A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

Transition towards E-mobility in Armenia

Tsimafei KAZLOU

June, 2020

Budapest

Erasmus Mundus Masters Course in Environmental Sciences, Policy and Management

MESPOM

This thesis is submitted in fulfillment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

Notes on copyright and the ownership of intellectual property rights:

(1) Copyright in text of this thesis rests with the Author. Copies (by any process) either in full, or of extracts, may be made only in accordance with instructions given by the Author and lodged in the Central European University Library. Details may be obtained from the Librarian. This page must form part of any such copies made. Further copies (by any process) of copies made in accordance with such instructions may not be made without the permission (in writing) of the Author.

(2) The ownership of any intellectual property rights which may be described in this thesis is vested in the Central European University, subject to any prior agreement to the contrary, and may not be made available for use by third parties without the written permission of the University, which will prescribe the terms and conditions of any such agreement.

(3) For bibliographic and reference purposes this thesis should be referred to as:

Kazlou, T. 2020. *Transition towards E-mobility in Armenia*. Master of Science thesis, Central European University, Budapest.

Further information on the conditions under which disclosures and exploitation may take place is available from the Head of the Department of Environmental Sciences and Policy, Central European University.

Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Tsimafei KAZLOU

CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS submitted by:
Tsimafei KAZLOU
for the degree of Master of Science and entitled: Transition towards E-mobility in Armenia
Month and Year of submission: June, 2020.

To achieve the goal of the Paris Agreement, emissions from the transportation sector should be cut by 90% by 2050. In the same period, the number of vehicles in the developing world is expected to double. One of the ways to reconcile this tension is to increase the share of electric vehicles. However, the transition to electric transport in developing countries has been slow. Therefore, it is essential to understand whether, under what conditions, and which E-mobility support policies can be feasible and effective. This thesis advances the understanding of feasible E-mobility strategies in developing countries. Using Armenia as a case-study, it seeks to answer three questions: (1) how cost-effective and affordable are electric vehicles (EVs) for different types of consumers, (2) which feasible policies can make EVs more attractive, and (3) what effects they would have. The thesis concludes that EVs are still more expensive than conventional vehicles for private consumers, mainly because of higher upfront costs. For the public sector, EVs in Armenia can provide significant savings, due to their extensive usage and low electricity costs. A review of EV policies in five Eastern European EU states has demonstrated the range of monetary and non-monetary incentives that can be feasibly adopted in Armenia. The analysis has shown that up to a 1.8% share of EV sales may be achievable within the next five years with the introduction of ambitious monetary stimulus policies, awareness raising campaigns, and supportive regulations.

Keywords: electric mobility, electric vehicle, decarbonization, energy transition, total cost of ownership, EV adoption

---

Acknowledgements

First of all, I would like to thank my thesis supervisor, Dr. Aleh Cherp, for his support throughout these two years, indispensable ideas, and assistance in the process of thesis writing. I would also like to extend my gratitude to the staff and faculty of the MESPOM program. Thanks to you, these two years have been a unique and unforgettable experience.

I am also immensely grateful to my external supervisors, Aleksandra Novikova and Marina Olshanskaya, who gave me the opportunity to continue studying E-mobility and were always there to help and share their experience and knowledge. Their responsiveness and hard work will serve as an example of professionalism to me for a long time to come.

Likewise, I would like to thank the Environmental Project Implementation Unit State Agency of the Republic of Armenia, namely Lusine Hovhannisyan and Ruzanna Voskanyan for their help in arranging stakeholder workshops.

Most importantly, all of this would not have happened without my parents, Ala Ralko and Siarhei Kazlou, my family, my new friends from MESPOM, and my old friends in Belarus. I dedicate all my achievements in this life to these people, without whom I would not be where I stand now.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Full text
ACEA	European Automobile Manufacturers Association
ADB	Asian Development Bank
BAU	Business-as-usual
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditures
DC	Direct Current
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EU	European Union
EUR	Euro
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GBP	Great Britain Pound
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gases
GNI	Gross National Income
HEV	Hybrid Electric Vehicle
ICCT	International Council on Clean Transport
ICEV	Internal Combustion Engine Vehicle
ICT	Information and Communications technology
IEA	International Energy Agency
kWh	Kilowatt-hour
LCA	Lifecycle Analysis
MoT	Ministry of Transport
NECP	National Energy and Climate Plan
NPF	National Policy Framework
O&M	Operations and Maintenance
PHEV	Plug-in Hybrid Electric Vehicle
POS	Point of Sales
R&D	Research and Development
RES	Renewable Energy Sources
TCO	Total Cost of Ownership
TtW	Tank-to-Wheel
UK	United Kingdom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
USD	U.S. Dollar
VAT	Value Added Tax
WHO	World Health Organization
OECD	The Organisation for Economic Co-operation and Development
OPEX	Operational Expenditures
NEDC	New European Driving Cycle
WLTP	Worldwide Harmonised Light Vehicle Test Procedure

1 Introduction

1.1 Background

Transportation is a mirror of demographical and economic growth, and road transport has always been an indicator of wealth, freedom, and modernity. Along with an increase in population, improvement in the global economy, and development of road infrastructure, the number of cars on the planet has also steadily increased, periodically slowing down during the global economic crises. Since 1998, the number of cars on Earth has almost doubled. According to forecasts, due to the increases in population and economic growth in the developing world, the number of vehicles is expected to double again by 2050 (IPCC 2014).

With such booming rates of economic growth from 1990 and onwards, a greater responsibility has arisen for what is its result. Regarding transport, these are, first of all, greenhouse gas emissions, air quality, safety, and health damage, each of which is somehow associated with global warming.

National pledges to decrease greenhouse gas emissions were signed by a vast majority of countries as a part of the Paris Agreement. However, out of 184 pledges, only 36 are identified as efficient to decrease GHG emissions by 50% by 2030 under the 1.5C scenario proposed by the Intergovernmental Panel on Climate Change (The Universal Ecological Fund 2019). Higher economic and institutional capacities to bear the costs of GHG reductions, as well as political feasibility, can all contribute to an actual willingness of a country to reduce more emissions than others or one-way round. Emission reductions are taking place in different sectors of the economy through a range of mechanisms. To achieve the goal of the Paris Agreement, emissions from the transportation sector should be cut by 90% by 2050 (Transport & Environment 2018). One of the climate change mitigation mechanisms in the transportation sector is the propulsion of zero-emission vehicles.

Electric mobility remains quite a polar, heterogeneously dispersed and developed, sometimes even a controversial topic around the globe, which shifts the transportation systems' paradigms only in some, mainly developed countries. Being highly dependent on carbon intensity of electricity generation, it is considered to be undesirable, in some cases even deteriorative technology for developing economies' environment.

By 2020, the majority of European countries have set their targets for achieving a certain percentage of electric vehicles in national fleets and introduced appropriate strategies, policies, and incentives to meet these targets. Moreover, at the European Union level, there is a range of directives pushing European countries towards the widespread usage of electric vehicles, alternative fuels (biofuels, hydrogen, electricity, etc.), and development of the appropriate infrastructure. However, within the EU, the level of success in e-mobility transitions varies significantly.

In developing countries, despite lower economic capacities, there are some EV market stimulation mechanisms and projects being implemented, most of them are aimed at the initial EV uptake and promotion if forms of pilot projects. In these cases, government initiative is usually supported by multilateral and bilateral aid institutions (e.g. World Bank, European Bank for Reconstruction and Development, etc.) or public-private partnerships due to the scarcity of private and public resources. Another significant role in funding such projects is possessed by the United Nations Development Programme (UNDP), which serves not only as a source of finances but as an indicator of financial safety and quality for other potential sponsors. The role of government is to set up an appropriate policy and regulatory environment for a project to be implemented with the least risks possible.

Quite recently, during the UN Climate Change Conference (COP25) in Madrid, the "Global Programme to Support Countries with the Shift to Electric Mobility" was announced, funded by GEF, UNEP, EBRD, ADB, and UNDP. The main goal of this project is to enable developing countries to implement their pilot e-mobility projects. Among seventeen developing countries participating in the project, there are two European countries – Ukraine and Armenia. While Ukraine has already implemented E-mobility policies and considered to be a regional leader of the project, Armenia is only at the initial stage of E-mobility development. Possessing a cleaner energy system even though located in between Russia and the Middle East, this country might be so far the most unique place where national E-mobility strategy will be introduced.

1.2 Problem Definition

Despite the relative success of E-mobility as a decarbonization mechanism in developed countries, the transition to electric transport in developing countries has been quite slow, mainly due to the interplay of financial imperfections of the electric vehicle technology and the

unwillingness of economies in transition to overpay for these imperfections. However, the growth of mobility demand and, as a result, the growth of vehicle fleets takes place in low- and middle-income countries, being a major threat to the environment (IPCC 2014).

In terms of E-mobility policymaking, lots of lessons can be learnt from experiences of countries at a more advanced stage of transition, which have been promoting electric vehicles for decades. However, the actual applicability and feasibility of such measures in low- and middle-income countries is questionable. This is especially relevant for E-mobility introduction strategies and projects when there is a need to balance regional economic and political contexts of a developing country with those best practices implemented in OECD countries.

While some of the adoption barriers and feasibility constraints might be the same in developing and developed countries, their actual impact varies significantly (e.g. higher purchase price barrier). Additionally, there are other local factors that might influence transition pathways: political feasibility of the transition, market conditions, and actors involved in the transportation sector.

Overall, there is a clear research gap in the methodology for policymaking and project design – it is not clear whether, how, and which E-mobility measures and policies implemented in developed countries can be applicable in developing countries, and what outcome they can bring.

1.3 Research Aim and Objectives

The aim of the thesis is to advance understanding of feasible e-mobility strategies in developing countries using Armenia as a case-study. The objectives are:

- To analyze economic attractiveness of electric vehicles for various groups of users in Armenia;
- To analyze E-mobility adoption barriers and feasibility constraints in Armenia;
- To review the experiences of E-mobility strategies and measures, their design, success and impact in different economies (particularly in transition countries);
- To model EV potential adoption rates in Armenia based on the E-mobility strategies reviewed;

- To recommend economic and political measures for promoting a long-term adoption of electric vehicles in Armenia.

The thesis builds upon and contributes to an ongoing UNEP-GEF project which aims to support the establishment of E-mobility institutional and policy framework, as well as framing an EV pilot project in the Republic of Armenia. The "Transition towards E-mobility in Armenia" project provides an opportunity to collect relevant data and arrange stakeholder consultations which are used for the thesis. Results and findings of this paper will serve as a policy recommendation to the Armenian government.

1.4 Thesis Structure

This thesis is composed of six chapters. Chapter 1 introduces background information, research objectives and its contribution to the topic of E-mobility policymaking. It also presents the research aim and the original project this research contributes to and builds upon. Chapter 2 is a literature review introducing the concept of E-mobility and EV technology, adoption barriers and market drivers associated with it, and policymaking approaches identified in academic literature. Chapter 3 presents the research framework, methods used to answer the research questions, and their limitations. Chapter 4 describes the analysis, final results, and policy recommendations, while Chapter 5 provides the discussion of these findings in a broader context. Lastly, Chapter 6 concludes with a summary of the research and states further research directions.

2 Literature review

The following literature review consists of three sections. The first section begins with the definition of electric mobility, different types of electric vehicles (EVs), drivers and barriers that are commonly associated with this technology. The second section provides an overview of the wide range of incentives and other E-mobility policy instruments aimed at different stakeholders and outlined in current literature. The last section summarizes this literature review, emphasizing the complexity and variability of E-mobility policymaking.

2.1 What is E-mobility?

The topic of E-mobility transition and adoption combines a myriad of research areas. Environmental sciences help to identify carbon dioxide, nitrogen oxides, sulfur oxides, and other emission reduction benefits from using an EV; public policy knowledge enables to design the most feasible E-mobility strategies, while finances and economics make it cost-efficient; social sciences knowledge helps to gain an understanding of consumer and other stakeholders preferences, needs, and perceptions, and to raise awareness; political science sheds a light into political feasibility of E-mobility. Figure 1 demonstrates only one, market dimension of E-mobility transition dynamics, showing its complexity and causality (Pasaoglu et al. 2015).

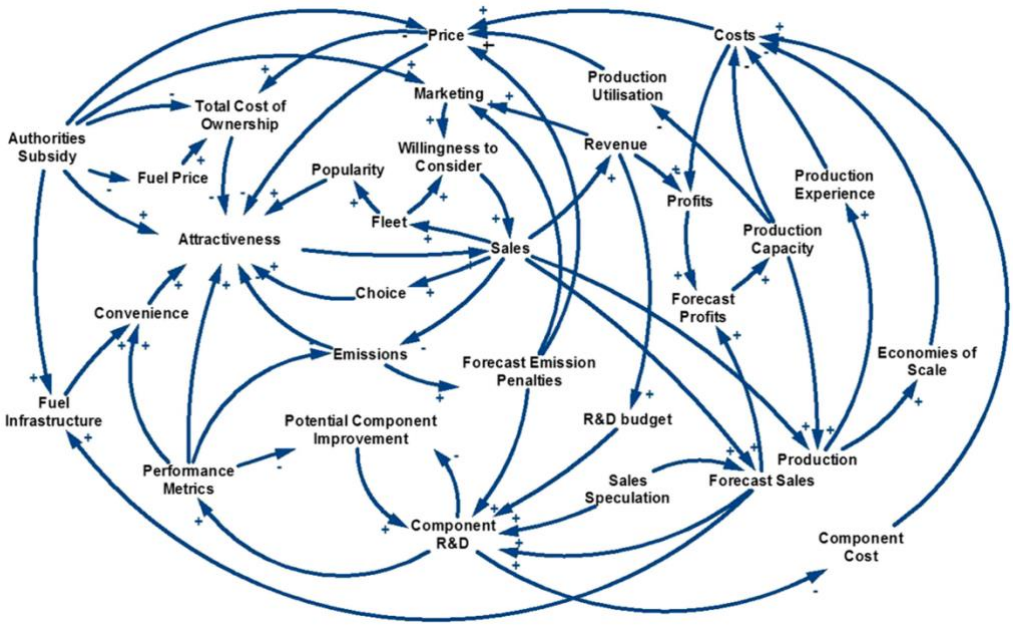


Figure 1. Causal loop diagram of market agents
Source: Pasaoglu et al. 2015

2.1.1 Definition

Due to a novelty of the concept, E-mobility should be defined first. It can be described as "a road transport system based on vehicles that are propelled by electricity" (Sandén 2013) or as "all means of transport of people and/or goods that results in a vehicle that (1) can be moved

partially or totally by an electric drivetrain and (2) can be plugged-in to charge its energy storage" (GCF 2019). However, it must be pointed out that the definition "electric vehicle" might also include or be combined with other types of vehicle engines.

Battery Electric Vehicles (BEVs) operate entirely by rechargeable battery packs; Hybrid Electric Vehicles (HEVs) use both conventional fuel and electricity, recharging the battery through the braking system of the car so that it does not need to be charged; Plug-in Hybrid Electric Vehicles (PHEVs) integrate both of these functions so it can be charged both internally and externally, therefore decreasing tail pipe emissions as compared to HEVs (i.e. PHEVs are capable of completing more 'electric miles').

Other zero-emission vehicle technologies, such as hydrogen cell vehicles and biofuel mixture are not a subject of this thesis. E-mobility itself also includes other battery-based means of transport, such as electric buses, two- and three- wheelers, trucks, as well as charging infrastructure procurement. Nowadays, some pilot projects were introduced in aviation and shipping (IEA 2019). Therefore, broadening of the definition of E-mobility is just a matter of time.

Here and thereafter, BEVs are referred to as EVs.

2.1.2 Drivers and barriers for the EV technology

The only crucial difference between internal combustion engine (ICEV) vehicles and EVs is their engine, but differences in production costs, efficiencies, and supplementary infrastructure availability of these engine technologies are what truly make the transition to zero-emission vehicles so complex. EV policies are designed to ease this complexity and overcome barriers for the transition. This subchapter will briefly discuss a range of barriers for EV adoption and policy measures aimed to overcome them.

High upfront costs of EVs is the most commonly recognized adoption barrier. The main reason for the upfront price divergence between EVs and ICEVs is the **battery technology cost** which has been developing quite rapidly during the last decade. Besides the engine, ICEV and EV manufacturing has relatively the same cost. Bloomberg New Energy Finance publishes their annual Battery Price Survey, concluding the average battery pack price to drop by about 85% from 2010 to 2018 – from 1160 to 176 USD/kWh. The experts forecast the price to drop to

around 94 USD/kWh by 2024 and 62 USD/kWh by 2030, underlining that these are average prices and one can expect a company to penetrate the market offering a lower price (Goldie-Scot 2019; IEA 2019; Nykvist and Nilsson 2015).

International Energy Agency forecasts that **the total cost of ownership** (TCO) of a 36 kWh battery EV will become lower than TCO of ICEV when the battery pack price will reach 150 USD/kWh which, according to the abovementioned forecast from BloombergNEF, will happen in the beginning of 2020s (IEA 2019; Goldie-Scot 2019). Other authors (Delucchi and Lipman 2001) indicate the battery pack price range to be 100-130 USD/kWh, which might be achieved in 2025-2030 (Weiss et al. 2012).

Battery lifetime is another crucial factor since it affects the frequency of battery replacement, hence additional investments. In 2019, the maximum extended warranty on a battery offered by automotive companies to the public sector in the EU was 8 years, thus indicating the minimum lifetime (Rodríguez Quintero et al. 2019). Other price forming factors are **battery design**, chemistry, economies of scale, and commodity (metal) prices (Goldie-Scot 2019).

In order to promote the initial uptake of EVs despite the cost divergence, governments in different countries implement various monetary and fiscal policy measures. **Fiscal incentives** in combination with **regulatory policies** positively affect EV market share and continuous diffusion of the technology, and the uptake impact of such policies, in some cases, is proportional to the size of incentive (Rietmann and Lieven 2019; Munzel et al. 2019; Plotz et al. 2016).

Abovementioned cost barriers are always accompanied with **low maintenance costs** associated with an EV usage. Due to a more simplistic mechanical design of an EV and a relatively longer lifetime of electric components (as opposed to oil-based), EVs, in general, require less maintenance. Various studies have identified the annual maintenance cost difference to be around 25-50% (AECOM 2011; EPRI 2013).

Another ‘unintended’ cost-related adoption factor (i.e. can serve both as a driver and barrier) is the **purchasing power** of the population, which partially explains the relative success of EV uptake and policies in the developed world (Rietmann and Lieven 2019; Plotz et al. 2016). The

significance of this barrier, however, does only make sense before the cost parity achievement between ICEVs and EVs.

With rare exceptions, one universal cost-related advantage of EVs is the ratio between relatively low **electricity costs** and often unstable high **fuel prices**. Moreover, the variability of electricity tariffs (e.g. for public and private consumers; day-night tariffs) can make EVs even more attractive for various groups of drivers. For example, EV users charging their vehicles at home tend to do it overnight, so cheaper electricity prices during this period of a day might also attract new consumers. This cost factor varies across the world due to different subsidy and taxation mechanisms on fuels and electricity, therefore should be studied locally (Hardman et al. 2018).

Range anxiety of EVs can be defined as "a result of a perceived limited driving range of electric batteries versus the perceived range needed in daily car use, charging time of batteries and lack of infrastructure of charging stations compared to fossil fuel stations" (Rezvani et al. 2015; Sovacool and Hirsh 2009). However, one might say that this barrier is in the past, with some of EV models range of more than 400 kilometers, which makes it more than enough for urban environment, though still not for everyone.

One of the market-related barriers to EV adoption is EV **model availability** since different EV models are not distributed uniformly, which is especially relevant for developing economies. Slowik and Lutsey (2017) have found the availability of EV models to be a significant factor affecting the uptake of EVs. IEA (2019) indicates that a high pace of adoption in developed countries might also benefit developing world with a cheaper EV options offered at the second-hand car market, thus bridging the gap in model availability and high upfront costs.

Lack of public charging infrastructure is one of the most often mentioned barriers to EV adoption. Some studies confirm that, in countries with a high share of private houses, the importance of public charging infrastructure is often overexaggerated – around 50-80% of charging events happen at home, usually overnight. More than 15% of charging events occur at work, and so-called 'corridor' charging stations are being used in 5% of all charging events. This barrier is multidimensional and can be tackled through a network planning analysis, small pilot projects, and a range of incentives and subsidies for a corporate, public, and household charger installation (Hardman et al. 2018).

The main behavioral barrier to EV adoption is a natural **resistance to new technologies** which are unproven or at least considered to be such. Egbue and Long (2012) argue that social barriers are as important as technological to an actual consumer resistance towards EV adoption. Authors also quite frequently notice the **lack of consumer knowledge** related to this driver and inability to calculate the total cost of ownership (TCO) of an EV compared to an ICEV (Rezvani et al. 2015).

Langbroek et al. (2016) emphasize the importance of improving public stage of change towards EVs adoption through **awareness programs** and increase public intrinsic motivation ("actual tendency to perform an action", i.e. to buy an EV). This way, less policy incentives would be required. Another valuable measure outlined in the literature is to inform the society about political concern around EVs and show **political leadership** in this field (Bakker and Trip 2013), as well as in the area of climate change as a whole (Davies et al. 2016).

2.2 E-mobility policymaking – trial and error

E-mobility has become a global concern quite recently, and, as a result, the process of initiating a national EV uptake possesses a range of difficulties and requires a complex approach. Held and Gerrits (2019) point out the configurational nature and complex causation of policies aimed at EV uptake. This causation is characterized by equifinality (when different policies lead to the same results) and multifinality (when same policies lead to different results). Moreover, the nature of the causality can also be described as partial and contingent (i.e. dependent on time and place).

When it comes to E-mobility transition, there is a whole range of stakeholders involved besides consumers – automotive and mechanical industries, charging network companies, and so on. The final decision, however, still depends on consumers. In this subchapter, policy instruments targeting these stakeholders will be discussed, including their most recent applications.

2.2.1 E-mobility consumer incentives

E-mobility related incentives can be defined as any stimulus which pushes a consumer from buying or willing to buy a conventional car and/or pulls a consumer to buy an electric vehicle. Therefore, the range of policy instruments aimed at electrifying the transportation sector might be concentrated on both ICEVs and EVs. Overall, the majority of EV policies are designed in

order to decrease the total cost of ownership (TCO) of an EV and bring it closer to the TCO of a similar conventional vehicle, while the cost parity has not yet been reached naturally.

As concluded above, governmental initiative and concern reflected in financial help for EVs uptake and market diffusion is a must. Although the concern around E-mobility arose quite recently, there have been many attempts to incentivize the usage of EVs. For example, Norway has started to incentivize EV buyers from around 1990 (OFV AS 2017). By now, all European countries offer some kind of incentive for EVs (ACEA 2019). These policies vary mainly in a type of incentive, size, and time length.

Munzel et al. (2019) provides a comprehensive consumer incentive classification which emphasizes financial and temporal variability of such policy instruments and aims at different consumer groups (private and corporate). This subchapter explains different types of incentives based on this classification and provides actual examples of such policy instruments. The European Automobile Manufacturers'Association (ACEA) publishes the annual "ACEA Tax Guide" review of vehicle taxes in Europe and other main auto markets and is used as a source for incentive introduction examples in this subchapter (ACEA 2019). ICCT (2019b) provides a comprehensive overview of the most efficient incentives in the world, supporting different policy packages with comments about their advantages and disadvantages.

According to the classification, all EV consumer incentives are divided into two main groups: monetary and non-monetary. Monetary incentives are divided into one-time and recurring, while the former is also subdivided into one-time monetary payment upon purchase and after purchase (Munzel et al. 2019).

One-time monetary incentive upon purchase

Point of sales (POS) tax reduction and VAT reduction. This type of consumer incentive is aimed directly at upfront costs reduction. For example, in Norway, vehicle import taxation system consists of the weight tax, CO_2, NO_x, and VAT (25%), which are paid once together with a purchase price. When buying an EV in Norway, a consumer does not pay any of these taxes, therefore the total import cost becomes usually lower than of a similar ICEV even though initial purchase price (without taxes) was higher. The overall EV policy package has been developing since 1990, but the first incentive that made an actual difference and initiated the world-leading adoption of EVs in the country was the VAT exemption in 2001. These fiscal

incentives are also backed by a range of other incentives which will be discussed further (OFV AS 2017). Munzel et al. (2019) classifies this type of incentive as POS (point of sales) taxes and combines all other vehicle purchase-related tax exemptions or reductions. Other examples of POS taxes are those which based on an engine capacity, fuel consumption, and vehicle age.

Rebates and grants. This incentive group is also referred to as 'direct subsidy' – unlike tax reductions discussed above, this type of incentive enables a consumer to receive a certain amount of money either to buy (before the actual purchase) or right after buying an EV. The way rebate stimuli work is that the payment bonus for an EV purchase is financed from a malus (tax) for an ICEV purchase. The amount of bonus and malus given depends on the emission factor (gCO_2/km) or fuel efficiency (l/100km) of a vehicle. This scheme was initially introduced in France in 2008 and was annually reassessed in order to balance revenues and expenditures, as well as to gradually make the system 'stricter' to more polluting vehicles (Ecofys 2018). This type of incentive has been implemented in different forms in Sweden, France, Cyprus, Slovenia (Munzel et al. 2019). Overall, while EV grants just provide a subsidy for a certain number of EV consumers (i.e. based on the annual governmental allocation of funds for the subsidy), vehicle fee-rebate system seems more appropriate for developing countries since it can be designed to be profit neutral and for unlimited number of consumers (ICCT 2019b). On the other hand, this type of incentive implies an increased taxation of ICEVs, which might have problematic implications for both ICEV drivers (which is still the vast majority) and a government.

Another incentive from this group, **home charger subsidy**, has not yet been developed widely. This subsidy serves as a stimulus to install domestic EV chargers and possibly overcome the barrier of an underdeveloped charging infrastructure, which can be a significant motivation for a potential rural consumer. By 2017, only Ireland and the Netherlands have introduced this subsidy (Munzel et al. 2019).

Same types of incentives may vary in size depending on a country. Eventually, when leading to a continuous market diffusion of EVs, monetary incentives are redesigned with some type of vehicles being excluded and the size (financing) of incentive decreased. In the UK, EV purchase incentive is issued in a form of grants which vary depending on the mean of transport (e.g. vans, cars, mopeds, etc.). Hybrid cars, however, have already been excluded from this incentive system (ACEA 2019). In France, HEVs were initially eligible for a bonus, but had also been

excluded later when the TCO reached the price parity with ICEVs (Ecofys 2018). In some countries, however, due to a number of reasons, monetary incentives keep growing. For example, in November 2019, having not met the expected EV sales targets, the German government announced the change of conditions for the main EV incentive increasing to up to EUR 6,000 (50% increase).

This group of EV incentives is the most effective for EVs adoption but at the same moment the most expensive for a government, costing up to EUR 150 million (purchase subsidy in the UK) and EUR 300 million (tax exemption in Norway) (ICCT 2019b).

One-time monetary incentives after purchase

This group of incentives targets private and corporate income taxes and is usually implemented in forms of **tax deduction**, **income grant allowance** in a given year of purchase or a period of time. Depending on a country, these policies are being introduced on a national or regional level. Under certain conditions, the deduction may reach up to 100% of income tax (UK) which may lead to significant savings, especially in a corporate sphere. However, by 2017, this type of incentive was introduced only in Luxemburg, Belgium, UK, and Portugal (Munzel et al. 2019).

In the Netherlands, the government cut the annual company tax break (deduction) incentive in 2015. Depending on the size of a company, this incentive could save up to USD 7,000 per one company car every year. This incentive resulted in the Netherlands being a top EU adopter of EVs, and reduction of the tax break pushed the sales back to regular (Gibbs 2015). Similar situation happened in Denmark as well (Munzel et al. 2019).

Recurring monetary incentives

The last subdivision of monetary incentives provides continuous benefits throughout the usage of an EV. The most usual example of such tax is a **vehicle registration fee exemption or deduction**, which is known under different names depending on a country (e.g. circulation fee, licensing fee), paid monthly or annually, and calculated based on emissions, fuel consumption, type of vehicle, number of cylinders, vehicle's age, etc. In the EU, this type of incentive is in place in the majority of countries. This group of incentives also includes electricity supply and price subsidies (e.g. **free charging** and price discounts) and **parking fee waivers**, **road toll exemptions**, and **free access to ferries** (Munzel et al. 2019).

