



**HAL**  
open science

# Which developing countries are ripe for electric vehicle investment? An analytical framework

Wale Arowolo, Yannick Perez

► **To cite this version:**

Wale Arowolo, Yannick Perez. Which developing countries are ripe for electric vehicle investment? An analytical framework. *International Journal of Automotive Technology and Management*, 2023, 23 (2/3), pp. 322-338. 10.1504/IJATM.2023.10057060 . hal-03987449

**HAL Id: hal-03987449**

**<https://centralesupelec.hal.science/hal-03987449v1>**

Submitted on 6 Sep 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Which developing countries are ripe for electric vehicle investment? An analytical framework

Wale Arowolo<sup>a</sup>, Yannick Perez<sup>a</sup>

<sup>a</sup> Sustainable Economy Research Group, Department of Industrial Engineering, CentraleSupélec (Paris Saclay University), 9 Rue Joliot Curie, 91192 Gif-sur-Yvette Cedex, France.

March 2023

## Abstract

While some developed countries (especially in the West) are making some progress in electrifying their transport sector with electric vehicles, it is also important to focus on developing countries since the climate change challenge is global. This paper contributes knowledge on transport electrification in developing countries. First, we analyse the evolution of the industrial organisation of electric utilities. Second, we discuss the interaction of electric utilities with the increased uptake of electric mobility in the context of the megatrends of decarbonisation, digitalisation, decentralisation, demand disruption and disintermediation in developing countries. Then, we develop an analytical framework as a decision-support tool to provide insight to policymakers, utilities, regulators, and stakeholders willing to invest in electric mobility in developing countries.

**Keywords:** electric mobility, electric utilities, industrial organisation, developing countries

Dr Wale Arowolo  
Sustainable Economy Research Group, Department of Industrial Engineering,  
CentraleSupélec (Paris Saclay University),  
9 Rue Joliot Curie,  
91190 Gif-sur-Yvette Cedex,  
France.  
Corresponding author e-mail: [adewale.arowolo@centralesupelec.fr](mailto:adewale.arowolo@centralesupelec.fr)

Prof. Yannick Perez  
Sustainable Economy Research Group, Department of Industrial Engineering,  
CentraleSupélec (Paris Saclay University),  
9 Rue Joliot Curie,  
91190 Gif-sur-Yvette Cedex,  
France.  
E-Mail : [yannick.perez@centralesupelec.fr](mailto:yannick.perez@centralesupelec.fr)

## Biographical notes

Wale Arowolo is an energy and transport economics researcher at CentraleSupélec (Paris Saclay University), France. He has a multidisciplinary background in engineering, economics and policy analysis and about 14 years of industry and applied research professional experience. He holds a PhD in Economics from Paris Saclay University and Master's degrees

in Engineering and Policy Analysis (TUDelft, the Netherlands) and in the Electric Power Industry (Pontifical Comillas University, Spain). His expertise is in market design and reform, institutional design, regulation, power and transport sector coupling, project management, and applied public policy. He contributes knowledge with applied research to inform public policy choices and has published papers in international journals.

Yannick Perez is an energy and mobility economics professor and the Armand Peugeot chairholder at CentraleSupélec (Paris Saclay University). In the last 20 years, he has published over 80 articles and a book chapter on mobility and energy-related topics, including contributions to Energy Policy, Ecological Economics and Renewable and Sustainable Energy Review journals. He has also conducted research for a number of industrial companies: EDF, Areva, Gaz de France, PSA, l'Agence Nationale de Régulation de l'Energie (ANARE) de Cote d'Ivoire, Verbund and Edison. He holds a PhD in Economics from Paris Sorbonne University.

## 1. Introduction

The automotive industry is undergoing a disruptive change towards a new era of electric mobility (Müller and Stephan, 2020). Electric mobility is fundamentally changing the traditional interaction between technology, market dynamics, production capacity, government policy, supply chains and manufacturing (ESMAP, 2018). Electric Vehicles (EVs) are rapidly progressing from a small niche in the automotive market to a larger share of automotive sales (Goracinova et al., 2022). According to the International Energy Agency (IEA), there are over 10 million EVs globally in the year 2020 (IEA, 2021). Moreover, there is an expected increase in end-users' EV acquisition in the coming years due to declining battery costs. Thus, there is mass production of battery cells and energy density increase that allows the reduction of the battery pack size. Electric Vehicles (EV) market penetration is quickly increasing, driven by progressive improvements in the driving range and purchase price that reduce the competition gap with internal combustion engine vehicles (ICEVs). For example, in 2020, the average range for a new battery electric vehicle was about 350 kilometres (km), up from 200 km in 2015 (IEA, 2021). Besides, the most recent environmental policies and industrial efforts in the transport sector have paved the way for significant electrification (ENTSOE, 2021)

If energised with decarbonised electricity and smart charging, EVs can help reduce emissions, thus helping to mitigate climate change (Kempton et al., 2014). In 2019, EVs in operation globally avoided the consumption of almost six hundred (600) thousand barrels of oil products per day. Moreover, replacing ICEVs with EVs avoided the emission of 53 MtCO<sub>2-eq</sub>, about half the amount that would have been emitted without EVs (IEA, 2020). Electric mobility operates in a broad ecosystem with many actors from the transport and electric systems. Therefore, there is an interaction between electric mobility and electric utilities. In this context, five megatrends are impacting the interaction of electric mobility with electric utilities and transforming the subsisting modus operandi of traditional electric utilities. These megatrends are (i) decarbonisation, (ii) digitalisation, (iii) decentralisation, (iv) demand disruption and (v) disintermediation. Decarbonisation is the removal of carbon emissions from energy sources to mitigate the impact of climate change. For electric utilities, decarbonisation implies a shift in power generation sources. As a flexibility resource via smart charging approaches, EVs can reduce the need for investment in carbon-intensive, fossil-fuel power plants to balance renewable power generation.

Digitalisation is the increasing application of information and communications technologies (ICT) in energy and transport systems (IEA, 2017). Digitalisation will be key in optimising EV transport and grid services in the planning and operation stages. Disintermediation is reducing

the number of intermediaries and, in the process, reducing the time and cost to offer products or services to customers (Linton, 2018). For example, blockchain technology can facilitate the payment and billing for EV services and simplify the provision of EV flexibility services to the grid (IRENA, 2019). Demand disruption creates new risks and opportunities with the potential to transform the traditional electric utilities service delivery model, reshape the stakeholders' landscape, and redefine how government agencies and consumers engage with the energy markets (Elizondo-Azuela et al., 2017). The plummeting cost of solar photovoltaic power and new developments in battery storage, combined with digitised power grids, are creating possibilities for decentralising energy services, with power provided by various actors. EV battery storage will empower consumers and other decentralised actors to participate in electricity production and demand response services. EV owners can charge their batteries from the grid and discharge them back to the grid (vehicle-to-grid), generating reverse flows in power networks and increasing trade possibilities at the retail level.

