Challenges and Opportunities Regarding Circular Strategies for Electric Vehicle Components in Thailand

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Abstract

Aim: The purpose of this research is to explore the challenges and opportunities regarding circular strategies in the automotive industry for electric vehicle (EV) components in Thailand. It focuses on the life cycle management of EV battery packs, such as repair, reuse, refurbishment, remanufacturing, and recycling. Furthermore, it aims to explore future challenges and opportunities for such strategies in the market in Thailand and to evaluate them from an economic, ecological, and technical perspective.

Research methods: Primary data from online surveys, observations, and market exhibition visits are generated. Additionally, secondary data from literature reviews, web searches, and market forecast data are explored. Using the foresight method, this input is summarized, evaluated, and the basis for an outlook of future challenges and opportunities.

Results: This research provides information on the local attitude towards circular strategies in the market and culture in Thailand. It maps the existing circular strategies in the EV market and provides a forecast of the potential future challenges and opportunities for such strategies in this market in Thailand.

Conclusion: The strong automotive infrastructure in Thailand and incentives from the Thai administration to increase to share of sold and locally produced EVs are providing market opportunities for circular strategies for battery packs in Thailand. At the same time, missing national Thai standards and regulations as well as a lack of remanufacturing awareness within Thai society are challenges for this business concept.

Keywords: 1) Circular Economy 2) End-of-Life (EoL) 3) Closed-Loop-Supply-Chain (CLSC) 4) Remanufacturing 5) Electric Vehicle (EV)

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Introduction

For more than two decades the global automotive industry has been facing major changes. The classical form of propulsion using combustion engines is increasingly replaced by electric solutions. In 2021 for the first time 6.6 million electric vehicles have been sold. Double the volume of the previous year (Deloitte, 2022, pp. 9-16; Mopidevi, et al., 2022, pp. 264-284; Schiffers, 2022, pp. 1-2).

An important driver of electrification in the automotive industry is the increasing awareness of sustainability. This rise in awareness is of high importance for the automotive industry, as this industry branch is on the one hand responsible for many environmental issues but on the other hand, is a driver of innovation in technology, efficiency, and management concepts (Cioca, et al., 2019, pp. 10-13; Orsato and Wells, 2007, pp. 989-993).

One approach to gain more sustainable production concepts is to transform business and production strategies from a classical supply chain to a closed-loop supply chain (CLSC) concept. A CLSC can be achieved by adding reverse logistics and returning used parts to a previous chain link of the supply chain. Examples of such activities are reuse, remanufacturing (the industrial process to bring a product 'as good as new' back into the market, ref. to Singhal, Tripathy and Jena (2020, pp. 1-3), or recycling ("substitution of primary resources by secondary resource" by utilizing used parts and materials (Ragossnig and Schneider, 2019, pp. 109-111).

Such remanufacturing concepts have been performed in the automotive industry in Europe and North America for many years. In developing countries, they are nowadays of increasing importance. Remanufacturing concepts provide environmental, financial, and social benefits when compared to the production of new parts (Chakraborty, Mondal and Mukherjee, 2019, pp. 1117-1135; Singhal, Tripathy and Jena, 2020, pp. 1117-1118).

These benefits from the remanufacturing of automotive parts, the increasing awareness of sustainable manufacturing concepts, the global transformation of the automotive industry towards EVs, and the strong incentives of the Thai administration to reach the aim of being the Southeast Asian hub of EV production, lead to the research question of this exploration: What are the challenges and opportunities regarding circular strategies in the automotive industry for EV components in Thailand?

Literature Review

The following section describes the latest trends within the automotive industry and its transition from combustion engines to electric propulsion. It summarizes the latest technological and market developments and gives insights into governmental programs and incentives in Thailand. Finally, sustainable production concepts in the automotive industry, focusing on the Thai market, are discussed.