Non-monetary incentives

This group of incentives is mostly related to local areas, big cities and towns. It includes **access to bus lanes**, **restricted traffic zones and lanes** (Munzel et al. 2019). Even within a particular city or town, this incentive is only influential to people who can actually use them (Langbroek et al. 2016).

Although all abovementioned incentives are directly related to EVs or EVSE (EV Supply Equipment), disincentivizing ICEVs (making the ownership less attractive or affordable) can also be considered as a driver to the adoption. In his study, Hardman (2019) includes **gasoline taxes** in the group of non-monetary and recurring incentives. Since highly dependent on the conditions and specificities of a transportation system, range of such measures and potential implications may vary significantly. will be reassessed and their efficiency under Armenian circumstances will be considered.

Another peculiar policy instrument is **incentivized electricity tariffs**. In order to avoid electricity demand fluctuations caused by a large number of EVs on the road, some electricity providers in California offer tariffs with a cheaper price during off-peak hours (usually during the night) so that EV users are incentivized to charge their vehicles at home during the night and saving more money (Hardman et al. 2018; Dunckley and Tal 2016). However, depending on the region, some environmental implications (positive or negative) might occur due to energy generation profiles (Graff Zivin et al. 2014).

The range of discussed consumer incentives is summarized in Table 1.

Table 1. Consumer incentives
Source: Munzel et al. 2019

Category	Subcategory	Incentive
Monetary	One-time upon purchase	Rebates and grants
		Home charger subsidy
		POS tax reduction
		VAT reduction
	One-time after purchase	Income tax reduction
		Company tax depreciation
	Recurring	Circulation tax reduction
		Company car tax reduction
		Electricity supply subsidy
		Fee waivers
Non-monetary	Recurring	HOV lane access
		Restricted traffic zones access
		Charging infrastructure

2.2.2 Policies charging infrastructure development

So far, we have discussed different ways of governmental stimulation from a consumer perspective. However, this literature review would be insufficient without an overview of policy mechanisms enabling charging infrastructure development. As briefly discussed above, there are different types of stakeholders that can be involved at this stage, from petroleum companies to individual households. Current literature does not provide a comprehensive framework of such incentives, although there are plenty of examples worldwide.

Zhang et al. (2018) classifies charging infrastructure into private (e.g. home charging), semi-private (available for a certain group of users, e.g. workspace charging), and public. Here, we comprise some examples of governmental subsidies and schemes for a continuous development of charging infrastructure in accordance with this classification (Table 2).

Table 2. Charging infrastructure measures review

Measure	**Country**	**Source(s)**
PPP financing scheme introduction for a wide-scale deployment of infrastructure	China, Germany, US	Yang et al. (2018); Zhang et al. (2018); Wu et al. (2018); Liu and Wei (2018); Spöttle et al. (2018)
Governmental budget allocation	UK, Singapore, Canada	Philip and Wiederer (2010); IEA (2019)
Enabling direct communication between a government and businesses regarding green growth	The Netherlands	Spöttle et al. (2018)
Enabling local authorities to apply for financial help from a national government	The Netherlands, Germany	
Direct subsidy (rebate, purchase grant) for public chargers	Germany, France, Italy, Spain, Sweden, UK	Spöttle et al. (2018); EAFO (2019)
Direct subsidy for private chargers	UK, France, Italy, Sweden	
Direct subsidy for semi-private chargers	UK, Finland, France, Italy, Spain, Sweden	
Tax credits	US, France	
Office parking space tax waiver	Belgium	
Electricity price rebates	Denmark	
Request-system of charger's installation	The Netherlands	

Some authors argue that the uncertainty of the future demand for electricity from EVs is the most challenging barrier for private stakeholders (Philip and Wiederer 2010; Serradilla et al. 2017). Therefore, at the early stage of adoption, significant governmental intervention is required in order to enable a private sector to participate in infrastructure development.

For example, the Chinese government has launched a nation-wide deployment of charging infrastructure through **Public Private Partnership** (PPP) projects coupled with a range of **tax**

incentives (e.g. VAT, land use tax, enterprise income tax, deed tax). The main advantage of this intervention is that the application of the PPP model for charging infrastructure development enables businesses to avoid some risks and uncertainties and promote innovation. Moreover, financial resource efficiency, project life cost accuracy due to private sector involvement, and risks allocation are the main benefits for a government when launching a PPP infrastructure project (Wu et al. 2018; Yang et al. 2018).

Other policy instruments used within the PPP framework in China are investment subsidies, free allocation of land, dividend rights transfer, preferential tax policies, and loans with discounted interest (Yang et al. 2018).

In Europe, governments do not directly participate in infrastructure development, stimulating it 'remotely' through a range of separate incentives for private companies and individuals. Under certain conditions, this approach can be more effective – some authors consider independent EV charging network companies to be the most efficient in terms of market development (Spöttle et al. 2018). Incentives are introduced in forms of a direct **governmental subsidy** to commercial enterprises, housing cooperatives or individuals; **company income tax deduction** from charging costs; **electricity tax rebates**; subsidies based on the charger capacity.

Quite an interesting approach for a charging infrastructure planning was taken in France and the Netherlands, where it is based on users' requests, which is a good example of incentive and awareness-raising solution, especially at the early stage of transition (EAFO 2019). Philip and Wiederer (2010) give the example of the annual governmental budget allocation for charging infrastructure development in the UK and Singapore.

2.2.3 Enabling national attractiveness to manufacturers

Automotive sector serves as a source of jobs and innovativeness, but it also might be influential for EV uptake in a certain country by increasing EV model availability and incentivizing local consumers and, in turn, local production facilities. However, not every country possesses a strong automotive sector, especially when it comes to economies in transition. This subchapter of the literature review discusses policy instruments used to attract investments in the automotive sector, and, eventually, to boost EV production once car manufacturing facilities are in place.

Foreign investors have a myriad of factors to analyze before entering a certain market. Some of them are of economic or institutional nature: size of economy, inflation, exchange rate volatility, institutional capacities, other companies already present in the market, etc. However, when it comes to economies in transition, there are a lot more barriers for a market penetration. Therefore, it is mostly a government's responsibility and opportunity to lower these barriers and make the national market more attractive for investment (Haiss et al. 2012).

Incentives for vehicle companies might be classified as intended and unintended. Intended incentives include specific policies and programs implemented in order to increase investment attractiveness of a country which might result in investments from big companies. These programs and policy packages usually relate to fiscal and tax policy (e.g. VAT reduction or exemption) and to budget allocation for continuous subsidization of materialized investment projects through direct subsidies. Other, less frequent examples are infrastructure provision (e.g. railway networks), support in training and construction, exchange rate guarantees, etc.

Unintended incentives are economic, financial, and technical characteristics of a country which can increase its attractiveness for foreign investors. These could be (but not limited to) trained labor, market clusterization, stable currency rate, low taxes, etc. (Haiss et al. 2012).

However, these measures are aimed to promote foreign investments in the entire automotive sector, which might or might not include production and assemblance of EVs. The International Council on Clean Transportation has recently recommended a package of policies aimed at production of EVs to policymakers in India (ICCT 2019a). These and abovementioned policies and incentives are summarized in Table 3.

Table 3. Policies for automotive market players

Category	Subcategory	Example	Source
Attraction of vehicle manufacturers	Intended	Guaranteed state loans	Haiss et al. 2012
		Direct subsidy for automotive companies	
		Tax breaks and exemptions (corporate and personal income tax; equipment VAT exemption; untaxable R&D spending	
		Infrastructure provision	
		Construction support	
		Training support	
		Exchange rate guarantees	
		Healthcare repayments for young and disabled employees	
		Scrappage programs	
		Equity participations	

	Unintended	Low labor costs	
		Low land costs	
		High motorization rates	
		Developed automotive parts manufacturing industry	
		Good credit ratings	
		Stable currency and inflation rates	
		Size and competitiveness of a market	
		Institutional and political stability	
		Supply availability	
Promotion of EV production	Stimulation of investment in EV production	EV production mandates	ICCT 2019a
		Intended attraction of vehicle manufacturers having EVs in their production portfolio (see above)	
		Product and technology marketing support	
	R&D support	Support R&D and demonstration activities (research hubs, universities, demonstration projects, stakeholder events)	
		Collaboration with existing industry to promote E-mobility	

2.2.4 EV demonstration projects

EV demonstration projects have been widely used as an instrument to promote the technology in its pre-commercial stage, hence it still might be used in late-adopter countries to raise awareness about the technology. Liu et al. (2020) highlights the wide usage of demonstration projects and a limited research in this area, claiming that the majority of publications concentrate on studies related to consumer incentives instead. Therefore, this subsection of the literature review provides some examples of EV demonstration projects.

Liu et al. (2020) analyze the effectiveness (i.e. impact on private adoption of EVs) of the EV public procurement project that took place in 44 Chinese cities in 2009-2012. By analyzing EV sales data in pilot and non-pilot cities, the study provides an empirical evidence that demonstration projects do influence the uptake of EVs in the private sector. Moreover, public procurement mechanisms possess a higher market influence potential than other awareness raising mechanisms, such as manufacturer's marketing campaigns and technology exhibitions, especially in the early stages of transition. Also, the impact on the private adoption of EVs was higher when EVs were procured instead of e-buses.

In the EU, some states have started to procure EVs in their public fleets after the introduction of the Clean Vehicles Directive (2009/33/EC). The Directive sets specific minimum country-based percentages (targets) for the procurement of clean vehicles. These targets currently vary from 17.6 to 38.5% for light duty vehicles (European Parliament 2009b). Although the definition of a "clean vehicle" also implies the usage of biofuels, hybrid vehicles, and even low-

polluting petrol vehicles, the Directive has led to a growing number of introductory EV public procurement projects.

One of such projects took place in Swedish municipalities in 2010, which was a starting point of the transition, with only a few hundred of EVs operating in Sweden by that time. Palm and Backman (2017) analyze the role of Swedish municipalities in promoting the EV market via public procurement projects. The study highlights that public institutions and municipalities may generate a greater purchasing power through cooperation, thus increasing the ability to create better procurement options in terms of, for example, prices and model availability, which still serve as significant adoption barriers. Moreover, the leadership role of the public sector has the potential to reach an average consumer and, as a result, speed up the adoption. As any other EV policy instrument, public procurement projects should be complemented with other consumer-centered adoption policies.

Overall, we can see that demonstration projects, as well as other EV policy instruments, can be helpful in overcoming adoption barriers (e.g. raise awareness, increase purchasing power, etc.) at the initial stages of transition. Public sector can be an effective frontrunner in late-adopter countries.

2.3 Summary of literature review

This literature review has defined E-mobility, discussed the main adoption barriers, and provided a comprehensive overview of the most commonly recognized E-mobility policy instruments.

With rare exceptions, the EV technology is yet on its way to achieve the cost parity with ICEV. Diffusion of EVs includes various costs borne by different stakeholders: total cost of ownership is vital for a consumer, while production and infrastructure development costs are divided between private and public sectors. In order to facilitate the diffusion of EV and other related technologies (e.g. charging) and promote the uptake of EVs, various policy instruments are designed and implemented in the three key areas: vehicle market, manufacturing, and infrastructure development.

Another significant constraint for the uptake is a lack of consumer awareness about the technology, which is especially important for EV newcomers. This literature review also discusses EV demonstration projects and their effectiveness in awareness raising at early stages of EV adoption.

E-mobility policy design and implementation requires a complex approach – examples have shown that an ambitious monetary incentive would have a better uptake impact when accompanied by other non-monetary incentives. Different variations of policies, combined in E-mobility policy packages, is the most effective way to promote EVs.

The following illustration depicts the wide range of E-mobility policy packages discussed in this section (Figure 2).

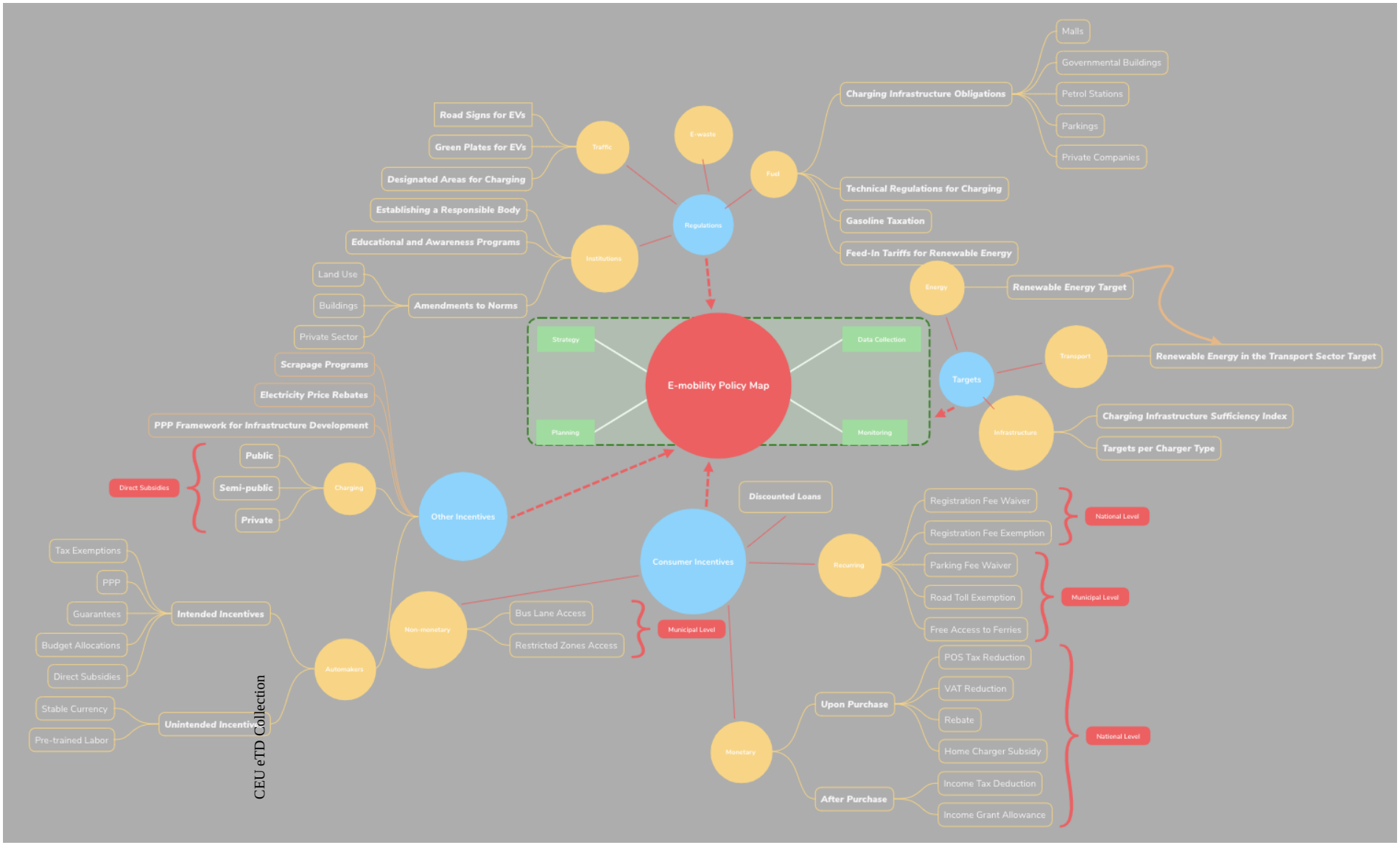


Figure 2. E-mobility Policy Mind Map
Source: Author

3 Theory and Methods

The following section provides an overview of theories and methods used in this thesis. First, it describes the "EV Policy Cycle Framework", which was amended and applied in this research as the main analytical framework, and the Theory of Change, which was used for the project and policy recommendation design. Next, this section provides a more in-depth overview of methods used in this thesis.

3.1 Theory

3.1.1 Three perspectives on E-mobility transition

National energy transitions are influenced by changes in techno-economic, socio-technical, and political systems (Cherp et al. 2018). Within the scope of E-mobility, this framework might also be applied with the following reinterpretation of relationships within and between systems and their definitions.

The techno-economic system includes manufacturers, mining and infrastructure companies, software developers which are involved in separate activities related to E-mobility, where developmental, technological, and organizational changes controlled by automotive industry and markets increase the quality of a product and drive down the total cost of ownership of an EV, thus influencing a consumer's willingness to consider this technology when making a purchase decision in a certain country.

According to the socio-technical approach to transitions (Geels 2012), E-mobility transition, as any other one, is based on non-linear processes caused by multi-level (niche, regime, and landscape levels) developments achieved via interaction between various actors (public, car users, EV and ICEV manufacturers, car service workers, etc.) between multiple dimensions (e.g. government, industry, science, markets, etc.). The electric vehicle industry is still at a promising niche-level (novelty) globally, associated with some ambiguity and a range of uncertainties, though the pace of transition is heterogenous in different parts of the world. This complex interdependence between various dimensions, as well as energy and transport infrastructures diffusion, some of which are also new (i.e. diffusion of EVs is not possible without charging infrastructure), prevents the rapid uptake of EVs worldwide, especially in the developing world (Grübler 1996). In a limited number of countries (e.g. Norway), EVs have already evolved into a new socio-technical regime capable of self-reproduction.

Another crucial role is played by EV policies. Political actions in the field of E-mobility can be caused by various factors representing national interests, such as fossil fuel dependency, excess of electricity, GHG emissions, job creation, etc. Despite the undeniable importance of EV policies for a continuous uptake, policies aimed at the taxation of petrol and diesel, imports of old polluting vehicles in favor of EVs, or subsidization of EVs production instead of ICEVs might be against societal preferences. Furthermore, some of the policies discussed during the literature review require significant allocations of public funds, which might be seen as excessive in the developing countries. As a result, the political feasibility of the most effective EV policies might be quite low in the developing world.

3.1.2 S-curves of new technologies diffusion

The pace of transition from one technology to another is highly affected by two main factors – profitability of entry and profitability of shift (Griliches 1957). Profitability of entry relates to vehicle companies and retailers, which assess the feasibility (e.g. market density, marketing cost, etc.) of entering a new market. This factor determines the starting point of a transition, when a new product becomes available to consumers. Profitability of shift relates to a consumer, who considers all benefits and drawbacks from a shift (e.g. environmental and financial). This factor affects the pace of a long-run uptake. Within the scope of E-mobility, both factors are dependent on socio-technical, political, and techno-economic mechanisms.

S-curves are used in order to describe a life cycle of innovations, technologies, policies, and so on. In our case, we are not only interested in the diffusion of EVs, but also in the transition from ICEVs to EVs. Griliches (1957) studies the shift from pollinated to hybrid corn in the U.S. by analyzing the influence of entry and shift conditions on the three key parameters of adoption S-curves: origins (starting point), slopes (transition pace), and ceilings (saturation point) (Figure 3).

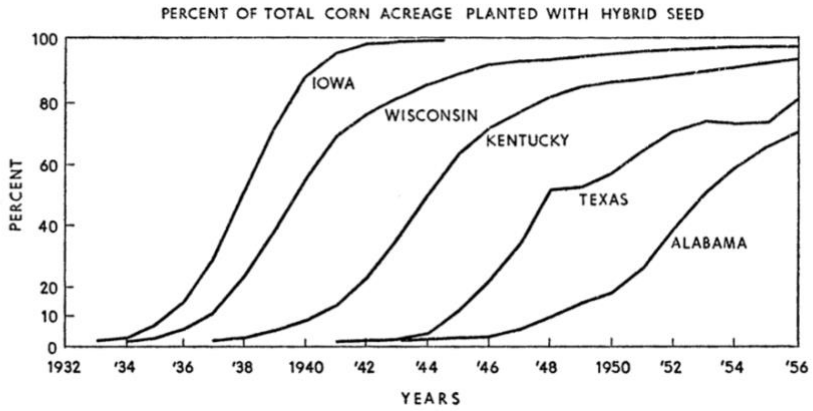


Figure 3. Percentage of total corn acreage planted with hybrid seed
Source: Griliches 1957

Vinichenko et al (2020) analyze the diffusion of renewable energy generation through the lens of S-curves, dividing the transition process into three stages: formative, growth, and saturation (Figure 4). Unlike E-mobility, energy transitions have started around the 2000s, and, according to this study, have already reached saturation stages in some countries. Wide commercialization of electric vehicles started about 10 years later, so the main reasoning of integrating S-curves to the adoption of EVs is rather forecasting than analyzing.

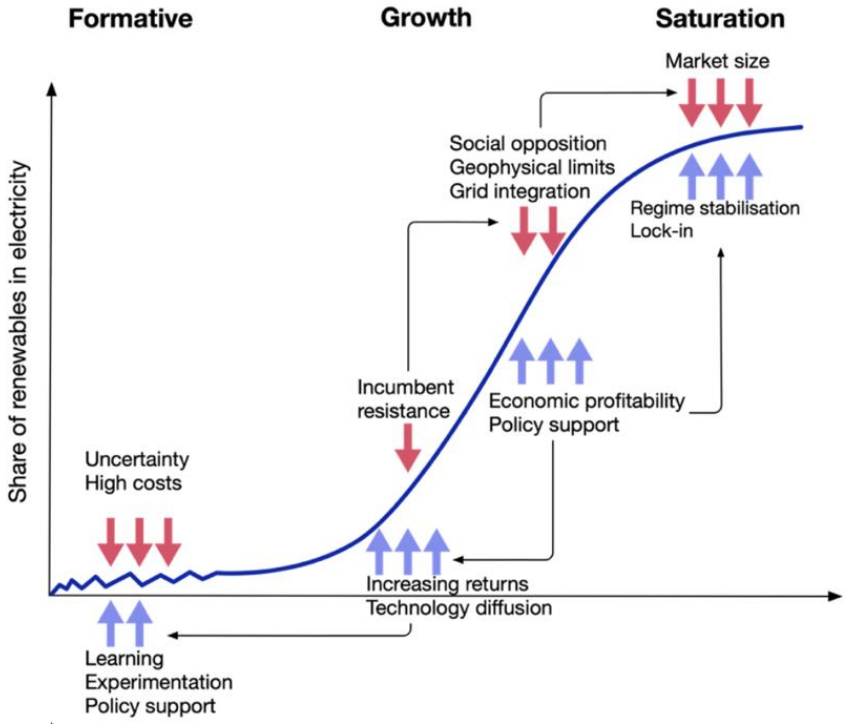
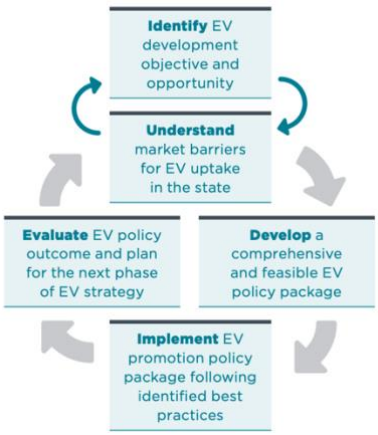


Figure 4. Phases of renewable electricity uptake
Source: Vinichenko et al. 2020

3.1.1 EV Policy Cycle Framework

This research partially mirrors and makes a number of additions to the "EV Policy Cycle" (Figure 5) methodological framework for E-mobility policy development in developing countries (Figure 6). The main idea behind this framework is to focus on the best practices in E-mobility development worldwide in order to provide policy recommendations. This methodology is described in "Electric Vehicle Guidebook" which was published by the International Council on Clean Transportation (ICCT) for Indian states in 2019 (ICCT 2019a).



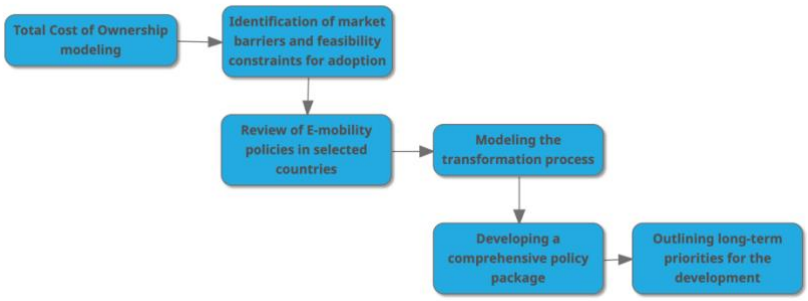


Figure 5. EV Policy Cycle
Source: ICCT 2019a
Figure 6. Research steps
Source: Author

Comparing to the Policy Cycle framework, first of all, this thesis goes beyond the process of a best-case-based policy recommendations design – in the original version of this framework, policy recommendations for India consist of examples from developed countries and regions of the world (e.g. California, Germany, etc.). Unlike the Framework, the thesis provides a comprehensive analysis of E-mobility development potential in Armenia through the review of EV policies in countries with similar economic contexts, allowing to recommend the most feasible policies.

Moreover, in the thesis, the process of adoption barriers identification and prioritization is conducted through stakeholder consultations, whilst the Policy Cycle framework concentrates on the "most commonly recognized" market barriers without analyzing which of them are of the most importance for a country.

In order to "develop a comprehensive and feasible policy package", the thesis analyzes and models different policy options and their impact on the transition process. Cost-effectiveness

and feasibility of these different options is also discussed in the thesis, and the whole range of options are recommended.

Next, this work also provides an in-depth analysis of EV affordability in Armenia. It helps to identify financial gaps for different consumer groups (e.g. public, private) and design policies targeted specifically at certain groups of consumers.

Finally, besides policy recommendations, this thesis also provides recommendations for a long-term E-mobility development within a given context. Implementation and evaluation parts of the EV Policy Cycle are outside the scope of this thesis.

3.1.2 Theory of Change

Although there is a range of definitions, in most of the cases the theory of change explains the pathway through which a certain specific result or goal can be achieved. The complexity of these pathways varies significantly, but the key three terms should always be defined in the following sequence: expected result(s), activities to reach the result(s), and the way these activities lead to the expected results (sometimes referred to as "preliminary results" identification). Vogel (2012) points out policy theories of change as a way to analyze and design country or sector-level changes based on the identification of "intervention options to influence change in the specific implementation context".

Some examples of the theory of change also provide contextual information that might affect proposed activities, such as, for example, stakeholders involved or to be involved into the project. In general, the theory of change allows to formulate a coherent methodology to achieve a goal at the organizational, governmental, or project level, taking into account all internal and external factors that may affect the achievement of these results. In the theory of change, all or some of the results may not depend on the organization that is interested in the change. In this case, the proposed actions lead to assumptions, that is, to what should happen as a result of the implementation of the proposed actions in order to achieve the goal.

3.2 Methods

This thesis incorporates the following methods and steps:

- Modeling affordability of electric vehicles using total cost of ownership (TCO) model;

- Identification of market (adoption) barriers and feasibility constraints for electric mobility in Armenia through a stakeholder workshop and online questionnaires involving ministries, municipalities, public and private sector;
- Review of past and ongoing E-mobility projects and policies in transition countries;
- Identification of feasible E-mobility targets based on the policy review and modeling the transformational process in Armenia;
- Designing the pilot E-mobility project using the Theory of Change approach, including policy recommendations for a continuous E-mobility transition based on the abovementioned steps.

3.2.1 Modelling the affordability of EVs in Armenia

When it comes to affordability and costs, in automotive industry, social, and environmental research of transport, total cost of ownership calculations and models are designed and used. Such "life-cycle costing" approach helps to forecast long-term capital savings (or losses) for products with high initial price but a relatively long lifetime (Brown 1979). As it was concluded above, this might be the case for electric vehicles which have a high upfront cost but lower operational costs when compared to a conventional car (ICEV).

TCO calculations for EVs have already been studied for some markets. However, this type of models is very much dependent on the transport-related financial inputs which vary geographically. The vast majority of these studies were made in the major EV hotspots in the world – USA (Hutchinson et al. 2014; Lipman and Delucchi 2006; Al-Alawi and Bradley 2013) Germany (Wu et al. 2015), Japan (Palmer et al. 2018), and UK (Hutchinson et al. 2013). Moreover, the development of the technology leading to decrease in prices, as it was pointed out above, also highlights time-dependency of such models. In Palmer et al. (2018), reviewed models were dated from 2000 to 2015. As we could see from the literature review, lithium-ion battery price has dropped down by 50% since 2015. Therefore, inventories and inputs for such models should be corrected and updated at least on annual basis.

The first part of the thesis presents results of the model designed solely using Excel environment and divided into three parts. First, it calculates the cashflow structure for a vehicle purchase for both public and private sectors based on the data collected from banks in Armenia. The model includes average inputs from financial products (loans) offered for consumers willing to buy a

vehicle. This part of the model only includes the purchasing process, while other financial aspects of a vehicle ownership (e.g. fuel prices, taxes, etc.) are calculated further. The main financial indicator of this part of the model is the internal rate of return (Equation 1):

Equation 1. Internal Rate of Return (IRR)

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0$$

Where C_t – net cash flow during the period t; C_0 – investment costs; IRR – the internal rate of return; t – a number of time periods.