This paper contributes knowledge on transport electrification investment and deployment in developing countries in the context of the five megatrends mentioned above. First, we analyse the evolution of the industrial organisation of electric utilities. Second, we discuss the interaction of electric utilities with the increased uptake of EVs in the context of the five megatrends. Then, we develop an analytical framework as an investment decision-support tool to provide insight to policymakers, utilities, regulators, and other stakeholders willing to invest in EVs in developing countries. Finally, we provide a list of developing countries potentially viable for electric utilities integration with EVs for further studies.

Section 2 is the literature review. Section 3 discusses the interaction of electric utilities with electric mobility in the megatrends' context. Section 4 presents an analytical framework to provide insight into the interaction of electric utilities with electric mobility in the context of the megatrends in developing countries. Section 5 is the conclusion.

## **2. Literature Review**

This section reviews two strands of related literature to the subject: (i.) EV deployment and (ii.) EV investment in developing countries.

### **2.1 EV deployment in developing countries.**

Dioha et al. (2022) discussed the factors to be considered in EV deployment in developing countries: the nature of the electricity supply system, market structure and consumer perception, the political economy of fossil fuel, and the nature of the existing vehicle fleet and transport infrastructure. Collett et al. (2021) argued that context-specific approaches and technologies, different from developed countries, and the associated business models should

be developed to deploy EVs in sub-Saharan African countries. The authors recommended designing and manufacturing affordable EVs, redirecting fossil fuel subsidies to clean technologies, and integrating the transport and power sectors. Goel et al. (2021) discussed the key challenges to EV deployment in India as market-related challenges (vehicle servicing, high capital cost, consumer perception, battery raw materials) and technical challenges (battery lifespan/efficiency, driving range, safety requirements, charging infrastructure and battery recycling). Tuan et al. (2021) analysed the barriers to the EV market growth in Vietnam: battery and charging infrastructure issues and services, lack of incentives, lack of EV standards and small market size. Mali et al. (2022) discussed the need to facilitate EV deployment in developing countries using Nepal as a case study. The authors found that the key issues are the high initial cost, lack of supportive government policies, lack of power availability to meet EV demand, and lack of charging infrastructure. Draeck et al. (2021) found that the barriers to EV deployment in Malaysia and South Africa are the need for more infrastructure, insufficient incentives, and a lack of stakeholder coordination and awareness of electric mobility. Grütter et al. (2019) identified deployment issues in developing countries with small grids when there is a significant EV penetration rate. The authors found that EV charging can have a sizable impact on the loads applied to the grid at certain times and locations.

## 2.2 EV investment in developing countries.

Ayeter et al. (2021) found that replacing the ICEV bus fleet with an electric bus fleet reduces the lifetime cost of the electric bus by 62% and the hybrid-electric bus by 50% when charged from the national grid in seven African countries. Gomis et al. (2018) discussed electric mobility development in Latin America and the Caribbean. The authors found that the small market size is a notable investment challenge. They proposed the need for incentives to reduce the capital costs of EVs, accelerate the deployment of charging infrastructure, and facilitate collaboration between the government and the private sector for market expansion. Sustainable Mobility for All (2022) found that the challenges in twenty-three (23) low-income African countries are EV investment costs, lack of access to grid electricity and governance. The authors suggested allocating scarce resources in low-income African countries by investing in public transport and two and three-wheelers as a first step toward electric mobility. Rajper and Albrecht (2020) argued that electric two-wheelers might benefit developing countries due to low capital and operational costs, lack of charging infrastructure and grid power in some developing countries.

## 2.3 Contribution of our paper

The existing literature generally identified lack of grid power access, small grids, charging infrastructure and investment costs as mitigating challenges to EV deployment in many developing countries. Our paper contributes to the existing literature in two distinct ways. First,

we analyse the interaction of electric utilities and electric mobility in the context of the megatrends of decarbonisation, digitalisation, decentralisation, demand disruption and disintermediation in developing countries. Then, we develop an analytical framework as an investment decision-support tool to identify some developing countries ripe for EV investments.

### **3. Electric utilities interaction with electric mobility in the megatrend's context**

This section discusses the five megatrends changing the mode of operation of traditional electric utilities and the interaction of electric utilities with electric mobility.

#### **3.1 Decarbonisation**

Decarbonisation entails reducing carbon emissions by phasing out fossil fuels from electricity generation. Decarbonisation involves shifting the generation to carbon-neutral electricity sources to limit the effects of climate change and contribute to sustainable development, for example, replacing coal and gas plants with variable renewable energy sources such as wind and solar photovoltaic power. On one hand, complexity increases with increasing intermittent renewable energy shares in the power system while phasing out fossil fuels. On the other hand, the electrification of other sectors (for example, transport via EVs) will increase the electricity demand that needs to be met with more renewable energies.

Decarbonisation also brings the possibility of stranded assets to electric utilities as the market structure changes. For example, some power generation assets may no longer be needed in the market before the end of their lifetime and thus become stranded assets. Variable renewable energy sources can also become stranded assets, for instance, when policy support schemes such as feed-in-tariffs or renewable purchase obligations end. Moreover, renewable technologies reduce the average electricity prices since they have zero marginal cost. Thus, renewable energies can amplify market design flaws, leading to negatively priced periods. This challenge calls for well-designed and flexible electricity markets. Moreover, making the right investments in the power sector under uncertainties can result in reduced electricity supply that may not meet demand. Deploying EVs that increase electricity demand while decarbonising the power and transport sector is particularly challenging in developing countries. Electric utilities have to deal with high interest rates, less robust credit markets and high currency risk, making the conditions for decarbonisation investment less favourable. The need for investments in developing countries is high and will continue to increase with increasing power demand. The main challenge remains to overcome market capital scarcity (Papadis and Tsatsaronis, 2020). Nevertheless, pursuing a low-carbon transition in developing countries should be integrated into the overall development agenda. The goal is not just to decarbonise but to decarbonise development (Marianne et al., 2015).

Electric mobility has garnered growing interest and significant momentum in many countries, often motivated by its transport sector decarbonisation potential (Briceno-Garmendia et al. 2022). EV fleets can also create vast electricity storage capacity to support decarbonisation. However, the optimal charging patterns will depend on the precise energy mix. EV integration will differ in power systems with high shares of solar-based generation compared with systems with a high percentage of wind power. Using EVs as a flexibility resource via smart charging approaches would reduce the need for investment in flexible but carbon-intensive, fossil-fuel power plants to balance renewables. Although EVs do not release emissions when driven, they use electricity that often comes mainly from fossil fuels, although the overall emission is lower than for ICEVs. To reap the full benefits of decarbonisation, transport electrification must go hand in hand with decarbonising the power sector (IRENA, 2019). Nonetheless, the required investment for decarbonisation remains a critical challenge in many developing countries.