A. A predominant and increasing trend in electrification in the global automotive industry

The strive for the usage of cleaner energies, to decrease CO_2 emissions and reduce pollution resulting from vehicles is leading to major changes within the automotive industry for several years. Especially the transition from

using combustion engines for propulsion to electric motors is a megatrend that dominates all stakeholders of this complex industry (Mopidevi, et al., 2022, pp. 264-284; Schiffers, 2022, pp. 1-2). The market is more and more demanding for EVs and the share of customers planning to buy a classical car with combustion engines has for the first time globally decreased to less than 50% (Deloitte, 2022, p. 9). The sales of EVs in 2021 have doubled in comparison to the previous year. In the year 2012, just ten years ago, worldwide 120,000 EVs were sold. In 2021 the sales reached a volume of 6.6 million EVs worldwide. The strongest increase in sales was in China followed by the United States and Europe (International Energy Agency, 2022, pp. 1-3).

As of data from mid-2022, in Thailand in the year 2022, a total of 64,000 EVs have been sold. An increase of 48% compared to the previous year. With a volume of 42,000 units, the vast majority of these EVs were hybrid EVs (Manakitsomboon, 2022a, p. 1). Schröder (2021, pp. 33-60) sees the position of Thailand in this process of transition under risk. The global competition in know-how and skilled staff are today led by other industrial countries, such as for example China.

B. Current Thai electrification strategies and governmental incentives

Thailand is the country with the highest production output of vehicles in the Southeast Asian region. In the peak year 2013, locally 2.5 million units have been assembled. After the decrease during the COVID-19 pandemic, it has been 1.7 million units. A strong dominance lies in companies of Japanese origin, but lately, competition from other countries is growing stronger. A low-cost manufacturing structure and a strong domestic market seem attractive to many international companies (Uchida, 2022, p. 1).

The Thai administration has issued several incentives for companies manufacturing EVs and EV parts (Theparat and Apisitniran, 2022, p. 1). The aim of these incentives is to increase the transformation of its today's automotive production and to manufacture up to 50% EVs or 725,000 units by the year 2030, be carbon-neutral by the year 2050, and consist of net zero emissions by 2065. All of Thailand's resources, such as information technology and logistics, shall be used and updated to support foreign investments. A regional focus of such investments shall be in the Eastern Economic Corridor (EEC) two hours south of the capital Bangkok. This economic zone shall cluster all such efforts and be a "hub for advanced industries" (Nationthailand, 2022, p. 1; Thaichareon, 2022, p. 1; Wipatayotin, 2022, p. 1).

It has clearly been announced that Thailand shall take the lead in the production of emission-friendly cars in Southeast Asia. The Thai government agency responsible for foreign investments, the 'Thailand Board of Investment' (BOI), highlights its objective to turn Thailand into a major production hub for electric vehicles of all kinds (Thailand Board of Investment, 2022a, pp. 1-4; Thailand Board of Investment, 2022b, pp. 1-4). The Thai prime minister Prayut Chan-o-cha emphasizes this aim and even reached for global dominance. To accomplish this aim he defines Japan as a major strategic partner (Wipatayotin, 2022, p. 1). Before car companies had raised concerns that Chinese car manufacturers would benefit

more due to the free trade agreement previously signed between China and Thailand. As an answer to these concerns, a government spokesman announced that the incentives and all government programs will be created to serve and support all international OEMs (Theparat and Apisitniran, 2022, p. 1).

The incentive package issued by the Thai administration is consisting of a budget of 3 billion THB (~90 million USD) in 2022 and another 40 billion THB (~1.2 billion USD) between 2023 and 2025. It shall especially promote the sales and the production of EVs and improve the barriers for EVs in Thailand, such as an insufficient infrastructure for EVs with a low quantity of charging stations which are mainly available in the capital, and high EV sale prices (ASEAN Briefing, 2022, pp. 1-5; Bangkok Post, 2022a, p. 1; Phakdeetham, 2022, p. 1; Reuters, 2022, p. 1).

