Article

Perspectives for Mitigation of CO₂ Emission due to Development of Electromobility in Several Countries

Karol Tucki ^{1,*} , Olga Orynych ^{2,*} and Mateusz Mitoraj-Wojtanek ¹

¹ Department of Production Engineering, Institute of Mechanical Engineering, Warsaw University of Life Sciences, Nowoursynowska Street 164, 02-787 Warsaw, Poland; mateusz.wojtanek@gmail.com

² Department of Production Management, Bialystok University of Technology, Wiejska Street 45A, 15-351 Bialystok, Poland

* Correspondence: karol_tucki@sggw.edu.pl (K.T.); o.orynych@pb.edu.pl (O.O.); Tel.: +48-593-45-78 (K.T.); +48-746-98-40 (O.O.)

Received: 29 June 2020; Accepted: 6 August 2020; Published: 10 August 2020

Abstract: The creep trend method is used for the analysis of the development of electric car production in three regions: The United States, the European Union and Japan. Based on vehicle registration and population growth data for each year the creep trend method using historical data for the years 2007–2017 is applied for forecasting development up to 2030. Moreover, the original method for calculating the primary energy factor (PEF) was applied to the analysis of power engineering systems in the regions investigated. The assessment of the effects of electromobility development on air quality has been performed, reduction values for pollutant and greenhouse gas emissions have been determined, which was the main objective of this manuscript. Mitigation of air pollutant emissions, i.e., carbon dioxide (CO₂), carbon monoxide (CO) and nitrogen oxides (NO_x) was estimated and compared to the eventual expected increase of emissions from power plants due to an increase of the demand for electricity. It can be concluded that electricity powered cars along with appropriate choices of energetic resources as well as electricity distribution management will play the important role to achieve the sustainable energy economy. Based on the emission reduction projections resulting from the projected increase in the number of electric cars, (corrected) emissions will be avoided in 2030 in the amount of over 14,908,000 thousand tonnes CO₂ in European Union, 3,786,000 thousand tonnes CO₂ in United States and 111,683 thousand tonnes CO₂ in Japan.

Keywords: electromobility; CO₂ reduction; energy distribution management; energy generation technology management; biofuels

1. Introduction

Continuous development of the economies of the European Union, North America and Asia has been clearly observed in recent years [1–3]. This development results in the growth of transport, including private road transport [4,5]. In 2010, approximately 58.4 million passenger cars were produced worldwide and in 2018, production reached 70.5 million [6,7].

The highest number of registered passenger cars in the European Union was recorded in Germany (46.5 million—data from 2017), Italy (37.9 million—data from 2016) and France (32 million—data from 2016) [8]. On the first position of the list of EU's most motorized societies is Luxembourg (670 registered passenger cars per 1000 residents), followed by Italy (625 cars per 1000 residents) and Finland (617 cars per 1000 residents) [8]. During the period of five years (from 2013 to 2017), the highest growth in the number of registered passenger cars was recorded in Slovakia (18%), then in the Czech Republic and Portugal (17% each), Estonia (15%), Malta and Hungary (14% each). In 2017, the highest number of cars aged over 20 years within the European Union occurred in Poland (35.2%).

Preferences as to whether a brand-new passenger car should be powered with petrol or Diesel engine differ among the member states of the European Union (EU). The highest share of petrol-powered vehicles among newly registered ones in 2017 was that in The Netherlands (80.0%), Estonia (74.8%), Finland (68.7%), Denmark (64.4%) and Malta (62.8%). On the other hand, the highest share of cars with Diesel engines among brand new passenger cars was recorded in Croatia (76.1%), Lithuania (68.5%), Romania (67.3%), Ireland (65.6%), Portugal (62.1%) and Spain (50.7%). In 2017, the highest share of alternative fuels in new passenger car registrations occurred in Poland (8.7%) and Italy (8.2%) [6].

Continuous growth in the number of cars with combustion engines contributes to a continuous increase in greenhouse gas emissions—carbon dioxide (CO₂) [9,10]. The volume of this substance in car exhaust gases depends on the type of engine and composition of the air-fuel mixture [11–15].

Irrespective of origin, the CO₂ is recognized as a one of the most influential greenhouse gases [16,17]. State authorities worldwide attempt to resolve that problem in many different ways [18,19]. These include supporting the shift to alternative fuels in the sector of private road transport [20–22]. The electric car is an example of alternative drive vehicle [23,24]. While moving, they do not emit any impurities into the environment [25,26]. Thus, they provide a solution allowing local elimination of increased pollutant emissions, e.g., in large cities where the effect of scale could occur [27,28]. An alternative to those are hybrid vehicles, which have an electric engine and a small combustion engine [29–31]. There are also other low-carbon alternative drive vehicles (for example hydrogen powered), but due to their very low popularity and low availability on the market, they were not included in the calculations.

Growing interest in electric cars has been noticeable on the global automotive market in recent years, which is a signal for the development of innovative research [32–34]. More and more automotive concerns are offering vehicles powered with electric engines or hybrid cars.

Poorly developed network of charging stations is one of the main barriers hindering more dynamic development of the electric vehicle (EV) market in many EU states [35,36]. That poses challenges to electricity providers, transmission system operators and electricity distributors. Undoubtedly, development of electromobility impacts operation of transmission and distribution networks [37,38]. Appearance of an increased number of electric vehicles on the market will cause local electricity consumption changes. Systems for power balancing in low voltage networks, management of balance differences and electricity technical losses are necessary [39–41]. As the sector of electric vehicles and vehicle charging stations is only at an initial development stage and taking into account its interdisciplinary character, it is attractive to potential investors, both in areas directly connected with electric cars and in related industries satisfying the needs of the electromobility sector [42–44].

This study will compare three economic regions belonging to different cultural circles, remaining in different economic environments on three different continents: North America, Asia and Europe.

The United States of America is the third country of the world in terms of population and the most densely populated country of North America. The country is inhabited by nearly 330 million people, a great majority of whom (82.5%) living in urbanized areas [45,46]. Relatively low petrol prices and the country's large area played an important role in popularization of passenger cars (in particular those with a large engine capacity) as a means of personal transport [47,48]. Initially, the global ecological trend caused by climate changes was not an important issue in the US. Recently, however, increasing attention has been paid to air quality [49,50]. The trend initiated by the manufacturer of premium electric cars—Tesla—is being continued and developed [51–53].

The European Union is an economic and political union of 28 democratic European states. It is considered as a single region, because it is formed as a result of deep political, economic and social integration [54,55]. In terms of legal and regulatory aspects, the European Union exercises significant influence onto member states, e.g., by imposing emission limits or regulating environmental issues [56–58]. Nearly one fourth of EU's CO₂ atmospheric emissions come from transport (including 72% accountable to road transport) [59–62]. Many countries recognise the significant role of road transport, including the increasing number of personal forms of transport, in the emissions of greenhouse gases and other harmful substances into the atmosphere, which directly translates into deteriorating quality of air in European

cities [63,64]. Some of those countries have undertaken actions aimed at development of electromobility and other alternative fuels to enable reduction of the emissions [65,66].

Japan is an island country in eastern Asia, characterised with one of the world's highest social development indexes [67–69]. According to the report published by the United Nations, Japan takes the nineteenth place in the world and the third place in Asia (after Hong Kong and Singapore) [70,71]. The Human Development Index (HDI) is a summary measure for assessing long-term progress in three basic dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. Japan has paid great attention to climate related issues, renewables sources of energy and environment protection for many years now. It was already in 1997 that the Japanese automotive concern Toyota launched the first serially manufactured hybrid car—Toyota Prius [72,73]. Until this day, the brand has remained the leader of the hybrid vehicle market [74–76].

2. Materials and Methods

The following list contains a collection of the most important quantities used in calculations, together with appropriate symbols and units (Table 1).

Table 1. Symbols and units used in calculations.

Parameter	Description	Unit
k	smoothing constant equal to the number of consecutive expressions of the time series	-
i	segmental equation number ($i = 1, \dots, N - k + 1$)	-
a_i, b_i	evaluation of the parameters of the i -th segmental equation	-
$f_i(t)$	smoothed (theoretical) value for the period t obtained from the i -th segment equation	-
Y_t	the value of the forecast in period t	-
Y_N	the smoothed value of the forecast variable	-
$\bar{u}$	the smoothed value of the trend increment of the forecast variables	-
N	number of words of the time series of the forecast variables	-
V_T	point prediction error	-
W_r	Theil's discrepancy coefficient	-
E_i	quantity of electricity produced from the given source in the year in the country	[MWh]
E_c	total quantity of electricity produced in the year in the country	[MWh]
η_i	efficiency of primary energy conversion into electricity for the respective fuel	[%]

The study is based on an analysis of official reports devoted to the electromobility sector and the power engineering sector in the European Union, US and Japan. Other source materials available on this subject were also used for the calculations and assumptions. Based on the information obtained, an analysis concerning development dynamics of the sector in the European Union, US and Japan was carried out. The official reports and source materials used in the analysis were referred to in individual parts of the manuscript.

Using the creeping trend method [77], a forecast illustrating the condition of the sector in the countries covered was prepared in the perspective of the year 2030. The primary energy factor (PEF) used therein reflects efficiency of the power engineering system of the analysed areas in the context of primary energy conversion into electricity. The factor connects primary and final energy, it is a “conversion factor” that simplifies the calculations and allows to compare different energy sources. The PEF is a good indicator of the condition of the power grid and the efficiency of the whole system, but it is also a simplification. Of course, it does not consider all influencing factors, such as for example low conversion for RES due to losses. In this paper, authors assume that the PEF is a determining indicator.

