

IMPACT OF ENERGY CULTURES FOR ADOPTION OF ELECTRIC VEHICLES

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Abstract: The preeminent reliance on fossil fuel-powered transportation systems poses critical risks to human prosperity and environmental sustainability. As a result, transitioning to sustainable mobility has gained prominence, with electric vehicles (EVs) emerging as a transformative solution. EVs not only challenge carbon-dependent travel patterns but also exemplify the principles of sustainable transportation. Energy culture is identified as a research domain that provides an understanding of energy behaviors and energy-related changes in transportation systems. This study aims to develop an Energy Cultures framework to promote EV adoption by understanding the intricate dynamics of energy behaviours and transitions within transportation systems.

Grounded in the Energy Cultures framework, this research explores the interrelationships between societal norms, practices, and material culture, and how external influences shape these dimensions.

The need to conduct a study on energy culture arises from the lack of comprehensive research in the field, and it is essential to delve into the subject to understand its profound implications on social behaviour, environmental sustainability and economic development. Hence, this study helps to fill a critical gap in understanding the socio-cultural and behavioral dimensions of EV adoption. By providing actionable insights, contributes to advancing environmental sustainability, fostering behavioral shifts, and supporting the transition toward cleaner, more sustainable transportation systems.

Keywords: *Electric Vehicle (EV); Energy Cultures; Internal Combustion Engine (ICE); sustainable mobility.*

1. Introduction

The release of harmful substances from vehicles constitutes approximately 60% of the overall emissions produced by the automotive industry (Sneha Angeline & Newlin Rajkumar, 2020). However, the Sustainable Mobility development process aims to ensure that transport systems meet society's economic, social and environmental needs whilst minimizing their undesirable impacts on the aspects, economy, society and the environment (Gallo & Marinelli, 2020). EVs have the potential to significantly lower the cost of driving and reduce the environmental impact of the transportation sector, making them a central element in the future of mobility (Elbanhaway, 2019).

In the pursuit of fostering more efficient, sustainable, and cost-effective modes of transportation, the influence of culture can often present challenges and hinder progress. Sovacool & Griffiths (2020), Lutzenhiser (1992) and Stephenson et al., (2010) developed theoretical models which describe the energy culture concept. Stephenson et al., (2010) identified energy cultures as a framework that indicating consumer energy behaviour at its most fundamental level by examining the interactions between cognitive norms (beliefs, understandings), material culture (technologies, building form) and energy practices (activities, processes). The decision-making processes regarding eco-friendly products, like electric cars, may indeed diverge based on cultural inclinations and the specific contextual backgrounds (Kilbourne et al., 2002). According to Barbarossa et al., (2015), need of a proper cultural model examines the specific role of individuals' green self-identity in shaping their ethical motives (both teleological and deontological), attitudes towards EVs, and their intentions to adopt them. Hence, this study will identify the need of energy cultures for EV sector.

Recognizing these complexities, this study focuses to identify the role of energy cultures in the EV sector and achieve the following objectives;

1. Review the concept of sustainable transportation and EVs as a mode of sustainable mobility.
2. Analyze the driving factors within energy cultures that influence EV adoption.
3. Examine the challenges associated with EV adoption.
4. Propose strategies to overcome the challenges within the context of energy cultures.
5. Develop a conceptual Energy Cultures framework to support the adoption of EVs.

By addressing these objectives, this research seeks to bridge the gap in understanding the socio-cultural dimensions of EV adoption and contribute to the development of a sustainable, low-carbon transportation future.

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2. Methodology

The comprehensive literature review explored the concept of sustainable mobility, EVs and its' driving factors, challenges and strategies in context of global perspective. An extensive literature review is vital to conduct for a better understanding of the research outcomes, methods, theories, and practices or applications in relation subjected research area. To conduct the literature review, books, journals, conference proceedings, dissertations, reports, magazines, websites and government publications were used as sources. Developing a framework under EV related to energy culture perspective is not yet discussed under transport culture. It played a crucial role in pinpointing important aspects of the current transportation culture (Stephenson, Hopkins, et al., 2015). The literature search utilized a comprehensive approach to ensure the inclusion of high-quality and relevant sources involved identifying relevant keywords, such as "sustainable mobility," "electric vehicles," "energy cultures," etc. and terms were used in various combinations across databases like Google Scholar.

