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Why Polish market of alternative fuel vehicles (AFVs) is the smallest in Europe? SWOT analysis of opportunities and threats

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Why Polish market of alternative fuel vehicles (AFVs) is the smallest in Europe? SWOT analysis of opportunities and threats

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Abstract

A holistic approach regarding the Strengths, Weaknesses, Opportunities and Threats (SWOT) of the sector of alternative fuel vehicles (AFVs) in Poland, with particular regard to passenger electric vehicles (EVs), has been proposed to explore and evaluate the current state and to propose some future actions lines towards sustainable development in transportation. The most important problems faced currently by the Polish EVs market include unstable and unclear regulations that may discourage both: producers and buyers from engaging in this market segment. Secondly, the much higher prices of EVs in comparison to the conventional vehicles together with many unsolved issues with the batteries and charging stations belong to the most significant barriers of adoption. The formulated portfolio of actions towards enabling sustainable development of transportation in the segment of passenger vehicles proposes the implementation of mini-maxi strategy that would minimize the current weaknesses by maximizing the potential opportunities of the market.

Keywords: e-mobility; sustainable transport; electric vehicles; plug-in electric vehicles; hybrid electric vehicles; policy regulations; SWOT analysis

1. Introduction

1.1. Background and motivation

The transportation sector faces currently various challenges. Firstly, since 1980 the total global energy demand has almost doubled and according to the International Energy Agency (IEA), currently 20% of the global energy is consumed by the transportation sector [1]. Secondly, the same IEA forecasts that between 2012 and 2040, the total volume of road vehicles will double. Thirdly, transportation, both public and private belongs to one the main sources of greenhouse gas emissions [2]. Finally, sustainable transport, even if not directly mentioned in the 2030 Agenda for

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Sustainable Development, has a significant contribution in fulfilment of many of the sustainable development goals (SDG), especially those related to food security, health, energy, infrastructure, cities and human settlements, and climate change. That is why, transport services and infrastructure are essential to achieving most of SDGs and sustainable development of the planet [1].

To overcome the mentioned challenges, recently most of the governments have clearly stated their aims to promote the production and sale of alternative fuel vehicles (AFVs), which are seen to be an environmentally-friendly and sustainable means of transport [3–5]. AFVs can be defined as vehicles operating exclusively on an alternative fuels (e.g. electricity or compressed natural gas (CNG)) or on a hybrid of alternative and traditional fuels [6]. In particular AFV can be divided into: (1) battery electric vehicles (BEV, EV[2]); (2) hybrid electric vehicles (HEVs); (3) plug-in hybrid electric vehicles (PHEV); (4) fuel cell vehicles (FCEVs), and (5) compressed natural gas (CNG) and liquefied petroleum gas (LPG) vehicles.

According to the IEA, because of the rapid growth of transportation and its increasing share in the global CO_2 emissions, AFV may occur to be a promising option for decreasing energy consumption and maintaining energy security [1]. AFVs have the potential to reduce gasoline consumption as well as resulting greenhouse gas emissions and air pollutants. Successful diffusion of these vehicles will depend on the readiness of the demand side of the market, which turns to consumer awareness, attitudes and interests, their willingness to pay, travel patterns and access to charging/ refueling infrastructure [1, 7–10]. At the same time, to enhance the AFVs diffusion, the supply side of the market can not be neglected, with the manufacturers' offer, charging infrastructure, as well as financial and legislative background [10, 11].

In the last decade a large amount of papers have been released, discussing advantages and disadvantages, as well as trends and best practices of the innovative technologies in e-mobility. These analysis have been usually done on the national level. AFVs in general, and EVs in particular have been widely discussed as an available option for: the United States [12, 13], China and Taiwan [14], Indonesia [15], Canada [4, 5, 16, 17], Iceland [18], Germany [19], Ireland [9], Italy [20], and Australia [21]. There is also plenty of papers examining the AFV market in the whole EU, such as for example [22–25]. In the region of the Central and Easter Europe an AFV market has been also investigated, in particular in Poland [3, 26–29], in the Czech Republic [30, 31] and in Lithuania [32].

A number of studies have analyzed the opportunities and challenges for the development of AFV market in various countries from various perspectives, such as social acceptance and consumers' preferences or supporting policies and market growth. Dissemination and diffusion of EVs have been studied in the city urban areas [8], as well as in particular countries, such as Germany, Poland and Ireland [9–11, 29]. Adoption of EVs among consumers have been investigated in Nordic countries, such as Sweden [33], and for all EU member states [24, 34]. Also the work of [35] is an example of modelling of AFV diffusion and adoption rate among consumers. Another

[1] for more details see: http://www.slocat.net/sdgs-transport (accessed February, 2nd 2020)

[2] Within the paper, we use notation EV for battery electric vehicles. Although there are classification which include FCEVs or other types of vehicles which may use electric drive, such as PHEV, into EV category, in our analysis we will mostly focus on classical battery electric cars (without combustion engine). The reason for that is the negligible number of FCEVs on Polish roads and the limited number of PHEVs in the manufactures' offer in the Polish market. Moreover Polish legislation exclude other types of AFV than EV and FCEV from the policy support system.

group of papers explore financial, economic and policy incentives promoting EVs (see for example [13, 23, 25, 36–39]). Consumers' acceptance, their attitudes and preferences towards AFV have been broadly discussed for such countries as: Slovenia, Canada, Poland, Italy, Ireland, and for Northern & Eastern countries in general [5, 9, 20, 26, 37, 40, 41]. There are also examples of papers dealing with health and environmental benefits of AFV and the environmental lice cycle assessment (LCA) for Poland and the Czech Republic [22, 30, 31].

Within our paper we want to focus on Poland and the passenger vehicle sector of transportation. Similarly to other countries, also in Poland the government has recently announced a National Plan for Development of E-mobility and introduced the Act on Electromobility and Alternative Fuels (AEAF) [42]. These documents create incentives for the deployment of AFV market in Poland by lowering the excise tax on electric cars, enabling drivers of such vehicles to use the bus lanes in cities, or removing paid parking fees [43]. According to the reports of the European Automobile Manufacturers' Association (ACEA) Polish consumers are mainly interested in hybrid electric vehicles (HEV), and conventional vehicles (CV). As the ACEA indicates, Poland is nowadays, one of the EU countries with the highest sales rates of HEVs. At the same time, the number of battery electric vehicles registered in Poland has increased by 130% between the first quarters of 2017 and 2018 (but EV's market share is still close to zero (0.1%))[3]. But still, according to the latest report of LeasePlan company, the share of EVs sold among Polish consumers is the lowest in the whole Europe! LeasePlan has assessed individual countries based on four determinants: the number of electric cars per 1000 inhabitants, the number of chargers per 1000 inhabitants, government subsidies and other incentives to buy an electric car, and the company's own experience regarding the interest of drivers in buying an electric car. In the ranking the Netherlands and Norway have taken the first places (with 34 points each), whereas Poland was at the end of the list with 11 points, together with Slovakia and Romania [4].

There is plenty of reasons for such a condition of EV market in Poland. This paper explores and explains these reasons by means of the SWOT analysis of the Polish AFV passenger vehicle market, with particular regard to EVs. Although various scenarios of AFV market development in Poland has been investigated in the recent work of Romejko et al. [1], to the best of authors' knowledge, the holistic approach and SWOT analysis has not been used yet to examine the conditions of the AFV further diffusion.

In particular we want to investigate the internal strengths and weaknesses of EV market as well as the external opportunities and threats in the economic, social, technology and policy environment. Special attention is given to the legal aspects and the lack of their stability. Within our research, we will use the following methods: quantitative, comparative and critical analysis of the EV market in Poland, with regard to the EU market, together with SWOT analysis. Our work provides some insights to the EVs potential in Poland. Based on our study we propose the strategy for further EV deployment and some policy recommendations to the key stakeholders of the Polish transportation and energy market.

[3] for more information visit https://www.acea.be/statistics/tag/category/passenger-cars-registrations (accessed December, 12th 2019)

[4] https://motoryzacja.interia.pl/raporty/raport-samochody-elektryczne/samochodyelektryczne/news-krajem-najmniej-gotowym-na-auta-elektryczne-jest-polska,nId,4281499 (in Polish), accessed January, 23rd 2020

The structure of the article is as follows. After presenting the background and motivation of the study, in Section 2 the Polish e-mobility market is discussed. Then, Section 3 provides detailed information about the legal aspects of the e-mobility development. Finally, Section 4 discusses the internal and external aspects of the AFV market in Poland by means of SWOT analysis. Section 5 includes conclusions and policy recommendation as well as limitations of the study and its future scope.

2. Status quo of e-mobiliy in Poland

2.1. Division of AFV

The passenger vehicles that make a usage of the electric power, and can be observed on the Polish passenger vehicle market, can be divided into four main categories [44]:

- HEV (Hybrid Electric Vehicle): includes vehicles equipped with both a gasoline engine and an electric motor. The batteries in classic hybrid vehicles are recharged using recuperative braking systems and engine energy. Recuperative braking systems convert heat energy generated during vehicle braking (lost in conventional vehicles) into electricity, which extends the life of the braking system. HEVs are often seen as a bridge between combustion conventional vehicles (CV) and EVs.

- PHEV (Plug-in Hybrid Electric Vehicle): are hybrid electric vehicles with the possibility of charging from the outside, from an electrical outlet (”plug-in”). Vehicles in this category have two types of drives: internal combustion engine and electric motor. In PHEV vehicles, the electric motor and the internal combustion engine can work separately or in parallel, which is why they can only operate on electricity when charged frequently. The batteries can be recharged from a classic electrical outlet or a special charging station for faster charging. PHEV are seen as a developed kind of HEVs .

- EV, EV (Battery Electric Vehicle); this category includes only (battery) electric cars. Cars in this category do not have an internal combustion engine, they use only stored electricity in rechargeable batteries.

- FCEV (Fuel Cell Electric Vehicles): this category includes electric vehicles equipped with fuel cells, which have a function of the battery (accumulator). Due to the poorly developed hydrogen station network and the currently small number of commercial FCEV solutions, this category should be rather considered as a future alternative to EV and is not included in the further analysis in this paper.

Figure 1 shows simplified construction diagrams for each of the categories of electric vehicles mentioned.