• Reduced import taxes on imported EVs in 2022 and 2023 (40% tax for vehicles with a price of up to 2 million THB; 20% for vehicles with a price between 2 and 7 million THB)

• Decrease excise taxes on imported EVs from 8% to 2%

• Subsidies between 70 and 150 thousand THB per EV for car manufacturers

• Incentives for foreign experts to choose being an ‘expat’ (expatriate / 'high potential foreigner’) in Thailand

The incentives announced by the Thai administration beginning of 2022 did not immediately show an effect on the registration numbers for EVs in the first months of the year. Nevertheless, the Automotive Trade Fare in Bangkok ‘Bangkok International Motor Show 2022’ in March and April 2022 reported a significant increase in bookings of ‘green cars’ resulting from the tax incentives, decreased sales prices for EVs, and globally risen prices for diesel and petrol. Forecasts see a growth in the sales of EVs in Thailand at 15 to 20% in 2022. The awaited growth rates are recognized by all major international manufacturers, which see future potential in the Thai market as a sales and production market for EVs (Apisitniran, 2022, p. 1; Bangkok Post, 2022a, p. 1; Bangkok Post, 2022b, p. 1; Manakitsomboon, 2022b, p. 1; Phoonphongphiphat, 2022, p. 1; Setboonsarng, 2022, p. 1; Zhu, 2022, p. 1).

C. Sustainability and closed-loop supply chain concepts in the global automotive industry

Internationally operating manufacturing companies are globally seen as one of the sectors generating the most CO_2 emissions. Lately, all kinds of stakeholders increased their focus on such companies and how they act in respect of environmental and social aspects (Cioca, et al., 2019, pp. 10-13). The automotive industry has due to its size, broad organization, and diversity a global influence on all kinds of aspects. It is often seen as a trendsetter for management systems and production procedures. Their products are providing work, prosperity, and mobility to a large scale of people worldwide. At the same time, this industry also is partly responsible for environmental pollution, a decrease in air quality, and global warming. This circumstance and the complexity of the complete industry, need to be taken into account when evaluating its sustainability (Orsato and Wells, 2007, pp. 989-993).

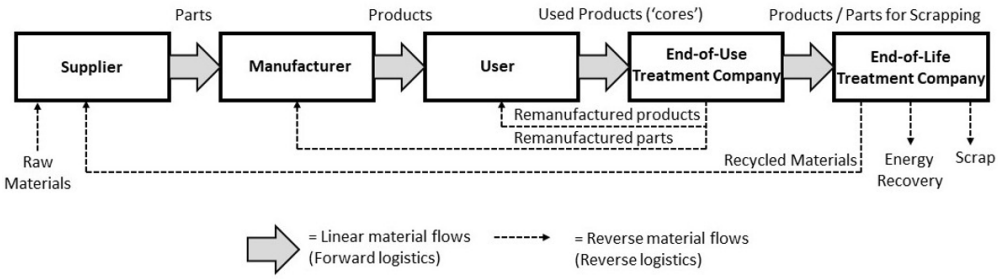

Figure 1 Visualizing Material Flows in Closed-Loop Supply Chain Concepts

(Source: Own Figure Based on Sakao and Sundin, 2019, pp. 1-13)

In their research Ghadimi, et al. (2012, pp. 10-21) stress different dimensions of sustainability for the manufacturing of goods: Environmental aspects, economic aspects, and social aspects. They illustrate that simple improvements in product sustsainability were leading to sustainable manufacturing. At the same time, they stress the fact, that improving certain dimensions of sustainability do not always lead to an improvement of all three dimensions of sustainability. Szász, Csíki and Rácz (2021, pp. 1-14) analyzed the management of sustainability within international automotive OEMs. One finding is, that pressure coming from external stakeholders on the OEM has a benefit on the process of implementation of sustainability. Moreover, sustainability was improving the operational performance and otherwise had no impact on financial performance.

The actual transition toward electrification is seen as one major approach of the automotive industry to increase sustainability (Günther, Kannegiesser and Autenrieb, 2015, pp. 220-233).