3. Sustainable Mobility

3.1 ELECTRIC VEHICLES

As a substitute for Internal Combustion Engine (ICE) vehicles which combust fuel to drive the engine, EVs have been selected as new technological and eco-friendly transportation mode (Banister, 2008). The EV was invented in 1834 and during the last decade of the 19th century, a number of companies produced EVs in America, Britain, and France (Chan, 2007). Development of EVs has taken on distinctive features across different historical eras, with variations in driving forces, technical attributes, applications, charging infrastructure, and business models (Chan, 2013). Chan (2007) described that EVs can be partially or fully electric and identified four types of EVs; Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs). . HEVs use a gasoline engine and regenerative braking to charge the battery, (Hannan et al., 2014) while PHEVs have a larger battery and can be recharged by plugging into an external power source (Curtin et al., 2009). BEVs run entirely on electricity stored in a rechargeable battery pack and produce zero emissions, while FCEVs use hydrogen to produce electricity through a fuel cell (Muthukumar et al., 2021).

3.2 EV AS A SUSTAINABLE MODE OF MOBILITY

Sustainable mobility refers to the movement of people and goods in a way that minimizes negative impacts on the environment, society, and the economy (United Nations, 2021). In India, Goswamy et al. (2023) stated that sustainability is the number one priority in car-buying and mobility-usage habits, and 75% of Indians are starting to change their behaviour and consumption patterns based on sustainability considerations. EVs are being seen as a promising and eco-friendly mode of transportation to mitigate carbon-dependent travel patterns (Cocone, 2023). According to Xiong et al (2016), EVs have been selected as a new technological and eco-friendly transportation mode, replacing Internal Combustion Engine (ICE) vehicles that combust fuel to drive the engine. EVs offer substantial economic and environmental advantages throughout their entire lifespan, surpassing the benefits of ICE vehicles (Thilakshan et al., 2019). Kumar & Alok (2020) demonstrates the sustainability impact of EV adoption in three consequence variables: Economic (revenue generation, profit, net present value analysis), Environmental (encompassing GHG emissions, carbon emissions) and social aspects (maximize employment opportunities, providing assessment of the impact of EV development).

3.3 PROMOTION OF EVS

Well-functioning transportation networks create a range of socioeconomic prospects, providing positive impacts on trade, employment, overall well-being, and health (Maat, 2001). As reported by the Global Environment Facility (2020), approximately 70% of the imported oil consumption in Sri Lanka is attributed to the transport sector, making it the predominant source of energy consumption in the country. However, Sri Lanka seem inclined to support modern eco-friendly transportation options, as evident from their adherence to the Clean Air 2025 action plan and the commitments outlined in the Paris Agreement's Nationally Determined Contributions (Kumarage & Silva, 2022).

Sri Lanka also had created a big wave in moving towards EVs (Abeywickrama, 2017). Further to the author, registered electric motor cars in Sri Lanka have increased from 90 to 3,238 from year 2014 to 2015 showing a 97% of growth. .. According to IEA (2021), electric cars come in three main types: HEVs, PHEVs, and BEVs in Sri Lanka and it is important to implement strategic approach to fostering the expansion of the EV market. In world wide Electric car sales neared 14 million in 2023, 95% of which were in China, Europe and the United States.

4. Energy Cultures

Energy Cultures was an interdisciplinary approach that focused on enhancing comprehension of household energy behaviour (Suarez Marcillo, 2012). Stephenson et al. (2010) aimed to identify ways to encourage the adoption of energy-efficient practices and technologies, leveraging expertise from diverse fields such as human, mobility, geography, physics, economics, marketing, and law. Understanding the impact of cultural formations on sustainability outcomes is an opportunity to investigate its correlation with cultural theory (Stephenson, 2018). This framework illustrates that energy dynamics primarily result from the interplay of three elements: norms (individual and collective expectations of 'normal

behaviour'), material culture (physical attributes of people, their structure and energy technologies), and energy practices (actions related to energy) (LaBelle, 2020) as illustrates in **Error! Reference source not found.**