Based on data obtained from the review of reports and literature, as well as with the use of calculation results, forecasts and the factors mentioned above, the environmental effect accompanying the changes was calculated. Expected impact of electromobility onto air quality in the regions covered was calculated thanks to the analysis of change dynamics and the forecast made; moreover, that enabled

determination of the values related to reduction of pollutant and greenhouse effect emission, which is the main objective of this study.

The analysis was conducted using data since year 2010 because that is the breaking point when something serious started to happen in the electromobility sector. Previously, there were no or a negligible number of electric cars in the areas concerned. The parameters of market (prices, car characteristics, infrastructure etc.) change, but in a positive way for electric cars and inducing their development. The simplified mathematical approach has been chosen because it resembles the phase of introduction and growth of a new product (which can be assumed to be electric cars appearing on the market) in the product life cycle.

The manuscript is a continuation of the article published by the authors on the dynamics of development of the electromobility sector in Poland and Europe [78].

2.1. Development of Motorization in the Analysed Regions

Continuous economic development directly contributes to development of the road transport sector, in terms of both passenger and cargo transport [79–81]. According to the US transport statistics department, over 272.5 million “lightweight vehicles” were registered in the US in 2017, a great majority of which were passenger cars [82]. In 2016, nearly 383 million vehicles were registered in the European Union, including over 85% of passenger cars [83,84]. According to the Ministry of Infrastructure, Transport and Tourism of Japan, almost 62 million cars were registered in that country in 2017 [85,86].

Still, the total number of registered vehicles is not a reliable measure. Each of the analysed regions is characterised with a completely different population [87–89]. The value illustrating the correlation among these two figures is the so-called motorization index or passenger car saturation coefficient (PCS) [90,91]. It is expressed as the number of passenger cars per 1000 residents and constitutes an important measure indicating the degree of road transport development as well as civilizational development of the society. A positive change indicates increasing mobility of societies and accompanying development of passenger transport and individual motorization. PCS is treated, in particular with regard to less wealthy countries, as one of economic outlook growth indicators.

(a)

Figure 1. Cont.

(b)

Figure 1. Motorization development in the analysed regions: (a) Population in the US, EU and Japan in 2007–2017 [m]; (b) Number of cars registered in the US, EU and Japan in 2007–2017 [m vehicles].

Figure 1a,b above present a comparison among the number of registered cars and the number of residents of the analysed regions in years 2007–2017. It can be seen that, over all the years, the European Union had the most numerous population and the highest number of registered passenger cars. Growth in the number of residents in 2007–2017 was the most significant in the US: 7.94%, with 2.85% in the EU and a negative value of -0.95% in Japan. On the other hand, the greatest increase in the number of registered vehicles was observed in the European Union: 9.6% , with 6.51% in Japan, while the United States recorded a decrease of 1.43% .

A more reliable method for evaluating the society's motorization degree is the motorization index mentioned above, whose values in 2007–2017 are illustrated on the graph below (Figure 2). Its definitely highest value is observed in the United States—in 2017, it was equal to 595.7. As the same time, in the European Union it was 503.2, with 483.1 in Japan. That means that per each two residents of the US and EU there falls more than one car, with only slightly less in Japan. During the analysed period, the coefficient showed a growing trend in Japan and in the European Union, with its values increasing year by year. On the other hand, in the United States it reached its maximum value in 2007 and was continuously falling afterwards. That correlates with the trends noticeable in the area of new passenger car registrations and demographic data. Changes of the coefficient over time have been influenced by many different factors. For example, decrease in the number of car registrations in the US since 2008 was strictly connected with high prices of oil which peaked at that time [92]. As far as the European Union is concerned, the increase is related to continuous development of its member states as well as new member states joining the European Union. In this case, even if highly developed countries do not increase the country's PCS coefficient materially, other countries on a lower development stage demonstrate significant year-on-year growth. Consequently, continuous growth of the indicator is maintained over time.

Figure 2. Motorization indexes in the United States, European Union and Japan in 2007–2017.

Regardless of reasons underlying the changes, if the trends observed are maintained, this may cause growth in the absolute number of cars on the roads, increased consumption of oil, followed by increases in the quantities of generated air pollutions, including carbon dioxide.

2.2. Analysis of Electromobility Development Dynamics in the European Union, US and Japan

Based on figures concerning vehicle registrations in European Union member states, contained in the report published by the International Council on Clean Transport (ICCT) [93], data concerning vehicle pools of individual European countries monitored by the European Alternative Fuels Observatory (EAFO), “The Motor Industry of Japan” report published by the Japan Automobile Manufacturers Association [94], as well as sales figures compiled by the US Alliance of Automobile Manufacturers [95], a graph comparing development dynamics of the electric vehicles market in the European Union, United States and Japan was prepared. The graph starts from 2009, as no significant interest in electric vehicles was observed before that year [96].

Historical data concern the period of 2009–2016, while data for the subsequent period result from the creeping trend predictive method forecasting [77].

The mathematical model used for the creep trend method is presented in the literature [77,97–99].

The creeping trend method is one classified as an adaptive model, using harmonic weights. For the predefined $Y_1, Y_2, Y_3, \dots, Y_N$ time series and the k smoothing constant set on any level (while $k < N$), linear parameters of the trend function are estimated based on consecutive fragments of the series:

$$f_1(t) = a_1 + b_1 t \text{ for } 1 \leq t \leq k \quad (1)$$

$$f_2(t) = a_2 + b_2 t \text{ for } k+1 \leq t \leq 2k \quad (2)$$

$$f_{N-k+1}(t) = a_{N-k+1} + b_{N-k+1} t \text{ for } (N-k+1) \leq t \leq N \quad (3)$$

For any t , where $1 \leq t \leq N$, Y_t values are matched by smoothed theoretical values obtained by means of the $f_i(t) = a_i + b_i t$, functions presented above where $i = 1, 2, 3, \dots, N - k + 1$. This rule concerns the following functions:

$$d(t) \leq i \leq g(t) \text{ for } d(t) = \begin{cases} 1 & \text{for } t = 1, 2, 3, \dots, k \\ t - k + 1 & \text{for } t = k + 1, \dots, N \end{cases} \quad (4)$$

and:

$$g(t) = \begin{cases} t & \text{for } t = 1, 2, 3, \dots, N - k + 1 \\ N - k + 1 & \text{for } t = N - k + 2, \dots, N \end{cases} \quad (5)$$

An additional and final smoothening of the function is calculation of average values of all smoothenings:

$$\bar{t} = \frac{1}{1 + g(t) - d(t)} \sum_{i=d(t)}^{g(t)} f_i(t) \quad (6)$$

A linear function is constructed from the values calculated as above. Consecutive calculated points are connected by sections, thus creating a graph of the time series' development trend expressed as a segment function. Extrapolation of the model into the future is possible after application of the harmonic weights methods, involving calculation of trend function gains (u), determination of average value of the gains ($\bar{u}$) and determination of standard deviation of the gains. The moment or period T is determined based on the following relationship:

$$Y_t = \bar{Y}_N + (T - N)\bar{u} \quad (7)$$

Values calculated with the use of the above model are applied to construct a graph presenting the aggregated number of electric car registrations in EU member states, the US and Japan. The said graph is presented on the figure below (Figure 3). Continuous lines identify actual data, while dotted lines—forecast gain.

The point prediction error (V_T) is calculated from the relationship:

$$V_T = W_r \cdot Y_t \quad (8)$$

Theil's discrepancy coefficient determined from the relationship:

$$W_r = \sqrt{\frac{\sum_{t=1}^n (Y_t - Y_N)^2}{\sum_{t=1}^n Y_t^2}} \quad (9)$$

Theil's discrepancy coefficient used in Hellwig's forecasting (in harmonic weighting forecasting) takes into account the sum of the squares of the differences of the empirical values (Y_t) and the theoretical values (Y_N) of the forecast variable. This sum relates (in the sense of a quotient) to squares of empirical values (Y_t). The root from this quotient allows to calculate the relative (percentage) share of the prediction error in the value of forecast point. This contribution (as a percentage) is the same for all point projections, regardless of how far the projections are from the future.

In the analyzed case, the discrepancy between the empirical and theoretical values of the predicted variable was very small (0.95%).

Figure 3 presents as well the relation of the absolute number of electric cars registered during the year to the number of residents of the respective region, together with a forecast. The population related forecast, as well as the one related to the number of electric cars, was compiled with the use of the creeping trend predictive method. The forecast was prepared based on the assumption that the trends observed so far will be maintained in the analysed regions, markets and the automotive industry. Moreover, it is assumed that the European Union will consist of 28 member states until 2020. Due to the procedure related to Great Britain's exits from the European Union, calculations after 2020 do not include Great Britain [100–103].

Figure 3. Aggregated number of electric cars in the European Union, United States and Japan, including forecast until 2030 and relation of the absolute number of electric cars to the number of residents, including forecast until 2030 [own calculations].

The graph clearly shows that the United States is the definite leader of the sector, taking into account the aggregated number of vehicles and the relation of car registrations to the population. The aggregated number of electric cars in the US is forecast to exceed 4.8 m in 2020, while in 2030 it is anticipated to be over 20.8 m. In the European Union the values are, respectively, app. 2 m in 2020 and 9 m in 2030. In the EU, countries with the biggest aggregated number of electric cars are: Germany with 348 thousand in 2020 and 1.9 m in Great Britain with 342 thousand in 2020 and 1.6 m in 2030. Japan is characterised with the lowest expected values of app. 1.3 m in 2020 and 5.3 m in 2030.