### 3.2 Digitalisation

Digitalisation entails the increasing interaction and convergence between the digital and physical worlds. The digital world has three fundamental elements: data (digital information), analytics (using data to produce useful information and insights) and connectivity (the exchange of data between humans, devices, and machines (including machine-to-machine) through digital communications networks. Automated smart charging and, then, increasingly, vehicle-to-anything applications should also boost synergies with renewable energies. In the automotive industry, digitalisation is causing disruptive changes that are driving changes in companies' traditional processes, products/services and business models and leading to long-term discontinuous change (Sommer et al., 2021; Knobbe and Proof, 2020). The automotive supply chain is characterised by a strong need to invest in digitalisation (Calabrese and Falavigna, 2022). Digitalisation will also play a vital role in optimising EV transport and grid services in the planning and operation stages. Digital technologies and data analytics will make it possible to match mobility demand with power supply patterns and to identify the most optimal locations and charging points for EVs (IRENA, 2019). Digitalisation will also facilitate EV integration in Mobility-as-a-Service (MaaS) innovation. MaaS entails the integration of public and private mobility options through the definition and commitment to a single standardised interface for offering passengers a seamless multimodal and intermodal trip (Fournier et al. 2022).

### 3.3 Decentralisation

Decentralisation brings more market players providing supply, storage and energy management services and requires increased coordination (Bernard et al. 2014).



Decentralisation impacts electric utilities' power generation, systems operation, demand planning, investment, and network asset management. Centralised, asset-heavy electricity production may remain in the near future, but utilities must explore new horizons in clean energy, downstream markets, and digitally enabled, customer-centric business models (Elizondo-Azuela et al., 2017). Decentralisation will bring profound changes to the power and transport sector. For example, installed rooftop solar panels can charge EVs in parking lots. Also, through bidirectional charging, EV battery storage will empower many EV owners and power consumers to become prosumers.

### 3.4 Disintermediation

Disintermediation reduces the number of intermediaries, thereby reducing the number of supply chain partners and, in the process, reducing the time and cost of offering products or services to customers (Linton, 2018). Blockchain technology-enabled peer-to-peer transactions are a good example of disintermediation in the power sector. Blockchain introduces a database that functions like a distributed network, hence the term 'distributed ledger' with the promise of cooperation between complex network members that transfer value to one another without central authorities or middlemen. Blockchain's ability to provide disintermediation and improve transparency can reduce transaction costs, introduce efficiency into existing value chains, change revenue models, and create new markets. Disintermediation can reduce cost, increase efficiency, and remove retail utilities from the energy supply value chain in many markets with active retail utilities (Marina, 2017).

In the transport sector, blockchain technology can facilitate the payment and billing for EV services and simplify the provision of flexibility services to the grid. Blockchain can facilitate smart charging by connecting market players and facilitating monetary transactions between aggregators and customers through open-source standards. Consumers can also use blockchain technology for customer-to-customer charging solutions, such as sharing a private charger with someone else at a fee (IRENA, 2019).

### 3.5 Demand disruption

Renewable energy resources can make consumers bypass the electric utilities, leading to demand disruption. For example, consumers can buy and sell electricity through an aggregator or involve in peer-to-peer trade. Also, prosumers can self-produce electricity, for example, from solar panels and supplement their production with battery storage or their EV battery that can be discharged to meet power needs. Therefore, they can defect from the grid, causing demand disruption for electric utilities. The falling costs of solar PV and the rising cost of grid power have made self-generation become promising for consumers. As consumers defect from the

grid, electric utilities will have to spread their fixed and sunk costs of the generation, transmission and distribution infrastructure over a smaller number of consumers. The cost to remain on the grid increases, making partial or total defection an increasingly attractive option for consumers and endangering the viability of electric utilities (OECD, 2018).

EV deployment can put enormous power demand burdens on the grid system. The power demand may cause challenging technical issues (such as overloading, voltage instability, frequency fluctuations and power losses) that can affect the power system's performance and lead to power failure. Centralised coordination can be effective in solving the EV integration to grid issues. Centralised coordination reduces load variance, voltage variations, power losses, and computational complexity and helps to determine the EV charging locations. Optimising the system/interaction between the EV and the grid variables can accurately solve the optimal power, energy capacity and location of EVs in centralised coordination by optimising the system/interaction between the EV and the grid variables (Sulaiman et al., 2021).

To address the challenges of demand disruption, integrated resource planning (IRP) modelling tools that account for the integration of demand-side resources will become increasingly important as new information and communication technologies, renewable energy technologies, cloud and data services, power storage in distributed energy applications, EVs market penetration with smart charging and bidirectional charging capabilities, and prosumers emerge as active market participants (Elizondo-Azuela et al. 2017).

#### **4. Framework of the five megatrends in the developing countries' context**

The classic industrial organisation models of electric utilities have experienced fundamental changes with the increasing impact of electric mobility in the megatrends' context. In this section, we attempt to understand this change. Building upon the works of Hunt (2002) and (Vivien and Rana, 2020), we discuss the representative industrial organisation models of electric utilities and provide new ones to depict the contemporary state of electric utilities. Thereafter, we present a framework to analyse the impact of the megatrends on the utilities based on their current state in developing countries.

##### 4.1 Industrial organisation model of electric utilities

###### 4.1.1 Vertically integrated utility model

Before the 1980s, electric utilities were vertically integrated in most countries under state control. The vertically integrated utility operates as a monopoly responsible for the generation, transmission, and distribution/retail of electricity to end-users (see Figure 1).

Model 1: Vertically integrated electric utility (monopoly at all levels)

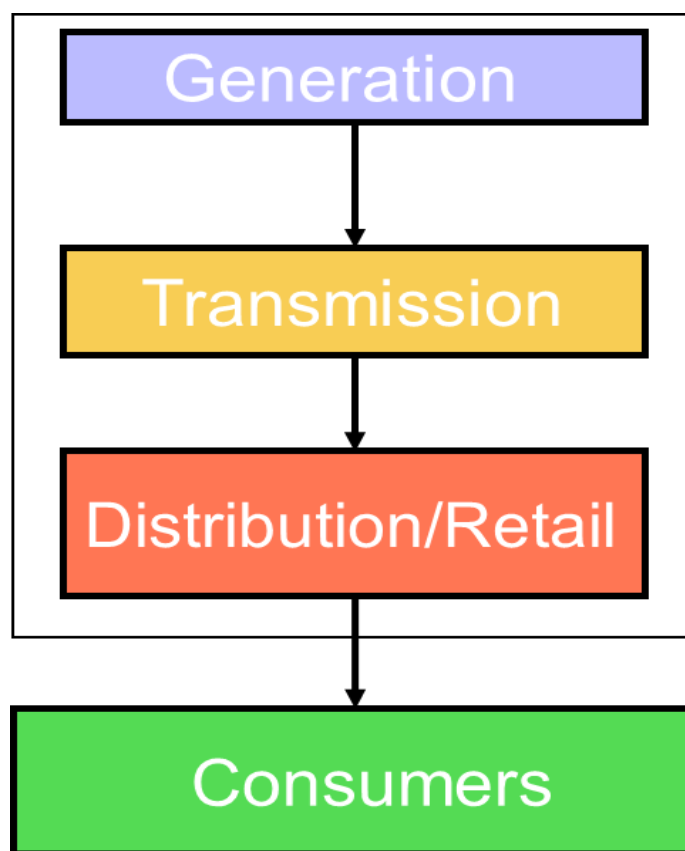


Figure 1: Vertically integrated utility industrial organisation

The challenges with vertically integrated utilities are poor accountability since the government's agency is not directly accountable to consumers or shareholders, the lack of sufficient incentives to improve customer service or to engage in technology innovation and the taxpayers bearing most of the investment risks. For some developing countries, a key challenge is the lack of sufficient resources from the government to invest, resulting in chronic power outages and poor service quality (Sioshansi and Pfaffenberger, 2006).