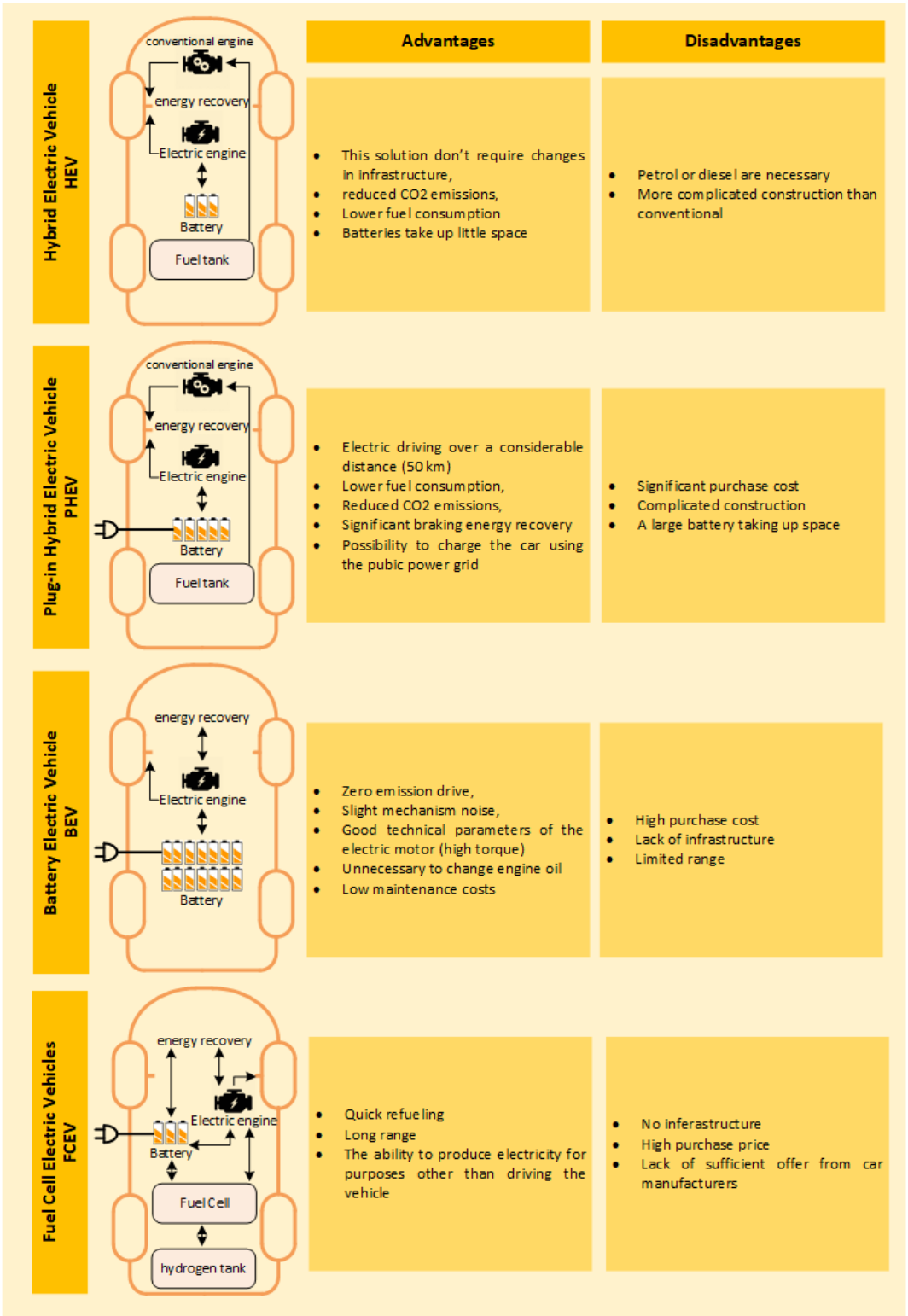

Figure 1: Categories of vehicles using electric drive.

Table 1: The passenger car market in Poland against the background of the European Union. Sources: [44–50]

	EU	Poland	Notes
Vehicles in use	267,834,417	23,429,016	8.7% of the passenger car market in the EU
Average age in years	10.80	13.90	18th place among 28 EU countries
Motorisation rates per 1,000 inhabitants	531	617	5th place among 28 EU countries
New passenger car registrations per 1,000 inhabitants	30	14	22 place among 28 EU countries
CO_2 emissions of new passenger cars in g CO_2/km	120.6	127.7	20th place among 28 EU countries

Table 2: Passenger cars market in Poland by fuel type. Sources: [47–49]

Type of fuel	EU	Poland
	share (in %)	share (in %)
Petrol	54	52.9
Diesel	41.9	31.2
HEV	0.7	less then 0.1
EV	0.2	less then 0.1
PHEV	0.1	less then 0.1
LPG + Natural gas	2.8	13.9
Other + Unknown	0.3	1.7

2.2. Polish passenger vehicle market

The Polish passenger car market is one of the largest in the European Union (EU). In 2018, over 23.4 million passenger cars were registered in Poland, which is 8.7% of all registered cars in the EU [45, 46]. The motorization rate is also one of the highest in Europe and amounts to 617 passenger cars per 1000 inhabitants. It is also important to note that one of the oldest cars in Europe are moving around Poland. The average age of passenger cars in Poland is over 13 years [46–48]. The number of newly registered cars in Poland is twice lower than the EU average. In addition, newly bought cars in Poland have a 6% higher average CO_2/km indicator than the EU average for this indicator [47–49]. Detailed data on the passenger car market in Poland and EU as w whole has been presented in Table 1. A characteristic feature of the Polish current passenger market is also the large share of LPG-powered cars and a negligible percentage of EVs. The division of cars according to the fuel used with regard to the average EU indicator is presented in Table 2.

Recently, however, a change in consumers' interest towards buying brand new cars can be observed. HEVs, PHEVs and EVs cars are becoming more and more popular. The popularity of buying EVs has almost doubled over the past few months. The reason is, among others, government announcements of the introduction of price reductions and subsidies for the purchase of EVs, see Section 3 for more details. In Poland, there is also a greater interest in buying HEVs and

Table 3: New passenger car registrations in UE and Poland in the first three quarters of 2018 and 2019. Sources: [47–49]

	EU			Poland		
Fuel type	Q1-Q3 2018	Q1-Q3 2019	% change	Q1-Q3 2018	Q1-Q3 2019	% change
Petrol	6,702,726	6,929,897	3.4	282,268	291,598	3.3
Diesel	4,316,528	3,607,037	-16.4	97,151	82,581	-15.0
HEV	444,710	636,631	43.2	16,831	26,634	58.2
PHEV	118,379	109,996	-7.1	570	736	29.1
EV	97,994	198,464	102.5	411	1,190	189.5

PHEVs in comparison to the EU average. A detailed list of newly registered cars is presented in the Table 3.

2.3. The offer of the passenger vehicles in the Polish market

The EV market in Poland still accounts for a very small percentage of the entire market. There are currently around 5,000 EVs and around 3,000 PHEVs on Polish roads [51]. 20% of EVs were registered only in 2019 [46, 51]. The increased dynamics of EV purchase is caused, among others, by the constantly growing number of models offered by car manufacturers. It is estimated that in the first quarter of 2020 over 50 EV models will be available on the Polish market in various market segments. Table 4 shows that not every segment of the passenger car market is equally represented. The largest EV selection can be seen in the city car segment. The greatest variety of designs can be found in the SUV segment, while in the luxury car segment the selection is significantly limited to two models in different variants. There are also segments that do not have the EV offer at all. An example of such segments may be estate cars, off-road vehicles or convertibles.

Depending on the segment, EVs offered on the Polish market differ in technical parameters. One of the most important technical parameters of EV cars are the battery capacity and average electricity consumption (vehicle consumption), which directly affect the range of an electric car. Figure 2 compares these two technical parameters, which allowed drawing the following conclusions: (1) Cars with a large battery capacity are characterized by high energy demand; (2) Tesla currently offers the largest battery capacities and they amount to about 100 kWh; (3) Cars that use the most energy to move, belong to the luxury limousine and SUV segments; (4) The largest group of cars are those with an average consumption of between 14 and 18 kWh/100km; (5) Small city cars are characterized by low battery capacity and the lowest demand for energy.

Figure 3 shows the indicator - the cost of buying a 1 km range of an electric car, which combines the price of the car and the limited range of its battery, both affecting the popularity of electric cars. The cost of purchasing 1 km range was calculated based on the formula 1:

$$PC(Euro/km) = \frac{P(Euro)}{ER(km)} \tag{1}$$

where PC is the purchase cost of 1 km electric range (Euro/km), P is the price of the car on the Polish market (Euro) and ER is the electric range of the car (km).

The average value of this indicator for selected EVs was about 144 Euro/km and is significantly higher than for cars with combustion engines. City cars achieve the most favorable value of this

Table 4: List of selected EV models offered in the Polish market

car market segment	car brand and model	release year on the Polish market	Electric range [km]	vehicle consumption on [kWh/100km]	battery capacity[kWh]	price on the Polish market [Euro]
City car	BMW i3s [52, 53]	2017	230	16.5	42.2	40,186
	Renault Zoe R110 [54, 55]	2018	300	13.4	41	33,233
	Renault Twizzy [56]	2012	100	6.3	6.1	12,349
	Smart EQ Fortwo [57]	2017	160	12.9	17.6	22.535
	Smart EQ Fortfour [58]	2017	155	13.4	17.6	22,884
	VW e-up! [59, 60]	2020	258	14.4	32.3	22,393
	Skoda citygo-e iV [61]	2020	260	13.5	36.8	18,907***
	Opel corsa-e [62]	2020	337	16.8	50	28,951
	Peugot e-208 [63, 64]	2020	340	16.1	50	29,047
	SEAT Mii Electric [65]	2020	200	16.2	36.8	20,650*
	Mini Copper SE [66]	2020	180	16.1	32.6	32,500*
Crossover	Hyundai Kona Electric 136KM [67]	2018	289	15	39.2	38,581
	Hyundai Kona Electric 204KM [67]	2018	449	15.4	64	44,163
	KIA e-NIRO 136KM [68, 69]	2020	289	15.3	39.2	34,290*
	KIA e-NIRO 204KM [68, 69]	2020	455	15.9	64	39,090*
	Peugeot e-2008 SUV [70]	2020	275	17.3	50	39,000*
	Volvo XC40 P8 AWD Recharge [71]	2020	375	20	78	59,000*
Compact	Hyundai IoniQ Electric [72]	2017	280	11.5	28	38,256
	Nissan LEAF [73]	2018	270	20.6	40	36,674***
	Nissan LEAF e+ [73]	2018	385	18	62	45,558
	VW ID.3 Long Range [74]	2020	450	17.1	77	45,000*
	VW ID.3 Standard Range [74]	2020	275	16.4	48	29,000**
	Tesla model 3 long range [75]	2018	560	15.6	74	54,090
	Tesla model 3 standard plus [75]	2018	409	14.7	50	44,390
Luxury	Tesla model S performance [75]	2017	593	18.6	100	102,700
	Tesla model S long range [75]	2017	610	18.1	100	86,800
	Porsche Taycan 4S Plus [76, 77]	2020	425	19.7	93.4	112,128*
	Porsche Taycan Turbo [76, 77]	2020	415	20.2	93.4	152,136*
SUV	Jaguar I-PACE [78]	2019	470	21.2	90	82,930
	Mercedes EQC 400 4Maltic [79]	2019	450	22.2	80	76,349
	Tesla model X performance [75]	2016	487	21.3	100	107,600
	Tesla model X long range [75]	2016	507	20.7	100	91,700
	Audi e-tron 55 quattro [80]	2019	370	23.4	86.5	80,900*

Note: * current price level from the German market; the car available in Poland in 2020; ** no official price lists; expected price in Poland; *** special offer