It ought to be stressed that even though the aggregated number of electric cars anticipated for the coming years is the lowest in Japan, the country clearly outpaces the European Union if the value is recalculated into the number of residents. Depending on the year, the value in Japan is, on average, three times higher than in the EU. In 2017, the relation between the number of electric cars and the number of residents was equal to 0.005 in Japan, while in the European Union it was 0.002.

That number is surprisingly high in Sweden with a value of 0.005. If the current trends and tendencies are maintained, the difference will be growing over time. The relationship is forecast to reach 0.011 in Japan in 2020, with 0.004 in the EU (0.01 in Sweden), while in 2030 it ought to be 0.04 in Japan and 0.02 in the EU (Sweden 0.06), respectively.

2.3. Energy Sources Mix

Electric vehicles use electricity accumulated in their batteries in order to drive [104–106]. Batteries are usually charged at charging stations directly connected to the power supply network [107,108]. Electricity supplied through the network comes from the country's production sources. These may be both conventional sources, such as coal power plants or gas ones, but also nuclear power plants and renewable energy sources such as, among others, wind, sun or water power plants. Each of the above mentioned sources of electricity is characterised with different operation and fuel consumption but, above all, they differ among themselves in terms of emission of greenhouse gases and other kinds of pollutant [109–111].

Table 2 below presents a comparison of steam systems using coal and natural gas as fuel and of the gas turbine block in terms of emissions of the following gases: carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NO₂), sulphur dioxide (SO₂) and dust [112].

Table 2. Comparison of systems using different fuels in terms of emissions of greenhouse gases and air pollutants [112].

Type of System	Fuel	Efficiency [%]	Emission Coefficients [g/kWh]				
			CO ₂	CO	NO _x	SO ₂	Dust
Steam power plant	Coal	34	1034	0.18	3.13	19.9	1.41
	Natural gas	31	651	0.09	3.04	0	0.05
Gas turbine block	Natural gas	38	532	0.3	0.5	0	0.04

As it can be concluded based on the above table (Table 2), electricity sources using coal or gas as fuel generate a significant amount of air pollutants and greenhouse gases per each kilowatt hour produced. The steam power plant is characterised with the highest level of emissions [113–115]. Gas turbine blocks generate much less emissions [116,117]. The above table (Table 2) also shows that coal causes many times more emissions than natural gas. On the other hand, electricity sources based on nuclear transformations (nuclear power plants) or renewable sources of energy generate virtually no greenhouse gases and other air pollutants during electricity production.

Consequently, considerations concerning use of electric cars as a measure allowing reduction of air pollution and greenhouse gases ought to take into account the crucial element of the energy sources mix used in the respective region. If zero- and low-emission sources have a significant share in electricity generation, then, next to local benefits caused by reduced combustion of fuels in vehicles even in case

of electricity prices growth, improvement of air quality and an overall positive environmental effect may be achieved.

Figure 4 below presents a comparison regarding the share of particular energy sources in electricity generation in the United States, European Union and Japan (figures for 2018) [118]. The figure clearly shows that in the case of Japan and the United States, the dominant fuels are natural gas and coal. In both cases, the share of natural gas exceeds 35%, while the share of coal is approximately 30%. Similarly, the share of renewable sources in both cases is 16.8% (US) and 18.4% (Japan). In the case of electricity generated at nuclear power plants, the difference between these countries is significant—whereas nuclear power plants are responsible for production of 19% of electricity in the US, in Japan the ratio is below 5%. The European Union is characterised with an exceptionally high share of renewable sources in electricity production, at 32%. The share of nuclear power plants is 25.2%, coal power plants: 20% and gas power plants at nearly 19%. Liquid fuels in all of the analysed regions account for a marginal share of production, and their share is the highest in Japan at 5.7%. On the figure there is also a scenario on how the energy mix could change in the year 2030. The anticipation is based on the national and international plans and the observed tendencies in energy mix changes.

Figure 4. Share of particular energy sources in electricity generation 2018 with a scenario for 2030 in: (a) the United States; (b) European Union; (c) Japan.

The fundamental conclusion which may be drawn from analysis of the data presented hereinabove is that electricity produced in the European Union will involve the lowest level of emissions. That results from the fact that the main sources of electricity are renewable energy sources and nuclear power plants. In total, they account for approximately 57.2% of total production, as opposed to sources based on coal and natural gas, responsible for 38.9%. To compare, a similar comparison in the USE demonstrates that RES together with the nuclear power engineering segment account for 35.8% as opposed to coal and gas at 63.3%. In Japan, the values are, respectively, 23.1% and 69.8%. The share of particular sources of energy in electricity generation is one of several factors impacting environmental friendliness of that kind of electricity and constitutes one of the primary energy factor's components [119–122].

2.4. Primary Energy Factor

Electricity used to drive electric vehicles is the so-called final energy. Its generation and delivery require a certain quantity of primary energy, i.e., energy contained in energy sources and media (e.g., in fuels burned at the power plant) [123–125].

To perform simple recalculation of primary energy needed to produce electricity required to power a vehicle, the primary energy factor (PEF) was used. The factor is a measure of the overall energy efficiency of the power engineering system, and its value depends on many factors, such as the energy sources mix, kind of fuels used in thermal power plants and efficiency of generation units.

In this study, calculations for all analysed regions were performed using an original primary energy factor calculation method. The method constitutes a simplified manner of calculating the factor and enables determination thereof with the use of basic, publicly available data on the power engineering system. It is mainly based on the share of particular fuels in the power generation structure and considers efficiency of electricity generation from different sources. What is more, it considers primary energy contained in particular kinds of fuel.

The most important input data for PEF calculation is the share of particular fuels used at electricity generation sources, expressed as the quotient of electricity produced from the given source and total production. This share is of particular importance due to significant differences regarding efficiency of electricity production from a respective source. The data for 2018 are visualised on the preceding figure (Figure 4).

Efficiency of primary energy conversion in all analysed regions was assumed and estimated pursuant to the Commission Delegated Regulation (EU) 2015/2402 of 12 October 2015. Efficiency in individual years depends on the fuel's calorific value and technological advancement of generation sources [126]. In the case of renewable energy sources, the efficiency of 100% was applied due to the fact that they do not use any fuels for electricity generation. Efficiency values estimated as above are presented in the table below (Table 3).

Table 3. Comparison of energy conversion efficiency for particular sources.

Kind of Primary Energy	Solid Fuels	Gas Fuels	Liquid Fuels	Nuclear Fuel	Renewable Energy Sources
Efficiency	38.9%	43.0%	33.9%	33.0%	100.0%

PEF is calculated pursuant to the following formula:

$$PEF_r = \sum_{i=1}^n \frac{E_i}{E_c} \cdot \eta_i^{-1} \quad (10)$$

where, for the number n of sources i :

- E_i [MWh] is the quantity of electricity produced from the given source in the year r in the country,
- E_c [MWh] is the total quantity of electricity produced in the year in the country,
- η_i [%] is the efficiency of primary energy conversion into electricity for the respective fuel.

The lower the value of the primary energy factor, the higher efficiency of primary energy conversion into final energy (electricity) is demonstrated by the power engineering system. Value of the factor strives towards the value of 1, denoting ideal energy conversion without any losses whatsoever.

It is difficult to say clearly how the coefficient will change in the coming years. Although, to make the analysis as realistic as possible, the value of PEF has been forecasted until year 2030. Its final value (in 2030) was estimated on the basis of plans for the share of renewable energy sources in energy production in the areas concerned [127–129]. Values between 2018 and 2030 were interpolated. PEF values calculated as above for the United States, European Union and Japan in 2010–2018 with a forecast until 2030 are presented in Figure 5.

The lowest PEF value is that for the European Union, at 2.18 in 2018. In the case of the United States, the value is 2.31, while for Japan it is equal to 2.26. The United States demonstrated the lowest decrease in the factor over the analysed period (−5.71%) and the lowest average annual decrease (−0.73%). The highest fall is noticeable in the case of Japan (−9.96%), just as the highest average annual decrease (−1.30%). As far as the EU is concerned, the decrease is stable, on average at −0.99% per year and −7.63% throughout the analysed period. In the year 2030 predicted values of the PEF factor are: 2.20 in the US, 1.96 in EU and 2.19 in Japan.

That means that the European Union is characterised with the best efficiency of primary energy conversion into final energy, while the United States is characterised with the worst efficiency in

the same area. Change dynamics indicates that the efficiency is being continuously improved in all analysed regions. Improvements are the most noticeable in Japan, and the least noticeable in the US.

Figure 5. Comparison of the primary energy factor for the United States, European Union and Japan in 2010–2018 with a forecast to year 2030.

Primary energy factor may be considered as an indicator that enables projective evaluation of the environmental effects of electromobility expected in the countries other than discussed in the present paper. The highly emissive power plants, used in particular country, together with an increase of the number of electric automobiles will result only in shift of pollution from the roads to the regions where power stations are located. Moreover, the transmittivity of electric grid has to be taken into account. An increase of the share of biofuels in the electricity mix appears to be a factor improving the situation. It has to be considered that biofuel production, both within the agricultural as in industrial production subsystems, requires consumption of energy what decreases energetic effectiveness of that production [130–132].