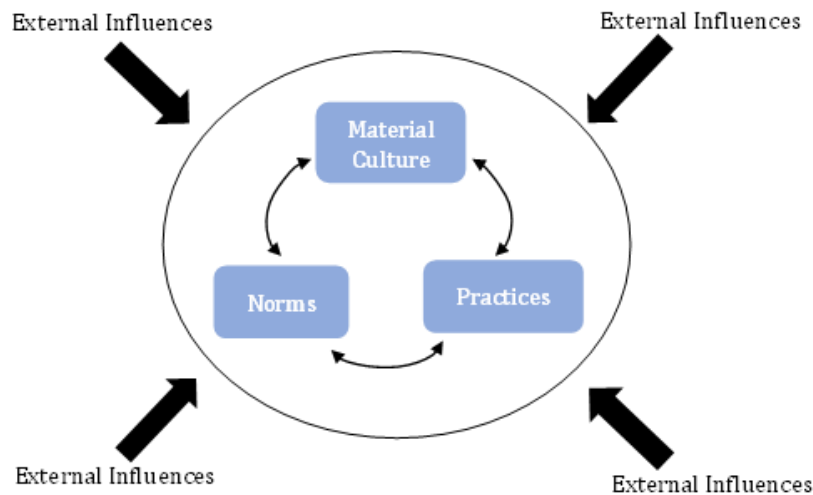


Figure 1 The core concept of energy culture framework (Source: Stephenson et al., 2015)

Norms are like common beliefs about how people should act in a certain situation (Stephenson et al., 2015). Gelfand & Jackson (2016) argue that norms serve as tools for adaptation and can help cultures evolve in changing conditions. Material culture, borrowed from anthropology, encompasses the tangible aspects of a culture, such as objects, buildings, and infrastructure (Woodward, 2007). The initial presentation of the energy cultures framework identified 'energy practices' as the third essential component of energy culture. It emphasized the idea that many activities involving energy are not primarily intended for energy use (Stephenson et al., 2015). External factors shape the backdrop in which an energy culture develops and persists c.

5. Driving Factors influencing EVs Adoption

The changes in how people interact within society due to EV usage vary greatly between those who drive these cars and those who buy them (Hui, 2019). As discussed by Liao et al (2017), driving factors are which drive the growing trend of EVs in the transportation sector.

As stated by Ehsani et al (2007) less maintenance cost is one driving factor provide smoother trips even on rough roads and it supports to less maintenance and less upkeep and ultimately contribute to less fee. According to the United States, US \$ 2.5 billion savings in fuel import by a converting conventional vehicle to EV which leading to economic saving (Levinson & West, 2018). Simões & Vieira (2002) revealed EVs as an energy efficient vehicle technology with high torque. Zero emissions in operation and low noise emissions have identified as environment friendliness, one of major enabler which drives EVs as future travel need (Wu et al., 2015). Armenta-Déu & Cattin (2021) identified EVs as a solution for fuel consumption when compared with ICE vehicles. Moreover, Liao et al (2019) stated that convenience for EVs owners since it provide access to home charging when compared with conventional vehicles enabler EVs as more convenient vehicle choice.

6. Different challenges face in adoption of EVs

Urry, (2012) highlighted that changing the transportation system is tough because it requires more than just technology switch it involves changing people's behaviours, habits, practices, systems, and landscapes. Using EVs as a transportation choice has encountered various challenges that have affected their widespread adoption (Steinhilber et al., 2013).

6.1 NORMS

According to Ryghaug & Toftaker (2014) EV consumers have lack of confidence on riding EV because they believe vehicle should be more pleasurable than previous used vehicle. Consequently, consumers are less confidence to use EV as a mode of transportation (Egbue & Long, 2012). As another norm Graham-Rowe et al. (2012) revealed because of limitations in driving range, EVs were commonly perceived as fitting for use primarily as a second car, suitable for short and local trips. Limited battery capacity of EVs cause frequent charging and it is act as a one of the main barriers which influence to the user dissatisfied (Steinhilber et al., 2013). As a barrier for EVs, Torchio & Santarelli (2010) stated that consumers might think that life cycle environment effect of EVs is in a negative level, but according to the authors it is depending on the fuel mix of electricity generation. Aziz et al., (2016) have identified generally 6-8 hours take to fully charge the EV when using home charging as barrier for refuse EVs. However, since electricity prices fluctuate throughout the day in many countries, and it

affect to economic cost (Sanguesa et al., 2021). Additionally, Sun et al. (2019) pointed out that the substantial upfront cost hinders consumer acceptance of EVs, serving as another primary barrier to their widespread adoption.