Another approach to raise the sustainability of businesses is shifting from a classical supply chain, starting from the raw material extraction and ending at the end customer, to a closed-loop supply chain (CLSC). Berlin, Feldmann and Nuur (2022, pp. 1-10) are stating that CLSCs are targeting "to return (...) products to the original equipment manufacturer (OEM) and reprocessing to sell these products as perfect substitutes in the original markets" Zhou, et al. (2012, pp. 482-487) highlight the role of logistics in remanufacturing businesses which "includes reverse logistics and forward logistics, and the former transports the discarded or old products from the place of consumption to production manufacturer, whereas the latter runs in an opposite way."

CLSC or so-called circular economies can be reached by "enduring design, reuse, repair, refurbishing, recycling, and remanufacturing." (Singhal, Tripathy and Jena, 2020, pp. 1117-1118) CLSC are consisting of a reverse logistic process, which returns the used products to the user (then called 'remanufactured products'), to the manufacturer (then called 'remanufactured parts'), or to the (raw material) supplier (then called 'recycling') as illustrated in Figure 1. CLSC can reduce the consumption of resources and the carbon footprint (Ferguson and Souza, 2010, pp. 1-257; Sakao and Sundin, 2019, pp. 1-13; Tavana, et al., 2022, pp. 1-15).

Singhal, Tripathy and Jena (2020, pp. 1117-1118) stated that of all CLSC concepts, remanufacturing is the only one of these concepts providing "the latest feature and warranty to the products." The main process steps of remanufacturing are the "disassembly, sorting and cleaning, scanning, refurbishment or substitution, reassembly, and testing" of the part prior to being brought back to the market. It is offering benefits from environmental, economic, and social perspectives (Singhal, Tripathy and Jena, 2020, pp. 1117-1118). Kerin and Pham (2020, pp. 1205-1235) emphasize the opportunities resulting from new models of ownership and the increasing product-service-systems for remanufacturing business and add that this development is "supported by changes in society, user expectations and workforce attributes".

In an exploration of automotive remanufacturing, Chakraborty, Mondal and Mukherjee (2019, pp. 1117-1135) define it as "a process in which the original functionality of End-of-Use (EoU) or End-of-Life (EoL) product is restored and the remanufactured product is treated as good as a new product" and are listing typical remanufactured automotive products, such as combustion engines (and single components of them), starters and injectors. Orsato and Wells (2007, pp. 989-993) describe EoL as the "treatment of products after they have reached the end of their useful functioning period."

With the increasing electrification in the automotive industry, lately, parts for EVs became into the focus of remanufacturing. Especially remanufacturing of Lithium-ion battery packs is a process, that "can mitigate the raw material problem for the EV industry, decline import dependency, counteract price volatility, reduce the carbon footprint, and ensure sustainable e-mobility" (Deveci, Simic and Torkayesh, 2021, pp. 1-20).

D. Remanufacturing and End-of-Life Strategies in the Thai automotive industry

Singhal, Tripathy and Jena (2020, pp. 1117-1118) stressed the circumstance that remanufacturing is already today performed successfully in Europe and Northern America whereas developing countries are still in the phase of implementation of such business concepts. Chaowanapong, Jongwanich and Ijomah (2018, pp. 369-378) explored the determinants for remanufacturing in the Thai industry. They summarized the key factors which influence companies to perform remanufacturing:

• Business feasibility (such as technical and financial aspects, working skills)

• Policy (such as regulations, intellectual property protection, environmental laws, and regulations)

• Company strategy (such as corporate image, and brand protection)

• At the same time, they highlight the challenges remanufactured products are facing in Thailand:

• Lack of strategies, laws, and regulations for End-of-Life vehicles (ELVs)

• Missing or insufficient promotion or support from the Thai governmental side to set standards and testing requirements

This influences and increases the negative perspective of Thai customers on remanufactured products confirm the importance of

regulations and standards, as they will have a positive effect on the market for remanufactured goods, customer perception, production, and the availability of product information (Chaowanapong, Jongwanich and Ijomah, 2018, pp. 369-378).