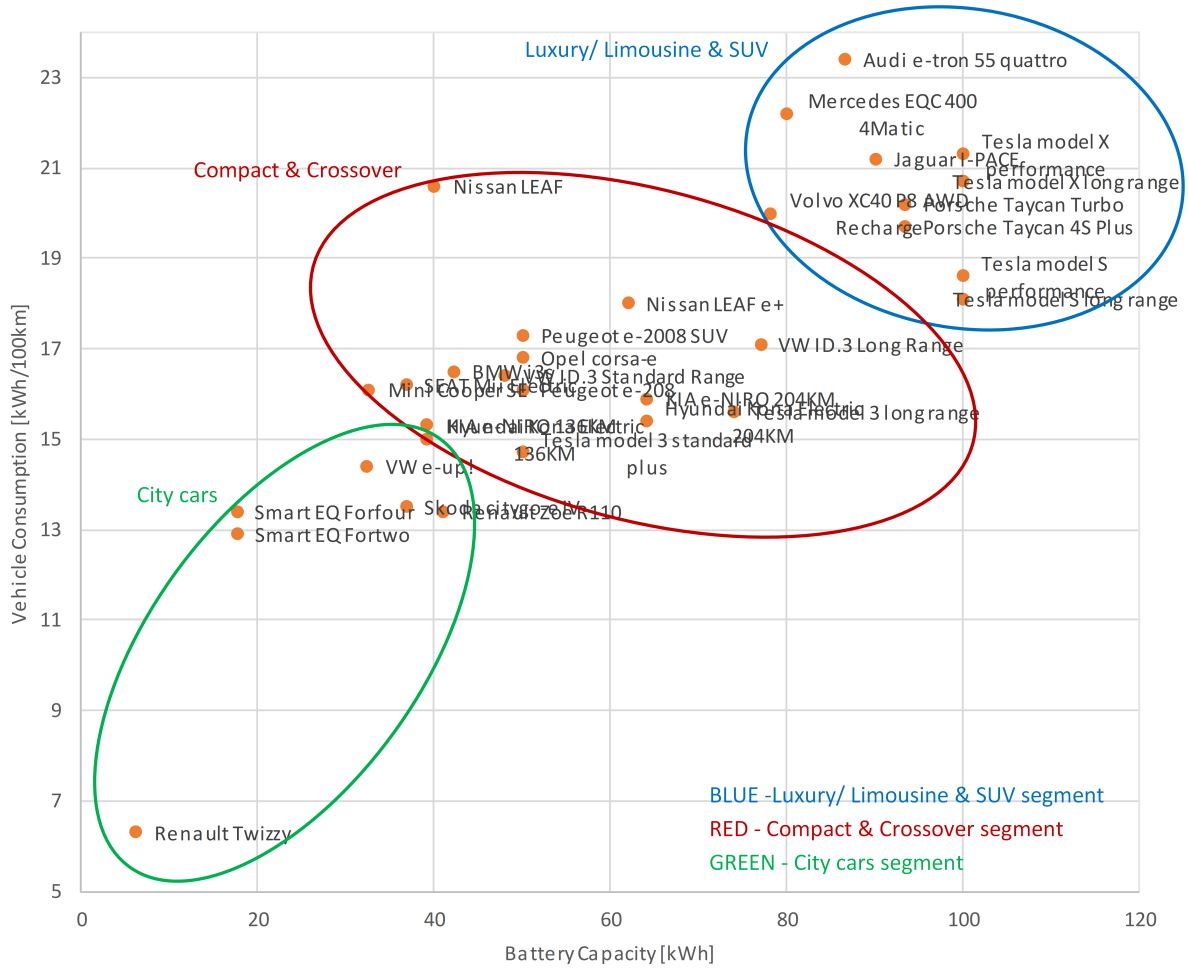

Figure 2: Battery Capacity vs Vehicle Consumption for selected EVs. Note: blue circle illustrates luxury/ limousine & SUV segment; red circle illustrates compact & crossover segment; green circle illustrates city car segment. Sources [52–82].

Table 5: Requirements for car charging points in Poland acc. to AEAF Act [42]

The required number of charging points for EV to 31.12.2020	Characteristics of the commune
1,000	population > 1,000,000 number of registered vehicles >600,000 automotive index* > 700
210	population > 300,000 number of registered vehicles > 200,000 automotive index* > 500
100	population > 150,000 number of registered vehicles > 95,000 automotive index* > 400
60	population > 150,000 number of registered vehicles > 95,000 automotive index* > 400

* Note: number of registered motor vehicles per 1,000 inhabitants

indicator. However, attention should be paid to models with so-called extended range. They are characterized by a lower value of the purchase cost of 1 km range than EV with a standard power supply (for example, Tesla model 3 long range - 95.6 Euro/km vs Tesla model 3 standard plus - 108.5 Euro/km).

2.4. Subsidies for the consumers

Poland is another European country where the government intends to introduce incentives and subsidies for the purchase of electric cars. The mere information about work on legislative documents introducing EV subsidies has contributed to a significant increase in interest from buyers of these vehicles. Figure 4 shows the co-financing values for selected EU countries.

Some of the EV sellers began to adjust the price of the offered models to the newly created regulations. The result is a list of 10 EV models subject to government subsidy. Figure 5 shows the costs of buying a new car with the amount of the subsidy. At the time of submitting this paper, the regulations enabling the EV subsidy have not been implemented yet.

2.5. Electric vehicles charging infrastructure

Charging infrastructure is one of the key elements of the large-scale implementation of e-mobility [10]. A properly developed and properly functioning network of charging points is necessary to change consumer preferences and reduce the fear of using vehicles with an alternative drive to a traditional internal combustion engine. The above issue has been included in strategic documents adopted in Poland. Table 5 summarizes the requirements for charging points in Poland.

In Poland, the number of available charging points for electric vehicles is growing dynamically, however, it still remains at a relatively low level compared to other EU countries. According to the Act on Electromobility and Alternative Fuels (AEAF), the number of operating charging points in Poland in 2018 exceeded 800 and represents only 0.6% of the total vehicle charging stations in the

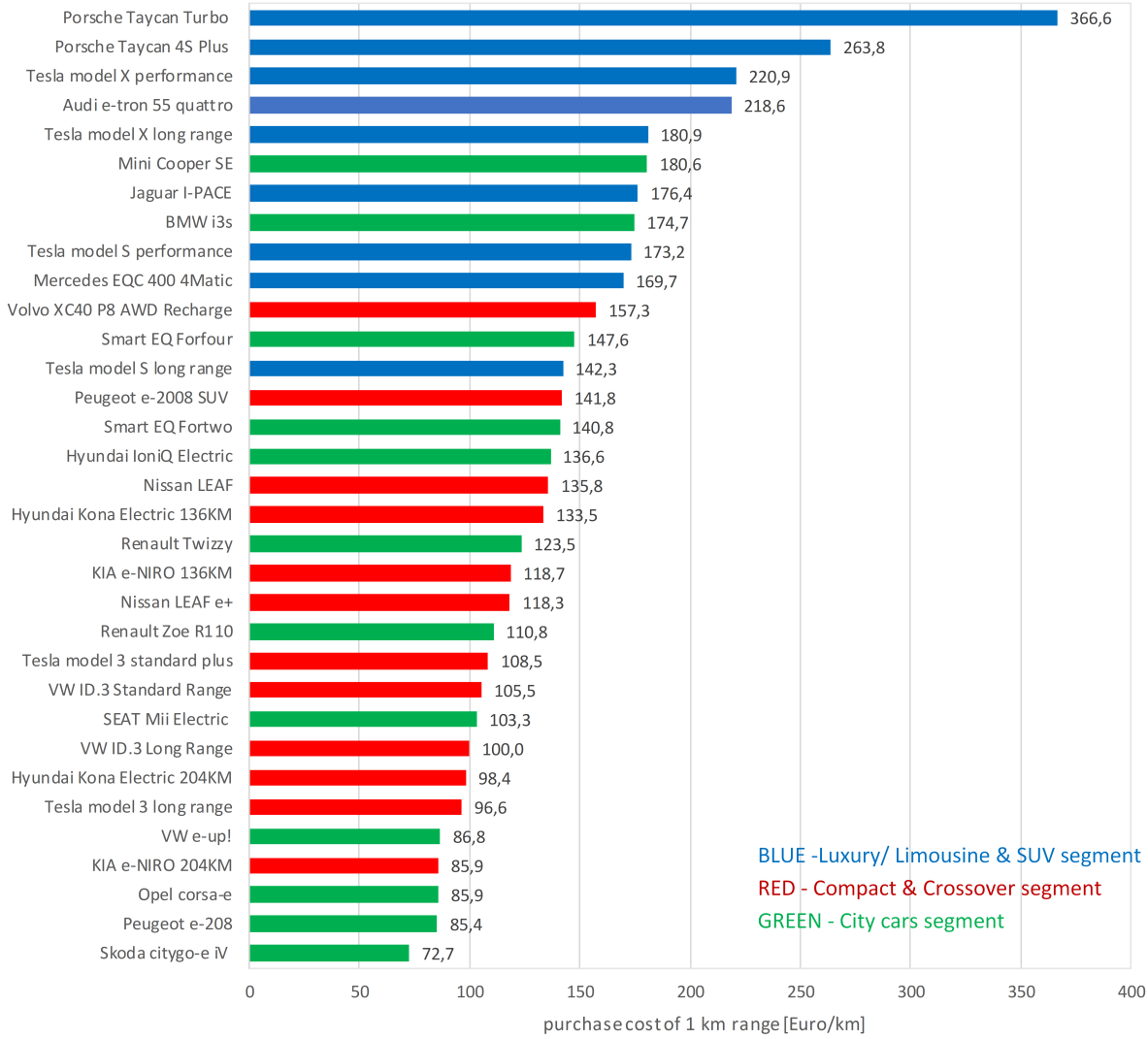

Figure 3: Purchase cost of 1 km electric range in Euro/km. Note: blue circle illustrates luxury/ limousine & SUV segment; red circle illustrates compact & crossover segment; green circle illustrates city car segment. Sources [52–82]