#### 4.1.2 Wholesale electricity market model

The need to surmount the challenges of vertically integrated utilities led to power sector reforms. Power sector reforms can be traced back to Chile (1981), England and Wales (1990), and Norway (1991). Beginning in the early '80s, there have been four deregulation waves. The first wave was in the '80s, for example, in Chile. The second wave was in the early '90s and was led by the Nordic countries: Norway and Sweden. The third wave in the European Union began with the European 'Single Act' in 1986 and an EU internal market goal in all industries in 1992. The fourth wave is global and was led by the World Bank. Consequently, electric utilities have faced a continuous series of changes. Technical changes to electricity generation have allowed competition in many countries, hoping to lower power supply provision costs.

Therefore, many developed countries have liberalised the power sector and established the wholesale electricity market (see Figure 2).

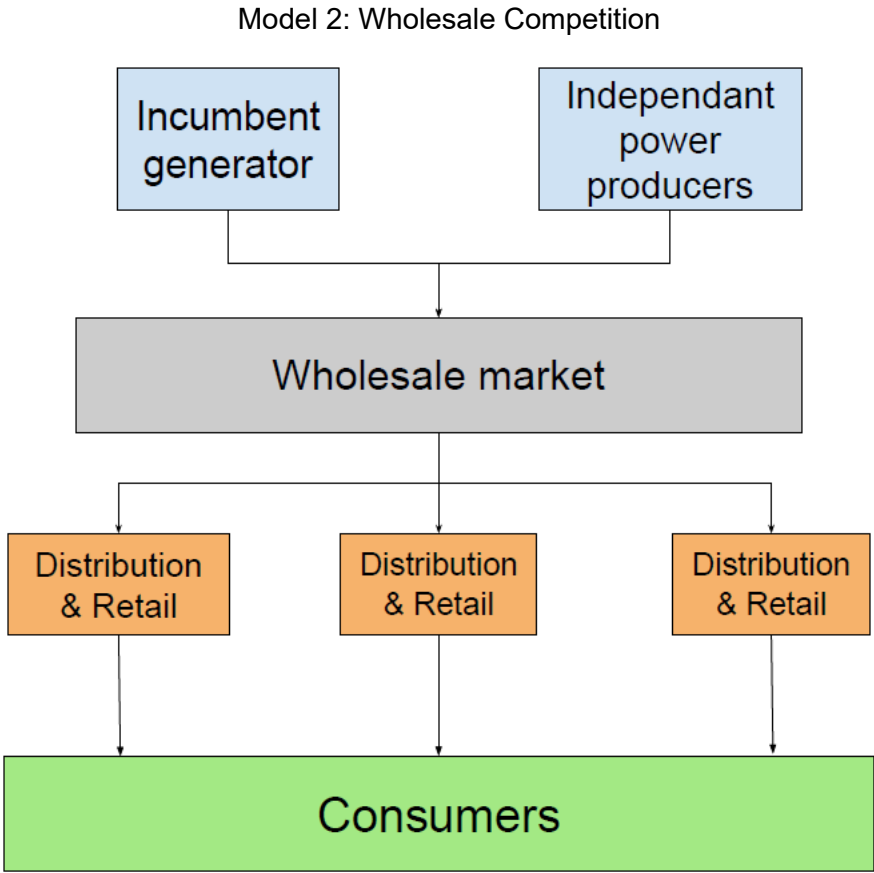


Figure 2: Electric utilities wholesale market industrial organisation

In the wholesale market model, the utility's generation, transmission and distribution functions are unbundled or separated, and competition is introduced among power generators. Electrical energy is traded as a commodity in the market, while transmission and distribution remain services provided by monopoly companies. If properly regulated, the expected benefit of unbundling and privatisation is that the utility gets the revenues it needs when the price of electricity reflects its true cost. Other benefits include the optimal allocation of economic resources and access to private-sector capital. Moreover, it may be worthwhile in developing countries where governments lack investment funds and can earn revenue from selling privatised assets. Therefore, many developing countries tried to set up wholesale power markets.

4.1.3 Wholesale and retail electricity market model

Some developed countries further established competition in the retail market (see Figure 3). In the wholesale and retail market model, there is full access to the market for all the

participants. Consumers can purchase power supplies from competing retail suppliers (Sioshansi and Pfaffenberger, 2006).