As indicated in the papers [133,134] also internal and external transport of crops affects the energetic effectiveness of biofuel's production systems. It is seen, therefore, that the use of biofuels as a remediation for harmful emissions from fossil fuels also requires careful choice of production technology, and appropriate location of industrial conversion facilities with respect to plantations—just in order to optimize the energy consumption and maximize the energy gain. This means, that careful technology management, as well as processes organization management become the important factors in achieving positive environmental and economic gains connected to electro-mobility development.

2.5. Environmental Effect and Emission Reductions (Tank-To-Wheel)

Road transport transformations involving replacement of internal combustion vehicles with electric and plug in-hybrid vehicles involve a number of changes. The most important ones are those which have direct influence onto air quality, namely reductions related to emissions of carbon dioxide and other air pollutants [135–139].

The environmental effect of electromobility development in the European Union, United States and Japan is calculated on the basis of data concerning electromobility development dynamics, figures concerning vehicles and drivers' habits as well as emissions from particular fuels. Subsequently, the emission reduction values were adjusted by emissions caused by increased electricity consumption, calculated on the basis of PEF values. Drivers' habits and data concerning vehicles include the average annual distance driven by a passenger car and approximate period of use in the respective country [140–143]. Annual mileage of the vehicle is important for correct estimation

of the distance to be driven by an electric car and, consequently, the quantity of electricity it will consume. The period of using the vehicle denotes the period during which the car is used before being replaced with a new one. This datum is important for calculating the environmental effect, as many changes concerning emission limits have been implemented over the last 30 years. As a result, vehicles manufactured over that period differ in terms of quantities of emitted greenhouse gases. The table below (Table 4) presents a comparison of those data in the three analysed regions.

Table 4. Average annual distance covered by passenger car drivers and average period of vehicle use in the European Union, United States and Japan [140–143].

	Distance [km/year]	Period of Use [years]
EU	23,639.69	20.31
US	21,687.56	17.62
Japan	9300.00	12.91

The above figures indicate that the greatest annual distance (over 23,600 km) is covered in the European Union. Only slightly less is driven each year in the United States—nearly 22,000 km. In the case of Japan, the difference is significant, as it is only 9300 km per year. The data look similar regarding the period of use, which is also the shortest in Japan—less than 13 years, and the longest one is in the European Union—over 20 years. This long average period of use in the EU results from the character of the community itself. It is formed by 28 member states, each of them on a slightly different stage of economic development. In highly developed countries with advanced economies, the period of use is much shorter than the average; for example, in Denmark it is 11 years, while in Austria the period is 13 years. In contrast, the average period of use in Greece and Spain is, respectively, 35 and 30 years.

Reduction of CO₂ emissions was calculated using all of the previously mentioned data, and considering the percentage share of cars with Diesel engines and petrol ones, as well as data concerning average carbon dioxide emission for a passenger car in the respective country [144]. The calculations took into account the year of manufacturing and, thus, the emission rate of the car replaced with an electric vehicle. The above was estimated based on the period of vehicle use, typical for the respective country.

Figure 6 presents carbon dioxide emissions avoided on an annual basis. The calculations were based on the data from European vehicle market statistics [9].

Figure 6. Tank-to-wheel CO₂ emissions avoided on an annual basis in the EU, US and Japan.

The graph shows that the greatest quantity of emissions will be avoided by 2020 in the United States. Still, from 2021 onwards, the European Union will clearly take the first place. Growth of the data bars suggests that development of electromobility in the EU is much more dynamic. Growth regarding avoided emissions is nearly exponential, while in the case of the United States it is more linear. Japan is characterised with such low values that increase in the graph is barely noticeable.

2.6. Environmental Effect and Emission Reductions—Adjusted Values (Well-To-Wheel)

The above values concern reduction of air pollutant emissions during use of the vehicle. If they are reduced, that will directly impact air quality, especially in cities. That may allow reducing the effect of smog and improving air quality [145–148]. However, although electric vehicles do not emit any harmful substances during operation, their drive uses electricity. Electricity itself is generated at power plants and, depending on the condition of the power engineering system and the energy sources mix in the respective country, electricity generation causes emissions of various substances into the atmosphere. In connection with the above, the environmental effect from replacement of fleet with electric vehicles was calculated taking account as well emissions occurring in connection with electricity generation.

Adjustment of calculated values was performed on the basis of primary energy factors (PEF) estimated beforehand. This enables determination of primary energy from various media, needed to power an electric vehicle.

Annual electricity consumption was calculated on the basis of data concerning average annual mileage of cars in the respective country as well as the assumed energy consumption by electric cars in road traffic conditions [149]. Next, using PEF values, primary energy consumption was estimated. Based on the energy sources mix typical for the given country and average emission rate values typical for all kinds of fuel (solid, gas and liquid), additional emissions accompanying use of electric cars were determined. Finally, previously calculated emission reductions were adjusted by additional emissions connected with electricity generation. The values of CO₂ emission factors in all the analysed areas come from the data & statistics of the International Energy Agency. The recalculated values are presented in Table 5 below.

The results of the avoided and additional emissions calculations are presented in Table 6 below and in Figures 7 and 8.

Figure 7. Well-to-wheel avoided CO₂ emissions (adjusted) with forecast for the EU, US and Japan.

Figure 8. Avoided CO₂ emissions with forecast for the EU, US and Japan.

Table 5. CO₂ emission factor.

	CO ₂ Emission Factor [kg/kWh]		
	EU	US	Japan
2010	501.15	529.92	577.88
2011	490.24	594.45	556.56
2012	480.31	620.21	531.61
2013	473.39	625.79	533.42
2014	470.49	628.10	528.44
2015	446.32	592.15	497.14
2016	423.49	571.71	472.19
2017	408.20	558.69	457.67

Table 6. Adjusted CO₂ emission reduction values.

	Avoided Emissions [thousand tonnes]			Additional Emissions [thousand tonnes]		
	EU	US	Japan	EU	US	Japan
2010	29,451	1994	5925	14,206	1935	5897
2011	47,474	105,019	27,172	22,062	96,917	26,105
2012	120,951	412,410	68,307	53,263	362,031	66,671
2013	321,165	970,375	116,917	139,410	851,197	111,647
2014	534,977	1,683,452	171,267	228,747	1,462,883	163,125
2015	1,170,973	2,343,927	212,769	471,331	1,900,218	197,183
2016	1,499,694	3,187,182	254,328	574,613	2,433,557	232,322
2017	2,502,919	3,803,375	296,882	922,341	2,778,997	267,304
2018	3,099,789	4,450,027	339,446	1,106,378	3,223,574	304,281
2019	4,315,720	5,096,686	382,010	1,529,564	3,679,789	341,699
2020	5,125,305	5,743,338	424,574	1,803,432	4,132,652	378,937
2021	6,155,468	6,389,997	467,139	2,149,948	4,582,087	415,993
2022	7,532,924	7,036,649	509,703	2,611,182	5,028,002	452,860
2023	8,855,955	7,683,308	552,267	3,046,024	5,470,321	489,535
2024	10,459,466	8,329,960	594,831	3,569,014	5,908,953	526,013
2025	12,008,579	8,976,619	637,395	4,064,299	6,343,822	562,290
2026	13,838,149	9,623,271	679,959	4,644,509	6,774,837	598,361
2027	15,613,327	10,269,930	722,525	5,195,600	7,201,922	634,223
2028	17,668,980	10,916,582	765,088	5,828,257	7,624,985	669,870
2029	19,670,222	11,563,241	807,652	6,430,280	8,043,950	705,298
2030	21,951,944	12,209,894	850,216	7,044,401	8,423,596	738,533

3. Results

The analysis performed leads to the following conclusions:

- During the period from 2007 to 2017, the population of the European Union increased by 2.9%, in the United States—by 7.9%, while the population of Japan decreased by 0.9%. During the same period, the number of passenger cars in the EU grew by 9.6%, in Japan—by 6.5%, and decreased in the US by −1.4%.
- The motorization index shows a growing trend in Japan and the European Union. In 2000–2017, it increased, respectively, by 33.8 in Japan (from 449.3 to 483.1) and by 31.0 in the EU (from 472.2 to 503.2). It was only in the territory of the US that a decrease by 56.6 was observed (from 652.3 to 595.7).
- The total of 868,320 electric cars were registered in 2010–2017 in the European Union, 2,163,569 in the United States and 685,301 in Japan. Based on the forecast, it was estimated that as many as 2,048,000 electric cars will be registered in the European Union in 2020, and the number will grow to 9,029,000 by 2030. In the US and Japan, the numbers will be respectively 4,808,000 and 1,366,000 cars in 2020, with 20,895,000 and 5,279,000 electric cars in 2030.
- The share of particular sources of energy used in electricity production in the analysed regions varies. The European Union is characterised with the highest share of renewable energy sources (35%) and nuclear power plants (23%). In the United States, RES account for as little as 17%, while in Japan—for 18%. In both those countries, the highest share is that of gas power plants—at 35% in the US and 37% in Japan, respectively. In all of the analysed regions, liquid fuel as a source of energy has a negligible share—under 1% in the US, 2% in the EU and 6% in Japan.
- Calculated pursuant to the authors' original method, the primary energy factor has the lowest value in the European Union at 2.18, while in the United States it takes the value of 2.31, with 2.26 in Japan. As compared with historical data, a declining trend regarding PEF is observed in all the regions. The greatest PEF decrease is recorded in Japan (−9.96% during the analysed period), while the lowest decrease takes place in the US (−5.71%). The European Union is characterised with a stable decrease regarding this factor over the years covered – the average annual decrease is approximately −0.99% per year, while total decrease for the analysed period is −7.63%.
- The environmental effect resulting from car fleet replacement with electric vehicles is a significant reduction of air pollutant emissions, such as carbon monoxide (CO) and nitrogen oxides (NO_x). In the territory of the European Union, emission reductions by 2017 were, respectively: 86,867 thousand tonnes of CO and 20,321 thousand tonnes of NO_x. In the US, emissions of 122,453 thousand tonnes of CO and 17,594 thousand tonnes of NO_x were avoided, while in Japan the reductions concerned 17,208 thousand tonnes of CO and 1719 thousand tonnes of NO_x.
- The environmental effect also concerns carbon dioxide (CO₂) emission reduction. In this area, enormous emission quantities were reduced. By 2017, it concerned 6,228,000 thousand tonnes in the EU, 12,508,000 thousand tonnes in the US and 1,154,000 thousand tonnes in Japan.
- However, this paper considers increased electricity requirements and resulting increased CO₂ emissions from power plants. Despite that, the environmental effect in all the regions is still positive. After adjustment, the EU avoided the emission of 3,802,000 thousand tonnes of CO₂ by 2017, the US—of 2,620,000 thousand tonnes, and Japan—of 83,312 thousand tonnes.
- It is forecast that during the year 2020 alone, emissions (adjusted) of 3,322,000 thousand tonnes of CO₂ will be avoided in the EU, with 1,611,000 thousand tonnes avoided in the US and 46,000 thousand tonnes in Japan. If current trends are maintained, the reductions in 2030 may concern, respectively, over 14,908,000 thousand tonnes (EU), 3,786,000 thousand tonnes (US) and 111,683 thousand tonnes (Japan).
- Strategic planning of electricity generation sources including alternative resources together with implementation of electricity powered automobiles, and appropriate electric energy generation