The next part of the model calculates the total cost of ownership of an EV compared to an ICEV. For this comparison, the analysis of key car market players in Armenia was conducted first, and a sample of two comparable (based on the technical characteristics) ICEV and EV models was prepared and described in the Results section. In basic terms, vehicle's Total Cost of Ownership can be explained in the following way (Equation 2):

Equation 2. TCO – basic explanation

$$TCO_t = RV_t - TCE_t$$

Where TCO_t – total cost of *t* years of ownership; TCE_t – total cumulative expenditures for *t* years; RV_t – vehicle resale value at the end of ownership (year *t*).

Vehicle expenditures, in turn, can be broken down and classified in different ways. In this analysis, the model calculates capital costs ($CAPEX$), maintenance (MC), fuel (FC), tax (TAX), battery replacement (BRC, only for EVs), and interest payment (IR) expenditures. While capital and battery replacement costs are just one-time payments, tax costs were calculated based on the Armenian tax policy, and interest rates were calculated based on the loan terms available in Armenia banks. Maintenance and fuel costs were calculated in the following way (Equation 3 and
Equation 4):

Equation 3. Maintenance costs

$$MC = \sum_{t=1}^{T} \frac{DMC_x \times km_x \times (1 + \omega_x)}{(1 + d)^t}$$

Where MC – maintenance costs for T years of ownership; t – year; DMC_x – direct maintenance costs of a model x ($/km); km_x – annual mileage of a model x; ω_x – annual growth of direct maintenance costs for a model x (%); d – discount rate (%).

Equation 4. Fuel costs (ICEV)

$$FC = \sum_{t=1}^{T} \frac{km_x \times FE_x \times (1 + \alpha_x) \times FP_x}{(1 + d)^t}$$

Where FC – fuel costs; km_x – annual mileage of a model x; FP_x – fuel price; FE_x – fuel economy of a model x (lge/km); d – discount rate (%); α_x – adjustment factor. The adjustment factor combines factors affecting fuel consumption rate, such as gaps between technical and actual fuel consumption data, air temperature, and driving conditions (urban or highway). These parameters are further discussed and described in the Results section.

Vehicle resale value and depreciation rates were calculated based on similar models and literature available due to its high volatility and divergence between EV and ICEV models.

The simplified version of the TCO equation used in this thesis is the following (Equation 5):

Equation 5. TCO – simplified version

$$TCO_{t,x} = \frac{RV_t}{(1 + d)^t} - \left(CAPEX + \sum_{t=1}^{T} \frac{MC + FC + TAX + IR + BRC}{(1 + d)^t} \right)$$

Overall, the model calculates the total cost of ownership (if one considers a possibility to resell the vehicle), cumulative expenditures (if one does not), and draws a cashflow pattern for four vehicle-scenarios (public EV, public ICEV, household EV, household ICEV). The last part of the model provides the sensitivity analysis of the factors used in the model, also indicating the price and mileage parity conditions (i.e. under which pricing and mileage conditions the difference in the TCO between EV and ICEV equals to zero).

3.2.2 Identification of E-mobility feasibility constraints and adoption barriers in Armenia

Based on the literature review, data collection, and consultations with the Ministry of Environment in Armenia, a preliminary list of E-mobility feasibility constraints and adoption barriers was created. Here, adoption barriers can be defined as a set of issues reflecting the willingness to consider, buy, and own an EV perceived by the average consumer in Armenia. Feasibility constraints relate to the discussion of the possibility of a continuous E-mobility transition in Armenia at the national level through a lens of different actors.

After the pre-identification of barriers and constraints, a stakeholder workshop was arranged and held. The workshop has engaged stakeholders related to the topic of electric mobility

development from ministries, municipalities, public and private sectors in Armenia. The main aim of the event was to present current findings and development scenarios modeled as a result of the previous section completion and discuss adoption barriers and feasibility constraints. The workshop was divided into two parts – presentations (current findings and development scenarios) and discussion (round table). During the discussion, stakeholders were asked to elaborate on a set of subject-specific questions that were sent in advance to the workshop – these questions were mostly stakeholder-specific questions to collect more data. The workshop was held in Zoom video-conference software.

In order to prepare the stakeholders for the discussion, draw some conclusions on the importance of certain barriers and constraints, and design a project in accordance with it, the stakeholders were also asked to fill in a questionnaire in advance to the workshop. The questionnaire was prepared in Google Forms and consisted of four multiple-choice questions ('strongly agree' to 'strongly disagree') and two optional open-answer questions for those who wanted to elaborate on their opinion. Unlike sets of questions for the round table discussion, questions in the Google form were the same for everyone. They were related to benefits, barriers, and awareness about E-mobility in Armenia. Some of the findings from the questionnaire were used for long-term policy recommendations.

3.2.3 Method for the selection of country case studies and E-mobility policy review

In order to come up with feasible policy recommendations for a continuous E-mobility development in Armenia, the next step of this thesis was to review E-mobility policies and their outcomes in countries comparable (i.e. with similar economic contexts) to Armenia.

Selecting countries for the policy review, two main factors were taken into consideration: economic capacity and vehicle market size. According to the European Automobile Manufacturers' Association (ACEA), the share of EVs in countries with GDP per capita rates below EUR 18,000 is practically 0% (Ralev 2018). This statement is partially true, although it implies that there is some correlation between GDP per capita and EVs share in a vehicle fleet. Due to the dynamic nature of prices, incentives occurrence, awareness raising, and other factors, this correlation has to be tested on an annual basis in order to track the worldwide transition.

The most recent data regarding EV sales in the EU was used for the country selection, and a linear regression trend was built using these two variables. Next, a sample of European

countries was selected, including those with the most 'successful' ratio of two abovementioned factors (low GDP/cap, high share of EV sales) and 'baseline' countries (low GDP/cap, low share of EV sales) in order to make a meaningful comparative policy analysis and understand which policies drive the uptake of EVs.

After the countries were selected, a top-down approach was taken for the policy review. First, the review of the "Integrated National Energy and Climate Plan (NECP) for the period from 2021 to 2030" was conducted. NECPs are required to be published by every EU country in accordance with the Regulation (EU) 2018/1999 on the Governance of the Energy Union (European Parliament 2018). The last draft versions of NECPs were sent by EU countries by the end of 2018, consisting of the main climate-related measures and targets from national energy, transport, and other national plans and strategies.

Secondly, a further review of national transportation and energy policy documents was undertaken, especially when some of NECPs were lacking any relevant information about the transportation sector and, in particular, E-mobility. For example, reports on the assessment of National Policy Frameworks in accordance with Directive 2014/94/EU provide a comprehensive review and assessment of national targets and objectives related to alternative fuels infrastructure development and vehicle stock.

This thesis also analyzes the historical data on charging infrastructure development and its actual significance to the EV adoption in the region based on the European Commission methodology. This methodology introduces a standard measure for understanding the level of charging infrastructure development – "Infrastructure Sufficiency Index", which is the total number of EVs in a country divided by the total number of public chargers (European Commission 2019).

Due to the initial stage of E-mobility development in Armenia, a specific attention was given to the very first signs of E-mobility in selected regions, such as small-scale demonstration projects, first incentives introduced, or first investments made. Academic publications and news articles were additionally reviewed for this information.

Overall, the main objective of this policy review was to analyze the range of EV policies in late-adopter EU countries with low economic capacities and small vehicle market sizes; drivers

and barriers for E-mobility; outcomes and plans; and to understand what lessons can be learnt and used for a subsequent policy recommendation and project design in Armenia.

3.2.4 Modeling the transition scenarios

In this section, transition scenarios of E-mobility uptake in Armenia were modeled based on the country case study's findings from the previous subsection of this thesis. Scenarios with different policy packages implemented were applied to the Armenian car market in order to analyze potential short-term (5 years) impacts of different measures for EV uptake. To do this, observed trends of EV sales growth in selected countries were firstly analyzed and modeled using compound annual, exponential, and linear growth trends in order to approximate different fluctuations in observed data caused by external (non-policy) factors. The best-fitting growth pattern for each country was then applied to the current market data in Armenia in order to see the potential differences between implemented measures and their outcomes. By using the coefficient of determination (R squared) values, we could see which of the above trends better explain current and approximate the future growth of EVs based on the already observed data. The interrelation between these groups of scenarios was also analyzed.

3.2.5 Designing the E-mobility project for Armenia

This thesis finishes with the development of the Theory of Change for the project. Once the barriers and the problem for E-mobility development in Armenia are identified, the Theory of Change tree was designed, consisting of the overall goal and the list of sample measures for each barrier. Overall, these measures are a set of policy recommendations for short and long-term adoption of electric vehicles and continuous E-mobility transition in Armenia. The simplified version of the project part of this thesis is presented below (Figure 7).

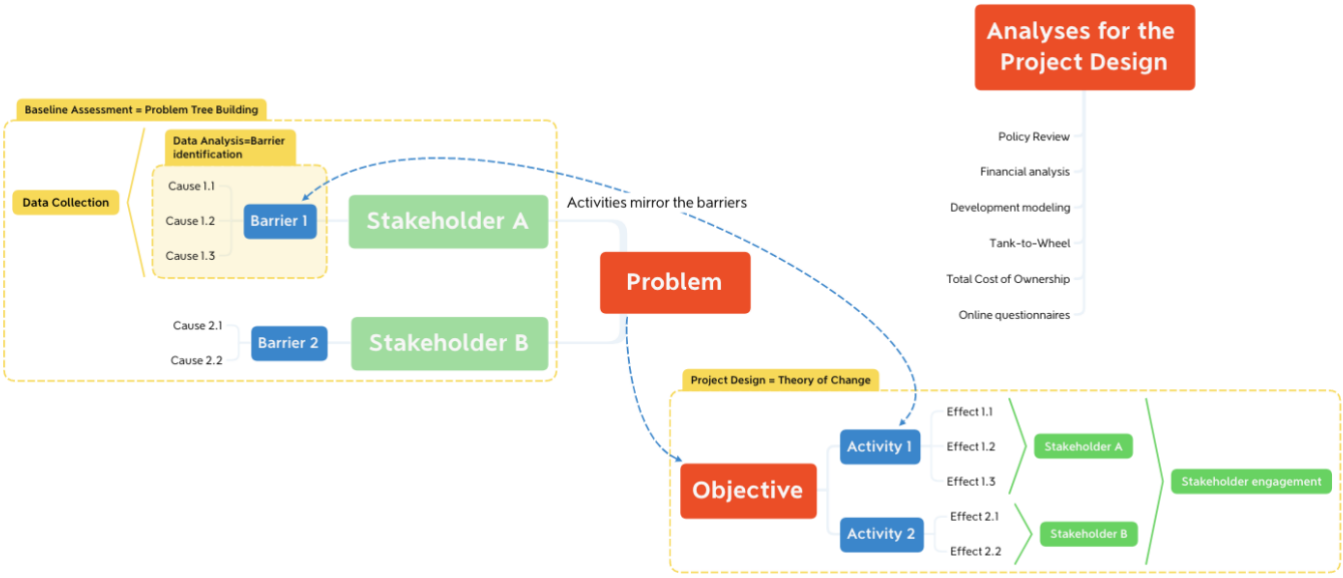


Figure 7. Simplified project workflow
Source: Author

3.3 Limitations

Keeping in mind the novelty of E-mobility policymaking and the experimental nature of additions to the "EV Policy Cycle" framework, there is a range of limitations related to every method used in this thesis.

As in any other model, the limitations of the TCO model used in this thesis relate to input values used in it. While prices for fuel and electricity in Armenia were acquired from stakeholders, the average costs of vehicle maintenance are based on the range of external (mainly European and American) sources which do not always imply the differences in labor costs. However, what is more important, the difference between maintenance costs of EV and ICEV models is relatively same in any location. Another value equally uncertain for any TCO model which studies EVs are depreciation rates of an EV. The main reason for this uncertainty is the novelty of the technology – there are not that many drivers who would own an EV for more than 10 years, which makes it difficult to predict what would be the residual cost of the vehicle after such a long period of ownership.

Stakeholder workshops conducted for this study were held during the state of emergency in Armenia caused by the COVID-19 outbreak. Therefore, the workshops were held online, and some of the assumptions had to be taken by a limited number of stakeholders on the behalf of an average consumer in Armenia in order to identify adoption barriers.

The selection of countries was based only on two parameters – shares of EV sales in total vehicle sales in 2019 and GDP per capita rates (2018, current US$). This study uses the latest values available at the moment and specifically chooses these two parameters in order to analyze the current condition of E-mobility transitions in the EU. Nevertheless, the growth in the share of electric vehicle sales in different countries can be chaotic, due to factors not affected in this work. Lastly, despite of some contextual similarities between selected countries and Armenia, there are still significant differences in economic, social, and political contexts.

As for the E-mobility policy review in selected countries, some uncertainties can also be identified. The existence of some policies, plans for their implementation, and in some cases even statistical data for EVs were contradicting in the range of documents reviewed. In some of the selected countries, these types of data could vary significantly from one national policy document to another. Therefore, the policy review, as stated above, is using a top-down approach, firstly having a look at EU databases (e.g. EAFO), and only then, when data gaps are identified, turning to academic articles, national policy documents, market reports, and, lastly, news articles.

The main limitation associated with the scenario modelling of an EV uptake in Armenia is a short historical period of observations caused by the novelty of the EV technology for the selected countries. This 'immaturity' of trends may lead to significant discrepancies between the modeled and actual EV uptake in Armenia. Moreover, despite monetary incentives, it has been difficult to measure the impact of a single policy (e.g. free parking) due to the lack of information on when they were introduced in the selected countries. As a result, these modeling scenarios rather compare policy packages instead of a single policy impact. Another limitation of this part of the thesis is that the recent E-mobility fiscal incentives introduced in Armenia, VAT and custom duty exemption, are not included in the modeling results (but included in the TCO model) – it is difficult to assess its actual impact on the uptake since it has been introduced quite recently (less than a year ago).

The sectoral disaggregation of EV uptake was not provided in this research due to the lack of data. For example, the Clean Vehicle Directive and public procurement targets for EU countries include not only EVs, but fuel-efficient petrol, hybrid, and biofuel vehicles, making it challenging to acquire EV-specific data. This is the main reason for the lack of sectoral disaggregation within collected data and uptake modeling.

4 Results

This section describes the results of this work. The first four subsections describe the results of various analyzes carried out within the framework of this work, while the last subsection is a product of these results and describes the recommendations for policymakers in Armenia.

4.1 Economic Attractiveness of EVs in Armenia

For this research, it is essential to conduct an economic analysis of electric vehicle ownership in the early stages of E-mobility development, since the 'high upfront cost' was pointed out as a significant adoption barrier during the literature review. Secondly, it is also necessary to calculate this parameter for various consumer groups as their vehicle usage, purchasing power, and, ultimately, ownership costs might vary. In this study, two consumer groups are compared – private (households) and public. Hereafter, a "public vehicle" would refer to as a passenger car used in the public sector (do not confuse with buses).

4.1.1 Scenarios and initial calculations

Based on the data collection and preliminary stakeholder consultations, numerous gaps in the data regarding the transport sector were identified. However, one of the documents developed for Yerevan in 2016, the Yerevan Sustainable Energy Action Plan (Yerevan SEAP), includes a detailed description of the municipal fleet. More precisely, the publication contains data on the approximate number of cars assigned to the administrative territories of Yerevan and their fuel consumption for 2012. Moreover, it is stated that all of the vehicles are run solely on petroleum (gasoline). Even despite the relative age of the data, representatives of the municipality of Yerevan assured that these data remained approximately identical in 2020. Therefore, we assume that these values used from the Yerevan SEAP are the same (see Equation 6 below).

Moreover, the Yerevan Green City Action Plan (Yerevan GCAP), prepared in 2017, also includes data on the average age of cars in Yerevan. Such data was a good starting point for creating the model – it became possible to calculate the average annual mileage of a car based on the average fuel consumption of a car produced in 2004 (since the average vehicle age in Yerevan is 16). One additional value used in the equation, fuel economy gap, refers to the study by the International Council on Clean Transport, which investigates the actual fuel consumption and emission rates of a vehicle based on the real-world data from more than 1,500,000 vehicles, comparing research findings to manufacturer's technical notes on a vehicle. Such reports are

published annually from 2012, but some data also available for earlier years. In the equation, we use the fuel economy gap for 2001 (ICCT 2019).

Equation 6. Mileage calculation

$$M = \frac{FC_{2020} \times FE_{(2020-age)} \times (1+G)}{n_{2020}} \times 100$$

Where M – mileage; FC_{2020} – total fuel consumption of vehicles assigned to administrative districts of Yerevan in 2020 (liters of gasoline); age – average age of a vehicle in Yerevan; $FE_{(2020-age)}$ – fuel economy of an average aged vehicle in Yerevan (liters per 100 kilometers); G – fuel economy gap (ICCT 2019); n_{2020} – number of vehicles assigned to administrative districts of Yerevan in 2020.

Based on the results obtained from Equation 6, the average mileage of the vehicles assigned to administrative districts of Yerevan is approximately 40,000 km, which is a significant number comparing to the average mileage of a household car. Therefore, according to the modeling objectives indicated above, two scenarios were designed based on the annual mileage of a vehicle. Based on the initial literature review of TCO studies and in order to make the comparison of results more comprehensive, the annual mileage of 20,000 km was chosen as the second (private sector) scenario for the model.

Due to the comparative nature of the model (one EV compared to one ICEV) and specific geographical allocation, the next step of the model building was the review of key car market players in Armenia. Due to the small size of the EV market in Armenia, we were able to find only one EV model available for sale (new) – MG ZS EV. According to the technical specifications of this vehicle (mainly related to performance, dimensions, and weight, regardless of a purchase price), a similar ICEV model was found available for sale in Armenia – Nissan Kicks (Table 4).

Table 4. Vehicle model characteristics
Source: Author

	MG ZS EV	**Nissan Kicks**
		
Fuel type	Electricity	Petrol (gasoline)
Length (mm)	4314	4295
Width (mm)	1809	1960
Height (mm)	1644	1590

Engine power (kW/HP)	105/150	118 HP
Battery (kWh)	44,5	n/a
Max. speed (km/h)	140	185
Fuel consumption	186 Wh/km	7,8 lge/100km
Purchase price	USD 32,000	USD 20,000
Other	The MG ZS EV has a 5-year or 100,000 km warranty on the car and an 8-year or 150,000 km warranty on the battery.	

4.1.2 Assumptions

Speaking of fuel consumption, similar to the fuel efficiency gap used to calculate the annual mileage of vehicles owned by administrative districts of Armenia, the gap between actual and technical fuel consumption of new European passenger vehicles in 2017 was 39%. However, the "Emob calculator" model designed by UNEP uses the coefficient of 0.3 (30%) (UNEP 2020). This reduction might be explained by the uncertainty caused by a high number of cars participated in this research, so our model uses the same coefficient of 30%. Fuel consumption data for the EV model is presented in Table 5.

Table 5. Electricity consumption of MG ZS EV

Conditions	**Fuel consumption**	**Range**	**Source**
Average – NEDC Test	13.3 kWh/100km	335 km	Manufacturer's website
Average – WLTP Test (incl. charging losses)	18.6 kWh/100km	263 km	Manufacturer's website
City – Cold Weather (heating on)	18.5 kWh/100km	n/a	EV Database, based on real data
Highway – Cold Weather (heating on)	27.8 kWh/100km	n/a	EV Database, based on real data
City – Mild Weather (AC off)	12.7 kWh/100km	n/a	EV Database, based on real data
Highway – Mild Weather (AC off)	21.7 kWh/100 km	n/a	EV Database, based on real data

In order to balance the 'reality' of fuel consumption for both ICEV and EV, we also calculate EV's electricity consumption with regard to climatic conditions in Yerevan. For this purpose, daily average temperatures for 2019 were obtained from Yerevan Meteorological Unit. Here, we assume that heating impacts fuel consumption the same as air conditioning, therefore for average daily temperatures lower than 7°C and higher than 20°C we use 'Cold Weather' consumption, and for temperatures in between – 'Mild Weather'.

As for city and highway driving conditions, we use the combination of 90% city and 10% highway for 40,000 km scenario, as it is based on the data from administrative districts of Yerevan, implying that the vast majority of a vehicle operation takes place in Yerevan.

Moreover, we calculate it based on 260 working days per year. It should be pointed out that despite the significant annual mileage of public vehicles, the daily range covered by a fully charged battery of the EV model is still considerably higher (155 km/day mileage and 240 km range). For the 'household' 20,000 km scenario, the model uses 80% city and 20% highway, because private car owners tend to be more mobile.

The model assumes the lifetime of both vehicles to be 16 years – this is partially done due to the 8-year warranty on the battery when buying MG ZS EV, so the model assumes one battery replacement at the beginning of the year 9. Secondly, even though 16 years is only the average vehicle age in Yerevan, it gets challenging to model operational expenditures – different damages and breakages tend to have a random frequency and cost. Operational costs of EVs have not been documented for such a long ownership period due to the novelty of the technology. For this reason, results for both 8- and 16-year total cost of ownership will be provided further.

As for the maintenance costs (also referred to as "operational expenditures", or OPEX; do not include fuel costs), the model uses average values of 0.038 and 0.056 USD/km for EVs and ICEVs respectively, based on the UNEP "Emob calculator" model and Propfe et al. (2012). However, due to the mileage difference of the two scenarios, we make two assumptions related to maintenance costs in the model: in 40,000 km scenario, maintenance costs increase by 2% annually, and 1% annually in 20,000 km scenario during the first ten years of ownership. Starting from the eleventh year of ownership, maintenance costs remain the same as the year before.

Due to the lack of available data and underdeveloped charging infrastructure in Armenia, the costs calculated for charging are based on the household electricity tariffs. As was pointed out during the workshop by UNEP and Armenian representatives, the vast majority of charging events occurs at home. Moreover, electricity tariffs in Armenia are time-based. In the model, we use a 50/50 day/night charging pattern and costs.

TCO calculations relate to depreciation rates (costs) of a vehicle (i.e. how much a vehicle price drops down annually) in order to calculate annual resale prices and understand when the right moment is to resell the vehicle. It is commonly assumed that due to the immaturity of the technology and constant decrease of prices for EVs, they tend to depreciate a lot faster. The

information related to the depreciation rates of EVs is quite limited. A similar model designed by UNEP uses the depreciation rates of 70% for EVs and 60% for ICEVs for a 10-year ownership cycle, though it does not specify the annual divergence of depreciation rates. Some basic assumptions were drawn from the CAPP automotive consulting database, also used in Palmer et al. 2018 (Figure 8).

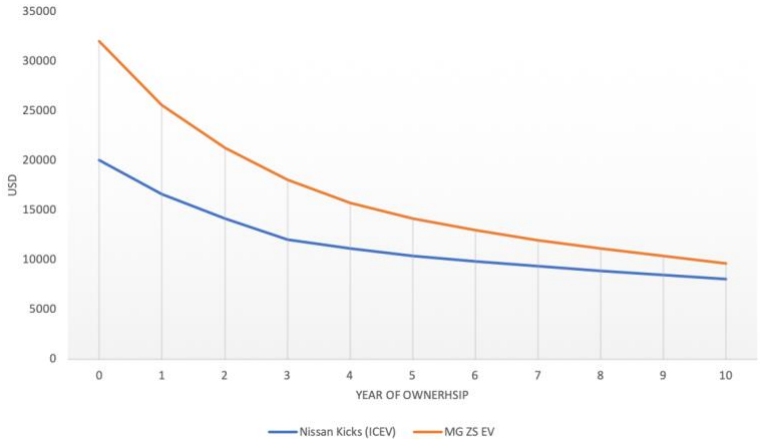


Figure 8. Assumed Resale Price Depreciation for selected vehicles
Data Source: Palmer et al. (2018) with amendments

4.1.3 TCO modeling results

TCO results for two mileage scenarios using two different vehicle models over 8 and 16 years of ownership are presented below (Figure 9, Figure 10). The costs were calculated in Armenian Dram for a financial accuracy.

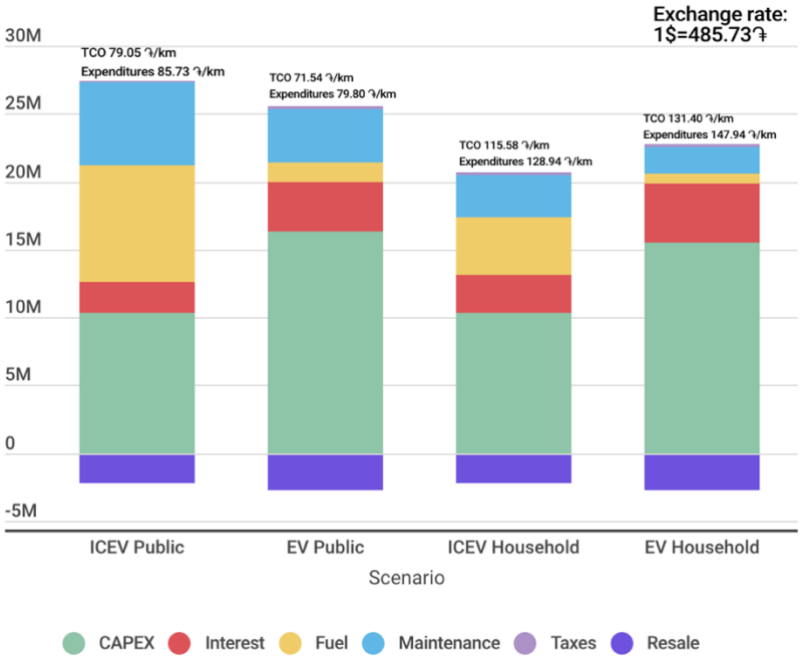


Figure 9. TCO results for 8 years of ownership
Source: Author

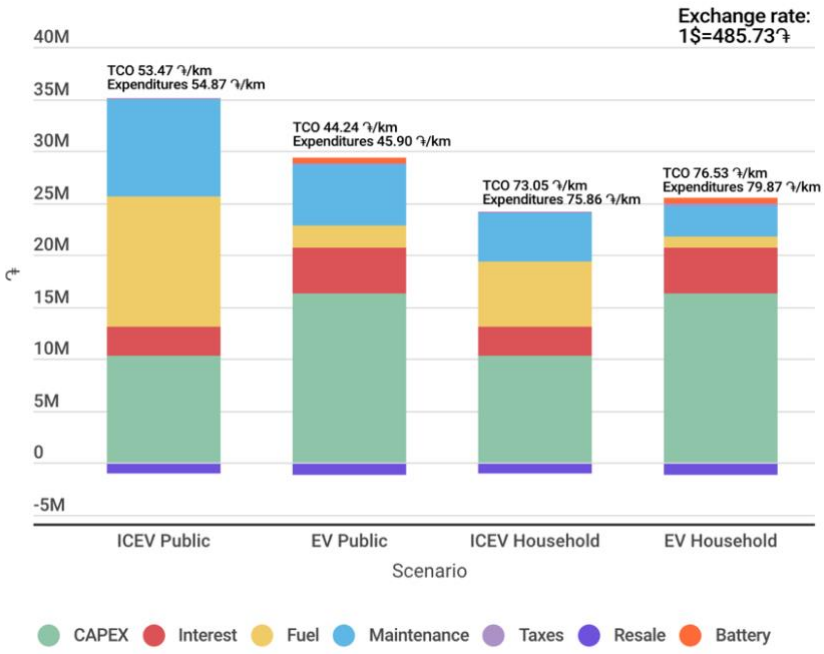


Figure 10. TCO results for 16 years of ownership
Source: Author

For more temporal clarity of TCO values, differences in annual TCOs between the vehicle models were also calculated (Figure 11). This figure shows the cumulative savings (or expenditures) of the EV usage over the ICEV usage for a specific time period, including the resale costs. Figure 12 only shows differences in cumulative expenditures, including the upfront price but excluding the resale. On both figures, monetary savings occur in a year when the line passes through a 0 value on the y-axis.