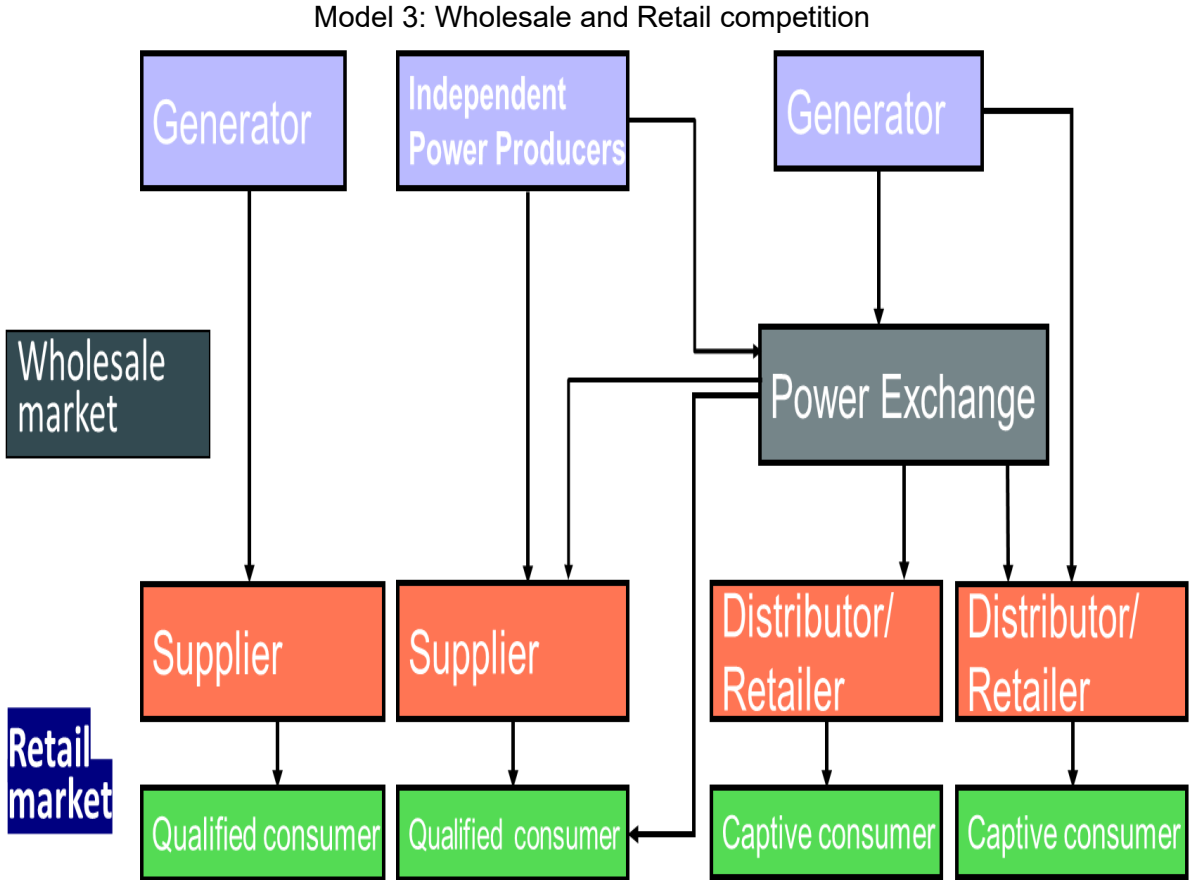


Figure 3: Electric utilities wholesale and retail market industrial organisation

It is worth noting that power markets (wholesale only and wholesale and retail) are mostly found in developed countries where the power systems are relatively large and financially viable. In many developing countries, reforms were not fully implemented, resulting in a hybrid model in which markets coexist with state dominance because of the challenges involved in establishing competition in the wholesale power markets. For example, the long-term contracts required to induce independent power producers to invest in power generation can distort power dispatch and hinder competition (Vivien and Rana, 2020).

4.1.4 The Single-buyer model

In the single-buyer model, the independent power producers compete with existing generation to supply electricity to the single buyer. The single buyer can be the transmission or distribution utility (see Figure 4). Sometimes, the single buyer is neither the transmission nor distribution utility but a publicly owned special purpose vehicle (SPV). About half of the developing countries have adopted this model (Vivien and Rana, 2020).

Model 4: The Single-Buyer Model

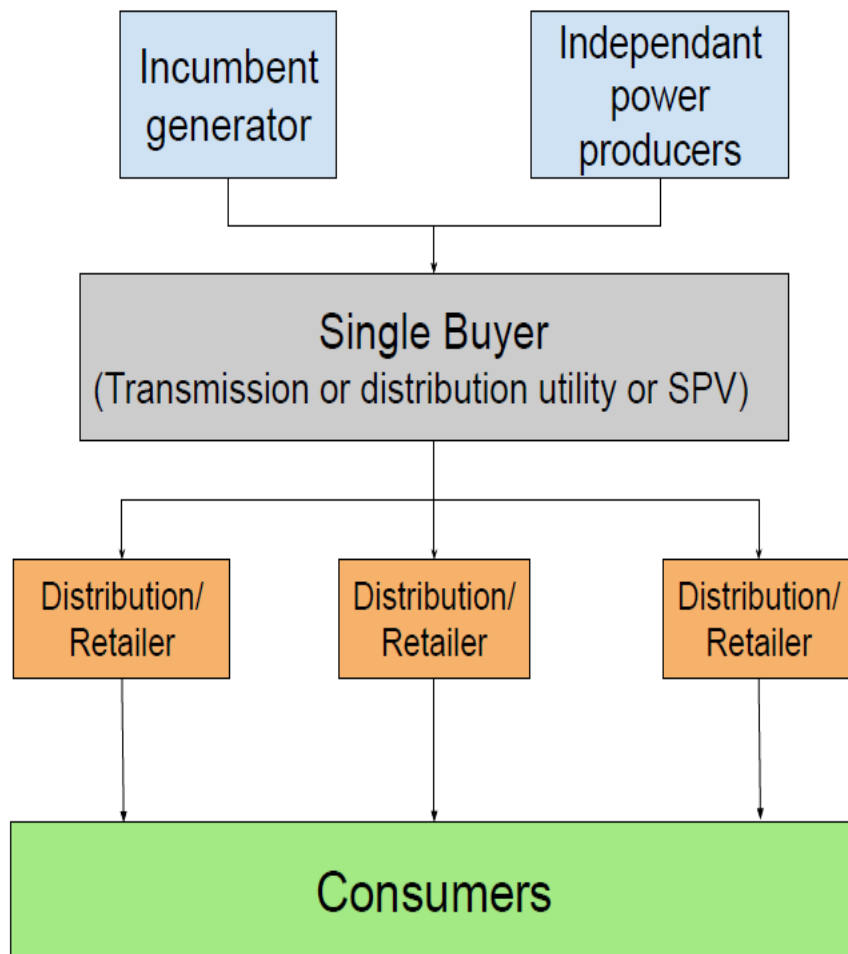


Figure 4: The single buyer model industrial organisation

#### 4.1.5 Peer-to-Peer innovation with electric mobility model

With the combined impact of the megatrends transforming electric utilities (see section 3), a progressive peer-to-peer innovation with electric mobility is unfolding in developed and developing countries. This contemporary and burgeoning innovation is hitherto an unorganised market based on peer-to-peer energy and transport services (see Figure 5).

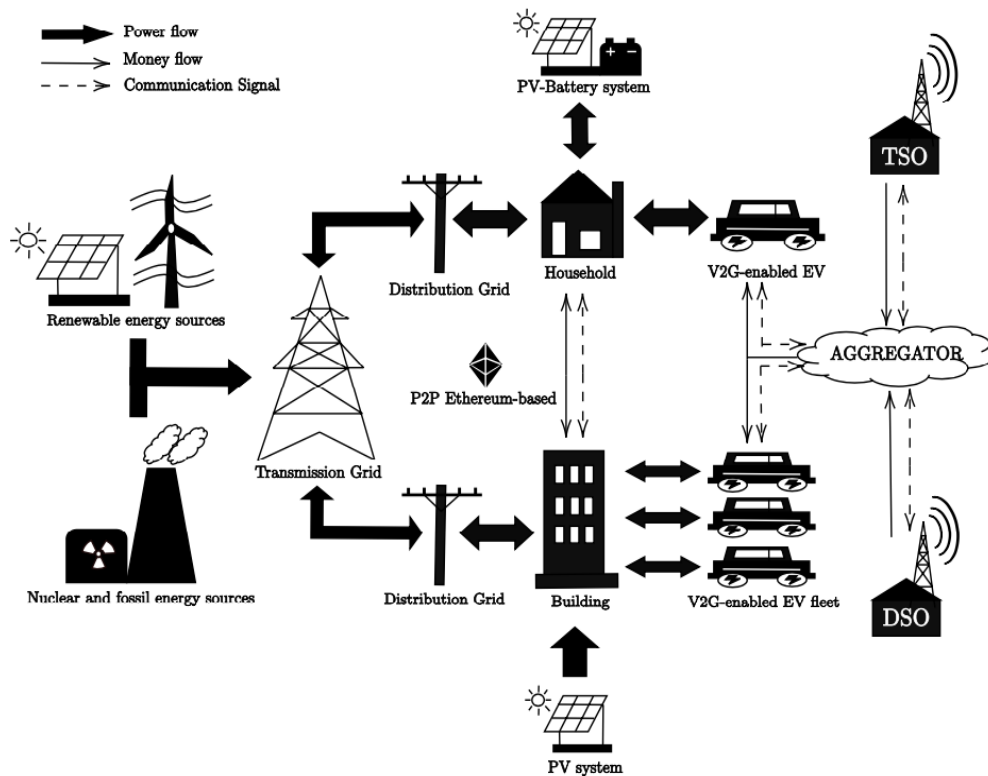


Figure 5: Peer-to-peer innovation with electric mobility. Source: (Gomes et al. 2020)