and distribution management should cause evident environmental impact also in countries other than analysed in the present paper.

- The existing fleet of vehicles with internal combustion engines must be replaced gradually. Future studies should consider vehicle replacement scenarios and the resulting effects on the climate and the economy. Research should also focus on technical aspects regarding the construction of vehicles, engines and methods of supplying electricity.
- During the development of the manuscript, the authors focused mainly on the topic of electromobility development in the studied areas. The calculation of the expected energy mix is based on historical data concerning changes in the structure of electricity sources, development of power grids and energy infrastructure. The assumptions do not take into account situations in which top-down decisions about giving up or subsidizing individual energy sources are taken at government level (for example, switching off nuclear power plants or subsidizing renewable energy). The assumptions made result from the nature of the method used—the creep trend, which is based on historical data. On the basis of these, a trend of change is determined under the assumption of the invariability of unpredictable external factors, such as the above mentioned top-down findings of national governments.

Author Contributions: Conceptualization, K.T., O.O. and M.M.-W.; Methodology, O.O. and K.T.; Software, M.M.-W.; Validation, K.T. and O.O.; Formal analysis, M.M.-W. and K.T.; Investigation, O.O.; Data curation, M.M.-W. and K.T.; Writing—original draft preparation, K.T.; Writing—review and editing, K.T., O.O., and M.M.-W.; Visualization, M.M.-W., K.T.; Supervision, K.T.; Funding acquisition, K.T. All authors have read and agreed to the published version of the manuscript.

Funding: The research was carried out under financial support obtained from the research subsidy of the Faculty of Engineering Management (WIZ) of Białystok University of Technology. From the grant No. WI/WIZ-INZ/4/2019 (Olga Orynycz). APC was funded by Institute of Mechanical Engineering money, SGGW.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References

1. Swain, R.B.; Karimu, A. Renewable electricity and sustainable development goals in the EU. *World Dev.* **2020**, *125*, 104693. [CrossRef]
2. Kristensen, H.S.; Mosgaard, M.A. A review of micro level indicators for a circular economy—Moving away from the three dimensions of sustainability? *J. Clean. Prod.* **2020**, *243*, 118531. [CrossRef]
3. Matuszek, J. Trends and directions of production engineering development. *Prod. Innov. Prod. Innov.* **2005**, *1*, 2–7.
4. Brodny, J.; Tutak, M. Analysis of the diversity in emissions of selected gaseous and particulate pollutants in the European Union countries. *J. Environ. Manag.* **2019**, *231*, 582–595. [CrossRef] [PubMed]
5. Wiegman, B.; Champagne-Gelinas, A.; Duchesne, S.; Slack, B.; Witte, P. Rail and road freight transport network efficiency of Canada, member states of the EU, and the US. *Res. Trans. Bus. Manag.* **2018**, *28*, 54–65.
6. Production of Passenger Cars Worldwide from 1998 to 2018. Available online: <https://www.statista.com/statistics/268739/production-of-passenger-cars-worldwide/> (accessed on 27 January 2020).
7. Pettersson, P.; Johannesson, P.; Jacobson, B.; Bruzelius, F.; Fast, L.; Berglund, S. A statistical operating cycle description for prediction of road vehicles' energy consumption. *Trans. Res. Part D Trans. Environ.* **2019**, *73*, 205–229. [CrossRef]
8. Passenger Cars in the EU. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/Passenger_cars_in_the_EU (accessed on 8 August 2020).
9. European Vehicle Market Statistics. Pocketbook 2016/17. Available online: https://theicct.org/sites/default/files/publications/ICCT_Pocketbook_2016.pdf (accessed on 8 August 2020).
10. Tucki, K.; Mruk, R.; Bączyk, A.; Botwińska, K.; Woźniak, K. Analysis of the Exhaust Gas Emission Level from a Diesel Engine with Using Computer Simulation. *Rocz. Ochr. Środowiska* **2018**, *20*, 1095–1112.

11. Tucki, K.; Bączyk, A.; Klimkiewicz, M.; Mączyńska, J.; Sikora, M. Comparison of Energy Performance and Toxicity of Diesel Engine Fuelled with Diesel Oil, Rapeseed Oil and Oil Mixture. Available online: <https://iopscience.iop.org/article/10.1088/1755-1315/214/1/012102> (accessed on 23 November 2019).
12. Ghadikolaei, M.A.; Yung, K.F.; Cheung, C.S.; Lau, P.C. Chemical properties and composition of PM emitted from a diesel engine fueled with ternary fuel (diesel-biodiesel-ethanol) in blended and fumigation modes. *Fuel* **2019**, *251*, 368–382. [\[CrossRef\]](#)
13. Nordelöf, A.; Romare, M.; Tivander, J. Life cycle assessment of city buses powered by electricity, hydrogenated vegetable oil or diesel. *Trans. Res. Part D Trans. Environ.* **2019**, *75*, 211–222. [\[CrossRef\]](#)
14. Szymczyk, K.; Kadłubek, M. Challenges in general cargo distribution strategy in urban logistics—Comparative analysis of the biggest logistics operators in EU. *Trans. Res. Procedia* **2019**, *39*, 525–533. [\[CrossRef\]](#)
15. Andrés, L.; Padilla, E. Driving factors of GHG emissions in the EU transport activity. *Trans. Policy* **2018**, *61*, 60–74. [\[CrossRef\]](#)
16. Kondratyev, K.Y.; Varotsos, C. Atmospheric greenhouse effect in the context of global climate change. *Il Nuovo Cimento* **1995**, *18*, 123–151. [\[CrossRef\]](#)
17. Adamenko, V.V.; Kondratyev, K.Y.; Varotsos, C.A. Climate Change in the Arctic and its Empirical Diagnostics. *Energy Environ.* **1999**, *10*, 469–482. [\[CrossRef\]](#)
18. Veum, K.; Bauknecht, D. How to reach the EU renewables target by 2030? An analysis of the governance framework. *Energy Policy* **2019**, *127*, 299–307. [\[CrossRef\]](#)
19. Haasz, T.; Vilchez, J.J.G.; Kunze, R.; Deane, P.; Fraboulet, D.; Fahl, U.; Mulholland, E. Perspectives on decarbonizing the transport sector in the EU-28. *Energy Strategy Rev.* **2018**, *20*, 124–132. [\[CrossRef\]](#)
20. Krzywonos, M.; Skudlarski, J.; Kupczyk, A.; Wojdalski, J.; Tucki, K. Forecast for transport biofuels in Poland in 2020–2030. *Przem. Chem.* **2015**, *94*, 2218–2222.
21. Katinas, V.; Gaigalis, V.; Savickas, J.; Marčiukaitis, M. Analysis of sustainable liquid fuel production and usage in Lithuania in compliance with the National Energy Strategy and EU policy. *Renew. Sustain. Energy Rev.* **2018**, *82*, 271–280. [\[CrossRef\]](#)
22. Capros, P.; Zazias, G.; Evangelopoulou, S.; Kannavou, M.; Fotiou, T.; Siskos, P.; De Vita, A.; Sakellaris, K. Energy-system modelling of the EU strategy towards climate-neutrality. *Energy Policy* **2019**, *134*, 110960. [\[CrossRef\]](#)
23. Santini, D.J. Electric Vehicle Waves of History: Lessons Learned about Market Deployment of Electric Vehicles. Available online: <http://Cdn.intechweb.org/pdfs/18663.pdf> (accessed on 23 November 2019).
24. Chakraborty, D.; Bunch, D.S.; Lee, J.H.; Tal, G. Demand drivers for charging infrastructure-charging behavior of plug-in electric vehicle commuters. *Trans. Res. Part D Trans. Environ.* **2019**, *76*, 255–272. [\[CrossRef\]](#)
25. Cansino, J.M.; Sánchez-Braza, A.; Sanz-Díaz, T. Policy Instruments to Promote Electro-Mobility in the EU28: A Comprehensive Review. *Sustainability* **2018**, *10*, 2507. [\[CrossRef\]](#)
26. Ahmadi, P. Environmental impacts and behavioral drivers of deep decarbonization for transportation through electric vehicles. *J. Clean. Prod.* **2019**, *225*, 1209–1219. [\[CrossRef\]](#)
27. Mersky, A.C.; Sprei, F.; Samaras, C.; Qian, Z. Effectiveness of incentives on electric vehicle adoption in Norway. *Trans. Res. Part D Trans. Environ.* **2016**, *46*, 56–68. [\[CrossRef\]](#)
28. Hooftman, N.; Oliveira, L.; Messagie, M.; Coosemans, T.; Van Mierlo, J. Environmental Analysis of Petrol, Diesel and Electric Passenger Cars in a Belgian Urban Setting. *Energies* **2016**, *9*, 84. [\[CrossRef\]](#)
29. Arat, H.T. Alternative fuelled hybrid electric vehicle (AF-HEV) with hydrogen enriched internal combustion engine. *Int. J. Hydrogen Energy* **2019**, 1–12, in press. [\[CrossRef\]](#)
30. Shankar, R.; Marco, J. Method for estimating the energy consumption of electric vehicles and plug-in hybrid electric vehicles under real-world driving conditions. *Intell. Trans. Syst. IET* **2013**, *7*, 138–150. [\[CrossRef\]](#)
31. O'Driscoll, R.; Stettler, M.E.J.; Molden, N.; Oxley, T.; ApSimon, H.M. Real world CO₂ and NO_x emissions from 149 Euro 5 and 6 diesel, gasoline and hybrid passenger cars. *Sci. Total Environ.* **2018**, *621*, 282–290. [\[CrossRef\]](#)
32. Electric Vehicles from Life Cycle and Circular Economy Perspectives. TERM 2018: Transport and Environment Reporting Mechanism (TERM) Report. Available online: <https://www.eea.europa.eu/publications/electric-vehicles-from-life-cycle> (accessed on 8 August 2020).
33. Tomczak, J.; Pater, Z.; Bulzak, T. Effect of technological parameters on the rotary compression proces. *Eksplot. Niezawodn.* **2013**, *15*, 279–283.