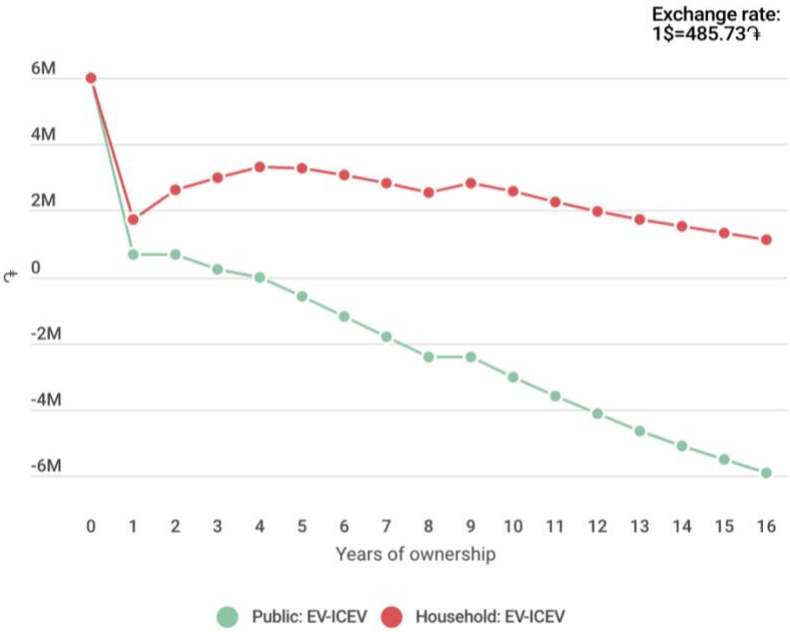


Figure 11. Differences in annual TCOs
Source: Author

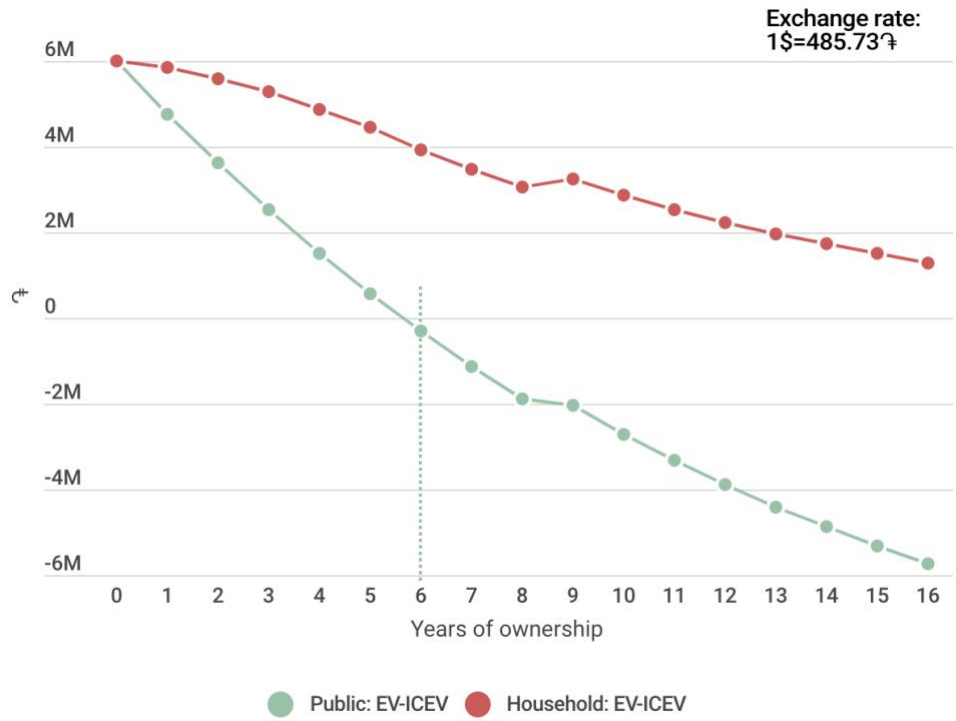


Figure 12. Differences in cumulative expenditures
Source: Author

4.1.4 Sensitivity analysis

In this subsection, a sensitivity analysis of factors included in the TCO model will be conducted. We will have a look at two groups of factors: factors with a temporal or subjective volatility (upfront costs, fuel and electricity prices, mileage) and factors that are uncertain due to the novelty of the EV technology or other factors (depreciation rates, maintenance costs). The main output value of the model is the difference in cumulative TCO by the year 8, so we test the sensitivity of this value to changes in the abovementioned factors.

In order to do so, we conduct a single factor sensitivity analysis, fluctuating the factors separately (for both EV and ICEV) in +20 and -20 per cent for public and household scenarios and analyze the change in the "difference in cumulative TCO" value. First, we look at the public sector (Figure 13).

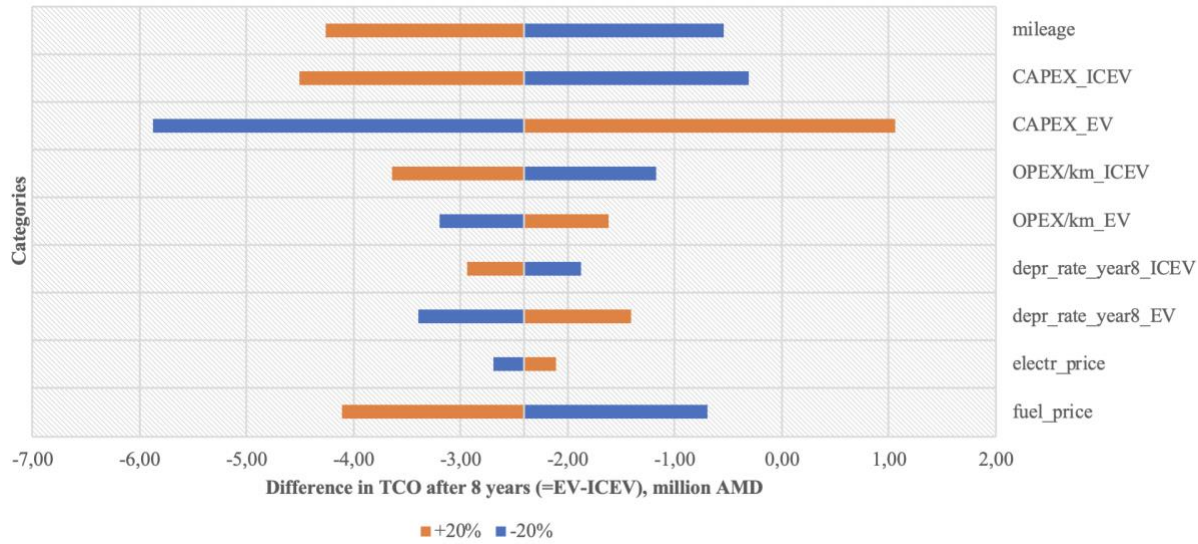


Figure 13. Sensitivity analysis 1 – Public sector, 8 years of ownership
Source: Author

We can see that the most influencing factors are upfront costs, mileage, and petroleum price. The only single factor change that brings the TCO of the EV to be more than of the ICEV is the EV upfront cost (20% increase in CAPEX_EV makes the difference in TCO higher than zero).

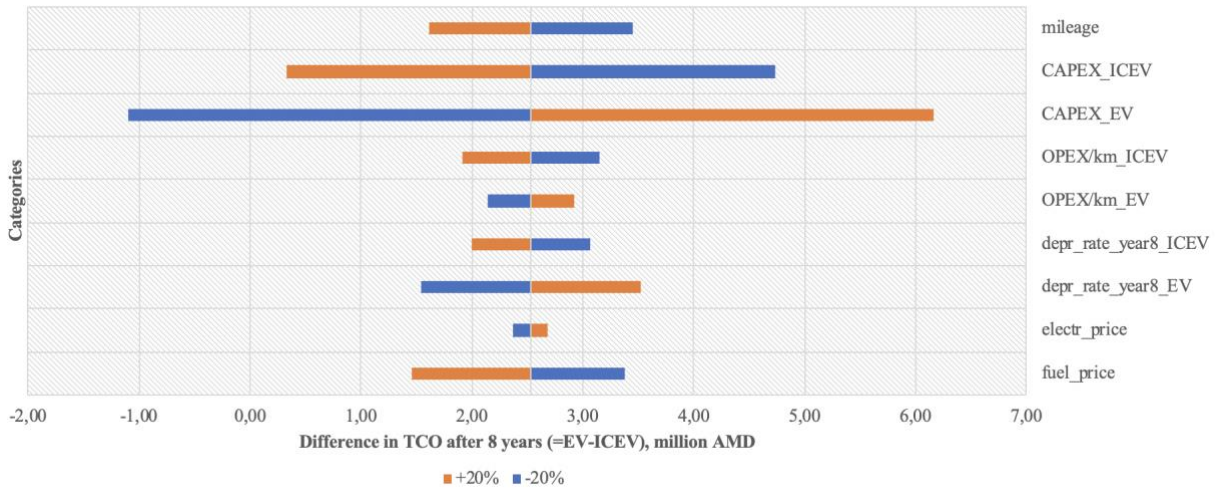


Figure 14. Sensitivity analysis 2 – Households, 8 years of ownership
Source: Author

As for the household scenario, the model shows that sensitivity of fuel and electricity prices and maintenance costs goes down in parallel with a mileage decrease assumed in this scenario (Figure 14).

Upfront costs and mileage are user-specific factors which tend to vary across different drivers. In order to see the actual gap in upfront prices between the two vehicle models, we conduct a

multiple-factor sensitivity analysis by creating the scenario with the difference in TCO (8 years) equal to zero, where the only factors to change are ICEV and EV upfront costs while other factors remain untouched. As for mileage, the same step was performed with the only factor to change being the mileage (Table 6).

Table 6. TCO parity scenario 8 years of ownership
Source: Author

Scenario	**Scenario 1 – upfront costs**		**Scenario 2 – mileage**
Factor	CAPEX_ICEV, AMD	CAPEX_EV, AMD	Mileage, km
Public	9666915	17955815	29646
Household	10937388	14636184	30984

We can see that in order to achieve parity between EV and ICEV TCOs, the annual mileage of a public sector vehicle should be about 11,000 km less than it is, meaning that these extra 11,000 km per year actually make EVs more affordable according to the model. As for the household scenario, where TCO of the EV is higher, an additional 10,000 km per year are needed to make EVs as affordable as ICEVs.

When considering CAPEX costs of the vehicles, the analysis has shown that in the public sector, an EV with the cost almost twice as high as an ICEV can be purchased, and the difference between TCOs (EV-ICEV) would still be less or equal to zero. As for households, the allowed CAPEX difference is significantly less. Nevertheless, it means that EVs do not have to be initially cheaper in order to be cost-effective.

4.2 Feasibility analysis and barrier identification

4.2.1 Stakeholder mapping

Based on the reviewed literature related to the transportation and energy sectors, climate change mitigation and adaptation measures in Armenia, as well as consultations with the Environmental Project Implementation Unit of the Ministry of Environment of the Republic of Armenia, the following stakeholders were contacted and invited to participate in the workshop (Table 7).

In these invitations, a preliminary sample of questions to be asked was also attached in order to prepare stakeholders for the discussion. These stakeholders were also asked to fill in the questionnaire in advance to the workshop. For the questionnaire, please see Annex A. In total, seven stakeholders have filled in the questionnaire, ten stakeholders have participated in a

multilateral discussion, and two in additional bilateral discussions. Some results of the questionnaire are also used further in the thesis.

Table 7. List of stakeholders to participate in the workshop
Source: Author

Organization	**Questions**
"Environmental Project Implementation Unit" State Agency (2)	Participation in the discussion
UNEP (2)	Participation in the discussion
Ministry of Environment (3)	Role of transportation sector in CC mitigation in Armenia; GHG emission trends and planned measures. Yerevan Green City Action Plan e-mobility measures implementation.
Armenian Energy Agency; Plug.am project (GEF small grant project for charging infrastructure development in Armenia)	Charging infrastructure development in Armenia; market players; power demand readiness; **probable incentivization of market players;** discussion of business models for charging. Regulations and infrastructure availability; ways to improve the quality of e-mobility related services, including **private and public charging stations** installation technical regulations.
Yerevan Municipality	Discussion on institutional environment for e-mobility and other conditions for EV uptake;
Gyumri Municipality	Discussion on institutional environment for e-mobility and other conditions for EV uptake;
Ministry of Finance (separate discussion)	Current state of public procurement of vehicles: expenditures, vehicle models, end-users, mileage, etc. Information about financial products for a vehicle purchase offered in Armenian banks; finance schemes and business models
Ministry of Transport and Communication (separate discussion)	Recent and current developments in the transportation sector; priorities for development; ongoing projects and policies; e-mobility development;

4.2.2 Identification of barriers for E-mobility in Armenia

Keeping in mind the state of transition of the Armenian economy, there is a range of barriers that will have to be tackled in order to promote and develop electric mobility in the country. Based on the literature review of adoption barriers and feasibility constraints, as well as the EV Policy Cycle framework used in this thesis, the following list of barriers was initially created and used in the online questionnaire (Figure 15).

1. High upfront cost;
2. Insufficient charging infrastructure;
3. Lack of consumer and stakeholder awareness, capacity and knowledge;

4. Lack of EV model availability in Armenia.

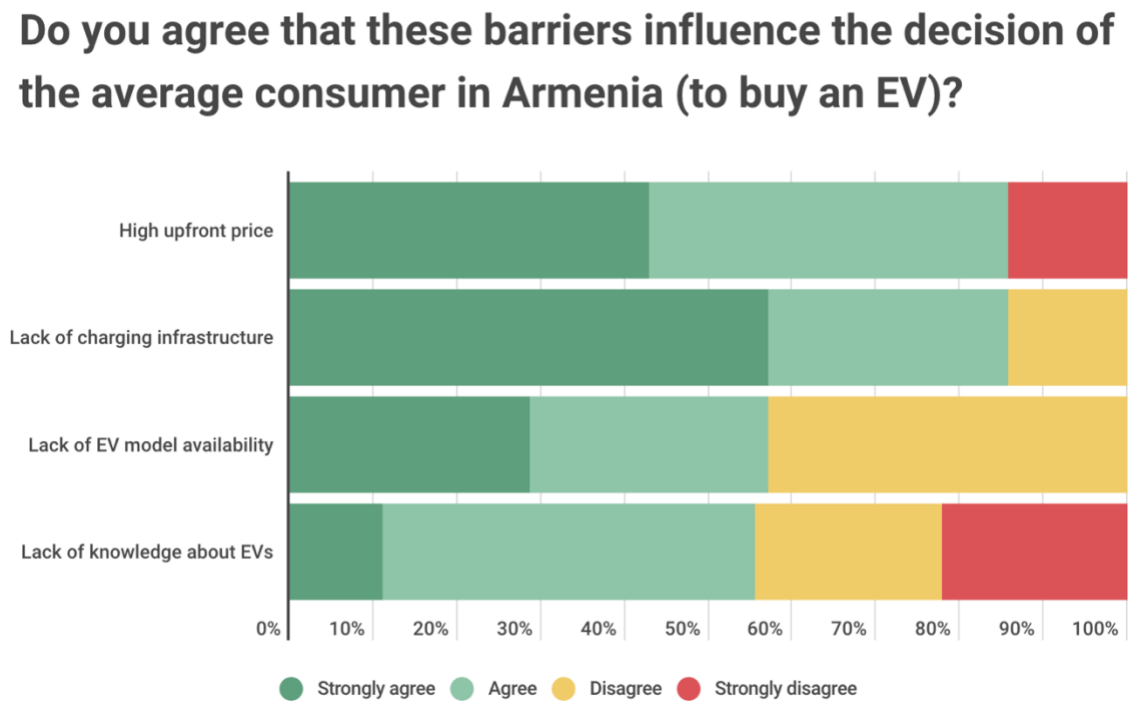


Figure 15. Importance of selected adoption barriers in Armenia
Source: Author

However, as a result of the workshop, another (sub)barrier was raised by stakeholders and subsequently added to this subchapter – "lack of coherent policy framework and absence of strategical vision for E-mobility". This barrier was included in the further analysis and project design instead of the "lack of EV model availability" barrier which (despite of the questionnaire answers) was referred to as insignificant during the workshop since all vehicles, ICEV and EV, are imported to Armenia by companies and households. Moreover, average consumers tend not to buy new vehicles due to a high upfront price.

"Prioritization of country activities in the field of E-mobility is the best way to achieve positive outcomes [for the transportation sector]…however, we do not have any priorities now".

Lack of a coherent policy framework for E-mobility (1). At present, there is a limited general and technical knowledge regarding E-mobility development and implementation of supportive policies in key transport agencies, as well as among representatives of the municipality and national authorities. The majority of politicians also do not have information about the effectiveness, efficiency, and, more importantly, feasibility of relevant political actions at the international level and locally.

There is a strong need in assistance on framing and implementing different types of policies, incentives, norms and regulations under the umbrella of E-mobility strategy, technical regulations for charging infrastructure, transport system regulations for EVs, introducing national targets and plans for a continuous EV adoption, data collection, designing performance indicators and monitoring mechanisms of potential outcomes of policies introduced. Although some incentives have recently been introduced in Armenia, there is still no framework for a continuous development of electric mobility. Whether or not implemented measures will lead to any uptake, how long they will last, and what is a consumer perception about it is still unknown.

"I hope that one of the outcomes of this program will be a vivid action plan".

Absence of strategical vision for E-mobility (1). For a successful and continuous transition to E-mobility, a coordinated and structured approach for policymaking is vital, requiring the organization of interaction between key institutions, such as ministries of energy, transport, and environment; municipalities; customs, and so on. Subsequent cooperation with private businesses, public organizations, and consumers is possible only after appropriate allocation of powers from above.

"Monetary incentives in such distant locations, as California, decrease second-hand prices for EVs, making them more accessible for Armenians".

Higher upfront costs (2). EVs still have not reached the price parity with conventional vehicles, as it was also proved by the TCO model in the previous subsection. In Armenia, there are two major fiscal incentive in place – VAT and custom duty tax exemption for EVs, which has been announced quite recently, so its actual long-term effectiveness on the uptake is uncertain.

Still, individual choices are influenced mainly by short-term considerations, established preferences and convenience, and, most importantly, the limited availability of finance to afford the initial investment. High upfront costs of new vehicles, both EVs and ICEVs, force Armenians to import old, sometimes damaged, or right-handed vehicles for the U.S. and Japan for a relatively low price and repair them in Armenia. High upfront costs of EV makes such investment not affordable for the vast majority of potential consumers in Armenia.

"An actual importance of [public] charging infrastructure is a bit overrated. What is necessary right now is to look at public charging as a mean of advertisement, whilst research shows that the majority of EVs are charged at home".

Lack of infrastructure (3) is one of the most often mentioned barriers to adoption and is always an issue to consider when taking the first steps towards E-mobility. Besides a government, there are lots of potential stakeholders in Armenia who might be involved: local authorities, companies, charging companies, shopping malls, gas stations, construction companies, urban developers and planners, parking companies, etc.; therefore, the process of charging infrastructure development might be allocated to these agents by a government through a regulatory policies and standards;

The most complicated piece of charging network planning is defining the location and capacity of a charger. Overall, more than 50% of charging events happen at home, including charging in residential areas. When it comes to charging specifically at home, it usually happens overnight. The proportion of home and public chargers varies globally. More than 15% of charging events occur at work, with BEV users using this opportunity more often than PHEV users. So-called 'corridor' charging stations are being used in 5% of all charging events, but their importance should still be underlined since these charging events usually happen during a long-distance travel (Hardman et al. 2018). However, this is not the case for Armenia since it is a small landlocked country with borders opened only with Georgia. According to the workshop consultation, the main transport corridor with Georgia is already under the charging infrastructure development. Therefore, although there is a need for more public chargers in Armenia, it does not imply a huge national rollout program.

According to the workshop consultation, there are about ten charging points in the entire country. In January 2019, a USD 50,000 "PLUG.am" project funded by the Global Environmental Facility (GEF) had started, aimed at installing 23 charging points around the country, focusing mainly on Yerevan and the corridor with Georgia.

Finally, charging infrastructure regulations and policies should be conceptualized and incorporated in a broader E-mobility strategies, plans, and policy packages. The long-term planning for charging infrastructure development should go in line with a potential driving range extension due to the technology advancement.

"At first, we [charging network company] spent a lot of time trying to explain what we are going to do, what is a charging station, what is an EV".

Lack of technical knowledge and expertise (4). Another potential issue with electric vehicles is its integration in the transportation system of Armenia. First, although the need for maintenance is not as frequent as for ICEVs, there is a lack of expertise and capacity among service technicians caused by a small number of EVs on the roads. Second, there is no single carmaker in the Armenian automotive market, meaning that all vehicles are imported from abroad through a range of dealers that might or might not have electric vehicles in their portfolio. Third, technical knowledge is required for a charging network development, both from a technological and business perspective, which was indicated as "poor" by the charging network developer who participated in the workshop.

Therefore, this relationship between the governmental representatives, car dealers, as well as charging networks and repair services, should be maintained in order to enable knowledge generation and awareness raising. The integration of electric vehicles in the transportation system should be supported by facilitated processes of vehicle legal registration and road signs introductions (especially vital when non-monetary incentives are introduced e.g. free parking). Lastly, a certain level of technical knowledge is required to integrate EV chargers into the country's energy system, connecting them to the grid, balancing and forecasting supply and demand for electricity from EVs, etc.

"[One of EV adoption barriers in Armenia is] the lack of a strong willingness to become a part of environmentally friendly and green activities by the usage of green equipment, such as electric vehicles".

Lack of awareness and behavioral perceptions of consumers (4). From the consumers' perspective, the main concerns about electric vehicles (besides the price) are mostly related to its technical constraints, such as range anxiety and lack of charging infrastructure. The majority of consumers are unaware of the rapid EV technological development and other benefits of the technology, such as air quality improvement, health and safety, noise pollution reduction, etc. There are currently about 150 EVs on the roads in Armenia, which also reflects the level of awareness and lack of potential to increase it.

Based on the discussion during the workshop, the extended list of stakeholders was created, and the following stakeholders were contacted to take part in further bi- and multilateral

consultations and the implementation part of the project, with their roles also described in Table 8.

Table 8. List of stakeholders for a further involvement and their roles
Source: Author

Institution(s):	**Role(s):**
Ministry of Environment	The Ministry will act as an executing agency and will play an advisory role, providing expert advice on aspects related to climate change mitigation.
Ministry of Energy Infrastructures and Natural Resources (MENR)	The Ministry will be involved in discussion on power demand from e-mobility and on the business relationship between distributors and charging companies.
Ministry of Transport and Communication	The Ministry will be responsible for EVs integration in the transport sector providing necessary regulations, policies, and norms.
The State Urban Development Committee	The Committee will support in the design and implementation of demo projects and co-financing investments.
The Energy Regulatory Commission	The Commission will provide required information about electricity tariffs, operating licenses, and other regulations that might be related to EV charging infrastructure development.
Ministry of Finance	The Ministry will play an advisory role and provide expert advice on aspects related to policy formulation and legal / regulatory measures related to public and private sector charging infrastructure providers.
City Council and Local Government Authorities	The ministry will provide project technical inputs and information on the demo planning, design, integrated inventory data collection, as well as policy inputs to the Project Document.
Human Rights Defender's Office	Provision of gender-specific quantitative and qualitative data for the project
Municipal Governments	Support in the design and implementation of demo projects and co-financing investments.

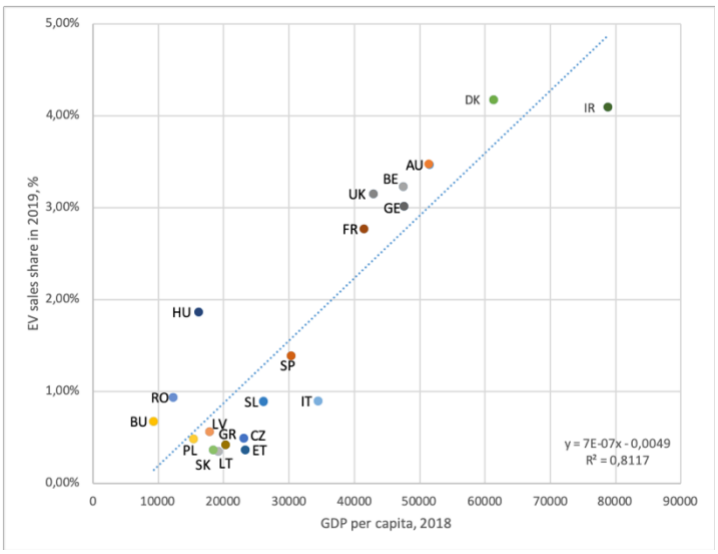
4.3 Measures and strategies for E-mobility – policy review

4.3.1 Country selection

Using the latest data available from the World Bank and ACEA, we produce a graph to test the relationship between GDP/cap (current US$) and EV's share of sales (among total car sales) in EU countries which have not reached a 5% share in 2019 (Figure 16). No sales data was found for Malta, Croatia, Luxembourg, San-Marino, Monaco, and Lichtenstein. EV shares of sales in the Netherlands, Finland, Portugal, and Sweden are above 5% (ACEA 2020), therefore also excluded from the analysis.

We can see that there is a correlation between GDP per capita and EVs share in vehicle sales in the EU ($R^2 = 0.81$, p<.001). Since Armenia possesses a low economic capacity, aiming at the EVs share more than 2% would be indeed too optimistic. Therefore, we have a closer look at the same relationship but within countries with GDP per capita less than USD 30,000 (Figure 17). Here, we see that this relationship is rather reverse and there is no such correlation – Romania and Bulgaria are closer to reaching 1% of EV share of sales than the majority of countries selected, although these countries are the only upper-middle-income economies in the

EU, same as Armenia. Therefore, we pick these two countries for the policy review as examples of perhaps the most effective E-mobility transitions in the EU in relation to economic capacities.



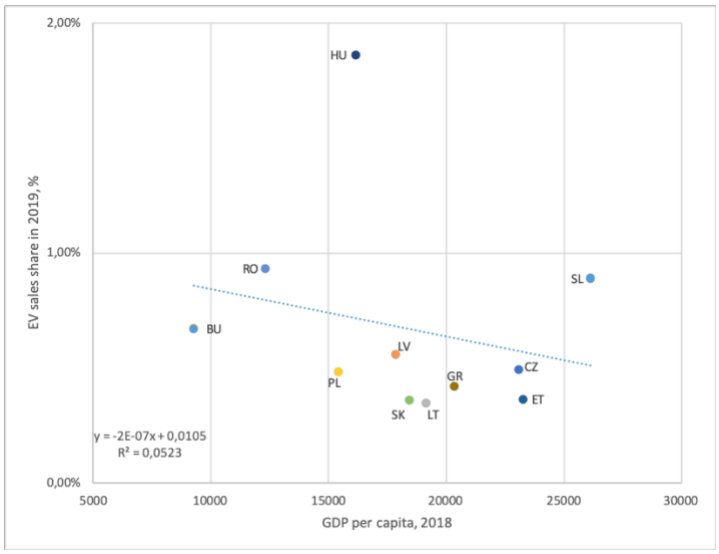


Figure 16. Share of BEV and HEV sales in 2019 in relation to GDP per capita in EU (EV share < 5%)
Figure 17. Share of BEV and HEV sales in 2019 in relation to GDP per capita in EU (EV share < 2%)
Data source: ACEA 2020; World Bank 2020

Besides a lower economic capacity (GDP/cap) than any of EU states, Armenia has a relatively small vehicle market, and there are also no vehicle manufacturing facilities. For this review, relying only on Romania and Bulgaria would be insufficient, so in order to balance both capacities and sizes of economies of these countries, we also add Lithuania, Latvia, and Estonia to our policy review as this region (Baltics) has the smallest vehicle market out of selected countries. With relatively similar economies and EV shares, selecting these countries will also allow us to make a meaningful comparative analysis and help to understand which policies drive the uptake of EVs the most.

4.3.2 General Overview

The European Union aims to achieve a long-term zero emission target through sustainable investments into decarbonization of the economy. One of the most prioritized sectors is the transportation, and electric mobility is considered to be the most efficient decarbonization mechanism together with energy efficiency measures in buildings and sustainable energy transitions (Biresselioglu et al. 2018). At EU level, E-mobility transition is supported by a range of policies and initiatives, such as:

1. White Paper “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system” (European Commission 2011);

2. Directive 2009/28/EC "On the promotion of the use of energy from renewable sources…" (European Parliament 2009a);
3. Directive 2009/33/EC "On the promotion of clean and energy-efficient road transport vehicles" (European Parliament 2009b);
4. Directive 2014/94/EU "On the deployment of alternative fuels infrastructure" (European Parliament 2014).

