions. • Commercial fleets have often provided some of the best economic cases for PEVs because they often drive more miles than personal vehicles, and therefore see larger gasoline and maintenance savings versus conventional vehicles. Distribution company fleets can provide a useful demonstration of PEV technologies for others to follow.

Category	Recommendations for Distribution Companies	Rationale
Public DCFC infrastructure	• Distribution companies could expand their DCFC infrastructure as needed to meet demand and/or fill holes in the network, installing EVSEs with best-in-class charging power.	• As model availability and battery range barriers begin to lessen, the availability of public charging infrastructure is likely to become a top barrier to PEV adoption. • Experience in other countries suggests that the levels of PEV adoption likely in this timeframe will be insufficient to support DCFC business models, even with increased tariffs. Funding from distribution companies will therefore likely still be required during this timeframe to support PEVs. • Waiting until this later timeframe to more fully expand the DCFC network will enable the distribution companies to take advantage of lower costs and continually install best-in-class infrastructure to lower stranded asset risk.

‘Promoting PEVs’ recommendations that could be implemented by *other entities* in the medium term (4-6 years). These are listed from lowest to highest predicted financial cost to the Sultanate, though note that some low-cost initiatives could face political and popular opposition.

Category	Recommendation	Rationale
Charging in multi-unit housing	• Government bodies relevant to building codes (i.e., Ministry of Housing, municipalities) could introduce regulation that prevents landlords and homeowners associations from installing EV charging at their own expense on leased premises	• This will prevent a barrier for some prospective PEV drivers in multi-unit housing, increasing their likelihood of purchasing a PEV.

Category	Recommendation	Rationale
Zero-emission or PEV adoption goals	• Oman could set a goal for the number of PEVs or zero-emission vehicles (ZEVs: fuel cell vehicles plus PEVs) sold or on the road by a given year • Oman could set PEV fleet conversion targets or mandates for government fleets	• These kinds of goals signal policy commitment by the government. They can be used as an anchor for further policy change and implementation and can send an investment signal to the private sector that PEV adoption will be encouraged in Oman and is expected to increase. Note however that such a goal may have little impact if not followed by further action on PEVs. • Government fleets can be valuable first movers for fleet conversion, as they are often public-facing, drive a significant number of miles (improving their economic case) and can share lessons learned with other government agencies and private fleets.
Public charging infrastructure	• Oman could engage automakers and private sector EVSP networks to understand the barriers they face in Oman, and changes they would require to incentivize their investment in public charging infrastructure	• As PEV adoption increases beyond early adopters and public charging utilization rates increase, ratepayer funding will ideally be complemented by private sector investment in both DCFC and Level 2 public charging.
Zero-emission vehicle mandate	• Oman could set a zero-emission mandate such as that enacted in 10 U.S. states and in China, which would require automakers to make sufficient sales of zero-emission vehicles in Oman to gain a defined number of ZEV credits in each year. Credits are earned on each ZEV, with vehicles that have longer electric ranges earning more credits. Credit requirements are generally set to increase over time.	• This action would increase PEV adoption by forcing automakers to sell PEVs in Oman and would likely spur automakers to offer more vehicle models in the Oman market. This action should be dependent on automakers having developed the PEV models that consumers in Oman are willing to purchase.

Category	Recommendation	Rationale
Non-pecuniary benefits	• Oman could offer free public parking to PEVs at any paid locations, as well as free airport parking • MoTC could provide high-occupancy (HOV) lane access and waivers on toll roads to PEVs, if and when these forms of congestion management are implemented in Oman • Oman could provide upfront, priority parking spaces with charging to PEV drivers at government buildings, and encourage retail locations to do the same	• Non-pecuniary benefits have in other jurisdictions been considered significant by PEV owners. • Retail locations may be enticed to provide priority parking and charging in order to draw PEV drivers into their store or restaurant.
Education and outreach	• Oman could embark on proactive education campaigns targeted at drivers, fleet owners, building owners, employers, homeowners associations, and dealerships on the availability and benefits (including lower fueling cost) of PEVs and the details of PEV charging. Such education campaigns could include mailouts, advertising, 'Ride and Drive' events, dealership trainings, and workplace / multi-unit housing 'how to' guides for EVSE deployment • Oman could engage rental car companies and Mwasalat to assist in enabling PEV conversion of these fleets as existing vehicles are retired	• Knowledge of PEVs has been shown to be a key adoption barrier in all jurisdictions. • Commercial fleets have often provided some of the best economic cases for PEVs because they often drive more miles than personal vehicles, and therefore see larger gasoline and maintenance savings versus conventional vehicles. Public fleets can provide a useful demonstration of PEV technologies for others to follow. However, engaging with these users before PEVs are available and affordable will likely not be successful.
Financial incentives for dealerships	• Oman could offer financial incentives to automobile dealers to sell PEVs	• Dealerships are currently disincentivized to sell PEVs because they require less maintenance than ICE vehicles and therefore provide less return business. Providing financial incentives is intended to create additional incentive for individual dealers to sell PEVs.

Category	Recommendation	Rationale
Financial incentives for vehicles and/or charging	• Oman could lower the upfront cost of PEVs by providing upfront subsidies, tax credits, tax exemptions or registration fee exemptions on vehicles and/or charging equipment	• Upfront cost of PEVs is currently an adoption barrier in all jurisdictions studied. Even when total cost of ownership for PEVs is lower than for ICE vehicles, many consumers do not factor the lower fueling savings into their assessment and instead focus on the upfront vehicle cost differential. Depending on when Oman begins promotion of PEVs, the level of incentive needed may be small or zero.