34. Gajek, J.; Awrejcewicz, J. Mathematical models and non-linear dynamics of a linear electromagnetic motor. *Nonlinear Dyn.* **2018**, *94*, 377–396. [\[CrossRef\]](#)
35. Charge Your Car at One of Energa Network of Electric Vehicle Charging Points. Available online: <https://emobility.pl/index.php/en/charging-network-eng/> (accessed on 23 November 2019).
36. Kouchachvili, L.; Yaici, W.; Entchev, E. Hybrid battery/supercapacitor energy storage system for the electric vehicles. *J. Power Sources* **2018**, *374*, 237–248. [\[CrossRef\]](#)
37. Tucki, K.; Orynych, O.; Wasiak, A.; Świć, A.; Dybaś, W. Capacity market implementation in Poland: Analysis of a survey on consequences for the electricity market and for energy management. *Energies* **2019**, *12*, 839. [\[CrossRef\]](#)
38. Cao, Y.; Huang, L.; Li, Y.; Jermstittiparsert, K.; Ahmadi-Nezamabad, H.; Nojavan, S. Optimal scheduling of electric vehicles aggregator under market price uncertainty using robust optimization technique. *Int. J. Electr. Power Energy Syst.* **2020**, *117*, 105628.
39. Monteiro, V.; Afonso, J.A.; Ferreira, J.C.; Afonso, J.L. Vehicle Electrification: New Challenges and Opportunities for Smart Grids. *Energies* **2019**, *12*, 118. [\[CrossRef\]](#)
40. Varga, B.O.; Mariasiu, F.; Miclea, C.D.; Szabo, I.; Sirca, A.A.; Nicolae, V. Direct and Indirect Environmental Aspects of an Electric Bus Fleet Under Service. *Energies* **2020**, *13*, 336. [\[CrossRef\]](#)
41. Alface, G.; Ferreira, J.C.; Pereira, R. Electric Vehicle Charging Process and Parking Guidance App. *Energies* **2019**, *12*, 2123. [\[CrossRef\]](#)
42. Kvisle, H.H. The Norwegian Charging Station Database for Electromobility (NOBIL). *World Electr. Veh. J.* **2012**, *5*, 702–707.
43. Dong, G.; Ma, J.; Wei, R.; Haycox, J. Electric vehicle charging point placement optimisation by exploiting spatial statistics and maximal coverage location models. *Trans. Res. Part D Trans. Environ.* **2019**, *67*, 77–88. [\[CrossRef\]](#)
44. Zhao, Q. Electromobility research in Germany and China: Structural differences. *Scientometrics* **2018**, *117*, 473–493.
45. United States Population. 2019. Available online: <http://worldpopulationreview.com/countries/united-states-population/> (accessed on 23 November 2019).
46. Rivera-Monroy, V.H.; Danielson, T.M.; Castañeda-Moya, E.; Marx, B.D.; Travieso, R.; Zhao, X.; Gaiser, E.E.; Farfan, L.M. Long-term demography and stem productivity of Everglades mangrove forests (Florida, US): Resistance to hurricane disturbance. *For. Ecol. Manag.* **2019**, *440*, 79–91. [\[CrossRef\]](#)
47. Selected Automakers' U.S. Ytd Market Share in 3rd Quarter 2019, by Key Manufacturer. Available online: <https://www.statista.com/statistics/343162/market-share-of-major-car-manufacturers-in-the-united-states/> (accessed on 23 November 2019).
48. How Many Polish Genes in the Polish Automotive Industry? Available online: https://www.arp.pl/_data/assets/pdf_file/0011/76178/Raport.pdf (accessed on 7 August 2020).
49. Hu, L.; Dong, J.; Lin, Z.; Yang, J. Analyzing battery electric vehicle feasibility from taxi travel patterns: The case study of New York City, US. *Trans. Res. Part C Emerg. Technol.* **2018**, *87*, 91–104. [\[CrossRef\]](#)
50. Feng, W.; Figliozzi, M. An economic and technological analysis of the key factors affecting the competitiveness of electric commercial vehicles: A case study from the US market. *Trans. Res. Part C Emerg. Technol.* **2013**, *26*, 135–145. [\[CrossRef\]](#)
51. Thomas, V.J.; Maine, E. Market entry strategies for electric vehicle start-ups in the automotive industry—Lessons from Tesla Motors. *J. Clean. Prod.* **2019**, *235*, 653–663. [\[CrossRef\]](#)
52. Liu, J.H.; Meng, Z. Innovation Model Analysis of New Energy Vehicles: Taking Toyota, Tesla and BYD as an Example. *Procedia Eng.* **2017**, *174*, 965–972. [\[CrossRef\]](#)
53. Guo, Z.; Zhou, Y. Residual value analysis of plug-in vehicles in the United States. *Energy Policy* **2019**, *125*, 445–455. [\[CrossRef\]](#)
54. Population and Population Change Statistics. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/Population_and_population_change_statistics (accessed on 23 November 2019).
55. EU: Total Population from 2009 to 2019. Available online: <https://www.statista.com/statistics/253372/total-population-of-the-european-union-eu/> (accessed on 23 November 2019).
56. Auvinen, H.; Järvi, T.; Kloetzke, M.; Kugler, U.; Böhne, J.A.; Heintz, F.; Kurte, J.; Esser, K. Electromobility Scenarios: Research Findings to Inform Policy. *Trans. Res. Procedia* **2016**, *14*, 2564–2573. [\[CrossRef\]](#)