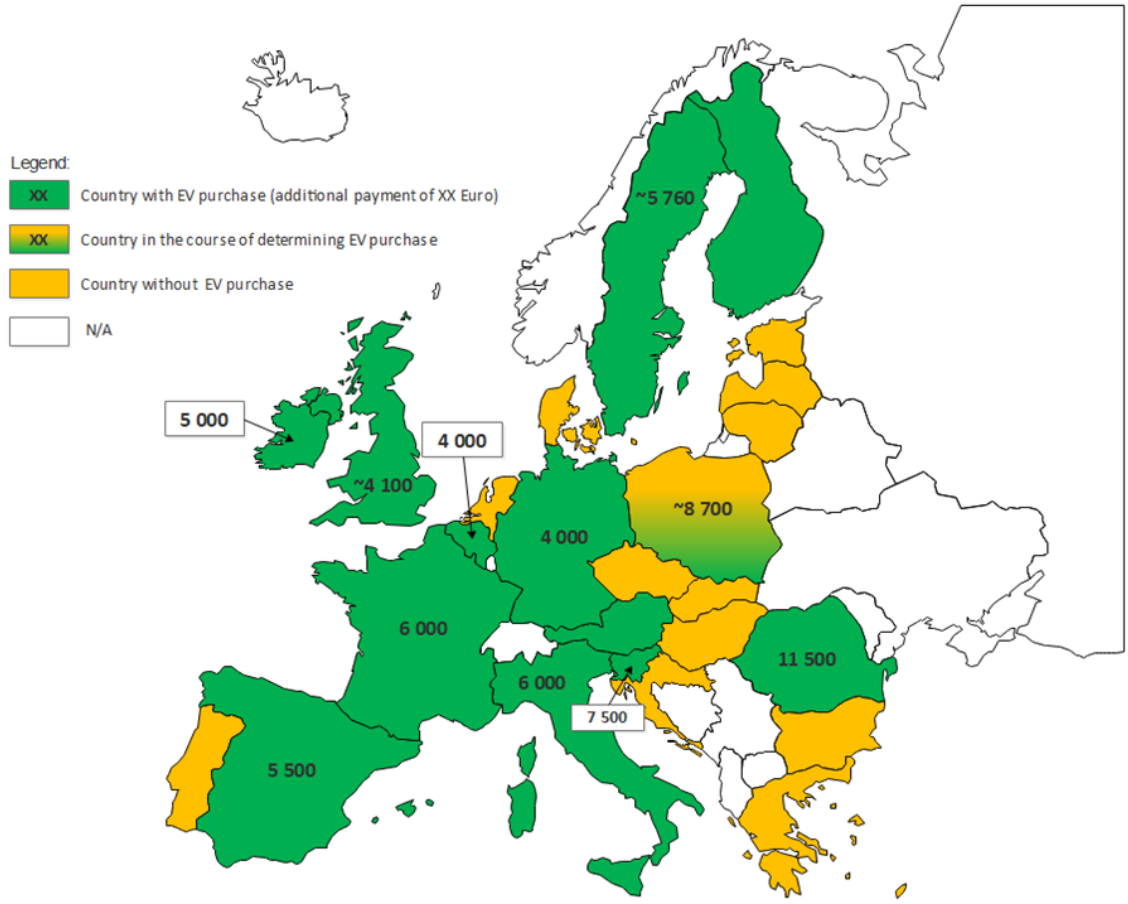

Figure 4: Consumer purchase incentives and uptake of EV [42, 49].

EU. So far, in Poland there are only 0.2 EV charging points per 100 km of roads, which is one of the lowest rates in the EU [49, 50]. Detailed data is presented in Figure 6.

2.6. Purchasers of AFV

According to the Electromobility Barometer 2018, published by PSPA, the number of Poles who are considering a purchase of an electric car in the near future (period of 3 years) has increased from 12% in 2017 to 17% in 2018 [51]. Poles' growing interest in buying AFV is indicated by the still high interest in buying traditional hybrids HEVs (28%) that can be treated as a substitute for the electric vehicle market (less harmful impact on the environment and lower exploitation costs are the main reasons for such a decision). Nevertheless, still the most popular types of drives considered in the car, which respondents plan to buy in the near future are gasoline (50%) and diesel engines (35%).

The price of the AFV car, especially EV, is still too high for most of the Poles. PSPA report states that the respondents could spend on a EV amount around 35%-40% less that the actual price is, which is well below the new catalog prices of electric cars available on Polish market [51]. Respondents most often intend to charge their electric cars at home (even 40%) and they intend

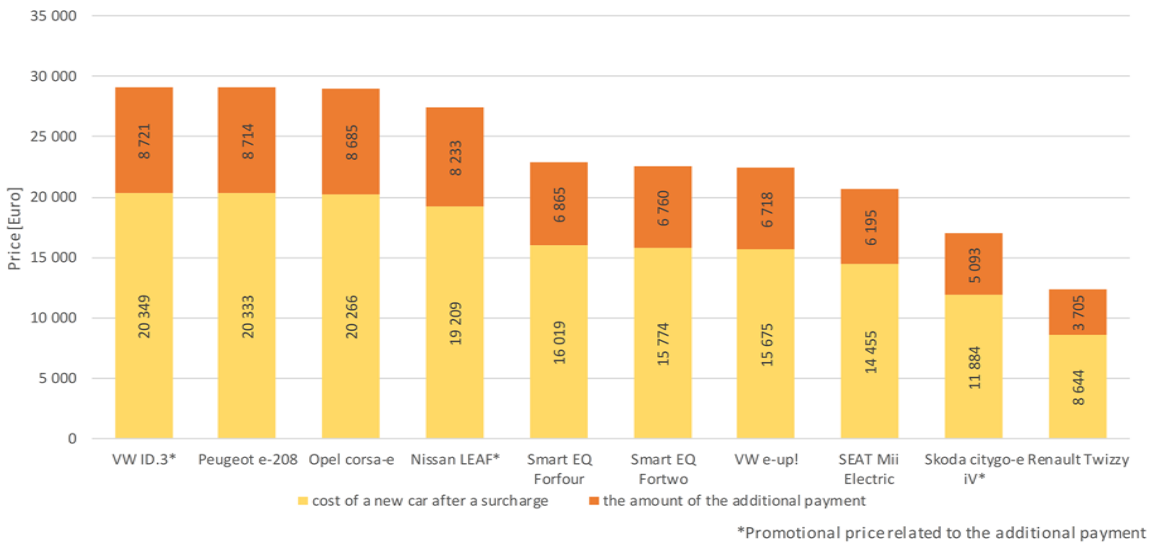

Figure 5: The EV prices and proposed subsidies in Poland [42, 56–61, 65, 73, 74, 81].

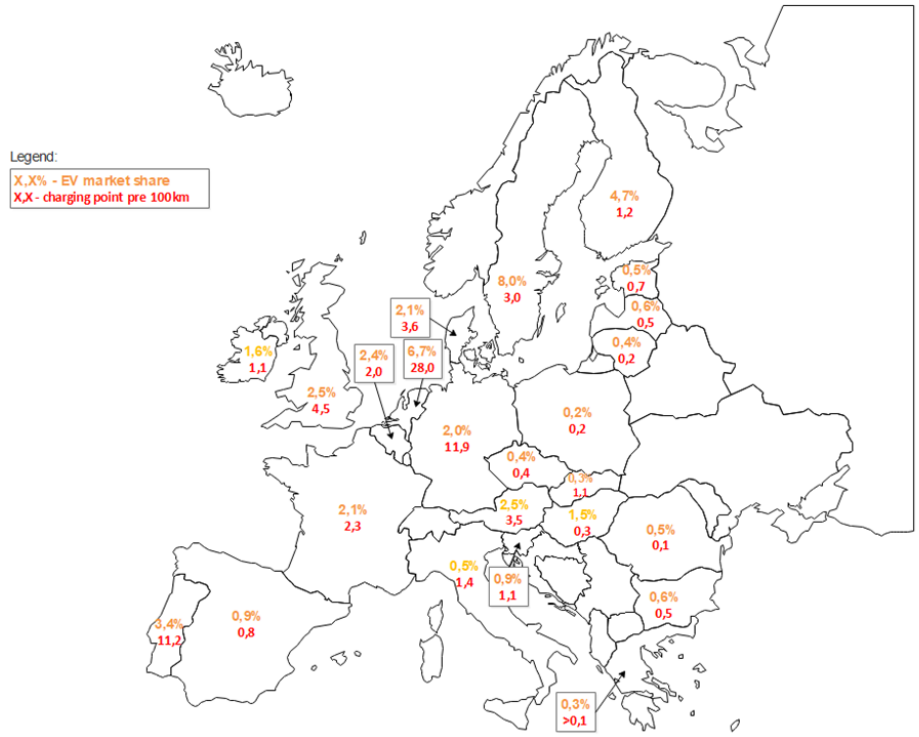

Figure 6: EV market share and charging point per 100km of road in 2019 [49, 50].

to do this everyday. 60% of respondents would like to be able to connect the car to the charger in their workplace several times a week. Another 36% of respondents intend to use public and paid charging points located in the city up to 2 times a week, and those located at routes between cities about 2 times a month. Almost half of the respondents would like to charge their electric car outside their place of residence and work, assuming its payment, not longer than 30 minutes (47%). Fast chargers that allow the car to be charged in 20-40 minutes are a priority for areas such as transit routes between major cities (62%) and medium in workplaces and public utilities.

Finally, the report reveals that to the most important incentives that could convince Poles to buy EV instead of the conventional car with a combustion engine belong: (1) VAT tax and excise duty exemption and the subsidized purchase of EV, (2) free parking and entry to low-emission zones, (3) the use of bus lanes, and (4) a developed system of charging stations [51].

3. Legislative framework of the AFV market in Poland

3.1. EU legislative framework for e-mobility development

One of the most important components of the e-mobility development process in Poland are both national and EU formal and legal regulations. Poland, as a member of the European Union, is obliged to adapt the national legal system to the requirements of the EU. Figure 7 shows the selected strategic EU documents, both acts and directives that have led to introduction of strategic documents regarding the development of e-mobility in Poland.

One of the key EU documents transposed into the Polish legal order is Directive 2014/94/EU of the European Parliament and the European Council of October 22, 2014 on the development of alternative fuels infrastructure [95]. The main objective of this directive is to: *"establish a common framework for the extensive development of alternative fuels infrastructure in Europe"*. This aim has been motivated by the need of reduction the dependence on oil transport, reduction its impact on the environment, and thereby strengthen Europe's leading role in the fight against climate change. The minimum requirements were set for the development of AFV infrastructure, including EV charging stations and natural gas and hydrogen refueling points [95].

3.2. The Polish legislative framework for e-mobility development

EU legislation has led to the origin of three strategic documents at the national level (see, Figure 8). Firstly, the Strategy for Responsible Development (SRD) until 2020 (with a perspective up to 2030) represents the basic document, currently binding and shaping the Polish zero-emission transport system [95]. The Strategy formulates a new vision and model of the country's development in response to the challenges facing the Polish economy. As part of implementing the sustainable transport paradigm and implementing the e-mobility process in Poland, SRD has set up an Electromobility Development Program (EDP) [97].

The EDP has taken into account EU requirements and national development strategies. This plan defines the benefits associated with the widespread use of electric vehicles in Poland and identifies the economic and industrial potential that lies behind it. It points to the improvement of air quality, energy security related to the development of e-mobility, improvement of the stability of the power grid and the development of advanced industry.