These four interrelated documents highlight the importance of the transportation sector in reducing GHG emissions and energy dependence (1), set goals for EU members to achieve a 10% renewable energy consumption in the sector (2), set national target levels for public procurement of clean vehicles (3), and push member-countries to create a regulatory framework and charging infrastructure for market penetration of alternative fuel vehicles, including EVs, on a national level (4). Ultimately, they lead national governments to a steady transition in the energy sector, including transport. Keeping in mind the size of the EU and the diversity of economies within it, the main assumption of this policy review is that regardless of factors such as the purchasing power of the population and the size of the market, EU membership encourages a gradual transition of the transport sector through an EU-wide comprehensive policymaking process.

Naturally, effectiveness, feasibility, and implications of different EV policy instruments depend on its type, scope, and timing. Policy instruments can be considered effective "if they considerably increase the probability of buying an electric vehicle" (Langbroek et al. 2016). Bakker and Trip (2013) define policy measure's effectiveness as "its impact on the uptake of EVs in a city"; efficiency as "the costs that are involved in comparison to the measure's impact"; and feasibility as "the likelihood that a measure can indeed be implemented given its financial, social, and political costs". Sections below will provide short country-specific overviews of E-mobility policy development in selected countries, and the 'Summary' section will provide a comparative framework and draw conclusions.

4.3.3 Lithuania

"Use of alternative fuels in the transport sector and its electrification" are one of the main focuses of the Lithuanian "Integrated National Energy and Climate Plan (NECP)" due to energy dependence and growth of motorization rates (European Parliament 2018). However, by "alternative fuels", this document emphasizes the importance of biofuels, which are commonly

used in the country, but outside of the scope of this thesis. There is no single mention of any monetary incentive for EV drivers, while biofuel-powered cars and liquified natural gas vehicle drivers do get financial incentives, namely excise tax exemption.

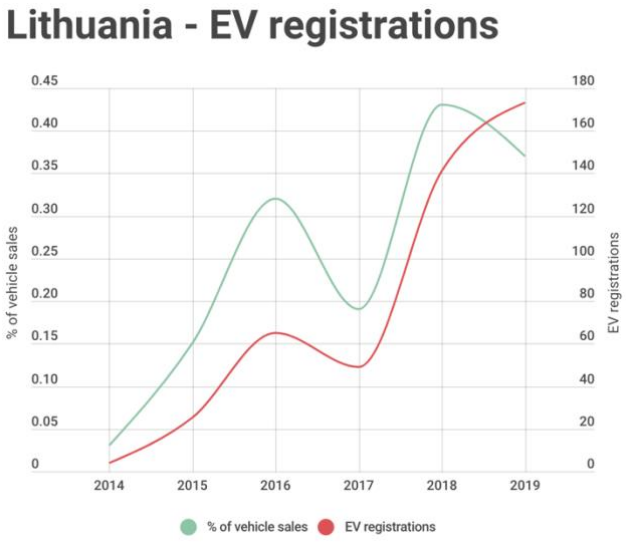
The skeptical attitude of the Lithuanian government to any type of financial incentives for EV consumers was pointed out in the study by Raslavičius et al. (2015). By now, the Lithuanian government is still lacking any motivation to incentivize EV users – there are no monetary incentives in Lithuania at the moment (ACEA 2019a). Already implemented E-mobility measures in Lithuania include the introduction of a regulatory framework for EVs and integration of EVs into the transportation system (new traffic signs and special vehicle plates); governmental support of EUR 3 million for a charging infrastructure development; free parking and priority lane incentive (Republic of Lithuania, Ministry of Energy and Environment 2018).

Despite the short list of E-mobility measures implemented in the country, one interesting development that can be learnt from Lithuanian experience is the contribution of academia towards E-mobility. Two Lithuanian universities, Kaunas University of Technology and Klaipeda University, together with a private business focused on renewable energy, have been developing e-bus, BEV, and HEV battery technologies and prototypes from 1997. Furthermore, these universities have introduced EV technology related degree programs. KSU has also signed a cooperation agreement with the Ministry of Transport (Raslavičius et al. 2015). As a part of the "EV Energy" project funded by the European Regional Development Fund (Interreg program), a team from the Kaunas University of Technology together with the Ministry of Transport have developed the "Action Plan for Lithuania for the Development of Environment-friendly Mobility to Reduce Emissions" in 2019 (Kaunas University of Technology 2019).

Regarding electrification of the road transportation sector, the following tasks, objectives, and targets were mentioned in the NECP (Republic of Lithuania, Ministry of Energy and Environment 2018):

1. By 2020, to install a minimum of 100 charging stations in urban areas of Lithuania – achieved;
2. By 2020, to install 19 DC chargers along the Lithuanian part of Trans-European network; then to gradually install 3-4 DC chargers per year – achieved;

3. By 2020, EVs sales share should be 5% of all new cars registered per year, and 10% by 2025 (app. 15000) – not achieved;
4. To assess a possible impact of fossil fuel taxation schemes (2014-2030).



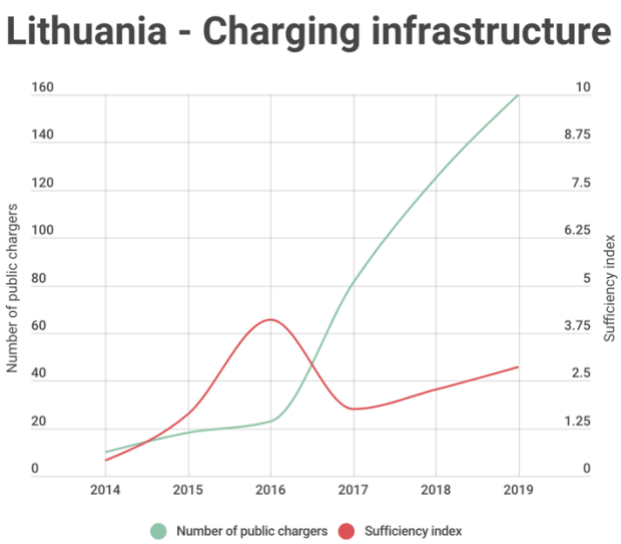


Figure 18. Annual EV registrations and percentage of sales in Lithuania
Figure 19. Charging infrastructure development in Lithuania
Data Source: CarSalesBase 2020; EAFO 2020

As a result, with only 0.37% share of EVs in total vehicle sales in 2019, Lithuania is significantly far from the 2020 target (Figure 18). Sales of electric vehicles in Lithuania are developing rather slowly due to the lack of financial incentives for consumers. Despite this, the Lithuanian government has set overestimated sales goals that are not feasible without such incentives in either the short or the long run, regardless of the achievement of infrastructure development goals (Figure 19).

4.3.4 Estonia

According to Estonian NECP, charging infrastructure development is listed among key issues of cross-border relevance, and, overall, E-mobility adoption is prioritized in the strategy regardless of the biofuel domination in the region. However, no specific measures aimed directly at E-mobility were identified in the document. Other documents, such as Sustainable Urban Mobility Plan and Transport Plan for Tallinn Region, have not been updated since 2010 (Government of the Republic of Estonia 2018).

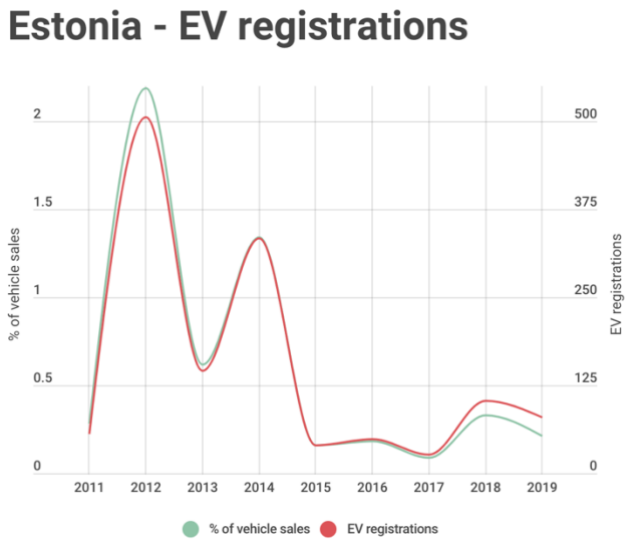
In 2011, the Estonian government launched the first E-mobility project through a Green Investment Scheme with Mitsubishi Corporation under the Kyoto protocol. As a result, more

than 150 fast chargers were installed by 2015 in the entire country, which was a pioneering technology by this time (Government of the Republic of Estonia 2018). Moreover, this project enabled the country to obtain more than 500 EVs for free (which were given to social workers around the country) and establish a small car rental pilot project. One of the ministries has designed an incentive package that included a purchase grant for EV consumers. The main monetary incentives were in the form of a purchase grant up to EUR 18,000 and a grant of up to EUR 1,000 to those who wanted to install a charging point at home (Joller and Varblane 2016). As a result, more than a thousand EVs were running on Estonian streets, and, in relation to the density of population, Estonia had the largest number of EV chargers after Norway in 2018 (Palevičius et al. 2018).

However, as can be seen from the NECP and other related documents, the Estonian E-mobility program had finished in 2014, and there have been no signals for further development or incentive introduction (ACEA 2019a). The National Policy Framework pursuant to the Directive 2014/94/EU does not indicate any target neither for 2020 nor 2025, hence no policy instruments for a further adoption of EVs were indicated (European Commission 2019). This trend did reflect on the sales – BEV sales grew only by 5% in 2018-2019, although HEV sales grew by 35%, which can be explained by its lower price.

However, at the very beginning of 2020, the Estonian government had announced a new support program for BEV consumers consisting of a purchase grant of up to EUR 5,000 and a total budget of EUR 1.2 million, which was exhausted the very same day it was announced. It should be pointed out that this budget was also coming from carbon emissions trading auctions. The Ministry of the Environment promises to announce the second round of the program soon (Eesti Rahvusringhääling 2020).

In general, after 2014, electric vehicle sales trend in Estonia is not that different from the Lithuanian trend, regardless of the implementation of one of the biggest and earliest electric mobility projects in Eastern Europe in 2012-2014 which provides an exciting example of using carbon finance instruments for E-mobility development (Figure 20). As the example of Estonia shows, such short-term E-mobility programs do not increase the sale of electric vehicles after they end. Nevertheless, another attempt to promote EV uptake is currently taking place. As for the charging infrastructure, its development had stopped after 2016, installing a couple of chargers annually in order to keep the sufficiency index around 3-4 (Figure 21).



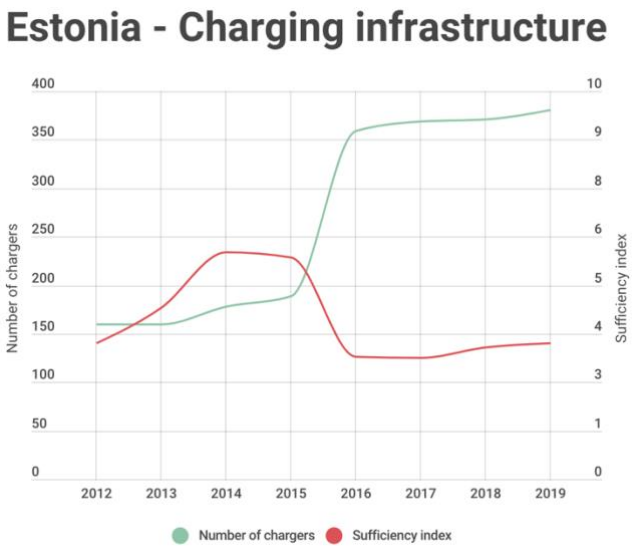


Figure 20. Annual EV registrations and percentage of sales in Estonia
Figure 21. Charging infrastructure development in Estonia
Data Source: CEICData 2020; EAFO 2020

4.3.5 Latvia

Unlike Estonia, the Latvian government includes a sufficient amount of information regarding E-mobility in its NECP. According to it, a continuous adoption of EVs is constrained with high purchase prices, coupled with "the low rate of GDP per capita as well as low personal income". The NECP refers to the consumer survey which argues that relatively underdeveloped charging infrastructure does not act as a serious barrier as the price does (Government of the Republic of Latvia 2018).

The list of EV incentives also appear in the NECP. First, EV drivers are exempt from vehicle operation tax, which is paid annually and based on its emission rate, gross weight, and engine capacity, and can be approximately estimated as minimum EUR 500 on average. Secondly, a company car tax was slashed from around EUR 43 to EUR 10 per month. Regarding non-monetary incentives, there are free green plates, access to bus lanes, free parking, and congestion fees exemptions in some of the municipalities. As for more substantial monetary incentives, the vision of the Latvian government is to rather increase taxes for ICEVs than to incentivize EVs – 20% excise duty tax increase and 10-30% operation (ownership) tax increase are currently under discussion (Government of the Republic of Latvia 2018).

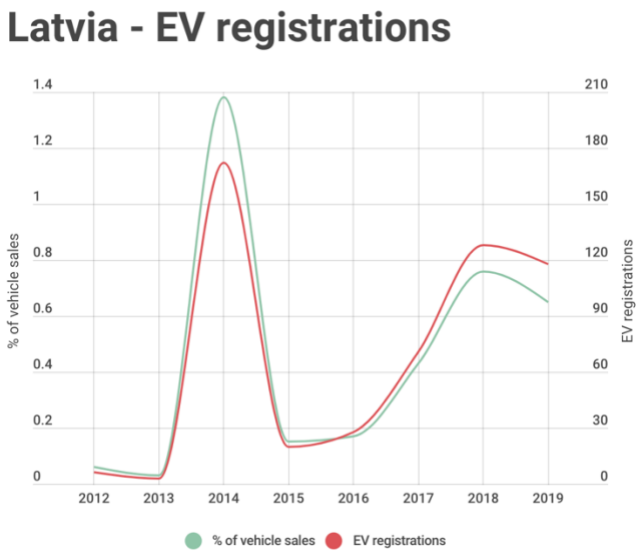
Nation-wide E-mobility development in Latvia began around 2013 with the "Electromobility Development Plan 2014-2016" issued by the Cabinet of Ministers. The plan has set EV sales

targets and governmental intentions towards the promotion of E-mobility by introducing the main action directions (R&D support, charging infrastructure, consumer stimulation) in accordance with EU directives described in the beginning of this subchapter. Furthermore, it suggests establishing Electromobility Control and Co-ordination Centre, which would work closely with the Ministry of Transport and serve as a non-governmental body consisting of experts from public organizations, while the Ministry will be responsible for the provision of support services (e.g. grants). The plan clearly states that "direct financial support is intended as the chronologically last activity", giving an example of Estonia and emphasizing its short and ineffective outcomes (Cabinet of Ministers of the Republic of Latvia 2014).

However, in 2014-2015 the government has announced a support program for people willing to buy a BEV, covering 35-85% of the capital costs. This program has increased the number of BEVs in Latvia by around 200, a tenfold growth compared to the previous year (15 BEVs in 2014). Clearly, this measure was taken in order to catch up to the numbers which were targeted in the plan (206 BEVs by 2015; 747 by 2016). Interestingly, the same number of EVs (747) was mentioned as a target for 2020, and afterwards for 2023 in the National Policy Framework pursuant to the Directive 2014/94/EU. Moreover, the NPF informs that three levels of financial support to EV consumers are under discussion, namely EUR 3,000 to 7,000 from 2018 to 2020 (European Commission 2019). None of these discussions materialized.

In order to meet the target of 150 fast DC chargers, which was introduced in the "Alternative Fuels Development Plan 2017-2020", the first phase of infrastructure rollout was implemented in 2018 with 70 fast chargers' installation. Prior to the massive rollout, two pilot chargers were installed in Riga in 2015-2016, from which data collection was done and further analysis of charging behavior conducted.

Since 2013, Latvia has introduced a whole range of monetary and non-monetary incentives for different groups of EV drivers (private and public) and has even tried direct subsidies for EVs. With the same outcome as in Estonia, this measure has not led to an increased uptake after, but gradually EV sales have been growing up for three years, almost reaching the 0.8% sales share (Figure 22). This uptake has also led to a subsequent charging infrastructure development (Figure 23).



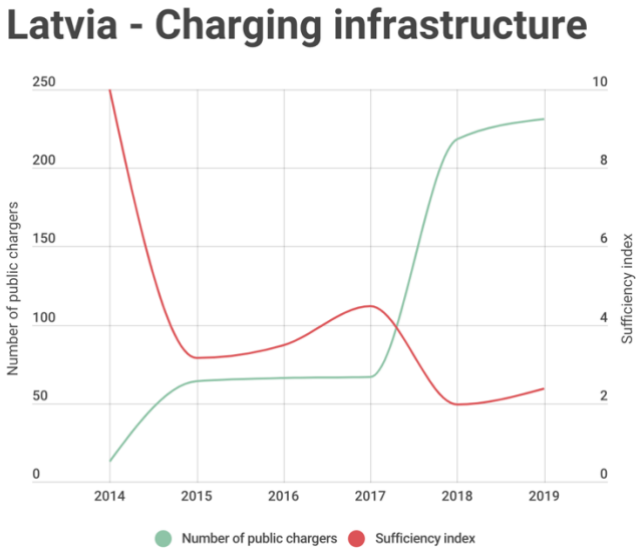


Figure 22. Annual EV registrations and percentage of sales in Latvia
Figure 23. Charging infrastructure development in Latvia
Data Source: CarSalesBase 2020; EAFO 2020

4.3.6 Bulgaria

According to the NECP, core elements of the GHG emissions reduction policy in the transportation sector of Bulgaria are R&D, awareness raising, and stakeholder engagement in promotion and manufacturing of EVs, road toll systems based on the environmental indicators of a vehicle, and development of charging infrastructure. It also states that the possibility of introducing some financial support for electric mobility deployment "will be considered when relevant". The government passes the responsibility of stimulating EV usage to local authorities, implying that they have to come up with their specific measures (Republic of Bulgaria Ministry of Energy 2018).

The NPF highlights an active participation of Bulgaria in various EU-wide projects, programs, R&D actions focused on alternative fuels. However, it also states a conservative view of the Bulgarian government towards E-mobility, which emphasizes it as a complement to ICEV technology rather than its competitor. However, they estimate EV fleet to be more than 1.1% by 2020 and 4% by 2030, which is far from a realistic estimate, especially without any financial support from the government (European Commission 2019).

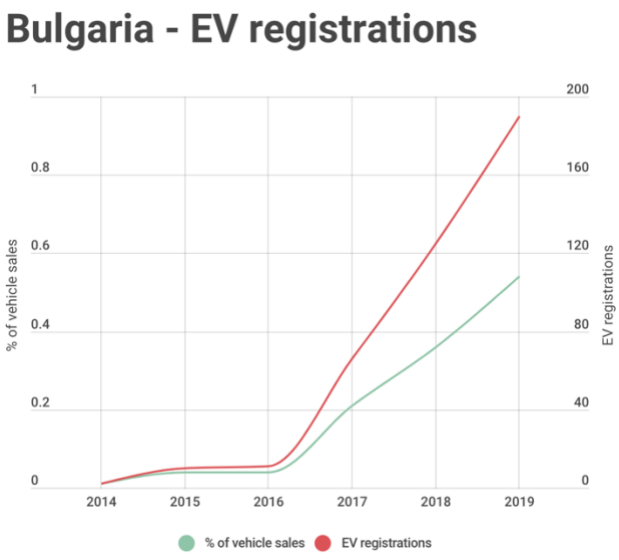
Increased energy efficiency, reduced fuel consumption, environmental and health impact from the transportation sector, and promotion of electric vehicles through a tax exemption system are stated as strategic objectives in the Integrated Transport Strategy by 2030 (Republic of

Bulgaria Ministry of Transport, Information Technology and Communications 2017). Second National Energy Efficiency Action Plan sets a requirement for purchasing energy efficient vehicles for the public transportation fleet in 2014-2020 with the budget of BGN 56 million (EUR 29 million), although it is not clear what is considered to be an "energy efficient vehicle". Most likely, this definition implies biofuels and LNG in the first place, and E-buses "when relevant", since as in the Baltic states, much attention is given to biofuels (Republic of Bulgaria Ministry of Energy 2017).

There were two incentives introduced as a result of the E-mobility strategy, namely registration tax exemption and road toll exemption. However, except for these low-scale incentives, there are no monetary incentives for an EV consumer in Bulgaria, and the only non-fiscal one is free parking. The NPF declares that there is a large number of different initiatives related to E-mobility, but the majority of them are still under discussion. There also was an attempt to make local authorities early adopters of EVs, incentivizing them to buy one with a grant funded by the National Eco Trust Fund and the Investment Climate Program varying from EUR 5,000 to 20,000, but it has not been quite successful reaching slightly more than 20 new EVs (Ralev 2018). From October 2020, newly registered EVs will be receiving individual green plates (Balkan Green Energy News 2019).

With still a slow pace of adoption (64 new EVs in the first half of 2018), Bulgaria has, in total, around 700 EVs and more than a hundred charging stations. In 2018, the ABB delivered a nation-wide charging infrastructure project, installing 53 fast DC chargers around the country (InsideEVs 2018).

From the graphs below, we can see that the uptake of EVs in Bulgaria has begun in 2016 and has been growing ever since without any monetary and a relatively short list of non-monetary incentives (Figure 24). However, in relative terms, the share of EV sales is only slightly more than 0.5%. EV numbers reported by various stakeholders in Bulgaria differ significantly, from one hundred to a couple of thousands EVs registered annually, which brings some uncertainty to the actual influence of implemented E-mobility measures. Charging infrastructure develops at a slower pace, with the sufficiency index growing from 2 to 4 in slightly more than a year (Figure 25).



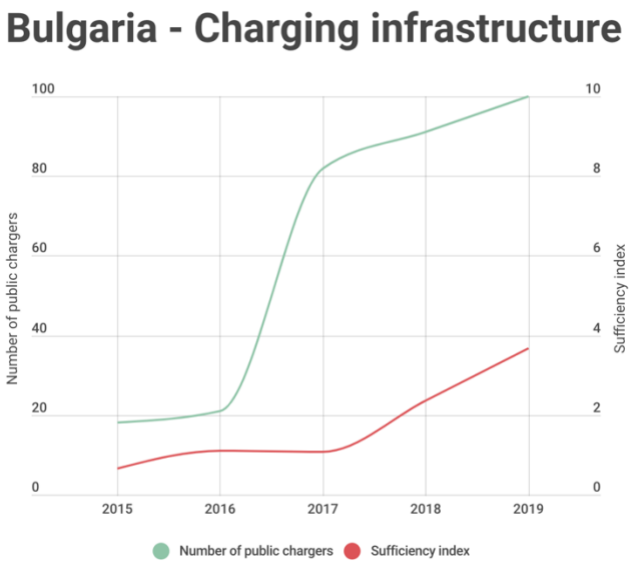


Figure 24. Annual EV registrations and percentage of sales in Bulgaria
Figure 25. Charging infrastructure development in Bulgaria
Data Source: CarSalesBase 2020; EAFO 2020

4.3.7 Romania

One of the operational objectives listed in the Romanian NECP is related directly to E-mobility. Referring to the Energy Strategy, the Romanian government highlights the necessity of R&D spending and support on the energy transition studies, including e-mobility, and defines it as one of the objectives to be achieved (European Commission 2019). The Strategy on the National Policy Framework (NPF) includes the stimulation of alternative fuel vehicles, including EVs. Industrial Policy 2018 prioritizes the creation of technical regulation, adoption, research, and development of EV charging infrastructure (Romanian Government 2018).

Comparing to what has been observed in the Baltic countries' NECPs, the motivation of the Romanian government to support the E-mobility transition is quite noticeable. In the evaluation of Romanian NPF, the European Commission representatives noted that "the number of proposed measures is high and is covering various fuels and modes but is concentrating on road electro-mobility" (European Commission 2019).

Among them, Rabla scrappage program, being in place from 2005, introduced an eco-premium for EV purchase in 2017, reaching up to EUR 10,000. Also, in 2016, the government introduced a year-long incentive covering up to 80% of capital costs for a charger. Similar to Estonia, Romanian NPF does not provide a target for EVs stock but sets a target of more than 292 chargers by 2020 (European Commission 2019) which was successfully achieved. Moreover, EVs are a subject of annual circulation tax exemption, and some of the charging providers in

Romania offer free charging. In total, the Rabla Plus program resulted in 500 new EVs and HEVs in 2017. By the first half of 2019, 3,513 new hybrid cars and 1,562 used ones, and 1,503 new electric cars and 97 used ones were registered at Romania's Automotive Registry. In July 2019, the government announced to double the budget of the Rabla Plus program (Romania Insider 2019).

In February 2020, the European Commission has approved Romanian plans to introduce a EUR 53 million state aid program aiming at incentivizing companies willing to install public chargers in Romania on a tender basis (Balkan Green Energy News 2020). Although Romania has not provided any specific EV stock targets, increased uptake of EVs backed by financial support from the government will require additional EVSE development, as opposed to the Baltic countries.

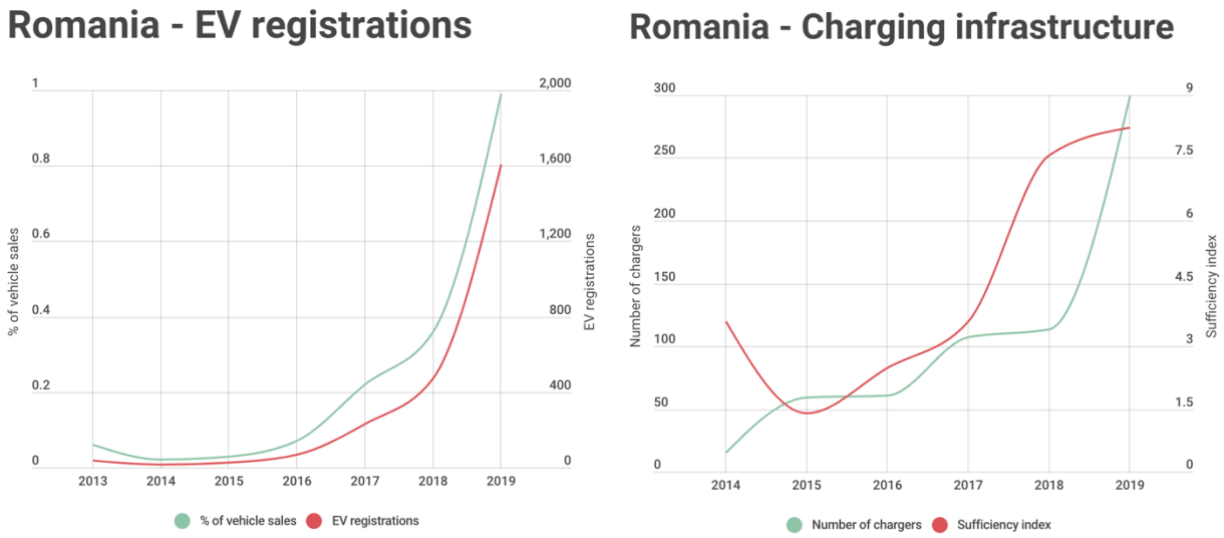


Figure 26 Annual EV registrations and percentage of sales in Romania
Figure 27. Charging infrastructure development in Romania
Data Source: CarSalesBase 2020; EAFO 2020

Romania's long-term incentive program for electric vehicle users has led to similar to an exponential increase in electric vehicle registrations in the country since 2016 (Figure 26). Despite the growing number of charging stations, infrastructure development is not catching up with the growth of EVs, having a sufficiency index of 8, which is significantly higher than in other reviewed countries (Figure 27).

4.3.8 Summary of case studies

Full policy packages and related information on E-mobility development in selected countries is presented in Table 9.