Thailand and comparable developing countries were seeing policies on environmental issues in the past rather as an additional cost factor. New market opportunities were hardly seen. Major reforms of the Thai waste disposal policy would lead to increased costs for disposal and could potentially bring a new perspective on economic opportunities in this sector (Ramstetter, 2012, pp. 87-108).

In a research work by Matsumoto, Chinen and Endo (2018, pp. 1029-1041) the customer perception in Southeast Asian countries including Thailand towards remanufactured automotive parts was explored. They found out that the knowledge about the product and the perceived benefits from remanufactured parts are strongly influencing the purchase decisions. At the same time, consumer-perceived risks linked to remanufactured parts had a lower influence. They moreover stress the need for certifications for remanufactured automotive parts. Pisitsankkhakarn and Vassanadumrongdee (2020, pp. 1-11) researched the purchase intention of car owners in Thailand and the key influences to purchase remanufactured parts. They found out that the purchaser's subjective opinion is the main driver in this decision-making process.

Chinen, et al. (2022, pp. 536-547) explored the relevance of the functionality when buying remanufactured parts in Asian countries including Thailand. They found out that the customers' purchase decision for remanufactured products can be positively influenced by providing additional information about the product, especially about the benefits from an ecological perspective and the identical functionality compared to a new part.

Foresight Methodology

Foresight is the "capacity to think systematically about the future" and needs to be performed in general by individuals, organizations, and society (Conway, 2014, p. 2). Rohrbeck, Battistella and Huizingh (2015, pp. 1-30) explored corporate foresight and defined it as "a practice that permits an organization to lay the foundation for a future competitive advantage".

To perform foresight systematically, Saritas (2013, pp. 83–117) describes the need and the phases for systematic thought experiments in which systems, such for example industries, are explored, modeled, and modified in order to accomplish desired results and changes. In their research, Cook, et al. (2014, pp. 531-541) propose six foresight steps and methods as summarized in Table 1.

Table 1 Foresight Steps and Methods (Own Table Adapted From Cook, et al., 2014, pp. 531-541)

	Aim	Action
Step 1	Setting scope	Framing
Step 2	Collecting inputs	Gather information
Step 3	Analyzing signal	Spotting trends & forecasting
Step 4	Interpretation	Making sense & Visioning
Step 5	Determining	Agreeing on response & planning
Step 6	Implementing the outcome	Acting & transforming

A. Foresight Step 1: Setting scope

In the initial step, the scope of research needs to be set. For this research, the scope has been set by defining the research question already introduced in the first section: What are the challenges and opportunities regarding circular strategies for EV components in Thailand?

B. Foresight Step 2: Collecting inputs

Conway (2014, pp. 1-43) stresses the critical step of environment scanning in the first foresight stage. This stage tries to identify changes to provide this finding for later stages. Popper (2008, p. 59) lists the most common scanning techniques such as observation, examination, and systematic description. They may be but must not be formalized and include gathering information from literature reviews and web searches. Rohrbeck and Bade (2012, p. 9) see environment scanning as a way to respond to external change and performed "by (top) management, by networking or active search for weak signals". For this research input has been generated mainly using three approaches:

• Literature review and web search: Stapleton (2005, pp. 177-189) identified the web as "to grow as an alternative, if not primary, research source". When performing a web search, the person searching for information must define his/her query and enter it into a web search engine in an understandable form for this engine. These are most often short queries using keywords (Spink and Jansen, 2000, p. 1).

• Observation on exhibition and conference: Observation provides researchers with a method to "study people in their native environment in order to understand "things" from their perspective" (Baker, 2006, pp. 171-189). Boote and Mathews (1999, pp. 15-21) see observation as an exploratory method and state that it "may be the only method to obtain data on consumers' behavior in certain situations, and in others, it may prove to be highly appropriate."