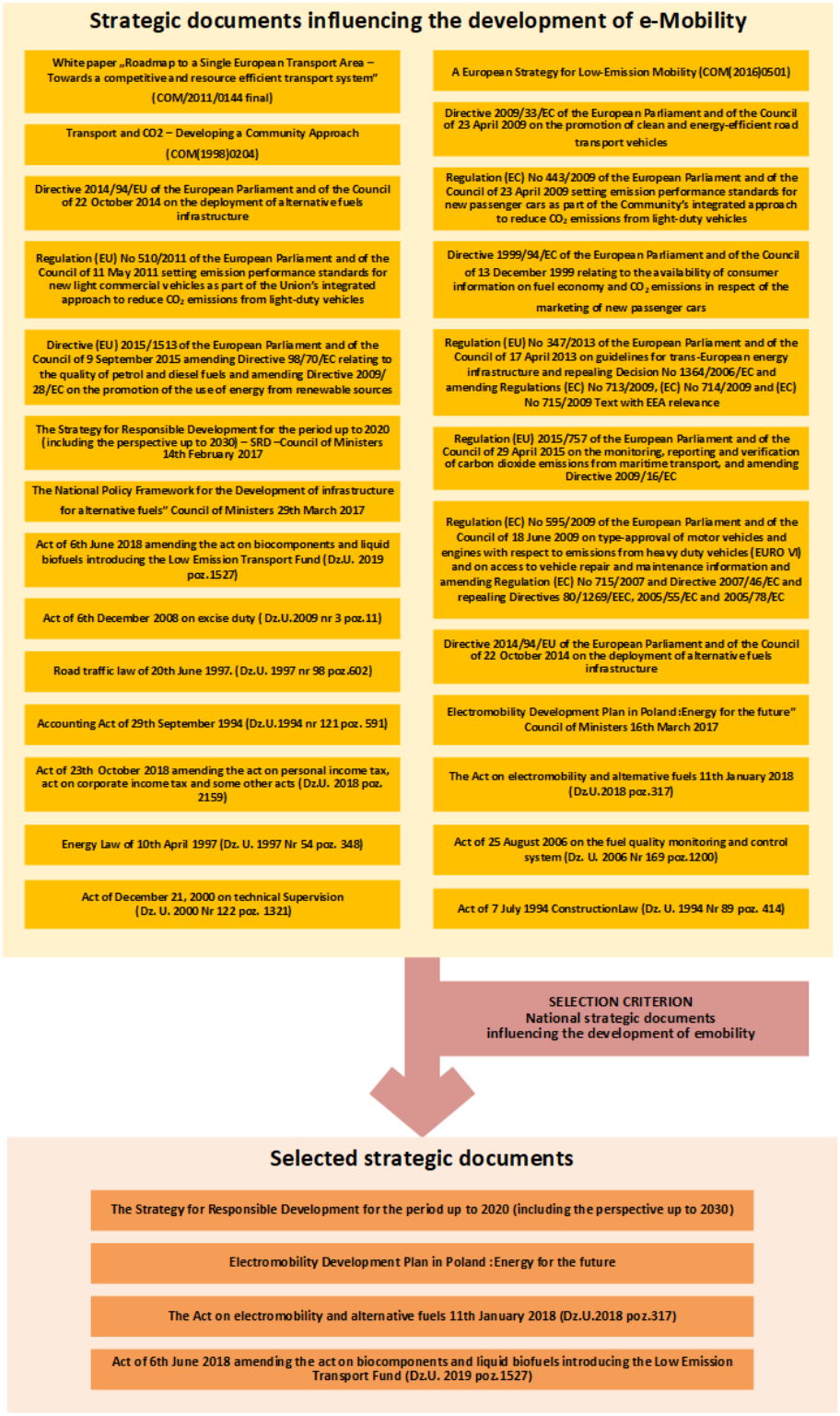

Figure 7: EU and national legislative framework of e-mobility development. Sources: [42, 83–105]

Policies	Issuers	Date	Main contents
The Strategy for Responsible Development for the period up to 2020 (including the perspective up to 2030)	Council of Ministers	14 th February 2017	✓ establishes Electromobility Develeopment Plan in Poland: Energy for the future; ✓ it creates conditions for the development of electromobility, among others by purchasing electric buses and supporting cities in the development of low-emission public transport; ✓ it introduces legal and organizational regulations contributing to the increase in the use of electric vehicles;
Electromobility Development Plan in Poland :Energy for the future	Council of Ministers	16 th March 2017	✓ it creates conditions for the development of electromobility by promoting charging infrastructure and encouraging the purchase of electric vehicles; ✓ develops the electromobility industry; ✓ stabilizes power networks by integrating vehicles with the network; ✓ indicates the need for action in five areas: changing the awareness of potential users; developing a system of benefits for the electric vehicle user; development of producers in the electromobility segment; adaptation of the energy network;
National framework for alternative fuels infrastructure development policy	Council of Ministers	29 th March 2017	✓ assesses the current state and possibilities of future market development with regard to alternative fuels in the transport sector; ✓ defines national general and specific objectives for the development of infrastructure for charging electric vehicles and for refueling natural gas in the form of CNG and LNG, as well as the market for vehicles powered by these fuels; ✓ formulates instruments supporting the achievement of the above-mentioned objectives and necessary for the implementation of the Electromobility Development Plan; ✓ presents lists of urban agglomerations and densely populated areas in which publicly accessible charging points for electric vehicles and refueling points for CNG are to be created;
The Act on electromobility and alternative fuels 11th January 2018 (Dz.U.2018 poz.317)	President	11 th January 2018	✓ sets out the rules for the development and operation of infrastructure for the use of alternative fuels in transport, hereinafter referred to as "alternative fuel infrastructure", including the technical requirements to be met by that infrastructure; ✓ formulates the obligations of public entities regarding the development of alternative fuels infrastructure; ✓ formulates information obligations regarding alternative fuels; ✓ describes the operating conditions for clean transport zones; ✓ defines the National Framework for the development of alternative fuels infrastructure policy and the manner of their implementation;
Act of 6th June 2018 amending the act on biocomponents and liquid biofuels introducing the Low Emission Transport Fund (Dz.U. 2019 poz.1527)	President	6th June 2018	✓ develops infrastructure for refueling natural gas, liquid biofuels and other alternative fuels, and for charging electric vehicles; ✓ introduces new business models based on alternative fuels and their infrastructure; ✓ develops a fleet of low-emission vehicles and low-emission public transport; ✓ makes it possible to reduce the costs of using vehicles based on alternative fuels for citizens; ✓ improves air quality resulting from the reduction of emissions of harmful substances by road vehicles - especially in large agglomerations; ✓ introduces an issue fee; ✓ funds from the Fund carry out the activities listed inter alia in the National Framework for the Development of Alternative Fuels Infrastructure, the Electromobility Development Plan in Poland and in the Act of 11 January 2018 on electromobility and alternative fuels;

Figure 8: The legislative framework of e-mobility in Poland. Sources: [42, 96–99].

Finally, the basis for the development of alternative fuels infrastructure in Poland is the National Framework of Policy for the Development of AFV. According to the National Policy Framework, in 2020, in 32 selected agglomerations 6,000 charging stations with normal charging power, and 400 charging stations with high charging power, which will be used by at least 50,000 EVs, are planned to be installed. At the same time, 70 compressed natural gas (CNG) refueling points are to be built in selected agglomerations for an estimated number of 3,000 vehicles powered by this fuel. The implementation of the objectives of the National Policy Framework is to contribute to the development of innovative and ecological transport in Poland, and the program itself is consistent with the EDP [97, 98].

Directive 2014/94/EU has given also the rise to two national legislative documents, such as: The National Framework for the Development of Alternative Fuels Infrastructure Policy and the Act on Electromobility and Alternative Fuels (AEAF) [42, 95, 98] (see, Figure 11). The AEAF is a very important legal act, whose necessity to be adopted results from both the need to implement European law and the need to regulate the alternative fuels market in Poland. This legal act resolves, among others the problem of lack of infrastructure in agglomerations, in densely populated areas, and along trans-European road transport corridors, which will allow free movement of vehicles powered by AFVs. The Act creates a regulatory system enabling the construction of public EV charging infrastructure by 2020, as well as refueling CNG and LNG vehicles. These investments should contribute to the development of low- and zero-emission transport, which in turn will lead, among others to reduction of air pollution level.

3.2.1. The system of incentives for e-mobility development

As described in Figure 9, the AEAF act provides for a system of incentives, including the abolition of excise duties on electric cars, larger depreciation charges for companies, exemption from parking fees or the possibility of electric vehicles moving along bus lanes. The document also introduces an obligatory share of electric vehicles in the fleet of parts of central administration bodies and selected local government units. The act also includes a legal framework for testing autonomous vehicles on public roads. In addition, it gives municipalities a legal basis to introduce clean transport zones for environmentally friendly vehicles.

Another legal document having a significant impact on the development of low-emission transport and alternative fuels in Poland is the Act of June 6, 2018 amending the Act on Biocomponents and Liquid Biofuels. Based on this document, the Low Emission Transport Fund (FNT) was created [99]. The main task of the FNT is to finance projects related to, among others: (1) construction or development of charging infrastructure for EVs used in transportation; (2) supporting manufacturers of EVs and entrepreneurs operating in the production of components of EVs for the means of transport, such as for example public collective transport operating in particular in urban agglomerations, or health resorts; (3) supporting tests and operational implementations of test results related to the use of electricity in transport; (4) educational programs to promote the use of electricity in transport; and (5) purchase of new vehicles using electric drives and others.

According to the latest provision of the AEFA Act, the support will be provided in the form of a subsidy, the amount of which will depend on the price and type of vehicle. Physical buyers of electric cars (EV) and fuel cell powered cars (hydrogen, FCEV) will be entitled to additional

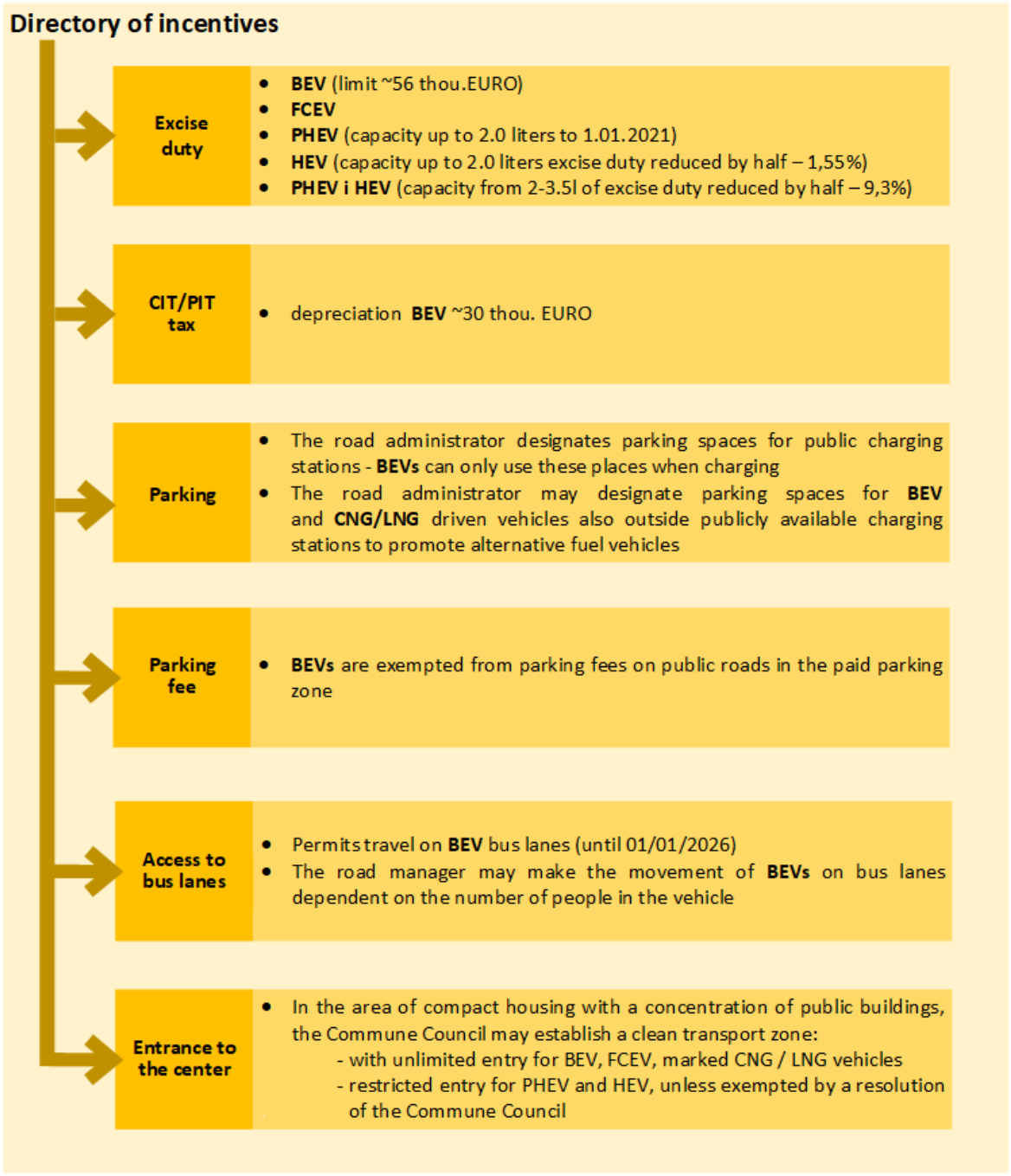

Figure 9: The set of incentives for e-mobility development in Poland.