Table 9. E-mobility policy packages in selected countries
Source: Author
Note: Gray – no data found

Incentives	**Lithuania**	**Estonia**	**Latvia**	**Bulgaria**	**Romania**
Direct subsidies		Up to EUR 18,000 (2012-2014); Up to EUR 5,000 (2020)	Grant covering 35-85% of capital costs (2014)		Scrappage eco-premium of up to EUR 10,000 (2017-ongoing)
Charging grant		Home: up to EUR 1,000			80% coverage (2016)
Company car tax reduction			77% reduction		
Circulation tax reduction			Exemption	Exemption	Exemption
Fee waivers	Free parking		Free parking	Road toll exemption; Free parking	Free charging (some providers)
HOV lane access	Priority lane access		Bus lanes		
Restricted traffic zones access			Some cities		
Institutional arrangements					
E-mobility (specific) mandated body			Electromobility Control and Coordination Centre		An inter-ministerial body from six ministries and public institutions
E-mobility Plan/Strategy	Action Plan for Lithuania for the Development of Environment-friendly Mobility to Reduce Emissions (2019)	Estonian E-mobility program (2012-2014)	Alternative Fuel Development Plan (2017-2020); Electromobility Development Plan (2014-2016)	"National Action Plan for the Promotion…Electric Mobility in Bulgaria for the period 2012-2014"	
Targets for public adoption of clean vehicles (2021-2031)	20.9%	23.1%	22%	17.6%	18.7%
Targets for private EV adoption	5% of sales in 2020 (not achieved); 10% by 2025		206 EVs by 2015 (achieved); 747 by 2017 (not achieved)		
Targets for charging infrastructure	2018-2020 targets for 100 chargers and 19 DC; then 3-4 DC per year		150 DC chargers (until 2050)		

Institutional cooperation	MoT, 2 Universities, and private companies	Academia involvement in the pilot project	Experts from different sectors in the mandated body		
Charging					
National budget allocation	EUR 3 million 2018-2020				EUR 53 million aid (2020)
Charging Infrastructure Sufficiency index (share of fast chargers > 22 kW)	2.9 (51.5%)	3.5 (48.1%)	2.4 (65.1%)	3.7 (42.6%)	8.2 (32.2%)
Charging pilot projects		Massive rollout as a part of the pilot project	Two pilot DC chargers (2015)	Nation-wide DC rollout (2018)	
Other					
ICEV/EV production and assemblance				Charging stations manufacturing; EV supercar manufacture; EV manufacturing plant is under construction	Strong automotive sector with HEV, trolleybuses manufacturing;
EV pilot projects	EV taxis in a local resort (2012)	Big pilot project launched via the Green Investment Scheme (2012)			
Traffic signs					
Green vehicle plates					
EV growth development					
Compound Annual Growth Rate (CAGR)	**26.3%** (2015-2019)	**8.3%** (2015-2019)	**45.3%** (2015-2019)	**59.5%** (2017-2019)	**112.1%** (2017-2019)
EV share of car registrations in 2019	**0.21%**	**0.37%**	**0.65%**	**0.54%**	**0.99%**

In order to compare the outcomes of EV policy packages in selected countries, annual shares of EV sales (Figure 28) and sufficiency indices (Figure 29) were analyzed.

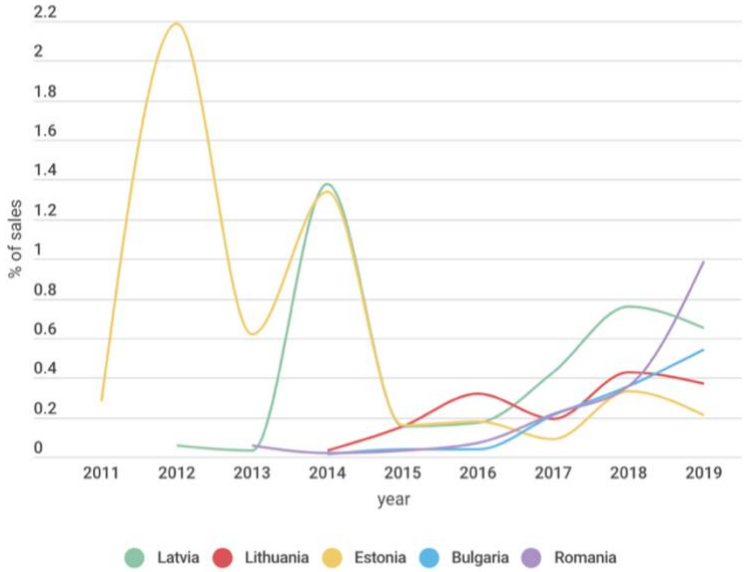


Figure 28. Annual share of EV sales in selected countries
Data Source: CarSalesBase 2020; EAFO 2020

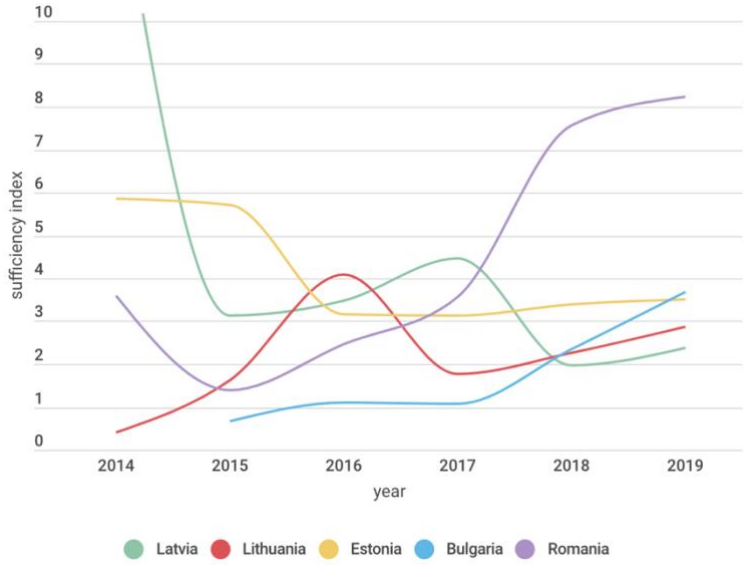


Figure 29. Charging infrastructure development in relation to the total number of EVs in selected countries
Data Source: CarSalesBase 2020; EAFO 2020

As can be seen from the figures above, in the selected countries, there is no specific pattern of growth in purchases of electric vehicles in the early stages of development (five years). The only exception may be Romania, where the development of the electric car market was quite stable, vaguely reminiscent of exponential growth, apparently due to the introduction of a policy package with a subsidy program. In other cases, we can see that EV market development was chaotic. Some of the up and down spikes can be explained by short-term subsidy programs,

however, smaller fluctuations in sales are probably due to other external factors not analyzed in this work. A separate obstacle to the analysis was the practical impossibility to track the years of non-monetary incentives introduction.

Within the groups of countries, an obvious similarity is observed in the group of Baltic countries. Moreover, in addition to the lack of direct subsidies in the countries of this group since 2017, there is a relative correlation between the number of small incentives and the growth in the share of electric vehicles among the total sales of cars in these countries.

In Estonia, where non-monetary incentives were not found during the review, the maximum share of electric vehicles in sales peaked at about 0.3%. In Lithuania, with several small incentives, a relatively new strategy for electromobility, as well as the involvement of the private sector at the institutional level were found during the analysis, the growth curve has the same shape, but it is higher than the Estonian one. In Latvia, where incentives are quite widespread, aimed at various consumer groups, and there is also an institutional unit for the development of electric mobility in the country, the growth curve again has a shape reminiscent of the rest of the Baltic countries, but it is located much higher.

The last finding from this group of countries is the positive correlation between infrastructure sufficiency indices, shares of fast charging infrastructure (>20 kW), and EV sales shares in the three countries.

Due to the early development of the market and synchronous decrease in the growth curve in the Baltic countries in 2018-2019, there is no reason to say that it has reached an inflection point, followed by a slowdown and stabilization of growth – similar trends were also observed in Estonia and Lithuania before, in 2016-2017 .

Regarding Romania and Bulgaria, the growth stability of the latter in the framework of this analysis can be explained only by a strong automotive sector which has been developing quite rapidly after Bulgaria entered the EU. This factor also applies to Romania (Haiss et al. 2012).

Overall, reviewed policy packages for EVs promotion are heterogenous and lead to different outcomes. By covering these five countries in the policy review, the main objective was to

understand what lessons can be learnt and used in Armenia. Besides the abovementioned results, other findings of the analysis described in this subchapter are:

1. Short-term monetary incentives do not increase the uptake of EVs after they are phased out. These measures influenced the uptake only when they were implemented – 2012-2014 in Estonia and 2014 in Latvia. Romanian subsidy program has been offered since 2017 and led to a sustainable growth of EV sales in the country.
2. The size of incentives should go in parallel with the average price decrease of and demand for EVs over time. In Romania, for example, evaluation of the subsidy is conducted on the annual basis.
3. Without continuous financial incentives, it might be useful for a government to define early adopters and arrange demonstration projects. It might be social workers (Estonia), local authorities (Latvia), or taxi drivers (Lithuania).
4. Transport regulations development (traffic signs, vehicle plates, etc.) should go in line with initial non-monetary incentives which was proved by the Latvian example and subsequent growth of the EV market;
5. Four out of five countries have introduced national E-mobility plans, which seem to be the case when the state is not willing or not capable of providing financial incentives;
6. Cooperation with a range of stakeholders, such as academia, industry, businesses, is essential prior to policymaking, as it was demonstrated in Lithuania, Latvia, and Bulgaria. International cooperation and knowledge sharing among the key stakeholders have proved to be useful at the initial stage of adoption, preferably with more E-mobility developed countries, based on the Lithuanian example. Establishing an E-mobility responsible governmental body is another initial measure which should be taken, gathering public and private experts in the field, in order to enable knowledge sharing at the governmental level (Latvia).

4.4 Modeling the transition process

4.4.1 Scenario design

The main lesson learnt from the Section 4.3 is that it is possible to achieve a 1% share of EV sales in an upper-middle-income country within three to four years, according to the Romanian example. Even though it can be achieved only with the introduction of direct subsidies, non-monetary incentives can also influence the uptake of EVs, yet on the considerably lower scale and over a longer period.

As a result of the review, the grouping of countries and the subsequent design of scenarios for development was compiled as follows. The Baltic group of countries was divided into three scenarios based on the comprehensiveness of EV policy packages, leading to a certain increase in EV uptake since 2015: low effort (Estonia); mild effort (Lithuania); high effort (Latvia). Another group of countries and scenarios for the development of their markets will show the impact of fiscal consumer incentive measures aimed at acquiring an electric vehicle and related charging equipment: no measures (Bulgaria); with measures (Romania). These scenarios will be approximated and then applied to the Armenian car market in order to analyze potential short-term (5 years) impacts of different measures for EV uptake. Since the Romanian incentive program has been in place for three years and we want to analyze the difference on a five-year timeline, the future uptake of EVs in the country has to be modeled.

In order to analyze and model the growth of EVs in selected countries (as well as to apply these growth patterns to Armenia), compound annual, exponential, linear growth trends are used in this part of the thesis. Firstly, due to the lack of stable growth that would fully correspond to any of the above growth patterns, we have to analyze which trend is of the best fit for a particular country. This is especially important for the Baltic countries, where there are numerous spikes in growth (Figure 30), as a result of which none of the patterns matches the actual growth observed in the selected time periods. Moreover, applying a specific function also influences the future market development forecasts, which is essential for the second group of countries. By using the coefficient of determination (R-squared) values, we can see which of the above trends will better explain current and approximate the future growth of EVs based on the already observed data.

Secondly, such growth spikes might have been caused by factors that are independent of the implemented or non-implemented measures to stimulate the market. In general, it may make sense to assume that stabilization of growth appears after reaching a certain percentage or number of electric vehicles sold – for example, after reaching 2% of sales (Figure 31). This issue needs a more detailed further study. The coefficient of determination will also show which of the trends better loosens the volatility effect of the data observed.

4.4.2 Results

Figure 30. Growth trends (Latvia, Lithuania, Estonia)
Source: Author

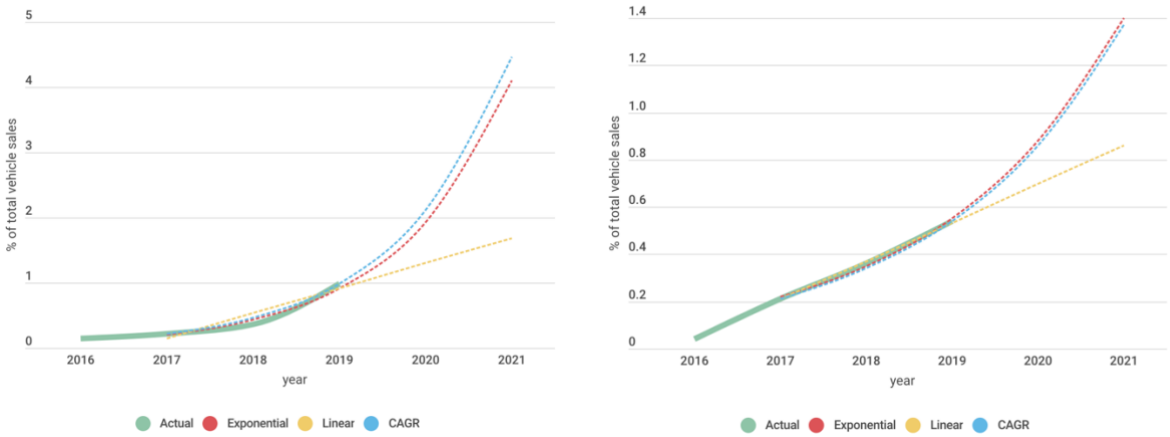


Figure 31. Growth trends (Romania and Bulgaria)
Source: Author

These coefficients for each country are presented in Table 10. For the scenario building, we will only acquire country-trends that explain at least 50% of the variance in actual EV share sales trends in these countries (i.e. $R^2 > 0.5$). For Romania and Bulgaria, this value is high for all the trend patterns due to the short period of observations (e.g. short timeline analyzed) of 3 years.

Table 10. R-squared values for selected countries
Note: Green – selected trends

	Lithuania	**Estonia**	**Latvia**	**Bulgaria**	**Romania**
Actual vs. CAGR	0,511	0,226	0,745	0,991	0,979
Actual vs. linear	0,542	0,223	0,835	0,999	0,882
Actual vs. exponential	0,513	0,227	0,718	0,991	0,979

After these trends were applied to the EV import data (2018-2019) in Armenia, the following market transition scenarios were obtained (Figure 32). Overall, these two subsections provide an 'if-then' framework, where certain groups of incentives lead to a specific outcome in EV sales in Armenia

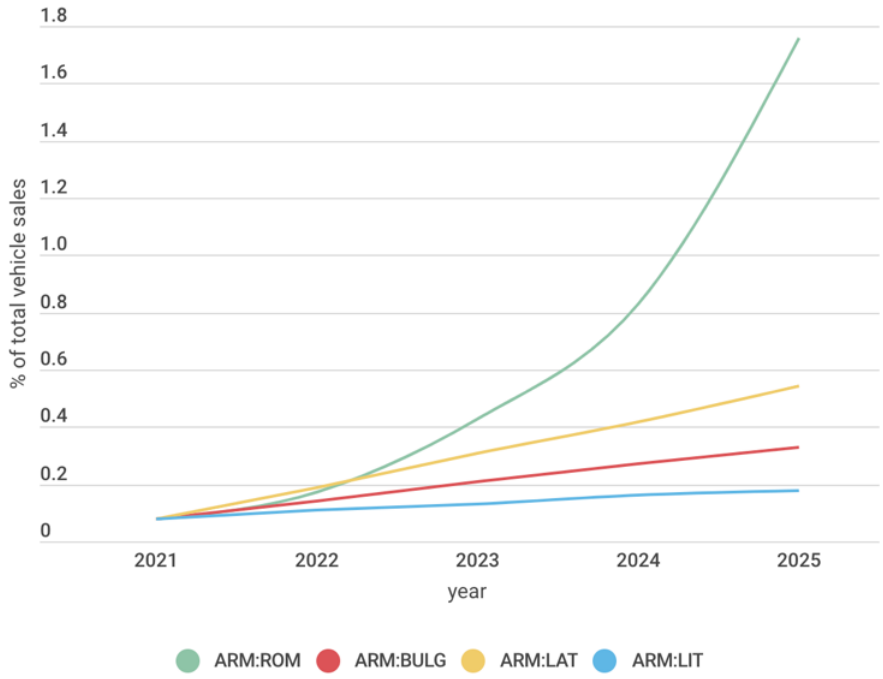


Figure 32. EV transition development scenarios in Armenia
Source: Author

This part of the thesis has modeled the impact of different policy packages on the uptake of electric vehicles in Armenia. In this study, the recent VAT exemption was not taken into the consideration since it was introduced in Armenia less than a year ago, so its actual impact is rather questionable. One of the scenarios (Lithuania) can be assumed as the baseline scenario since besides the priority lane access there is only a free parking incentive that has already been introduced in Yerevan.

We can see that a considerable difference in these scenarios becomes noticeable after three years. By the year 5, the difference between the Romanian (monetary incentive) and other scenarios is more than 1%, while non-monetary scenarios differ by 0.1-0.4%. However, this difference can also be considered significant as 0.1% of vehicle sales in Armenia, according to additional calculations, would contribute to about 70 new EVs annually – 50% of the current number of EVs in the country.

As a result, we can see that implementation of monetary incentives in form of grants, subsidies, scrappage programs, and so on, would lead to a very fast-paced uptake of EVs in a short term. Nevertheless, various non-monetary policy packages would also have a distinctive impact on EV sales in the country – a more comprehensive policy package implemented would lead to

the faster uptake. The baseline scenario showed only a 0.1% growth in five years (from about 0.1 to 0.2%).

4.5 Designing the E-mobility project for Armenia

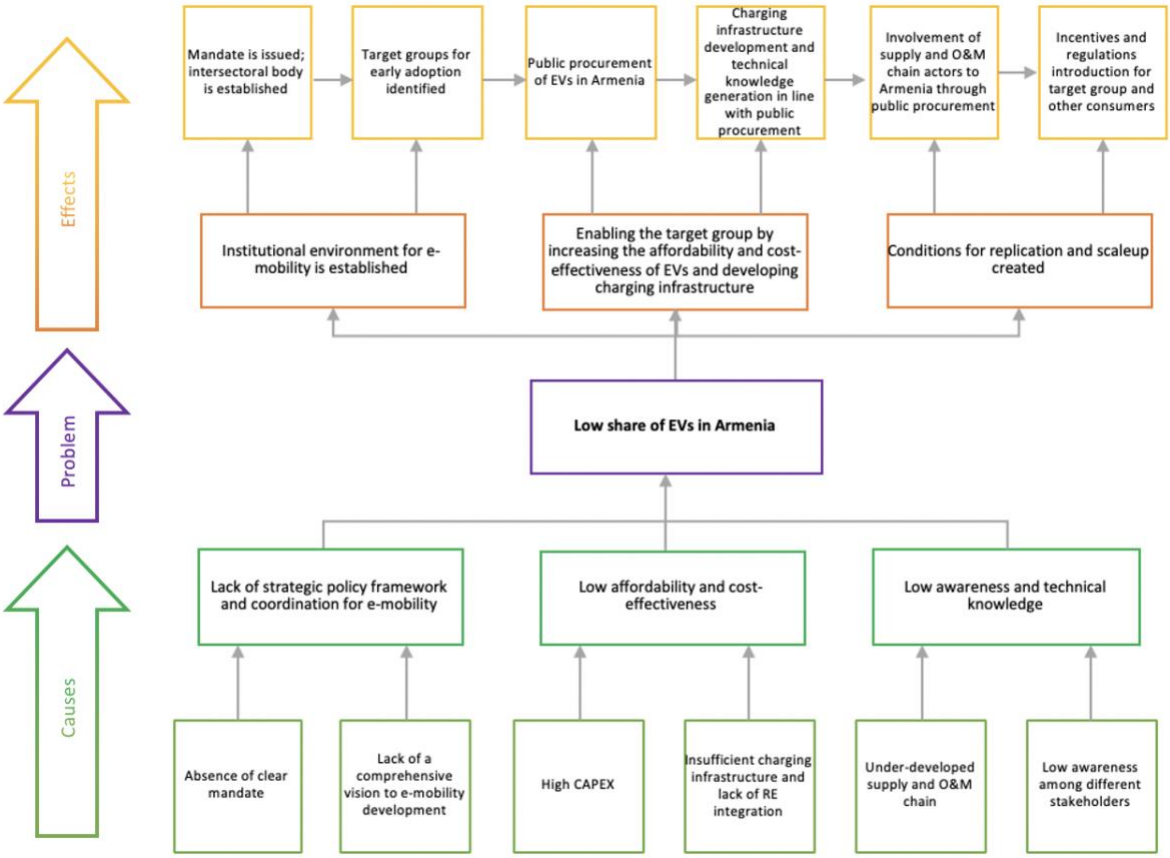


Figure 33. Theory of Change tree in application to the E-mobility project in Armenia
Source: Author

As a result of all the steps accomplished by this work so far, the final product of this project is the design of an introductory E-mobility project in Armenia. As shown in Figure 33, the project consists of three components aimed directly at three barriers identified during stakeholder consultations (here, the 'High upfront cost' barrier is put together with 'Insufficient charging'). Moreover, the project's structure also corresponds to the Armenian vision for E-mobility development (Figure 34). All analyzes and consultations performed in this work and their results are key data sources for constructing this Theory of Change tree. This subsection will provide a short description of the proposed components.

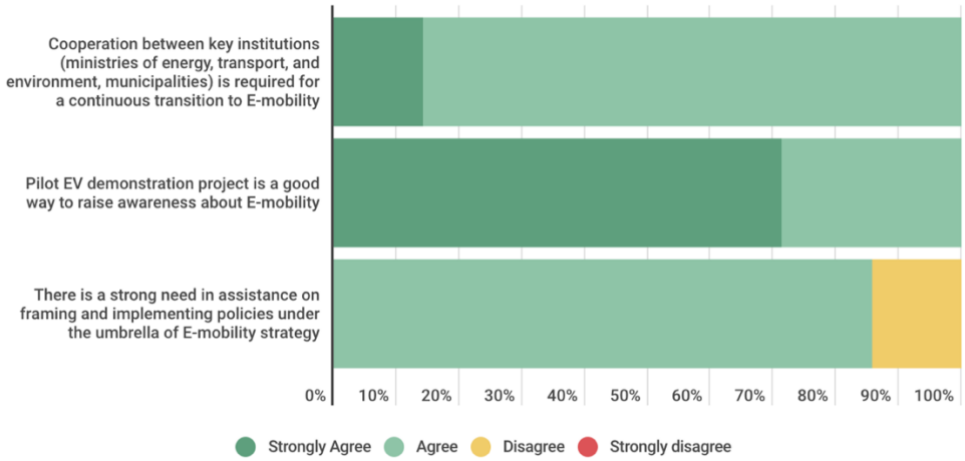


Figure 34. Stakeholders' agreement with a preliminary structure of the project
Source: Author

4.5.1 Component 1. Institutional environment.

The first component of the project is focused on the institutionalization of electric mobility in Armenia. Based on the examples discussed, it is clear that a more structured and coordinated policymaking approach has a positive impact on EV adoption, since the area of E-mobility policymaking touches upon a whole range of different stakeholders, such as ministries, municipalities, private companies, etc. However, the final purchasing decision is still taken by a consumer. Therefore, understanding consumer needs from different angles (e.g. infrastructure, affordability, etc.) is required in order to continuously promote the adoption of electric vehicles. The best way to achieve this goal is to create an institutional setup focused around the area of E-mobility, which has not been done in Armenia so far.

According to the E-mobility policy case studies described in Section 4.3, some examples of such institutional arrangements were derived and showcased during the first round of the stakeholder consultations. For example, in Latvia, the Electromobility Control and Coordination Center was established and governed by the Ministry of Transport, while including representatives of different ministerial and local authorities and private businesses. In Lithuania, a strong emphasis has been put into the cooperation between the Ministry of Transport and two leading universities, which not only introduced E-mobility related degrees, but also served as 'thinktanks' for E-mobility planning, policymaking, and EV technology development. These two universities, together with the Ministry of Transport, have also participated in the design of the first "Action Plan for Lithuania for the Development of Environment-friendly Mobility to Reduce Emissions" in 2019. These examples show that, besides issuing a mandate for E-mobility decision-making to a certain ministry (which still has

not been done in Armenia), there is a space for innovative cooperation when it comes to the institutionalization of E-mobility at the national level. As a result of the stakeholder discussion, an extended list of agencies to involve in the intersectoral E-mobility group was prepared, headed by the Ministry of Transport.

Secondly, this component identifies the early-adopters target group for the pilot project based on the actual examples of first EV rollout programs and a preliminary analysis of EV cost-effectiveness for the public vehicle fleet, followed by a discussion of these findings with stakeholders and making the final decision (Section 4.1-4.3). According to the case studies and TCO analysis, due to the low operational costs of EVs compared to conventional vehicles (ICEVs), both cost-effectiveness and, consequently, environmental benefits are maximized for those social groups which use a vehicle more frequently. Moreover, the frequent usage of a vehicle makes it more visible to the public, thus increasing the awareness among other social groups.

This way, for example, in Lithuania, the first demonstration project was focused on a taxi fleet in a local resort, maximizing the benefits of EV usage and raising awareness among passengers. This measure, however, has some disadvantages related to the replicability potential – it might be challenging to transition the entire or at least some part of the taxi fleet to EVs since taxi companies and private drivers still have the final decision.

In Estonia, a different approach was taken, providing social workers with EVs as a part of EVs public procurement scheme and introducing an EV rental pilot project at the same moment. Despite the potential to continuously provide some share of public procurement of vehicles with EVs, the replicability of these measures was constrained by the business model used for financing these measures – the finances were obtained as a one-time payment through the Green Investment Scheme, carbon finance mechanism which, in Estonia, was only used for EV promotion only once in every 4-5 years.

According to the demonstration of these examples followed by the discussion of potential target groups for the pilot projects, the stakeholders have unanimously agreed that the best way to promote EVs through a pilot project at this initial stage of E-mobility development in Armenia is the public procurement option. Based on the case studies and the discussion, this option was supported with the following assumptions:

1. Potential for a long-term scaleup of EVs in the public fleet through a target setting of a percentage of annual public procurement of EVs;
2. Awareness raising among key governmental stakeholders (including those participating in the intersectoral E-mobility institutional body) and knowledge generation for further development;
3. Monitoring, evaluation, and data collection from the pilot project is centralized in the public sector instead of private (e.g. taxi fleet);
4. Less expenditures are required for the infrastructure development; charging stations will be located in the city center next to municipal and/or ministerial buildings;
5. The bidding and procurement processes are centralized and streamlined by the responsible governmental bodies.

This component, the reasoning behind it, as well as examples provided, have had a positive feedback from the stakeholders who participated in the first round of consultations. The final design of the intersectoral body for E-mobility development will be further discussed during subsequent rounds of consultations with an extended list of participants from the abovementioned sectors. In order to provide the most comprehensive further engagement of stakeholders, additional experts from the academia and private sector were also considered for further engagement. A preliminary list of banks (including the only bank which was offering financial products for potential EV consumers) and car dealers having low-to-middle cost EVs in their portfolio present in Armenia. Bringing these actors together with the public procurement body (Procurement Support Center – State Procurement Agency, Procurement Complaint Review Board, Ministry of Finance) would be the most efficient way to come up with procurement options and arrange an intersectoral body for E-mobility (Table 11).

Table 11. List of suggested actors to engage in the intersectoral body for E-mobility
Source: Author

Institution(s)	**Role(s)**
Ministry of Environment	The Ministry will act as an executing agency and will play an advisory role and provide expert advice on aspects related to climate change mitigation.
Ministry of Energy Infrastructures and Natural Resources (MENR)	The Ministry will be involved in discussion on power demand from e-mobility and on the business relationship between distributors and charging companies.
Ministry of Transport and Communication	The Ministry will be responsible for EVs integration in the transport sector providing necessary regulations, policies, and norms.

The State Urban Development Committee	The Committee will support in the design and implementation of demo projects and co-financing investments.
The Energy Regulatory Commission	The Commission will provide required information about electricity tariffs, operating licenses, and other regulations that might be related to EV charging infrastructure development.
Ministry of Finance	The Ministry will play an advisory role and provide expert advice on aspects related to policy formulation and legal / regulatory measures related to public and private sector charging infrastructure providers.
City Council and Local Government Authorities	The ministry will provide project technical inputs and information on the demo planning, design, integrated inventory data collection, as well as policy inputs to the Project Document.
Municipal Government	Support in the design and implementation of demo projects and co-financing investments.
Yerevan Electric Transport	This company will share its vision on the integration of the public EV fleet in parallel with the private fleet and also share its expertise about charging.
YerevanRide (private company, e-scooters and e-bikes rental)	Provision of technical and business expertise, as well as potential opportunity for EVs scale up via EV rental in Yerevan.
ACBA-Credit Agricole Bank (ACBA Leasing)	One of the leading financial institutions of Armenia, providing numerous banking services to its customers, including an exclusive leasing terms for electric vehicles in cooperation with MG Motors Armenia.
Toyota, Nissan, Chevrolet, MG Motors (tbc)	Car dealers in Armenia (includes only those having low-cost EV models in their portfolio)
HSBC, Evoka Bank, Ameria Bank, VTB Bank, Global Credit, Converse Bank (tbc)	Banks with transport-related financial products (car loans or leasing terms, etc.) without specific EV offers

4.5.2 Component 2. Public procurement

Before the adoption group was identified, the cost-effectiveness analysis was conducted for the public vehicle fleet. The results of this analysis have shown that EVs are indeed a more cost-effective option for public vehicles with at least about 30,000 km of annual mileage (Section 4.4).