57. Habib, K.; Hansdóttir, S.T.; Habib, H. Critical metals for electromobility: Global demand scenarios for passenger vehicles, 2015–2050. *Resour. Conserv. Recycl.* **2020**, *154*, 104603. [CrossRef]
58. Pregger, T.; Nitsch, J.; Naegler, T. Long-term scenarios and strategies for the deployment of renewable energies in Germany. *Energy Policy* **2013**, *59*, 350–360. [CrossRef]
59. Council Directive 91/441/EEC of 26 June 1991 Amending Directive 70/220/EEC on the Approximation of the Laws of the Member States Relating to Measures to Be Taken Against Air Pollution by Emissions from Motor Vehicles. Available online: <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A31991L0441> (accessed on 8 August 2020).
60. Directive 94/12/EC of the European Parliament and the Council of 23 March 1994 Relating to Measures to Be Taken Against Air Pollution by Emissions from Motor Vehicles and Amending Directive 70/220/EEC. Available online: <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A31994L0012> (accessed on 8 August 2020).
61. Commission Directive 2002/80/EC of 3 October 2002 Adapting to Technical Progress Council Directive 70/220/Eec Relating to Measures to Be Taken Against Air Pollution by Emissions from Motor Vehicles (Text with EEA Relevance). Available online: <https://eur-lex.europa.eu/legal-content/HR/TXT/?uri=CELEX:32002L0080> (accessed on 8 August 2020).
62. Commission Regulation (EU) 2016/427 of 10 March 2016 Amending Regulation (EC) No 692/2008 as Regards Emissions from Light Passenger and Commercial Vehicles (Euro 6) (Text with EEA Relevance). Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0427> (accessed on 8 August 2020).
63. Progress of EU Transport Sector towards Its Environment and Climate Objectives. Available online: <https://www.eea.europa.eu/publications/progress-of-eu-transport-sector-1> (accessed on 8 August 2020).
64. Helmers, E.; Leitão, J.; Tietge, U.; Butler, T. CO₂-equivalent emissions from European passenger vehicles in the years 1995–2015 based on real-world use: Assessing the climate benefit of the European “diesel boom”. *Atmos. Environ.* **2019**, *198*, 122–132. [CrossRef]
65. Teixeira, A.C.R.; Sodré, J.R. Impacts of replacement of engine powered vehicles by electric vehicles on energy consumption and CO₂ emissions. *Trans. Res. Part D Trans. Environ.* **2018**, *59*, 375–384. [CrossRef]
66. Hooftman, N.; Messagie, M.; Van Mierlo, J.; Coosemans, T. A review of the European passenger car regulations—Real driving emissions vs local air quality. *Renew. Sustain. Energy Rev.* **2018**, *86*, 1–21. [CrossRef]
67. Japan Population. 2019. Available online: <http://worldpopulationreview.com/countries/japan-population/> (accessed on 23 November 2019).
68. Yagi, M.; Managi, S. Demographic determinants of car ownership in Japan. *Transp. Policy* **2016**, *50*, 37–53. [CrossRef]
69. Portugal-Pereira, J.; Esteban, M. Implications of paradigm shift in Japan’s electricity security of supply: A multi-dimensional indicator assessment. *Appl. Energy* **2014**, *123*, 424–434. [CrossRef]
70. United Nations Reform: Priority Issues for Japan. Available online: <https://www.mofa.go.jp/policy/un/reform/priority.html> (accessed on 1 February 2020).
71. Universal Periodic Review Japan. Available online: <https://www.ohchr.org/EN/HRBodies/UPR/Pages/JPIIndex.aspx> (accessed on 1 February 2020).
72. Orecchini, F.; Santiangeli, A.; Zuccari, F. Hybrid-electric system truth test: Energy analysis of Toyota Prius IV in real urban drive conditions. *Sustain. Energy Technol. Assess.* **2020**, *37*, 100573. [CrossRef]
73. Prokhorov, D.V. Toyota Prius HEV neurocontrol and diagnostics. *Neural Netw.* **2008**, *21*, 458–465. [CrossRef] [PubMed]
74. Iwata, K.; Matsumoto, S. Use of hybrid vehicles in Japan: An analysis of used car market data. *Trans. Res. Part D Trans. Environ.* **2016**, *46*, 200–206. [CrossRef]
75. Mishina, Y.; Muromachi, Y. Are potential reductions in CO₂ emissions via hybrid electric vehicles actualized in real traffic? The case of Japan. *Trans. Res. Part D Trans. Environ.* **2017**, *50*, 372–384. [CrossRef]
76. Paladugu, B.S.K.; Grau, D. Toyota Production System—Monitoring Construction Work Progress with Lean Principles. In *Encyclopedia of Renewable and Sustainable Materials*, 1st ed.; Hashmi, S., Choudhury, I.A., Eds.; Elsevier: Amsterdam, The Netherlands, 2020; Volume 5, pp. 560–565.
77. Augustyn, K. Forecasts of Electricity Demand in Poland in the Period to 2015—Optimization Role of Business Intelligence. Available online: <https://depot.ceon.pl/handle/123456789/9989> (accessed on 27 January 2020).

78. Tucki, K.; Orynycz, O.; Świć, A.; Mitoraj-Wojtanek, M. The Development of Electromobility in Poland and EU States as a Tool for Management of CO₂ Emissions. *Energies* **2019**, *12*, 2942. [CrossRef]
79. Nævestad, T.O.; Størkersen, K.V.; Laiou, A.; Yannis, G. Framework conditions of occupational safety: Comparing Norwegian maritime cargo and passenger transport. *Int. J. Trans. Sci. Technol.* **2018**, *7*, 291–307. [CrossRef]
80. Popova, O.; Gorev, A.; Shavyraa, C. Principles of modern route systems planning for urban passenger transport. *Trans. Res. Procedia* **2018**, *36*, 603–609. [CrossRef]
81. Türe, Y.; Türe, C. An assessment of using Aluminum and Magnesium on CO₂ emission in European passenger cars. *J. Clean. Prod.* **2020**, *247*, 119120. [CrossRef]
82. Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances. Available online: <https://www.bts.dot.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances> (accessed on 23 November 2019).
83. Report: Vehicles in Use—Europe. 2018. Available online: https://www.acea.be/uploads/statistic_documents/ACEA_Report_Vehicles_in_use-Europe_2018.pdf (accessed on 8 August 2020).
84. The Automobile Industry Pocket Guide 2018–2019. Available online: https://www.acea.be/uploads/publications/ACEA_Pocket_Guide_2018-2019.pdf (accessed on 8 August 2020).
85. Automobile Inspection & Registration Information Association. Available online: <https://www.airia.or.jp/publish/statistics/number.html> (accessed on 23 November 2019).
86. Japan Automobile Manufacturers Association (JAMA). Available online: <http://jamaserv.jama.or.jp/newdb/eng/index.html> (accessed on 23 November 2019).
87. GMS Regional Information Portal. Available online: <https://portal.gms-eoc.org/charts/overview/vehicle-motorization-index> (accessed on 1 February 2020).
88. International Organization of Motor Vehicle Manufacturers. Available online: <http://www.oica.net/world-vehicles-in-use-all-vehicles-2/> (accessed on 1 February 2020).
89. Transport Statistics at Regional Level. Statistics Explained. Available online: <https://ec.europa.eu/eurostat/statistics-explained/pdfscache/14273.pdf> (accessed on 1 February 2020).
90. Andrzejczak, K. Changes in the growth rate of passenger cars saturation. *Wiad. Stat. Pol. Stat.* **2012**, *11*, 22–34.
91. Jamroz, K. Modelling motorization index at national level. *Zeszyty Naukowo-Techniczne Stowarzyszenia Inżynierów i Techników Komunikacji w Krakowie* **2012**, *2*, 111–120.
92. Crude Oil Prices—70 Year Historical Chart. Available online: <https://www.macrotrends.net/1369/crude-oil-price-history-chart> (accessed on 23 November 2019).
93. International Council on Clean Transport. Available online: <https://theicct.org/publication-type/reports> (accessed on 23 November 2019).
94. The Motor Industry of Japan. 2019. Available online: <https://www.jama.org/the-motor-industry-of-japan-2019/> (accessed on 23 November 2019).
95. U.S. Light-Duty Advanced Technology Vehicle (ATV) Sales (2011–2019). Available online: <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/> (accessed on 23 November 2019).
96. International Energy Agency. Nordic EV Outlook. 2018. Available online: <https://www.nordicenergy.org/wp-content/uploads/2018/05/NordicEVO Outlook2018.pdf> (accessed on 1 February 2020).
97. Gnat, S. Prediction of Weekly Magazines Sale—Chosen Approach. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania / Uniwersytet Szczeciński* **2008**, *2*, 97–108.
98. Iwanejko, R.; Bajer, J. Application of mathematical models for prognosing the failures in water supply systems - the Krakow case study. *Czas. Tech. Śr.* **2012**, *109*, 19–148.
99. Sroka, W.; Musiał, W. Multifarious forecasts concerning the use of mineral fertilizers in Poland in 2014–2025. *J. Agribus. Rural Dev.* **2015**, *2*, 291–302. [CrossRef]
100. Holden, P. Territory, geoeconomics and power politics: The Irish government's framing of Brexit. *Polit. Geogr.* **2020**, *76*, 102063. [CrossRef]
101. Shaw, D.; Smith, C.M.; Scully, J. From Brexit to Article 50: Applying Critical Realism to the design and analysis of a longitudinal causal mapping study. *Eur. J. Oper. Res.* **2019**, *276*, 723–735. [CrossRef]
102. Prescott, C.; Pilato, M.; Bellia, C. Geographical indications in the UK after Brexit: An uncertain future? *Food Policy* **2020**, *90*, 101808. [CrossRef]
103. The Society of Motor Manufacturers and Traders (SMMT). Brexit. Available online: <https://www.smmmt.co.uk/industry-topics/brexit/> (accessed on 1 February 2020).