• Secondary data analysis: Secondary data have "already been created and already exist" (Largan and Morris, 2019, p. 1). In the analysis of secondary data, "individuals who were not involved in the collection of the data analyze the data" are involved (Church, 2002, pp. 32-45). Secondary research involves "using pre-existing data for a purpose different from that for which they were originally collected" in order to extract relevant data from previ-

ous research, find facts supporting research, build models by finding relationships between variables, data mining (computer-based data analysis, or to define relevant information to prevent plagiarism (Kalu, Unachukwu and Ibiam, 2018, pp. 53-63).

C. Foresight Step 3 Analyzing signal

Trends are non-final information. To analyze trends, qualitative and quantitative data can be used following an extrapolation of trends, which can provide a rough idea of the future. Blind-spots and misleading results are a risk (Conway, 2014, pp. 1-43; Popper, 2008, p. 59).

To analyze the signals in the large amount of input, the collected information has been gathered in Table 02. The main motivation is to analyze patterns and make an interpretation possible.

D. Foresight Step 4: Interpretation

Baskarada, Shrimpton and Ng (2016, pp. 414-433) see interpretation as a step to give data meaning. Kuosa (2011, pp. 18-23) defines the key aim of interpretation in a strategic foresight process to explore and understand 'what is really happening'.

The results of this interpretation are provided in section IV of this research.

E. Foresight Step 5 & 6: Response and Action

A response to the research question and recommendations on actions for the different groups of stakeholders based on the previous foresight steps are provided in section V of this research.

Results on Challenges and Opportunities Regarding Circular Strategies for Electric Vehicle Components in Thailand

The stages of a foresight approach described in the previous section have been performed for the Thai market for EVs. Below the results of each step are provided.

A. Collecting and analyzing inputs from the Thai EV market

Literature review and web search: To scan the environment of the Thai EV market, queries have been performed using these keywords: 'electric vehicles', 'Thailand', and 'Automotive'. The following web searches using have been used:

- Automotive manufacturers and distributors (e.g. Toyota and Mercedes-Benz)
- Newspapers and popular literature sites (e.g. Bangkok Post, Nationthailand)
- Academic literature (e.g. Google Scholar, Researchgate)

In total 56 files with information about 14 companies manufacturing or distributing cars in Thailand or planning to do so have been reviewed.

Observation of exhibitions and conferences: To gain direct insight and perspective on the actual status of the market and production of EVs in Thailand, the exhibition and conference Electric Vehicle Asia and iEVTech 2022 has been visited. This event defines itself as a "special business platform to showcase solutions, technology, and infrastructure related to energy efficiency, power conversion systems including electrical systems for electric trains, battery

Table 2 Summary of Electrification Strategies of Automotive Manufacturers in Thailand.

		Auto Alliance (JV)	BMW	BYD	Great Wall	Honda	Isuzu	Mercedes-Benz	Mitsubishi	Nissan	PTT Foxconn (JV)	SAIC Motor-CP	Suzuki	Tesla	Toyota
Origin		US-JP-TH	GER	CH	CH	JP	JP	GER	JP	JP	TH-TW	TH-CH	JP	USA	JP
Vehicle production in Thailand		Yes	Yes[1]	No	Yes	Yes	Yes	Yes[1]	Yes	Yes	No	Yes	Yes	No	Yes
Production capacity in Thailand (p.a.; in 1,000)		175 K	33 K[2]	0	80 K	420 K	361 K	19 K	424 K	370 K	50 K[4]	100 K	50 K[12]	0	770 K
xEV production in Thailand	BEV	No	No[3]	No	No[3]	No[3]	No	Yes[11]	No	No	O[10]	No[3]	No	No	tbd
	(P)HEV	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	O[10]	Yes	No	No	tbd
	xEV in Planning	P	U[8]	U	D[8]	U[8,9]	O	P	P[10]	U[8]	P[10]	D[8]	O	O	P[10]
Battery production in Thailand / Capacity (p.a.)						No[7]	No	Yes[3]	No	Yes		Yes[3,6] 4 K[5]	No	No	
Battery recycling in Thailand							No					D	No		
Legend			[1] CKD; [2] including motorcycle; [3] only PHEV; [4] extension to 150 K in planning; [5] planned to be extended to more than 8,000; 6 for BEV in planning [7] Plans unconfirmed, [8] for BEV, [9] in JV with Sony, [10] concept unclear, [11] By end 2022, [12] status of planned extension to 100 K unclear P = planned / U = unconfirmed / D = discussed / O = open										

management components, monitoring & control equipment systems and charging stations" (iEVTech, 2022, p. 1).