As it was described in the previous subsection, examples of pilot EV projects in selected countries have not led to a continuous and significant uptake of EVs in the social groups they were aimed for. On the contrary, the motivation of Armenian stakeholders regarding the public procurement program is to sustain a steady growth of EVs in the public vehicle fleet instead of procuring a lot of EVs in a short-term period. Therefore, an additional review of similar pilot projects in the EU was conducted. The baseline design for the Armenian demo project was based on the Swedish procurement project that took place in 2010, when the share of EVs in the country was also way below 1%, similar to the current situation in Armenia. Back in 2010, this national procurement project was one of the first attempts to introduce EVs and stimulate the market in Sweden (PRIMES 2020; Palm and Backman 2017).

Based on this case study and stakeholder consultations, the following scope was designed for a successful implementation of this demonstration project:

1. Organization of the public call for expression of interest among public and private institutions willing to participate in a joint nation-wide EV public procurement program;
2. Assistance to the project by defining the parameters (e.g. inclusion of specific environmental and safety parameters that an EV should have to participate) for bidding qualification and implementation of the tender process;
3. Facilitation of the procurement process and structuring of contract provisions, including environmental and social risks management, data collection, feasibility studies, and assessment of results;
4. GEF co-financing to cover upfront costs difference between an EV and similar ICEV.

Another potential development in this regard, depending on the number of participants in the public procurement project, might be target setting of a minimum annual procurement share of EVs, as it is implemented in the European Union according to the Clean Vehicles Directive of 2009 (2009/33/EC). The Directive sets those specific minimum country-based percentages (targets), which currently vary from 17.6 to 38.5% for light-duty vehicles. For Armenia, these percentages might be derived from the total number of annual procurement of light-duty vehicles and the total number of participants in the EV public procurement project. This target setting process will enable the continuous scaleup of EVs adoption rates in the public vehicle fleet, ultimately leading to the subsequent charging infrastructure development, awareness raising, and knowledge generation.

4.5.3 Component 3. Conditions for scaleup.

As experiences of other countries show, there is a significant variety of monetary (e.g. grants), non-monetary (e.g. free parking), and recurring (e.g. ownership tax exemption) E-mobility policies, which in turn generate policy packages for the promotion of electric vehicles. This study has reviewed past and current policies that have been implemented in Lithuania, Estonia, Latvia, Romania, and Bulgaria, claiming that any of these policy packages are feasible to implement in Armenia due to contextual similarities between the countries.

Some measures to promote electric mobility in Armenia have already taken place. Recent amendments to the fiscal policy of the Republic of Armenia have exempted electric vehicles

(including cars, and two- and three-wheelers) from the VAT tax. Moreover, in Yerevan, free parking for EVs is available in designated areas. Although fiscal measures have a significant impact on adoption rates, they tend to be temporal (till 2022 in this case), thus bringing only a short-term impact. Therefore, there is a need to implement other, less costly and long-term measures that would increase the attractiveness of owning an EV in the long-term.

The study has also modeled the impact of different sets of policy packages on the uptake of electric vehicles in Armenia. In this study, the recent VAT exemption was not taken into consideration since it was introduced less than a year ago, so its actual impact is rather questionable. One of the scenarios (Lithuania) was assumed as the baseline scenario since besides the priority lane access there is only a free parking incentive that has already been introduced in Yerevan (Figure 32). It has shown a slow growth of EV sales from 0.1% to 0.2% in five years.

In order to further promote the usage of EVs, the Armenian government and other stakeholders were provided with the information necessary for the strategical vision on E-mobility for the period from 2020. The stakeholders were provided with the whole range of policy and incentive options, while the following policies have been highlighted and recommended based on the current state of E-mobility in Armenia and this study (Table 12). The table includes both the short- and long-term policy recommendations, while the latter are described in Section 4.5.4.

Table 12. E-mobility policies in selected countries. Recommendations for Armenia
Source: Author
Note: Red – not implemented in selected countries; Yellow – recommended for Armenia; Green – implemented in selected countries; Gray – no data found or not applicable.

Incentives	**Lithuania**	**Latvia**	**Bulgaria**	**Romania**	**Armenia**
Direct subsidies		Grant covering 35-85% of capital costs (2014)		Scrappage eco-premium of up to EUR 10,000 (2017-ongoing)	VAT exemption (till 2022); excise duty tax exemption (till 2021)
Charging grant				80% coverage (2016)	
Company car tax reduction		77% reduction			
Circulation tax reduction		Exemption	Exemption	Exemption	
Fee waivers	Free parking	Free parking	Road toll exemption; Free parking	Free charging (some providers)	Free parking (only in Yerevan); Gyumri recommended
HOV lane access	Priority lane access	Bus lanes			N/A
Restricted traffic zones access		Some cities			N/A
E-mobility (specific) mandated body		Electromobility Control and Coordination Centre		An inter-ministerial body from six ministries and public institutions	
E-mobility Plan/Strategy	Action Plan for Lithuania for the Development of Environment-friendly Mobility to Reduce Emissions (2019)	Alternative Fuel Development Plan (2017-2020); Electromobility Development Plan (2014-2016)	"National Action Plan for the Promotion…Electric Mobility in Bulgaria for the period 2012-2014"		Long-term E-mobility planning is required (see Section 4.5.4)
Targets for public adoption of clean vehicles (2021-2031)	20.9%	22%	17.6%	18.7%	Recommended from 2024
Targets for private EV adoption	5% of sales in 2020 (not achieved); 10% by 2025	206 EVs by 2015 (achieved); 747 by 2017 (not achieved)			
Targets for charging infrastructure	2018-2020 targets for 100 chargers and 19 DC; then 3-4 DC per year	150 DC chargers (until 2050)			Recommended from 2024 (see Section 4.5.4)
Institutional cooperation	MoT, 2 Universities, and private companies	Experts from different sectors in the mandated body			Arranged and recommended

National budget allocation	EUR 3 million 2018-2020			EUR 53 million aid (2020)	
Sufficiency index (EVs per public charging point)	2.9	2.4	3.7	8.2	Recommended minimum of 10
Charging pilot projects		Two pilot DC chargers (2015)	Nation-wide DC rollout (2018)		Plug.AM project
ICEV/EV production and assemblance			Charging stations manufacturing; EV supercar manufacture; EV manufacturing plant is under construction	Strong automotive sector with HEV, trolleybuses manufacturing;	Recommended for a long-term development (see Section 4.5.4)
EV pilot projects	EV taxis in a local resort (2012)				Public procurement project arranged
Traffic signs					
Green vehicle plates					

4.5.4 Long-term development

Although Section 4.5.3 recommends specific policies which can be introduced in a relatively short-term (1-3 years), some additional recommendations for a long-term E-mobility development can also be drawn from this research. This subsection outlines such recommendations minding complexities of this topic. It covers the automotive sector development, charging infrastructure, awareness raising and knowledge generation, and climate policy.

Long-term E-mobility development should go in parallel with national priorities in other related sectors of the economy

Some fiscal measures to stimulate the electric car market were introduced by the Armenian government for a period of up to 2023. Thus, the introduction of additional monetary stimuli, close to the Romanian-type incentives, at the moment may adversely affect the economy of Armenia. First of all, it would imply subsidizing electric car manufacturers abroad, because at the moment cars are not produced in the country. Therefore, the attraction of foreign investment and automotive companies should be prioritized. At this stage, it can be initiated by analyzing the investment environment and the subsequent amendment of the relevant legislation, norms, and incentives. Moreover, as a result of the questionnaire, "attraction of vehicle manufacturing companies" was listed as the main benefit of E-mobility development in the country (Figure 35).

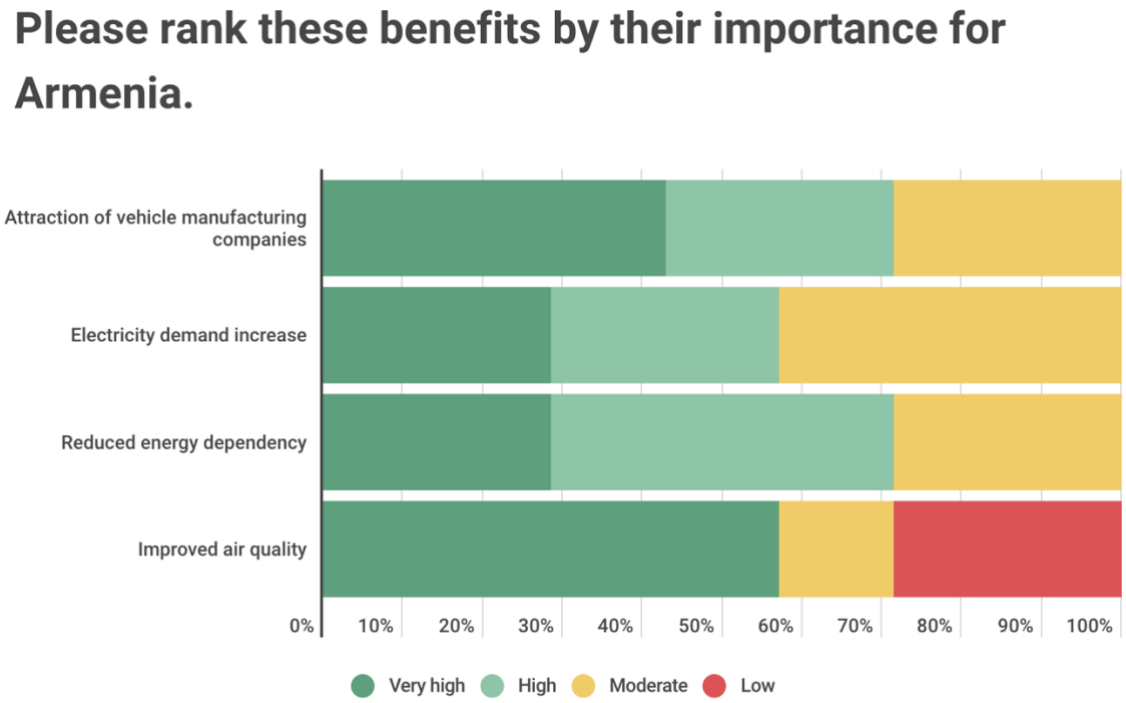


Figure 35. Benefits of E-mobility in Armenia
Source: Author

The above applies not only to cars but also to vehicle components production, charging stations, batteries, and so on. An analysis of the current situation of the automotive sector will allow to find potential development vectors, and the already recommended intersectoral group on electric mobility, due to its versatility, may be able to conduct this assessment. Moreover, the monetary incentive introduced in Romania is a scrappage program aimed to replace an old car with an EV, while the old car is sent for further processing to the factories of the Romanian automobile industry. Thus, additional subsidization of electric vehicles in Armenia is most likely to be cost-effective and expedient only if there is mutual benefit and circulation of resources within the country.

Charging infrastructure development needs should be studied more

This work conducted a comparative analysis of the development of charging infrastructure in selected countries. Today, the sufficiency index in Armenia is at the level of about 20 (electric vehicles per public charging station), while in the four countries out of five it ranged from 2-4. It is worth noting that in the EU, the development of this infrastructure is assigned to each country with the corresponding directive in order to make the EU a single transport space for EVs. This approach differs significantly from the motivation of Armenian stakeholders. In addition, EU countries have access to the structural funds to achieve the objectives of the directive.

Due to the relative segmentation of the initial development of electric mobility (only Yerevan and Gyumri municipalities have participated in the consultation), as well as the lack of transport corridors in the country (except the one to Georgia, where the infrastructure is already developing), compliance with European sufficiency indicators should not be a priority for Armenian policymakers. As one of the participants in the consultation during the preparation of the project noted, at this stage of development, the infrastructure should primarily be of a media nature until the number of electric vehicles in the country reaches a significant size.

The development of charging infrastructure should be aligned to the local context. A good starting point for determining development needs is to analyze existing charging stations (temporal and spatial patterns of use), a survey of EV drivers in the country, as well as an analysis of the housing structure in Yerevan and Gyumri (for residential charging).

Another important and yet underdeveloped area for development relates to technical regulations in the energy sector for the facilitation of charging infrastructure. Further, the adoption of minimum goals for the development of infrastructure in the above municipalities, followed by the deployment of infrastructure in small towns, will be an appropriate step.

E-mobility development should be aligned with climate policy targets

Climate policy documents are lacking any relevant information on E-mobility as a decarbonization mechanism. E-mobility development targets, policies, and plans should be incorporated into climate-related policies and GHG emission scenarios submitted under the United Nations Framework Convention on Climate Change.

Data collection mechanisms and periodical evaluation of the development should be in place

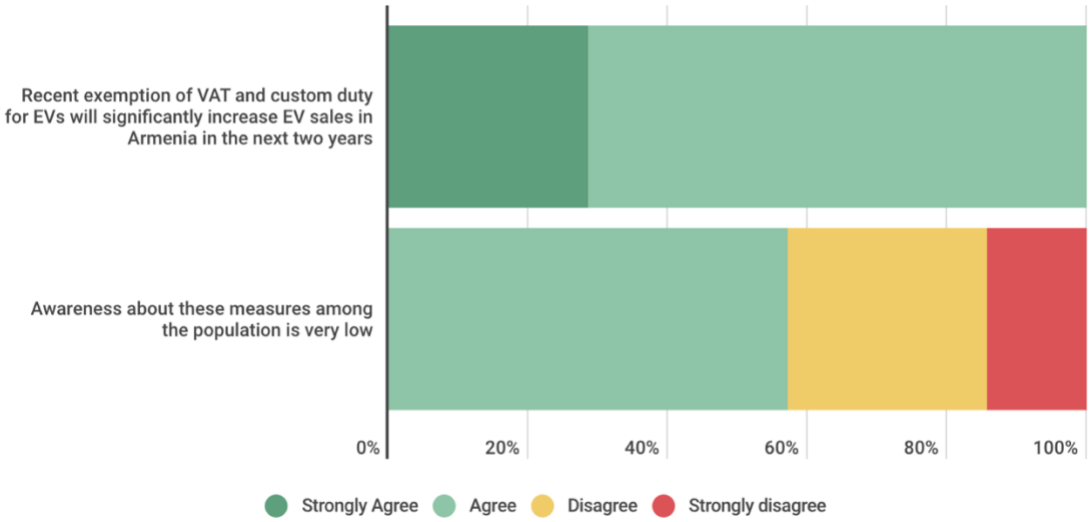


Figure 36. Short-term development in Armenia
Source: Author

As the results of the questionnaire showed (Figure 36), the current fiscal stimulation measures for potential electric car drivers will significantly increase sales and imports of electric cars in the country. This situation signals about the possibility of introducing modern mechanisms for collecting data on the behavioral patterns of electric vehicle drivers (e.g. regarding the level, time, and place of use of the charging infrastructure), the number of electric vehicles and their registration place (for local development of infrastructure and O&M), as well as marketing and awareness raising about this technology and the role of the state in its promotion.

Awareness raising campaigns

After stakeholder training proposed by the project, it is crucially important to educate consumers about the EV technology and the availability of incentives simultaneously with or prior to incentive introduction. Implementation of a pilot project has already been recommended as one way to do this. However, awareness raising campaigns must be organized through a range of different sources. For example, according to the study conducted in Lithuania, ICT development measures have proved to enhance awareness and knowledge raising among the population. This may include (but not limited to) apps for charging infrastructure locations, websites, and apps with information regarding incentives, repair services availability, free parking locations, public forums, etc.

Knowledge generation and sharing with other countries

Important for a long-term development, Armenia should continue learning about E-mobility development from other countries by taking part in international E-mobility communities, conferences, sharing experiences with other countries participating in the Global Electric Mobility Programme and countries discussed in this thesis.

5 Discussion

High upfront costs of EVs still act as the most significant barrier for their adoption. The analysis of the total cost of ownership shows that EVs are still more expensive than ICEVs for households, but cheaper for the public sector. More specifically, the ownership of EVs in the private sector could be cheaper only if its initial price does not exceed the price of a conventional vehicle by more than USD 8,250. In the public sector, an electric vehicle would be economically superior unless its price does not exceed the price of conventional vehicle by more than USD 16,500. In reality, the current price of an EV is about USD 12,000 more than of a comparable conventional model, which makes it economically attractive for public but not for private use.

The model has also shown that for those private drivers using a vehicle 50% more frequently than the assumed average (20,000 km annually), EV usage can be more cost-effective than ICEV. Secondly, the model analyzed and compared new vehicle models, while the majority of private drivers tend to buy second-hand vehicles, which also applies to EVs due to the recent tax amendments (VAT and excise tax exemption for EVs). EVs tend to depreciate faster than ICEVs, therefore for second-hand EVs, the cost gap might be significantly lower. Therefore, in the private sector, EVs cost of ownership parity with ICEVs in Armenia is very close to be reached or, probably, has already been reached for some models.

As for the public sector, a single EV used instead of an ICEV can save about USD 5,000 and USD 13,000 after 8 and 16 years of usage respectively. Moreover, the public sector, using its significant purchasing power, can potentially generate even more savings through the tendering and public procurement processes.

Stakeholders have validated and commented on this and three other adoption barriers: insufficient charging infrastructure, lack of consumer and stakeholder awareness, and lack of coherent policy framework and a strategical vision for E-mobility. Overall, some policy measures have already been introduced by municipal authorities (free parking in Yerevan), national government (VAT exemption) and as a result of economic integration with the Eurasian Economic Community (custom duty tax exemption). However, despite stakeholders' interest and motivation, they consider the existing measures insufficient to lead to fast uptake of EVs in Armenia.

There is a correlation between GDP per capita and the rate of EV adoption in the EU, but this correlation is much weaker (or virtually absent) for lower-income countries which are at the initial stage of adoption (EVs comprising less than 1% of annual sales).

EV policy analysis of late-adopter countries (Estonia, Latvia, Lithuania, Romania, and Bulgaria) confirms that in countries without monetary incentive measures, the increased number and variability (i.e. focus on different groups of consumers) of incentives leads to a higher demand for EVs.

The historical trends of EV sales in late-adopter countries highlight the difference in growth patterns caused by incentive mechanisms used. The adoption of EVs depends on both monetary incentives and, to a lesser degree, non-monetary policies. Applying a monetary policy, similar to the one in Romania, leads to an exponential uptake of EVs, whereas non-monetary policies (e.g. such as those applied in four other countries) leads to a nearly-linear growth pattern. The development of charging infrastructure did not seem to affect the rate of uptake of EVs in middle- and low-income countries, at least in early stages. The comparative analysis has shown that a combination of a monetary incentive and slow charging infrastructure development leads to a significantly higher uptake than no monetary incentives and a high number of public chargers.

According to our model, if such policies were applied in Armenia, they would result in either linear growth (non-monetary incentives) or exponential growth (monetary incentives). Starting from the point of 0.1% share of EV sales in 2020, it might change up to 0.2% (minimum value, BAU scenario) to 1.8% (maximum value, monetary incentive) in five years. However, findings also show that even weaker non-monetary policies could increase the annual share of EV sales from 0.1% to 0.2-0.4%, thus bringing hundreds of new EVs every year. Therefore, in absolute values, even the application of non-monetary policy packages for EV adoption in Armenia could bring about 700 new EVs annually (after 5 years) as opposed to the BAU scenario.

The final product of this thesis was the design of an introductory E-mobility project in Armenia. According to the Theory of Change, the project consists of three components aimed directly at the barriers identified during stakeholder consultations, also corresponding to the Armenian vision for E-mobility development.

The first component of the project is focused on the institutionalization of electric mobility in Armenia. Based on the examples reviewed at earlier stages of the thesis, it recommends establishing an intersectoral institutional body for E-mobility and issuing a mandate for E-mobility decision-making to the Ministry of Transport. Secondly, this component identifies the public sector as an early-adopters target group for the pilot project based on the actual examples of first EV rollout programs and a preliminary analysis of EV cost-effectiveness for the public vehicle fleet.

The second component suggests an EV public procurement system for the pilot project, recommending the scope for a successful implementation of this demonstration project. It also provides recommendations on target-setting and subsequent replication of this procurement system based on examples from the EU.

The last suggested component provides policy recommendations for a continuous scaleup among the private vehicle fleet in Armenia. Since some fiscal measures to stimulate the electric car market have already been introduced by the Armenian government for a period of up to 2023, the introduction of additional monetary stimuli, close to the Romanian-type incentives, at the moment may adversely affect the economy of Armenia. Instead, non-monetary incentives, such as free parking, circulation and company tax exemptions are recommended for a short-term E-mobility development in the country.

The study has also pointed out long-term priorities for E-mobility development in the country. This includes (but not limited to) enabling an appropriate investment and policy environment for foreign investments from EV manufacturing and assemblance, awareness raising, knowledge generation, and electrification of the public transportation sector.

6 Conclusion

The advance of electric mobility significantly differs across countries, with developing countries lagging behind. Feasible strategies for accelerating the uptake of electric vehicles around the world are needed for addressing the climate challenge These strategies should consider both the international experience and the specific national contexts.

The aim of this thesis was to advance understanding of feasible E-mobility strategies design in developing countries using Armenia as a case-study. The work uses and further develops the "EV Policy Cycle" methodological framework by enriching it by the elements of analyzing specific international experiences and the local context.

To achieve its aim, the thesis provides a comprehensive analysis of E-mobility development potential in Armenia through the review of EV policies in countries with similar economic contexts. The analysis has shown that up to a 1.8% share of EV sales may be achievable within the next five years with the introduction of ambitious monetary stimulus policies, awareness raising campaigns, and institutional regulations. More modest and realistic measures are likely to increase, the share of EVs by at least 0.2%.

Second, this thesis analyzes the local E-mobility context in Armenia through stakeholder consultations and data collection, focusing on the main EV adoption barrier – the high upfront costs. Through the total cost of ownership analysis, this thesis shows that there is still a cost gap between EVs and ICEVs for households, however EVs can already provide significant savings for the public sector.

The thesis concludes with a design of the first introductory E-mobility project in Armenia using the Theory of Change approach, which aligns project components with local barriers for EV adoption, identified during the consultations., The E-mobility project components include recommendations on different policy packages and their potential impacts, establishment of appropriate institutional environment for E-mobility, and implementation of a pilot public procurement EV project.

The thesis has several limitations which can be overcome in future studies. The TCO model used was primarily designed for new vehicles, not for the second-hand vehicles dominating the

private-sector market in Armenia. As more data accumulate on second-hand EVs and ICEVs, it would be important to update the TCO calculations. The first arises from the fact that due to data limitations it did not analyze whether EVs in comparison countries were used in private or public sector. Secondly, modelling growth curves is highly uncertain if only the data on very early deployment stages are available. Future research should continuously monitor and update growth model parameters as more empirical data in different countries become available. This may provide explanation for acceleration, stabilization and eventual slow-down of growth. Thirdly, the analysis did not clearly differentiate between policy and non-policy factors and their dynamics which may be behind growth patterns (such as economic developments, technology developments, etc.).

Additional research may be needed to develop more effective policies for e-mobility in Armenia. First, it could use the methodological framework from this thesis to analyze the potential of e-buses and 2- and 3-wheelers. The thesis methods and findings can also be used for UNEP-GEF "Global Programme to Support Countries with the Shift to Electric Mobility" program now unites more than 20 developing countries implementing various introductory E-mobility strategies around the world. Finally, non-monetary benefits (e.g. energy security, environmental benefits, air quality, etc.) of e-mobility in Armenia should be further investigated.

The main policy recommendation arising from this thesis is to adopt the e-mobility project developed here, to analyze the results of its implementation and to move towards more ambitious promotion of e-mobility supported by rigorous research.

Annex A

Transition towards Electric Mobility in Armenia

A new Global Environment Facility (GEF) Global E-Mobility Programme is the first global, coordinated effort to promote and accelerate the uptake of electric mobility. It will help an initial set of 17 countries around the world, including Armenia, to deploy electric vehicles at scale.

On the behalf of the "E-mobility transition in Armenia" project team, we would like to ask for your opinion on E-mobility development in Armenia. The survey aims to identify the barriers for adoption of electric vehicles and potential feasibility constraints of E-mobility in Armenia. Adoption barriers can be defined as a set of issues reflecting the willingness to consider, buy, and own an EV perceived by the average consumer in Armenia. Feasibility constraints relate to the discussion of possibility of a continuous E-mobility transition in Armenia at the national level through a lens of different actors (policymakers, consumers, O&M operators, etc.).

We would be thankful if you could fill out the survey by the 27th of April 2020. We would also be grateful, if you refer us to other experts who could fill out the questionnaire. Comments can be added in Russian or English. If required, we can also assist with translating this questionnaire to Armenian.

In case of any questions, please do not hesitate to contact (English/Russian):

Marina Olshanskaya - olshanskaya@avantgarde-energy.com
Aleksandra Novikova - aleksandra.novikova@ikem.de
Tsimafei Kazlou - kazloutsimafei@gmail.com
*Required

1. Potential benefits of E-mobility in Armenia. Please rank these benefits by their importance for Armenia. 1 - highest importance; 4 - lowest importance. *

Mark only one oval per row.

	1	2	3	4
Improved air quality	◯	◯	◯	◯
Reduced energy dependency on petroleum products	◯	◯	◯	◯
Attraction of vehicle manufacturing companies	◯	◯	◯	◯
Increasing the electricity demand	◯	◯	◯	◯

2. EV adoption barriers. Do you agree that these barriers influence the decision of the average consumer in Armenia (to buy an EV)? *

Mark only one oval per row.

	Strongly disagree	Disagree	Agree	Strongly agree
High upfront price				
Lack of charging infrastructure				
Lack of EV model availability in Armenia				
Lack of knowledge about EVs				

3. Please feel free to provide additional thoughts about barriers and benefits about E-mobility in Armenia.

4. Do you agree with the following statements? *

Mark only one oval per row.

	Strongly disagree	Disagree	Agree	Strongly agree
Recent exemption of VAT and custom duty for EVs will significantly increase EV sales in Armenia in the next two years				
Awareness about these measures among the population is very low				

5. Lack of knowledge about EVs. Do you agree with the following statements? *

Mark only one oval per row.

	Strongly disagree	Disagree	Agree	Strongly agree
Cooperation between key institutions (ministries of energy, transport, and environment, municipalities) is required for a continuous transition to E-mobility				
Pilot EV demonstration project is a good way to raise awareness about E-mobility				
There is a strong need in assistance on framing and implementing policies under the umbrella of E-mobility strategy				

6. Please feel free to provide additional thoughts about knowledge and monetary measures for E-mobility in Armenia.

References

AECOM. 2011. Forecast uptake and economic evaluation of electric vehicles in Victoria. Melbourne (Victoria): AECOM Australia Pty Ltd. URL: http://www.ehcar.net/library/rapport/rapport002.pdf

Akopov, A.S., Beklaryan, L.A., Beklaryan, G.L. 2019. Data on air pollutants and greenery in the city of Yerevan, Armenia. *Data in Brief* 25: 104028. https://doi.org/10.1016/j.dib.2019.104028

Al-Alawi, B.M., Bradley, T.H. 2013. Total cost of ownership, payback, and consumer preference modeling of plug-in hybrid electric vehicles. *Applied Energy* 103: 488-506. https://doi.org/10.1016/j.apenergy.2012.10.009

Alonso, E., Sherman, A.M., Wallington, T.J., Everson, M.P., Field, F.R., Roth, R., Kirchain, R.E. 2012. Evaluating rare earth element availability: a case with revolutionary demand from clean technologies. *Environ. Sci. Technol.* 46: 3406-3414, http://dx.doi.org/10.1021/es203518d

Archsmith, J., Kendall, A., Rapson, D. 2015. From Cradle to Junkyard: Assessing the Life Cycle Greenhouse Gas Benefits of Electric Vehicles. *Research in Transportation Economics* 52: 72-90. https://doi.org/10.1016/j.retrec.2015.10.007

Bakker, S., Trip, J. 2013. Policy options to support the adoption of electric vehicles in the urban environment. *Transportation Research Part D: Transport and Environment* 25: 18-23. https://doi.org/10.1016/j.trd.2013.07.005

Balkan Green Energy News. 2019. Bulgaria taking steps to improve electric vehicle environment – CMS Sofia. URL: https://balkangreenenergynews.com/bulgaria-taking-steps-to-improve-electric-vehicle-environment-cms-sofia/

Barisa, A., Rosa, M., Kisele, A. 2016. Introducing Electric Mobility in Latvian Municipalities: Results of a Survey. *Energy Procedia* 95: 50-57. https://doi.org/10.1016/j.egypro.2016.09.015

Bauer, C., Hofer, J., Althaus, H.-J., Del Duce, A., Simons, A. 2015. The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework. *Applied Energy* 157: 871-883. https://doi.org/10.1016/j.apenergy.2015.01.019

Bellocchi, S., Klöckner, K., Manno, M., Noussan, M., Vellini, M. 2019. On the role of electric vehicles towards low-carbon energy systems: Italy and Germany in comparison. *Applied Energy* 255: 113848. https://doi.org/10.1016/j.apenergy.2019.113848

Biresselioglu, M.E., Demirbag Kaplan, M., Yilmaz, B.K. 2018. Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes.