104. Alamerew, Y.A.; Brissaud, D. Modelling reverse supply chain through system dynamics for realizing the transition towards the circular economy: A case study on electric vehicle batteries. *J. Clean. Prod.* **2020**, *254*, 120025. [CrossRef]
105. Zhou, Y.; Wen, R.; Wang, H.; Cai, H. Optimal battery electric vehicles range: A study considering heterogeneous travel patterns, charging behaviors, and access to charging infrastructure. *Energy* **2020**, 116945, in press. [CrossRef]
106. Wang, Y.N. Power Battery Performance Detection System for Electric Vehicles. *Procedia Comput. Sci.* **2019**, *154*, 759–763. [CrossRef]
107. Bellocchi, S.; Klöckner, K.; Manno, M.; Noussan, M.; Vellini, M. On the role of electric vehicles towards low-carbon energy systems: Italy and Germany in comparison. *Appl. Energy* **2019**, *255*, 113848. [CrossRef]
108. Palkowski, K. Electric Car and Atmosphere Protection. *Rocz. Ochr. Środowiska Ann. Set Environ. Prot.* **2016**, *18*, 628–639.
109. Kosowski, K.; Tucki, K.; Piwowarski, M.; Stępień, R.; Orynycz, O.; Włodarski, W.; Bączyk, A. Thermodynamic Cycle Concepts for High-Efficiency Power Plans. Part A: Public Power Plants 60+. *Sustainability* **2019**, *11*, 554. [CrossRef]
110. Mikielwicz, D.; Kosowski, K.; Tucki, K.; Piwowarski, M.; Stępień, R.; Orynycz, O.; Włodarski, R. Gas Turbine Cycle with External Combustion Chamber for Prosumer and Distributed Energy Systems. *Energies* **2019**, *12*, 3501. [CrossRef]
111. Tucki, K.; Orynycz, O.; Wasiak, A.; Swic, A.; Wichlacz, J. The Impact of Fuel Type on the Output Parameters of a New Biofuel Burner. *Energies* **2019**, *12*, 1383. [CrossRef]
112. Dołęga, W. Ecology in Manufacturing. Available online: <https://www.cire.pl/pliki/2/wytwarzanieenergiiiaakologia.pdf> (accessed on 23 November 2019).
113. Meratizaman, M.; Monadizadeh, S.; Sardasht, M.T.; Amidpour, M. Techno economic and environmental assessment of using gasification process in order to mitigate the emission in the available steam power cycle. *Energy* **2015**, *83*, 1–14. [CrossRef]
114. Kosowski, K.; Domachowski, Z.; Próchnicki, W.; Kosowski, A.; Stępień, R.; Piwowarski, M.; Włodarski, W.; Ghaemi, M.; Tucki, K.; Gardzilewicz, A.; et al. *Steam and Gas Turbines with the Examples of Alstom Technology*, 1st ed.; Alstom: Saint-Quen, France, 2007; ISBN 978-83-925959-3-9.
115. Chmielniak, T. *Technologie Energetyczne*; Wydawnictwo Politechniki Śląskiej: Warrenton, OR, USA, 2008; pp. 230–560. (In Polish)
116. Bejan, A. *Advanced Engineering Thermodynamics*; John Wiley & Sons: Hoboken, NJ, USA, 2016; pp. 394–460.
117. Kotowicz, J.; Brzeczek, M. Analysis of increasing efficiency of modern combined cycle power plant: A case study. *Energy* **2018**, *153*, 90–99. [CrossRef]
118. BP Statistical Review of World Energy. 2019. Available online: <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf> (accessed on 8 August 2020).
119. Latšov, E.; Volkova, A.; Siirde, A.; Kurnitski, J.; Thalfeldt, M. Primary energy factor for district heating networks in European Union member states. *Energy Procedia* **2017**, *116*, 69–77. [CrossRef]
120. Wilby, M.R.; González, A.B.R.; Díaz, J.J.V. Empirical and dynamic primary energy factors. *Energy* **2014**, *73*, 771–779. [CrossRef]
121. Schicktan, M.D.; Wapler, J.; Henning, H.H. Primary energy and economic analysis of combined heating, cooling and power systems. *Energy* **2011**, *36*, 575–585. [CrossRef]
122. Data and Statistics. Explore Energy Data by Category, Indicator, Country or Region. Available online: <https://www.iea.org/data-and-statistics> (accessed on 1 February 2020).
123. Final Report. Evaluation of Primary Energy Factor Calculation Options for Electricity. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/final_report_pef_eed.pdf (accessed on 8 August 2020).
124. Directive of the European Parliament and of the Council amending Directive 2012/27/EU on energy efficiency. Available online: <https://www.actu-environnement.com/media/pdf/news-27990-directive-efficacite-energetique.pdf> (accessed on 8 August 2020).
125. Bukrejewski, P.; Skolniak, M.; Kowalski, L. Comparison of the environmental effect of M1 category vehicles fed with traditional and alternative fuels. *Arch. Automot. Eng.* **2017**, *75*, 5–21.

126. Commission Delegated Regulation (EU) 2015/2402 of 12 October 2015 Reviewing Harmonised Efficiency Reference Values for Separate Production of Electricity and Heat in Application of Directive 2012/27/EU of the European Parliament and of the Council and repealing Commission Implementing Decision 2011/877/EU. Available online: https://eur-lex.europa.eu/eli/reg_del/2015/2402/oj (accessed on 8 August 2020).
127. 2030 Climate and Energy Framework. Available online: https://ec.europa.eu/clima/policies/strategies/2030_en (accessed on 8 January 2020).
128. Strategic Energy Plan. Available online: https://www.enecho.meti.go.jp/en/category/others/basic_plan/ (accessed on 8 January 2020).
129. Center for Climate and Energy Solutions. Available online: <https://www.c2es.org/content/renewable-energy> (accessed on 8 January 2020).
130. Wasiak, A. *Modeling Energetic Efficiency of Biofuels Production*. *Green Energy and Technology*, 1st ed.; Springer Nature Switzerland: Cham, Switzerland, 2018; pp. 29–47. ISBN 978-3-319-98430-8. [CrossRef]
131. Wasiak, A.; Orynycz, O. Formulation of a model for energetic efficiency of agricultural subsystem of biofuel production. In Proceedings of the 2014 IEEE International Energy Conference, Cavtat, Croatia, 13–16 May 2014; pp. 1333–1337. Available online: <https://ieeexplore.ieee.org/document/6850586> (accessed on 29 November 2019).
132. Wasiak, A.; Orynycz, O. The effects of energy contributions into subsidiary processes on energetic efficiency of biomass plantation supplying biofuel production system. *Agric. Agric. Sci. Procedia* **2015**, *7*, 292–300. [CrossRef]
133. Wasiak, A.; Orynycz, O. The Effect of Transportation Choices on Energetic Effectiveness of Rapeseed Plantation. IX International Scientific Symposium Farm Machinery and Processes Management in Sustainable Agriculture 2017, 400–405. Available online: <https://depot.ceon.pl/handle/123456789/14763> (accessed on 29 November 2019).
134. Orynycz, O.; Świć, A. The Effects of Material's Transport on Various Steps of Production System on Energetic Efficiency of Biodiesel Production. *Sustainability* **2018**, *10*, 2736. [CrossRef]
135. Climate for Poland—Poland for Climate: 1988–2018–2050. Available online: <https://cop24.gov.pl/news/news-details/news/climate-for-poland-poland-for-climate-1988-2018-2050/> (accessed on 8 August 2020).
136. Plötz, P.; Funke, S.A.; Jochem, P. The impact of daily and annual driving on fuel economy and CO₂ emissions of plug-in hybrid electric vehicles. *Trans. Res. Part A Policy Pract.* **2018**, *118*, 331–340. [CrossRef]
137. Lin, W.Y.; Hsiao, M.C.; Wu, P.C.; Fu, J.S.; Lai, L.W.; Lai, H.C. Analysis of air quality and health co-benefits regarding electric vehicle promotion coupled with power plant emissions. *J. Clean. Prod.* **2020**, *247*, 119152. [CrossRef]
138. Pearce, P.; Johnston, V. A new fast lane or just a roadblock? Mitigating road transport GHG emissions under Australia's Emissions Reduction Fund. *Environ. Plan. Law J.* **2016**, *33*, 181–202.
139. Hunter, T.S. Offshore Petroleum Drilling and Risk. A Study of Proposed Deep-Sea Exploration Drilling in Commonwealth Regulated Waters of the Great Australian Bight. Available online: <https://www.greenpeace.org.au/wp/wp-content/uploads/2019/05/Professor-Soliman-Hunter-GAB-Report-April-2019.pdf> (accessed on 27 June 2020).
140. Federal Highway Administration. Average Annual Miles per Driver by Age Group. Available online: <https://www.fhwa.dot.gov/ohim/onh00/bar8.htm> (accessed on 23 November 2019).
141. Japan's Used Cars Are Newer with Lower Mileage. Available online: <https://integrityexports.com/japan-car-auction-academy/why-cars-from-japan/japans-used-cars-are-newer-with-lower-mileage/> (accessed on 23 November 2019).
142. Average Lifespan for U.S. Vehicles. Available online: <https://berla.co/average-us-vehicle-lifespan/> (accessed on 23 November 2019).
143. Japan Automobile Manufacturers Association (JAMA). Motor Vehicle Statistics of Japan. Available online: <http://www.jama-english.jp/publications/industry.html> (accessed on 23 November 2019).
144. Tucki, K.; Mruk, R.; Orynycz, O.; Wasiak, A.; Botwińska, K.; Gola, A. Simulation of the Operation of a Spark Ignition Engine Fueled with Various Biofuels and Its Contribution to Technology Management. *Sustainability* **2019**, *11*, 2799. [CrossRef]
145. European Vehicle Market Statistics, 2018/2019. Available online: <https://theicct.org/publications/european-vehicle-market-statistics-20182019> (accessed on 23 November 2019).
146. Den Tonkelaar, W.A.M. CAR Smog: System for on-line extrapolation from hourly measurements to concentrations along standard roads within cities. *Sci. Total Environ.* **1996**, *189–190*, 423–429. [CrossRef]

147. Frankowski, J. Attention: Smog alert! Citizen engagement for clean air and its consequences for fuel poverty in Poland. *Energy Build.* **2020**, *207*, 109525. [[CrossRef](#)]
148. Reducing Pollution with Electric Vehicles. Available online: <https://www.energy.gov/eere/electricvehicles/reducing-pollution-electric-vehicles> (accessed on 23 November 2019).
149. Moćko, W.; Ornowski, O.; Szymańska, S. Estimation of energy consumption of electric vehicle during road driving test. *Zeszyty Problemowe Maszyny Elektryczne* **2013**, *2*, 31–35. Available online: http://www.komel.katowice.pl/ZRODLA/FULL/99/ref_05.pdf (accessed on 8 January 2020).

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).