6.2 MATERIAL CULTURE

Moreland City Council (2014) has identified limited vehicle choice as a negative impact on EVs. EV buyers are seeking for infrastructure availability and quality of the vehicle making their decisions with comparing other vehicles (Hopkins & Stephenson, 2014). Rathnayake et al., (2019) mentioned that lack of charging stations, which makes it difficult for EV buyers to be satisfied with the current number of charging stations. Capacity, performance storage of batteries are main aspects when selecting an EV (Walton et al., 2017). Negarestani et al. (2012) indicates that the most dependable performance in combined EV can be attained through the utilization of improved batteries.

6.3 PRACTICES

As described by Jorge & Correia (2013) shared vehicle systems like car-sharing enable individuals to lease a vehicle from numerous rental stations, utilize the vehicle for a specific duration, and subsequently return it. Users are discourage to use EV as sharing option due to its characteristics (Kim et al.,2015). Another practice is efficient and cost-effective public transportation system can encourage people to replace cars with buses, trains, and trams and it lower the amount of car usage (Holden et al., 2020). Low level of car ownership also affect as a barrier as per the study in Seoul. It highlighted that regarding owning EV cars, 68.1% of those surveyed own a car, similar to the 32% car ownership rate among individuals aged 20 (Kim et al., 2015).

6.4 EXTERNAL FACTORS

Unawareness about government subsidies for EVs identified as another barrier for EVs popularity (Miller J, 2016). Further, author stated that if people are well aware about the government's support system on EVs, purchasing rate of EVs in the market will be increased. Fluctuations in energy prices directly impact the cost of charging an EV, which significantly influencing the economic considerations for potential EV owners (Camus & Farias, 2011). The removal of financial incentives can create a barrier for EV adoption by affecting the total cost of ownership, which is a key consideration for consumers when evaluating the economic feasibility of purchasing an EV (Sierzchula et al., 2014). Investing more in bike lanes and pedestrian infrastructure could help encourage more people to choose walking or biking instead of using EV as private cars (Hopkins & Stephenson, 2016).

7. Strategies to overcome challenges

7.1 AWARENESS PROGRAMS

Implementing educational initiatives to increase public understanding of EV technology, benefits, and the environmental impact (Jin & Slowik, 2017). Further author stated that this can involve workshops, seminars, and campaigns to inform individuals about the advantages of using EVs. Enhance consumer awareness to words EVs promote the development of EV industry (Zhang et al., 2011).

7.2 TAX EXEMPTIONS/ SUBSIDIES FOR EVS

Encouraging the use of EVs is probably going to depend on financial policies, like tax benefits (Davis & Sallee, 2020). The extent of incentives for EVs can vary based on how vehicle taxes and subsidies are structured (S. Yan, 2018). Same author stated across several countries tax incentives are the main reason for EVs are cheaper than the ICEs. In US EVs including benefits such as discounts on vehicle purchases, subsidies for home chargers, reductions in vehicle license taxes or registration fees, and the annual fees associated with owning an EV. The focus was on quantifying the monetary value of these policy instruments (Wee et al., 2019).

7.3 GOVERNMENT POLICIES

As an example Norway's quick increase in electric car adoption is probably due to attractive financial and regulatory perks and these include free access to public parking, toll roads, ferries, and charging stations (Ryghaug & Toftaker, 2014). Same author mentioned reduced taxes and the ability to use bus lanes further contribute to the popularity of electric cars in the country.]

7.4 EMERGING TECHNOLOGIES FOR DEVELOPMENT OF EV

As stated by Sun et al. (2019) with the use of modern technologies in transportation and instant communication, like vehicles talking to each other (V2V), connecting with infrastructure (V2I), communicating with pedestrians (V2P), and interacting with the power grid (V2G), can improve safety and make traffic flow more smoothly.