Peer-to-Peer innovation with electric mobility innovation is under development in many countries. The innovation includes new decentralised storage solutions (such as from EVs and battery energy storage systems), new communication protocols and the coupling of local renewable energies (for example, solar PV and wind power). The innovation also includes new market actors, such as aggregators and EV manufacturers. The fundamental changes in the peer-to-peer innovation with electric mobility model compared to other models include bidirectional power flow and active management at the distribution and transmission levels (Gomes et al. 2020). Power can flow bidirectionally between households or commercial buildings and the distribution grid. Moreover, peer-to-peer energy trading can take place between buildings (commercial or residential). The aggregator can coordinate transactions between the EV owners and the transmission and distribution utilities. The aggregator can coordinate bidirectional vehicle-to-grid-enabled EV and EV fleet participation in the electricity markets. The aggregator can also facilitate distributed energy resources supply to the market, for example, through solar PV auctions or other transactions in the electricity (energy or reserve) market, based on the allowed network-safe limit imposed (for example, by the distribution system operator (DSO) or distribution utility). The peer-to-peer innovation with electric mobility model has a higher impact of the five megatrends than the aforementioned industrial organisation models. For example, there is power flow from renewable energy sources such as solar PV systems directly to homes and buildings (decentralisation), EVs

supported by advanced technologies and flow of communication signals (digitalisation), renewable energy sources of generation (decarbonisation), bidirectional power flows from EVs to households and buildings that will lead to (demand disruption) and disintermediation for the utilities. Consequently, electric utilities in developed and developing countries are gradually transforming from Models 1, 2, 3 and 4 to include features of peer-to-peer innovation with electric mobility (see Figure 6). We coin the transformation of the electric utilities industrial organisation as Model 1+, Model 2+, Model 3+ and Model 4+.

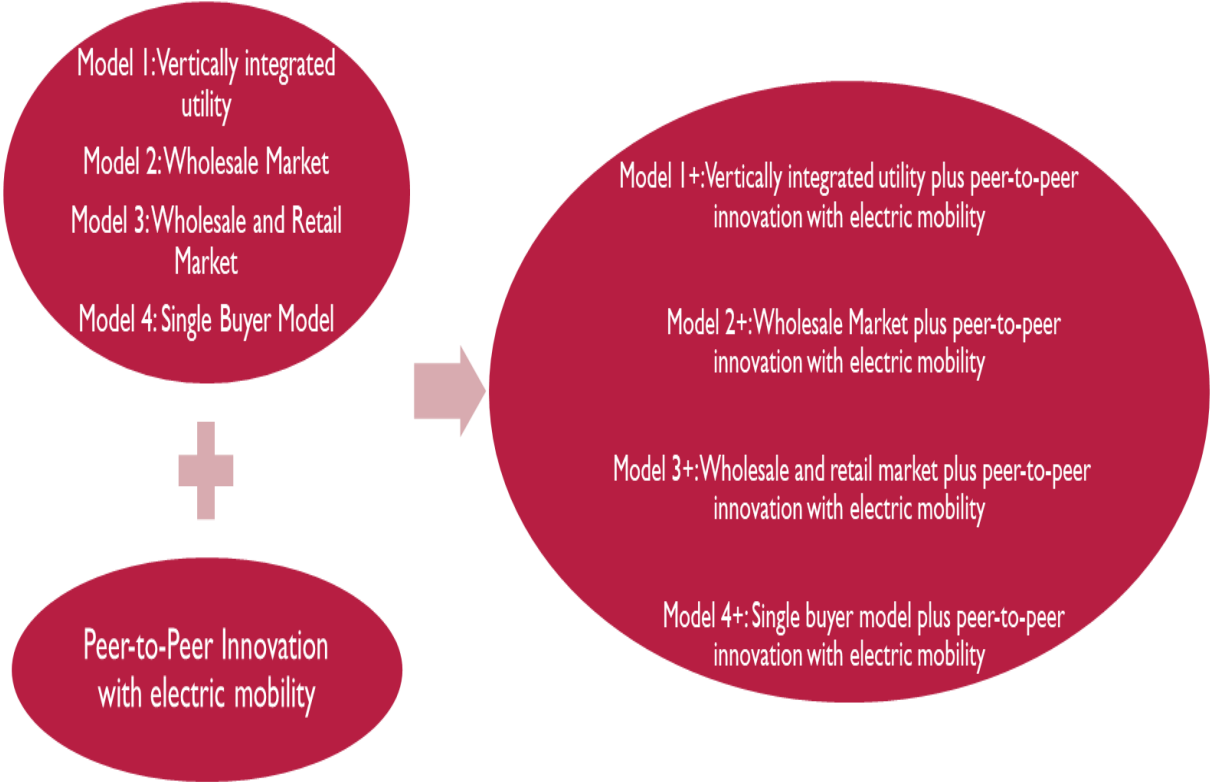


Figure 6: Utilities transformation by the peer-to-peer innovation with electric mobility

Based on the preceding analysis, we present our newly developed framework to explain the transformation of electric utilities due to the megatrends. Many utilities in developing countries are still in the Model 1+ (vertically integrated utility plus peer-to-peer innovation with electric mobility) classification. The framework (see Table 1) explains the transformation of the utilities with electric mobility. The plus sign represents the order of magnitude of the increasing impact of the megatrends on the electric utilities depending on their industrial organisation. This means that the higher the level of electricity market liberalisation plus peer-to-peer innovation with electric mobility, the higher the expected impact of the five megatrends on the electric utilities industrial organisation.



For developing countries, the magnitude of the transformation of the utilities with electric mobility caused by the impact of the megatrends is highest in those with functional wholesale and retail markets (Model 3+). It is followed by the countries with the wholesale market only (Model 2+), then the single-buyer model (Model 4+), while it is lowest in developing countries still operating state-owned vertically integrated utilities (monopoly) coined as (Model 1+). Many countries in Sub-Sahara Africa appear to fall in this Model 1+ classification. For example, vehicle-to-grid, peer-to-peer trading, the burgeoning aggregator business models, and the relationships among aggregators, distribution and transmission utilities, and EV owners are not topical issues of electric utilities in sub-Sahara Africa (SSA). EV ownership rate and charging infrastructure are still very low in SSA, and peer-to-peer energy trading and aggregator issues are not topical. The topical issue seems to be investment in electricity access. Therefore, the developing countries in Model 1+ have the lowest impact of the megatrends.