payments[5]. The regulation does not apply to companies, sole proprietorship, natural gas cars, plug-in hybrids, electric buses, and electric motorcycles. All these vehicles will be included in the regulation for companies, which is being developed as part of a separate project.

The subsidy for a EV will be 30% of the cost, but no more than 9,375 EUR for one vehicle [6]. For a hydrogen car (FCEV) the surcharge is also 30% of the price, but the threshold is up to 22,500 EUR. The maximum purchase price of EV is 31,250 EUR, the maximum purchase price of FCEV is 75,000 EUR (these are gross prices, understood in accordance with Article 28 (2) of the Accounting Act), [102]. The additional payment is to be determined as a percentage depending on the maximum price, which the car cannot exceed.

We would like to emphasize, that although the regulations have been released a while ago, it is not yet known how large the subsidies will be. A refund can be obtained after showing the invoice for the purchased new car, which was not previously registered. Applications to obtain a subsidy will be considered as they arrive in a non-competitive manner until the funds are exhausted[7] To obtain a subsidy, the consumer will need to submit an application with a copy of the purchase invoice issued to a natural person, a copy of the registration certificate, a copy of the civil liability and AC insurance document for a year, an obligation to conclude such insurance for the next year. The car cannot be sold for another two years.

According to the Act, the FNT is to be supplied from many sources, including funds from the state budget as part of excise tax receipts, substitution fee receipts, funds transferred by the electricity transmission system operator and the emission fee. The fund is managed by the National Fund for Environmental Protection and Water Management, which deals with the announcement and recruitment of applications [99].

Figure 11 summarizes the policy issues of AFV market in Poland by presenting the schedule of legislative and strategic changes in Poland related to the process of implementing e-mobility in Poland. Summing up the analysis of national strategic documents, it should be stated that the provisions contained therein are consistent and should lead to the development of e-mobility in Poland. They also fit into the EU ideas promoting clean transport in the Community. The legal regulations developed justify the growing popularity of electric vehicles in public transport and in households, which is supposed to lead to the creation of new business models that will stimulate demand. The supporting system is supposed to bring several benefits, such as for example: (1) development of infrastructure for refueling natural gas, liquid biofuels and other alternative fuels, and for charging electric vehicles; (2) the possibility of introducing new business models based on alternative fuels and their infrastructure; (3) development of low-emission vehicle fleets and low-emission public transport; (4) improvement of air quality resulting from the reduction of harmful substances emission by road vehicles - especially in large agglomerations.

[5] As already mentioned, nowadays FCEV presence in Poland is negligible.

[6] According to the average exchange rate from the last quarter of 2019, it 1 EUR = 4 PLN

[7] On January 1st, 2020, 90 million Euros was already on the account of the government's Low-Emission Transport Fund .

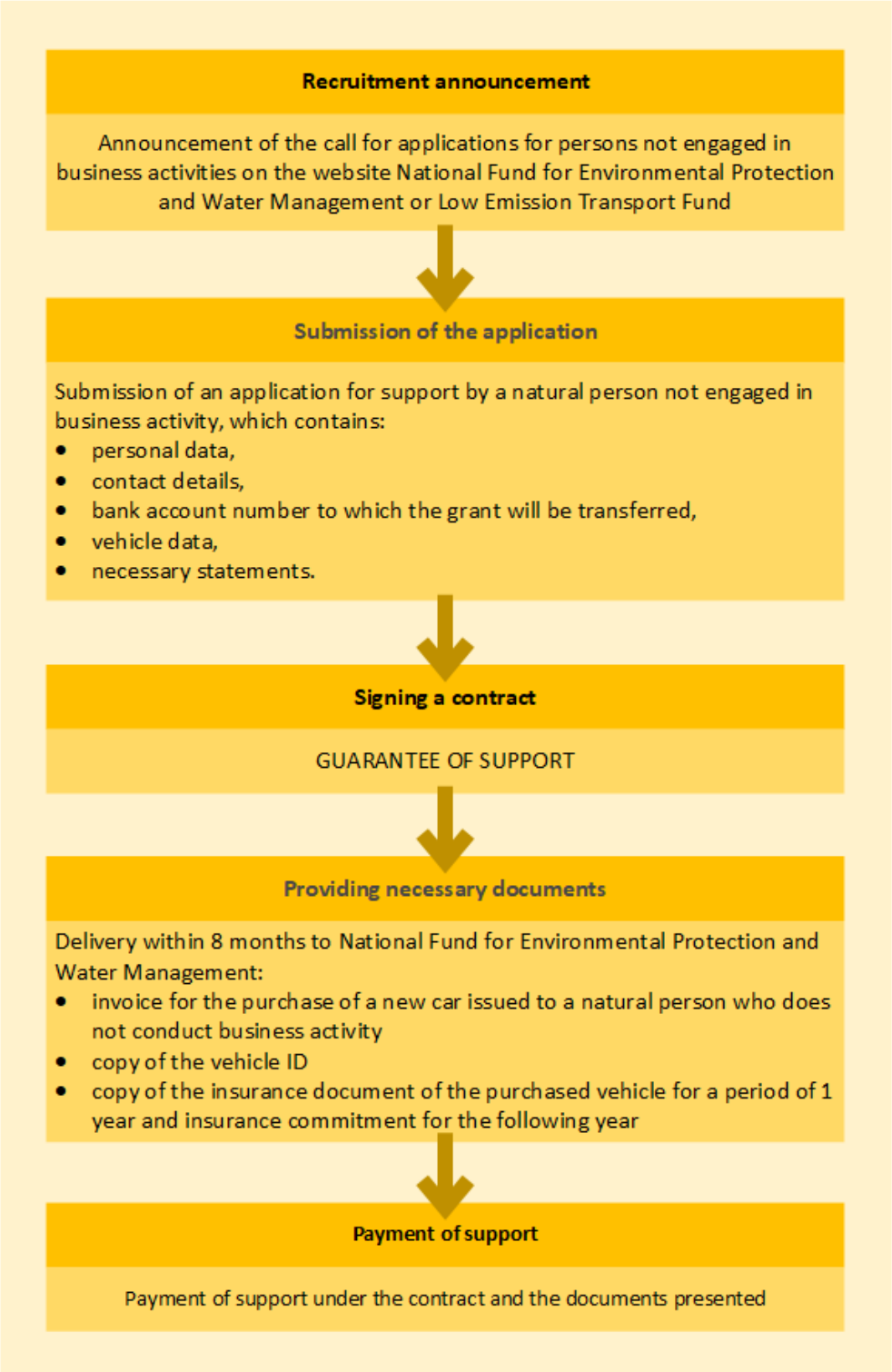

Figure 10: Procedure for granting support for the purchase of new EVs from the funds of the Low-Emission Transport Fund to natural persons not engaged in business activities.

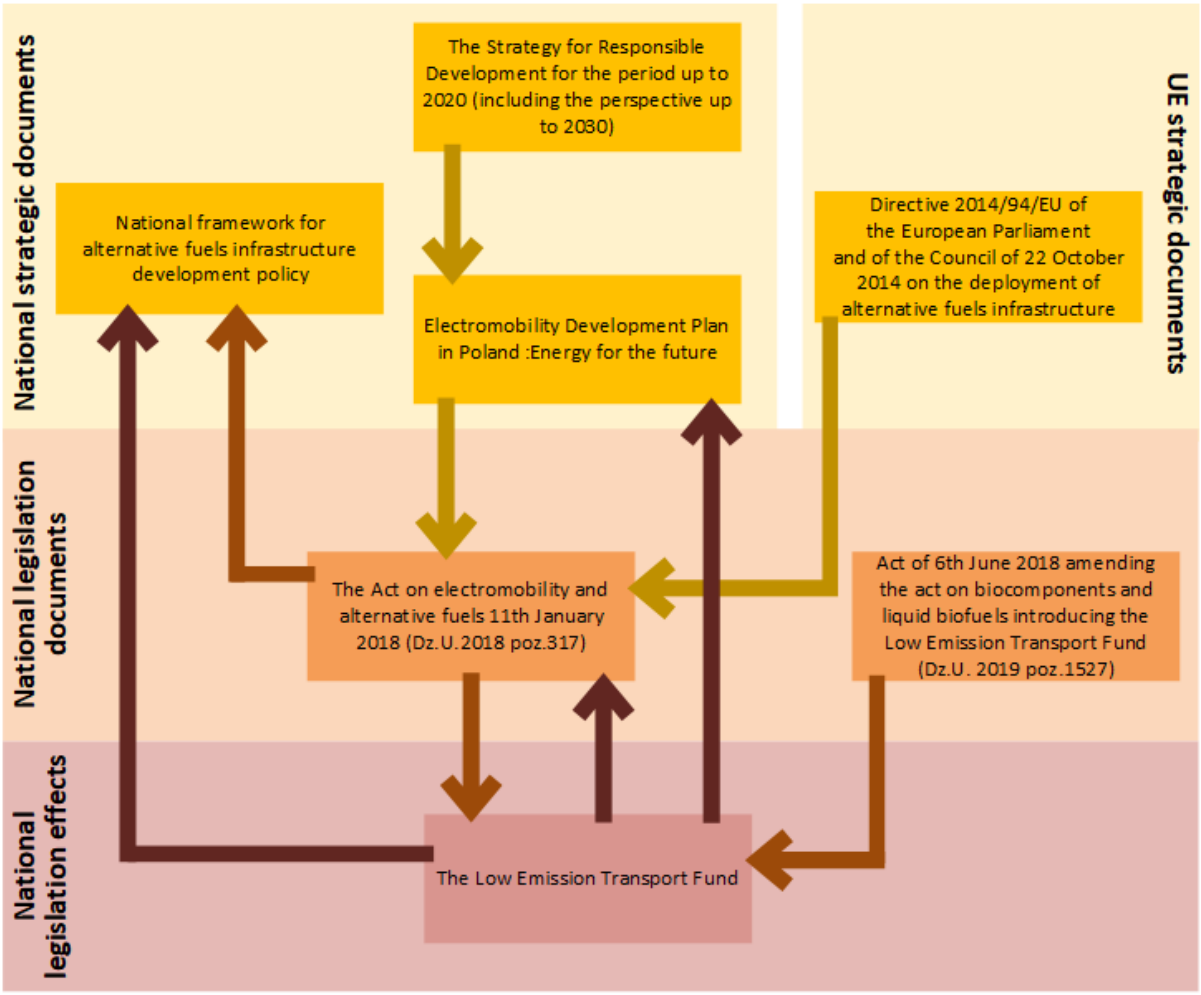

Figure 11: Schedule of legislative and strategic changes in Poland related to the process of implementing e-mobility in Poland. Sources [42, 95–99].