Transportation Research Part A: Policy and Practice 109: 1-13. https://doi.org/10.1016/j.tra.2018.01.017

Brand, C., Anable, J., Tran, M. 2013. Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK. *Transportation Research Part A: Policy and Practice* 49: 132-148. https://doi.org/10.1016/j.tra.2013.01.010

Burchart-Korol, D., Jursova, S., Folęga, P., Korol, J., Pustejovska, P., Blaut, A. 2018. Environmental life cycle assessment of electric vehicles in Poland and the Czech Republic. *Journal of Cleaner Production* 202: 476-487. https://doi.org/10.1016/j.jclepro.2018.08.145

Cabinet of Ministers of the Republic of Latvia. 2014. Order #129 "On Electromobility Development Plan 2014-2016". URL: https://likumi.lv/ta/en/en/id/265261-on-electromobility-development-plan-2014-2016

Car Sales Base. 2020. Statistical vehicle market database. Access date: 05.03.2020. URL: https://carsalesbase.com/about/

CEICData. 2020. CEICData statistical database. Access date: 05.03.2020. URL: https://www.ceicdata.com/

Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E., Sovacool, B. 2018. Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework. *Energy Research & Social Science* 37: 175-190. https://doi.org/10.1016/j.erss.2017.09.015

Choi, W., Song, H.H. 2018. Well-to-wheel greenhouse gas emissions of battery electric vehicles in countries dependent on the import of fuels through maritime transportation: A South Korean case study. *Applied Energy* 230: 135-147. https://doi.org/10.1016/j.apenergy.2018.08.092

Clougherty, J.E. 2010. A Growing Role for Gender Analysis in Air Pollution Epidemiology. *Environmental Health Perspectives* 118: 167-176. https://doi.org/10.1289/ehp.0900994

Covenant of Mayors. 2016. Yerevan City Sustainable Energy Action Plan. URL: https://mycovenant.eumayors.eu/docs/seap/21190_1472392319.pdf

Cox, B., Mutel, C.L., Bauer, C., Mendoza Beltran, A., van Vuuren, D.P. 2018. Uncertain Environmental Footprint of Current and Future Battery Electric Vehicles. *Environ. Sci. Technol.* 52: 4989-4995. https://doi.org/10.1021/acs.est.8b00261

Davies, H., Santos, G., Faye, I., Kroon, R., Weken, H. 2016. Establishing the Transferability of Best Practice in EV Policy across EU Borders. *Transportation Research Procedia* 14: 2574-2583. https://doi.org/10.1016/j.trpro.2016.05.350

Delucchi, M.A., Lipman, T.E. 2001. An analysis of the retail and lifecycle cost of battery-powered electric vehicles. *Transportation Research Part D: Transport and Environment* 6: 371-404. https://doi.org/10.1016/S1361-9209(00)00031-6

Dunckley, J., Tal, G. 2016. Plug-In Electric Vehicle Multi-State Market and Charging Survey. EVS29 1-12.

Ecofys: Monschauer, Y., Kotin-Förster, S. 2018. Bonus-Malus Vehicle Incentive System in France. 1-20. URL: https://www.euki.de/wp-content/uploads/2018/09/fact-sheet-bonus-malus-vehicle-incentive-system-fr.pdf Access Date: 25.01.2019

Econoler. 2015. Second National Energy Efficiency Action Plan for Armenia. First Draft. URL: http://policy.thinkbluedata.com/sites/default/files/Second%20National%20Energy%20Efficiency%20Action%20Plan%20%28NEEAP%29%20%282015%20Draft%29.pdf

Eesti Rahvusringhääling. 2020. Funding increased for first round of electric vehicle purchase measure. URL: https://news.err.ee/1029345/funding-increased-for-first-round-of-electric-vehicle-purchase-measure

Egbue, O., Long, S. 2012. Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy* 48: 717-729. https://doi.org/10.1016/j.enpol.2012.06.009

Electric Power Research Institute (EPRI). 2013. Total cost of ownership model for current plug-in electric vehicles. URL: http://www.ehcar.net/library/rapport/rapport079.pdf

Ernst & Young. 2017. Yerevan Green City Action Plan. URL: https://www.yerevan.am/uploads/media/default/0001/72/e7224f93ad7096478f9aaddb96ba61ea0ca693c9.pdf

European Alternative Fuels Observatory (EAFO). 2019. EAFO Country Database. URL: https://www.eafo.eu/countries/european-union/23640/summary

European Automobile Manufacturers Association (ACEA). 2019. ACEA Tax Guide 2019. URL: https://www.acea.be/publications/article/acea-tax-guide

European Automobile Manufacturers Association (ACEA). 2019a. Electric Vehicles: Tax Benefits and Incentives in the EU. URL: https://www.acea.be/publications/article/overview-of-incentives-for-buying-electric-vehicles

European Automobile Manufacturers Association (ACEA). 2020. ACEA Statistics. Access Date: 10.02.2020. URL: https://www.acea.be/statistics

European Commission. 2011. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. White Paper. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN

European Commission. 2019. Report on the Assessment of the Member States National Policy Frameworks for the development of the market as regards alternative fuels in the transport sector and the deployment of the relevant infrastructure pursuant to Article 10 (2) of Directive 2014/94/EU. Commission Staff Working Document. URL: https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190029.pdf

European Parliament. 2009a. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. URL: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

European Parliament. 2009b. Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0033&from=EN

European Parliament. 2014. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=EN

European Parliament. 2018. Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN

Faria, R., Marques, P., Moura, P., Freire, F., Delgado, J., de Almeida, A.T. 2013. Impact of the electricity mix and use profile in the life-cycle assessment of electric vehicles. *Renewable and Sustainable Energy Reviews* 24: 271-287. https://doi.org/10.1016/j.rser.2013.03.063

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy* 31: 1257-1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F.W. 2012. A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. *Journal of Transport Geography* 24: 471-482. https://doi.org/10.1016/j.jtrangeo.2012.01.021

Geels, F.W., Schot, J. 2007. Typology of sociotechnical transition pathways. *Research Policy* 36: 399-417. https://doi.org/10.1016/j.respol.2007.01.003

Gibbs, N. 2015. Dutch plug-in hybrid boom set to end. Automotive News Europe: May 10, 2015. URL: https://europe.autonews.com/article/20150510/ANE/150509993/dutch-plug-in-hybrid-boom-set-to-end

Goldie-Scot, L. 2019. A Behind the Scenes Take on Lithium-ion Battery Prices. Bloomberg New Energy Finance (BloombergNEF). URL: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Government of the Republic of Armenia. 2015. On approving the Intended Nationally Determined Contributions of the Republic of Armenia under the UN Framework Convention on Climate Change. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Armenia%20First/INDC-Armenia.pdf

Government of the Republic of Bulgaria. 2014. Innovation Strategy for Smart Specialisation 2014-2020. Version 22.12.2014. Access Date: 17.02.2020. URL: https://rio.jrc.ec.europa.eu/en/library/innovation-strategy-smart-specialisation-republic-bulgaria-2014-2020

Government of the Republic of Estonia. 2018. Estonian national energy and climate plan (NECP 2030). Estonia's Communication to the European Commission under Article 9(1) of Regulation (EU) 2018/1999. URL: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_ee_necp.pdf

Government of the Republic of Latvia. 2018. National Energy and Climate Plan of Latvia 2021-2030. Draft for submitting to the European Commission for evaluation. URL: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_lv_necp.pdf

Graff Zivin, J.S., Kotchen, M.J., Mansur, E.T. 2014. Spatial and temporal heterogeneity of marginal emissions: Implications for electric cars and other electricity-shifting policies. *Journal of Economic Behavior & Organization* 107: 248-268. https://doi.org/10.1016/j.jebo.2014.03.010

Green Climate Fund (GCF). 2019. "Advancing a regional approach to e-mobility in Latin America" Readiness Proposal. 1-34.

Green, E.H., Skerlos, S.J., Winebrake, J.J. 2014. Increasing electric vehicle policy efficiency and effectiveness by reducing mainstream market bias. *Energy Policy* 65: 562-566. https://doi.org/10.1016/j.enpol.2013.10.024

Griliches, Z. 1957. Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica* 25: 501-522. https://doi.org/10.2307/1905380

Grübler, A. 1996. Time for a Change: On the Patterns of Diffusion of Innovation. *Daedalus* 125: 19-42. URL: http://www.jstor.org/stable/20027369

Grütter, J.M., Kim, K-J. 2019. E-mobility Options for ADB Developing Member Countries. *ADB Sustainable Development Working Series*. URL: https://www.adb.org/publications/e-mobility-adb-developing-member-countries

Haiss, P.R., Ballsi, Z., Meissl, C. 2012. Automotive Industry Strategies by CEE Governments: Who Does What to Attract Business? *SSRN Journal*. https://doi.org/10.2139/ssrn.2347105

Hardman, S. 2019. Understanding the impact of reoccurring and non-financial incentives on plug-in electric vehicle adoption – A review. *Transportation Research Part A: Policy and Practice* 119: 1-14. https://doi.org/10.1016/j.tra.2018.11.002

Hardman, S., Chandan, A., Tal, G., Turrentine, T. 2017. The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence. *Renewable and Sustainable Energy Reviews* 80: 1100-1111. https://doi.org/10.1016/j.rser.2017.05.255

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., Figenbaum, E., Jakobsson, N., Jochem, P., Kinnear, N., Plötz, P., Pontes, J., Refa, N., Sprei, F., Turrentine, T., Witkamp, B. 2018. A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment* 62: 508-523. https://doi.org/10.1016/j.trd.2018.04.002

Hawkins, T.R., Singh, B., Majeau-Bettez, G., Strømman, A.H. 2013. Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles. *Journal of Industrial Ecology* 17: 53-64. https://doi.org/10.1111/j.1530-9290.2012.00532.x

Held, T., Gerrits, L. 2019. On the road to electrification – A qualitative comparative analysis of urban e-mobility policies in 15 European cities. *Transport Policy* 81: 12-23. https://doi.org/10.1016/j.tranpol.2019.05.014

Hernandez, M., Messagie, M., De Gennaro, M., Van Mierlo, J. 2017. Resource depletion in an electric vehicle powertrain using different LCA impact methods. *Resources, Conservation and Recycling* 120, 119–130. https://doi.org/10.1016/j.resconrec.2016.11.005

Hutchinson, T., Burgess, S., Herrmann, G. 2014. Current hybrid-electric powertrain architectures: Applying empirical design data to life cycle assessment and whole-life cost analysis. *Applied Energy* 119: 314-329. https://doi.org/10.1016/j.apenergy.2014.01.009

InsideEVs. 2018. ABB Charges Up Bulgaria With Network Of Fast Chargers. URL: https://insideevs.com/news/335196/abb-charges-up-bulgaria-with-network-of-fast-chargers/

InsideEVs. 2018. Alieno Arcanum Is A 5,221-HP Electric Hypercar With Alien Tech. URL: https://insideevs.com/news/339417/alieno-arcanum-is-a-5221-hp-electric-hypercar-with-alien-tech/

International Council on Clean Transportation (ICCT). 2019a. Electric Vehicle Guidebook for Indian States. URL: https://theicct.org/sites/default/files/publications/India_EV_State_Guidebook_20191118.pdf

International Council on Clean Transportation (ICCT). 2019b. Funding the Transition to all Zero-Emission Vehicles. White Paper. October 2019. URL: https://theicct.org/publications/funding-ZEV-transition

International Energy Agency (IEA). 2019. Global EV Outlook 2019: Scaling-up the Transition to Electric Mobility. OECD, 2019. https://doi.org/10.1787/35fb60bd-en.

International Energy Agency (IEA). 2020. Countries and Regions Statistical Database. URL: https://www.iea.org/countries

Joller, L., Varblane, U. 2016. Learning from an electromobility living lab: Experiences from the Estonian ELMO programme. *Case Studies on Transport Policy* 4: 57-67. https://doi.org/10.1016/j.cstp.2015.11.001

Kaunas University of Technology. 2019. Action Plan for Lithuania for development of environment-friendly mobility to reduce emissions. EV Energy Interreg program. Developed in cooperation with the Ministry of Transport and Communications of the Republic of Lithuania. URL: https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1569595899.pdf

Kelleher. 2019. Research Study on Reuse and Recycling of Batteries Employed in Electric Vehicles: The Technical, Environmental, Economic, Energy and Cost Implications of Reusing and Recycling EV Batteries. Project Report. URL: https://www.api.org/~/media/Files/Oil-and-Natural-Gas/Fuels/Kelleher%20Final%20EV%20Battery%20Reuse%20and%20Recycling%20Report%20to%20API%2018Sept2019.pdf

Kushnir, D., Sandén, B.A. 2012. The time dimension and lithium resource constraints for electric vehicles. *Resources Policy* 37: 93-103. https://doi.org/10.1016/j.resourpol.2011.11.003

Langbroek, J.H.M., Franklin, J.P., Susilo, Y.O. 2016. The effect of policy incentives on electric vehicle adoption. *Energy Policy* 94: 94-103. https://doi.org/10.1016/j.enpol.2016.03.050

Lipman, T.E., Delucchi, M.A. 2006. A retail and lifecycle cost analysis of hybrid electric vehicles. *Transportation Research Part D: Transport and Environment* 11: 115-132. https://doi.org/10.1016/j.trd.2005.10.002

Liu, J., Wei, Q. 2018. Risk evaluation of electric vehicle charging infrastructure public-private partnership projects in China using fuzzy TOPSIS. *Journal of Cleaner Production* 189: 211-222. https://doi.org/10.1016/j.jclepro.2018.04.103

Low Carbon South East Europe (LOCSEE). 2014. Estonian Electro-mobility Programme (ELMO) Factsheet. Access Date: 07.02.2020. URL:

http://www.locsee.eu/uploads/documents/good%20practices/EE1%20-%20Estonian%20electro-mobility%20programme.pdf

Ma, H., Balthasar, F., Tait, N., Riera-Palou, X., Harrison, A. 2012. A new comparison between the life cycle greenhouse gas emissions of battery electric vehicles and internal combustion vehicles. *Energy Policy* 44: 160-173. https://doi.org/10.1016/j.enpol.2012.01.034

Mitchell, G., Dorling, D. 2003. An Environmental Justice Analysis of British Air Quality. *Environ Plan A* 35: 909-929. https://doi.org/10.1068/a35240

Moro, A., Lonza, L. 2018. Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. *Transportation Research Part D: Transport and Environment* 64: 5-14. https://doi.org/10.1016/j.trd.2017.07.012

Münzel, C., Plötz, P., Sprei, F., Gnann, T. 2019. How large is the effect of financial incentives on electric vehicle sales? – A global review and European analysis. *Energy Economics* 84: 104493. https://doi.org/10.1016/j.eneco.2019.104493

Nordelöf, A., Messagie, M., Tillman, A.-M., Ljunggren Söderman, M., Van Mierlo, J. 2014. Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles – what can we learn from life cycle assessment? *Int J Life Cycle Assess* 19: 1866–1890. https://doi.org/10.1007/s11367-014-0788-0

Nykvist, B., Nilsson, M. 2015. Rapidly falling costs of battery packs for electric vehicles. *Nature Climate Change* (advance online publication). URL: http://www.nature.com/nclimate/journal/v5/n4/full/nclimate2564.html

Onn, C.C., Mohd, N.S., Yuen, C.W., Loo, S.C., Koting, S., Abd Rashid, A.F., Karim, M.R., Yusoff, S. 2018. Greenhouse gas emissions associated with electric vehicle charging: The impact of electricity generation mix in a developing country. *Transportation Research Part D: Transport and Environment* 64: 15-22. https://doi.org/10.1016/j.trd.2017.06.018

Opplysningsrådet for Veitrafikken AS (OFW AS). 2017. URL: www.ofvas.no/. Norway.

Palevičius, V., Podviezko, A., Sivilevičius, H., Prentkovskis, O. 2018. Decision-Aiding Evaluation of Public Infrastructure for Electric Vehicles in Cities and Resorts of Lithuania. *Sustainability* 10: 904. https://doi.org/10.3390/su10040904

Palm, J., Backman, F. 2017. Public procurement of electric vehicles as a way to support a market: examples from Sweden. *IJEHV* 9: 253. https://doi.org/10.1504/IJEHV.2017.087587

Palmer, K., Tate, J.E., Wadud, Z., Nellthorp, J. 2018. Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy* 209: 108-119. https://doi.org/10.1016/j.apenergy.2017.10.089

Pardo-Ferreira, M. del C., Rubio-Romero, J.C., Galindo-Reyes, F.C., Lopez-Arquillos, A. 2020. Work-related road safety: The impact of the low noise levels produced by electric vehicles according to experienced drivers. *Safety Science* 121: 580-588. https://doi.org/10.1016/j.ssci.2019.02.021

Pasaoglu, G., Harrison, G., Jones, L., Hill, A., Beaudet, A., Thiel, C. 2016. A system dynamics based market agent model simulating future powertrain technology transition: Scenarios in the EU light duty vehicle road transport sector. *Technological Forecasting and Social Change* 104: 133-146. https://doi.org/10.1016/j.techfore.2015.11.028

Petrauskienė, K., Skvarnavičiūtė, M., Dvarionienė, J. 2020. Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania. *Journal of Cleaner Production* 246: 119042. https://doi.org/10.1016/j.jclepro.2019.119042

Philip, R., Wiederer, A. 2010. Policy options for electric vehicle charging infrastructure in C40 cities.

Plötz, P., Gnann, T., Sprei, F. 2016. Can policy measures foster plug-in electric vehicle market diffusion? *WEVJ* 8: 789-797. https://doi.org/10.3390/wevj8040789

PRIMES. 2020. Procurement of electric vehicles. Mörbylånga Municipality, Sweden. Access Date: 02.03.2020. URL: http://primes-eu.net/media/22531602/no-53-sweden-case-study-electric-vehicle-moerbylaanga-sweden.pdf

RA Government. 2014. Armenia Development strategy for 2014-2025.

RA Ministry Of Nature Protection. 2015. National Greenhouse Gas Inventory Report of the Republic of Armenia for 2012. URL: https://unfccc.int/sites/default/files/resource/GHG%20national%20inventory%20report.pdf

RA Ministry Of Nature Protection. 2018. Second Biennial Report under the United Nations Framework Convention on Climate Change. URL: http://www.mnp.am/uploads/1/15302535542BUR_eng_final.pdf

Ralev, R. 2018. Bulgaria's E-mobility Dream. URL: http://top100.seenews.com/2018/10/bulgarias-e-mobility-dream/

Raslavičius, L., Azzopardi, B., Keršys, A., Starevičius, M., Bazaras, Ž., Makaras, R. 2015. Electric vehicles challenges and opportunities: Lithuanian review. *Renewable and Sustainable Energy Reviews* 42: 786-800. https://doi.org/10.1016/j.rser.2014.10.076

Republic of Armenia. 2010. National Energy Efficiency Action Plan. URL: http://www.inogate.org/documents/AM_1st_NEEAP_Armenia_final_2010.pdf

Republic of Armenia. 2015. Third National Communication on Climate Change under the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/armnc3.pdf

Republic of Bulgaria Ministry of Economy and Energy. 2014. National Energy Efficiency Action Plan 2014-2020. Access Date: 17.02.2020. URL: https://ec.europa.eu/energy/sites/ener/files/documents/NEEAPBulgaria_en.pdf

Republic of Bulgaria Ministry of Energy. 2017. National Energy Efficiency Action Plan 2014-2020. Updated 2017. Access Date: 12.02.2020. URL: http://www.seea.government.bg/documents/TRA%20BG%20NEEAP%202017%20EN.pdf

Republic of Bulgaria Ministry of Energy. 2018. Draft Integrated Energy and Climate Plan of the Republic of Bulgaria. Access Date: 17.02.2020. URL: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_bg_necp.pdf

Republic of Bulgaria Ministry of Transport, Information Technology and Communications. 2017. Integrated Transport Strategy for the period until 2030. Access Date: 12.02.2020. URL: https://www.mtitc.government.bg/sites/default/files/integrated_transport_strategy_2030_eng.pdf

Republic of Lithuania Ministry of Energy and Environment. 2018. Integrated National Energy and Climate Plan of the Republic of Lithuania. Draft version, 14th of December 2018. URL: https://ec.europa.eu/energy/sites/ener/files/documents/lithuania_draftnecp_en.pdf

Republic of Lithuania Ministry of Energy. 2018. National Energy Independency Strategy. URL: http://enmin.lrv.lt/uploads/enmin/documents/files/National_energy_independence_strategy_2018.pdf

Rezvani, Z., Jansson, J., Bodin, J. 2015. Advances in consumer electric vehicle adoption research: A review and research agenda. *Transportation Research Part D: Transport and Environment* 34, 122-136. https://doi.org/10.1016/j.trd.2014.10.010

Rietmann, N., Lieven, T. 2019. How policy measures succeeded to promote electric mobility – Worldwide review and outlook. *Journal of Cleaner Production* 206: 66-75. https://doi.org/10.1016/j.jclepro.2018.09.121

Rodríguez Quintero R., Garrido, C. V-A., Moons, H., Caldas, M.G., Wolf, O., Skinner, I., van Grinsven, A., Hoen, M., van Essen, H. 2019. Revision of the EU Green Public Procurement Criteria for Transport. Publications Office of the European Union, Luxembourg. URL: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC115414/eu_gpp_transport_technical_report_final.pdf

Romania Insider. 2019. Romania's Environment Ministry doubles budget for green car purchase program. URL: https://www.romania-insider.com/index.php/green-car-program-double-budget-july-2019

Romanian Government. 2018. Integrated National Energy and Climate Change Plan for 2021-2030. Access Date: 19.02.2020. URL: https://ec.europa.eu/energy/sites/ener/files/documents/romania_draftnecp_en.pdf

Romejko, K., Nakano, M. 2017. Portfolio analysis of alternative fuel vehicles considering technological advancement, energy security and policy. *Journal of Cleaner Production* 142, 39-49. https://doi.org/10.1016/j.jclepro.2016.09.029

Rubenis, A., Laizans, A., Zvirbule, A. 2019. Latvian Electric Vehicle Fast Charging Infrastructure: Results of the First Year of Operation. *Environmental and Climate Technologies* 23: 9-21. https://doi.org/10.2478/rtuect-2019-0051

Saeima of the Republic of Latvia. 2010. Latvian Sustainable Development Strategy. Access Date: 19.02.2020. URL: https://www.pkc.gov.lv/sites/default/files/inline-files/LIAS_2030_en_1.pdf

Sandén, B. 2013. "Systems Perspectives on Electromobility". Chalmers University of Technology. 10-21.

Serradilla, J., Wardle, J., Blythe, P., Gibbon, J. 2017. An evidence-based approach for investment in rapid-charging infrastructure. *Energy Policy* 106: 514-524. https://doi.org/10.1016/j.enpol.2017.04.007

Sierzchula, W. 2014. Factors influencing fleet manager adoption of electric vehicles. *Transportation Research Part D: Transport and Environment* 31: 126-134. https://doi.org/10.1016/j.trd.2014.05.022

Simon, B., Ziemann, S., Weil, M. 2015. Potential metal requirement of active materials in lithium-ion battery cells of electric vehicles and its impact on reserves: Focus on Europe. *Resources, Conservation and Recycling* 104: 300-310. https://doi.org/10.1016/j.resconrec.2015.07.011

Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M.J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J.J. Schauer, D. Sperling, and G. Tiwari. 2014. Transport. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Slowik, P., Lutsey, N. 2017. Expanding the electric vehicle market in U.S. International Council on Clean Transportation (ICCT).

Sovacool, B.K., Hirsh, R.F. 2009. Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition. *Energy Policy* 37: 1095-1103. https://doi.org/10.1016/j.enpol.2008.10.005

Spöttle, M., Jörling, K., Schimmel, M., Staats, M., Grizzel L., Jerram, L., Drier, W., Gartner, J. 2018. Research for TRAN Committee – Charging infrastructure for electric road vehicles, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

Tepanosyan, G., Sahakyan, L., Belyaeva, O., Saghatelyan, A. 2016. Origin identification and potential ecological risk assessment of potentially toxic inorganic elements in the topsoil of the city of Yerevan, Armenia. *Journal of Geochemical Exploration* 167: 1-11. https://doi.org/10.1016/j.gexplo.2016.04.006

The Universal Ecological Fund. 2019. The Truth Behind the Climate Pledges. 1-30. Access Date: 12.12.2020. URL: https://feu-us.org/behind-the-climate-pledges/

Transport & Environment. 2018. CO2 emissions from cars: the facts. URL: https://www.transportenvironment.org/sites/te/files/publications/2018_04_CO2_emissions_cars_The_facts_report_final_0_0.pdf

Transport Data Bank. 2020. The Transport DataBank Model. Access Date: 18.03.2020. URL: http://transportdata.net/en/page/11

United Nations Environment Programme (UNEP). 2020. Emob (Electric Mobility) Calculator. For national assessment of energy use, emissions, and costs of light duty vehicles until the year 2050. Access Date: 13.02.2020. URL: https://www.unenvironment.org/resources/toolkits-manuals-and-guides/emob-calculator

Vinichenko, V., Jewell, J., Tosun, J., Cherp, A. 2020. Later start of wind and solar power on technology periphery is not compensated by faster growth. Unpublished manuscript.

Vogel, I. 2018. Review of the use of 'Theory of Change' in international development. Review report. URL: http://www.theoryofchange.org/pdf/DFID_ToC_Review_VogelV7.pdf

Weiss, M., Patel, M.K., Junginger, M., Perujo, A., Bonnel, P., van Grootveld, G. 2012. On the electrification of road transport – Learning rates and price forecasts for hybrid-electric and battery-electric vehicles. *Energy Policy* 48: 374-393. https://doi.org/10.1016/j.enpol.2012.05.038

Woo, J., Choi, H., Ahn, J. 2017. Well-to-wheel analysis of greenhouse gas emissions for electric vehicles based on electricity generation mix: A global perspective. *Transportation Research Part D: Transport and Environment* 51: 340-350. https://doi.org/10.1016/j.trd.2017.01.005

World Bank. 2020. World Bank Country and Lending Groups. Access Date: 06.02.2020. URL: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

World Health Organization (WHO). 2011. Burden of disease from environmental noise: Quantification of healthy life years lost in Europe.

Wu, G., Inderbitzin, A., Bening, C. 2015. Total cost of ownership of electric vehicles compared to conventional vehicles: A probabilistic analysis and projection across market segments. *Energy Policy* 80: 196-214. https://doi.org/10.1016/j.enpol.2015.02.004

Wu, Y., Song, Z., Li, L., Xu, R. 2018. Risk management of public-private partnership charging infrastructure projects in China based on a three-dimension framework. *Energy* 165: 1089-1101. https://doi.org/10.1016/j.energy.2018.09.092

Yang, T., Long, R., Li, W. 2018. Suggestion on tax policy for promoting the PPP projects of charging infrastructure in China. *Journal of Cleaner Production* 174: 133-138. https://doi.org/10.1016/j.jclepro.2017.10.197

Zhang, Q., Li, H., Zhu, L., Campana, P.E., Lu, H., Wallin, F., Sun, Q. 2018. Factors influencing the economics of public charging infrastructures for EV – A review. *Renewable and Sustainable Energy Reviews* 94: 500-509. https://doi.org/10.1016/j.rser.2018.06.022

Zhili, D., Boqiang, L., Chunxu, G. 2019. Development path of electric vehicles in China under environmental and energy security constraints. *Resources, Conservation and Recycling* 143: 17-26. https://doi.org/10.1016/j.resconrec.2018.12.007