<b>Electric utilities industrial Organisation model</b>	<b>Digitalisation</b>	<b>Decentralisation</b>	<b>Decarbonisation</b>	<b>Demand disruption</b>	<b>Disintermediation</b>
Full vertical integration + peer-to-peer innovation with electric mobility (Model 1+)	+	+	+	+	+
Single buyer + peer-to-peer innovation with electric mobility (Model 4+)	++	++	++	++	++
Wholesale market + peer-to-peer innovation with electric mobility (Model 2+)	+++	+++	+++	+++	+++
Wholesale and retail market + peer-to-peer innovation with electric mobility (Model 3+)	+++	+++	+++	+++	+++

Table 1: Electric Utilities and the megatrends (framework) for developing countries.

When a developing country moves to the next model, for example, from the vertically integrated utility (Model 1+) to the single buyer (Model 4+), we expect the impact of the megatrends to increase as new players enter the market.

This framework can help gain further insight into the transformation and impact of the megatrends on the utilities with electric mobility in different developing countries. It can be

further enriched with qualitative or quantitative indicators for comparative analysis among developing and developed countries.

To apply the insight from the framework in Table 1, we study the literature on the current industrial organisation of electric utilities in most countries (Vivien et al. 2017). We list (see Table 2) the developing countries in the Model 2+ and Model 3+. These countries have functional wholesale and/or retail electricity markets with well-functioning electric utilities. Notably, most developed countries where electric mobility deployment, investment and integration with electric utilities are gaining traction are also in the Model 2+ and Model 3+ classifications.

List of developing countries in Model 2+ and 3+	
Latin America	Argentina, Brazil, Chile, Guatemala, Peru, Colombia
Eastern Europe	Romania, Russia, Türkiye, Ukraine, Poland
Asia	India, China, Philippines, Kazakhstan
Caribbean	Dominican Republic

Table 2: List of developing countries in Model 2+ and 3+. Source: Authors' elaboration and Vivien et al. (2017)

The framework can be applied for in-depth country case studies and analyses of the electric utilities and electric mobility interactions in the context of the megatrend or for comparative analysis among countries to support decision-making or policy design for developing countries.

The governments of some developing countries, such as (China, India, Chile, and Türkiye) identified in our framework (see Table 2), are already taking the lead with EVs, charging infrastructure investments and attracting private-sector investors. The governments are using tools such as subsidies, policy support programs and regulatory instruments such as vehicle purchase subsidies, registration tax rebates, mandatory targets for EV sales, investment in EV publicly accessible charging infrastructure, and incentives for EV owners to install home charging points to promote EV deployment. For example, China plans to spend US\$1.4 trillion on public digital infrastructure, including EV charging stations. Also, at least ten cities have announced plans to install over a million chargers by 2025. Moreover, more than 8,000 taxis in Taiyuan, China, were electrified in eight months, supported by financial subsidies to cover around two-thirds of the cost of a new vehicle (IEA, 2021).

In India, the government has commenced a 10-year scheme to incentivise setting up 50 GWh of domestic battery manufacturing through tax incentives and direct cash subsidies. The scheme is expected to cost the government about US\$ 920 million over ten years and attract more than US\$ 5 billion in investments from global battery manufacturers. The Faster Adoption and Manufacturing of Hybrid and EV (FAME) programme provide incentives to support

investment in EV charging infrastructure for electric buses with funding of about USD 135 million. Also, the GO Electric scheme was launched in 2021 to promote environmentally friendly, economically viable, and indigenous EVs in India (Digalwar et al., 2022; Goel et al., 2021).

In Türkiye (Izmir), solar PV (with a total power supply of 835 kW) has been installed on the bus depot roof to provide the daily energy needed to power twenty (20) electric buses, with a plan to scale up to four hundred (400) buses by 2024. The EV and charging infrastructure market is also developing rapidly; over seven thousand EVs were sold in 2022 (Statista, 2022a), and over two thousand charging stations have been deployed in Türkiye (Statista, 2022b). Some business models are also developing in Santiago, Chile, where seven hundred and seventy-six (776) electric buses operate. The vehicles were purchased by utility companies and leased to bus operators, separating up-front costs from operational costs (IEA, 2021).

## **5. Conclusion**

In this paper, we discuss the interaction of electric utilities and electric mobility in the context of the megatrends of decarbonisation, digitalisation, decentralisation, demand disruption and disintermediation in developing countries. We also discuss the transformation of electric utilities with electric mobility in the context of the megatrends. We then develop a framework to understand the transformation of the classic industrial organisation models of electric utilities with the impact of electric mobility in the context of the megatrends in developing countries. Our framework provides insight into which developing countries are ripe for EV investments and deployment. Then, we study the state of liberalisation of electric utilities in developing countries. Based on the insight from our research and analysis, we list some developing countries for electric utilities integration with electric mobility to apply our framework for further studies. The countries are - [in Latin America (Argentina, Brazil, Chile, Guatemala, Peru, Colombia); in Eastern Europe (Romania, Russia, Türkiye, Ukraine, Poland); in Asia (India, China, Philippines, Kazakhstan); and the Caribbean (Dominican Republic)].

## **References**

- Abhijeet Digalwar, S. Saraswat, Arpit Rastogi, Rohaan Thomas (2022), A comprehensive framework for analysing and evaluating factors responsible for sustainable growth of electric vehicles in India. *Journal of Cleaner Production* 378 (2022) 134601
- Bijen Mali, Ashish Shrestha, Anish Chapagain, Rajiv Bishwokarma, Pritam Kumar, Francisco Gonzalez-Longatt (2022), Challenges in the penetration of electric vehicles in developing countries with a focus on Nepal. *Renewable Energy Focus*, Volume 40, March 2022
- Cecilia Briceno-Garmendia, Wenxin Qiao, Foster Vivien (2022), *The Economics of Electric Vehicles for Passenger Transportation*. Mobility and Transport Connectivity Series. World Bank. November 2022

Elisa Papadis and George Tsatsaronis (2020), Challenges in the decarbonisation of the energy sector *Energy* 205 (2020) 118025

ENTSOE, (2021), European Network of Transmission System Operators for Electricity (ENTSO-E) Position Paper - Electric Vehicle Integration into Power Grids. March 2021.

ESMAP (2018), Electric Mobility and Development, Energy Sector Management Assistance Program (ESMAP), World Bank, 2018.