7.5 INFRASTRUCTURE DEVELOPMENT

Investing in the development of a robust charging infrastructure is crucial for the widespread adoption of EVs (Z. Yan et al., 2020). Yang et al. (2015) stated it includes the installation of charging stations in urban areas, along highways, and at workplaces to enhance the convenience of EV use. It's crucial to pick the best spots for charging stations and ensure a balanced distribution of power from the surrounding electric sources (Cheon & Kang, 2017). Many drivers felt sure that EVs

would see more improvements in technology and infrastructure, along with notable price drops. As a result, most were hesitant to buy EVs until these advancements were achieved (Graham-Rowe et al., 2012).

7.6 BATTERY MANAGEMENT CONTROL SYSTEM

Battery management and control systems play a crucial role in overseeing the battery cells it stop the charging process when the cells reach their ideal voltage and ensure a balanced performance for all cells (Walton et al., 2017). These systems prevent overheating and related problems, offer real-time monitoring, and significantly enhance safety (Hu, 2011).

7.7 SETTING UP A RECYCLING ECOSYSTEM FOR BATTERIES

The disposal of lithium-ion batteries is a major issue. Also, the recycling of lithium-ion batteries is hazardous to health (Patyal et al., 2021). As mentioned by Ali et al. (2019) proper recycling techniques not only reduce waste but also contribute to the circular economy, enhancing long-term viability of EV technology. Various innovation methods are developed like pyro metallurgy, hydrometallurgy and direct recycling, aiming to recover materials like cobalt, nickel, and lithium efficiently (Islam & Iyer-Raniga, 2022).

7.8 INCENTIVES FOR MANUFACTURERS

Provide incentives for automakers to produce EVs, including research and development grants encourage the development of diverse range of EV models (Liu et al., 2021). Shao et al. (2019) mentioned in study that suggest a policy or subsidy for EVs that encourages manufacturers to make choices that align with the best interests of society in promoting the adoption of EVs.

7.9 ENCOURAGING COMMERCIAL FLEETS TO ADOPT EVS

Target commercial fleets, such as taxi services and delivery companies, to adopt electric vehicles, promoting a broader shift in vehicle practices (Ramesan et al., 2022). Apart from that Goswamy et al. (2023) highlighted Leasing companies actively discourage funding EVs. It is mandatory to enforce regulations to ensure that EV s do get priority with a higher Loan Value ratio.

7.10 INTRODUCE OF ENERGY SOURCES

Using renewable sources popular approach for charging EVs for green and efficient energy use around the world (Kempton & Tomić, 2005). As stated by Colmenar-Santos et al. (2019) utilization of renewable energy resources in generating electricity has the potential to markedly decrease the emission of gases such as CO₂, SO₂ and NO_x, thereby safeguarding the environment against additional degradation.

7.11 COMMUNITY ENGAGEMENT PROGRAMS

According to Patyal et al. (2021) engage communities in discussions about sustainable transportation and involve them in decision-making processes related to the development of EV infrastructure. To make the awareness about the environment, health, and the use of environmentally-friendly vehicles such as EVs, an intensive public outreach program is required (Shashank et al., 2020).

8. Conceptual Framework

Conceptual framework developed based on the data gathered from existing research on the topic. Figure 2 indicates the developed framework adapted from Stephenson's energy culture framework relating EVs in the global context.

9. Conclusion

Sustainable Mobility is a process that aims to step up and broaden access to secure, dependable, and comfortable transportation for everyone, all while striving for zero traffic accidents, minimal environmental impact, affordability, and reduced energy and time demands. Negative impacts on current transportation were recognized, and sustainable transportation was identified as the best way to fulfil travel needs while eliminating the negative impacts of the current transportation system. Through this review, EVs were recognized as a promising mode of transportation to support sustainability in daily travel needs. Cultural norms, values, and perceptions regarding energy use and environmental sustainability play a pivotal role in influencing the acceptance and uptake of EVs. Understanding these energy cultures is essential for developing targeted strategies to promote EV adoption and mitigate barriers. The findings of this research emphasize the need for a holistic approach to promoting EV adoption.