4. SWOT analysis of AFV market

SWOT analysis, is a well known method, used in management and market analysis. It is a popular technique which helps to organize and analyse the information. The name is an acronym and comes from 4 components which are the elements of this analysis (Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T)). Strengths and weaknesses are internal factors, whereas opportunities and threats belong to external factors [106]. In the second interpretation: S and W represent the present state, and O and T describe expected future conditions. In management, the SWOT analysis is a handy tool to evaluate external and internal environment of an organization. But SWOT analysis can be also used to evaluate the market and to propose the solutions to enhance the diffusion of a certain product or service. The general aim of each SWOT analysis is to develop a strategy, which is based on strengths and opportunities while erasing weaknesses and threats.

Recently this method has been implemented to analyze and explore the market of photovoltaic solar power in Africa and in China [107], electric power substitution for coal [108], ASEAN energy mix [109], renewable energy market in Japan, South Korea and Taiwan or in Pakistan [106, 110], CCS technology development in China [111] or for the Lithuanian AFV market [32].

The Figure 12 reveals the current strengths, weaknesses, opportunities and threats of the AFV market in Poland. Within our analysis we focus mostly on the EVs, as they represent the segment of AFVs which is supposed to develop dynamically in the coming years.

4.1. Strengths and weaknesses analysis

Strengths are internal factors that constitute benefits, advantages and hence are often called as key success factors. These factors positively distinguish electric cars from vehicles with conventional (combustion) drive. In contrast, weaknesses are internal negative factors that must be eliminated so that they do not weaken the strengths. They limit the development of the EV market. We conducted an analysis of the strengths and weaknesses of the electric car market, which covers the following areas of activity: technical, economic & social and environmental.

The greatest advantage of electric cars over combustion vehicles is their technical parameters. Electric drive is characterized by much higher efficiency, and thus electric vehicles are more energy efficient. This means that most of the energy supplied to the engine is converted to torque transferred to the vehicle axles. In the case of conventional vehicles, a significant part of the energy supplied is converted into heat and not transferred to the vehicle axles. Another important feature of the electric drive is its relatively simple design, which in turn is associated with lower operating and maintenance costs. During periodic inspections of electric cars, the number of consumable parts covered by the replacement is smaller compared to combustion cars. The periodic inspection of electric cars does not include, among others: engine oil change, oil, fuel and air filter changes. It should also be noted that in the case of EV, the service life of some components (i.e. discs, brake pads) is much longer. This is due to the fact that electric vehicles have energy recuperation systems. This means that part of the energy is recovered during braking, not just converted into friction by heat, as in conventional solutions.

The another strength of EVs is also zero exhaust fumes travel without emissions of $C0_2$ and other harmful gases. This advantage allows, in the case of Poland, to shift the production of air pollution from city centers to their outskirts. However, this does not solve the problem of reducing

Figure 12: The SWOT analysis of the AFV market in Poland.

$C0_2$ emissions, because the Polish energy sector generates over 80% of energy from fossil fuels. EVs are perceived as giving pleasure from driving especially in urban conditions, where the traffic takes place at high dynamics, but at low speeds. The indisputable advantage of the electric motor is access to high torque in almost the entire range of its work. The final effect is therefore good acceleration values appreciated by drivers.

EVs are new to the automotive market. To a large extent, these are pioneering structures often using modern style, offering new ways of interior design and functionality not available until now in conventional vehicles. Each of the major car manufacturers strives to distinguish their range of electric vehicles from the other products offered. It should also be noted that most of the offered EVs are equipped with the latest active safety systems, i.e. lane maintenance system, dead zone monitoring system, adaptive cruise control with the option of automatic vehicle stopping before a collision, etc. On the other hand, electric cars are also new to emergency services, which currently do not have the necessary rescue equipment on a large scale and proven procedures in the event of a breakdown or car accident involving an electric vehicle. Another important feature of electric cars is low noise emissions, which we can classify simultaneously as an advantage for passengers traveling in silence and as a disadvantage for pedestrians who may not hear the approaching vehicle.

The biggest barrier to the development of the EV market is their limited range. Currently offered cars do not allow long journeys without having to recharge the battery. This is particularly burdensome in Polish conditions, where the network of charging points is poorly developed. It should also be noted that the battery charging time is much longer than the refueling time of a combustion car. In addition, the charging time depends largely on the technical parameters of the charging points. The range of an EV is influenced not only by road shape and driving style, but also by a number of other factors that are not taken into account in conventional vehicles. The weakness is the fact that the energy consumption of an electric car is also affected by heating and ventilation systems, air conditioning, lighting and other driver assistance systems. An undesirable final effect is therefore reduced mobility flexibility. The next unfavorable technical aspect of EV is their battery, which has a limited lifetime. This feature can be a big barrier on the secondary market. A car with a used battery will lose its value considerably or will not be suitable for further sale. It should also be remembered that EVs usually have lower maximum speed values compared to conventional constructions. This is particularly evident in the commercial vehicle segment, which is not discussed and considered in the article.

The developed SWOT analysis also includes the economic and social aspects. From the point of view of internal economic factors, the cost of purchasing electric vehicles is much higher than for conventional cars, despite the possibility of applying for subsidies, excise duty exemption or reduction of income tax. It should be remembered that largely limited production capacity and high costs of producing the battery for electric cars are other economic barriers. These restrictions also cause a longer delivery time of the vehicle to the customer, and sometimes lead to the formation of queues/ lists for registration for EVs. On the other side, due to the low availability of EVs and relatively high prices, these vehicles are regarded as prestigious, arousing public interest. Another incentive to buy an electric car are amenities in city traffic such as: the ability to travel by bus lanes, free parking, and in the future the opportunity to enter the so-called clean transport zones.

The strengths of EVs can also be sought in the environmental aspect. Electric cars are seen as

environmentally friendly because they do not directly emit greenhouse gases. At the same time, they contribute to raising public awareness of environmental protection, rational energy consumption and the use of renewable energy sources (RES). Often, when buying an electric car in Poland, a simultaneous investment in solar home photovoltaic installations for energy production is considered. This situation is also going the other way, i.e. when investing in a home solar installation, the purchase of an electric vehicle is increasingly being considered.

The weakness associated with the development of e-mobility in the environmental context is the need to significantly increase the global extraction of raw materials (such as coblat) necessary for the production of batteries. This can lead to increased environmental degradation in the long run. The lack of system solutions for recycling and utilizing batteries can be seen as a barrier to the development of the e-mobility market and can contribute to changing the perception of EVs as environmentally friendly. The further development of the EV market needs highlighting of the strengths of electric vehicles while eliminating the weaknesses. SWOT analysis of internal factors showed that there are still many technical, economic and environmental problems to be solved to strengthen the e-mobility market in Poland.

4.2. Opportunities and threats analysis

Opportunities include all favorable external factors that can enhance and support the AFV market, whereas threats refer to such external factors, which may hinder or even jeopardize the market success and diffusion. We have examined the external factors in terms of the technical, economic & social, environmental and legislative & policy issues. Each of them is equally important and interdependent.

In terms of technical issues the most significant opportunity is connected with the technology advancement and development of batteries and charging stations. Thanks to technology improvements not only in the production and maintenance of the batteries and charging stations, but also of overall design and construction of electric vehicles, many of the present shortcomings (such as for example limited battery life or long recharging times) can be solved. The ongoing standardization process, which is being implemented among the manufactures, may be also helpful in overcoming current technical problems faced on the supply side of the market. At the same time, most of the threats have also their origin in batteries and charging stations. Nowadays the charging infrastructure in Poland is still very limited, which of course hinders effective and comfortable usage of EVs. Moreover, manufactures deliver various types of chargers, which are often not compatible with the modern batteries, what in turn leads to inefficient time and energy needed to charge the car. Secondly, there are currently many accidents with EVs (e.g. backfire of the battery) which lowers the consumers' approval and interest. Thirdly, the issue with recycling the components of the batteries has not been solved yet.

Regarding external factors describing opportunities and threats in the macro- and microeconomic environment most of them concern cost and benefits analysis. In terms of cost, EVs are still and will continue to be much more expensive than conventional cars from the similar segments. Even the introduced system of policy support such as subsidies, VAT and excise duty exemption, does not make them really attractive to the customers. It is mainly due to the fact that the types of cars which are intended to be subsidized belong to the most basic ones. They do not posses any additional systems or devices, which make driving more comfortable and attractive. Moreover,

many of the car manufactures, decrease the price of their basic EV models to adopt to the price limits dictated by the regulation. This price does not truly reflect the real cost of production. It may lead to the sudden price change in the coming future. Most of Poles still buy their cars on the second-hand market. The second-hand market for EVs has not developed yet. Moreover it is not clear how to estimate the value of the used EV with regard to its components, such as a battery.

The future of EVs may be also endangered by the still high cost of new infrastructure, especially in terms of charging stations. At the same time, the increasing presence of EVs on the Polish roads, may lead to creation of new services, such as for example mobility concepts, such as EV car sharing. This in turns, bring new revenue possibilities for the car manufacturers. EVs can be also seen as an element of the smart house and smart cities [112].

Among social issues two have the greatest meaning. First, possessing an EV becomes a new fashion and the determinant of social prestige. And the same time, people perceive the current weaknesses of EVs and are not sure about the future development of this market. It limits their eagerness to buy and willingness to pay for such a car. Also the accidents with the EVs (e.g. sudden backfire, electric shock or collision with pedestrians) lower customers' acceptance and interest. There are some negative perceptions and negative word-of-mouth based to some extent on the messages in the social media (Twitter or Facebook).