Primary data analysis: To gain direct information from Thai OEMs about their actual and future plans to sell and produce EVs in Thailand, an online survey has been shared with 14 international OEMs operating in Thailand or planning to do so. Together with the secondary data collected as described below, the information from OEMs provided in the surveys (e.g. on production capacities, production locations and on the actual EV programs) has been taken into account and summarized in Table 2.

Secondary data analysis: Several research companies, consulting services, agencies, and data analysts are providing data on the automotive industry. For this research latest data on the specific fields of the automotive industry in Thailand and the electrification in the automotive industry have been reviewed. Analysis of the Thai EV Market

B. Interpretation of the Thai EV market

Based on the information and data gained in the previous section, the following interpretation about today's Thai EV market can be made:

Today's production (assembly) of EVs

As of today, eleven international operating automotive companies are manufacturing or assembling vehicles in Thailand. Two other car manufacturers and an energy company are checking the feasibility to do so. The strongest production capacity is provided by Japanese companies, followed by a Thai-American joint venture, and Chinese and German companies. Seven of the eleven companies assembling cars in Thailand are assembling electric vehicles in Thailand. The results are showing a strong focus on hybrid solutions. Three more companies are planning to do so. The Krungthai Compass research center explains this with two main arguments:

First, the production supply chain will take up to 10 years to adapt to produce the relevant parts. Secondly, the infrastructure makes "most buyers still prefer to own hybrid cars because Thailand lacks proper EV infrastructure, especially an insufficient number of charging stations" (Phakdeetham, 2022, p. 1).

Outlook production (assembly) of EVs

The production of passenger cars is awaited to steadily increase in the next ten years. The production volume of 0.59 million vehicles in the year 2021 is awaited to increase to 1.01 million cars in 2031. An increase in a year-to-year comparison between 1.2% p.a. and 6.6% p.a. (Fitch, 2022, p. 11). The sales of electric vehicles are awaited to raise in the same period of time for 12,841 units in 2021 to 80,456 units in 2031. The share of PHEV is awaited to decrease and the share of BEV is awaited to increase. From these EV sales, the Thai government is aiming to produce 50% within its own country (Fitch, 2022, p. 9).

Production (Assembly) of battery packs for EVs

Three companies are today assembling battery packs for EVs in Thailand. Besides the actual efforts and incentives to build EVs in Thailand, local manufacturers and administrations made efforts to locate the production of battery packs for EVs in this country. The Thai administration announced to consider promotions to locally produce such battery packs in Thailand and to have signed agreements about such efforts with Great Wall Motor Manufacturing (Thailand) Co and MG Sales (Thailand). Mercedes-Benz has already assembled PHEV battery packs locally since 2019 and Nissan opened a battery production site in 2022. The Thai administration has announced to support such efforts and stated that 192 billion THB shall be allocated to develop and produce zinc-ion batteries for EVs (Abhasakun, 2022, p. 1; Chantanusornsiri, 2022, p. 1; Mercedes-Benz Group AG., 2019, p. 1; Nissan Motor (Thailand) Co., Ltd., 2022, p. 1).

Recycling of battery packs

In addition to the production of battery packs for EVs, first attempts for CLSC strategies of such parts are discussed and implemented. In 2021 the first facility in the ASEAN region has been started to recycle up to 14 tons of lithium-ion batteries. SAIC Motor-CP has announced that is considering the increasing amount of battery packs and will study the feasibility of recycling batteries from EVs in Thailand (Bangkok Post, 2022b, p. 1; Chen and Hu, 2022, p. 1; Uchida, 2022, p. 1).