Fay Marianne, Hallegatte Stephane, Vogt-Schilb Adrien, Rozenberg Julie, Narloch Ulf, Kerr Tom (2015). *Decarbonizing Development: Three Steps to a Zero-Carbon Future*. Climate Change and Development; Washington, DC: World Bank

Fereidoon Sioshansi and Wolfgang Pfaffenberger (2006); *Electricity Market Reform: An International Perspective*, Elsevier, 2006

Florian Knobbe and Heike Proff (2020). Dynamic capabilities in the automotive industry under digitalisation - a quantitative study in the automotive supplier industry. *International Journal of Automotive Technology and Management (IJATM)*, Vol. 20, No. 4, 2020

Foster Vivien and Anshul Rana (2020), *Rethinking Power Sector Reform in the Developing World*. Sustainable Infrastructure Series. Washington, DC: World Bank

Foster Vivien, Samantha Helen Witte, Sudeshna Ghosh Banerjee, and Alejandro Vega Moreno (2017). "Charting the Diffusion of Power Sector Reforms across the Developing World." Policy Research Working Paper 8235, World Bank, Washington, DC.

Gabriela Elizondo-Azuela, Antonio Barbalho, Luiz Maurer, Susana Moreira, Catiana Garcia-Kilroy, Christophe de Gouvello, Juan Benavidez, David Reinstein, and Jiemei Liu (2017). "Energy Markets in Latin America and the Caribbean: Emerging Disruptions and the Next frontier", World Bank, Washington, DC

Giuseppe Giulio Calabrese and Greta Falavigna (2022). Does Industry 4.0 improve productivity? Evidence from the Italian automotive supply chain. *International Journal of Automotive Technology and Management (IJATM)*, Vol. 22, No. 4, 202 pp. 506-526

Godwin Ayetor, Innocent Mbonigaba, Albert Sunnu, Baafour Nyantekyi-Kwakye (2021), Impact of replacing ICE bus fleet with electric bus fleet in Africa: A lifetime assessment. *Energy* 221 (2021) 119852

Gustavo Gomis, Esteban Forn, Mónica Salas (2018), *Electric mobility development in Latin America and the Caribbean and opportunities for regional collaboration*, United Nations Environment Programme (UN Environment), November 2018

Goracinova, E., Galvin, P. and Wolfe, D.A. (2022) 'Emerging models of networked industrial policy: recent trends in automotive policy in the USA and Germany', *Int. J. Automotive Technology and Management*, Vol. 22, No. 1, pp.29–51.

Guy Fournier, Michael Thalhafer, Philippe Chrétien, Adrian Boos, Dorien Korbee, Ines Jaroudi, Eliane Nemoto, Gabriele Naderer, Dimitri Konstantas, Tobias Viere (2022), *System innovation in transport with automated minibuses and ITS: the citizen-centric approach of AVENUE* Transportation Research Procedia 00 (2022) 000–000

Icaro Silvestre Freitas Gomes, Yannick Perez, Emilia Suomalainen (2020), Coupling small batteries and PV generation: A review. *Renewable and Sustainable Energy Reviews* 126 (2020) 109835

IEA (2017), *Digitalization and Energy*, International Energy Agency (IEA), Paris, 2017

IEA (2020), *Global EV outlook: Entering the decade of electric drive?* International Energy Agency (IEA), Paris, 2020.

IEA (2021), *Global EV Outlook (2021): Accelerating ambitions despite the pandemic.* International Energy Agency (IEA), April 2021

IRENA (2019), *Innovation outlook: Smart charging for electric vehicles*, International Renewable Energy Agency, Abu Dhabi.

Jürg Grütter and Ki-Joon Kim (2019). *E-Mobility options for ADB developing member countries.* ADB sustainable development working paper series. No 60 March 2019

Katherine Collett, Stephanie Hirmer, Holger Dalkmann, Constance Crozier, Yacob Mulugetta, Malcolm D. McCulloch (2021), *Can electric vehicles be good for Sub-Saharan Africa?* *Energy Strategy Reviews* 38 (2021) 100722

Le Tuan, Nguyen Lien, Do Tue (2021). *Study of electric mobility development in Vietnam.* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH 2021.

Jonathan Linton (2018). *Open innovation/integration versus disintermediation/disintegration* *Technovation*, volume 78, December 2018, Pages 1-3

Lucas Müller and Michael Stephan (2020). *To separate or to integrate? The normative effect of national culture on organisational ambidexterity of automotive OEMs in transition towards electric mobility.* *International Journal of Automotive Technology and Management (IJATM)*, Vol. 20, No. 4, 2020

Mark Draeck, Katarina Barunica Spoljaric, Onay Geylan, Alexia Cujus, Armen Danielian, and Nicholas Dehod (2021), *Electric mobility in developing economies: Lessons drawn from UNIDO experience*, United Nations Industrial Development Organisation (UNIDO). 2021

Michael Dioha, June Lukuyu, Edgar Virgüez and Ken Caldeira (2022), *Guiding the deployment of electric vehicles in the developing world.* *Environ. Res. Lett.* 17 (2022) 071001

Nasri Bin Sulaiman, Muhammad Sabir Hussain, Muhammad Jabir (2021), *Optimal Management strategies to solve issues of the grid having Electric Vehicles (EV): A review.* *Journal of Energy Storage* 33 (2021) 102114

Niforos, Marina (2017). *Blockchain in Development, Part I: A New Mechanism of 'Trust'?* *EM Compass*, No. 40; International Finance Corporation, Washington, DC. International Finance Corporation.

OECD (2018), *A Chain Reaction: Disruptive Innovation in the Electricity Sector*, Retrieved from [www.oecd.org/competition/A-chain-reaction-disruptive-innovation-in-the-electricity-sector.htm](http://www.oecd.org/competition/A-chain-reaction-disruptive-innovation-in-the-electricity-sector.htm)

Sally Hunt (2002), *Making competition work in Electricity.* John Wiley & Sons, Inc, New York, 2002.

Sarmad Rajper and Johan Albrecht (2020), Prospects of Electric Vehicles in the Developing Countries: A Literature Review, Sustainability, 2020

Sonali Goel, Renu Sharma, Akshay Kumar Rathore (2021), A review on barrier and challenges of electric vehicle in India and vehicle to grid optimisation. Transportation Engineering 4 (2021) 100057

Statista (2022a), Number of electric vehicles sold in Turkey from 2020 to 2022, by brand. Retrieved from <https://www.statista.com/statistics/1321221/turkey-electric-vehicles-sold-by-brand/>. Assessed 29th March 2023

Statista (2022b), Number of electric vehicle charging stations in Turkey from Q1 2020 to Q4 2022, by type. Retrieved from <https://www.statista.com/statistics/935960/number-of-electric-vehicle-charging-stations-turkey/>. Assessed 29th March 2023

Stefan Sommer, Heike Proff, Harald Proff (2021). Digital transformation in the global automotive industry. International Journal of Automotive Technology and Management (IJATM), Vol. 21, No. 4, 2021

Sustainable Mobility for All (2022). E-mobility in Low-Income Countries in Africa: Finance, Governance, and Equity. Washington DC.

Tenenbaum Bernard, Greacen Chris, Siyambalapitiya Tilak, Knuckles James (2014). From the Bottom Up How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa. Directions in Development--Energy and Mining; Washington, DC: World Bank.

Willet Kempton, Yannick Perez, and Marc Petit (2014), Public Policy Strategies for Electric Vehicles and Vehicle to Grid Power. Revue d'Economie Industrielle. N° 148, pp 263-291