Finally, environmental issues include some controversial aspects of EVs. AFVs, are not fully pro-environmental. This is true that they support the decrease of exhausting fumes in the cities, and hence they have a positive impact on the quality of living. But at the same time, the ecological footprint of the production of the EV, and its components, such as a battery, have a negative impact on the environment [113]. There are still many unsolved problems, such as storage and recycling of the batteries. Moreover, to make EVs more ecological, most of the electricity should be produced in the renewable energy sources. This is still not the case of Polish power system, where most of the electricity is produced from the fossil fuels, and renewable energy cover only around 18% of the energy sources. Among the chances that may increase the position of EVs in the future, the following should be mentioned: (1) current promotion of e-mobility in mass-media raise consumers' awareness of environmental protection and interest towards sustainable transport in general, and AFVs in particular; (2) interdependence between e-mobility and renewable energy sources installed among residential consumers (i.e. we observe the increase of consumers' interest in PVs in Poland (see for example [114])) and the raise of independence from fossil fuels due to the usage of RES for e-mobility).

Last but not least, we would like to focus on the policy issues. As already mentioned in Section 3, Polish e-mobility is supported by the strategic and legislative regulations such as E-mobility Development Program, National Framework for Alternative Fuels Infrastructure Development Policy, as well as the Act on E-mobility and Alternative Fuels (AEAF). But these legislation does not provide clear rules on the practical level. Still, the consumers and manufacturers are not sure if and how large the subsidizes will be. This is the most important shortcoming of the e-mobility supporting system. So, from one side the existence of the regulations is a great opportunity, but because of the lack of stable and clear regulations regarding subsidizes and further growth of the charging infrastructure, it is also a severe obstacle for the further smooth development of AFVs market in Poland.

Here, it must be emphasized that the policy support for AFVs in Poland is very unstable and

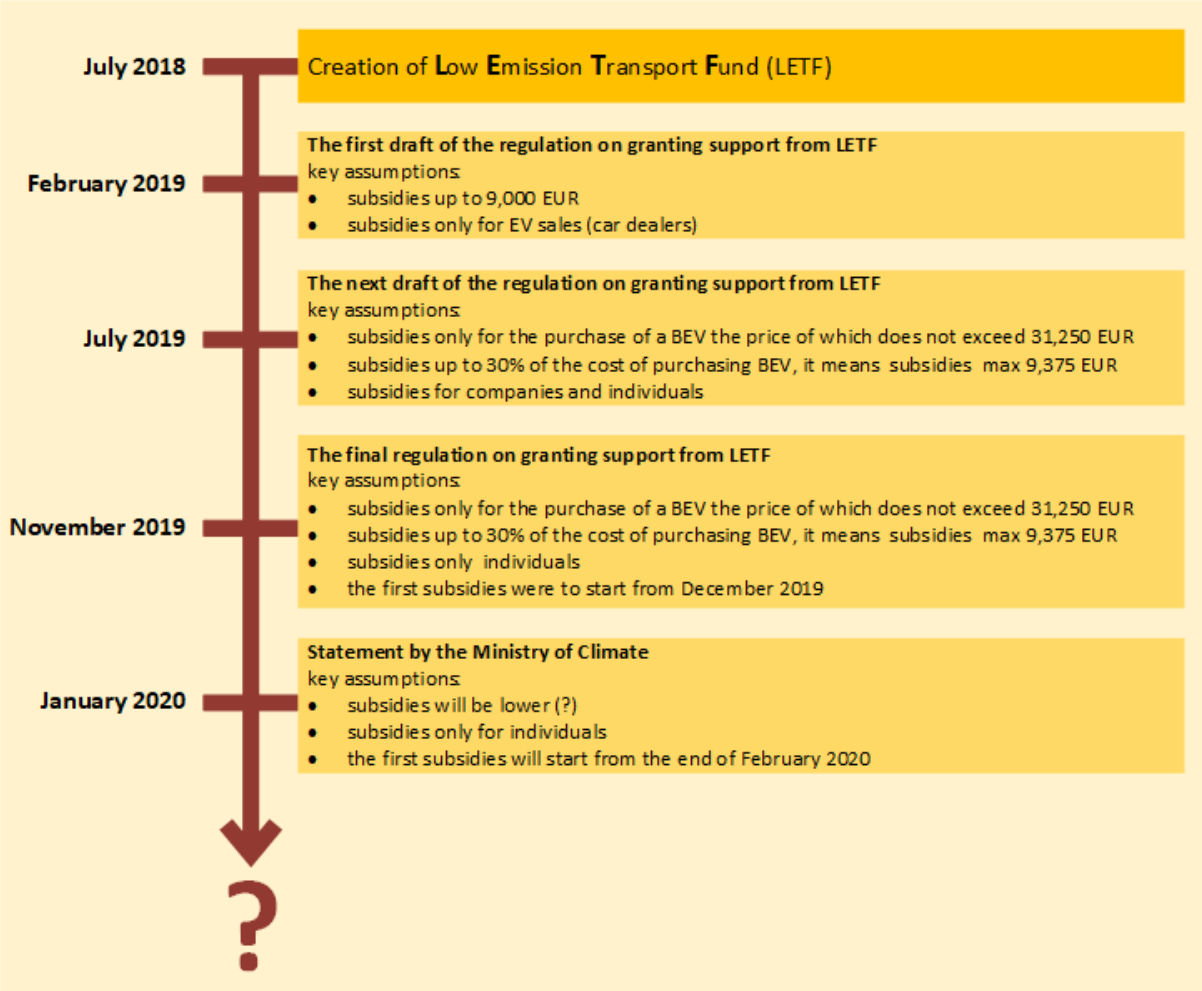

Figure 13: The illustration of the pace of changes to contracts regarding subsidies for EVs.

opaque. The pace of changes in legal regulation is fast and the market does not manage to adopt to these rapid changes. Figure 13 illustrates how many times the policy support system has been modified in the last couple of months. And this is not the end. According to the last news from the end of January 2020, the subsidies will be much lower than proposed before and the tax exemptions will be larger. As noticed by the Polish car market experts, the sudden change of the governmental policy support may prove to be the decisive factor in the resignation from buying an electric car[8]. It is also worrying that the introduction of the announced changes has not been in any way consulted with the industry. E-mobility in Poland is at an early stage of development, so the law should be adapted to market realities. At present, public opinion has not officially received key information

[8]https://auto.dziennik.pl/aktualnosci/artykuly/6428852,doplata-samochod-elektryczny-rzad-kwota-limit-jak-uzyskac-doplate-przepisy.html (in Polish), accessed February, 6th 2020

Table 6: Strategies derived from SWOT analysis.

	Strengths	Weaknesses
Opportunities	SO strategy	WO strategy
Threats	ST strategy	WT strategy

from the government about the exact date of starting subsidies, the amount of funds allocated to support or the rules for submitting applications. As a result, a significant number of potential FNT beneficiaries are delaying purchasing plans, and the Polish e-mobility market has been suspended for many months.

5. Conclusions and policy recommendation

5.1. Challenges for further development of AFV in Poland

Table 6 shows four possible strategies which may be derived from the SWOT analysis: (1) SO strategy use strengths to take advantage of opportunities (maxi-maxi strategy); (2) ST strategy use strengths to avoid threats (maxi-mini strategy); (3) WO strategy overcomes weaknesses by emphasizing the strengths (mini-maxi strategy), and (4) WT strategy minimizes weaknesses by avoiding the threats (mini-mini strategy). The conducted SWOT analysis let us conclude that currently Polish AFV market, with a special focus on EVs, needs first of all WO strategy to minimize the current shortcomings by strengthening the opportunities in technical, economic & social, as well as environmental and legislative environment.

Our quantitative analysis has revealed a lack of clear and significant privileges for customers of electric vehicles in comparison to other European countries (similar results have been also achieved in the up-to-data work of Slusarczyk et al. [27]). At the same time, electric car sales growth dynamics in Poland, which is over 306% year on year (from 2018 to 2019), indicates that Poles are interested in EVs, what is common to most EU countries [51]. But, even though the Polish transportation portfolio slowly changes, Poland is still far behind the European leaders, such as Norway (with 73,000 electric vehicles sold in 2018), Germany with 67,500, UK with nearly 60,000 and France with more than 45,000 [51]. What distinguishes Polish market is the still limited common access to the charging infrastructure and the lower purchasing power of most of the citizens in comparison to the West European countries. The first issue already shows some improvement. The implementation of the AEAF Act should be a flywheel in the process of change. Financially, Poles are also getting better, but EVs are still too expensive for most of them[9].

The most important problems faced currently by the Polish AFVs market in general, and EVs market in particular, include unstable and unclear regulations that may discourage both: producers and buyers from engaging in this market segment. Secondly, the much higher prices of EVs in

[9]Poles on average had EUR 7,589 to spend in 2019, which is a little more than half the average European purchasing power of EUR 14,730, putting them in 29th place out of 42 countries surveyed by GfK, for more details see https://www.gfk.com/de/insights/press-release/Europeans-spend-eur14739-per-person-in-2019/?utm$_campaign$ = $Global_Social_Posts_Non - Campaign_2019utm_source = twitterutm_medium = social(accessed7thFebruary2020)$

comparison to the conventional vehicles together with many unsolved issues regarding the batteries and charging stations belong to the most significant barriers of adoption.

The formulated portfolio of actions towards enabling sustainable development of transportation in the segment of passenger vehicles proposes three main directions in general: (1) further technology development in order to minimize the current technical weaknesses of the EV. Here, the construction, production and utilization and recycling of a battery is a vital issue that must be solved to include EVs into truly sustainable solutions; (2) further development of charging infrastructure to make usage of EVs, especially outside the cities, more comfortable and reliable. This aspect of EVs must be also taken into consideration in planning the future of the power system. Plenty of dispersed loads, as the EVs can be perceived from the electrical engineering point of view, may influence the technical parameters of the electrical grid, such as voltage level, and hence raise safety and reliability issues of the functioning of the power system. On the other side, the presence of EVs in the power system can be treated as an element of smart grid approach. Batteries could be seen as a storage of electricity, which can also be used in a clever way to improve the efficiency of the power system; (3) education of consumers regarding the advantages of the EVs, especially in the crowded city centers (e.g. lower noise level, zero exhaust fumes, etc) and provision the financial incentives to enhance consumers' willingness to buy an EV.

In Poland two more issues must taken into consideration. First is the policy support system, mentioned already earlier, which in case of Poland must provide clear and stable regulations. The policy support must take into account the market realities. It should consider the opinions of the manufactures, automobile market's experts as well as customers. For most of the countries, even those with a higher GDP per capita than Poland, some subsidies are needed to encourage customers to pay much more for an EV than for a similar CV. In case of Poland, where the purchasing power of an average citizen is much lower with regard to the EU average, the financial support is even more important. The Polish market seems to be open for new market solution, such as EVs, but only if the price is more acceptable and if the system of charging stations is guaranteed. Otherwise, the consumers will not buy such a car, even if it is fashionable.

5.2. Limitations of the study and future work

Our study has been limited to one country, but many of our observations are also true for other countries from the Central and Eastern Europe, where the introduction of e-mobility is on the similar stage. Many of the revealed strengths and weaknesses among AFV internal factors, as well as, part of the opportunities and threats in terms of technical, social and natural business environment are generally true for most of the modern economies.

The current survey will be followed by the field experiment among adult Poles, investigating consumers knowledge, awareness and preferences towards AFV in general, and EV in particular. The study will show which consumers' attributes on one side, and which EV's features on the other enhance the perspective of successful AFV diffusion in Poland.

Acknowledgments

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