Potential future scenarios

Based on these results, three potential future scenarios can be created:

1. Potential future scenario 1: The production and sales of EVs in Thailand have increased significantly. More than 50% of the locally produced cars are EVs. A transition from PHEV production to BEV production has taken place. A strong, country-wide charging network has been implemented.

2. Potential future scenario 2: Following an increased production of EVs in Thailand, most EV components (especially EV battery packs) are locally produced in Thailand.

3. Potential future scenario 3: With a higher number of EVs in Thailand and an increased number of EV battery packs reaching

their EoL, increased circular strategies have been implemented in the Thai market.

Discussion

The following section is providing answers to the research question, makes recommendations to the different groups of stakeholders, and is providing an outlook on future research.

A. Challenges and Opportunities Regarding Circular Strategies for Electric Vehicle Components in Thailand

Based on the previously described results, the research question about the challenges and opportunities regarding circular strategies for EV components in Thailand can be answered as follows:

Opportunities

• The infrastructure, the existing network of automotive companies, and automotive expertise are strong in Thailand and giving it a comparative advantage

• Several of the foreign automotive companies operating in Thailand have already EV expertise within their existing product range

• Several of the companies producing vehicles in Thailand are already today producing (hybrid) electric vehicles

• Some companies are already producing battery packs today in Thailand

• There are companies checking the feasibility of recycling battery packs in Thailand

• The Thai administration is massively supporting the transformation towards electric vehicles in the country. Being the production hub for EVs in Southeast Asia is a clearly defined aim.

• The awareness of sustainability in general; and for sustainable production concepts in particular in Thailand is lower compared to other regions globally but is increasing significantly A good momentum.

Challenges

• The network of charging stations is nowadays still weak hindering the significant increase of BEVs

• As of today, there are no clear end-of-life requirements for vehicles (so-called End of Life Vehicles / ELVs) defined in Thailand

• Perception of Thai customers towards remanufactured products is rather negative due to missing product information and lack of standards

• One-sided marketing within Thailand about remanufacturing highlighting mainly only the cost benefits

• Thai National standards for remanufactured part processes and testing are not existing

To conclude, it can be said that the Thai market today is offering many opportunities for recycling and remanufacturing of EV battery packs. The existing infrastructure, know-how, and government incentives are a good basis and are giving Thailand a comparative advantage over other countries in this region. At the same time, there are challenges in connection with a weak network of charging stations, a lack of regulations and standards, and a low perception of remanufacturing. Specially to overcome these challenges, the next section is providing recommendations to decision-makers.

After providing these comprehensive answers, it can be stated that it was possible to answer the research questions sufficiently. The next section is suggesting further research to support the findings.

B. Recommendations and Outlook

Following the opportunities and challenges described in the previous section, the authors would like to make the following recommendations. They are addressed to policymakers in Thailand, decision-makers in the Thai automotive industry, and to academia. The recommendations are divided into these groups.

For policymakers in Thailand

• Contribute and support the implementation of standards and clear definitions of remanufactured parts in Thailand

• Define EoL requirements in the automotive industry

• For decision-makers in the Thai automotive industry

• Promote remanufacturing by explaining the product. Thai customers require product knowledge

• Refrain from just opting for remanufactured products as a cheaper solution

• Highlight the "good as new" approach

• Use increasing awareness for environmental-friendly products to promote remanufacturing

• Use social media to extend knowledge about reman processes, products, and advantages (e.g. YouTube)

For academia

• Extend research, especially in respect of

• Analyzing the perception and determinants of remanufactured parts in Thailand

• Explore the global status of standardization for remanufactured and derive suggestions for Thai national standards

• Perform cross-country analysis to compare the Thai EV market with markets with a higher rate of remanufactured parts

This research work has demonstrated the opportunities for circular strategies of EV components in Thailand. At the same time, it has shown challenges. Using the foresight method, it was possible to create different potential future scenarios. Exploring these scenarios needs further investigation, potentially by a cross-country analysis, is needed to explore the Thai-specific challenges and potential approaches in a more detailed form.

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