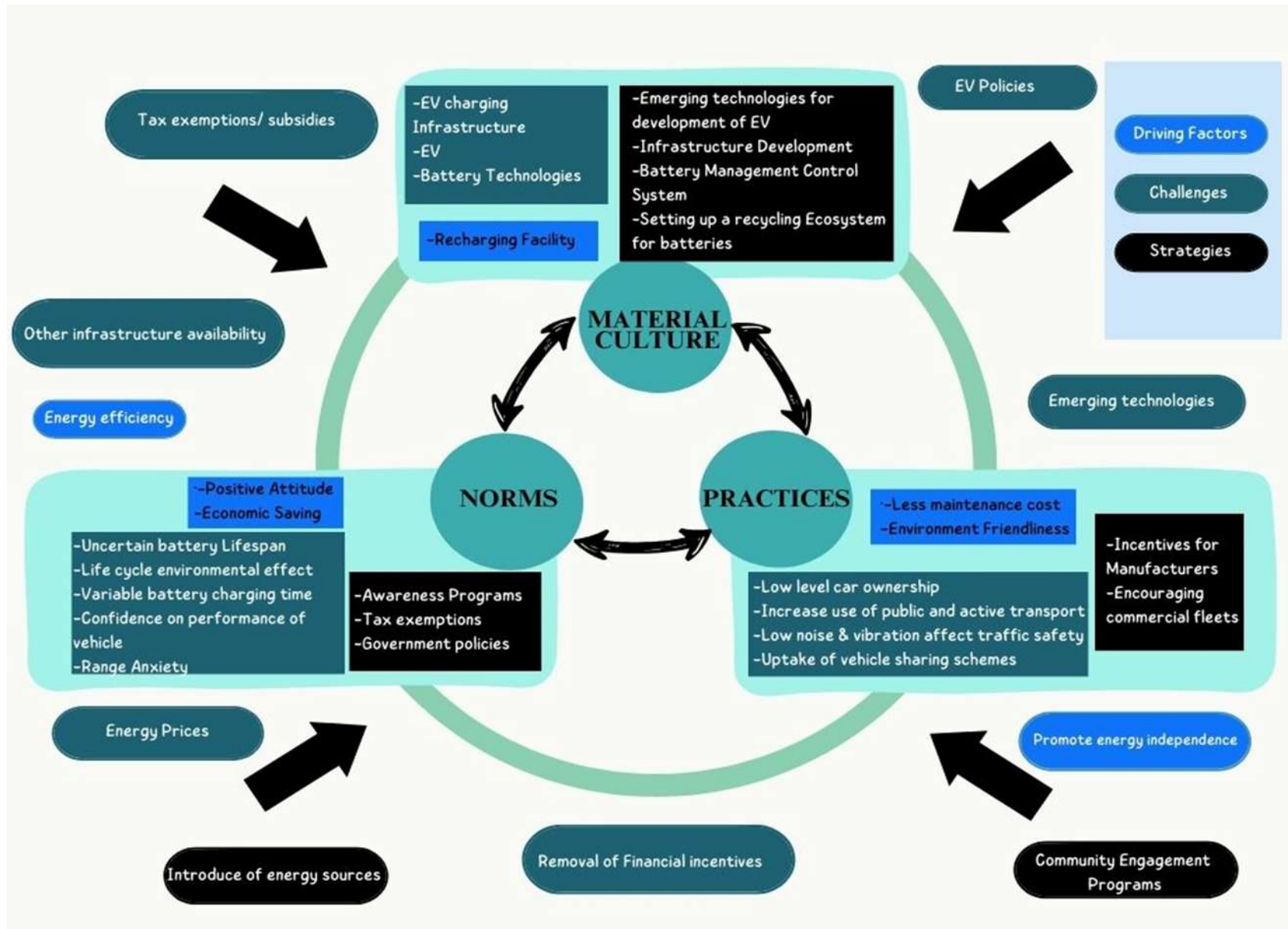


Figure 2 Developed framework for adoption of EVs in enery cultures

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